CHAPTER 1

Hydrocarbon exploitation in the gulf of Saint-Lawrence in the context of the global climate crisis

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Climate change is one of the main environmental issues of our times and respecting the commitments taken under the Paris Accord is essential in order to limit the extent of climate change. Canada, as well as Quebec and the Atlantic Provinces have developed climate plans for the medium-term future. This chapter will analyse the impact of the development of a hydrocarbon sector in the greater region of the Saint-Lawrence on the greenhouse gas emissions inventories at the provincial, national and planetary scales. The analysis includes the exploration and exploitation of hydrocarbons (natural gas, oil) in the terrestrial and marine environments of the Saint-Lawrence region (including the river, estuary and gulf), the transport of hydrocarbons across the region, in particular oil pipelines for crude oil from Western Canada in Quebec and New Brunswick, and refining. As the quantity of hydrocarbon reserves in the different deposits are very poorly constrained, it is difficult to perform a quantitative analysis for all parts of the emissions budget at this stage. Emissions stemming from hydrocarbon exploration and exploitation on Quebec soil will of course figure in the provincial greenhouse gas inventories. The same applies to all the Atlantic provinces. Those emissions are however typically much lower than those originating from the final use of these hydrocarbons, which will predominantly occur outside of the provinces and probably mostly outside of Canada. There could be limited substitution effects in comparison to other sources of oil or other forms of energy. Transport of crude oil from outside of the province by pipelines within a province causes some greenhouse gas emissions, which will appear in the inventories of the province in question. However, these transport emissions are fairly insignificant compared to

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those linked to the production, refining and final use of that oil. Since the crude oil comes from Western Canada, emissions from its production will not appear in Quebec or New Brunswick's inventories. Refining, if performed in the Levis, Montréal, or Saint John refineries would add to Quebec or New Brunswick's total emissions, but there are good reasons to think that the crude oil would be refined elsewhere, probably abroad. In any case, the main climate impact of this oil results from its final use, which will mainly occur outside of Canada. Therefore, even if it does not add to provincial or the federal greenhouse gas inventories, the consumption of this oil will still contribute to aggravate the planetary climate crisis. Its net contribution depends however on a number of hypotheses, including the question whether this oil will substitute other oil sources or simply add to global consumption, and if the first is true, how the greenhouse gas emissions budgets of the different oil sources compare. From a macroeconomic point of view, it is clear that a massive investment in the hydrocarbon sector will lead to a technological and economic lock-in and will determine energy trajectories for several decades, to the detriment of other sources of energy or energy efficiency, which is in contradiction to the climate goals announced by Canada, Quebec and the Atlantic Provinces, and to the commitment expressed by the international community, including Canada, to limit climate change to 2°C and preferably 1.5°C.

INTRODUCTION

In the context of the increasingly discernable impacts of climate change and of the adoption on December 12, 2015, of the Paris Climate Agreement, we want to analyse to which extent the development of the hydrocarbon sector in the greater Saint-Lawrence region could alter greenhouse gas (GHG) emissions budgets at the provincial, Canadian and global scale. In this analysis, we will consider the extraction of hydrocarbon resources (natural gas, oil) in the terrestrial and marine environments of the Saint-Lawrence region (river, estuary and gulf) as well as hydrocarbon to and through the region, and more specifically crude oil pipelines from Western Canada to Quebec and New Brunswick, and oil refining in Quebec and New Brunswick. Several factors have to be taken under consideration when performing such an analysis. In addition to GHG emissions directly resulting from the extraction, transport and transformation of hydrocarbons, indirect effects have to be considered, such as the substitution of other oil and gas sources or

HIGHLIGHTS

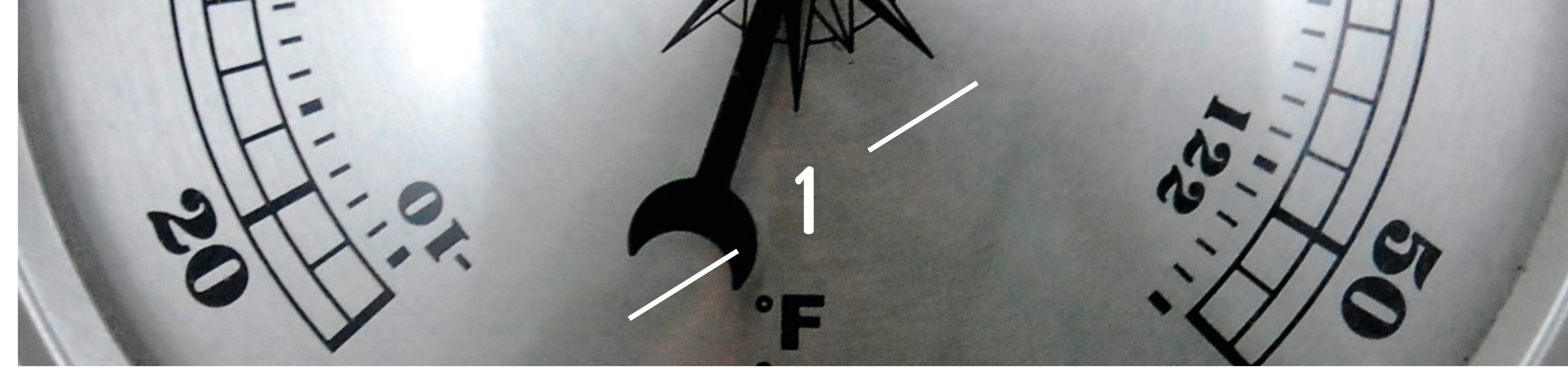
- In the context of an eventual energy transition linked to the fight against greenhouse gas emissions responsible for climate change, energy strategies based on massive investments in the hydrocarbon will determine energy trajectories for several decades.

- There is no reliable estimate of the total quantity of greenhouse gases which the exploitation of hydrocarbons might add to the Canadian and Quebec inventories.

- Part of the greenhouse gas emissions will be included in the provincial inventories, but emissions stemming from the production, transport and refining of hydrocarbons originating from outside the province or abroad won't, even though they contribute to a rise in atmospheric greenhouse gas concentrations.

- The substitution of coal for electricity production or of heating fuel by natural gas would lead to a decrease in greenhouse gas emissions; on the contrary, a substitution of hydroelectricity by natural gas for electricity production in Quebec would lead to an increase in greenhouse gas emissions.

other energy forms, as well as the impact of the development of the hydrocarbon sector in the Saint-Lawrence region and the investment in fossil fuels will have on North-American and global markets and on global oil and gas consumption. The latter is particularly important, since the climate impact of hydrocarbons results mainly from their final use, much more than from the production, transformation or transport stages. In this context, it is important to point out that the majority of hydrocarbons produced in or transported through the Saint-Lawrence region, will eventually be exported to the USA and other parts of the world. A full analysis is difficult to perform, since some fundamental data, such as the quantity of resources present in the soil or continental shelf, and hence the potential hydrocarbon production, are not available. Indirect effects are also difficult to accurately anticipate, since their evaluation relies on a certain number of hypotheses which cannot be validated ex ante. For Quebec, it is certain that the development of a hydrocarbon sector will lead to an increase in provincial emissions, since those hydrocarbons cannot replace hydrocarbons with higher emissions potential in the electricity sector, already entirely fueled by renewable energy, and only to some extent in the transport sector by replacing foreign by domestic oil or in the heating sector, by replacing heating oil by natural gas. The situation is more complex in the Atlantic provinces, which still use a fair amount of oil and coal for electricity production. At the Canadian scale, the main stake is the possible construction of the Energy East pipeline and the development of the oils sands sector in the Canadian West, which at least in the case of the Energy East pipeline, seems to have reached a dead end. At the planetary scale, the main issue is to determine whether the hydrocarbons produced in the Saint-Lawrence region will replace other fossil fuels, which if possessing a less advantageous lifecycle GHG emissions budget, may even lead to a slight decrease of global emissions, or if they will just be added to global hydrocarbon use, in which case global GHG emissions would increase in consequence. /



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THE PARIS CLIMATE AGREEMENT AND INTERNATIONAL EFFORTS

On December 12, 2015, the 195 participants of the 21st Conference of the Parties (CoP-21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris adopted the Paris Climate Agreement, which has the main goal of limiting planetary warming to 2°C and if possible, to 1.5°C above preindustrial levels (UNFCCC, 2015a). The 2°C limit had in principle already be adopted at the CoP-15 in Copenhagen in 2009 as the long-term goal of the new climate agreement destine to replace the Kyoto Protocol. This objective should allow to respect the fundamental objective of the UNFCCC from 1992, which is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, art. 2). The more ambitious 1.5°C target was proposed by some of the more vulnerable nations, most prominently the Alliance of Small Island States (AOSIS), set to disappear in case of a significant increase in sea levels.

In order to reach to targets of the Paris Climate Agreement, 186 countries submitted over the course of the year 2015 so-called intended nationally determined contribution (INDC), which set out their specific actions under the Paris Climate Agreement. These INDC will be reassessed every five years, starting in 2020, in order to ensure that they converge towards the long-term 2°C and 1,5°C objectives, which is currently not the case, since the sum of INDC submitted to date would rather lead to a planetary warming in the 2.5-2.7°C range (CAT, 2015, UNFCCC, 2015b), still a considerable progress compared to the 3.6°C warming which would result from current policies (CAT, 2015). Current emissions trajectories are indeed far from objectives set out in previous climate summits. Since the Toronto Climate Conference in 1988, which marked the onset of global mobilisation on the issue of climate change (Fenech, 2013), GHG emissions have increased at a frantic pace and are today 60% above their 1990 levels, far from the objective of the Kyoto Protocol (a 5.2% de reduction by 2008-2012 compared to

1990 levels). The rate of increase of GHG emissions has accelerated over the last two decades; from 1,1% per year during the 1990s to over 3% during the 2000s, thereby exceeding all emissions scenarios from the third assessment report of the Intergovernmental Panel on Climate Change (IPCC) (Olivier *et al.*, 2014; Raupach *et al.*, 2007).

The challenge is mighty and action urgent (Weissenberger *et al.*, 2015). Emissions and atmospheric concentrations of carbon dioxide (CO_2), as the main GHG responsible for anthropogenic climate change, have dramatically increased since the onset of the industrial revolution, and particularly rapidly in the second half of the 20th century (figures 1.1 et 1.2). In order to maintain planetary warming to less than 2°C above preindustrial mean temperatures, the atmospheric CO_2 concentration must not exceed 450 parts per million (ppm), which would require a reduction of CO_2 emissions of 46% below 1990 levels or 53% below 2005 levels by 2050 (UNEP, 2011). The final temperature response is very sensitive to the time when emissions reductions occur. Thus, delaying action by five years, from 2020 to 2025 would decrease the probability to reach the 2°C target by 34 to 56% and inversely, bringing forward action by five years, from 2020 to 2015, increases the chances to reach that target by 60% (Rogelj *et al.*, 2013). It is therefore important to engage as soon as possible in the "right" path. Of course, these insights are not new, since already in 1979, a report from the US National Academy of Science stipulated that "A wait and see policy may mean waiting until it is too late." (Charney *et al.*, 1979, p. viii). All following scientific work, including the five assessment reports from the IPCC and those of national science academies from over 80 countries have confirmed this assessment (Cook *et al.*, 2016). /

Figure 1.1
Human GHG emissions in the world (in CO_2 equivalents) from 1750 to 2011. *(From IPCC, 2014.)*

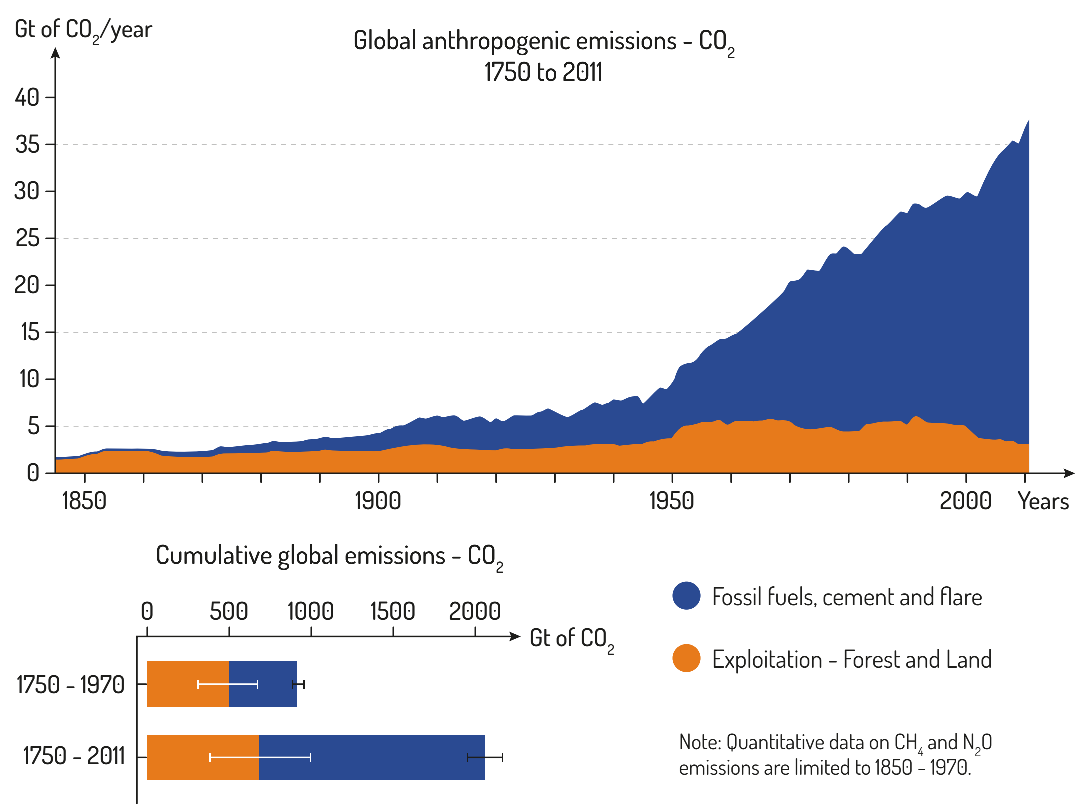
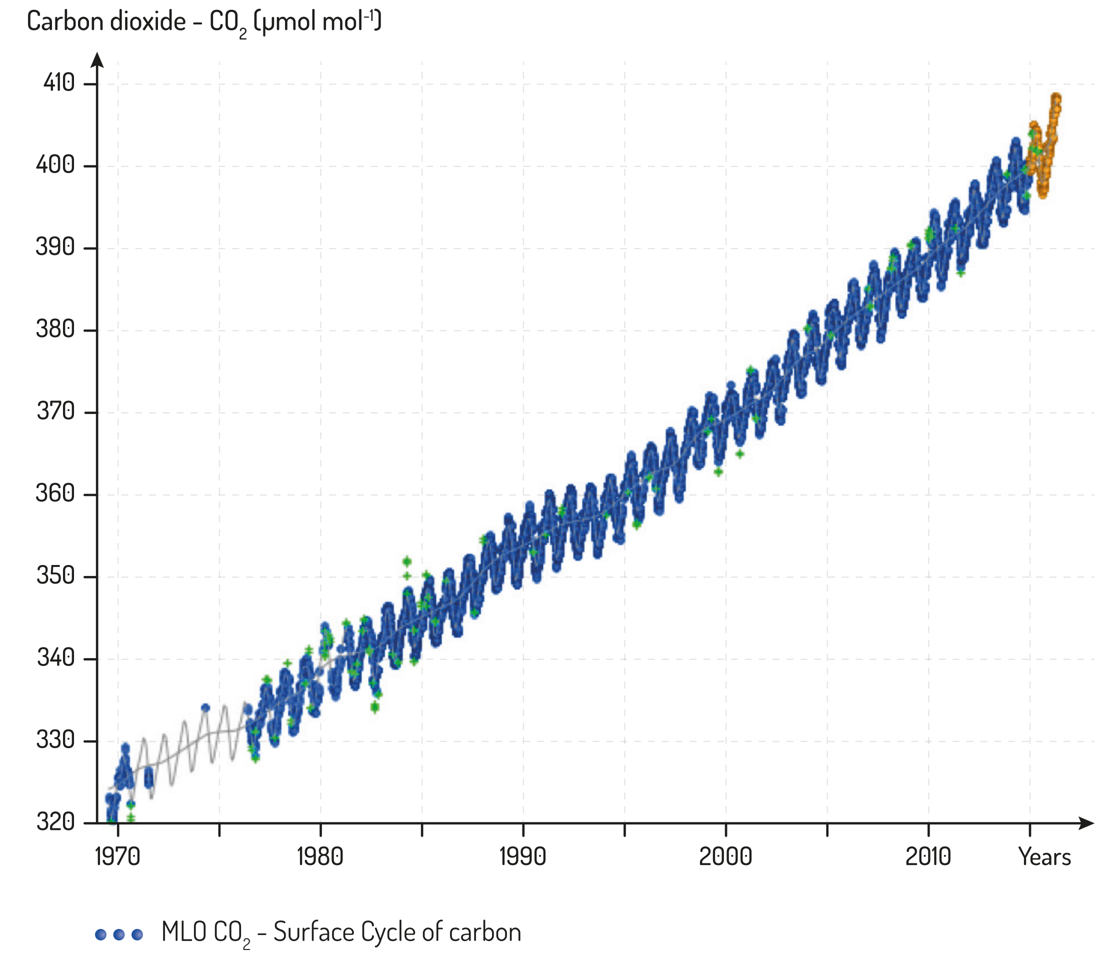


Figure 1.2
Atmospheric CO_2 concentrations measured at Mauna Loa, Hawaï, from 1969 to 2016. *(From NOAA, 2016.)*



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THE END OF THE FOSSIL FUEL AGE?

The phenomenon of climate change is in essence a problem of fossil fuel combustion. In 2010, 65% of GHG emissions (measured in tonnes of CO_2 equivalent or tCO_2eq)[1] were due to CO_2 from fossil fuel combustion, 11% to CO_2 from deforestation and land-use change, the remainder being spread over other GHG like methane, nitrous oxide, chlorofluorocarbons or hydrofluorocarbons (Victor *et al.*, 2014). Over time, the part of CO_2 from fossil fuel combustion has strongly increased, reflecting their ever-increasing use by humanity. For example, GHG emissions from the electricity sector have tripled and those of the transport sector doubled since 1970 (Victor et al., 2014). Since the beginning of the industrial revolution, CO_2 emissions from fossil fuels have increased in an exponential way, going from virtually 0 to over 30 Gt[2] of CO_2 per year (IEA, 2014). Atmospheric CO_2 concentrations are currently 40% higher than in the pre-industrial era (IEA, 2014).

It is therefore not surprising that the Climate Paris Agreement is often equaled to an end of the fossil fuel age and a transition to a carbon-free economy[3]. The calculation is simple. According to climate models, humanity can emit around 1000 Gt de carbon[4] as CO_2 over its lifetime (cumulative historic emissions), in order to possibly keep planetary warming to less than 2°C (Allen *et al.*, 2009; UNEP, 2014). This quantity is humanity's "carbon budget", which cannot be exceeded, if the 2°C is to be respected. Since the beginning of the industrial revolution, until the first half of the 21st century, 770 Gt of carbon have already been emitted, leaving only 230 Gt of carbon in humanity's carbon budget, which is the equivalent of 20 to 30 years of consumption at the current rate (Friedlingstein *et al.*, 2010). A more refined analysis by researchers of the Potsdam Institute for climate impact research concludes that limiting emissions to 272 Gt of carbon between 2000 and 2050 gives a 75% probability of restricting planetary warming to 2°C or less. Limiting emissions to 393 Gt of carbon over the same period reduces the probability of restricting planetary warming to 2°C or less to less than 50% (Meinshausen *et al.*, 2009).

Available fossil fuel reserves largely exceed humanity's carbon budget. The known reserves of the 200 largest fossil fuel companies can be estimated at roughly 750 Gt of carbon (*The Economist*, 2013, citing Carbon Action Tracker, 2012)[5], whereas total resources are estimated at 2 000 to 10 000 Gt of carbon. It clearly follows that the main part of these reserves, and the vast majority of potential resources must remain in the ground in order to be able to limit planetary warming to 2°C or less. This is coined as "unburnable carbon". This also means that by continuing to invest in the exploration of carbon products, we are creating a potential "carbon bubble" with potentially disastrous economic consequences, since a great part of those investments will be lost if the discovered reserves cannot be used. The size of that bubble is considerable. In 2012, for example, energy companies invested 674 billion US$ in the development of new fossil resources (*The Economist*, 2013, citing Carbon Action Tracker, 2012). The oil crisis in Canada since 2014-2015 gives a glimpse into the potential economic and social consequences of such a bubble.

In this context, the role played by state subsidies has to be considered. Those subsidies, as direct subsidies, tax breaks, reduced royalties, export subsidies, etc., but without including externalities, were in the range of 490-775 billion US$ per year (current dollars) (Bast *et al.*, 2014; IEA, 2015), equivalent to in 2011 to 0.7% of gross world product or 2% of world governments' revenues (Clements *et al.*, 2013). Half of that money is spent on oil. Those subsidies are four times higher than those allotted to renewable energies or to energy efficiency. The 88 billion US$ spent by the governments of the group of 20 countries (G20) on the exploration of new sources of oil, gas and coal, have been particularly criticised in the context of the "unburnable carbon" problem (Bast *et al.*, 2014). This is why the International Energy Agency (IEA) cites phasing out those subsidies as one of the most efficient measures in order to reduce global GHG emissions by 3.1 Gt of CO_2 by 2020 (IEA, 2013). In Canada, subsidies and tax breaks for fossil fuels were between 2.7 and 2.8 billion C$ in 2013-2014, of which 1.6 billion C$ were from federal sources and 1 billion C$ from provincial programmes (Bast et al., 2014; Sawyer and Stiebert, 2010). This compares to private investments of 81 billion C$ and government revenues of 17 billion C$ in 2014 in the fossil fuels sector (CAPP, 2016). /

[1] Since some GHG have a stronger radiation absorption power and a longer atmospheric lifetime than CO_2, a global warming potential (GWP) is calculated for each GHG, allowing to express radiative forcing for all GHG in units of CO_2.

[2] 1 kt (kiloton) = 1000 tons; 1 Mt (megaton) = 1 million tons; 1 Gt (gigaton) = 1 billion tons.

[3] See for example: Goldenberg, S., Vidal, J., Taylor, L., Vaughan, A. and Harvey, F. (December 12, 2015). Paris climate deal: Nearly 200 nations sign in end of fossil fuel era, *The Guardian*; Scott, M. (December 13, 2015). Paris climate change deal could spell the beginning of the end of the fossil fuel age, *Forbes*; Boulet, J. and Thijs, J. (December 17, 2015). L'accord sur le climat de Paris marque la fin de l'ère des énergies fossiles, *Greenpeace*; Evans-Pritchard, A. (November 29, 2015). COP-21 climate deal in Paris spells end of the fossil era, *The Telegraph*.

[4] 1 ton of carbon corresponds to 3.67 tons of CO_2.

[5] Reserves denote the quantity of economically and technically recoverable oil or gas, whereas resources denote the total quantity of oil and gas present in the ground, but which cannot be necessarily extracted with current technology or at a reasonable cost. The quantity of reserves therefore depends on projections of future technology and market prices. The higher the price of a resource on a market, the higher the reserves. For that reason, numbers from different sources do not always coincide.

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CANADA'S CLIMATE OBJECTIVES

FROM KYOTO TO COPENHAGEN

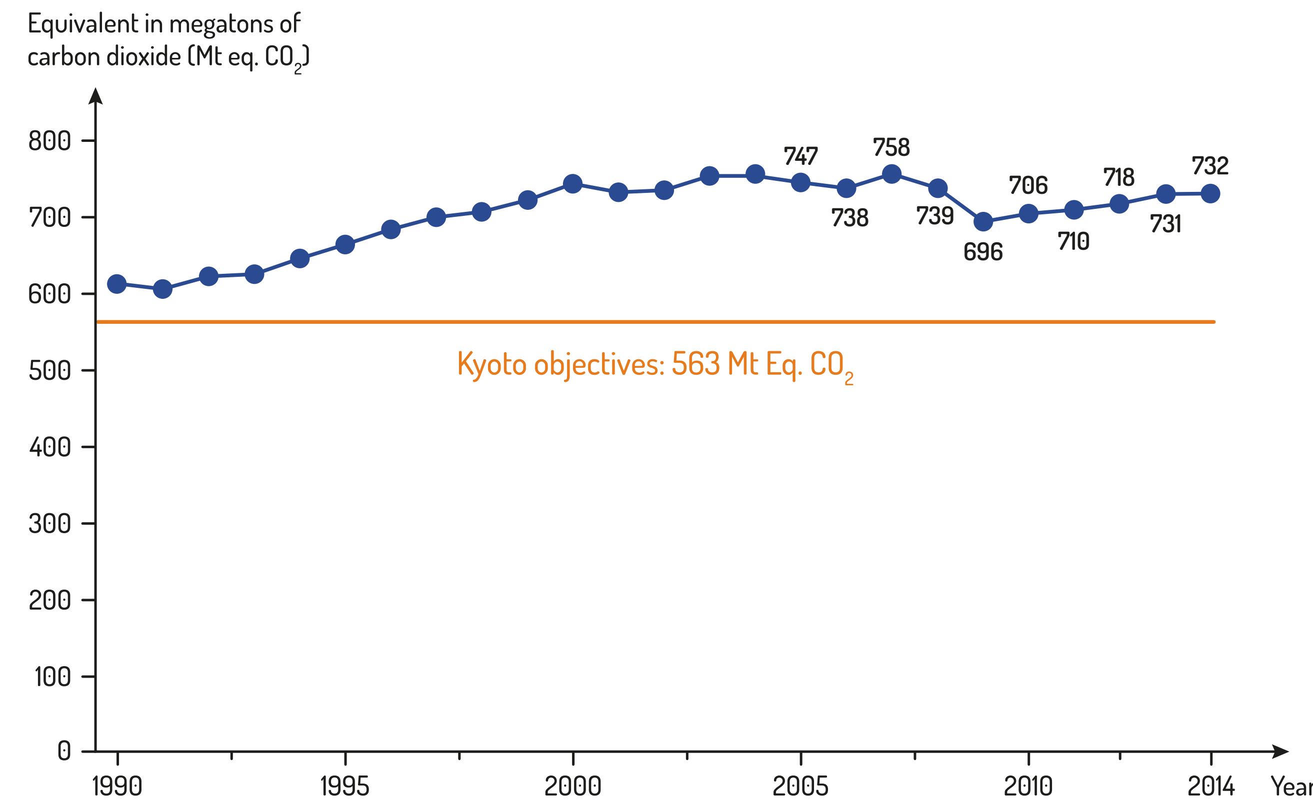
Canada has successively taken three international commitments to reduce its GHG emissions, first under the Kyoto protocol in 1997, then at the COP-15 in Copenhagen in 2009 and finally under then Paris Climate Agreement in 2015 (Table 1.1).

Table 1.1
Canada's international political commitments towards fighting climate change.

	DATE OF SIGNATURE	TARGET DATE	REDUCTION TARGET
Kyoto Protocol	1997	2008-2012	6% below 1990 levels
Copenhagen	2009	2020	17% below 2005 levels
Paris Climate Agreement	2015	2030	30% below 2005 levels

From the onset, Canada has been strongly involved in the international negotiation process. It is at the invitation of the Canadian government that the Toronto conference on the changing atmosphere was held in 1988, which yielded the first proposition of a global climate agreement. In 1992, Canada signed the UNFCCC at the Earth Summit in Rio de Janeiro. However, despite several climate change programs put in place by successive governments over the years, Canada was not able to respect its commitments (Figure 1.3). It pulled out of the Kyoto protocol in 2012, just before the end of the first commitment period, and did not join the second commitment period. This decision was the culmination of a period of climate disengagement from 2006 to 2015.

Figure 1.3
CO_2 emissions in Canada from 1990 to 2014. *(Adapted from Environment and Climate Change Canada, 2016.)*



CANADA AND THE PARIS CLIMATE AGREEMENT

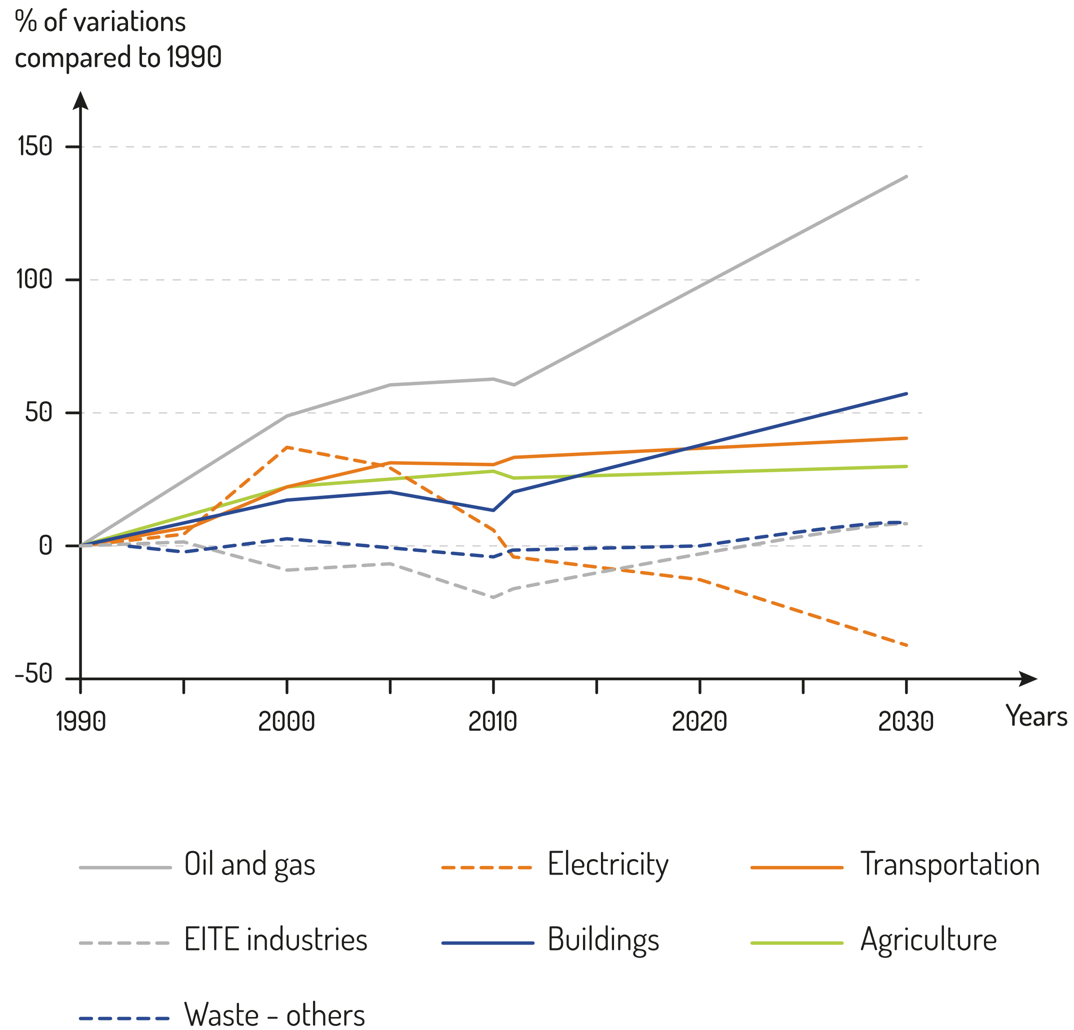
Canada's INDC submitted in May 2015 proposes a reduction of GHG emissions by 30% with respect to 2005 levels by 2030. In order to reach this objective, Canada proposes several measures such as the ban on the construction traditional carbon fueled power pants, the gradual retirement of those still in operation, CO_2 emissions standards for gas plants and road vehicles and a legislation on methane emissions from the oil and gas sector (Canada, 2015).

Canada's INDC has been criticized by several observers (box 1.1). Indeed, brought back to 1990, the basis year of the Kyoto protocol, the Canadian objective corresponds to an increase of 1% of GHG emissions, or a decrease of 11%, if natural sinks are factored in (Yeso, 2015). Compared to the 40% emissions reductions proposed by the European Union, the Canadian target appears seriously lacking in ambition (Damassa and Fransen, 2015).

Another criticism to Canada's sector-based approach is that no mention is made of the fossil fuels extraction sector, apart from a regulations of methane emissions. Yet, this sector accounts for 9% of Canada's GHG emissions and its emissions increased by 79% since 2005 (CAT, 2015). The oil and gas sector is the main projected source of the rise of GHG emissions in Canada by (figure 1.4). The INDC also specifies that the natural resources and energy sectors are under the authority of the provinces et territories, which may suggest that initiatives for the reduction of GHG emissions from these sectors should be undertaken by provinces and territories rather than by the federal government.

Canada's climate objectives could substantially change following the 2015 federal elections. As an indication of a changed attitude towards climate change, during COP-21 in Paris, Canada joined the informal *High Ambition Coalition* with the European Union, the United States (Under the Obama government) and several African, Oceanic, Caribbean and South-American countries, supporting the 1.5°C target. The electoral platform of the Liberal Party did not contain specific climate targets, but vowed to phase out fossil fuel subsidies and to introduce a carbon tax. The details of a new climate plan were supposed to be unveiled 90 days following the election, but that deadline was then postponed. /

Figure 1.4
Projected changes in GHG emissions in Canada from 1990 to 2030.
(From Holz, 2015 based on data by Environment Canada.)



COMMENTS ON CANADA'S INDC COMPILED BY *CLIMATE ACTION TRACKER* (2015)

"It's clear Canada is not serious about climate action. Without any new policies in place, its emissions are expected to balloon through to 2030, with the tar sands taking up a significant proportion. It is difficult to fathom how Canada will achieve both its 2020 pledge and its 2030 INDC."

Bill Hare, Climate Analytics

"Canada's forest sinks are expected to increase through to 2030 . This will create a substantial amount of carbon credits that the government can use to avert action on reducing fossil fuel emissions. The accounting options Canada proposes using are fraught with difficulties, not least because Canada is no longer a party to the Kyoto Protocol, so it can use much looser rules."

Louise Jeffery, Potsdam Institute
for Climate Impact Research

"With this inadequate target, Canada will not tap into its large potential to reduce fossil fuel consumption. Canada risks becoming a laggard in clean innovation, such as energy efficiency."

Kornelis Blok, Ecofys

"In rating Canada "inadequate," our lowest rating, we note that other governments will have to take a lot more action to make up for the hole left by Canada's lack of ambition – if warming is to be held to 2°C."

Niklas Höhne, NewClimate Institute

[6] It is however important to consider that the evolution of forest carbon sinks and sources in Canada will depend on the impacts of climate change on natural perturbation in coming years and decades. Thus, forest fires or mountain pine beetle epidemics have become more frequent over the past years and negatively affect the ability of the boreal forest to store carbon, so that it has become a net CO_2 source rather than a sink in some recent years (Kurz *et al.*, 2008; NRCan, 2016; Oris *et al.*, 2013). This might also have contributed to Canada's decision in 2007 to no longer include forest sinks and sources in its GHG inventory, after advocating for their inclusion in the Kyoto protocol at the COP-7 in Marrakech. In its implementation plan of 2002, those sinks represented 24% of anticipated GHG emissions reductions.

Photo: É. Pelletier

THE CLIMATE OBJECTIVES OF QUEBEC AND THE ATLANTIC PROVINCES

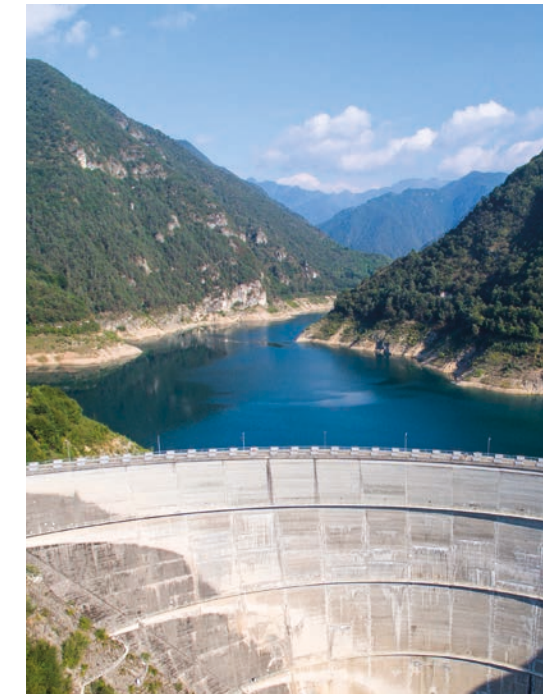
Among the provinces bordering the Saint-Lawrence River or Gulf, only Quebec and New Brunswick are involved in all aspects of the development of a hydrocarbon sector: exploitation and exploration, transport (by pipeline, train and boat) and refining. It is without question Quebec which would see the strongest impact of the development of the hydrocarbon sector on its climate objectives. Because of the importance of the Irving refinery and of the projected shale gas exploitation, New Brunswick might also have to revisit its climate plans.

Quebec has always been strongly in favour of the Kyoto Protocol and the fight against climate change. In 2006, the National Assembly unanimously adopted a motion supporting the Kyoto Protocol, which had of course only symbolic value since it is the federal government that is responsible for signing, ratifying and implementing such an international agreement. The Quebec government nevertheless issued a decree in 2007 aiming at implementing the Kyoto Protocol in fields of provincial responsibility. Quebec successively published three climate action plans: the 2000-2003, 2006-2012 and 2012-2020 plans. In its 2000-2003 action plan, a strong political will was put on display and agreements on GHG emissions reductions signed with several corporations. Quebec's industrial sector reduced its GHG emissions by 8.5% between 1990 and 2005 (Québec, 2008), mainly thanks to the modernisation of equipment and to a decrease in the emission of non-CO_2 or -methane greenhouse gases, in particular in the metallurgy and metal working sector.

Quebec has also been very active on the international stage. In 2011, it joined the Climate Change Action Plan of the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP), which had the goal to stabilize regional GHG emissions at 1990 levels and to reduce them to 10% below that level by 2020 (Québec, 2008). In 2008, Quebec became a member of the Western Climate Initiative, a group of US States working jointly to the implementation of a GHG emissions trading scheme for certain economic sectors characterized by high GHG emission (Québec, 2008). The same year, Quebec and Ontario launched an interprovincial initiative which resulted in an interprovincial carbon market, later also joined by Manitoba (Ontario, 2015; Québec, 2008).

QUEBEC'S 2006-2012 CLIMATE CHANGE ACTION PLAN

The 2006-2012 Climate Change Action Plan (fr. *Plan d'Action sur les Changements Climatiques* or PACC) was largely modeled after the Kyoto protocol and received 1.2 billion C$ in funding. Its objective was to reduce GHG emissions to 6% below 1990 levels, a decrease of 14.6 $MtCO_2eq$ (Québec, 2008). Since the energy sector, fueled to over 90% by hydroelectricity, offered very little options for emissions reductions, proposed actions were in other sectors, including transport, industry, waste, agriculture and energy efficiency. An improvement in energy efficiency would allow to export hydroelectricity to neighbouring markets and displace fossil based electricity there, but of course those emissions reductions would not be credited to Quebec, as inventories are territory-based. The 2006-2012 PACC also included technological innovation, economic instruments and public awareness raising (Québec, 2008). Given the importance of the energy sector for the development of Quebec, it was planned to closely link the 2006-2012 PACC to the 2006-2015 Energy Strategy, which included investments in renewable energies (hydroelectricity, wind and biomass) and an increase in energy efficiency (Québec, 2008).



QUEBEC'S 2013-2020 CLIMATE CHANGE ACTION PLAN

The 2013-2020 PACC directly followed the 2006-2015 PACC. It introduced a new target for GHG emissions reductions to 2013-2020 to 20% below 1990 levels (Québec, 2012). It received 2.7 billion C$ in funding, almost entirely stemming from the revenues of the carbon market. As in the preceding plan, efforts are geared towards the transport, industry and building sectors, which cumulate 85% or provincial emissions.

Regarding the energy sector, the 2013-2020 PACC mentions that 97% of electricity production is from renewable sources (hydroelectricity and wind). It stresses that "this enviable situation is in great parts the result of good choices on the energetic development of Quebec made 50 years ago through the massive development of the province's hydroelectric potential" (Québec, 2012, p. 32). According to the 2013-2020 PACC, the future or Quebec's energy supply lies in the development of renewable energies, mainly hydroelectricity and wind, and of bioenergy. There is an apparent discrepancy between the praise for past choices and the promotion of renewable energies and of the 2013-2020 PACC and the development of a hydrocarbon sector, advocated in other government policies such as the 2030 Energy Policy. The objectives of the 2013-2020 PACC do not coincide with those of the 2030 Energy Policy, which leaves little room for the development of wind power (it is only mentioned within the Plan Nord and as an option for electricity exports). On the opposite, an entire chapter, out of the four contained in the 2030 Energy Policy, is devoted to the development of the hydrocarbon sector, suggesting that a 'limited and controlled hydrocarbon exploitation is compatible with the GHG emissions reduction objectives [of Quebec]" (Québec, 2016a, p. 60).

QUEBEC'S CARBON MARKET

Quebec's carbon emissions trading market (fr. *Système québécois de plafonnement et d'échange de droits d'émission de gaz à effet de serre* or SPEDE) was launched on January 1st, 2013. Since January 1st, 2014, the SPEDE is coupled to California's carbon market in the framework of the Western Climate Initiative. Ontario and Manitoba signed a memorandum of understanding with Quebec in 2015 aiming at linking the carbon markets of the three provinces under the Western Climate Initiative (Ontario, 2015). Alberta and British Colombia have put in place carbon taxes, which means that about 90% of the Canadian population is now subject to a carbon pricing, but not at the same rate and not in a unified manner over the national territory. According to the Pan Canadian Framework on Clean Growth and Climate Change enacted by the Trudeau government, all provinces and territories will have to implement carbon pricing by September 2018, at a rate starting at 10 C$ a ton and increasing to 50 C$ a ton by 2022. In Quebec, the energy sector is part of the carbon market since 2013, meaning that every energy company emitting more than 25 000 tCO_2eq per year must purchase emission permits. The price of the permits is negotiated on the market, but there is a floor price incrementally increasing from 10.75 C$/$tCO_2eq$ in 2013 to 15 C$/$tCO_2eq$ in 2020 (in 2013 constant dollars) in order to prevent a market collapse as was observed in the European carbon market.

THE ATLANTIC PROVINCES' CLIMATE CHANGE ACTION PLANS

The Atlantic Provinces (Prince Edward Island, New Brunswick, Nova Scotia and Newfoundland and Labrador) adopted the objective of the Climate Change Action Plan of the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) to reduce GHG emissions by 10% by 2020 compared to 1990 levels (PEI, 2015; Nouveau-Brunswick, 2014; Nova Scotia, 2009; Newfoundland and Labrador, 2011). Prince Edward Island was able to reduce its emissions by 3% between 1990 and 2009 thanks to the development of wind power, which now provides 30% of the province's electricity (David Suzuki Foundation, 2012). Nova Scotia's emissions remain high (fourth highest per capita emissions in Canada), in great part due to the continued used of coal for electricity production. The province wants to reduce its emissions through its Climate Change Action Plan by favouring renewable energies and energy efficiency (Nova Scotia, 2009). The oil and gas sectors weighs heavily on Newfoundland and Labrador's GHG emissions budget as their production and refining account for 19% of the province's total, while mining and oil and gas extraction, including fugitive emissions, account for another 14% (David Suzuki Foundation, 2012). The emissions of these two sectors have increased by 50% since 1990 (David Suzuki Foundation, 2012). Offshore drilling started in 1997 off the coast of Newfoundland, leading to large CO_2 emissions due to the flaring of excess gas in oil reservoirs. These emissions have a tendency to decrease over time, as the amount of gas in the reservoirs diminishes.

In its 2014-2020 Climate Change Action Plan, New Brunswick pledged to reduce its GHG emissions to 10% below 1990 levels by 2020 (medium-term objective) and by 75-85% below 2001 levels by 2050 (long-term objective) (Nouveau-Brunswick, 2014). This second plan follows a first 2007-2012 action plan. The 2012 and 2020 targets are derived from the objectives of the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) (Nouveau-Brunswick, 2007). After a strong increase in the 1990s, the province's GHG emissions drastically decreased in the 2000s, thanks to the decommission of several thermal power plants. In 2012, emissions were more or less back to the same level as in 1990 (New Brunswick, s. d.). Despite this recent decrease, New Brunswick's per capita GHG emissions are still the third highest in the country, after Alberta and Saskatchewan. Between 1990 and 2012, the fossil fuels industry and mining were the sectors with the strongest increase in GHG emissions in the province (New Brunswick, s. d.). One fifth of the province's emissions come from the Irving refinery in Saint-John, the largest in the country, and also a cornerstone of the Energy East project, which will be discussed in sub-section 5.3. Fracking constitutes a potentially large emissions source, but for now, the Gallant government, elected in October 2014, has declared an indefinite moratorium on this activity. /

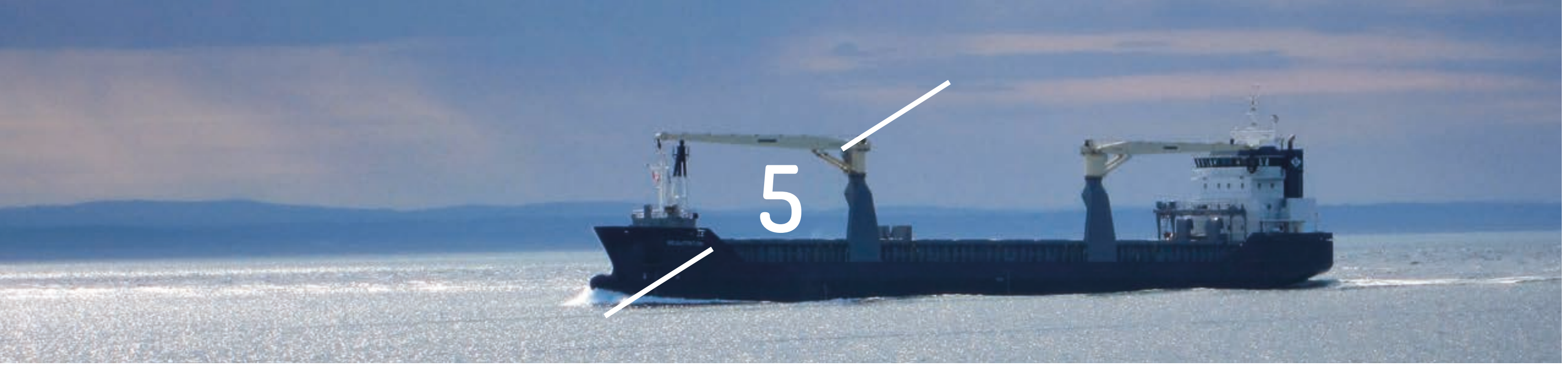


Photo: S. Weissenberger

THE CLIMATE IMPACT OF HYDROCARBON EXPLORATION, EXPLOITATION AND TRANSPORT PROJECTS IN THE SAINT-LAWRENCE RIVER, ESTUARY AND GULF REGION

The climate impact resulting from CO_2 and methane emissions from hydrocarbon exploration and exploitation is difficult to assess quantitatively at this point in time since the possible extent of these activities remains unknown. GHG emissions arise at the different stages of the hydrocarbon sector chain, that is, exploration, exploitation, refining, transport and final use. Part of those emissions is local and would be included in the inventories of the respective provinces. This includes the exploration and exploitation activities. Another part, including transport, which could occur to or from the USA, or refining, which could occur in a different province or country, and final use, which will largely take place abroad, would only in part be included in the province's inventories. Inversely, GHG emissions can also stem from imported hydrocarbons which are refined, transported or consumed in the Saint-Lawrence region. This would for example be the case of the Energy East pipeline, and is currently the case of oil imported from the USA or overseas. Finally, it has to be considered to which extent the production or transformation of hydrocarbons in the region of the Gulf of Saint-Lawrence might affect global markets by stimulating demand or by displacing hydrocarbons from other sources, or other energy sources, renewable or fossil. These indirect effects can lead to an increase or a decrease of global GHG emissions, depending on the case. In the following, we will address those different questions. We will keep a certain focus on the situation of Quebec, as the province potentially the most affected by GHG emissions from the hydrocarbon sector.

HYDROCARBON EXPLORATION AND EXPLOITATION

There is no reliable estimate of the total amount of GHG that hydrocarbon exploitation could add to the Canadian or Quebec inventories, as the recoverable reserves and the total resources are very poorly constrained. The precise constitution of the oil and gas reservoirs is also not well known, which can influence their exploitation conditions and therefore the GHG emissions linked to this exploitation. Currently, the emissions linked to the oil and gas sector in Quebec are small and result solely from transport and refining activities, since there is no exploitation, despite the fact that 400 research permits exist on the province's territory (Québec, 2014). Historically, hydrocarbon production has always been anecdotal and sporadic in Quebec. The production of natural gas in the Galt sector on the Gaspe peninsula lasted until 2005, while the oil production in the Haldimand sector, also on the Gaspe peninsula, lasted until 2013 (Roy and Ménard, 2014, citing Québec, 2014). In the Maritime Provinces, around 200 000 barrels of oil are produced every day off the coasts of New Brunswick and Newfoundland (CMM, 2015). The Hebron reservoir should add up to 120 000 barrels per day (b/d) to this total starting in 2017. This represents only a small part of the 3.3 million b/d of crude oil produced in Canada (figure from 2012) (CMM, 2015).

The efforts to assess potentially exploitable resources focus on some areas within the Saint-Lawrence region where oil and gas deposits, conventional or as shale deposits, seem promising. The estimations of potential resources remain highly uncertain and fragmentary (tableau 1.2). As an element of comparison, Quebec's hydrocarbon consumption in 2013 was 137 million de barrels of oil and 7,7 Gm^3 (272 Gft^3) of natural gas (MDDELCC and MERN, 2015, citing Whitmore and Pineau, 2014), and the combined production of the two refineries of Suncor in Montréal and Valero in Lévis was 4 599 million de barrels (MDDELCC and MERN, 2015, citing MERN, 2014).

The significant emission sources during the production stage depend on the type of hydrocarbon resource and its provenance. In the case of oil, refining is the main emission source (60% for conventional oil in a terrestrial environment and 78% for conventional oil in a marine environment) (Roy and Ménard, 2014). In the case of conventional natural gas, whether marine or continental, extraction and treatment, as well as transmission and distribution, make an important contribution to the emissions balance. The emissions from natural gas exploitation in marine environments are not well documented (Skone, 2011). For shale gas, the main source of emissions are fugitive emissions, i.e. the leaking of methane adjacent to the production site (Roy and Ménard, 2014). The evaluation of these emissions still carries a large degree of uncertainty. The different studies published between 2010 and 2013 give a large range of values, from 0.5% to 8% of total production, depending on the databases and methodologies used (Roy and Ménard, 2014). In some cases, fugitive emissions persist after the exploitation of a well, because in shale gas deposits, 80% of methane is still present in the well after exploitation, compared to 5% in a conventional gas well (Roy and Ménard, 2014, citing ONE, 2009). In the USA, half of the wells closed for 20 years or more still have positive pressure and therefore present a risk of leakage (Roy and Ménard, 2014, citing USMMS).

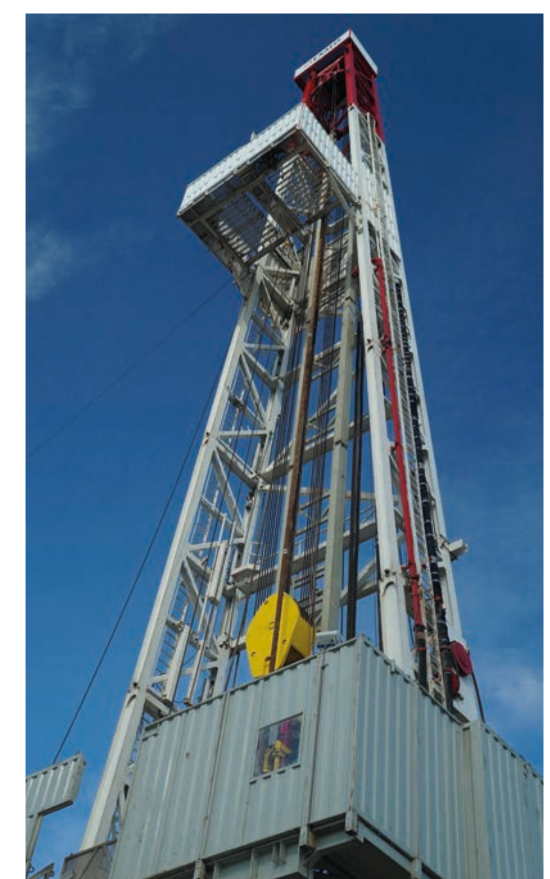


Table 1.2
Hydrocarbon potential in different areas in the Gulf of Saint-Lawrence region.
(Median estimations, figures and references from MDDELCC and MERN, 2015[i].)

AREA	POTENTIAL
Saint-Lawrence Lowlands (including the *Utica* shale zone)	Non-conventional oil: 1,87 Gbp Conventional natural gas: 182 Gft^3 Non-conventional gas: 100-300 Tft^3 total and reserves: 40 Tft^3 (MERN, 2010), 8-40 Tft^3 (SECOR, 2010), 4,5-13.7 Gft^3 (CERI, 2013)
Gaspe peninsula (including the *Haldimand* and *Galt* deposits)[ii]	Conventional oil: 432 Mbp
Lower Saint-Lawrence region (*Bas-Saint-Laurent*) (including the *Massé* deposit)[iii]	Conventional natural gas: 23 Gft^3
Gulf of Saint-Lawrence, maritime sector of the Anticosti basin[iv]	Conventional marine oil: 291 Mbp Conventional marine natural gas: 465 Gft^3
Gulf of Saint-Lawrence [vi], Madeleine basin (including the *Old Harry* and *Millerand* deposits)[v]	Conventional marine oil: 99 Mbp Conventional marine natural gas: 2 862 Gft^3
Anticosti Island (including the Macasty basin)	Conventional oil: 63 Mbp Non-conventional oil: 44-102 Gbp[vii] Conventional natural gas: 120 Gft^3
Nova Scotia	Shale oil: 50 Mbp Non-conventional natural gas: 10-50 Tft^3 (recoverable) (Nova Scotia Independent Panel on Hydraulic Fracturing, 2014)
Total	Conventional oil: 0,50 Gbp Shale oil: 104 Gbp Marine oil: 0.39 Gbp Conventional Natural gas: 302 Gft^3 Shale gas: 40 Tft^3 Marine natural gas: 2 862 Gft^3

Note. ; Mbp = million barrels of petrol; Gbp = billion barrels of petrol; Gft^3 = billion cubic feet; Tft^3 = trillion cubic feet
[i] Note that the economically recoverable proportion is only a small fraction of the total potential.
[ii] Only 2 of 5 zones were evaluated.
[iii] Only 2 of 6 zones were evaluated.
[iv] Only 3 of 4 zones were evaluated.
[v] Only 2 of 3 zones were evaluated.
[vi] The strategic environmental assessments (SEE) did not consider the western part of the estuary nor the gulf portion since the latter is not entirely situated in Quebec territory (Roy and Ménard, 2014).
[vii] Highly uncertain figures.

There are few estimates on potential GHG emissions in Quebec resulting from an exploitation of hydrocarbon resources. An estimate on shale gas was undertaken for the strategic evaluation on shale gas and hydrocarbons in Quebec by the *Bureau d'audiences publiques sur l'environnement* (BAPE). According to that estimate, Quebec's emissions could increase by 1%-23% depending on the scenario, but the authors only considered the exploitation of 0.5-3.75 Tft^3, a small part of the total potential (see table 1.2) over a period of 25 years (Roy *et al.*, 2013; Roy and Ménard, 2014). Another estimate was done by the *Institut de recherche et d'informations socioéconomiques* (IRIS), this one on shale oil exploitation on the Anticosti Island. According to that estimate, emissions during the presumed exploitation period from 2020 to 2050, GHG emissions could amount to 33,5 $MtCO_2eq$ (Schepper, 2015).

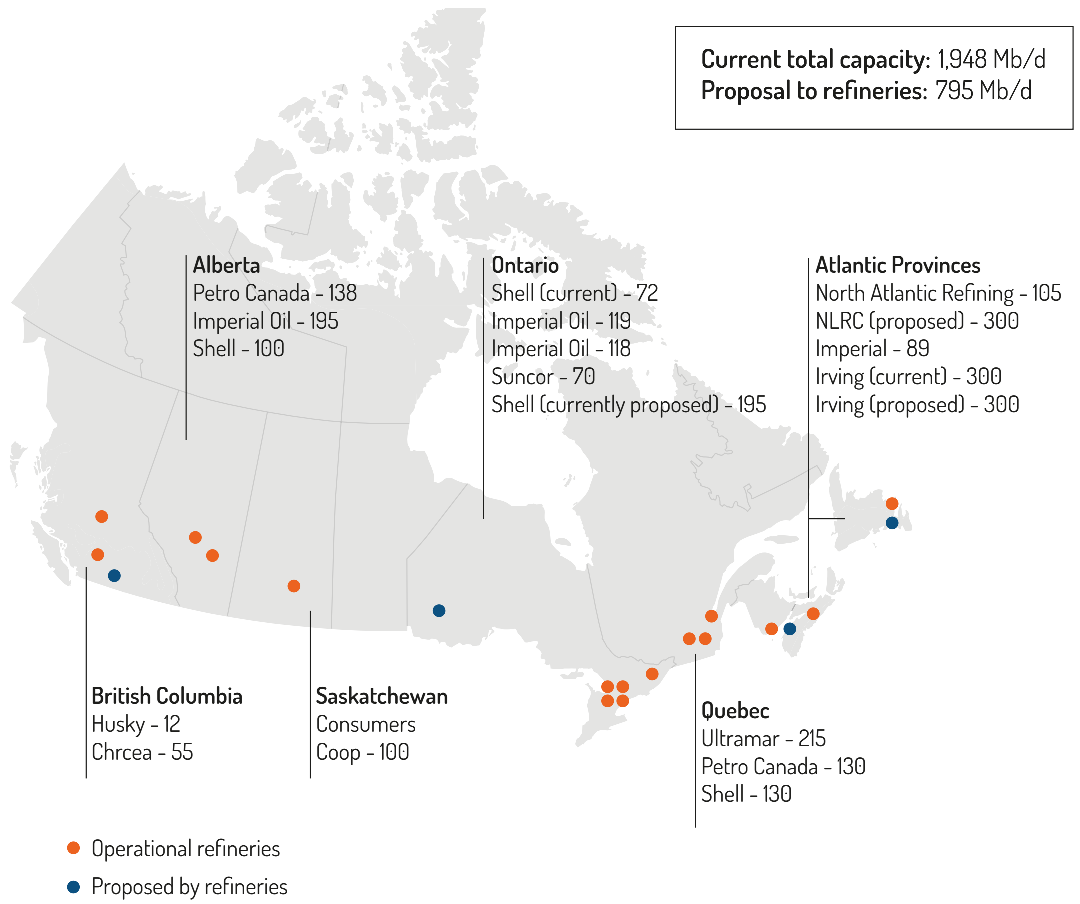
REFINERIES

Refineries are important sources of GHG emission. Half of Canada's refining capacity is concentrated in Quebec and Atlantic Canada, the most important ones being in Quebec and in New Brunswick (figure 1.5). The Irving refinery in Saint-John, New Brunswick, is the largest in the country with a production of 300 000 barrels per day (b/d). It emitted 2.8-3.3 $MtCO_2eq$ per year between 2004 and 2013, which represents around 20% of the total emissions of the province (CAPP, 2015; ECC Canada, 2014). Quebec has two important refining centres, Montreal East (Suncor) and Lévis (Valero), with respective production capacities of 137 000 and 265 000 b/d (CAPP, 2015). The two refineries emitted 2.2 $MtCO_2eq$ in 2012, which was 2.7% of Quebec's total emissions that year (Whitmore and Pineau, 2015). This is much less than in 2006, when GHG emissions from refining were still 3.8 $MtCO_2eq$, 5% of the province's total emissions (MDDEPQ, 2008). The decrease is explained by the closing of the Shell refinery in Montréal in 2009, which emitted 1.7 $MtCO_2eq$ (Whitmore and Pineau, 2015). In the 1980s, emissions were even higher, since Quebec's refining capacity was three times higher than today (MDDEPQ, 2008). Nova Scotia's Imperial Oil in Dartmouth closed in 2013. The North Atlantic refinery in Come By

Chance, Newfoundland, emitted 0.9-1.1 $MtCO_2eq$ between 2012 and 2013, which accounts on average for 12% of the province's GHG emissions (ECC Canada, 2014).

Given that Quebec does not have any oil production, the crude oil refined in Montreal and Lévis is imported, until recently mainly from North and

Figure 1.5
Map of existing and planned refineries in Canada. *(From Ressources naturelles Canada, 2007.)*



Sub-Saharan Africa and from the Middle East. Now, it mostly originates in the USA, and in particular from the Bakken Shale in Eastern Montana and Western North Dakota. The Irving refinery in Saint-John obtains its crude oil via the nearby maritime Canaport in the Bay of Fundy and by train, also from the Bakken Shale in the USA. It is one of those trains that caused the Lac Mégantic rail disaster, in which 47 people perished. The impact of a possible hydrocarbon extraction in the Saint-Lawrence region on the refining business is uncertain. Additional quantities of crude oil stemming from domestic production, or from the Energy East pipeline, may be treated locally, but may exceed Quebec's capacity or not be of a type suitable for its refineries and may be carried on to New Brunswick or Maine and from there to refineries on the Gulf of Mexico.

There are many open questions regarding the volume of crude oil to be processed by eastern Canadian refineries in the future and hence on future GHG emissions projections. To which extent can Alberta crude oil lead to an increase in production capacity of eastern Canadian refineries? Will that crude oil be treated in addition to Bakken shale oil and other crudes presently used or will it replace those sources? Will refineries in Quebec and New Brunswick adapt their equipment to handle Athabascan heavy crude, which cannot be processed by them at the moment as it is too heavy and viscous? Some plausible scenarios propose that these refineries will continue to treat the lighter crude oil from the Bakken Shale or other shales in Texas, while the heavy Athabascan crude oil from western Canada will transit through pipelines, such as Energy East or Keystone XL, and by maritime way, to refineries in the Gulf of Mexico which are equipped to treat that kind of crude oil. It is to that effect that the marine oil terminals of Cacouna, later abandoned and possibly replaced by another terminal in Matane (*Le Soleil*, April 2, 2015), and of Saint John were included in the now shelved Energy East proposal. The construction of the Keystone XL pipeline, rejected by the Obama government, but approved by the Trump administration, would make those installations redundant, as Keystone XL would directly carry crude oil from Alberta to the Gulf of Mexico.

HYDROCARBON TRANSPORT

At the global scale, oil is the most traded commercial asset (Comité sénatorial, 2013). In Quebec (table 1.3) as well as in the rest of Canada, large quantities of hydrocarbons are transported by pipeline, train, trucks or boat, and these quantities have dramatically increased in recent years. The number of tank cars transporting oil for the Canadian National and the Canadian went from 500 in 2008 to 140 000 in 2014. Oil exports from the east and west coasts of Canada now reach 80 million tons per year (Comité sénatorial, 2013).

Table 1.3
Overview of hydrocarbon transport in Quebec. *(From MDDELCC and MERN, 2015.)*

TRANSPORT	KEY FIGURES
Road	Hydrocarbon transport accounts for only 1.4% of vehicle-km of freight transport, but accounts for over half of all trips, due to the distribution of refined products over short distances.
Rail	Hydrocarbon transport by rail increased by 30% between 2007 and 2013.
Pipeline	Hydrocarbon transport by pipeline generates 0.6% of GHG emissions of the transport sector (MERN, 2013). Quebec has more than 12 000 km of pipelines that cross over 250 municipalities; 85% of transported oil comes from Quebec refineries and 87% is transported outside of the province.
Ship	On average, per year, 1 800 ships carry about 20 Mt of hydrocarbons on the Saint-Lawrence. In 2013, 250 of those were transatlantic tankers.

The development of the hydrocarbon sector in Quebec and Atlantic Canada would entail additional transport capacities, which is synonymous with an increase in GHG emissions and also of the risk of accidents. The amount of CO_2 emitted would of course depend on the final destination and on the mode of transport. On one hand, domestic production could reduce imports, which cover three quarters of Quebec's oil consumption. On the other hand, the vast majority of crude oil refined in Quebec is exported, and so may additional crude oil produced locally. This is also the case of crude oil potentially transported from western Canada, for which two important projects are currently under way or under consideration (CAPP, 2015; MDDELCC and MERN, 2015):

1) The inversion of the 9A and 9B Enbridge pipelines, which will allow to

transport up to 300 000 b/d of Albertan crude oil from Sarnia, Ontario, to Montreal;
2) TransCanada's Energy East pipeline project, which would entail the construction of a new pipeline, using parts of an existing pipeline[7], in order to transport up to 1.1 Mb/d of crude oil from Alberta to Saint-John, New Brunswick.

The GHG emissions in the transport sector linked to the Energy East pipeline would be around 500 ktCO_2eq per year (CMM, 2015), whereas the inversion of the 9A and 9B Enbridge pipelines would not generate any new emissions since they are already in operation. These emissions are much lower than those that would arise from the transport by railway of the same quantity of crude over the same distance (MDDELCC and MERN, 2015). According to TransCanada (2016), the pipeline could replace up to 1 570 tank car trips every day. The emission numbers do not take into account the upstream and downstream emissions, i.e. emissions arising from the production of the crude oil, and from its refining and final use, which are much more important than the transport emissions themselves. According to the Pembina Institute and the *Association québécoise de lutte contre la pollution atmosphérique* (AQPLA), upstream emissions would be of the order of 30-32 MtCO_2 per year and downstream emissions around 120 MtCO2 per year (Flanagan and Demerse, 2014). These indirect emissions will be discussed in sub-section 5.4.

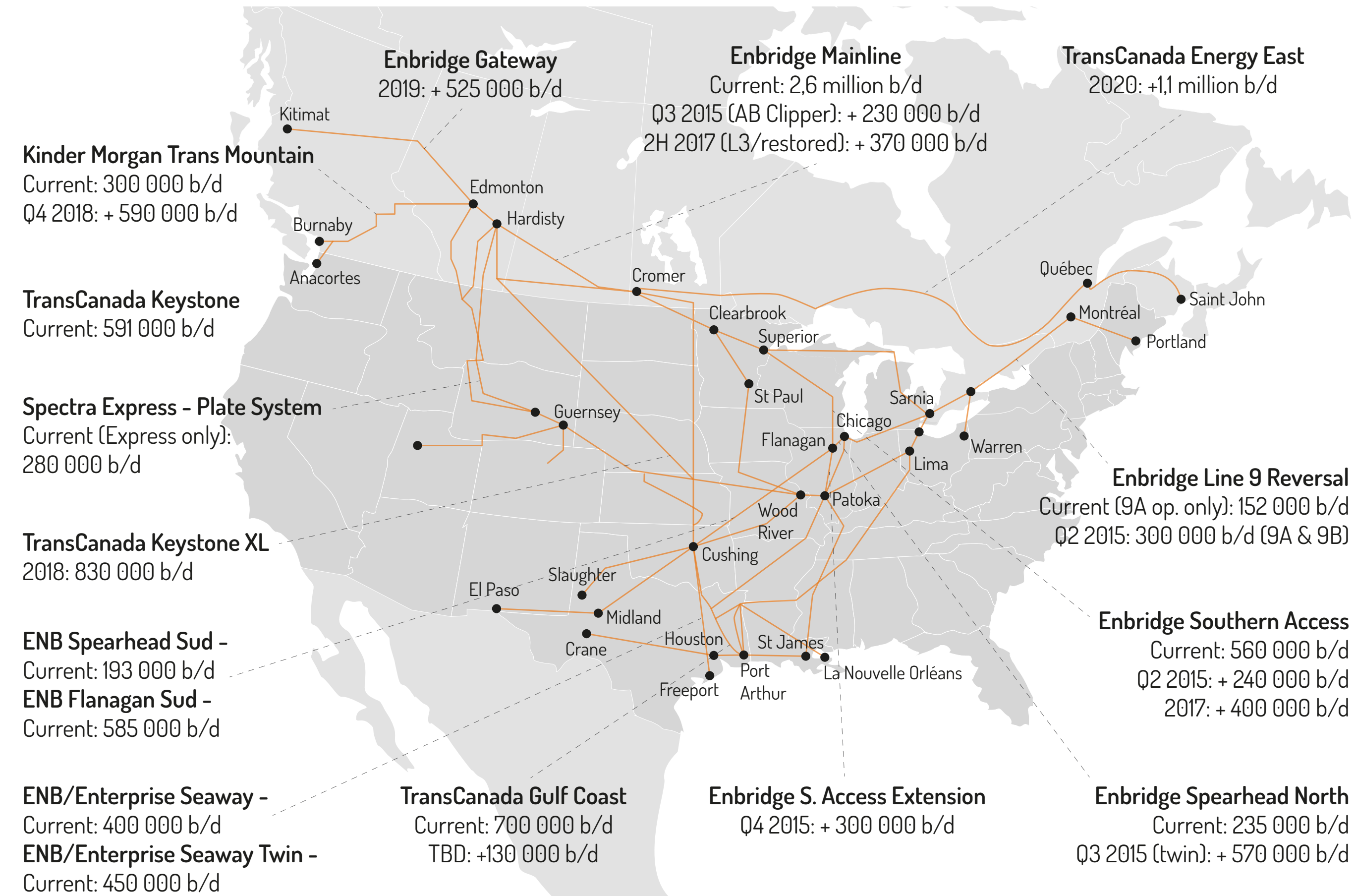
The GHG emissions in the transport sector linked to the Energy East pipeline [...] are much lower than those that would arise from the transport by railway of the same quantity of crude over the same distance.

The pipelines are embedded in a pipeline network at the continental scale aiming at transporting Albertan crude oil to the large refining centres and oceans in order to export it (figure 1.6). The network would include the Energy East project to the Atlantic Ocean and the Northern Gateway and Trans Mountain projects to the Pacific, as well as the Keystone XL project on the continental side leading to the refineries in Illinois and Texas. On the Atlantic side, it would be completed by the Canaport oil terminal, costing 300 million C$, and would allow to export Canadian crude oil by boat (Irving Oil, 2016), and possibly a second terminal in Matane or another sport on the Saint-Lawrence river, costing 840 million C$ (*Le Soleil*, April 2nd, 2015). Oil sands production in Alberta currently represent around 2% of the world's oil production (Brandt, 2011), but its continued development relies on having access to refineries and oil terminals in order to carry the crude or refined products to the USA, to Europe and to Asia.

Photo: Sean Lamb / Wikimedia

[7] Of the 4 600 km of the project, a 3 000 km segment from the Alberta-Saskatchewan border up to Ontario already exists as a gas pipeline, which would be converted into an oil pipeline. The remaining 1 600 km would be built in Alberta, Ontario, Quebec and New Brunswick (TransCanada, 2015).

Figure 1.6
Path and characteristics of crude oil pipelines planned in North America. *(From CAPP, 2015.)*



In Quebec, oil supply sources could drastically change as a result of these projects. The dominance of foreign, especially American, crude oil could give way to a dominance of Western Canadian oil, similar to the transition that has occurred in Ontario in recent years (figure 1.7), provided it is technically feasible to refiner this crude oil in Quebec refineries.

At the present moment, refineries in Quebec and New Brunswick import 77% of their crude oil from outside of the country, most of it by rail from the USA and the rest by ship from overseas (CAPP, 2015). The part of American crude oil has considerably increased in recent years, mostly through the contribution of shale oil from the Bakken formation in Montana and Dakota (CAPP, 2015) (figure 1.8).

Regarding the GHG emissions budget, different factors have to be taken into account. A transition from transport by rail or ship to pipelines, accompanied by a switch from foreign to local oil would decrease the transport emissions linked to crude oil. On the other hand, Albertan crude oil has higher CO_2 emissions during its production than conventional oil, but in the same range as shale oil from American sources. Here again, the effect on the total climate impact differs from that on provincial inventories, since the production-based emissions as well as the overseas transport-based emissions are not included in Quebec or New Brunswick's inventories (also see sub-section 5.4).

Figure 1.7
Portrait of the North American crude oil market. *(From CAPP, 2015.)*

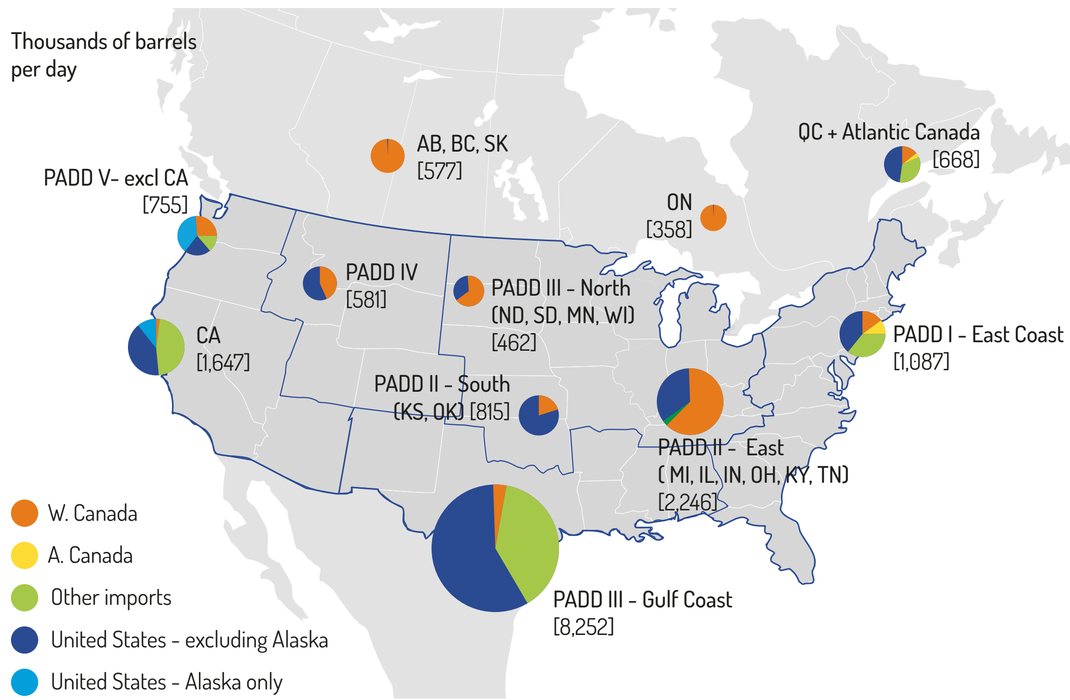
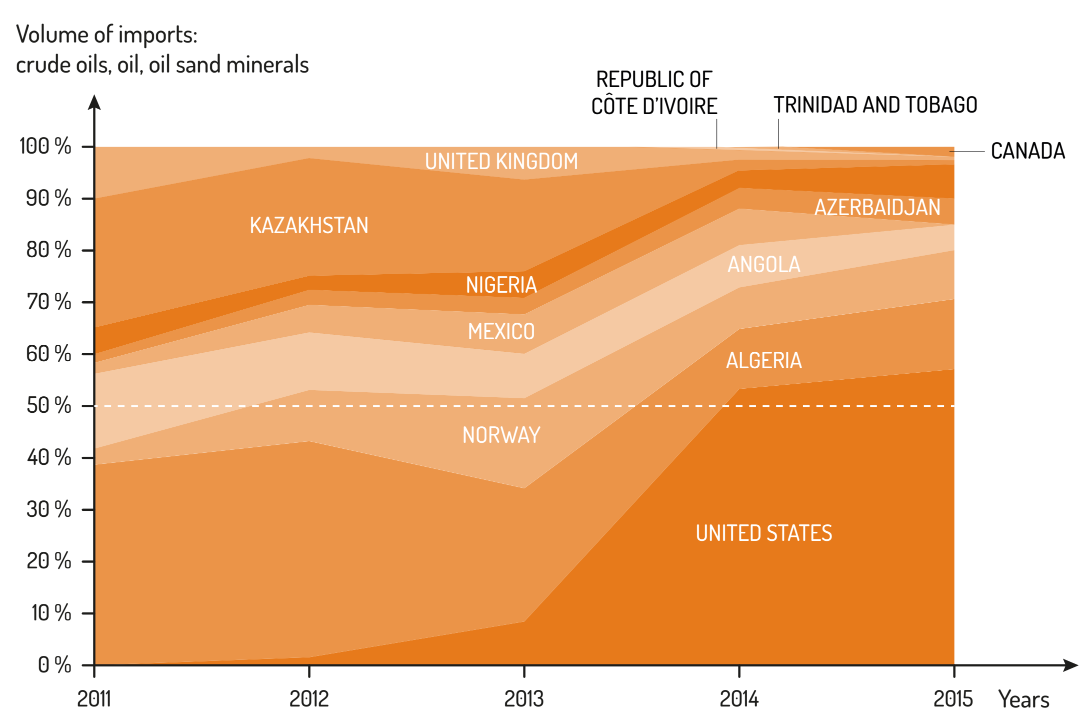


Figure 1.8
Sources of crude oil imports to Quebec from 2011 to 2015. *(From Whitmore et Pierre-Olivier Pineau, 2015.)*



SUBSTITUTION EFFECTS AND THE FINAL CONSUMER

In order to evaluate the global climate impact of the development of a hydrocarbon sector in the Saint-Lawrence region, it is necessary to go beyond the relatively narrow frame of provincial or national inventories. At the planetary scale, the impact of the hydrocarbon sector stems mainly from its use, followed by production, transformation, transport and distribution. For oil from tar sands, for example, extraction and transport only represent one fifth of lifecycle emissions.

In order to calculate the total climate impact of the hydrocarbon sector development in the Saint-Lawrence region, three main effects have to be taken into account:

1) The substitution of different forms of primary energy supply;
2) The substitution of hydrocarbons from different origins with different CO_2 signatures;
3) The impact of the hydrocarbon sector development on demand and offer.

› THE SUBSTITUTION OF DIFFERENT FORMS OF PRIMARY ENERGY SUPPLY

The different forms of fossil fuels likely to be developed in the Saint-Lawrence gulf region have very different GHG signatures, i.e. GHG emission per unit of energy produced (table 1.4). The emissions are all less than those of coal, which supplies 55.9% of Nova Scotia's electricity, but considerably higher than those hydroelectricity, prominent in Quebec and Newfoundland's electricity supply, or nuclear energy, still present in New Brunswick, but no longer in Quebec. The climate impact of a new hydrocarbon development in the Saint-Lawrence gulf region therefore depends of the energy mix of each province. Thus, in Nova Scotia, a substitution of coal by natural gas would lead to a decrease in GHG emissions, whereas a substitution of hydroelectricity by natural gas in Quebec would lead to an increase in the province's GHG emissions. At the planetary scale, a substitution of coal plants by natural gas plants is often viewed as one of the most promising solutions in the transition phase to a low-carbon economy, due to the relatively large supply of natural gas and the flexibility of this energy sector, characterised by a rather short lifecycle.

At the global scale, in 2014, coal accounted for 30% of all primary energy used (BP, 2015). However, in the USA, the shale gas boom led to a rapid decline in coal use, which is one of the main reasons for the recent decrease of GHG emissions in the country. In Eastern Canada, the potential of GHG emissions reductions through substitution by natural gas (conventional or non-conventional) is limited to Nova Scotia, the last province of the Atlantic region, and even of eastern Canada since Ontario's final phase-out of coal in 2014, to still use coal for electricity production.

At the planetary scale, a substitution of coal plants by natural gas plants is often viewed as one of the most promising solutions in the transition phase to a low-carbon economy.

In Quebec, the potential for substitution effects is limited. Electricity, which represents 39.7% of total energy consumption, is almost entirely produced by hydroelectric dams, which have little (or no, according to which inventories are consulted) GHG emissions (MERN, 2013). The second most important form of energy is oil, which represents 38.1% of total energy consumption (MERN, 2013). Since three quarter of oil use is due to road transport, a massive substitution massive by other energy sources is difficult to envisage in the short or middle term, even taking

into account the objective of Quebec's 2030 energy policy to bring the number of electric vehicles to 100 000, or 2% of all vehicles, by 2020, and one million, or 20% of all vehicles, by 2030 (Québec, 2016a). The sectors in which a substitution effect is the most likely are the residential and commercial sectors, responsible for 18.5% and 15%, respectively, of total energy consumption (MERN, 2013). During the 1980s and 1990s, a partial switch to electricity took place in those sectors, in reaction to high oil prices on world markets. The availability of more affordable hydrocarbons from domestic production could favour a transfer from electricity to natural gas, which would entail an increase in CO2 if it replaces electric heating, and a decrease if it replaces oil furnaces. The same reasoning applies to the industry sector, which accounts for 37.2% of energy consumption and is 49.8% electric (MERN, 2013), but with much less flexibility than the residential and commercial sectors.

Table 1.4
Lifecycle GHG emissions by unit of energy produced for different types of hydrocarbons based on the "well-to-wheels" approach. *(From Roy et Ménard, 2014.)*

TYPE OF HYDROCARBON	GHG EMISSIONS (GCO_2EQ/MJ)[i]	REFERENCES
Conventional oil, continental	12-47 (most likely range 20-30)	New Fuels Alliance (2009) IHS Cera (2012)
Conventional natural gas, continental	7-21 (most likely range 15-21)	Weber et Clavin (2012)
Shale gas, continental	7-34[ii]	Weber et Clavin (2012) Roy *et al.* (2013)
Shale oil, continental	9-13[iii]	IHS Cera (2014) Legendre (2014) US Department of State (2013)
Conventional oil, marine	10-28	New Fuels Alliance (2009) IHS Cera (2012)
Conventional natural gas, marine	7[iv]	Skone (2011)

Note: gCO_2eq/MJ = gram CO_2 equivalent per Megajoule.
[i] Does not include uncontrolled emissions from natural cracks or emissions after decommissioning.
[ii] There are uncertainties about fugitive emissions before and after the decommissioning of the site.
[iii] Based on a limited number of data and assuming flaring of shale gas.
[iv] Based on a a single study, whose validity is questionable.

› THE SUBSTITUTION IF HYDROCARBONS FROM DIFFERENT GEOGRAPHICAL ORIGIN

In the hypothetical situation in which hydrocarbons produced in Canada were to replace hydrocarbons made elsewhere, the net climate impact would result from the difference in lifecycle emissions, also called well-to-wheel emissions, of the hydrocarbons of different provenience, including extraction, refining, distribution and combustion. As far as oil from tar sands is concerned, it is generally admitted that those emissions are higher than those of most conventional oil used in Europe or in the USA. Brandt (2011) places the emissions of oil from tar sands at about 105 gCO_2eq/MJ and those of conventional oil in the European Union at about 85 gCO_2eq/MJ. The US State Department estimates that the emissions from oil from tar sands are on average 17% higher than those of conventional oil used in the USA (USDS, 2014). For the *Keystone XL* pipeline, supposed to carry 830 000 b/d of Canadian crude oil, this would lead to 1.3-27.4 $MtCO_2eq$ of supplementary emissions with respect to the reference crude oil (USDS, 2014). There are however large differences in lifecycle emissions of different crude oils (table 1.5). Emissions from Nigerian crude oil are comparable to those from crude oil from tar sands (Brandt, 2011), as are those of some crude oils from the USA or from Venezuela (not included in table 1.5) (CAPP, 2014). According to the International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG), GHG emissions from hydrocarbons produced in Québec would be lower than those of hydrocarbons from other comparable origins (Roy *et al.*, 2013; Roy and Ménard, 2014).

Table 1.5
Comparison of GHG emissions well-to-refinery of the 10 mains proveniences of oil to the European Union *(from Brandt, 2011)* compared to tar sands oil.

ORIGIN	PART OF OIL USE IN THE EUROPEAN UNION (%)	WELL-TO-REFINERY GHG EMISSIONS (GCO_2EQ/MJ)
Russia	20,9	5,5
Norway	16,3	1,0
Saudi-Arabia	9,5	2,3
Libya	6,8	7,0
Iran	5,6	7,0
United Kingdom	5,6	2,4
Nigeria	3,2	21,1
Algeria	2,7	5,8
Kazakhstan	2,2	7,0
Iraq	2,2	3,3
Canada: tar sands	**-**	**15,9-25**

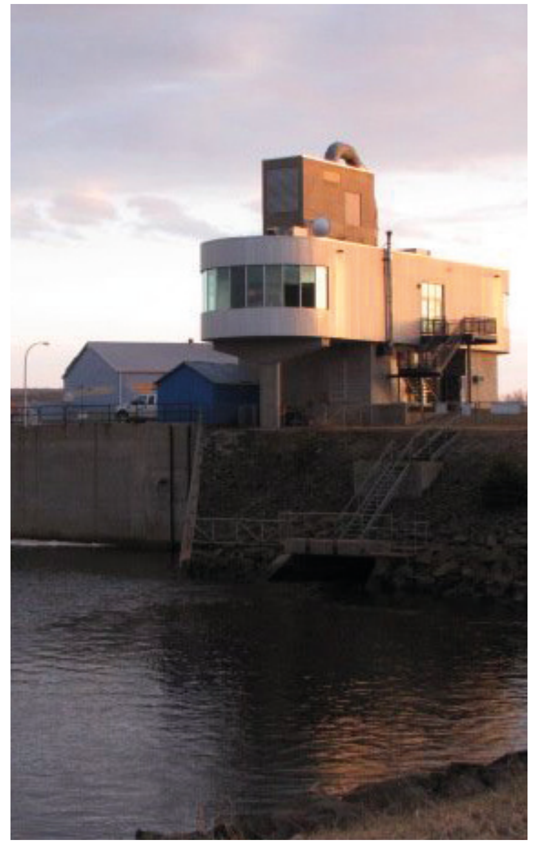
Note. gCO_2eq/MJ = gram equivalent of CO_2 per Megajoule.

› THE IMPACT OF SUPPLY ON DEMAND

The development of the hydrocarbon sector in the Saint-Lawrence gulf region would undoubtedly have an effect on world consumption, since the demand for energy products shows a certain elasticity to supply, mainly through the price signal, but also through investments and availability. In the long run, private and public investments in the energy sector are guided by public policies and can lead to a technological lock-in[8] that can determine energy trajectories for decades. The sums invested in the hydrocarbon sector will not be invested in hydroelectricity, wind power or still marginal or experimental technologies like solar energy, tidal energy (e.g. the Annapolis Royal plant in Nova Scotia) or marine current rotors. In Quebec, the electrification of the transport sector is the main lever in order to achieve a reduction in GHG emissions, given that this sector represents 44.7% of the province's emissions (MDDELCC, 2015). An overabundance of hydrocarbons would not send the appropriate signal to markets and legislators encouraging them to invest in carbon-free energy systems.

In Quebec, the electrification of the transport sector is the main lever in order to achieve a reduction in GHG emissions [...]. An overabundance of hydrocarbons would not send the appropriate signal to markets and legislators encouraging them to invest in carbon-free energy systems.

Photography of the Annapolis Royal plant in Nova Scotia: www.timarine.ca



The same question arises with the creation of new pipeline capacities, which can have an encouraging impact on the development of tar sands. It could of course be assumed that in the absence of pipelines, crude oil would continue to be produced at the same rate and transported by train, as is currently the case. However, this mode of transport is much more expensive (9-30 C$/barrel by train vs. 7-10 C$/barrel by pipeline) and faces capacity bottlenecks (Brunel, 2015), not to mention the risk of accidents. In a context in which investments in tar sands are volatile, the transport factor can play a determinant role. The International Energy Agency, in its *World Energy Outlook 2013*, concludes that the expansion plans for tar sands depend on the availability of pipelines. This opinion is ahred by many political figures in Canada, for example Joe Ceci, finance minister of Alberta: 'If we can bring our oil to the world market, it would significantly increase investments in the country" (CBC News, January 19, 2016). Some analysts play down the importance of pipelines and argue that rail transport could play the same role (Navius Research, 2015). The tar sands development plays a crucial role in Canada's GHG emission inventory since they represented 8.7% of emissions in 2012 and the largest source of increase since 1990 (Environment Canada, 2012; CAPP, 2014).

In the final end, the potential impact of the export of Canadian oil to Europe or Asia on the total oil use will be determined by price levels. Several studies expect an increase in world demand, assuming that Canadian oil would be cheaper than world reference prices (Erickson and Lazarus, 2014; Navius Research, 2015). This effect is however difficult to anticipate, given the uncertainty surrounding the elasticity of demand and future oil prices. These uncertainties explain the large range of 1-110 $MtCO_2eq$ of world GHG emissions that would be caused by the *Keystone XL* pipeline (Navius Research, 2015). /

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[8] The expression *carbon lock-in* comes from the PhD thesis of G. C. Unruh from 1999 and describes the process of technological and political co-evolution that has led to economies of scale and to the dominance of energy systems based on fossil fuels. The notion also conveys a temporal dimension as investments at a certain point in time determine the trajectory for the lifetime of the infrastructures created. This situation can lead to market and political failure in that competitive and low-emission energy production systems will be slowly or not at all adopted.

Photo: É. Pelletier

THE INCLUSION OF THE CLIMATE DIMENSION IN THE POLITICAL PROCESS SURROUNDING HYDROCARBONS IN QUEBEC

In Quebec, the fight against climate change is framed by the two latest climate change action plans (PACC 2005-2012 and 2013-2020). These plans insist on investments in renewable energies and do not mention the development of the hydrocarbon sector, to the contrary of the 2030 Energy Policy, unveiled in 2016, which includes a limited and managed hydrocarbon exploitation. The Quebec government had four strategic environmental assessments (SEE) realized, one about the global development of hydrocarbons in Quebec, including transport and local development (under way); one on the development of the hydrocarbon sector on the Anticosti Island (under way); one on the shale gas sector (2011-2014) and one on the hydrocarbon exploration and exploitation in the marine environment (2009-2013). All four address the question of GHG emissions, mainly due to hydrocarbon extraction.

The Energy East project was, before its shelving, also the object of hearings of the *Bureau d'audiences publiques sur l'environnement* (BAPE), in which the question of upstream and downstream emissions was controversially discussed (*Le Devoir*, April 27, 2016; May 12, 2016).

The 2030 Energy Policy aims at "making Quebec, by 2030, a North-American leader in the fields of renewable energies and of energy efficiency [and build] a new, strong economy with a small carbon footprint" (Québec, 2016a, p. 11, free translation). At the same time, this policy is "favourable to a limited and controlled hydrocarbon exploitation, compatible with the GHG emissions reduction objectives" (Québec, 2016b, p. 60, free translation). The policy also confirms that the Energy Est project will be submitted to an environmental evaluation process, which will include an evaluation of GHG emissions. This requirement derives from the Trade and Cooperation Agreement between Ontario and Quebec, specifying seven conditions for the approval of the Energy East project, including the question of climate change (Ontario, 2014). This particular condition was inspired by the "climate test", which the Obama administration submitted the *Keystone XL* to, in order to assess the net effect on the US emissions (Flanagan and Demerse, 2014).

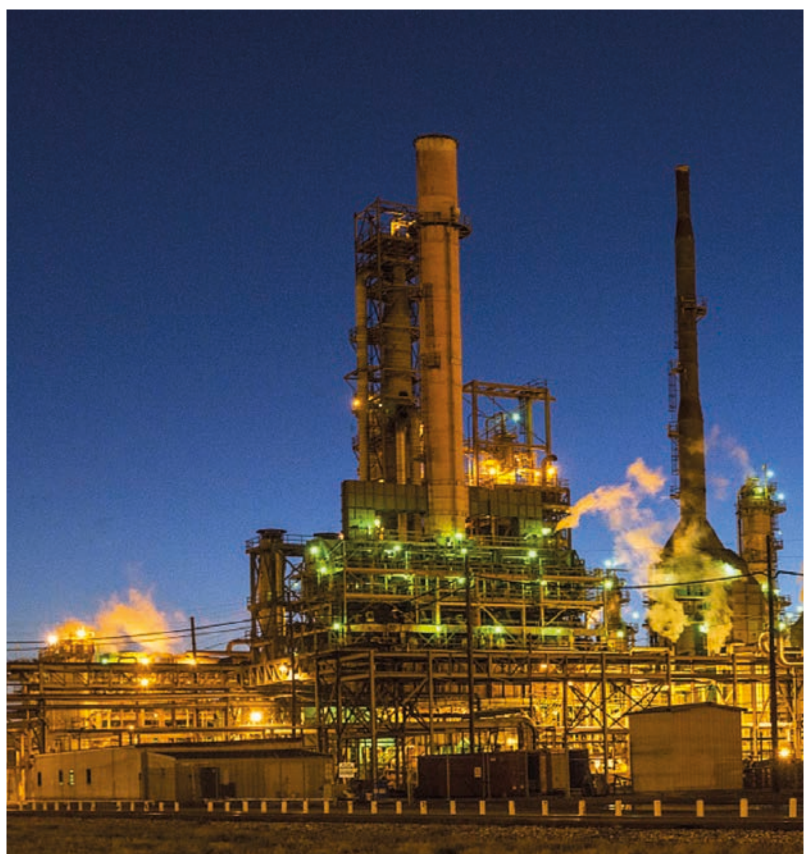
Environmental organisations as well as the Montreal Metropolitan Community want the federal government to add a climate test to energy infrastructure projects, allowing them to evaluate whether those projects are compatible with the national and international GHG emissions reduction targets (*Le Devoir*, February 24, 2016; CBC, January 27, 2016). The new Canadian government in place since November 2015 seems open to that suggestion since the methodology proposed by Environment and Climate Change Canada for the environmental evaluation of projects such as pipelines would not only include direct GHG emissions, but also those linked to the production of the oil and gas transported (upstream emissions), as well as the question, "whether the upstream emissions in Canada would occur if the project wasn't realized" (*La Presse*, March 18, 2016). /

The 2030 Energy Policy aims at "making Quebec, by 2030, a North-American leader in the fields of renewable energies and of energy efficiency [and build] a new, strong economy with a small carbon footprint". At the same time, this policy is "favourable to a limited and controlled hydrocarbon exploitation, compatible with the GHG emissions reduction objectives".

Photo: TransCanada - energyeastpipeline.com

CONCLUSION

There is little doubt that the development of the hydrocarbon sector in Quebec and Atlantic Canada would lead to an increase in GHG emissions. At the present time, it is virtually impossible to quantify a priori the emissions linked to the exploitation of continental or marine hydrocarbon deposits, given that their nature and quantity are too ill defined. The main climate impact of the exploitation of deposits in Eastern Canada and of the pipeline transport projects for Western Canadian oil through the Saint-Lawrence region will mainly occur outside of the country, since most of these resources are destined for exportation. It is difficult to evaluate the net climate contribution of the sector, given the numerous assumptions on substitution, additionality and supply-demand relationships that can be made. What is however beyond doubt is that massive investments in the hydrocarbon sector could determine energy trajectories for decades to come, just like the large hydroelectric investments did in Quebec in the 1970s. Norway, a Nordic country in many ways similar to Quebec (similar population, climate, hydroelectric resources, etc.), has demonstrated that it is possible to maintain a relatively good climate performance while developing an important hydrocarbon sector. Norway's per capita emissions are similar to those of Quebec, even though a third of those emissions comes from hydrocarbon exploitation in the North Sea. This means that, if Quebec wants to maintain or even improve its GHG emissions performance, while developing a hydrocarbon sector, it must undertake GHG reductions emissions in other sectors that go far beyond what current climate policies anticipate. This is the case, but to a lesser degree, in the Atlantic provinces, which already use hydrocarbons in their electricity supply. We can conclude that the development of the hydrocarbon sector in Quebec and in the Atlantic provinces would make it considerably harder to reach the climate goals that the provinces set themselves for 2020 and beyond and that an exploitation of hydrocarbon reserves in the Gulf of Saint-Lawrence can hardly be reconciled with the fight against the global climate crisis. /



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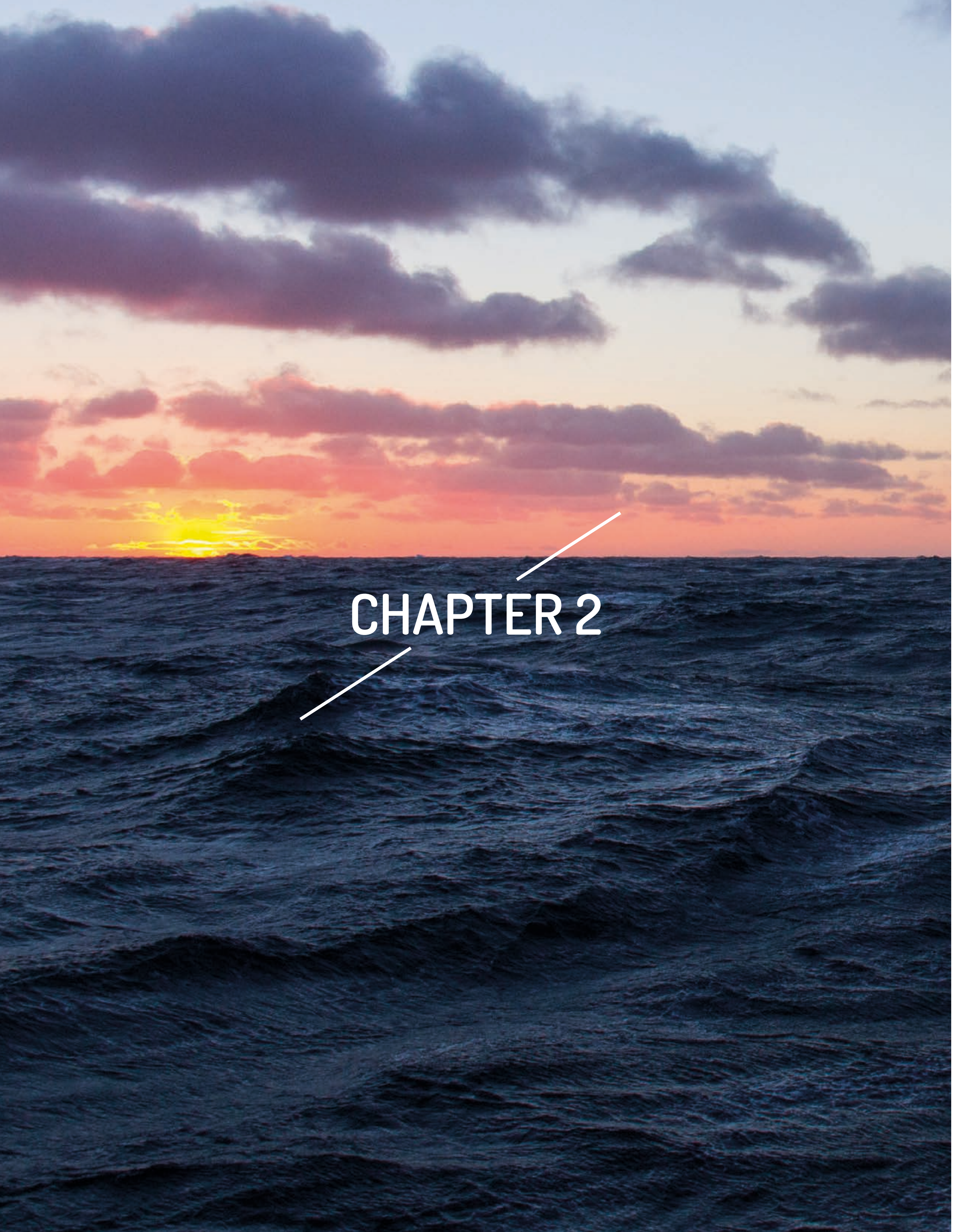

Hydrography of the gulf of St. Lawrence

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The present chapter presents some notions on the hydrography of the Gulf of St. Lawrence in the context of oil exploration and extraction. The properties of the water layers, the currents and the ice cover are featured with an emphasis on their great variability and on the difficulties in forecasting the dispersion of pollutants in a marine environment. We also emphasize the fact that deep circulation in the Gulf, i.e.: under around 30 meters deep, is moving upstream. Such is a counterintuitive property; yet, it is typical to circulation in coastal environments. The St. Lawrence Estuary and the Saguenay Fjord are not protected from a pollution associated to hydrocarbon exploration or extraction activities that could possibly occur upstream, in the Gulf. Furthermore, this chapter poses a few fundamental questions needing more depth before an oil and gas exploration attempt in the Gulf. One such question deals with the impacts that deep spills -30 to 470 m – could have, whether they are chronic or acute, on water quality, dissolved oxygen as an example, and on the ecosystem upstream from the St. Lawrence Estuary and especially at the head of the Laurentian Channel.

Photo:
D. Kalenitchenko

HIGHLIGHTS

- A large amount of uncertainty remains with respect to the dynamic of pollutants, such as hydrocarbons, released under the surface of the Gulf of St. Lawrence.

- Such a dynamic is conditioned by physics, water chemistry, biology, sedimentation and the type of hydrocarbons.

- The presence of ice affects extraction of hydrocarbons operations, consequences of a leak and clean-up operations, which must be taken into account when planning structures and operations at-sea.

- The St. Lawrence Estuary and the Saguenay Fjord could be affected by exploration or extraction of hydrocarbons occurring upstream in the Gulf.

- The west coast of Newfoundland is the most susceptible to receive floating contaminants from *Old Harry* and such a possibility could also affect the Îles-de-la-Madeleine.

INTRODUCTION

A question comes to mind, spontaneously, with oil exploration or extraction in the Gulf of St. Lawrence: What would become of a quantity of oil, or any other pollutant associated to oil activities at-sea, that would accidentally be spilled into the sea? Such a spill could occur just as much on the surface, as it would in deeper water, and turn out to be just as acute (i.e. a sudden and highly visible release of a large quantity of oil as would happen in the case of a tanker shipwreck) as it would be chronic (i.e. a weak leak, hardly detectable over a long period of time). Hence, where would the leaked oil go? Which coast, which marine ecosystems would be affected? How long would it take?

Answering questions relating to drifting, the spreading and the dispersion of pollutants in marine environments requires necessarily a good knowledge on water properties in marine environments, on marine currents and sea ice. Yet, the task is not that simple as dispersion processes are misunderstood due to the complexity of oceanic currents, let alone, in the Gulf of St. Lawrence, the presence of a seasonal mobile and fragmented ice cover. Such complexity is inherent in the fact that the ocean is a turbulent fluid influenced by several astronomic, hydrological, and atmospheric forces that vary greatly over time and space. That said, today, turbulence still represents one of the biggest un-resolved issues with respect to fluid mechanics and physical oceanography.

The turbulence propriety of water flow is at the base of the reason why, in water, currents fluctuate, swirl a lot and are hardly predictable. Furthermore, the swirls which characterize any oceanic flow occupy a huge slew of spatial and temporal dimensions, and that makes their representation a difficult task. The smallest eddies, characterizing the ocean, can be measured in centimeters while their lifespan could last but a few seconds. In technical terms, those are dissipation scales knows as the Kolmogorov Scales. These small eddies live side by side and interact on a continuum of eddies of variable size up to the largest ones; the latter are called the Rossby Vortices. In the Gulf of St. Lawrence, these vortices feature a diameter of 10 to 100 km; their life will span over several days. We will show hereafter an example of one of those vortices in the Gulf of St. Lawrence.

There is a large line of scales relating specifically to oceanic runoffs overlapping the extraordinary complexity of turbulent runoffs which makes it so difficult to represent, to understand and to predict marine currents. There is no computer powerful enough, nor is there any method of observation sophisticated enough, and capable of representing the currents of the overall Gulf area with all the time and space series. A compromise is then always necessary: one must choose between obtaining a fine representation of currents over a small region or a gross representation over a large one. Or, even though pollutants spills associated to exploration or extraction activities, chronic or acute, occur in a localised fashion at first, (e.g. pipe breach, capsizing of a ship or of a platform), the ensuing spread and dispersion could, in a few days, contribute to the increase of the area of a slick, until it is influenced by all the runoff scales, which characterize motion as per Kolmogorov's model (≈1 cm) all the way to Rossby's (≈10-100 km), hence making it difficult to track the slick for reasons mentioned above.

In this chapter we will insist on the vortices notions and runoff scales as they are fundamental to understand the complexities with respect to the prediction of spread and dispersion of pollutants in the Gulf of St. Lawrence. We will also raise a few research questions which, to us, seem fundamental in the context of the development hydrocarbons in this marine environment. /

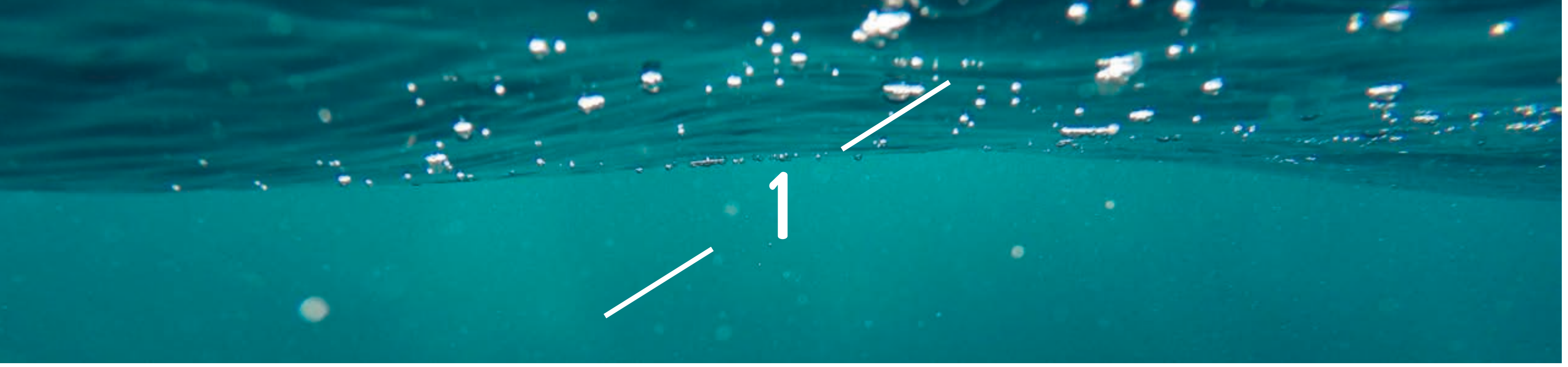


Photo: Pixabay

WATER LAYERS

Prior to discussing currents, it is important to present the larger vertical structure of the water layers which characterize the Gulf and to expose certain associated notions that will help understand vertical exchanges. Therefore, it will be easier to understand the way in which hydrocarbons may -or may not- move to one layer, depending on their density and the structure of the water layer.

A fundamental and general ocean characteristic, as it applies in this instance to the Gulf of St. Lawrence, lies in the fact that its environments are generally stratified from the surface to the bottom, i.e. the volume of the sea water mass (generally referred to with the Greek letter ρ), determined by temperature (*T*), salinity (*S*) and pressure, varies according to the depth. Even if more dense waters are usually found under lighter waters, the reverse is also possible, momentarily that is, when for example surface waters cool off in the fall and in the winter to a point of becoming more dense than warmer waters below them. That unstable situation then generates a diving motion of the denser waters and turbulent convection movements that mix that layer of dense surface waters with the lighter waters found underneath them, to a point when they create a new equilibrium. Below, we will explain that this process is important in the Gulf of St. Lawrence.

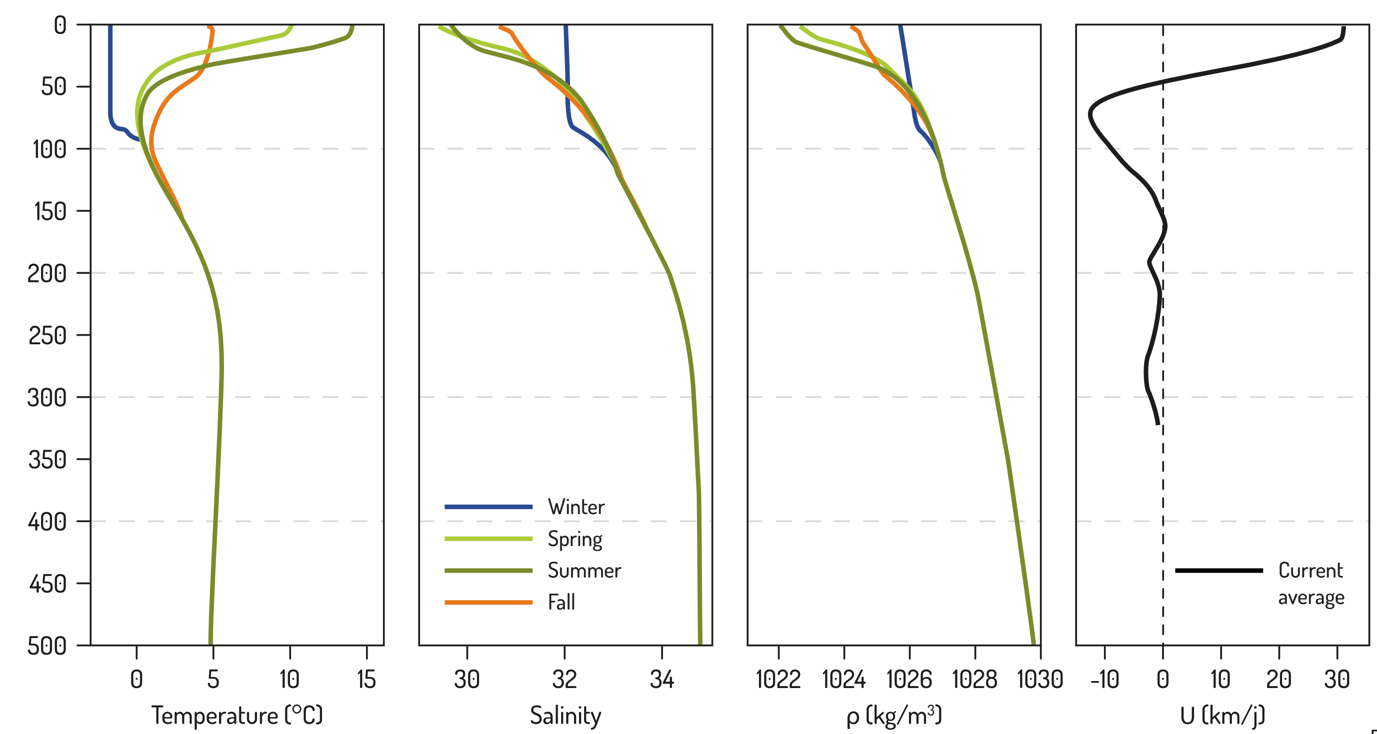
Vertical stratification in the Gulf and its seasonal variations play a fundamental role for the vertical exchange of energy, the quantity of movements (i.e. currents), heat, salt, nutrients, chlorophyll, larvae of invertebrates, zooplankton, sediments and pollutants. Generally, the stronger the stratification, i.e. the larger the differences in the volume of the masses between two depths, the more difficult it is for the vertical exchanges to occur. As an example, light hydrocarbons will tend to remain at the surface and diluting will become increasingly difficult in deeper layers if the surrounding stratification is strong. Conversely, heavier hydrocarbons could get trapped between two waters in some balanced depths, here again due to the surrounding stratification.

[...] light hydrocarbons will tend to remain at the surface [...] Conversely, heavier hydrocarbons could get trapped between two waters in some balanced depths.

Surface stratification, to a depth of around 75 m is very variable due to strong spring atmospheric variations which characterize the Gulf, while stratification in lower depths show very little seasonal variations.

Because of the importance of that stratification, and to make the St. Lawrence oceanographic system more understandable, for the purpose of multidisciplinary discussions, it is useful to simplify the non-uniform and variable vertical structure of the water layer to a reduced number of water layers. The vertical cut will take place where one can find strong stratification variations or other important temperature, salinity or current changes. However, properties are not generally uniform through the layers. As we are about to present, properties of some of those layers vary greatly over the seasons while others show very little change. Figure 2.1 illustrates seasonal evolution of typical temperature, salinity and density profiles of the whole of the Gulf. Temperature and salinity in the first 75 m vary greatly over the seasons while they vary very little in the deeper zones. At surface, average temperature over the whole of the Gulf varies from 15°C in the summer to water freezing point in winter

Figure 2.1
The first three boxes show the seasonal evolution of the typical profiles of temperature (*T*), of salinity (*S*) and mass density (ρ) in the overall of the Gulf, (adapted from Galbraith et al., 2015). The last box shows the vertical structure of the currents averaged on a yearly basis and spatially along a transect between Pointe-des-Monts and Les Méchins, simulated with a digital model of the circulation of the Estuary and of the Gulf. *(Adapted from Figure 7, Saucier et al., 2009.)*



(≈-1,7°C); salinity[1] varies between 29 and 32 g/kg. One should remember that these are spatial averages of the whole of the Gulf and regional differences occur. For example, in some regions of Chaleur Bay, surface waters can reach 20°C. Yet, in other areas, such as the head of the Laurentian Channel (Tadoussac area), surface temperature rarely exceeds 10°C. Below the 200 m mark, seasonal variations in these quantities will not be detected on Figure 2.1. This can be explained by the fact that surface waters are strongly influenced by the significant seasonal cycle - atmospheric cooling/warming – when bottom waters are not sensitive to such. This is a fair example of the effect of the stratification limiting exchanges of vertical waters. Indeed, a typical winter will only allow for the mixing within the first 75 m of the water layer. Should the environment be completely homogenous, cooling would be felt in deeper waters.

Throughout winter, the waters of the Gulf spread -more or less- into two layers, one fairly different from the other with the following characteristics:

1) *Winter surface layer:* over the first 75 m, a homogenous layer with freezing temperature ($T \approx -1{,}7$°C) and an intermediary salinity of ($S \approx 32$ g/kg);

2) *Lower layers:* between around 75 m and, at the bottom. A thick stratified layer - over that layer and the bottom - where temperature hovers varies between 1 and 7°C and where salinity varies between 32 and 35 g/kg.

One should note that, during winter, the surface layer is well mixed, and that the bottom layer remains stratified.

In the summer, there is no thoroughly mixed layer and the system is stratified from surface to the bottom. Surface stratification is created from the combined effect of atmospheric warming and by the increase of the amount of freshwater coming in from the St. Lawrence river and streams above. These two effects contribute in the production of warm and not very salty surface waters, that is lighter than icy and saltier water in that area from the preceding winter. Even though the system is stratified in all the water layers in the summer, we are simplifying this continuous structure in three distinct layers:

1) *The surface layer in the summer:* a highly stratified surface layer of around 40 m in thickness where surface waters are the warmest ($3 < T < 20$°C) and the least salty ($29 < S < 31$ g/kg);

2) *The intermediate cold layer:* stratifies and is found more or less between 40 and 150 m. This layer whose salinity is intermediary ($31 < S < 32$ g/kg) holds the coldest summer waters in the Gulf ($-1{,}7 < T < 3$°C). This cold water is produced the preceding winter through atmospheric cooling and finds itself stuck as a sandwich when surface stratification sets in again in the spring and summer;

3) *The deep layer:* below 150 m one finds very salty, ($32 < S < 35$ g/kg) and warmer water ($3 < T < 7$°C) from the Atlantic. This deep layer is the same as the winter deep layer.

At the end of fall and in the winter, strong winds, the decrease of water coming in from the St. Lawrence River and streams above, and the atmospheric cooling contribute to the production of surface waters denser than the summer surface layer. Such waters dive in and gradually homogenize the surface layer to reach the first 75 m generating in the process winter surface waters which, the following summer, will become the intermediary cold layer, and so on as the seasons go by.

Basically, the vertical structure of the water layer can be divided into two layers in the winter and into three layers in the summer. Only the winter surface layer is homogenous. Every other layer is stratified. Below, we will explain that runoff is very different in each and everyone of those layers.

In terms of environmental assessments, with respect to the dispersion of hydrocarbons in a coastal environment, such as the Gulf of St. Lawrence, it is to properly grasp that, even though it is the norm to cut the summer vertical structure of the Gulf into three distinct layers, as we have just laid out, none of these is well mixed. They are all stratified with different densities, and the strongest stratification is found at the surface layer (Figure 2.1). Such distinction is important because, otherwise, this could lead to significant errors of interpretation and choices of methods of analysis non-justified in environmental studies. Such was the case when, for example, in the SL Ross Environmental Research Ltd. (2012) study on dispersion of oil slicks which considered, erroneously, that the surface layer was homogenous at the first 30 m during summer. A more detailed critic of this study is found in Bourgault and his collaborators, (2014). Any new environmental study on oil dispersion in the Gulf of St. Lawrence shall imperatively take into account the stratification of the entire water layer. /

Photo: Brocken Inaglory / Wikimedia

[1] Salinity expresses the relative number of grams of salt contains in one kilogram of sea water. Historically, salinity was expressed °/oo (per thousand) or with the psu symbol which stands for practical salinity units. In several texts and articles, salinity can be expressed using no unit. In this paper, we use the g/kg. symbol to express salinity.

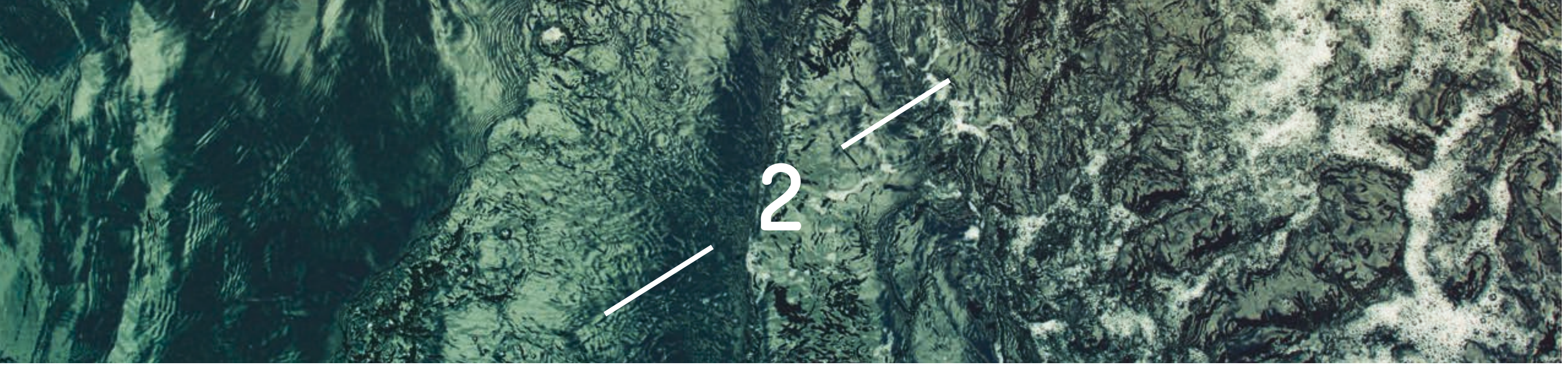


Photo: Pixabay

CURRENTS

Even though currents are complex, as they are variable in space and time (see introduction), there is a need to represent them in a sufficiently understandable manner to promote the exchange of ideas within a multidisciplinary framework. To achieve such a thing, it is necessary to use simplified statistical representations whereby vigilance shall be a must at interpretation time. In fact, these statistical representations might mislead if they are not interpreted properly or misused.

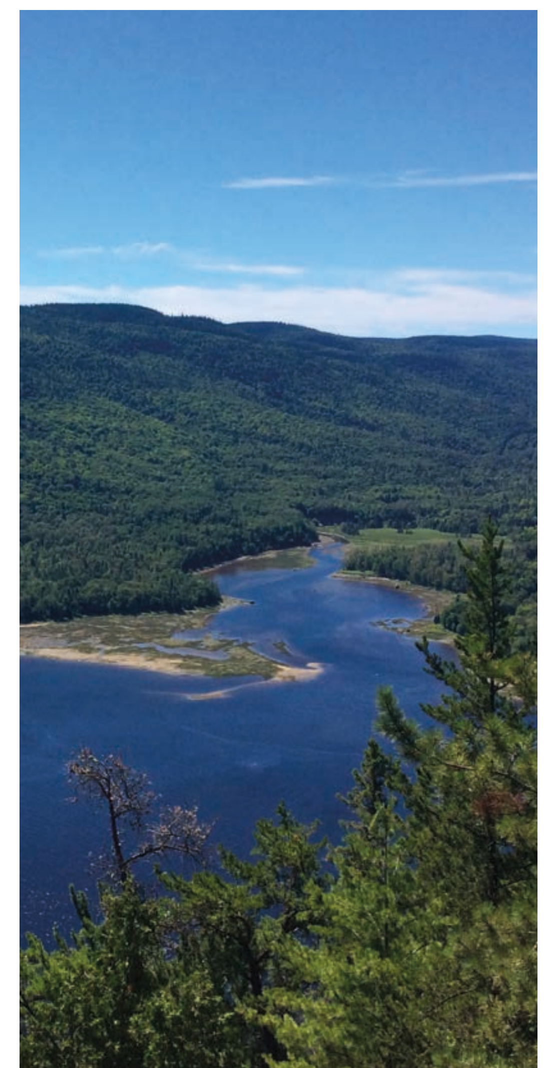
Statistical reduction is a necessary compromise when one wants to show an encompassing and understandable view of the situation, but that does not represent instantaneous conditions at the time of a specific spill. No doubt, the most popular way to simply illustrate currents of the Gulf of St. Lawrence consists in only showing the average of currents calculated over long periods. This statistical method makes larger movement patterns stand out, and currents, which otherwise would be hidden behind much more important current fluctuations caused by winds, tides and vortices. Therefore, we will herein discuss currents two ways: first, we will present average currents associated to estuary circulation and to the horizontal circulation; then we will discuss the variability of those currents and the impact on dispersion.

CIRCULATION IN THE ESTUARY

Gulf currents are moved about by an important influx of freshwater from the St. Lawrence River and stream above, by tides and winds, and by the Coriolis Force (i.e. force caused by Earth's rotation)[2]. The influx of freshwater and winds generate directly and mainly in the surface layer, over some dozens of meters, while currents generated from the on-going flux of tides affect the whole water layer. Coriolis Force does generate currents, but, in the Northern Hemisphere, it creates a deviation - to the right - on those currents generated by other forces. As we will explain below, the larger circulation patterns and greater vortices, such as the Gaspé current, the Anticosti Gyre and the Rossby vortices, are strongly determined by the Coriolis Force.

[2] Contrary to popular belief, Coriolis Force has no effect on smaller-scale runoffs; for example, those in sinks and bathtubs. In the Gulf of St. Lawrence, this Coriolis Force is important in vortices of around 10 km in diameter or more.

There is another phenomenon, a less intuitive one, though it is more fundamental in terms of the dynamic of the currents of the Gulf and especially significant in the context of this paper. We are referring to what is called the Estuarine Pump. As water in the summer or winter surface layer runs off downstream, not unlike a river, it is rather different in the case of layers below, i.e. the intermediary cold layer in summertime and the deep layer. As is found in most coastal, estuarine, and fjords environments, one finds in the deep of the Gulf of St. Lawrence - below 40m - a suction effect, one that drags upstream intermediary and deep waters. This suction effect, called the Estuarine Pump, is created through low-salinity surface water gradually mixing with intermediary and deep salted water and winding up upstream. As surface waters coming from



the watershed become gradually saltier as they run downstream, one must take into consideration that that volume of salted water, hence incorporated in the surface layer, must be replaced. Somehow, this loss of salted water from the intermediary and deep layers, towards the surface layer, that brings into the deep layers highly salted waters form the Atlantic Ocean. Once again, this is a direct consequence associated with the stratification and the longitudinal variability of this stratification. In technical terms, this estuarian pump is fed by the force known as the baroclinic pressure gradient.

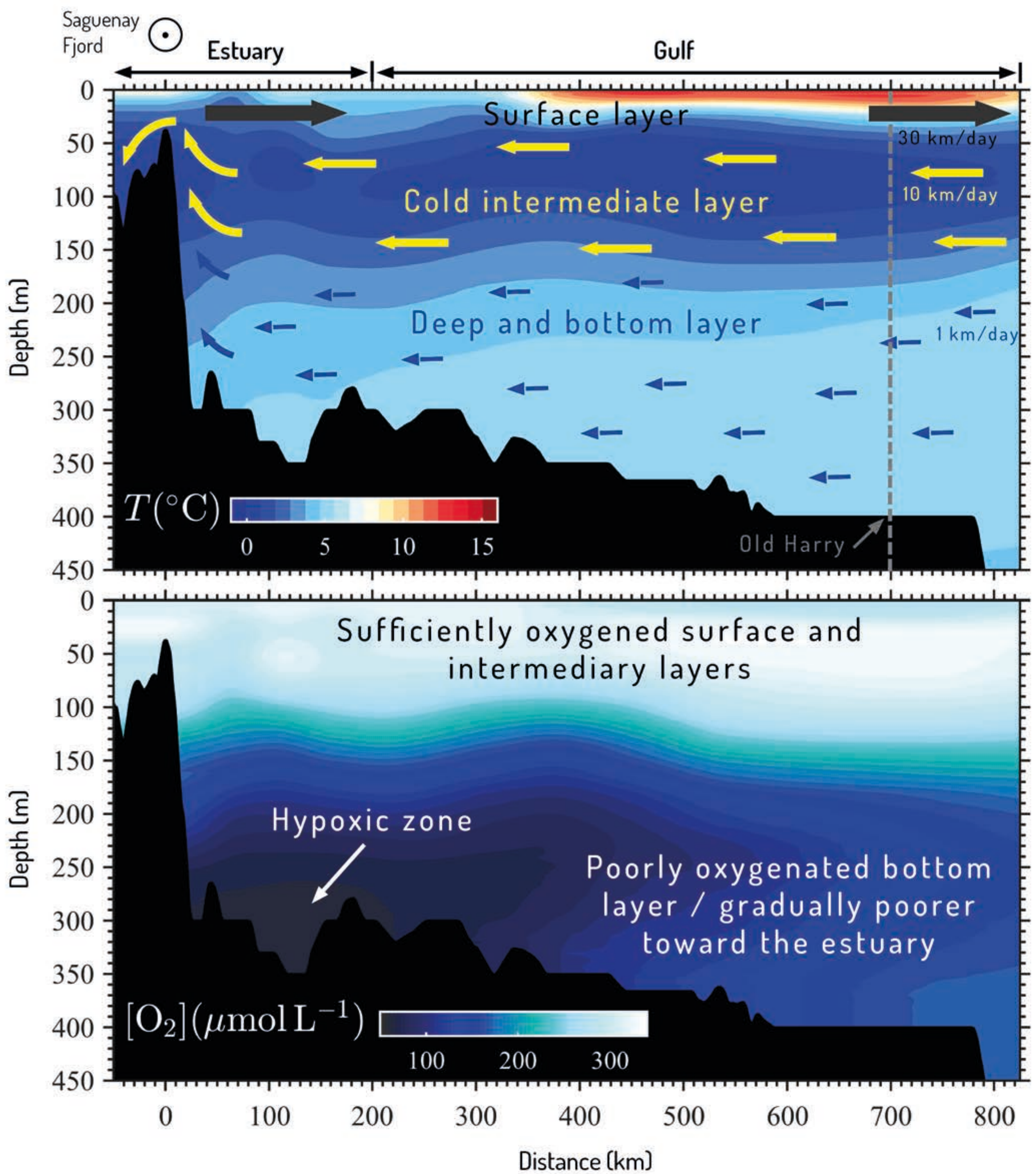
Then, in a simplified way, the average circulation along the Laurentian Channel may be represented as being made of the surface layer running downstream, under which intermediary cold and deep layers run the other way, upstream. That is how a portion of the water in the intermediary and deep layers make it back up to the tip of Île d'Orléans in the Middle Estuary and to the city of Saguenay in the Saguenay Fjord. So, the large majority of the water layer runs off, on average, upstream in the Gulf of St. Lawrence.

Quantitatively speaking, the vertical structure of the currents, as was simulated with a digital model of the circulation in the Estuary and the Gulf (Saucier *and al.*, 2009), is shown at Figure 2.1, (right hand side). This profile not only represents an over-the-years- time series average but also the spatial average along a transversal section between Pointe-des-Monts, on the North Shore and Les Méchins, in the Lower St. Lawrence. On average, the surface layer runs off downstream at an average speed of 30 km/day; the intermediary cold layer runs upstream at around 10 km/day and the deep layer, also going upstream, runs at 1 km/day.

Figure 2.2 shows the structure of the temperature fields and this longitudinal flow along the Laurentian Channel in a

Figure 2.2

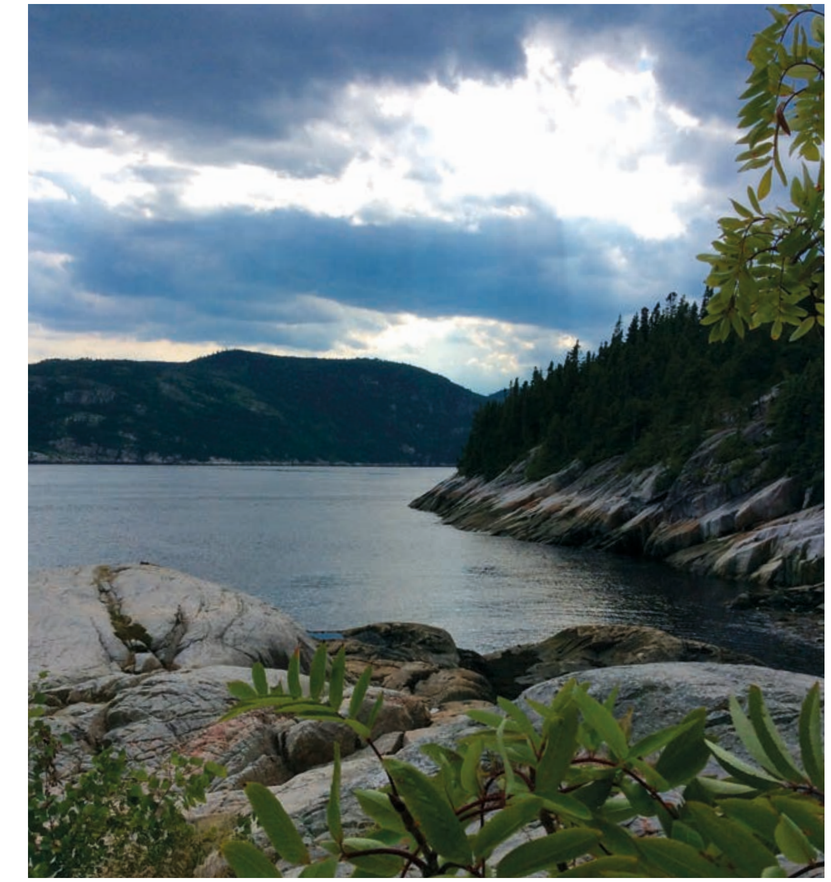
Transversal cut along the Laurentian Channel illustrating the average structure of the temperature fields (high) and dissolved oxygen (low). Arrows in the upper box illustrate in a semi-quantitative way the structure of the average annual circulation and also a crosswise average of the Laurentian Channel. *(Adapted from Bourgault and his collaborators, 2012.)*



most simplified and schematic way. Therefore, one must see such representation as a long-term average and a transversal average in the Laurentian Channel. Below, we shall explain the larger horizontal variations of such circulation and that such a point of view, albeit statistically simplified, is representative in transversal average only.

This aspect of the intermediary and deep counter circulation is fundamental and to be considered in the context of environmental studies relating to the development of hydrocarbons within the oceanographic system of the St. Lawrence. As such, it is the upstream circulation of the largest portion of the water layer, the maritime estuary, the Middle-Estuary and the Saguenay are not sheltered from pollutants coming from the Gulf. For example, the deep waters of the Saguenay Fjord are made by and large of water from the cold intermediary layer that has transited along the Laurentian Channel from the Gulf. These deep waters of the Saguenay are renewed a few times every year, (Belzile *et al.*, 2015). A similar mechanism, also renews the deep waters of the Middle Estuary to Île d'Orléans.

No scientific study has yet looked into what would happen if any oil or any type of pollutant were to be released under the surface layer of the Gulf. What is known in terms of the average longitudinal circulation – as we have so far discussed – suggests that a pollutant that would wind up in the cold intermediary layer, far downstream, for example, via a spill at *Old Harry*, at the Îles-de-la-Madeleine, could be carried upstream at a velocity of 10 km/day and reach the head of the Laurentian Channel (Tadoussac), the Middle Estuary and the Saguenay Fjord in approximately two to three months. If the pollutant ended up stuck in deeper waters, for example, below the 250 m mark, transiting to the head of the Laurentian Channel would span over two

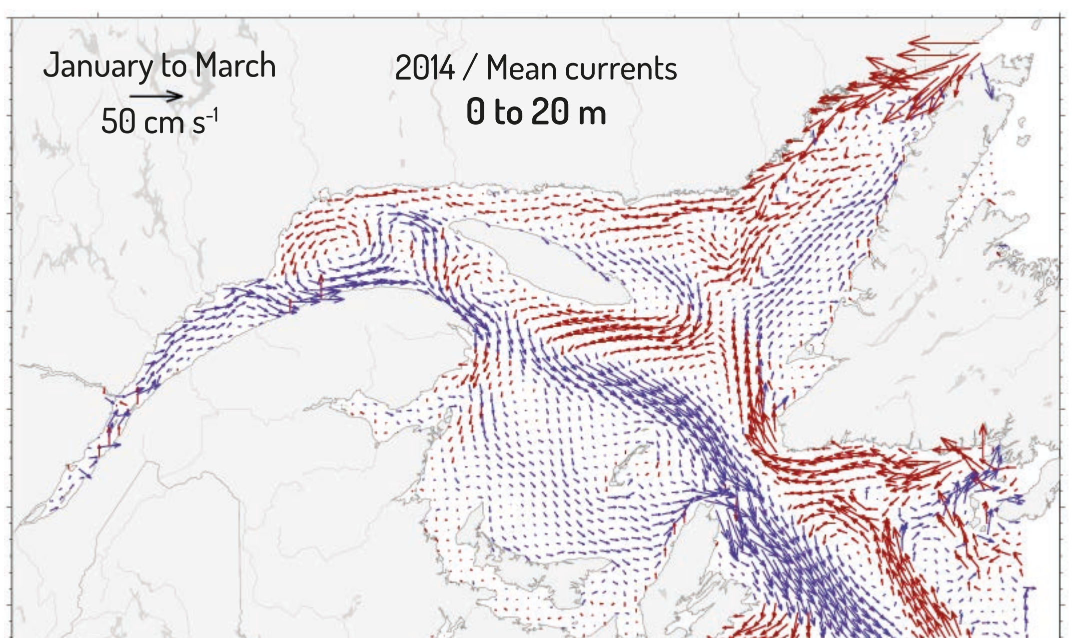


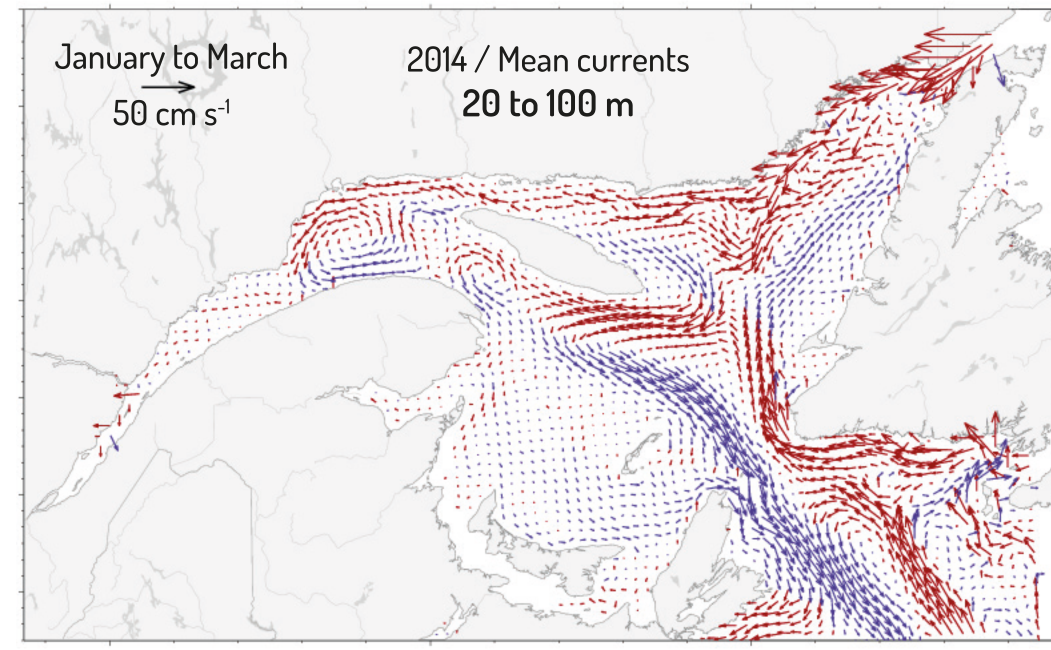
years at a speed of 1 km/day. Nevertheless, one must remember that this interpretation is very, better yet, too simplified to provide real conclusions at this point, in terms of the impact of a spill in the Gulf. Although it is understood and admitted that a portion of the waters in the cold intermediary and deep layers go back up, on a long-term average, all the way to the head of the Laurentian Channel, the exact route these waters follow to reach the area mentioned is much more complex than the scheme shown in Figure 2 would lead us to believe. Besides, these deep waters can go back up not only the Laurentian Channel, but also other channels that characterize the bathymetry of the Gulf, namely the Esquiman and the Anticosti channels. Finally, one must keep in mind that a spill occurring in the cold intermediary or deep layers of the Gulf could just as well be dragged outside of the Gulf, without necessarily going back up those channels, as an important horizontal variability of that deep circulation, (Figure 2.3). In fact, there is significant uncertainties as to what would happen in the case of a spill in deeper waters of the Gulf. Hence, this fundamental question which needs to be vigorously studied before undertaking any exploration and extraction activity.

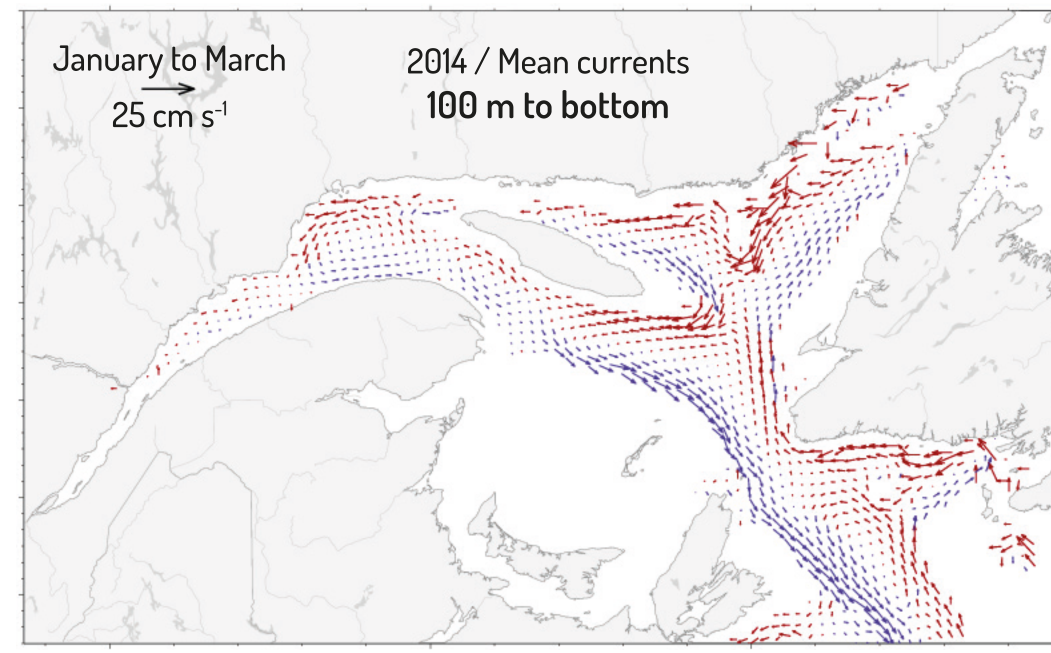
Nevertheless, one must admit that in the case of a deep spill (below 200 m), such would slowly go back up to the head of the Laurentian Channel in one year or two. According to the type of hydrocarbons and the nature of the spill, it could possibly be degraded in the deep layer within that transit period to the head of the channel. That said, this possible degradation does not guarantee inasmuch a negligible impact on the upstream ecosystem. For example, microbial degradation of hydrocarbons requires the consumption of dissolved oxygen. Yet, the deep St. Lawrence is poor in oxygen, (Gilbert *et al.*, 2005; Gilbert *et al.*, 2007; Bourgault *et al.*, 2012), with its hypoxic conditions – near the bottom of the maritime estuary –, (Figure 2.2). An increased consumption of dissolved oxygen downstream, as a result of a spill in deep waters, could exacerbate hypoxia in the maritime estuary a few years later. Such a fundamental question has yet to be studied and must imperatively be considered in the context of the potential development of hydrocarbons in the Gulf. What would the impacts be, on the medium term (a few months) and on the long term (a few years), if chronic or acute spills of hydrocarbons or other pollutants were to occur below the surface layer (= or - 40 m below) in the Gulf, on dissolved oxygen, on nutrients and on water quality in a general way, in the maritime estuary, at the head of the Laurentian Channel, in the Middle Estuary and in the Saguenay Fjord? These yet unanswered questions are discussed by Schloss and his collaborators (2017, this paper) and require deeper and multidisciplinary studies if one wants answers about the dispersion of hydrocarbons that does not depend only on water physics, but also on water chemistry, biology and on sedimentation.

Figure 2.3

Average seasonal currents between the surface and 20 m, between 20 m and 100 m, and between 100 m and the bottom for Year 2014 showing the main circulation of the cold intermediary layer. *(Adapted from Galbraith et al., 2015, with the permission of J. Chassé.)*



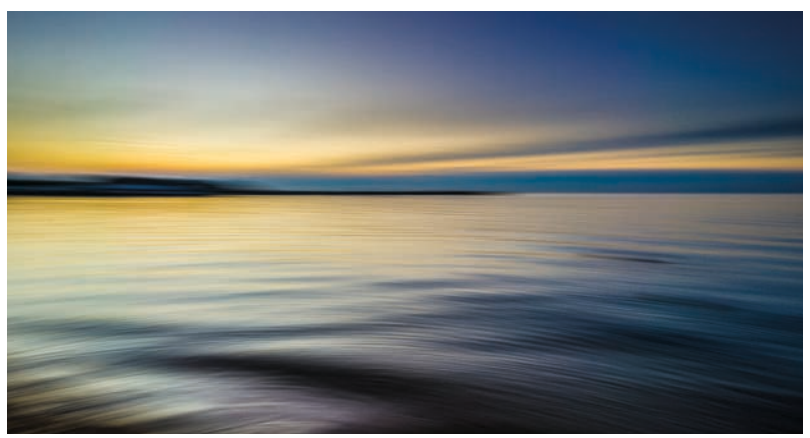




AVERAGE SEASONAL HORIZONTAL CIRCULATION

Figure 2.3 shows the average of the winter surface currents tabulated from January to March in the whole of the Gulf, taken from the simulation of a digital model based on the equations of the mechanics of oceanic fluids, (Chassé, 2016; Galbraith *et al.*, 2015). As we mentioned in the introduction, this capacity to model currents in the overall Gulf can only be done to the detriment of the finesse of the resolution. In this case, currents are simulated with a horizontal resolution of around 10 km (1/12 of a degree of latitude, to be precise; all modeled vectors are not plotted on the Figure) and with a vertical resolution of 6 m at the surface. Furthermore, Figure 2.3 shows not only a seasonal average but also an average on the first 20 m of the water layer. To keep focussed on the needs of this chapter, and to bring clarity, we will only show the winter current patterns. To look at current patterns for other seasons, we invite you, the reader, to consult Galbraith and his collaborators, (2015).

These digital simulations show that, even though intensity and some other details in the flow patterns vary from one season to the next, some currents and persistent structures are found within throughout the whole year, such as the de Gaspé current, the Anticosti Gyre, the Western Newfoundland current and a westerly current along the North Shore from the Strait of Belle Isle. Average seasonal currents in the intermediary layers (20 to 100 m, Figure 2.3) and in the deep layers (100 m to bottom, Figure 2.3) show circulation patterns fairly similar to those at the surface, but they are less intense.



Contrary to the current longitudinal cut – as previously discussed – it may have us believe, (Figure 2.1, right panel and Figure 2.2), that the following current maps show that there is a large spatial variability in horizontal currents, which is partly caused by the Coriolis Force; for example, currents only come out on the south-west side of the Cabot Strait even though they come in on the north-east side. This might seem incoherent considering the previous longitudinal representation of Figure 2.2 which suggests that the surface currents only come out and that deep currents only enter the Cabot Strait. In fact, there is no incoherence as long as it is understood that estuarine circulation presented at Figure 2.2 represents a transversal average throughout the entire width of the Laurentian Channel. Therefore, it is only in the transversal average that the current comes out at the surface and goes in deeper. Still, according to the location on the transversal section, it is possible the average seasonal current could be orientated toward the opposite of what is represented at Figure 2.2. This illustrates rather well the difficulty of representing complex and tridimensional currents of the Gulf and the necessary vigilance when interpreting the presented information.

INSTANTANEOUS CIRCULATION, VORTICES AND POLLUTANTS DISPERSION

In the context of environmental evaluations, relating to the dispersion of hydrocarbons at-sea, it is important to realize that the statistical procedure – which allows for the representation of average seasonal currents – as described in the previous sections (Figures 2.1, 2.2 and 2.3) – eliminates all vortices and other fluctuations occurring at much shorter time scales than the seasonal scale. Yet, the spread and the physical dispersion of pollutants at-sea by and large occur through these vortices and important oscillation currents, such as those caused by tides and winds, which are absent in the average seasonal representation. As such, seasonal currents - easier to understand - are fairly useful in the prediction of a dispersion. These seasonal current representations only indicate that, should they last over an entire season, three months that is, the center of the mass of the spill would runoff according to the average seasonal currents. But, this does not provide any information on dispersion and the horizontal spreads generated by vortices and other fluctuations which impact on a shorter time scales. Bourgault and his collaborators (2014; see their Figure 3) discuss instantaneous currents, including those created by tides and winds; they also assert that they are 10 times stronger than average currents.

Figure 2.6 shows an example of the structure in complex meanders and vortices which characterize the instantaneous runoff of the Gulf. A part of the runoff is visible here with the presence of phytoplankton (microscopic marine algae) carried through these meanders which allows for the possibility of seeing a snapshot of the fine structures of the runoff. However, these meanders are absent in the ordinary seasonal representations, (Figure 2.3). Although this information is not directly visible on this figure, currents associated with these meanders are recognized as being much more important than average seasonal currents.

One of these vortices is quite visible near the south-western tip of Newfoundland and close to *Old Harry* (Figure 2.4, insert). The diameter of that vortex is around 75 km; the image shows that it is spinning clockwise. That is a Rossby vortex de Rossby. Any oil spilled at the surface at *Old Harry* could very well be carried away by one such vortex and touch the south-western tip of Newfoundland a day or two later. This type of vortex can end up anywhere in the Gulf, just as well as near the Îles-de-la-Madeleine. This mode of transportation of pollutants via vortices

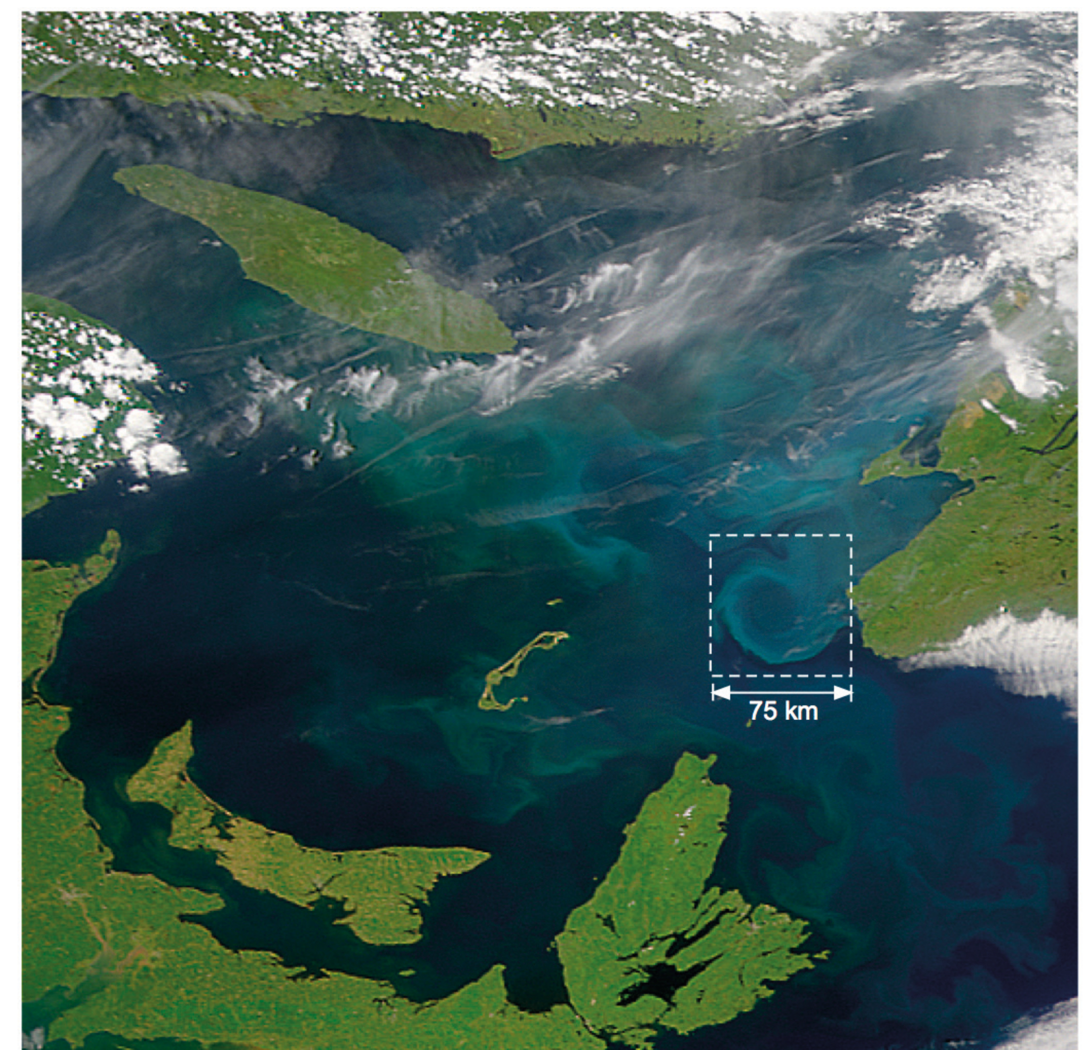
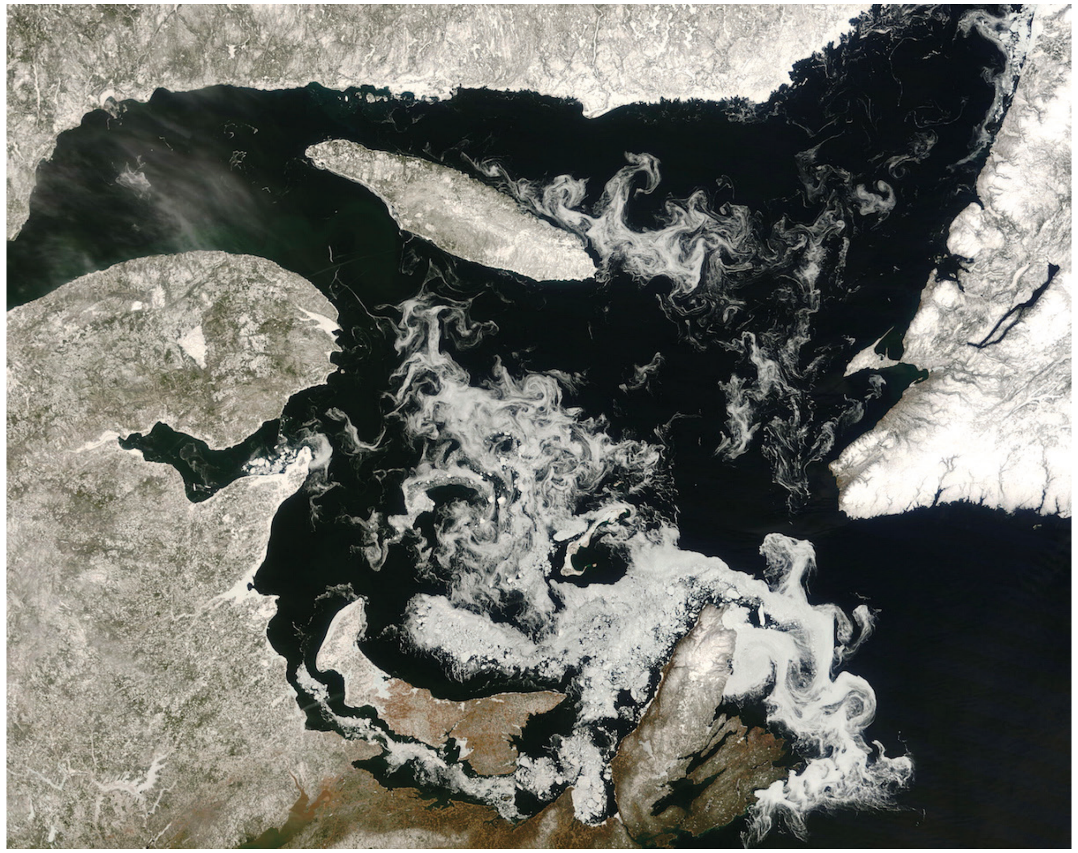


Figure 2.4
Satellite Image showing the distribution of chlorophyll and illustrating the eddying and filament-like structure in the Gulf of St. Lawrence as observed on June 20, 2001. The dotted insert shows one of these larger vortices, with a diameter of around 75 km. *(SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE.) Image downloaded on February 1, 2016 from http://visibleearth.nasa.gov/view.php?id=56410.*

Figure 2.5
Example of the distribution of the ice cover in the Gulf of St. Lawrence as observed on April 7, 2008 - Terra's MODIS satellite, at NASA. This picture shows rather well the eddying and filament-like structure and the surface runoff. *Image downloaded on the 1st of February from http://earthobservatory.nasa.gov/IOTD/view.php?id=8661&src=ve.*



cannot solely be discernable through the examination of seasonal currents. Figure 2.5 shows another example of the complex structure and the meanders of the surface currents, made visible, this time, thanks to the presence of sea ice.

Despite current work, there is nothing published that lays out the dispersion of hydrocarbons on the overall Gulf of St. Lawrence and in all the water layers; hence, knowledge on this matter is quite limited. One can find only one study focussing on the particular case of a surface spill, either chronic or acute, of an inert and light pollutant at the *Old Harry* site, (Bourgault *et al.*, 2014). This study shows possible patterns of dispersion, the time a mass of water transiting via *Old Harry* could take before reaching the neighboring coastlines and the probability of one specific point on the coast that could be reached. One of the important results shows that *Old Harry* is located smack between the Gaspé current, coming out of the Gulf, and the one entering Western Newfoundland current, making it possible for a pollutant dragged into it to use either one of these routes according to instantaneous conditions i.e. tides, winds and vortices at the time of the spill. Thus, a pollutant could, in an equiprobable way, either comes out through the Cabot Strait, licking both sides of Cape Breton, in Nova Scotia, or via Newfoundland's Cape Anguille, or heading north along the west coast of Newfoundland or touching it. The study also shows that even if the Îles-de-la-Madeleine are less susceptible to be reached, the probability is not negligible.

Some simulations also show lines of pollutant that could go back up to Île d'Anticosti. In the study, prepared with his collaborators, Bourgault has provided the possibility to profile the first large region known as *Old Harry*'s zone of influence (OLZI), (Figure 2.6, in pink).

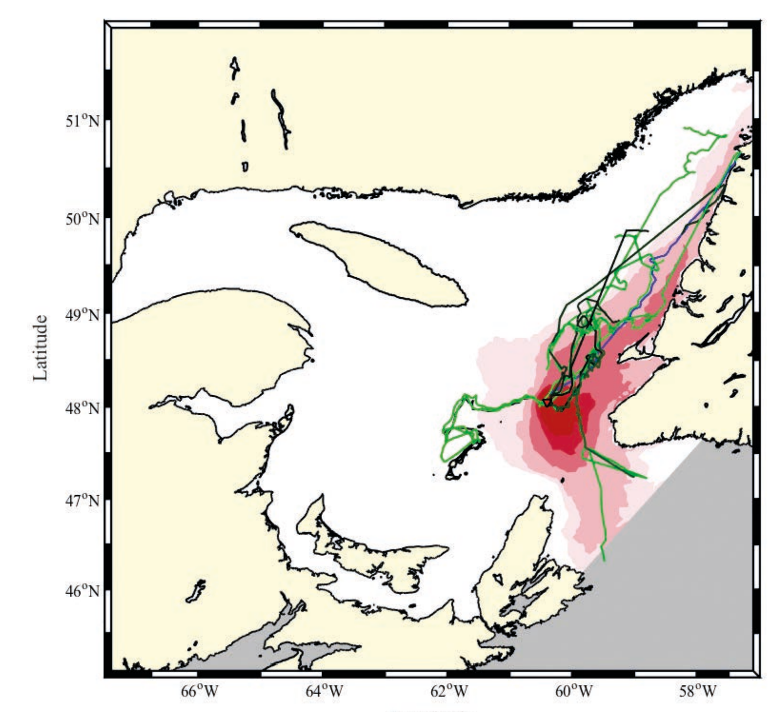
A pollutant could [...] either comes out through the Cabot Strait, licking both sides of Cape Breton [...], or heading north along the west coast of Newfoundland or touching it.

Ever since the 2014 publication of the study by Bourgault and his collaborators, some fifteen floating buoys were set at the *Old Harry* site as they wanted to test their forecast using at-sea measurements. Figure 2.8 shows all the trajectories inputs, as of now, and overlapped on of the probability maps derived from the study of Bourgault and his collaborators, (2014). Even though 15 buoys are not sufficient to validate, in a robust manner, the authors' results, these trajectories support rather well the conclusion which would show that the west coast of Newfoundland is the most susceptible area to see come-ashore floating contaminants from *Old Harry*. Further to that, out of the 15 launched buoys, two beached themselves at the Îles-de-la-Madeleine, some ten days after launch; which shows the possibility that the archipelago could be touched by a surface spill at *Old Harry*.

We have insisted on the important consideration that must be granted to instantaneous currents when one wants to address matters of pollutant diversion in the Gulf. The reason being is, amongst other things, that, yet again, such distinction has not been related properly by the industry in the course of environmental studies. In fact, in their simulations of surface spills, SL Ross Environmental Research Ltd. (2012) did not take into consideration average seasonal currents. Bourgault and his collaborators (2014) also raised that critique.

At the end of it all, there is a crying lack of more generalized studies on oil and pollutants dispersion in the Gulf of St. Lawrence. This question is particularly important, in terms of transportation and dispersion in intermediary and deep layers, as the majority of the water layers go back up on average to the head of the Laurentian Channel, the Middle Estuary and the Saguenay Fjord. /

Figure 2.6
Trajectories of the floating buoys launched in the *Old Harry* area since 2014 and overlapped on one of the maps of probabilities as per Bourgault and his collaborators, (2014) showing those regions most susceptible to be touched by pollutants released at *Old Harry*. Concentric regions -in pink- represent the probability they will be touched should a spill occur at *Old Harry*. The darkest area (dark red) represents a 90% probability and the lightest area (pink), a 10% probability. In this study, the pink area is referred to as *Old Harry*'s zone of influence, (OHZI). The grey area outside the Gulf is not being taken into account in the present study.



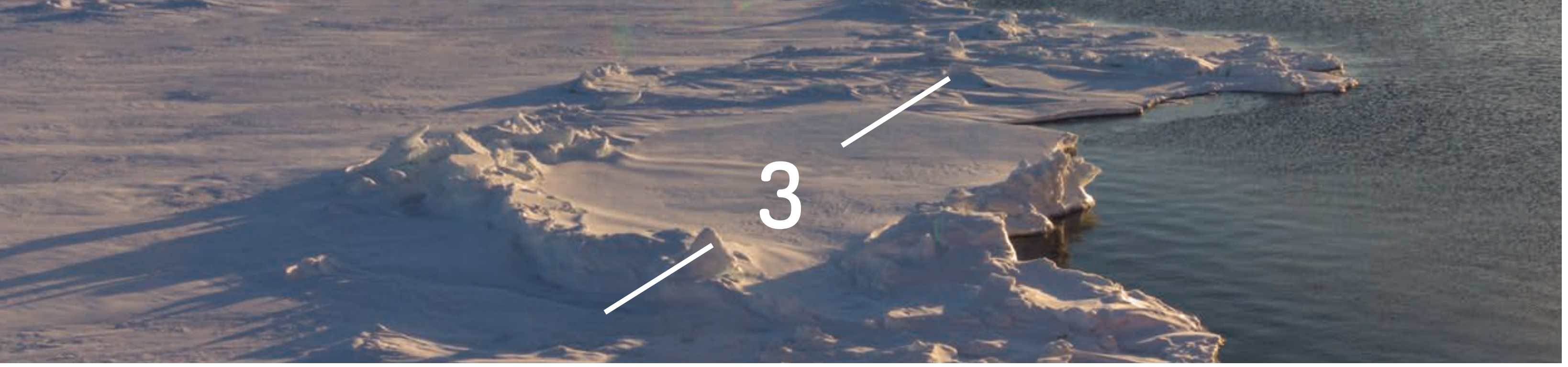


Photo: D. Kalenitchenko

THE ICE COVER

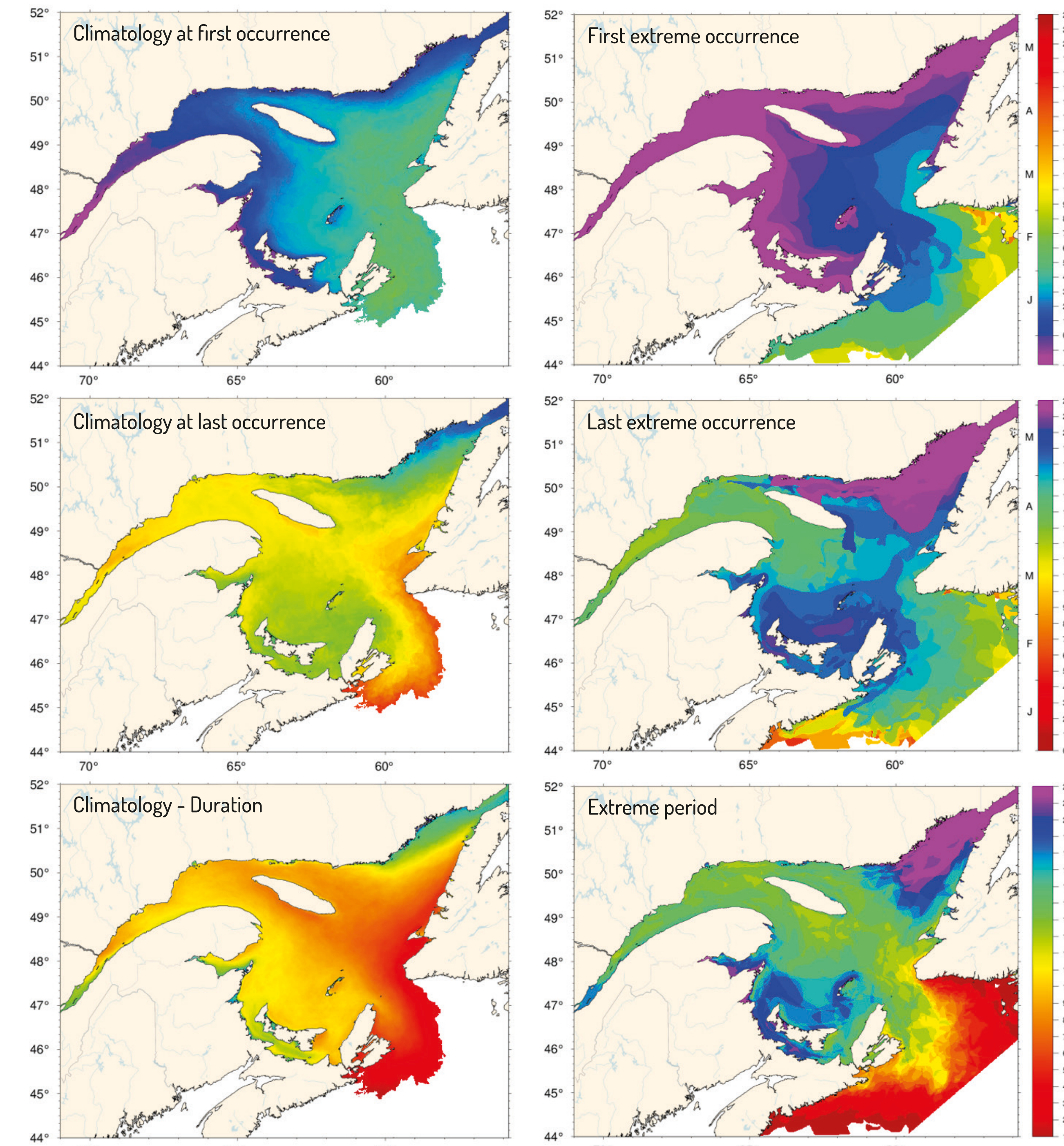
The Gulf of St. Lawrence is the southernmost extremity of the North Hemisphere where ice will form during winter. Not only would the presence of ice make oil extraction operations more risky, it would also complicate clean-up efforts after a spill or a leak.

The left-hand side of Figure 2.7 shows 1981 to 2010 climatology of the phenology of the ice cover i.e. the time of the year when that cover appears, disappears and the length of time it stays. The same figure also shows extreme conditions of the period extending from 1969 to 2015 (right hand side) which is pertinent in the context of extraction. Even if ice appears only in December in the estuary and along the coastline of New Brunswick, in normal conditions, over half of the Gulf area was covered with ice this early in the season when conditions were extreme. Just the same, in the next instance: even though the region covered by the southern part of the Gulf, between the Îles-de-la-Madeleine, Cape Breton and Port aux Basques (Newfoundland) is normally ice-free at the end of March or so, ice may remain for an additional month. Even if, recently, the ice cover is not generally as spread out as it was in the 1990's (ex., a near total absence of in 2010), the inter-annual variability of the cover remains strong. The atmospheric phenomenon of the polar vortex which supplied rigorous winters in 2014 and 2015 is a new one. In 2015, it has caused delays of five weeks in the withdrawal of the ice cover in the Southern Gulf. Such extremes in terms of withdrawal dates (see Figure 2.7) indicate that, just about anywhere in the Gulf, a withdrawal might occasionally be as late as normal climatology would have it in the Strait of Belle Isle and last just as long.

EVOLUTION OF THE ICE COVER THROUGHOUT THE NEXT CENTURY

Projections made via climatic models of the Intergovernmental Panel on Climate Change (2014) indicate that the temperature of global average air could rise by 2 to 6°C by the end of the century, according to scenarios involving greenhouse gases. A plausible and realistic scenario with respect to emission of greenhouse gases (SRES A2)[3], with the average temperature, excluding summer months in the Gulf of St. Lawrence, will rise by around 6°C, hence reducing the probability of forming or maintaining an ice cover. Figure 2.8 shows this tendency which is based on a set of global climatic simulations, the work of global models, i.e. the Coupled Global Climate Model - version 3, (CGCM3), Flato and Boer, 2001) and

Figure 2.7
Climatology (1981-2010) and extreme conditions in the occurrence of the ice cover (duration in weeks, first and last appearing). The ice had to have been present at one place for at least one week within the last 15 to 30 years of climatology to be shown, which explains the lack of data on the Scotia shelf where ice is rarely seen. Climatology is the same as that seen in the work of Galbraith and his collaborators, (2015). As to the extremes, one single year of data is sufficient to determine a value in one location.



[3] Scenario A2 of the *Special Report on Emissions Scenario* (SRES) is one of those used to produce the 4^{th} evaluation report of the IPCC, in 2011. The definition of these scenarios was modified for the 5^{th} report, published in 2014, but the diverge very little from their predecessors as to the projections of air temperature we are herein using.

regional models i.e. Canadian Regional Climate Model ((CRCM), Laprise *et al.*, 2003). This figure also shows strong variations from year to year, thus an extremely warm year, between 1980-2000, can be as warm as an extremely cold year would have been between 2040-2060. Therefore, how could this progression in the air temperature influence the evolution of the ice cover? Figure 2.9 shows how, from existing correlations with the evolution of the air temperature, the range and the duration of the ice cover will evolve in the next century, (Bismuth, 2015). According to these results, a normal winter between 2040 and 2060 would last but 100 days on average around 50% of the Gulf area. Nowadays, on average, a normal winter shows a 65% ice-cover of the area, and that, over a period of 130 days, one month longer. Once again, inter-annual variability is to be reckoned with: anticipated differences between the current climate and that of the future are basically of the same order as those observed from year to year in our current climate, (dots on Figure 2.9), i.e. more or less 50 days for the ice cover duration. This means that even if, in the case of a warmer climate, the probability of seeing a winter with a significant quantity of ice in the Gulf is not nil and that the ice should therefore be part of the elements to be considered in the design of structures and in the planning of at-sea operations for yet a few generations./

Figure 2.8

Averaged surface air temperature in the Gulf of St. Lawrence between October 1 and June 30 and deriving from a series of simulations representing one set of plausible trajectories of the future climate of scenario A2: greenhouse gases. The yellow line indicates the average of the five members of the Coupled Global Climate Model, version 3 (MCCG3), while the yellow area indicates the extremes. Black circles indicate the average temperature simulated by the Canadian meteorological model for forecasting (GEM). *(Figure taken from Neumeier et al., 2013.)*

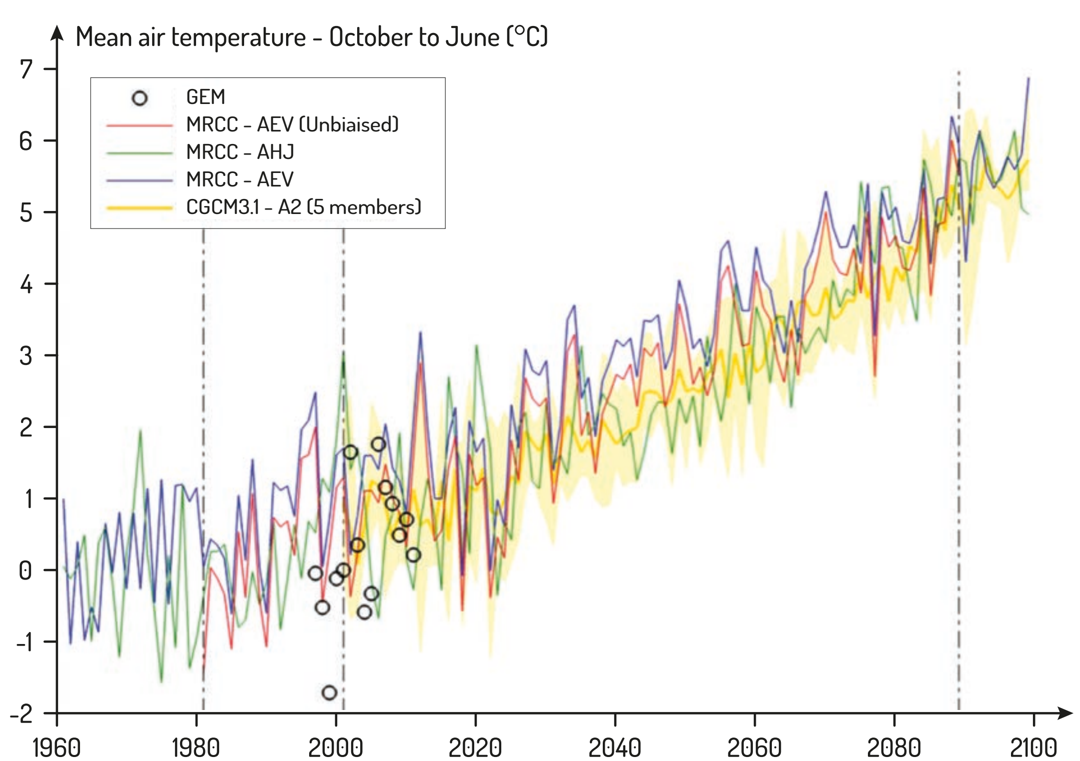
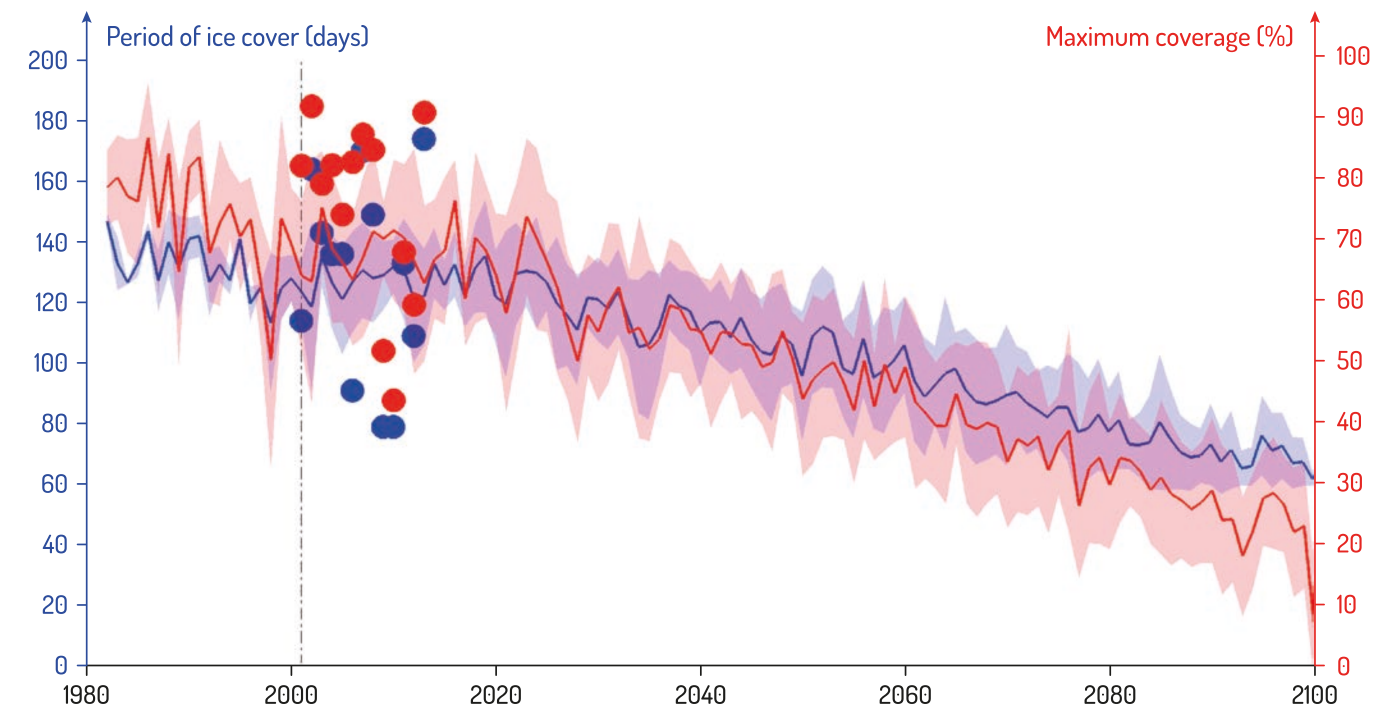


Figure 2.9

Evolution of the maximum range reached in one year (%, in red) and of the duration (days, in blue) of the ice cover in the Gulf of St. Lawrence estimated from existing relations between those variables and the evolution of the number of freezing degree-days. Dots indicate observations drawn from ice maps of the Canadian Ice Service. The solid lines show the overall average of eight simulations and the coloured zones show, more or less, a deviation. *(Modified - Bismuth, 2015.)*



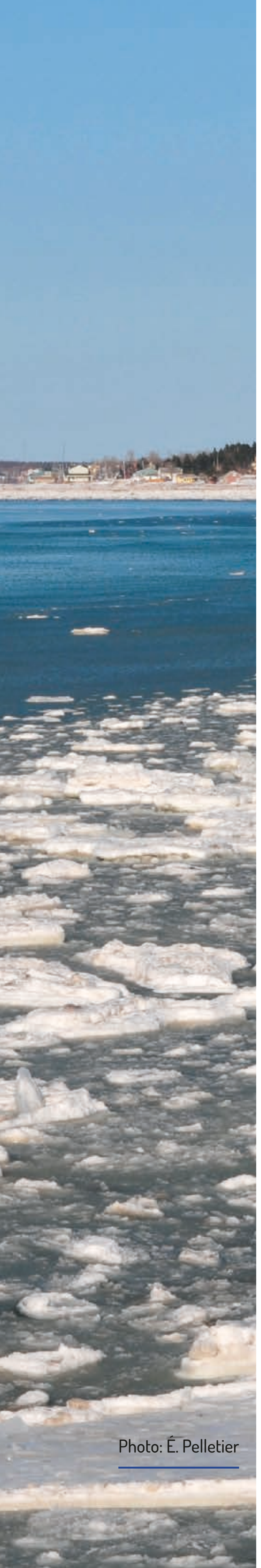


Photo: É. Pelletier

CONCLUSION

We have, herein, offered a general and simplified overview of the main oceanographic conditions which influence and characterize the movement and the distribution of the layers of water and of the ice cover in the gulf and the estuary of the St. Lawrence. We have seen that currents and dispersion of pollutants can hardly be detected - whether space- and/or time-dependant - due to the complexity and the eddying behavior of oceanic currents.

Although the Gulf of St. Lawrence is front and center in *Notre Golfe*, we have insisted in this chapter on the fact that sea water does not know geographical boundaries within the gulf, the estuary and in the fjord areas. Quite to the contrary, we have explained that, actually, a large amount of the water in the intermediary and deeper layers in the Gulf of St. Lawrence (i.e. approximately under 30 meters) goes back up the system and fills the deeper layers of the estuary and of the fjord, reaching as far as Ile d'Orléans in the estuary, and the city of Chicoutimi in the fjord (see figure 2.2). This less than intuitive aspect of the circulation of the Gulf of St. Lawrence is hardly known outside the scientific community. Although it must be understood and taken into account, in the frame of the evaluation of potential impacts, which the exploration and the exploitation of hydrocarbon could induce on the quality of the water in the gulf, the estuary and the Saguenay fjord, even if these activities were to take place at a great upstream distance in the gulf.

As the main questions remain, let's mention some of the actions which, we believe, must be undertaken on the short and medium terms:

1) Resume research to understand the processes by which the pollutants are carried and dispersed on the surface (i.e. going beyond preliminary efforts outlaid by Bourgault *et al.*, 2014); and, especially undertake new research on transportation and dispersion of pollutants in the intermediary and deep layers;

2) Assess the impact on the quality of water -such as dissolved oxygen, nutrients, etc.-, in the different areas of the gulf, the estuary and the fjord of the Saguenay which could result from a spill in the deep layers of the gulf;

3) Study the potential impacts a spill of pollutants could have if occurring during winter, by clarifying such aspects as transportation and dispersion in the presence of ice;

4) Study, in general terms, winter oceanography in the Gulf of St. Lawrence including all disciplines, namely physics, biology, chemistry, geology. Oddly enough, even with a winter oceanographic survey undertaken by Fisheries and Oceans, to characterize the layers of water of the gulf throughout the winter, has taken place every year since 1996 (Galbraith, 2006), we have yet to see large winter oceanographic missions aboard research icebreakers in the gulf and the estuary of the St Lawrence, as we have occasionally seen in the Canadian Arctic such as the Canadian Artic Shelf Exchange Study or the Circumpolar Flaw Lead. Significant and ambitious studies are necessary if one wants to characterize the general winter oceanography of the Gulf of St. Lawrence before proceeding with any attempt to explore and exploit hydrocarbon. /

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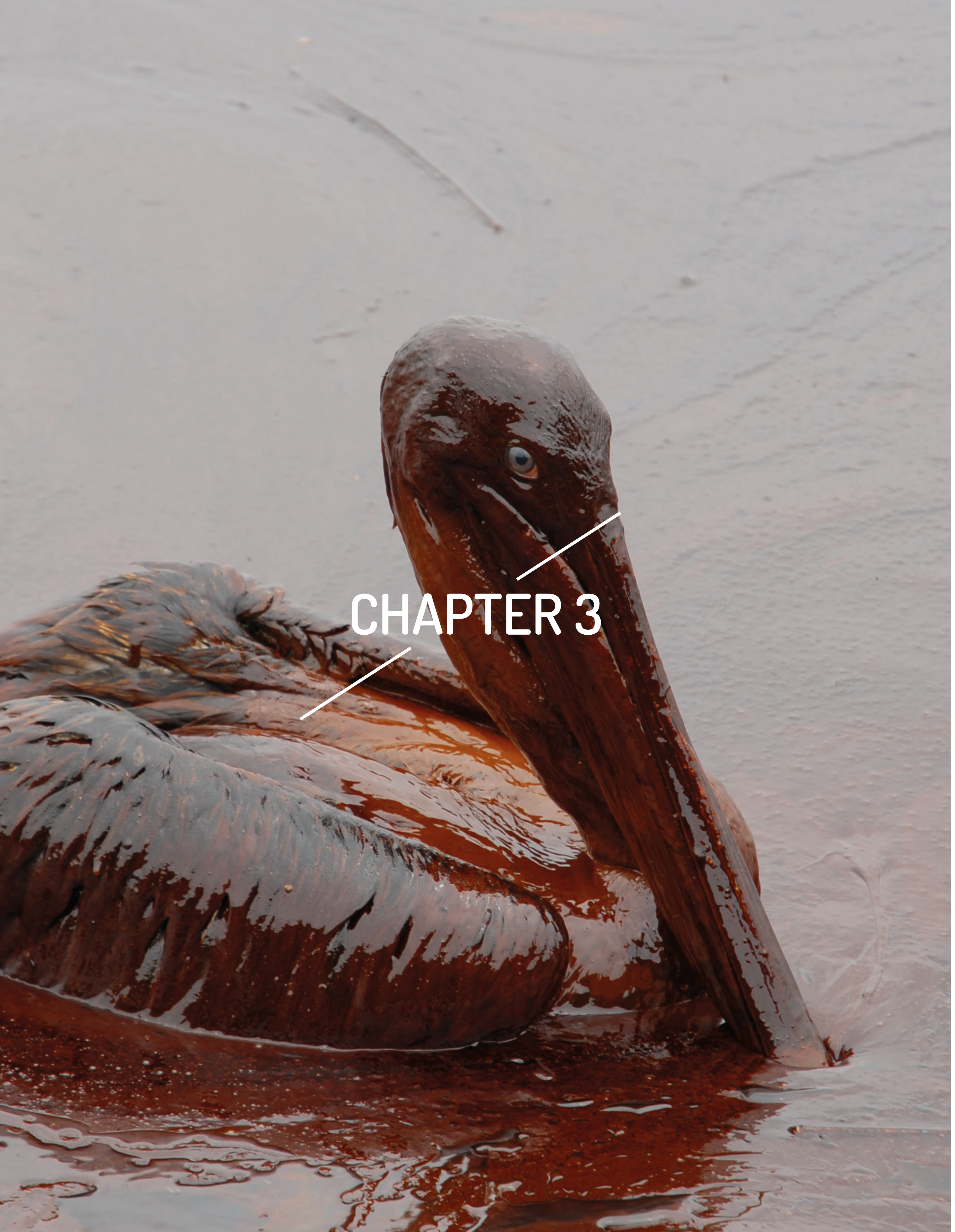

Toxicity of hydrocarbons and impacts of spills on marine organisms and their environment

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Risks related to operational and accidental spills of hydrocarbons will be intensified by the increase of the world's needs for oil. Although rare, the number of accidents increases and they cause numerous effects on the environment and living organisms. This chapter is an overview of the potential impacts hydrocarbons on organisms and their habitats along with the consequences on the functioning and the ecological services supplied by marine ecosystems. The nature and the behavior of spilled oil and risks associated with response techniques, for example the use of dispersants or the physical clean-up, are part of this chapter. The ways many organisms (microorganisms, phytoplankton, zooplankton, invertebrates, birds and marine mammals) are exposed and the effects of oil on their population are illustrated using examples arising from some of the unfortunate events such as the grounding of the *Exxon Valdez* in 1989 or the explosion of the *Deepwater Horizon* in 2010. The influence of spill conditions on the resilience of the affected ecosystems is also addressed.

Photo: Louisiana Gohsep / FlickR

HIGHLIGHTS

- Oil spill response techniques at sea and clean-up of hydrocarbons on shores showed little progress in the last 20 years and remain extremely costly, laborious and time consuming.

- When a spill occurs, the fate of the slick and the biodegradation of hydrocarbons change over time and largely depend on environmental and meteorological conditions and, especially in the presence of ice.

- Impacts of hydrocarbons and dispersants on marine organisms are variable and may last for decades.

- Negative effects of dispersants on marine organisms question alleged gains of their use.

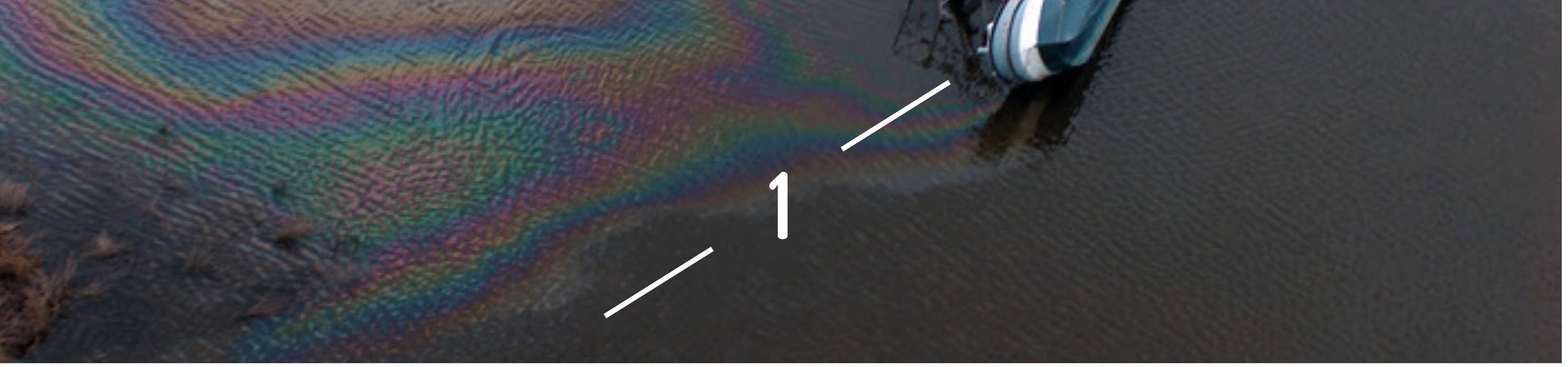
INTRODUCTION

Intensification of oil traffic around the world is influenced by ever-increasing energy needs. Despite the constant development of non-fossil energies, projections of the demand for oil and related maritime transportation remain high: an increase of 18.4% between 2014 and 2040 is forecasted according to OPEC (2015). In Canada, one of the main suppliers of oil products, the oil transportation from the extraction sites to the refineries is mainly done by land. Pipeline projects to the West (Northern Gateway and Trans Mountain projects toward the Pacific) and to Eastern Canada (Energy East Project, towards the Atlantic), if eventually implemented, will rather increase transportation of hydrocarbons via maritime lanes. Although such projects are not gaining in popularity - and might not all come to completion- transportation of oil products is highly increasing. Indeed, an increase of 40% in pipeline exports (2010-2014) and 300% via railroads (2012-2014) has been recently projected (National Energy Board, 2016). Furthermore, oil production increase in Canada between 2013 and 2035 could reach 75%, even though some adverse economic conditions could make this objective impossible to reach (National Energy Board, 2013). More frequent and more important transportation of oil products could occur on the St. Lawrence shipping lane (Shields, 2016), some of them on their way to refineries in the Atlantic Provinces or foreign countries. These products will be transiting through the fragile freshwater, estuarine and marine ecosystems of the St. Lawrence system. Furthermore, current or future facilities needed for the transit of those products will add to the risks of accidental or operational spills in the aquatic ecosystem of the St. Lawrence watershed. Additional pressure on the environment would include a large number of other sources of stress, such as noise, light, waves, collisions between marine animals and ships, and the introduction of new invasive species, potentially affecting ecosystems and their constituents (Québec, 2014; Schloss *et al.*, 2017, this document).

No major oil spills
(>700 tons) have yet reached the Estuary
nor the Gulf of the St. Lawrence

The many levels of government have clearly promoted their development strategies, such as the *"Stratégie Maritime du Québec"*, on the St. Lawrence transport artery, with a focus on the transportation of hydrocarbons. However, what could be the potential impact of oil products on the St. Lawrence ecosystems? No major oil spills (>700 tons) have yet reached the Estuary nor the Gulf of the St. Lawrence, but two minor spills attracted attention of some scientists (Pelletier *et al.*, 1991; Siron *et al.*, 1991). Biological impacts of oil-related accidents are more often studied in mesocosms (Siron *et al.*, 1993; Sargian *et al.*, 2005; Rodríguez-Blanco *et al.*, 2010) and experimental work in natural ecosystems remains limited because only a few species may be studied simultaneously and for a limited period of time. Acquiring knowledge on the impacts on marine organisms in natural environments is an opportunistic approach, and only focusses on large spill accidents such as the *Exxon Valdez* or *Deepwater Horizon*.

In this chapter, a review of the scientific knowledge regarding potential impacts of hydrocarbons on organisms and on habitats along with the consequences on the operation and the ecological services provided by marine ecosystems is presented. Firstly, we will address these impacts through a discussion on the nature and the behavior of spilled oils, and secondly, then the risks associated to the intervention methods, such as the use of dispersants or physical clean-up are discussed./



TYPES OF OIL SPILLED AND THE BEHAVIOR IN THE ENVIRONMENT

TYPES OF OIL

Conventional crude oil is described as oil that can be extracted from conventional vertical and/or horizontal wells by means of a simple pumping system using pressure gradients. Non-conventional oils are made available by means of fracking techniques of rocky formations (Bakken Formation) and also include bituminous oil extracted from oil sands and shales. Different types of crude oil are very complex mixtures of thousands of hydrocarbons only separable and characterized using the most advanced analytical techniques, such as liquid and gaseous chromatography coupled to mass spectrometry (Cho *et al.*, 2012).

Crude oils comprise in four main classes of chemical molecules: saturates, aromatics, resins and asphaltenes (SARA). The composition of each one of these classes, and their relative proportion in the overall oil mixture are two determining factors with respect to their environmental behavior and their toxicity of the studied product.

Two physical properties of oil dictate its behavior in an aquatic environment: density and viscosity. Density is the measurement of the mass against the volume and is expressed as g cm^{-3}. In the oil industry, liquid hydrocarbon density is provided in API degrees (American Petroleum Institute gravity). It is a practical density measure that allows for the classification of oils and their by-products. Light crudes show an API degree below 31.1; medium crudes stand between 22.3 and 31.3; heavy crudes are below 22.3 (more often between 10 and 15); and bitumen sits between 5 and 10 (Lee *et al.*, 2015). One should remember freshwater at 15°C shows an API degree of 10. Oils with an API degree below 10 will tend to sink to the bottom of a water body. Density is little, if at all, influenced by temperature.

The second fundamental property influencing the behavior of oil is its viscosity. Viscosity (mPa·s) is defined as the resistance of a liquid to spread. Viscosity is a function of the temperature and directly influences the velocity of the spread of the runoff of an oil slick and its tendency to form an emulsion (incorporating water to a mass of oil) (Lee *et al.*, 2015). As observed for density, viscosity of a crude oil will increase with the evaporation of light fractions. As an example, Table 3.1 shows the progress of the density of some oils against their ageing (loss of mass through evaporation). Heavy oil and dilbit (diluted bitumen) reach densities near or higher than 1.0 with mass losses between 19 and 30%. In the natural environment, formation of a stable emulsion (water in oil) and the attached particles in suspension increase the density even more and produce sedimentation of those oils to the marine bottom.

Table 3.1
Comparison of densities (g/cm^3) at 15°C different crude oils with ageing. *(from NAS, 2016.)*

Type of crude oil	Original density before evaporation (g/cm^3)	Density after 24 h of ageing (g/cm^3, % lost mass)	Density after 96 h of ageing (g/cm^3, % lost mass)
Light crude[i]	0,77	0,80 (25 %)	0,84 (64 %)
Intermediate crude[ii]	0,85	0,87 (10 %)	0,90 (32 %)
Heavy crude[iii]	0,94	0,97 (10 %)	0,98 (19 %)
Dilbit[iv]	0,92	0,98 (15 %)	1,002 (30 %)
Bitumen	0,998	1,002 (1 %)	1,004 (2 %)

[i] Scotia Light
[ii] West Texas Intermediate
[iii] Sockeye Sour
[iv] Cold Lake Blend

BEHAVIOR IN A MARINE ENVIRONMENT

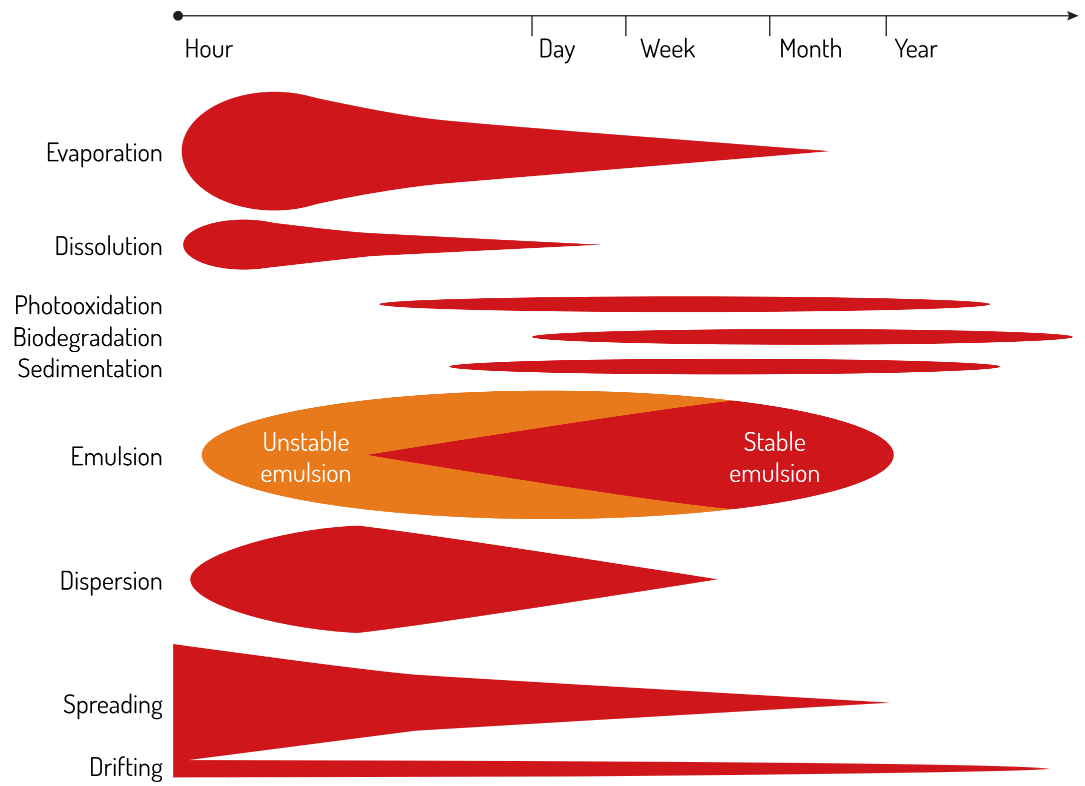
Generally speaking, the main physical and chemical phenomena to appear when an oil slick is forming at sea are as follows: evaporation, spreading, emulsification, dissolution, dispersion, sedimentation and biodegradation. Figure 3.1 offers a diagram of the ageing process of oil at sea against time and shows the relative importance of the mechanisms in action.

Evaporation is the main process of alteration with respect to mass loss. The efficiency varies between 10 and 40% in conventional crude as a function of the composition of the product and the volatility of its chemical compounds. In the case of non-conventional oils, the basic phenomenon is a rapid loss of the fraction containing the very volatile diluent, the proportion of which may vary from 20 to 30%. The main factor influencing evaporation is temperature; yet, the force of winds, the action of the currents and of the waves must be taken in account, all of which increase the evaporation area at the beginning of the process (Fingas, 2011).

Spreading of hydrocarbons at the surface of water is directly related to their viscosity and to the energy available at the surface. Light and intermediary oils spread quickly over a large surface, even at low temperature, and the combined action of the wind and of the currents are key factors. Wind, waves and Langmuir's circulation cells tend to break the slick into pieces thus creating long and more or less regular parallel ribbons, which often makes observation of the progress and the size of the oil spill difficult. Winds also contribute to the formation of an emulsion, first through the dispersion of fine droplets of oil in the water, and then through the incorporation of water in the oil to form a more or less viscous mousse. This mousse tends to float just below the water surface making its movement hardly observable (Fingas, 2013). Heavy fuel oil is very viscous at

The main factor influencing evaporation is temperature; yet, the force of winds, the action of the currents and of the waves must be taken in account.

Figure 3.1
Temporal scale and relative importance of the main alteration and transportation processes of oil products. *(Adapted from AMAP 2010.)*



low temperature and takes some time to reach a maximum surface. Water surface spreading is occurring at two different speeds: a swift spread of a thin iridescent layer associated to light components, and a slow spread of a more viscous, black mass matching the heavier compounds of the mixture.

If the kinetic energy at the sea surface is strong enough (e.g. light winds and very small waves), an emulsion is taking form, which means the incorporation of water droplets in the oil mass which later turns into a viscous and brown substance that is more or less mixed with the suspended particles and floating debris. **Emulsification** is an especially rapid and efficient process in seawater. The viscosity of an emulsion may be increased up to a factor of 800 to 1,000 following the type of oil, where the spread and evaporation processes are reduced by several orders of magnitude (National Research Council, 2005). The formation and stability of an emulsion depend on the chemical composition of the product, on the salinity, and the available hydrodynamic energy. This process acts also with heavy fuel oil to form small tar balls that mix with sand and that can be manually picked-up on beaches or alongside rocks.

Dissolution is the process by which some components contained in oil products are solubilized in the water column. It is a very important process as the soluble fraction is the one bioavailable to aquatic organisms and responsible for the acute toxicity of a spill (Fingas, 2011). This

CRUDE OILS ARE COMPRISED IN FOUR MAIN CLASSES OF CHEMICAL MOLECULES

The class of **saturates** includes molecules with chains containing only carbon and hydrogen atoms; they are attached to one another with simple either linear or cyclical links with multiple possibilities of lateral chains. That class includes paraffins, isoparaffins, cycloparaffins and olefins. All these molecules can hardly be dissolved in water; their level of toxicity is considered to be very low and they are easily degradable by microorganisms, (Lee *et al.*, 2015).

The **aromatics** include a large family of cyclic and planar compounds based on the structure of benzene. The fusion of two or more benzene rings and the addition of lateral aliphatic chains on the rings lead to a profusion of aromatic structures. The simplest of them, such as toluene, xylene and naphthalene, are relatively soluble in water (one milligram per litre, mg·L^{-1}). Polycyclic Aromatic Hydrocarbons (PAHs) derive from the fusion of several benzene rings and are well known for their toxicity to living organisms, (Engraff *et al.*, 2011). Light PAHs with two or three benzene rings are present in many crude oils and bitumen; they are also considered to be the main source of their toxicity. Yet, heavy PAHs with four or five cycles, such as benzopyrenes, are hardly present in crude oil.

Oil **resins** are heterocycles (containing sulfur, oxygen and nitrogen atoms); they are defined through their solubility in organic solvents or in water, but not through their structure. Those molecules are relatively small (6 to 30 carbon atoms), polar and soluble in pentane and heptane. Their structures are not well known. Partially soluble in water, resins resist biodegradation and are generally considered to be toxic, albeit based on the only few data yet available (Adams *et al.*, 2014).

Asphaltenes are large molecules; they contain at once aromatic cycles, heterocycles and complex organic functions. They are not volatile and they are highly resistant to biodegradation. They represent a rather small proportion of light and medium oils but a large portion of heavy oils and bitumen.

In addition to SARA classes described above, crude oils and bitumen contain low quantities of elementary sulfur, metals, organometals, naphthenic acids, mineral particles and water.

The chemical composition of bitumen from bituminous sands varies for each site. In all cases, they consist of a mixture of a large proportion of asphaltenes and resins, and a small proportion of saturates and aromatics. The viscosity of bitumen is so high, it is impossible to transport it in a liquid form. The solution to this problem was found in dilution with a solvent capable of forming a stable and homogenous mixture, even at low temperature. Bitumen is entirely soluble in a mixture of light saturated hydrocarbons and also in light aromatics. The exact composition of the diluent varies with the technology used by the drilling company. Similarly, the proportion of diluent varies according to the mode of transportation and the destination of the diluted bitumen, (NAS, 2016). /

fraction is mainly formed with light compounds (one to three aromatic cycles), out of which some may evaporate once they have been incorporated in solution.

Wind and wave energy also promote the **dispersion** of oil microdroplets in water; which considerably increases the surface of contact between water and oil, and therefore, the possibility of the dissolution of water-soluble compounds. All of these chemicals are very toxic and abundantly found in heavy fuel oil, (NAS, 2016).

In the particular case of dilbit with a density quickly increasing in natural conditions, and heavy fuel oil with a density already close to 1.0 g·cm^{-3}, it is therefore anticipated that evaporation might cause some **sedimentation** of these products several hours after their spill, (NAS, 2016). Contact of the microdroplets of heavy fuel oil and bitumen dispersed in water with suspended particulate matter induces an aggregation of fine clay particles (>2.0 g·cm^{-3}) with the compounds. The density of the aggrgates increases over time and, eventually, could surpass seawater density and begin the sedimentation process. This phenomenon occurs particularly in the intertidal and in the subtidal zones where the mixing energy is strong enough.

Biodegradation of the oil is the result of the action of bacteria naturally present in seawater and sediment. These bacteria create natural communities capable of decomposing most of the oil chemical compounds, but at a different rate (Hazen *et al.*, 2016). This mechanism represents the main natural elimination route for hydrocarbons spilled in the environment. Several factors influence the oil biodegradation. The viscosity of the oil product is the first limiting one as it determines the accessibility of the product to microorganisms. The chemical composition, which determines the level of complexity of the molecules to be degraded, is the second factor. The more complex the compounds are, such as it is with non-conventional oils, the more their biodegradation is affected.

Biodegradation of the oil is the result of the action of bacteria naturally present in seawater and sediment. [...] The more complex the compounds are, such as it is with non-conventional oils, the more their biodegradation is affected.

BEHAVIOR WITHIN SEDIMENTS

Once they have reached the sea floor, oil hydrocarbons associate strongly with sedimentary particles and are subjected to physiochemical and biological transformations. As a function of time, an equilibrium takes place between biota, the dissolved phase and particulate phase -an equilibrium which can be represented on a simple diagram (see Figure 3.2).

Di Toro and collaborators (1991) suggested that the uptake of hydrocarbons can proceed by two ways: the absorption of soluble molecules on the external walls of the animal via water, or by an internalisation via food. According to that model, the toxicity of hydrocarbons is estimated by their partitioning between organic carbon in sediment and interstitial water, using the partition coefficient K_{OC} –between organic carbon/water, and by their distribution between interstitial water and tissues of the organism. Such an approach suggests that the partitioning is at equilibrium and the concentration in each phase can be predicted using a partition coefficient and the measured or estimated concentration in the other phases. Hydrocarbons cannot return from biota to the water or the sediment because they are bioaccumulated and assimilated by the organisms.

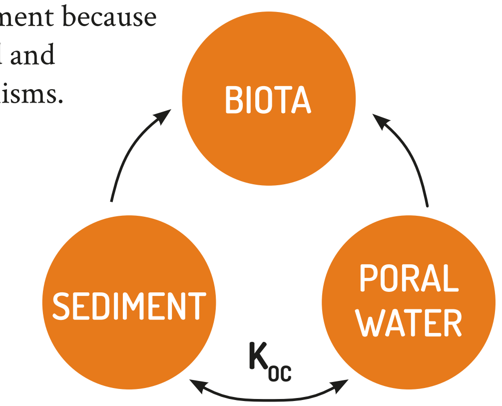


Figure 3.2
Model from partition to equilibrium of hydrocarbons in sediments. *(Adapted from Di Toro et al. 1991.)*
K_{OC} is the sharing coefficient – organic carbon/water.

BEHAVIOR IN ICE

Photo: R. St-Louis / UQAR 2016

During winter, low temperature modify properties of oil products by increasing their viscosity and consequently slow down alteration processes, such as evaporation and biodegradation (Lee *et al.*, 2015). Once salt is extruded from its formation, sea ice becomes porous and oil can infiltrate its inner structure. Oil becomes more or less trapped depending on the temperature of the environment (Figure 3.3).

The presence of ice poses a great challenge when the time comes to clean-up a spill,

Figure 3.3
Photo of an ice core with, at its base, a layer of oil incorporated in porous ice.

(Dickins and Buist, 1999). Indeed, the surface ice cover, the nature and the age of the ice, combined with the height of the waves and the air temperature influence the behavior of oil products. When ice is formed in the presence of light or intermediary crude oil, the latter can stay at the surface or can be incorporated in the cracks and spread under the ice cover, (Fingas and Hollebone, 2003). Should cold temperatures persist after the inclusion of the oil, a new layer of ice appears at the oil/water interface and the oil forms lenses of variable sizes completely inserted in the layer of ice, (Brandvik *et al.*, 2010). Therefore, oil can be encapsulated in the successive ice layers to eventually migrate to the surface via brine channels, (Figure 3.4). In the spring time, the sun warms up the oil located under or in the ice. Ice melts around the pockets of oil and allows its migration towards the surface and to form huge slicks floating on thawed water pools. Heavy or emulsified oils, too viscous and too dense to migrate to the surface, remain trapped in ice flows, until spring break-up or when all the ice has melted.

The spreading of oil under the ice is much slower than it is over a free surface since it is dictated by the ice/water interface roughness, especially in choppy marine environments and on a river. Low temperatures and reduced contact with the atmosphere and free flowing water decrease the evaporation, dissolution and biodegradation processes (Delille *et al.*, 1997). Thus, the most toxic light products remain intact under and in the ice until thaw (Fingas and Hollebone, 2003). There is no report of any study on the behavior of diluted bitumen in the presence of sea ice or freshwater. Taking into account the low viscosity of fresh dilbit, one may reasonably suggest its behavior will be similar to the conventional crude oil in icy water, (Figure 3.4). For dilbit under the ice or incorporated in the cracks, evaporation and dissolution should be low, and its original composition should be more or less preserved. A low sedimentation of the dilbit spilled under ice is expected as its density will not significantly increase. /

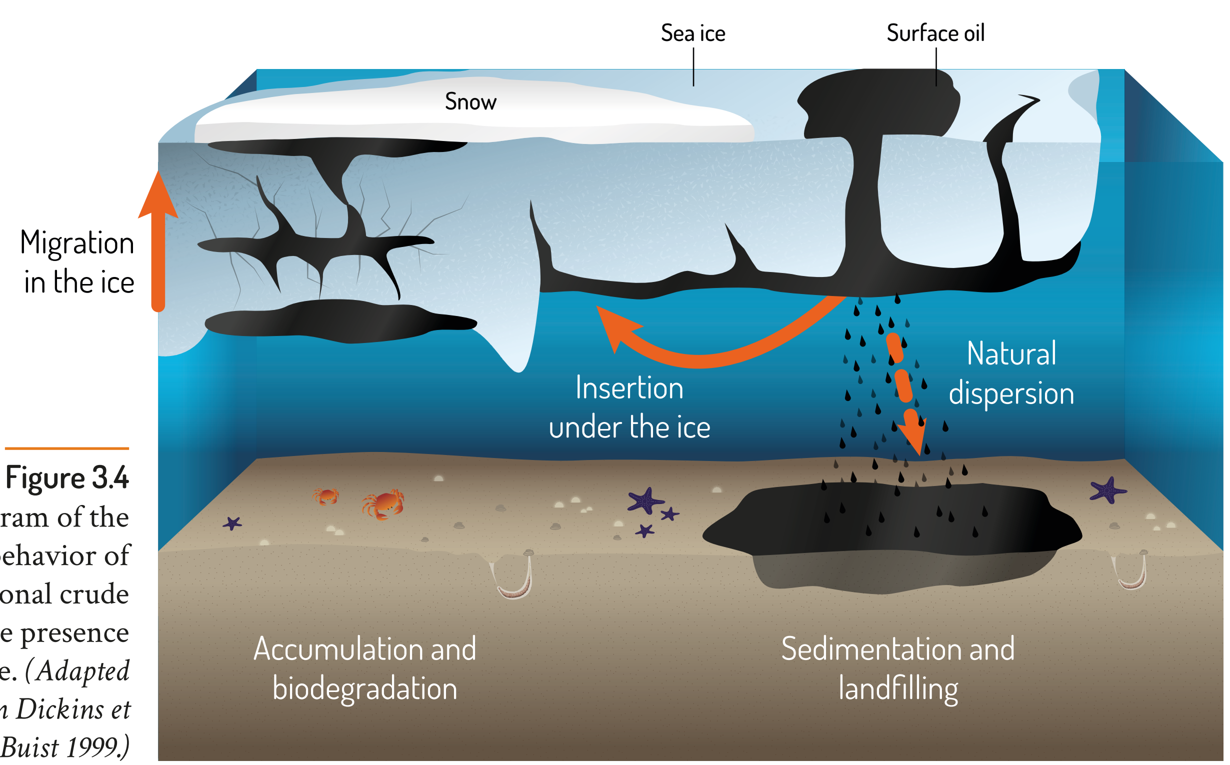


Figure 3.4
Diagram of the behavior of conventional crude oil in the presence of sea ice. *(Adapted from Dickins et Buist 1999.)*

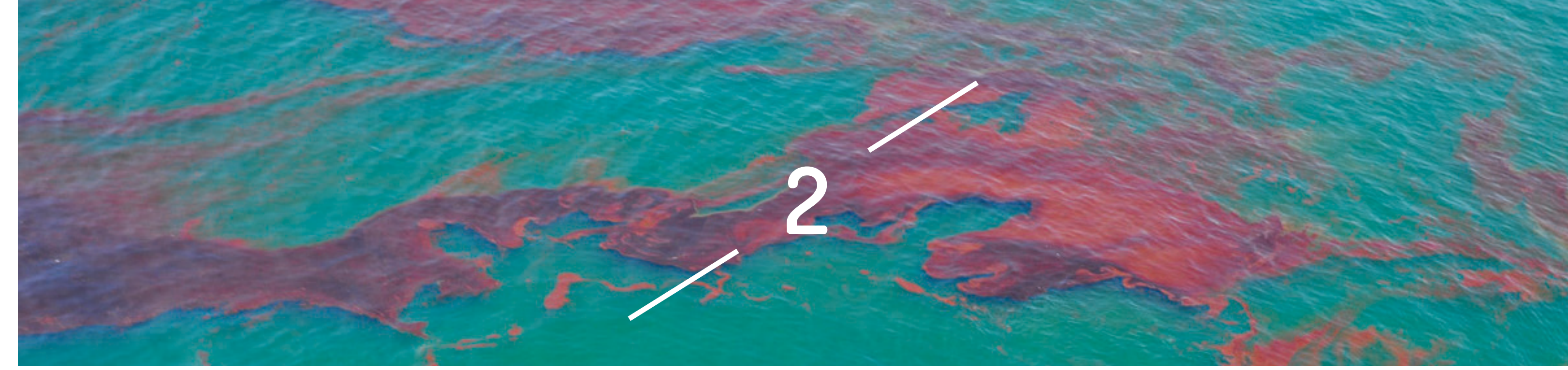


Photo: NOAA / FlickR

TOXICITY ASSOCIATED TO METHODS OF CLEAN-UP

There has been very little progress in field techniques used to address oil slicks and clean-up of oil off shorelines in the past 20 years. They remain very costly and labor-intensive. The classical approaches, in terms of manual and mechanical clean-up, are different from those using chemical agents capable of dispersing or solidifying oil (Fingas, 2013).

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MANUAL AND MECHANICAL TECHNIQUES

Generally, manual clean-up of beaches, marsh zones and rocky shores, without a chemical dispersant, does not increase toxicity of spilled oil. However, one must remember that intense walking in muddy and marshes zones would results in oil penetrating the soil and sediments while increasing contact with the roots of plants and benthic organisms living in these environments. Such oil landfilling consequently causes the reduction of the speed of biodegradation of the oil because of the reduction of oxygen required to maintain activities of aerobic oil-degrading bacteria.

Several beach and emerging rock clean-up techniques using fire nozzles and hoses were used at the site of some major accidents, such as the *Amoco Cadiz* on the coastlines of Brittany, the *Prestige* in Galicia and the *Exxon Valdez* in Prince William Sound, Alaska. Sometimes, such methods were combined with the use of dispersants and solvents, as it was the case with the *Torrey Canyon* on the British coastlines. These techniques are relatively efficient but they can lead to a substantial modification of indigenous microbial communities, hence delaying the restauration of the in situ biodegradation of the

Photo: ARLIS Reference / FlickR

spilled oil (Boufadel *et al.*, 2016). Some studies did mention that cleaning-up of the portion of fine sediments after the *Exxon Valdez* accident contributed to the considerable slowing down of the recolonization of some benthic species (Fukuyama *et al.*, 2014).

In addition, the clean-up using seawater, the weeding and the homogenisation of beach sediments can also alter the bacterial community. Indeed, even a year after the *Deepwater Horizon* catastrophe, microbial communities of sediment were still containing hydrocarbon degrading species associated to oceanic waters that could change their ecosystemic functions (Engel and Gupta, 2014). Beach oil clean-up contributes to the restoration of the sites, but in some cases removing macroalgae debris means that a number of species are deprived of their microhabitat and important source of food (de la Huz *et al.*, 2005).

Some clean-up techniques are invasive as they use high-pressure water jets or steam jets and chemical products to dislodge oil off beaches, as observed in the Prince William region, in 1989.

TECHNIQUES USING CHEMICAL MIXTURES

› DISPERSION AGENTS AND THEIR TOXICITY

The development and the use of dispersants as clean-up tools at the site of an oil spill go back to the late 1960's when the oil dispersion mechanism of a mixture of surface-active compounds and an application method onboard a ship were described (Canevari, 1969). A review of the scientific literature focussing on the chemistry, the application and the toxicity of the dispersants and other chemical agents was recently produced, (Pelletier, 2015).

The question pertaining to the toxicity of the surface-active agents, themselves, and of solvents and additives used in the formulation of the dispersants was raised as soon as the formulation of the dispersants began. Current commercial dispersants are not very toxic, with 50% lethal doses (LD_{50}) from 200 to 400 mg/L, which indicates a toxicity 10 times lower than the majority of oils (Fingas, 2013). Yet, their toxicity in natural environments does not seem so low. After the *Deepwater Horizon* platform accident in the Gulf of Mexico, huge quantities of Corexit 9500A and 9527 dispersants were used on the sea surface and in deep waters. According to authorized sources, (OSAT, 2011), between 7 and 9.8 million litres of these dispersants were used in the immediate vicinity of the platform (40% in depth) and on slicks drifting in the Gulf of Mexico. Surface-active agents were found in the coastal waters of Louisiana and Florida several weeks following the end of the operations. Biodegradation of these chemicals and their possible residual toxicity were questioned, (Zuijdgeest and Huettel, 2012). Even though their real effects on functions of the communities are unknown, the use of dispersants or flocculants has previously shown to be efficient to limit the effects of hydrocarbons, (Yamamoto *et al.*, 2003; Taylor and Rasheed, 2011).

The toxicity of dispersed oil makes no doubt and has been the object of numerous studies since the 1990's, (NRC, 2005; Prince, 2015; Esbaugh *et al.*, 2016). It only makes sense that myriads of oil droplets will contaminate the pelagic microfauna and the benthic macrofauna in shallow waters, especially bivalves and crustaceans, (Perhar and Arhonditsis, 2014).

Hydrocarbon toxicity increases with the addition of dispersants, due to their efficiency in fragmenting hydrocarbon droplets and their capacity to distribute oil all over the receiving environment, (Swedmark *et al.*, 1973; Bobra *et al.*, 1989). Dispersants also have the capacity to solubilize some PAHs, thus increasing the concentration of hydrocarbons in the water column, (Ozhan *et al.*, 2014b). The effects of the degradation of hydrocarbons on copepods and fish larvae in the presence of dispersants are variable following studied cases (Norregaard *et al.*, 2015; Sørhus *et al.*, 2015; Esbaugh *et al.*, 2016). Pelagic fish (especially their eggs and larvae) can be strongly affected by the use of a dispersant (Ramachandran *et al.*, 2004). In addition, the presence of dispersants and spilled oil increases by two to three times the mortality of zooplankton, incubated in mesocosms, (Almeda *et al.*, 2013). The use of dispersants could also reduce the transfer of microbial carbon via the reduction of grazing towards the upper levels, such as zooplankton, and ultimately reduce the production of fish, (Ortmann *et al.*, 2012). All these effects led researchers to strongly question the massive use of dispersants in natural environments, (Jung *et al.*, 2012).

Hydrocarbon toxicity increases with the addition of dispersants, due to their efficiency in fragmenting hydrocarbon droplets and their capacity to distribute oil all over the receiving environment.

- Swedmark *et al.*, 1973

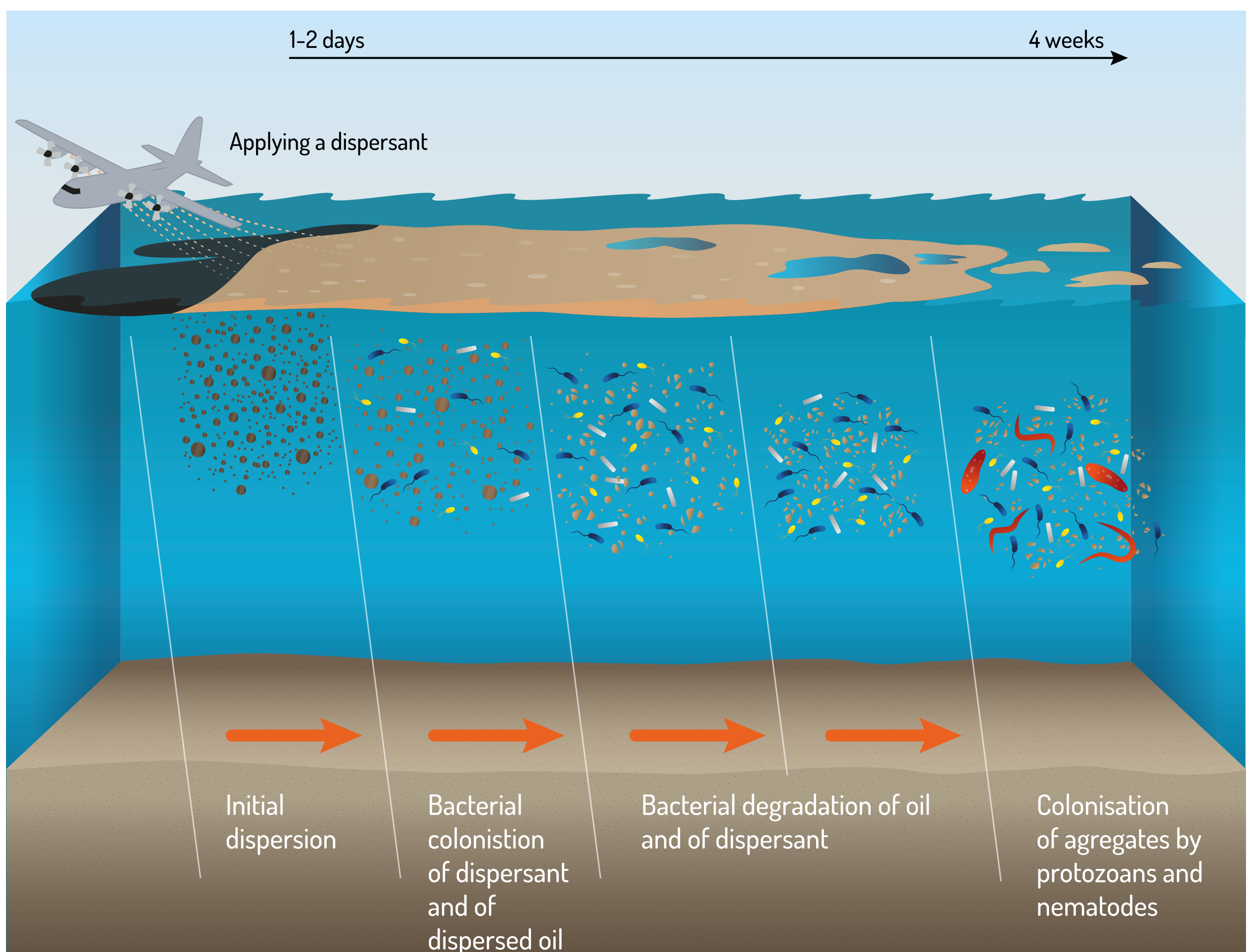
The question around the efficiency and, even the usefulness of dispersants is still an acrimonious debate within the scientific community. The massive use of dispersants on the site of the *Deepwater Horizon* platform spill was fiercely denounced by several scientists, especially marine ecologists who argued that losses of pelagic and benthic species of littoral zones due to the oil dispersion were superior to alleged gains. Some scientists seem to believe in a most generally negative effect on the microbial assemblages and on their degradation efficiency, (Joye *et al.*, 2014). On the contrary, the tenants of dispersants claim that dispersants may greatly reduce the effects of oil slicks on birds, mammals, marsh zones and beaches, (Prince, 2015). One must remember that oil companies have an interest in using dispersants as their use is cheaper than manual clean-up of the beaches and marshes, and better protect their image with the media.

On the other hand, it has also been clearly established, through numerous studies, that dispersed oil will be biodegraded faster by the local bacterial community, even at low temperature (McFarlin *et al.*, 2014; Hazen *et al.*, 2016), because the oil surface available to bacterial attachment is highly increased after dispersion, even if the droplets tend to return to the surface (Almeda *et al.*, 2014). Nonetheless, several recent studies have also shown that, unlike expectations, the use of dispersants could also limit the capacity of environment to efficiently remedy an oil spill by altering the growth of the bacterial species responsible for the oil biodegradation. Here are the reported reasons:

1) toxicity of dispersant or degradation products of some oil chemicals for some of the active bacterial strains

2) microbial biodegradation of the dispersant itself (see Figure 3.5), creating competition for nutrients (i.e. nitrogen and phosphorous) amongst bacterial strains that metabolize oil compounds and those metabolizing the dispersant, (Bælum *et al.*, 2012; Kleindienst *et al.*, 2015).

Figure 3.5
Steps in the microbial recovery of oil in the presence of chemical dispersants *(modified from Schmidt, 2010).*



The question around the real role of the dispersant is complex and has not yet been studied in details. However, modelling work by Zhao and collaborators (2015) sheds a new and revealing light on the topic. These authors highlighted the following points:

- the dispersant (herein Corexit 9500A) increases the solubility of some PAHs;
- the dispersant can be absorbed by sediment and strongly influences the sorption/desorption mechanism of PAHs;
- with the most soluble PAHs, their capture is linear against the increase of the concentration of the dispersant;
- conditions in very deep waters of the Gulf of Mexico, decrease solubilisation, while increasing the capture of PAHs by sediment.

These results are not really favorable to dispersants and show new issues that must be further examined.

› THE COBBLE CLEAN-UP AGENTS AND THE HERDER AGENTS

The surface washing agents of oil slicks are somewhat different from dispersants in their formula and use. They act according to the same principle laundry detergents do, by reducing the adhesive force between the oil and the solids to be cleaned. Unlike dispersants, these cleaning agents are more soluble in water than in oil. They move oil away from the surface and induce its flotation and then, allowing for a recovery by floating booms in a restricted zone.

Some chemical agents capable of concentrating oil slick at the surface of water can be found on the market. The simplest « herder » agent is made of surface-active agents not very soluble in water, though quite soluble in ethyl butanol, a solvent currently used in dispersants. When this mixture is applied to the water surface in the vicinity of an oil slick, the surface-active agent, being hardly soluble, tends to cover a rather large area and reduces the spreading energy of the slick, hence the mixture produces a grouping effect on hydrocarbons already spreaded in a thin layer. The « herder » effect allows for the thickening of the slick by reducing its surface and facilitating its clean-up, even at low temperature (Buist *et al.*, 2010).

› BIODEGRADATION AGENTS

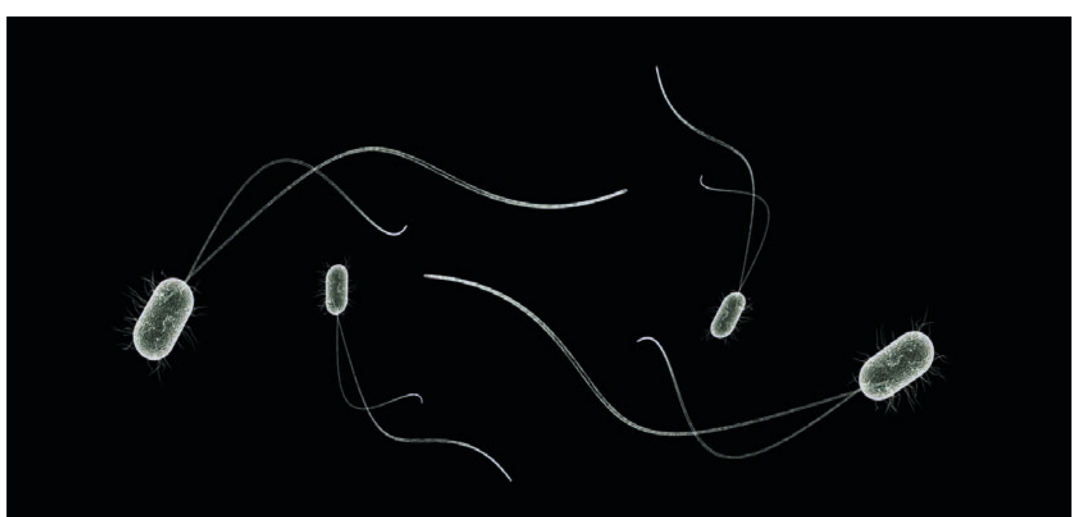
Multiple chemical agents have been developed to enhance oil biodegradation, either directly in water or in sediments and soils, (United States Environmental Protection Agency, 2015). In all cases, these agents content water-soluble nutrients (ammonium salts, phosphates, nitrates) to which carbohydrates and diverse natural products, also bioavailable to local bacterial communities, can be added. These added nutrients are generally beneficial to the oil biodegradation, even under severe conditions, (Coulon *et al.*, 2005).

Biodegradation of oil by microbial communities present in the natural environment can efficiently eliminates a large portion of the spilled oil, (Atlas, 1981; Atlas and Hazen, 2011), although it may leave toxic residues of an unknown nature, (Pelletier *et al.*, 2004). Several microorganisms have the capacity to use oil and transform it into cellular constituents, (Dash *et al.*, 2013). These microorganisms, mainly bacteria and fungi, are called oil-degrading microbes. They are capable of degrading hydrocarbons and use them as a source of carbon for their growth. No microorganism, on its own, can degrade all of the compounds of crude oil or of refined fuels spilled in the environment. Some bacteria can degrade several hydrocarbons or a whole class of hydrocarbons, but the tens of thousands of chemicals forming oil are not biodegradable without the combined action of an entire complex microbial community, (Head *et al.*, 2006). Generally, the introduction of oil into a natural environment is quickly followed by an increase of the presence of oil-degrading bacteria in the indigenous microbial community, (Haritash and Kaushik, 2009; Chronopoulou *et al.*, 2015).

The capacity to biodegrade oil by these communities depends:

1) on the type of oil and its state of degradation;
2) on the environmental conditions prevailing in the affected environment.

In fact, if environmental conditions are unfavorable to bacterial growth (temperature, light, availability of nutrients, etc.), in situ biodegradation will be limited (Juhasz and Naidu, 2000; Coulon *et al.*, 2005; Dash *et al.*, 2013). However, when growth conditions become more favorable, bacterial metabolism will be high and strong bacterial growth is observed, hence the high efficiency of biodegradation and consequently, an efficient elimination of the oil spilled. /



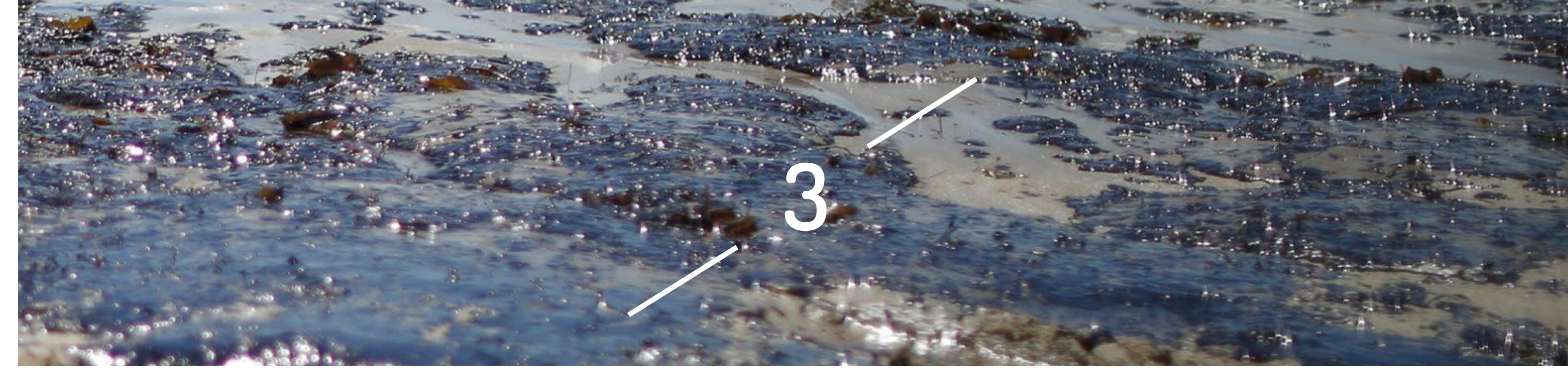


Photo: Pixabay

IMPACT ON MARINE ECOSYSTEMS

The impact of oil spills has strongly influenced public opinion, especially when the media broadcast seaside pictures of huge slicks where, fish, birds or mammals have died or are heavily oiled. Beyond that very strong visual impact these pictures provide, it is easy for a population to evaluate the negative impacts on the affected ecosystems. When algae, birds (ducks, geese, albatross) or marine mammals (sea otters) are affected, it is easy to imagine the harm caused on the ecosystems functions (food production, water purification, predation, control of invasive species) as well on the services they provide for the well-being of humans (for example, the cultural aspect via emblematic species; the economic aspect via fisheries and tourism), (Austen *et al.*, 2015; Johnson and Mayer-Pinto, 2015).

Comparing the effects of spills of hydrocarbons on ecosystems largely depends on the conditions in which they occur, such as the quantity of pollutants spilled, the type of hydrocarbons, the meteorological conditions at occurrence, the morphology of the coast line, the habitat and the type of affected biological community. Several studies with different ecosystemic approaches (Jewett *et al.*, 1999; Peterson *et al.*, 2001; Keller, 2005; Kimura and Steinbeck, 2005) have highlighted the lack of information with respect to the creation of a more representative basis for comparison of the diversity of the studied sites. As a matter of fact, only the before-after/control-impacted type of comparisons can clearly help to interpret the real effects of human impacts on ecosystems, (Underwood, 1992; Benedetti-Cecchi, 2001), including those with hydrocarbons (MacFarlane and Burchett, 2003). Still, one should keep in mind that the natural dispersion and potential attenuation of oil spill effects on marine environments are both a function to the conditions in which the event occurred. For example, the grounding of the Jessica in the Galapagos Archipelago (January 2001) turned out not to be a major catastrophe because:

1) the spill was rather limited (400 t. of diesel and 300 t. of heavy oil);
2) the oceanic waves and currents carried pollutants toward the open ocean environment;
3) the nearby mainly rocky shores decreased the beaching of the pollutants on the coasts;
4) the heavy oils was mixed with diesel;
5) a large portion of the pollutants was quickly evaporated in the absence of warm and sunny weather conditions, (Edgar *et al.*, 2003).

Fortunately, in the case of the *Jessica*, there were no significant impacts on plants or animals in the intertidal and shallow environments, (Edgar *et al.*, 2003). In this case, there were fortunate conditions compared to conditions often increasing adverse effects of an accidental spill and either delayed or prevented mitigation or recovery. The effect of hydrocarbons is often evaluated by their chemical contents, such as total petroleum hydrocarbons (TPHs) and the PAHs. As a consequence, in this section, when the term hydrocarbons is used without specification, we are referring to TPHs and PAHs in a broad sense. High quality literature reviews on the impact of hydrocarbons on aquatic organisms and their environment are available, such as the one by Dupuis and Ucan-Marine (2015). Here after, an overview of the main impacts on various species present within several marine ecosystems is presented, and in the following section, the observed temporal effects and recovery of the affected environments.

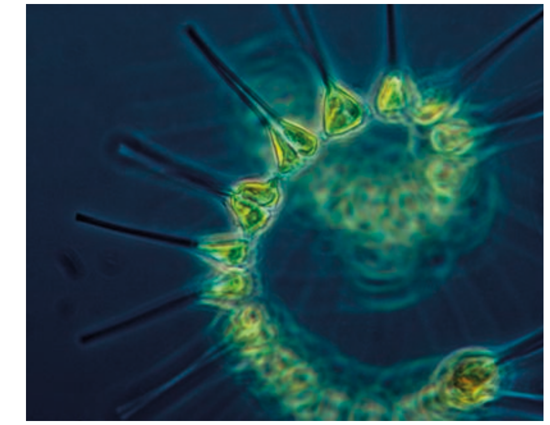
MICROORGANISMS

Small aquatic organisms (less than 0.1 mm) are the first to strongly react to the many changes in the ecosystem. After the *Deepwater Horizon* platform accident, bacterial communities on Louisiana beaches quickly moved towards typically oceanic communities with a high potential of hydrocarbon degradation (Engel and Gupta, 2014). Even six months later, microbial communities presented groups associated with a better hydrocarbon degradation capacity, and at the same time, changing the ecosystemic functions of these communities.

Facing the arrival of a large quantity of hydrocarbons from the platform, rapid changes in the microbial communities in several ecosystems (deep waters, coastal sediments, intertidal and deep benthos) of the Gulf of Mexico were observed; they were accompanied by observations of marine snow whose the formation process remains to be elucidated, (Joye *et al.*, 2014). That said, biodegradation of oil by natural microbial communities remains possible, even at low temperature and in the presence of ice, (Siron *et al.*, 1995).

Photo *Aeolidia papillosa*:
P. Archambault

PHYTOPLANKTON



In a marine environment, a large part of the primary production occurs through phytoplanktonic organisms. The effects of a possible spill on phytoplankton depend on many factors, such as the concentration of spilled hydrocarbons, temperature, currents, meteorological conditions, presence of nutrients, diversity and composition of the constituting species and the season, (Ozhan *et al.*, 2014a, 2014b). Based on growth experiences in laboratory, dinoflagellates proved to be less tolerant than diatoms to the presence of hydrocarbons. Furthermore, larger size species are less affected than smaller ones and an assemblages of five species increases the average resistance, (Ozhan *et al.*, 2014b). The difference in susceptibility between diatoms and dinoflagellates and a growth stimulation in the last group in the presence of low concentration of hydrocarbons might explain the abrupt changes in dominance within the phytoplanktonic populations, (Ozhan *et al.*, 2014b). It is very difficult to predict what a spill would cause on the phytoplankton dynamics, because of the speed of changes in the abundances and the large difference of tolerance among species in the presence of crude oil (Ozhan *et al.*, 2014a).

Work in mesocosms on natural plankton from the St. Lawrence Lower estuary (Sargian *et al.*, 2005) showed that the crude oil soluble fraction had powerful harmful effects on the phytoplanktonic community with a strong growth reduction and the increase of the average size of the cells, indicating a disturbance of the cellular division cycle. In addition, a strong increase in the bacterial abundance was attributed to the biodegradation of phytoplankton cells and the water-soluble oil compounds.

ZOOPLANKTON AND MACRO-INVERTEBRATES

Mortality in the zooplankton communities may be very strong when exposed to crude oil (Almeda *et al.*, 2013). A bioaccumulation of hydrocarbons (especially PAHs) in tissues of the zooplanktonic organisms has been observed along with a strong dependence on the type of hydrocarbons and the species studied. A bioaccumulation in tissues could transfer some compounds to their predators and, possibly towards higher trophic levels. However, the complexity of the zooplankton communities might maintain their integrity. Indeed, in the presence of copepods and protozoa, direct toxic effects or effects of the bioaccumulation of the hydrocarbons, by assimilation of fine droplets, might be reduced through the production of feces and by the transfer of the PAHs to the upper trophic levels (Almeda *et al.*, 2013). The assemblages of zooplanktonic species may however be very resistant to spills, as shown in the case of the *Sea Empress* accident (February 1996) in the Irish Sea where dominating or sensitive species were not significantly affected after the spill, (Batten *et al.*, 1998). Few changes were also observed in the

The growth of mollusks can be strongly affected by the presence of oil in water, and the size of hydrocarbon particles is among important identified factors for these results.

pelagic communities after the sinking of the *Prestige* in 2003 (Varela *et al.*, 2006). Yet, when the *Deepwater Horizon* platform exploded, the structure of the planktonic communities was greatly modified for a two-month period. Afterwards, the communities returned to their natural assemblages. That resilience is attributed to a strong activity by microbial organisms that would have stimulated the productivity of the zooplankton through complex trophic links (Carassou *et al.*, 2014).

Littoral macrobenthic communities can be affected or altered for several years due to an oil related accident. A study shows that structural changes, in the affected communities by spills of both the *Amoco Cadiz* (Brittany, March 1978,) and the *Aegean Sea* (Galice, December 1992), were detected at many taxonomical levels (species, genera and family), over several years, (Gomez Gesteira *et al.*, 2003). In the case of the *Amoco Cadiz*, effects on benthic and supra-benthic amphipods were very strong and they lasted over eight years following the catastrophe, (Dauvin 1987). This last dataset was abundantly used to illustrate the impacts on the marine benthic communities, (Clarke *et al.*, 2014). The effects of the spill of the *Prestige* tanker (September 2002) along the Spanish shores were numerous, though variable according to the taxonomic groups, (de la Huz *et al.*, 2005). Although marine crustaceans had not been or had hardly been affected on some beaches, eight months after the sinking, polychaetes, mollusks, insects and semi-terrestrial crustaceans had seen their numbers decreased by up to two-thirds. The growth of mollusks can be strongly affected by the presence of oil in water, and the size of hydrocarbon particles is among important identified factors for these results (Strömgren, 1987). Changes in the structure of the intertidal rocky shore communities were observed for several years following the accidental spill of the *Laura D'Amato* (August 1999) in Sydney Harbour, Australia, where opportunistic invertebrates dominated at the beginning of the recovery of the communities, (MacFarlane and Burchett, 2003). A comparison between the affected and non-affected sites following the *Exxon Valdez* accident showed a return to the normal abundance level at the polluted sites for a majority of the infaunal taxa (organisms living in sediment) after three years, but a slow recovery (up to 11 years) for some mollusk populations, (Fukuyama *et al.*, 2014).

FISH, CRUSTACEANS AND FISHERIES

Fisheries (including fish and crustaceans) were greatly affected as a result of the *Deepwater Horizon* platform catastrophe, as it led to their closure for months. Over five years after the explosion, some economic activities, such as crab and shrimp fisheries, had not yet totally recovered, (Gallucci, 2015). Already in 2012, forecasts of the economic impacts of the *Deepwater Horizon* accident were reaching \$8.7 billion US and a shortfall of \$4.9 and 3.5 billion US for both commercial and recreational fisheries, respectively, (Sumaila *et al.*, 2012).

When a spill occurs, the fractionation of the oil (including heavy fuel oil) leads to the dissolution of highly toxic substances, such as some PAHs, and to the formation of droplets that tend to stick to tiny organisms, such as larvae and juvenile fish. Multiple scientific studies have shown the short- and long-term damages caused to fish populations following the *Exxon Valdez* accident, (Rice *et al.*, 2001). Other papers have indicated that salmon embryos were killed or severely damaged due to concentrations of oil residues well below the level of concentrations normally observed after a spill (Brannon *et al.*, 2006). The effects were detectable on the long-term period of more than10 years following the accident, (Incardona *et al.*, 2013).

Effects of the spillage linked to the beaching of the *Exxon Valdez* and to the explosion of the *Deepwater Horizon* platform were huge. The survival of a large number of aquatic species, including fish, birds, turtles and marine mammals, was affected (Barron *et al.*, 2003; Barron, 2012). In both cases, authors indicated that the aquatic species have certainly suffered due to the decrease of their immune capacity which led to a greater susceptibility to diseases, a decreased reproduction capacity or a greater vulnerability to environmental and ecological factors (ex. predation). Fish, especially the larger ones, modified their diet after the explosion of the *Deepwater Horizon* as they abandoned zooplankton for small fish, (Tarnecki and Patterson, 2015).

Oil residues containing PAHs might bioaccumulate in groundfish, (Hellou *et al.*, 1995). As a matter of fact, oil deposits at the bottom of a bay are still a danger as they can be uptaken by fish species living on marine bottom and feeding off it. Lastly, numerous studies have shown that chemical products found in crude oil and in heavy fuel oil interfered directly with the embryonic development of fish and several genotoxic effects were observed, (Carls *et al.*, 1999; Incardona *et al.*, 2005).

The lifecycle and the behavior of crustaceans make them especially vulnerable to oil spills, and at every step of their development. As already mentioned above in the case of fish larvae, the first stages of crustacean development are sensitive to seawater soluble hydrocarbons. As an example, lobster larvae in the presence of crude oil for one to four days, if still alive, become lethargic or can hardly move; they also reduce their feeding (Wells and Sprague, 1976; Forns, 1977). Thus, they become easy prey for their predators.

Adult crustaceans exposed to hydrocarbons also tend to get the tainting of the oil due to the water-soluble sulfurized molecules in the oil products which are easily transferable to crustaceans. This appearance of an oil taste has often been noticed with fish and crustaceans following oil spills or in oil shipping lanes and exploitation zones, (Höfer, 1998). This oil tainting makes some fisheries and aquaculture products unmarketable and caused the closure of fishery activities in large areas around the site of an oil spill.

Bivalves are especially sensitive to the presence of the hydrocarbons because they are filter feeding organisms that draw their food from plankton and suspended particles (Pérez-Cadahía *et al.*, 2004). The presence of oil droplets leads to the rapid absorption of oil products and the contamination of bivalve stocks, which lose their commercial value. Adult bivalves generally offer a good resistance to hydrocarbons and tend to reduce their filtration rate as they await for their environment to return to a better quality. They can slowly depurate themselves in a cleaner environment, but the depuration rate depends on multiples factors, such as water temperature, hydrocarbon type and the filtration rate of the bivalve (Neff *et al.*, 1987; Martin *et al.*, 2003).

SEAGRASS BEDS AND COASTAL MARSHES

The known effects of oil contamination on coastal marshes include the alteration of the cohesive properties of the soils and the negative impacts on plants, populations of benthic invertebrates and fish that use the marshes to spawn or as a nursery, and on birds that use seagrass beds as their main feeding grounds, (e.g.: Canada geese and snow geese) when migrating in spring and fall. Effects on aquatic plants are numerous: reduction of photosynthesis and transpiration, reduction of the size and the density of shoots, reduction of growth, and complete mortality depending on the type of oil and the level of exposure and penetration of the oil in the soil, and the erosion of the margin exposed to waves (Lin and Mendelssohn, 2012).

BIRDS AND MARINE MAMMALS

Photo: Brocken Inaglory / Wikimedia

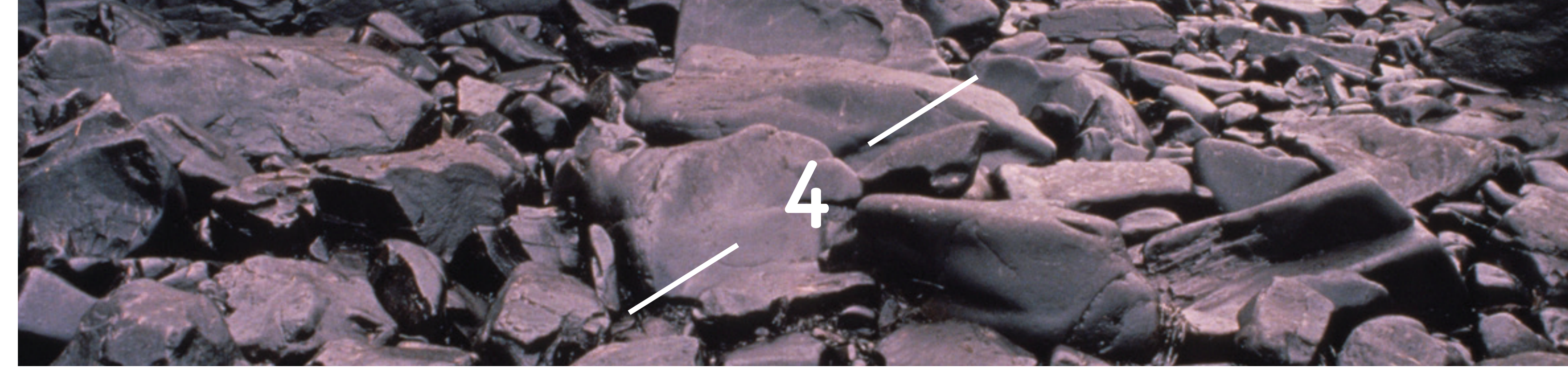
Hydrocarbon spills quickly affect birds and mammals as their plumage or fur are getting oiled and, eventually, as they accumulate hydrocarbons in their organism, through absorption or inhalation. Marine birds often are the first victims of oil spills as they live in the vicinity of the coastline and as they feed and rest on the surface of the water, (Leighton, 1993). Oil is adhering strongly to feathers which leads oil to accumulate in more or less important quantities depending on the amount of oil involved and its emulsion level. Birds ending up covered with a largest amount of oil can no longer fly and quickly drown. The other ones can go back to land where they will attempt to preen their plumage. The presence of oil on feathers greatly reduces their water-repelling capacity and result in the cold water being able to penetrate the plumage and reaching the skin, causing hypothermia and, often, death (Piatt *et al.*, 1990). Within six months following the *Exxon Valdez* accident (March 1989), over 30,000 dead birds from 90 species were found while it was estimated that 100,000 to 300,000 birds would have perished, (Piatt *et al.*, 1990). Sea ducks, Laridae (e.g. the seagull) and Alcidea (e.g. the guillemot) were the most affected families. After the explosion of the *Deepwater Horizon* platform (April 2010) in the Gulf of Mexico, over 7,000 dead birds (200 species) were recovered along the coasts but around 200,000 birds probably perished in the course of this gigantic spill (Haney *et al.*, 2014a, 2014b).

Marine birds are especially vulnerable to oil spills due to the exposure to PAHs at potentially high levels (Troisi and Borjesson, 2005). The ingestion of oil through feathers preening or eating contaminated prey can have long-term consequences on them and on their general health status (Giese *et al.*, 2000). For example, chronic exposure to PAHs can induce many physiological effects in birds, including an increase of the oxidative stress in the liver and the kidneys, of neurological and endocranial troubles, and immunity suppression which causes a deterioration of the general health status (Balseiro *et al.*, 2005; Alonso-Alvarez et al., 2007). This can also have a negative impact on their breeding success (Heubeck *et al.*, 2003). Nevertheless, too few studies paid attention to the sub-lethal physiological effects and on the ecological consequences of marine birds being exposed to crude oil, (Heubeck *et al.*, 2003).

As marine mammals come to breathe at the water/air interface, poisoning through inhalation, via contact with the skin and from ingestion is highly possible. The inhalation of oily water, mainly with those species that feed at the surface, leads to absorption in the circulatory system, to irritation and, possibly to permanent damage to the respiratory and nervous systems, (Rainer Engelhardt, 1983; Schwacke *et al.*, 2014). Seals are heavily affected by oil spills because, as a marine mammal, they spend part of their time between sea and land (haulout, rocks, beaches) to feed, to rest and to reproduce. As a result, and just as it is for birds, oil will reduce their capacity to insulate their fur and induce hypothermia, which becomes their main cause of death. Furthermore, as they ingest prey contaminated with hydrocarbons and try to clean their pelt, they end up with sever gastric, intestinal and renal problems, (Overton *et al.*, 1994).

The *Exxon Valdez* caused the (direct or indirect) death in the short- and medium-term to thousands of sea otters, (Ballachey *et al.*, 1994) as they could no longer count on the insulation capacity and floatability of their fur. The study of the dynamic of the sea otters populations after spills remained very difficult as many confounding factors (predation by killer whales, food availability) came up to entangle the interpretation of spatial-temporal indicators (Garshelis and Johnson, 2013). /

Photo: ARLIS Reference / FlickR



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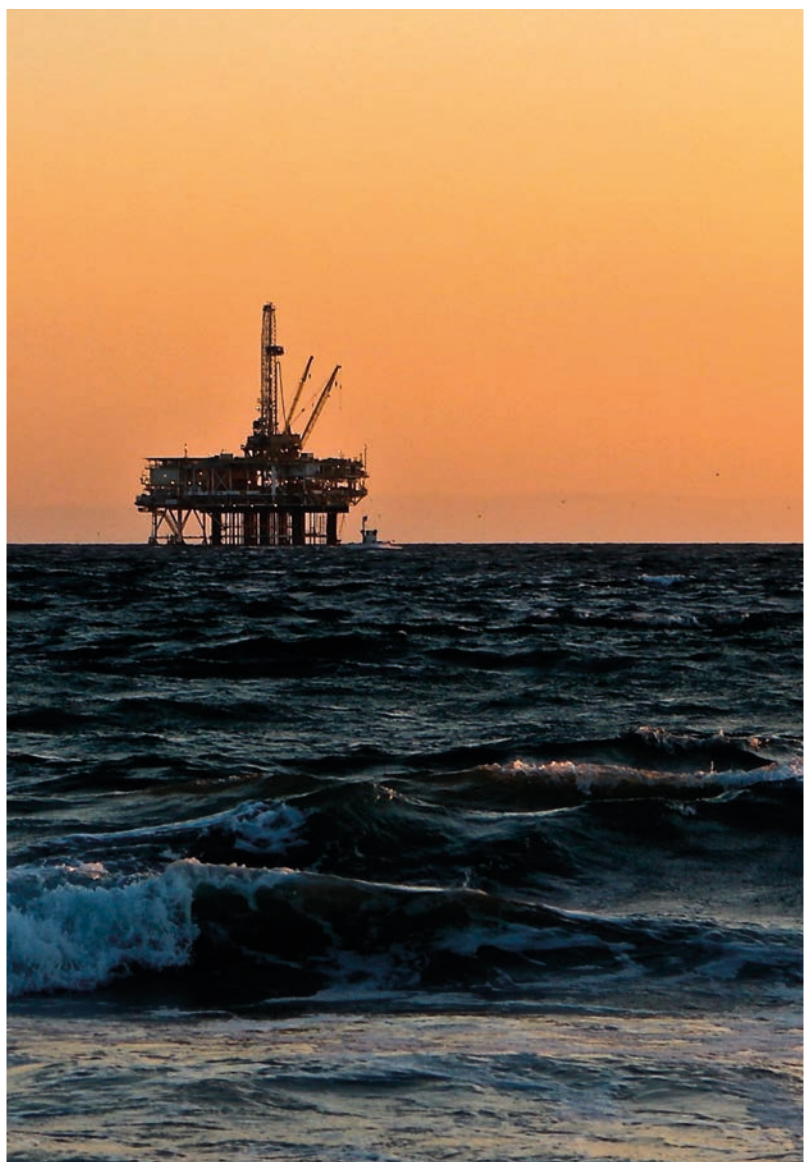
LONG-TERM IMPACTS AND RECOVERY

Huge oil spills are rare but their effects are immediate and often very marked on littoral rocky shores (Stevens *et al.*, 2012; Castège *et al.*, 2014) or sedimentary environments, (Andersen *et al.*, 2008; Bik *et al.*, 2012; Zabbey and Uyi, 2014). Studies conducted too early or at too short time after a spill might underestimate real or longer-term effects (Kingston *et al.*, 1995). The impact of operational spills (such as offshore platforms), that represent small but repetitive quantities are difficult to quantify due to the ecosystems adaptation capacity.

According to the ecosystems structure and the intensity of contamination, benthic communities might recover in a relatively rapid (<1 year), (Schlacher *et al.*, 2011; Egres *et al.*, 2012; Lee and Lin, 2013), a moderate, (1-5 years) (Yamamoto *et al.*, 2003; Lobon *et al.*, 2008; Castège *et al.*, 2014) or a slow rate (>5 years) (Jewett *et al.*, 2002; Gilfillan *et al.*, 2005; Fukuyama *et al.*, 2014). As an example, in January 2006, in the port of Gladstone (Australia) a small heavy oil spill produced deposits in the adjacent sediments, (Melville *et al.*, 2009). Even if a six-month period was long enough to observe a return to normal of an affected portion of the invertebrates community, defoliation of near-by mangroves remained very visible. Several years after the *Exxon Valdez*, high concentrations of pollutants in sediment and sub-lethal effects in fish, sea otters and shore birds were still observed, (Peterson *et al.*, 2003). Effects on populations at diverse trophic levels have even changed interactions between species and, possibly, affected the dynamic of the food network (Peterson *et al.*, 2003). Recovery is generally gradual, as was observed in the case of the sinking of the *Prestige*, where intertidal environments saw the richness, in terms of the number of species, to decrease by almost one-third after two years, (Castège *et al.*, 2014). Even if the richness of the communities has been re-established in three years, some observed species before the sinking remained absent. Recovery of the coastal marshes after an oil accident can be relatively swift or very slow, on a scale of decades (Hester and Mendelssohn, 2000). Several recent reports showed a swift recovery –within a few months- in the Spartina marshes of Louisiana after the *Deepwater Horizon* platform accident, (Lin and Mendelssohn, 2012; Silliman *et al.*, 2012). Massive spills following the Gulf War in 1990 strongly affected on a long term (>15 years) some communities of invertebrates of the Persian Gulf, (Joydas *et al.*, 2012). /

CONCLUSION

Aquatic environments have been used by human populations for thousand years. Today, the intensification of anthropic activities in these environments puts high pressure on ecosystems. Exploration and exploitation of hydrocarbons firmly turned towards marine zones, yet deeper ones, combined with the growth transit via maritime shipping lanes increase risks of accidental spills in coastal habitats. This chapter described the multiple elements to take into consideration as to the toxicity of hydrocarbons in coastal environments. When a spill occurs, behavior of hydrocarbons changes over time. Their incorporation in the pelagic environment and in sediments remains complex. An possible spill in arctic and subarctic environments, with the presence of ice, would profoundly change their dispersion dynamic and degradation rate, making clean-up extremely difficult, (Arctic Monitoring and Assessment Programme, 2010). Clean-up methods sometimes contribute to accentuating the toxicity of hydrocarbons, such as the use of chemical dispersants, which increases fragmentation of droplets and increases the absorption by many aquatic organisms. The impact of accidental spills on marine ecosystems largely depends on the quantity and on the type of oil released, on meteorological conditions on site, and on the type of habitat affected. Organisms in all trophic networks and their links can be affected: bacteria, phytoplankton, zooplankton, benthos, fish, birds and marine mammals. The duration of the effects is very variable, but in the case of major spills, such as the *Exxon Valdez*, effects remained perceptible over two decades.



Marine ecosystems are regulated by complex ecological processes. If, as in most of the cases of spills discussed in this chapter, environments turn out to be resilient, the impacts of those spills cannot be predicted with certainty due to the large number of variables influencing their extent. Although scientific knowledge on the toxicity of hydrocarbons in controlled environments is increasingly more detailed, studies on this topic can hardly translate the results on natural ecosystems. Greater knowledge is required on sublethal effects, on the long-term and at the scale of biomes to better preserve the integrity of coastal ecosystems and the ecological services they provide to human beings. /

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Cumulative potential impacts of the stress factors associated with human activities on the St. Lawrence marine ecosystem

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HIGHLIGHTS

- Human activities deriving from the occupation of the shores of the Estuary and the Gulf of St. Lawrence induce stress factors for marine organisms.

- The effects on the environment and the organisms of the interaction between these stressors (for instance hypoxia, acidification, organic pollutants, invasive aquatic species), and the presence of hydrocarbon are largely unknown.

- The complexity of these interactions, combined with natural variability makes it difficult to detect the residual and cumulative effects of a possible oil spill.

- The natural variability of environments likely to be exposed to hydrocarbons spills is such that it limits the extrapolation of laboratory experimental results to natural media.

Human activities modify natural environments, disrupting in the process inhabiting organisms. In the marine ecosystem of the Gulf of St. Lawrence, various perturbations affect ecosystems at different degrees. For some of them, the effects are little known or even unknown. Furthermore, several perturbations might simultaneously affect one component of the ecosystem or an entire system. The cumulative effects are even less known. In this chapter, we synthetize current knowledge on stress factors associated with human activities, and then, we try to determine their interactions and their cumulative effects on the St. Lawrence ecosystem.

INTRODUCTION

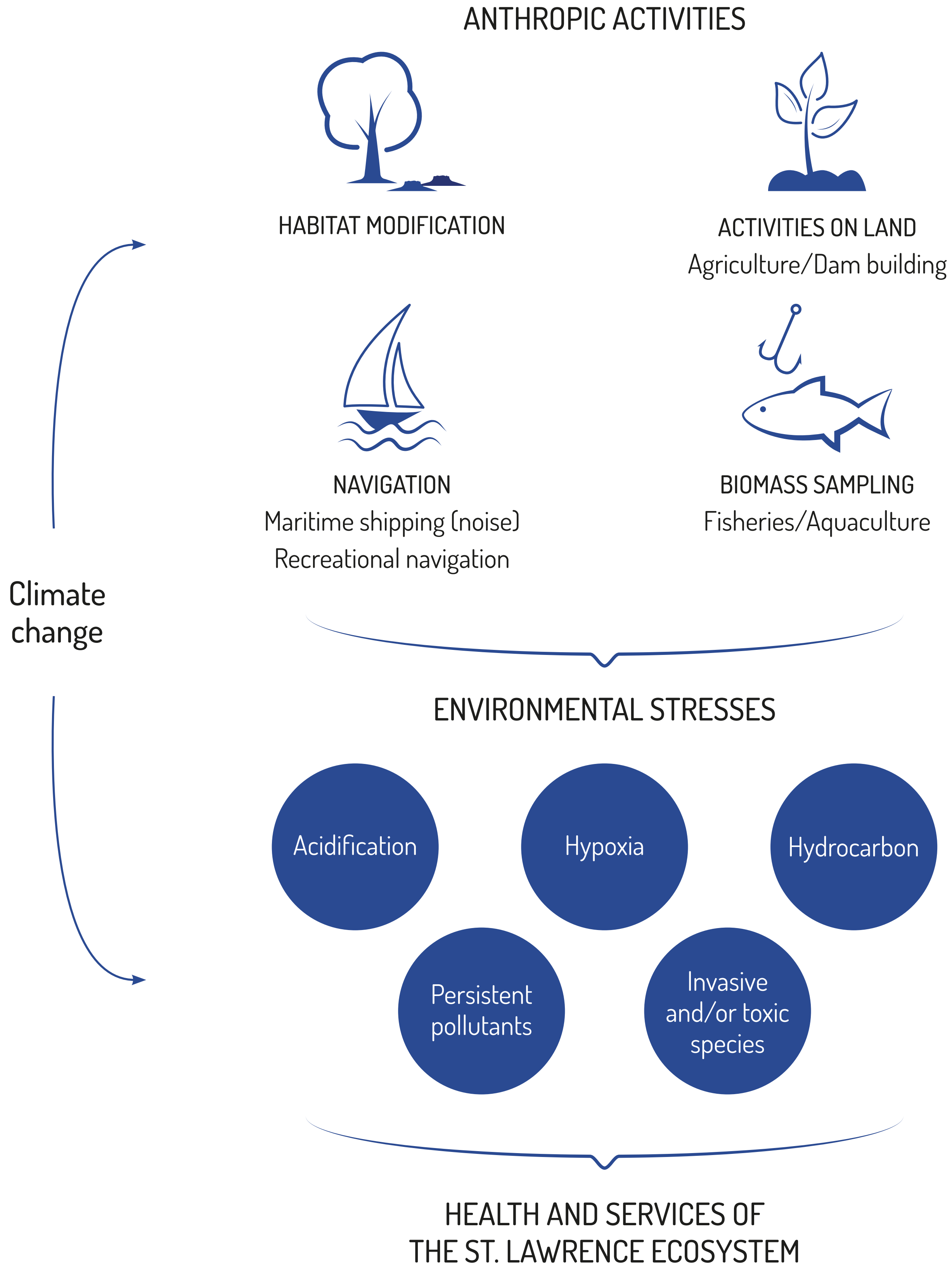
About 80% of the Quebec population and a large portion of that of the Atlantic Provinces, i.e. Newfoundland and Labrador, Nova Scotia, New Brunswick and Prince Edward Island, live along the shores of the Estuary and Gulf of St. Lawrence. To the inhabitants of these provinces, beyond a unique ecosystem, the St. Lawrence represents a lifestyle, an economic resource and a recreational area. Consequently, the St. Lawrence is a corner stone for the activities of the region. In this chapter, we are assessing the way some human activities, either regionally or globally, can affect the marine ecosystem of the St. Lawrence. A **human activity** is defined as a process by which human beings modify components of the a natural environment, as opposed to a **stress factor**, which is an intrinsic or extrinsic process capable of disrupting organisms and forcing them to adjust their physiology or their behavior to deal with the process (Killen *et al.*, 2013) which can push an ecosystem beyond its limits of tolerance. The list of stress factors to be taken in account herein is far from exhaustive. In addition, even though we acknowledge impacts on ecosystems due to extractive activities, such as fishing and aquaculture, these factors will not be considered in this chapter.

Water and organisms of the Estuary and Gulf of St. Lawrence are chronically exposed to impacts of human activities. These activities impose environmental stresses, such as hypoxia, acidification and the presence of invasive species, pollutants or hydrocarbons (Figure 4.1). Taken individually, these stress factors can strongly influence natural environments. When considered in combination, stressors can also interact among themselves; as a result, the combined effects can be additive, multiplicative or mitigative (Beauchesne *et al.*, 2016) when they can be expressed as a summation, a product or the result of a mitigation process of their individual effects, respectively. Synergies amongst environmental stressors are nevertheless difficult to predict, in such a way that they are typically ignored and preference is given to individual approaches, sector by sector.

The synthesis of current knowledge regarding environmental stressors associated with human activities is presented first, and then, their interactions and their cumulative effects on the ecosystem of the St. Lawrence are described. /

A human activity is defined as a process by which human beings modify components of the a natural environment, as opposed to a stress factor, which is an intrinsic or extrinsic process capable of disrupting organisms and forcing them to adjust their physiology or their behavior to deal with the process […].

Figure 4.1
Schematic representation of anthropic activities (addressed in the present chapter) and some of the environmental stresses that arise from those activities and might affect the services and the functioning of the ecosystem of the St. Lawrence. Climate change, deriving from human activities, will also have additional effects on these stresses.



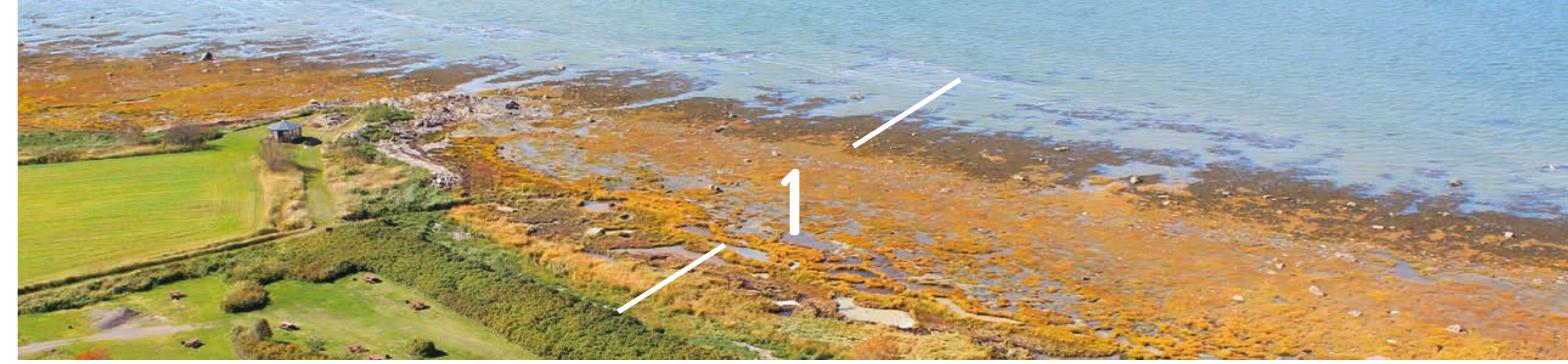


Photo: S. Weissenberger

HYPOXIA

> [...] hypoxia occurs when concentrations of dissolved oxygen are low enough to cause stress, and even the death of some organisms.
>
> - Gilbert *et al.*, 2007

In aquatic environments, hypoxia occurs when concentrations of dissolved oxygen are low enough to cause stress, and even the death of some organisms, (Gilbert *et al.*, 2007). Hypoxia is defined using a range of values going from 0.28 milligrams of oxygen per litre (mg $O_2 \cdot L^{-1}$) or 3.7% saturation (%sat), (Kamykowski and Zentara, 1990) to 4 mg $O_2 \cdot L^{-1}$ or 54.2%sat, (Paerl, 2006), but the majority of studies refer to a threshold of 2 mg $O_2 \cdot L^{-1}$ which is equivalent to 27.1%sat (Turner *et al.*, 2005). Hypoxic phenomena are mainly observed in estuaries and in coastal regions where vertical stratification of the water column limits exchanges between deeper and surface waters, the latter having higher oxygen levels (Diaz and Rosenberg, 2011). Hypoxic conditions result from poor ventilation (i.e., low input of oxygen from the atmosphere or from advection of low oxygen water) and respiration, essentially from marine microorganisms, (Karstensen *et al.*, 2008). In the St. Lawrence Estuary, hypoxic conditions have been observed since the 1980's. Unlike several places around the world where it is a seasonal issue, hypoxia is chronic in the deep waters of the Estuary and the Gulf of St. Lawrence. Bottom water (>300 m; Bourgault *et al.*, 2012) in a portion of the Lower St. Lawrence Estuary is showing persistent hypoxic conditions, with concentrations of dissolved oxygen below 62.5 micromoles of oxygen per litre (µmol $O_2 \cdot L^{-1}$) or 2 mg $O_2 \cdot L^{-1}$, (Gilbert *et al.*, 2005). This hypoxia -of natural origin- is accentuated by the eutrophication and by the presence of anthropic phosphorous and nitrate, (Gilbert *et al.*, 2005). This phenomenon can be partially explained by an increase of the relative proportion of warm waters, also poor in oxygen, of the Gulf Stream coming into the Gulf and the Lower Estuary, as opposed to highly oxygenated cold waters from the Labrador Current, (Gilbert *et al.*, 2007). Model studies also show that nutrients have a strong negative impact on dissolved oxygen concentrations in the Estuary and the north-west section of the Gulf of St. Lawrence, (Lavoie *et al.*, 2015). The increase of bacterial respiration associated with temperature increase of about 2°C compared with the 1930's has likely contributed to the increased oxygen demand (Genovesi *et al.*, 2011).

On the other hand, low dissolved oxygen concentrations observed in the north-east of the Gulf of St. Lawrence owe their origin to waters coming from the North Atlantic, (Bourgault *et al.*, 2012; Lefort *et al.*, 2012; Bourgault et Cyr, 2015). Even if the waters of the Gulf are not hypoxic (see Bourgault *et al.*, Chapter 2), circulation of the deep water layer in the hydrographic system of the St. Lawrence ensures a connectivity amongst water masses. A change in concentrations of dissolved oxygen in the deep-water layer at the mouth of the Laurentian Channel at the edge of the continental shelf would necessarily impact the concentrations of oxygen in the lower estuary.

Hypoxia can generate physiological and behavioral responses that have negative effects such as a reduced growth, loss of reproduction capacity, mortality, reduction of biodiversity, and the loss of secondary production (Wu, 2002). Hypoxia modifies the rate and mechanisms of organic matter and metals recycling (Andersson *et al.*, 2008; Middelburg and Levin, 2009), thus influencing the dynamics of the carbon dioxide (CO_2) biological pump. This process allows for the sequestration of atmospheric carbon at the bottom of oceans, one of the main gases responsible for the greenhouse effect. Larvae of several fish and crustacean species are less tolerant to hypoxia than adults are (Miller *et al.*, 2002). In particular, fish larvae with a high growth rate are more sensitive to hypoxic conditions, especially when they transit from diffusion respiration to branchial respiration (Davenport, 1983). Females at a reproduction stage suffer more from an oxygen limitation due to increased metabolic demands during gonads development. Fish growth is also affected by the decrease in dissolved oxygen. For example, the growth rate of cod, one of the commercial species of the Gulf of St. Lawrence, decreases when the oxygen saturation level is below 70% (Chabot et Dutil, 1999). Oxygen levels in the bottom waters of the St. Lawrence Lower Estuary are currently too low for their development. Therefore, an expansion of hypoxia could add barriers to the dispersion of organisms (Pörtner and Farrell, 2008). Even though some species such as the Greenland halibut and the Nordic shrimp -which hold a substantial commercial interest- have a high tolerance to hypoxia (Ait Youcef *et al.*, 2013), recent studies showed that an increase in the current hypoxia level will have a significant impact on their metabolism, growth and survival (Dupont-Prinet, 2013a, 2013b; Mejri *et al.*, 2012). Laboratory data showed that a species-at-risk, the spotted wolffish (*Anarhichas minor*), is acting as the cod when exposed to hypoxia. Its lethal threshold is around 16 to 21% saturation and its growth rate decreases when dissolved oxygen decreases below 65% saturation. Hypoxia could compromise the recovery of this species at the head of Laurentian Channel (Jetté *et al.*, 2011; Simpson *et al.*, 2013). A decrease in the level of dissolved oxygen in ocean, modifying animal communities by decreasing the presence of more vulnerable species, has also been documented (Lévesque *et al.*, 2010; Moritz *et al.*, 2013).

[...] the carbon dioxide (CO_2) biological pump
[...] allows for the sequestration of atmospheric carbon
at the bottom of oceans [...]

The ecological and biochemical responses to a decrease in dissolved oxygen can be fast as illustrated by mortality observed in some marine weeds and benthic animals. The effects of hypoxia and tolerance of species to a low dissolved oxygen concentration vary following the species and its size; the smallest organisms, with a high surface/volume ratio facilitating exchanges with their environment are more tolerant (Levin, 2003). Sessile benthic animals - with limited mobility - cannot quickly find a new habitat in response to hypoxic conditions. According to their intensity, frequency and duration, hypoxic events can therefore be lethal to benthic organisms. The structure of the macrobenthic community of the deep water layer of the St. Lawrence Estuary is different to the one of the Gulf where waters are oxygenated as opposed to the hypoxic waters of the Lower Estuary (Belley *et al.*, 2010). The benthic communities of the Estuary are dominated by groups of species tolerating low concentrations of dissolved oxygen, such as ophiura (Belley *et al.*, 2010). In general, benthic macrofauna in hypoxic zones is dominated by surface detritivores (feeding organic matter detritus from sediment), as they better tolerate low oxygen condition than suspension feeders do (feeding suspended organic matter suspended).

The effect of hypoxia on benthic communities might not be reversible (Levin *et al.*, 2009; Dale *et al.*, 2010). The response of organisms to the recovery of normal conditions in dissolved oxygen could take several years, if not several decades. It can cause transitory equilibrium states, i.e. different from those in the original communities (Contamin and Ellison, 2009; Levin *et al.*, 2009).

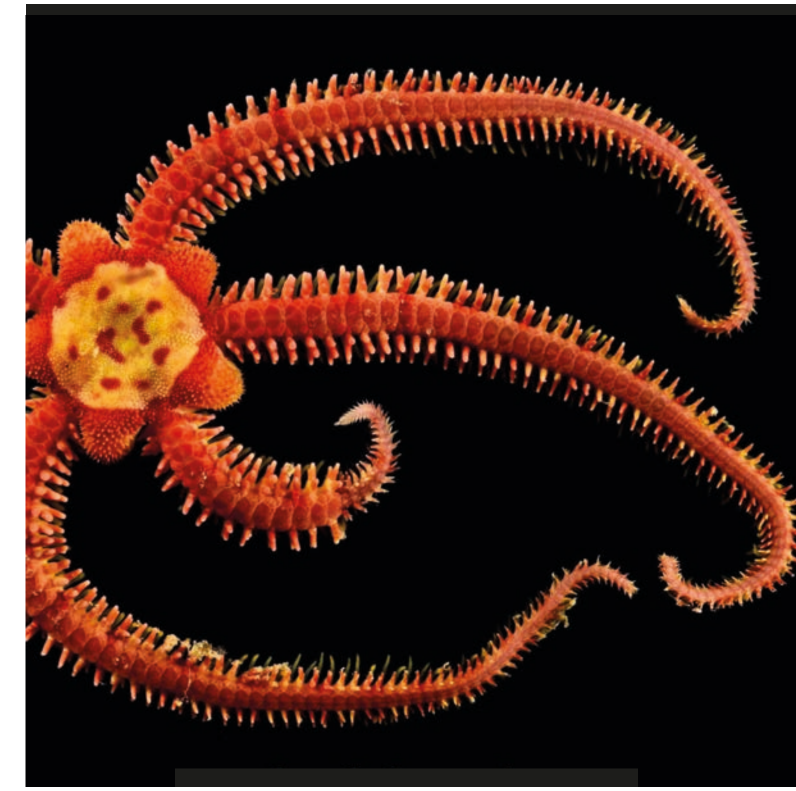


Photo *Ophiopholis aculeata*: Benjamin Davidson / FlickR

Hypoxia and its effects on organisms are actively studied by researchers at Fisheries and Oceans Canada (DFO) and by university researchers from Quebec, from the NSERC Canadian Healthy Oceans Network (CHONe) (see Snelgrove *et al.*, 2012), as well as from the rest of Canada (D'Amours, 1993; Chabot et Dutil, 1999; Ait Youcef *et al.*, 2013). /

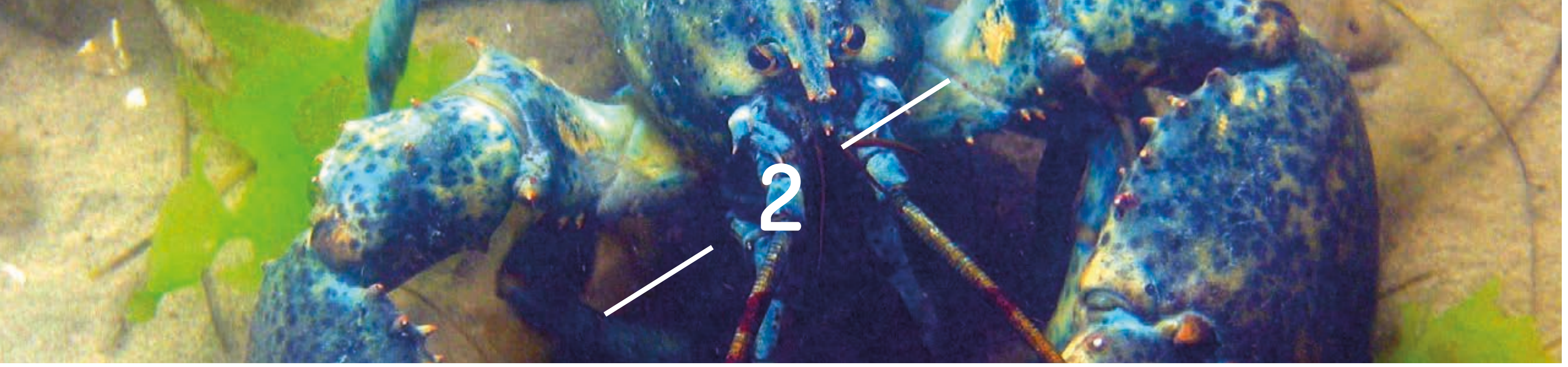


Photo: P. Archambault

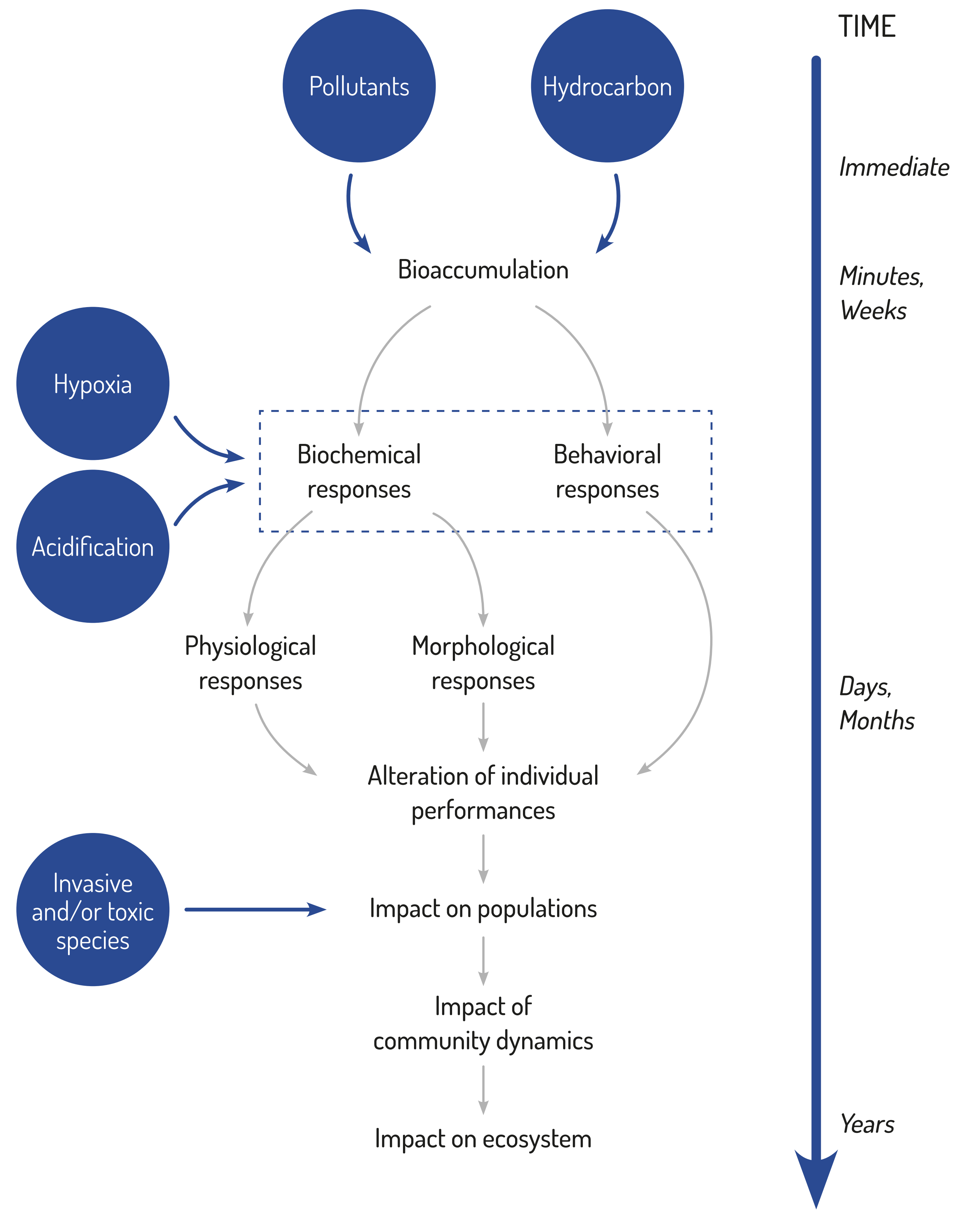
ACIDIFICATION

The dissolution of atmospheric gases such as oxygen and CO_2 in oceanic waters is a natural process depending on physical conditions (temperature and pressure), and on chemical (acid-base equilibrium) and biological (photosynthesis and respiration) mechanisms. Following the chemical equilibrium controlling the partitioning of dissolved CO_2, this gas reacts with water to produce carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) anions and hydrogen cations (H^+) are generated. The concentration of H^+ determines the water acidity which is measured by the potential of hydrogen (pH). Marine organisms are adapted to stable ocean pH values for thousands of years, as seawater behaves like a buffer system. Yet, the capacity of the ocean to control the concentration of H+ has its own limits. Ever since the industrial revolution, oceans have absorbed about 30% of the excess of CO_2 produced by the combustion of fossil fuels and other human activities, at a rate of 1 to 3 Gt of carbon per year (Battle *et al.*, 2000) through physical, chemical and biological processes (Sabine *et al.*, 2004). Even though this absorption helps to decrease CO_2 concentrations in the atmosphere, it has created an increase of acidity in seawater. In fact, the pH of the ocean surface waters has already decreased by 0.12 units, the biggest decrease recorded in several million years (Caldeira and Wickett, 2005). Ocean acidification represents a problem for all species with skeletons or shells made of calcium carbonate ($CaCO_3$), such as coccolithophores, pteropods (food for fish, such as salmon), mollusks, corals and crustaceans in a less extend. These species are an integral part of several trophic networks with a stability that could be compromised if some species see their biological characteristics affected by acidification (Harley *et al.*, 2006). The effects are especially important in mollusk larvae, for instance mussel larvae producing aragonite shells, because when the pH is low, aragonite shells are more soluble than the calcite shells produced by adult mussels (Bechman *et al.*, 2011). The negative consequences of the decrease of the pH level might not be limited to calcifying organisms, as the majority of physiological cellular processes are sensitive to pH (Fabry *et al.*, 2008). Other commercially exploited species in Quebec, such as lobsters, could also be affected (Figure 4.2). Still, the effects vary from species to species, but also within the same species, depending on its genetic background, life cycle, preadaptation mechanisms, and the synergic effect of environmental factors (Doney *et al.*, 2009). The sensitivity of marine ecosystems to acidification hence remains an intensely debated topic (Halloran *et al.*, 2008; Ridgwell *et al.*, 2009).

Even though the absorption of CO_2 by seawater helps to decrease CO_2 concentrations in the atmosphere, it has created an increase of acidity in seawater.

Research on acidification in the St. Lawrence system is hardly beginning. Mucci

Figure 4.2
Time scale – Anthropic disruptions and their different effects on organisms and on ecosystems.

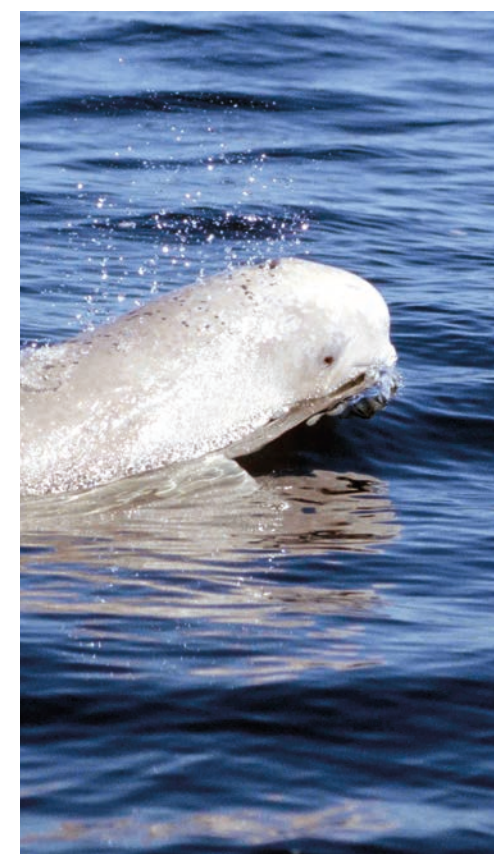


and collaborators (2011) reported pH measurements in the St. Lawrence Lower Estuary since the 1930's and showed that surface waters would have already slightly acidified, while in deeper water layer, a decrease of pH of around 0.2 to 0.3 units is observed. These reductions of pH are associated with the progressive decrease of the rate of dissolved oxygen reaching the Gulf and Estuary of the St. Lawrence, and to an increase in the concentration of metabolic CO_2 derived from the degradation of organic matter. The extent of the current acidification in deep water is of the same order of magnitude as the one predicted for the oceans by the end of the century. Deep waters of the estuary are currently heavily undersaturated in aragonite and at equilibrium with respect to calcite saturation, the two minerals forming shells and exoskeletons of many marine organisms, as mentioned above (Mucci *et al.*, 2011). Even though highly acidified waters are generally found well below 150 m in the St. Lawrence Estuary, intermediate waters are already showing a pH of 0.1 unit below levels measured in the 1930's (Mucci *et al.*, 2011). That intermediate acidified water reaches the surface in zones of the St. Lawrence characterized by water upwelling or intense vertical mixing (Gratton *et al.*, 1988). Furthermore, at the head of the Laurentian Channel, acidic water comes in to add to the acidic water of the Saguenay Fjord (Benke and Cushing, 2005). Therefore, the region located near the north shore of the head of the Laurentian Channel, between Tadoussac and Les Escoumins, is the most affected. However, the origin of the surface waters (0 to 150 m) in that region is complex and is constituted of variable water contributions from the St. Lawrence River, the Saguenay Fjord and also the upwelling from the deep hypoxic water of the Lower Estuary. In summary, the decrease of the pH observed in the St. Lawrence ecosystem is more important than predicted by models based on the increase in concentrations of atmospheric CO_2 by the end of the century. This is due to the presence of local processes, such as the addition of freshwater, the respiration in the water column and the hydrological changes. The influence of forecasted pH decreases on marine organisms of the St. Lawrence is now being studied in the field and under controlled conditions. /

Illustration: Harryarts / Freepik

PERSISTENT ORGANIC POLLUTANTS

Photo: Ansgar Walk / Wikimedia



Persistent organic pollutants (POP) are "carbon-based chemical compounds or groups of compounds of anthropic origin; they are inert from the biological or chemical point of view"[1]. This inertia and their lipophilic properties allow their persistence without biodegradation and their bioaccumulation in tissues of organisms living over short periods of time (Figure 4.2). Amongst these compounds, it is worth mentioning the organochlorinated pesticides (DDT and others), polychlorinated biphenyls (PCBs) and dioxins. Among the known effects of exposure to POPs on human health are: nausea, learning troubles, cancer, and even death, in extreme cases. Canada is among the 151 countries to have signed, in 2001, the Stockholm Convention on persistent organic pollutants[2], that prohibits the use of a certain number of chemical substances deemed to be very polluting and requiring the signatory members to reduce and eliminate current levels of POPs in human beings and in the environment.

Studies on the impacts of POPs on St. Lawrence marine animals include the effects of several families of molecules. In the St. Lawrence Estuary, beluga whale (*Delphinapterus leucas*) is deemed to be a sentinel of the presence of bioaccumulative POPs. In a review of data on the contamination of tissues of beached belugas of the St. Lawrence Estuary, several authors have concluded that contamination depends on a number biological factors, such as the sex and the age of the animals, along with physical and temporal factors, such as the length of exposure to POPs (Lebeuf, 2009). For controlled substances, it was shown that concentrations observed in the beluga blubber were either decreasing or stable in the 2000's. Nevertheless, for emerging substances, such as polybromodiphenylethers, concentrations doubled every two or three years throughout the same period (Lebeuf, 2009). These compounds are introduced in the marine environment via discharge of waste waters and atmospheric deposits. Some compounds tend to degrade into more toxic and bioaccumulating molecules

[1] www.encyclopediecanadienne.ca/fr/article/polluants-organiques-persistants-pop
[2] www.pops.int/documents/convtext/convtext_fr.pdf

[...] it is known that the immune system of contaminated animals is affected by some POPs, making these species more susceptible to get bacterial or viral infections [...]

(Lebeuf, 2009). According to the chemical structure of the initial product or the degradation product, there might be a harmful risk to the endocrinal system of fish and marine mammals, as well as groups of human consumers, such as the First Nations communities settled along coastal regions. Even if at low concentrations the effects on organisms are not lethal, it is known that the immune system of contaminated animals is affected by some POPs, making these species more susceptible to get bacterial or viral infections that could have major consequences (Bassim *et al.*, 2014).

The interactions between the presence of POPs and other disruptions of the marine environment can further promote bioaccumulation. For instance, hypoxia induces filtering organisms to filter more water to reach the adequate levels of oxygen. An increased filtration rate will let more pollutants (POPs, but also metals, hydrocarbons, etc.) get through the gills. These pollutants will then be accumulated in organisms in a greater proportion and be transferred to the rest of the trophic web, even amplify their concentrations, as illustrated by the case of concentrations of mercury in polychaetes (Miron, 1994). /

4

Photo *Botrylloides violaceus*: U.S. Geological Survey - Dann Blackwood (USGS) / Wikimedia

INVASIVE AQUATIC SPECIES

Exotic aquatic species (EAS) are exogenous aquatic organisms voluntarily or accidentally introduced in an environment where they were absent, and where conditions allow their proliferation (Simard *et al.*, 2005). In their new environment, these species may either have no impact on the ecosystem, or harm it by grabbing a portion of the natural resources necessary to endogenous species as they become efficient predators or when they introduce pathogenic organisms (Colautti *et al.*, 2006). Their presence translates into a potential threat to the biodiversity of the invaded ecosystems, as well as for fisheries and aquaculture, and human health. They might become a social and economic problem for the affected regions, a situation rarely quantified (Hayder, 2014).

[The presence of exotic aquatic species] translates into a potential threat to the biodiversity [...], as well as for fisheries and aquaculture, and human health.

EAS's have effects on the relationships inside the trophic web with possible consequences on the entire ecosystem. Invasive species often show high reproduction rates and will not -or hardly- have any natural predators. The introduction of an invasive species and the modifications caused to the environment can easily facilitate the establishment of other invasive species, for which the characteristics of the new disturbed habitat better meet their needs.

The EAS can reduce productivity in some commercially exploited species. One example of this is given by oysters, whose productivity has been considerably reduced due to the parasite MSX introduced near Cape Breton Island. This parasite then propagated to Prince-Edward-Island via ship ballast waters (Burreson and Ford, 2004; Transport Canada, 2010). Another example is the effect of tunicates, named for their "tunic" produced by their epidermis and covered with a cuticle. Depending on their developmental stage, they may alternate from free swimming to sessile forms. They are exogenous species that take advantage of mussel farms to settle in and hinder aquaculture activities (Ramsay *et al.*, 2008).

The DFO has identified at least 25 species that are established in the St. Lawrence Gulf[3] since 1994, (DFO, 2012). Human activities facilitated the invasion of some species as illustrated by the above mentioned tunicates needing to attach to a substrate. Hence, artificial substrates used

[3] www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2012/index-fra.html

Photo *Carcinus maenas*: CSIRO / Wikimedia

by mussel farmers could have facilitated the colonisation of invasive tunicates in the southern part of the Gulf (Locke *et al.*, 2007). Therefore, this industry is one of the most affected ones by the presence of these invasive species. A non-exhaustive list of the most important invasive species in the Gulf includes the clubbed tunicate (*Styethe clava*), the vase tunicate (*Ciona intestinalis*), the violet tunicate (*Botrylloi of violaceus*), the golden star tunicate (*Botryllus schlosseri*), the oyster thief, a green alga (*Codium fragile*), the Japanese skeleton shrimp (*Caprelthe mutica*), and the European green crab (*Carcinus maenas*). The latter is a predator damaging other crab populations, as well as eelgrass weed and other habitats important to mollusks, crustaceans, juvenile fish, and American lobster, (*Homarus americanus*). It was also shown that the Japanese skeleton shrimp can take advantage of mussel filtration to feed microalgae to the detriment of the latter (Turcotte, 2010). Amongst plankton invasive organisms, some species of dinoflagellates can produce toxins (Roy *et al.*, 2012) that can accumulate in mollusk tissues and crustaceans and affect human health.

The majority of exotic species would have originated from ballast water of commercial ships arriving from other Canadian regions and from elsewhere around the world (Casas-Monroy *et al.*, 2011). Nevertheless, the invasion rate has decreased ever since the enforcement of a Canadian regulation regarding oceanic ships entering Canadian waters stating that vessels must exchange their ballast waters at 200 nautical miles outside of the Exclusive Economic Zone. Other management measures are underway to decrease the transfer of invasive species when transporting cargo between two water bodies or when transporting fish stocks to processing plants. These measures include compulsory cleaning of ships and their equipment, interdiction to discard living bait and to empty stocking pools, and to provide public education to create awareness regarding the propagation of the EAS problem via leisure boats[4]. /

Nevertheless, the invasion rate has decreased ever since the enforcement of a Canadian regulation regarding oceanic ships entering Canadian waters stating that vessels must exchange their ballast waters at 200 nautical miles outside of the Exclusive Economic Zone.

[4] www.tc.gc.ca/fra/securitemaritime/tp-tp14609-2-lois-reglements-maritimes-617.htm

Photo: Pixabay

IMPACT OF HYDROCARBON ON THE ECOSYSTEM

The chapter 3 of this book (Cusson *et al.*, 2017) deals with the effects of hydrocarbons on marine ecosystems, on communities of various marine habitats, and on the physiology of their organisms. The great number of marine habitats along the St. Lawrence are obviously submitted to similar stresses, probably amplified in some cases by the subarctic nature of this environment. A scientific literature review on the environmental impacts of the development of hydrocarbons in Quebec published by the *Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques* (MDDELCC, 2014) highlighted a lack of knowledge on the effects of a potential exploitation of hydrocarbons. This report showed that the level of knowledge on the St. Lawrence River basin is better than on other Quebec regions. Particularly, data allowing for an evaluation of potential environmental impacts of hydrocarbons on the St. Lawrence Estuary, Anticosti Island, the Gaspésie peninsula, and the Lower St. Lawrence regions are rather poor.

Although lacking information, some effects should be expected in a scenario of oil and gas exploitation in Quebec. The document classified the effects according to:

1) atmospheric emissions;
2) impacts on water, soils and sediments;
3) impacts on fauna, habitats and ecosystems.

Among the effects associated with atmospheric emissions, there would be in first instance a substantial increase on the overall Quebec annual carbon budget, potential emissions of atmospheric methane following the closure of natural gas wells, and other effects associated with the hydraulic fracking technique. An increase in the quantity of nitrogen oxide in the atmosphere, a smog and acid rain precursor, would also be observable.

Regarding the impacts on seawater, soils and sediments, the effects could include the contamination of surface waters by effluents from waste waters or hydrocarbon specialized treatment plants. This contamination would be due to the partial efficiency of the treatment of salts and other chemicals rejected in the environment. Furthermore, a contamination of waters around offshore facilities following the discharge of effluents and contamination of marine sediments by hydrocarbons within 5 to 10 km around the drill platform could be expected (Bakke *et al.*, 2013).

The spills of crude oil and other heavy hydrocarbons have very severe impacts on the economy (mainly tourism and fisheries) just as much as on the environment (organisms and the ecosystem)

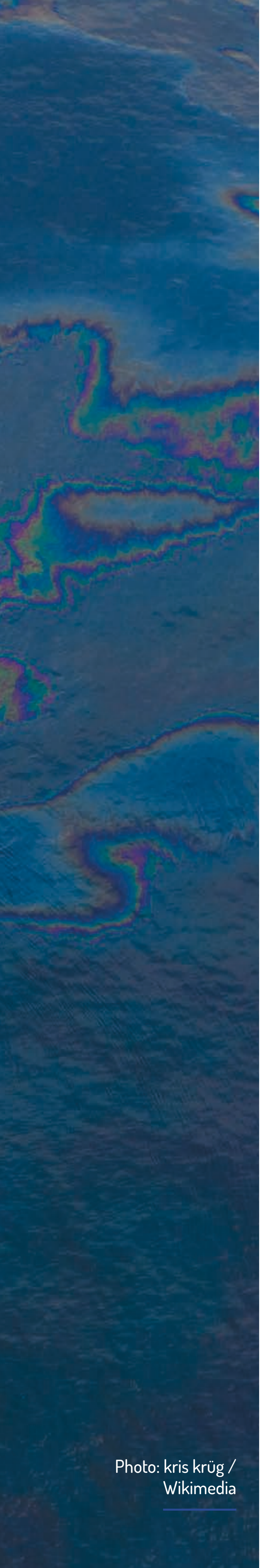


Photo: kris krüg / Wikimedia

(Peterson *et al.*, 2003). In the worst-case scenario of a major spill occurring during exploration and extraction operations at the *Old Harry* site, in the Magdalen Islands area, there is a possible huge oil contamination in the entire eastern sector of the Gulf of St. Lawrence (see Bourgault *et al.*, chapter 2). Ecosystems would be negatively affected, but the extent of the effects has never been quantitatively evaluated. This kind of effects will depend on the nature of the extracted oil, the period of the year, the affected locations and the species living therein. According to studies conducted in North Sea waters, chronic water contamination associated with drilling platforms can have worse impacts on biodiversity (Vella, 2013; Cusson *et al.*, 2017). Hence, companies operating offshore drilling platforms in Norway have to characterize the impact of their activities on the benthic fauna by calculating a BIOSTRESS index (Ugland *et al.*, 2008). This index shows how benthic communauties can be modified by a total hydrocarbon concentration of 50 mg per kilogram (mg/kg dry weight).

The combined effects of a spill, and the ensuing clean-up in a subarctic environment, have been well documented after the *Exxon Valdez* accident (March 1989) on the Alaska coasts, and thanks to contributions of several governmental and university scientific teams (Peterson *et al.*, 2003; Harwell and Gentile, 2006; Brannon *et al.*, 2012; Ballachey *et al.*, 2014; Shigenaka, 2014). Over 25 years after the accident, the Exxon Valdez Oil Spill Trustee Council (EVOSTC, 2015) concluded that, even if the spill and the clean-up have caused very significant ecological effects for months and years, natural variability and the presence of many other anthropogenic stressors not associated with the spill, make it so that the detection of potential residual effects is currently very difficult to establish.

There is insufficient data to determine what could happen in a potential spill of hydrocarbons in the ecosystem of the St. Lawrence. In the case of the Gulf itself, the risk evaluation must take into consideration the ice cover period. From 1968 to 2015, the maximum ice cover in the Gulf reached an average of 40% of the surface with a record minimum of 11.64% in 2010 (Environment and Climate Change Canada, 2016). The ice cover cannot be neglected as a factor in the dispersion of an oil slick when an accidental spill occurs. Ice acts as a barrier to the evaporation and to the photochemical degradation of the oil. Depending on the stability and the duration of the ice cover, oil will brew in the ice and remain trapped. When ice breaks away, the movement of the floes depends highly on the direction of prevailing winds. The contaminated ice could move alongside the south shore of the Estuary or south to New Brunswick, thus dispersing the oil on a large area with no possibility of post-spill response (see Bourgault *et al.* this book - chapter 2).

BIODEGRADATION OF HYDROCARBONS IN THE ST. LAWRENCE

Even if temperature is a limiting factor for microbial activity, biodegradation of crude oil, either light or medium oil, by natural microbial communities remains possible, even at low temperature and in the presence of ice (Siron *et al.*, 1993; McGenity *et al.*, 2012). However, the biodegradation of heavy fuel and bituminous oil is considered as very slow in cold waters, such as those of the Estuary and Gulf of St. Lawrence. This is due to the high viscosity of these products, to the formation of emulsions being refractory to bacterial attacks (NAS, 2016). Several years would be required to biodegrade chemicals of heavy oil products in the sediments of the St. Lawrence hydrographic system. The only well documented case regarding the persistence of heavy fuel oil in cold waters of the North Atlantic is linked to the sinking of the *Arrow* tanker (February 1970) along the coast of Nova Scotia, which has spilled 10,000 tons of heavy Bunker C heating oil (Owens *et al.*, 1993, 2008; Owens, 2010; Lee *et al.*, 2015). Successive studies have shown a great persistence of this heavy oil in a portion of Chedabouctou Bay, near Black Duck Cove, and a strong erosion in sectors mechanically cleaned (Owens, 2010). After 35 years, Chedabouctou Bay was no longer considered to be contaminated with hydrocarbons, but highly degraded residues of Bunker C were still present under a thick layer of sediment and vegetation. Heavy oil recirculation is still possible following a strong coastal erosion event (Lee *et al.*, 2015).

Photo Sinking of the *Arrow* tanker : National Archives

IMPACTS ON THE MARSHES OF THE ST. LAWRENCE

The St. Lawrence salt marshes are dominated by populations of salt-water cord grass (*Spartina alterniflora*), eelgrass, and populations of common eel-grass (*Zostera marinea*), and constitute highly productive environments (DFO, 2009). They are also a refuge to several land and marine animal species. The risks of damaging the ecosystem in a bay or at the mouth of a river following a spill would be important, no matter the season it would occur (Figure 4.3). The recovery rate of a coastal weed patch will be slower along the coasts of the St. Lawrence due to the winter period and the low temperature in the summer.

In terms of biodiversity of coastal marshes affected by an oil spill, several studies conducted in the Gulf of Mexico (Lin and Mendelssohn, 2012; McCall and Pennings, 2012; Able *et al.*, 2014; Fleeger *et al.*, 2015) and in the Prince-William Sound (Alaska) (Peterson *et al.*, 2012), have shown an increase in the abundance of some species that are more tolerant to the toxic effects of oil residues, to the detriment of more sensitive species. /

Figure 4.3
Illustration of the impact of the oil on coastal marshes. *(Lin et Mendelssohn, 2012.)*

Photo: É. Pelletier

INTERACTIONS BETWEEN PERTURBATIONS OF HUMAN ORIGIN

The increase in acidification (reduction in pH) is associated with the progressive decrease in the rate of dissolved oxygen feeding the Gulf and the Estuary of the St. Lawrence. Simultaneous effects from hypoxia and acidification were shown for the juvenile stage of bivalves of economic importance in the North Atlantic (Gobler *et al.*, 2014). In fact, the survival is decreased as opposed to the metamorphosis and the growth, which are inhibited in an additive way. However, the joint effect of these two stressors is more important for the larval stage than the addition of the effects of the two perturbations occurring separately. Furthermore, bacterial respiration is consuming dissolved oxygen (thus increasing **hypoxia**) and also releases metabolic CO_2 deriving from the degradation of organic matter (which promotes water **acidification**). These perturbations are then intimately associated, and any factor promoting bacterial activity will contribute to these two processes.

Experiments conducted in the Gulf of Mexico have shown that bacterial abundance was 10 times higher in sediments contaminated with oil than in clean sediments, (Kostka *et al.*, 2011). There are no similar studies for the St. Lawrence system. Nevertheless, an increase in bacterial activity linked to the degradation of oil could enhance other impacts in an environment already impoverished in dissolved oxygen such as the St Lawrence Lower Estuary (Table 4.1).

Coelho *et al.* (2012) have shown that acidification acting simultaneously with oil pollution significantly altered the taxonomic composition of bacteria, notably by reducing the abundance of desulfobactera (*desulfobacterium*), a group de bacteria involved in the degradation of hydrocarbons. In another hand, acidification can also interact with the toxicity of trace metals (Roberts *et al.*, 2013). This toxicity is not linked to the speciation of metals in an acid environment, but rather to the additive effects of these two perturbations on the physiology of benthic organisms. Other synergic effects could be observed in marine hypoxic coastal waters in the presence of oil by-products. Dasgupta and collaborators (2015) determined that hypoxia increased the mortality of fish larvae in the presence of HAP released during an oil spill.

The metals present in the sediments come often as metal oxides. These compounds could be released in the water under anoxic conditions following a spill. Once in the water, metals could be accumulated by organisms and have negative effects on their adaptive capability (*fitness*).

The cumulative effects of hypoxia, acidification and oil contamination should be

Table 4.1
Schematic representation of anthropic activities (addressed in this chapter) and their effects on the different environments in the ecosystems in the gulf of St. Lawrence.

	Shallow/intertidal and subtidal (<10 m)	Surface waters (0-5 m)	Winter (0-75 m) and summer (0-40 m) surface layers	Summer intermediate cold layer (40 - 150 m)	Winter (+75 m) and summer (+150 m) deep layer	Deep channels
Acidification	–	–	?	?	?	↗ (High)
Freshwater intake	↗ (Low)	↗ (High)	↗ (Medium)	↗ (Medium)	↗ (Low)	–
Contaminants	↗ (Very high)	↗ (High)	↗ (Medium)	↗ (Medium)	↗ (Low)	–
Nutrients/Organic waste	↗ (High)	↗ (High)	↗ (High)	↗ (Medium)	↗ (Low)	?
Invasive species	↗ (Very high)	↗ (Very high)	↗ (High)	?	?	↗ (Low)
Hypoxia	–	–	–	–	–	↗ (Very high)
Hydrocarbon	– (Very high)	– (Very high)	– (Medium)	– (Low)	– (Low)	?
Plastics	↗	↗	↗?	↗?	↗?	↗?
Climate change	↗ (Very high)	↗ (Very high)	↗ (High)	↗ (High)	↗ (High)	↗ (Medium)
TOTAL	↗ (Very high)	↗ (Very high)	↗ (High)	↗ (Medium)	↗ (Medium)	↗ (Very high)

Legend:

Sensitivity to stress factors
- No impact
- Low
- Medium
- High
- Very high

Temporal progress
- – No change
- ↗ Increase
- ↘ Decrease
- ? Unknown impact

Photo:
É. Pelletier

more important in the vicinity of drilling platforms where operators discard at sea tens of compounds required for the proper performance of the drill head, (Breuer *et al.*, 2004). In the North Sea, ever since the beginning of the exploitation of oil fields, over 12,000,000 m^3 of wastes from drilling have been discarded at sea. Amongst those compounds, surface-active agents, synthetic oil, and corrosion inhibitors can be found. Depending on the nature of the drilled geological layers, the discarded waste waters could exhibit increased radioactivity due to the radium content in oil, (Woodall *et al.*, 2003).

Studies simultaneously addressing the effects of several stresses or perturbations are rare (Lyons *et al.*, 2015). However, some experiences on the potential effects of the multiple stressors on macrobenthic communities were conducted in intertidal rocky habitats and in the weed patches of the St. Lawrence Lower Estuary. The results of these studies showed that the presence of a cover of macroalgae is very important regarding the resistance and the resilience of the communities of rocky environments at the time of the perturbations (Joseph et Cusson, 2015; Cimon et Cusson, data not published). In the presence of double perturbations, (absence of an algae canopy and an addition of nutrients), the richness was three times less than with no perturbations, as opposed to what happens when adding a third perturbation (reduction of grazers); the effects were diminished, showing an antagonistic effect between the perturbations. In eelgrass patches, the effects of perturbations (reduction of grazers or plants, shade and adding of nutrients) on the diversity or on the growth of plants diverge and may be temporary or antagonist, (Cimon et Cusson, data not published). The genetic diversity of associations can help to maintain the biomass in conjugate perturbations (such as less gazers and adding of nutrients) (Duffy *et al.*, 2015). It is easy to figure out that the coastal communities of the St. Lawrence are more affected in their capacity to maintain or recover their diversity or their biomass if perturbations, in part associated with human activities, are added one on the other (for instance persistent pollution, invasive species and spills of hydrocarbons).

Also to be considered is the risk of invasion by alien species which increases with marine traffic. As a matter of fact, the probability of an increase of the presence of harmful or toxic species increases as well, (Roy *et al.*, 2012). A possible increase of oil exploration and exploitation in the Gulf of St. Lawrence should lead to an increase of the shipping activities around the platforms as well as in the ports. (Shields, 2016). It is expected that Quebec harbors will see an increase in their activities, as predicted by *la Stratégie maritime of the Quebec*[5]. In fact, Quebec and deep water ports in Eastern Canada could become the main logistical poles of importation/exportation exchanges with Europe, North America and Asia thanks to the Comprehensive Economic and Trade Agreement (CETA) between Canada and the European Union, the North America Free Trade Agreement (NAFTA), the expansion of the new lanes and locks of the Panama Canal, the opening of the Northwest Passage, which will link the Atlantic to the Pacific, and the rise of cruise ship tourism.

The increase of navigation activities suggests additional risks in terms of noise, accidents, introduction of propagules and other biological invasions, etc.

INTERACTIONS WITH CLIMATE WARMING

As mentioned earlier, the solubility of gaseous oxygen (O_2) decreases with increasing temperature. Therefore, the warming of surface waters would lead to a decrease of dissolved oxygen in that specific layer. This warming would also result in an increase of the stability (or stratification) of the water column, reducing the capacity of the vertical mixing to oxygenate deeper waters. The process is expected to have an impact in the North Atlantic waters feeding Gulf of St. Lawrence deep waters as well as it should do to the Gulf itself.

With respect to acidification, and according to the most probable scenario provided by the Intergovernmental Panel on Climate Change (IPCC), pH should decrease by 0.3 to 0.4 units by the end of the century. This gap represents an increase of more than 100% of the concentration in H^+ ions (Orr *et al.*, 2005), resulting from the increase of atmospheric concentrations of anthropic CO_2. Hence the ocean pH would reach a level never recorded in over 20 million years. However, increasing evidence indicates that the flux of CO_2 between atmosphere and ocean could be somewhat reduced due to the oversaturation of this gas in the surface mixing layer (Raven, 2005). This oversaturation of CO_2 is associated with the global increase of the water column stratification and with the reduction of the vertical mixing induced by the global increase of the temperature.

Numerous indirect impacts remain to be determined, including the combined effects (synergetic, additive and cumulative) of hydrocarbons in a scenario where an increase of acidification, hypoxia and climate change are observed (Table 4.1).

[5] http://plq.org/pdf/strategie-maritime.pdf

To develop or predict consequences of anthropic perturbations on biological communities and on the functioning of the marine ecosystems, one must first recognize the great complexity of natural ecosystems (see Schmitz, 2010). It is known that, in complex food webs such as those found in the St. Lawrence, the response of several compartments of the ecosystem to anthropic disruptions is non-linear and hardly predictable (Thébault et Loreau, 2006). Considering the Intermediate Disturbance Hypothesis, a moderate level of perturbations would optimize the biodiversity by promoting the coexistence between colonizing and competitive species (Grime, 1973; Connell, 1978). Connell (1978) suggested that, at a low frequency/intensity of perturbations, competitors that are best adapted to the environment will overcome those species with less competitive capacity; the result being the creation of a new steady state system, albeit less diversified. On the opposite side, perturbations at a high frequency and/or intensity would leave many uninhabited spaces and would especially favor colonizing species, i.e. those with an intrinsically higher growth rate and a high dispersion capacity. For example, a recent study (Moritz *et al.*, 2015) suggested that the effect of a perturbation – mobile fishing gear – in the Gulf of St. Lawrence in the last 20 years would have reached a critical threshold as early as the first passage. As many other studies showed (Kaiser *et al.*, 1998; Collie *et al.*, 2000; Pitcher *et al.*, 2009; Lévesque *et al.*, 2012), this impact could be irreversible by the withdrawal of vulnerable and structuring species, such as those providing a tridimensional habitat. The benthic communities in the Gulf of St. Lawrence would therefore have reached a new state of equilibrium where mobile fishing gears would produce few notable impacts (Moritz *et al.*, 2015).

Ecological studies on the impacts of anthropic perturbations on the ecosystems of the St. Lawrence are scarce. Since the sensitivity to perturbations is species-specific, one way to simulate, in an experimental approach, these impacts is the withdrawal of species. In a laboratory experiment simulating the benthic communities of the St. Lawrence, Harvey *et al.* (2013) showed that the withdrawal of some species might have very important effects on the functioning of the food web. In that study, the response of the system depended on the identity of functional groups of benthic organisms and their disappearance. Furthermore, another experimental study (Séguin *et al.*, 2014) has shown that, in systems with organisms of several trophic levels (multitrophic), impact was higher when, by simulating perturbations, species went extinct following a sequential order than if the extinction of species was randomized. In that same study, the authors found that the size of the animal, considered jointly with its trophic position, was a good predictor of the disappearing effect of the species. That study concluded that it is urgent to develop ecosystem perturbation and response indices to quantify the anthropic impacts.

Controlled laboratory experiments to characterize the sensitivity of one or several species to environmental stress would allow for the identification of a link between a cause (one or two stressors, in general) and an observed effect, as it would be in nature. The interpretation of these laboratory efforts may be complicated due to the complexity of natural ecosystems. Especially regarding exposure to oil, experiments have been conducted under optimal environmental conditions, including optimal temperature, salinity, availability of oxygen, absence of predators and minimized competition. However, the environments most at risk to a hydrocarbon spill at sea, such as the coastal estuaries, are currently very dynamic and variable habitats, subjected to periodic and more or less random fluctuations (temperature, salinity, wind, hypoxia and the availability of nutrients), leading to the difficulty of extrapolating laboratory results to the natural environment. Experimental work with simulated ecosystems, such as mesocosms containing large water volumes (>1000 L), reproducing natural fluctuations of a number of variables would be a first approach. These systems would allow for the study of the impacts of hydrocarbons at different scales, from the physiology of different organisms to their impacts on the entire planktonic community. They would also allow for the determination of the interactions of the biological community (competition, predation) and trophic cascades. /

Photo of benthocosms at the ISMER Aquaculture Laboratory - Pointe-au-Père:
P. Archambault

Photo of large marine mesocosms at the ISMER Aquaculture Laboratory - Pointe-au-Père:
É. Pelletier

CONCLUSION

As concluding remarks, we would like to reiterate the words of Whitehead (2013), who mentioned that the challenge for researchers and managers of natural resources is to embrace the inherent complexity of interactions between contaminants and other natural stressors and then, to adopt and apply paradigms resulting from the findings in ecological physiology. The unicity, fragility, complexity and winter conditions found in the St. Lawrence highlight the importance for the managers to consider the effects of multiple perturbations on the biological communities. This will allow for the identification, the characterisation and the resolving of derived ecotoxicological problems. /

Photo:
É. Pelletier

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CHAPTER 5

Health and social impacts deriving from the exploitation of hydrocarbons on coastal populations

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Can the exploitation of hydrocarbons in the Gulf of St. Lawrence create effects on the health or on the well-being of populations living on the coast lines? An overview of the literature emphasized several health and social impacts on the coastal populations. These impacts are mainly associated with the boomtown effect and the accidental spills of hydrocarbons in the course of their extraction and transportation in marine environments. The exposure to crude oil and other oil products, when a major spill occurs, for example the exposure following the explosion of the *Deepwater Horizon* drilling platform in the Gulf of Mexico, in 2010, or the sinking of the *Exxon Valdez* oil tanker off the coast of Alaska, in 1989, is prone to produce effects on the physical, mental and social health of the individuals and communities they touched. We tend to believe that the direct exposure to oil products and to dispersants, along with the contamination of the food chain, have long-term physical and chronic impacts. However, the literature argues that additional research is necessary to better document them. Social disruptions (fragmentation of the social cohesion, social conflicts, loss of the network of acknowledgement and mutual help) might also occur when black tides come on shore, and they may last for several years. They are caused by the economic consequences of spills, the degradation of the environment and the strong pressures on the local and regional infrastructures such events generate. The cascade of physical, social and mental impacts associated with spills of hydrocarbon in marine environments emphasized in this chapter inspire the following recommendation: one must take into consideration the well-being and the health of the coastal populations in the decisions regarding hydrocarbons in the Gulf of St. Lawrence.

INTRODUCTION

In Quebec, recent environmental events, such as the railroad accident at Lac-Mégantic, in 2013, and environmental evaluations on the exploration and the exploitation of shale gas, along with the audiences for the TransCanada *Energy East* pipeline, lead to the realization of the state of scientific knowledge, with respect to the possible impacts of the exploitation and of the transportation of hydrocarbons on the health and the well-being of individuals and communities (Brisson *et al.*, 2014; *l'Agence de santé et des services sociaux de l'Estrie*, 2015; *BAPE*, 2007, 2011, 2013). However, little of the written documentation pays attention to taking stock of the activities occurring in marine environments. Hence, the question addressing the potential effects of the exploitation of hydrocarbons in the Gulf of St. Lawrence, on the health and on the well-being of populations living along the coasts, remains. This chapter will attempt to bring answers and will be based upon available international scientific literature. The objective of this first snapshot is to proceed with reflective thinking on this question. /

Photo: Brocken Inaglory / Wikimedia

HIGHLIGHTS

- Large spills create cascading impacts; first, they touch the environment and the physical health of the populations on the short-term and then, on the longer-term, the mental health of the individuals.

- The following groups are the most vulnerable ones to the health and psychosocial impacts: people who have decontaminated banks; local workers from the economic sectors associated with natural resources; people living in small communities; disadvantaged people, and populations whose collective identity is strongly associated with the sea, such as First Nation's people.

- The scope of the impacts associated with spills of hydrocarbons in marine environments calls for consideration to be given to the well-being and the health of coastal populations in decisions addressing hydrocarbon exploitation in the Gulf of St. Lawrence.

Two approaches lead to the targeting of pertinent written documentation.

On the one hand, information tallied from reviews of documents produced by the *Institut national de santé publique du Québec* (*INSPQ*) and by the International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG) were considered. Recently, these organizations have published reports on the status of the knowledge with respect to issues on public health (Chevalier *et al.*, 2015) and social and psychological issues (Bouchard-Bastien & Gervais, 2016; CIRAIG, 2015) of different types of exploitation and modes of transportation of hydrocarbons. Portions of these publications dedicated to the maritime context have been used to write the present chapter.

On the other hand, additional documentary research was done in the scientific databases to detail the health and social impacts on the populations and on the coastal communities in the offshore context, i.e. exploration, exploitation and transportation of hydrocarbons in marine environments off the coasts. This research was done between the months of November 2015 and January 2016 in the following scientific databases: *Medline*, Psychological & Behavioral Sciences Collection and Social Services Abstracts, using the following keywords and boolean operators:

(Ocean OR Gulf OR Sea OR Offshore)

AND

(Petroleum OR Petroleum pollution OR Oil spill)

AND

(Family OR Distress OR Anxiety OR Depression OR
Adverse effect OR Physiologic OR Population OR
Community OR Social OR Sleep disorders OR Stress OR
Neoplasm OR Risk factor OR Health OR Psycho).

The process of selection of the items is summarized at Figure 5.1. A total of 333 articles were first acquired. The duplicates were removed along with some articles written in languages other than French, English, Spanish or Portuguese. A first selection, based on the pertinence of the summaries, was done by four examiners from the titles and the summaries of the articles. To be considered, they had to specifically focus on the following themes: exploration, exploitation, incident of hydrocarbon, platform or black tide. This first selection produced 168 articles. Amongst them, those that dealt specifically with the health of workers on oil platforms and that did not refer to coastal populations were discarded (n = 76). Of the following 92 articles, 41 were rejected as per the following criteria: nature of the publications (editorials or news-highlights-like format); date of publishing prior to 1989 (year of the sinking of the *Exxon Valdez* oil tanker off the coast of Alaska); articles focussing on the impacts on the food chain or on methodological aspects, such as decontamination processes that did not show any link with the health of human populations. To conclude, 51 articles whose date of publication spanned from 1999 to 2015, were listed. Out of them, 10 had already been recorded in the status of scientific knowledge of the INSPQ and of the CIRAIG. Of those 51 articles, 49 focused on major spills, while the majority (n = 35) referred to the explosion of the *Deepwater Horizon* platform in the Gulf of Mexico, in 2010. The other ones touched on incidents that have occurred since 1989 involving oil tankers or barges. The themes or events of reference (including locations and dates), the number of articles and the nature of the documented impacts are summarized in Table 5.1 (next page).

The review of the selected documents and articles leads to the determination of two types of events susceptible to affect the health and the well-being of coastal populations. Those are the boomtown effects and the important accidental offshore spills requiring the clean-up of the banks.

Figure 5.1
Diagram of the process of selection of articles. The figure indicates the number of articles left after each selection step.

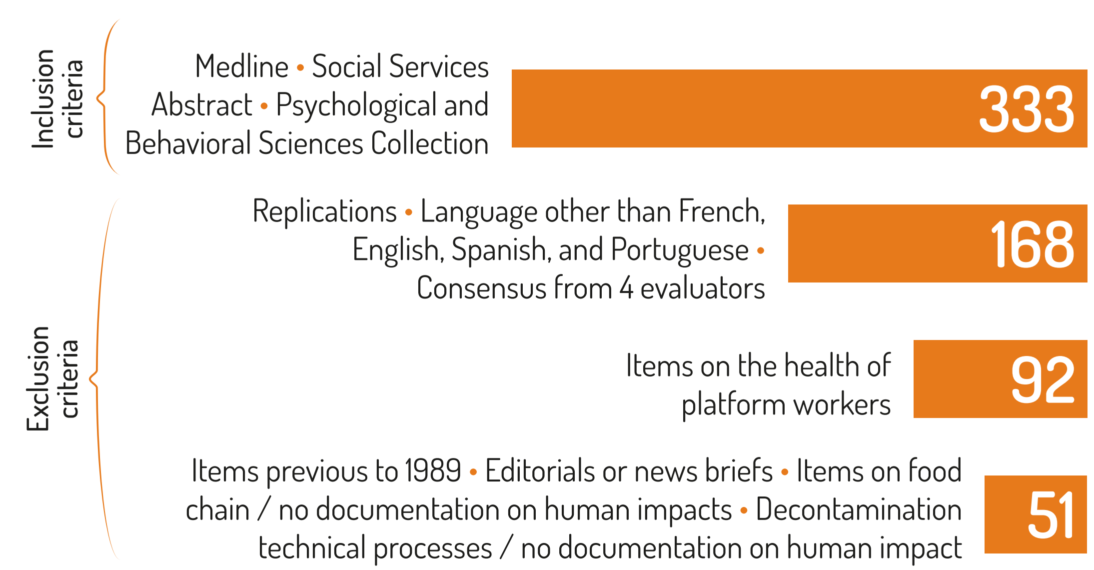


Table 5.1
Events or themes addressed in the identified articles (n = 51).

SPILLS			
EVENTS	LITTORAL	NO. OF ARTICLES	DOCUMENTED IMPACTS
Deepwater Horizon Plateforme (2010) • Gulf of Mexico • 4 900 000 barrels	Littorals of Louisiana, Mississippi, Alabama and Florida	35	Physical health Psychological Social well-being
Exxon Valdez – oil tanker (1989) • Prince-William Bay, Alaska • 37,000 tons	1,770 km of the coast Alaska	6	Physical health Mental health Social well-being
Tasman Spirit – oil tanker (2003) • Coasts of Karachi, Pakistan • 37,000 tons	A few polluted beaches Pakistan	2	Physical health Mental health
Prestige – oil tanker (2002) • Off the coast of Spain • 63,000 tons	1,900 km of coasts in Portugal, Spain and France	2	Physical health Social well-being
Sea Empress – oil tanker (1996) • Off the coast of Wales • 72,000 tons	200 km of the coast of Wales	2	Physical health Mental health
Hebei Spirit – Barge (2007) • Off the coast of South Korea • 10,500 tons	160 km of South Korea coasts	1	Physical health
Literature review of major several spills (*Exxon Valdez, Braer, Sea Empress, Nakhodka, Erika, Prestige, Tasman Spirit*) from 1989 to 2010	Several sites	1	Physical health Mental health
OTHERS			
THEMES		NO. OF ARTICLES	DOCUMENTED IMPACTS
Social impacts on the growth of the offshore industry – Northern Louisiana (2007)		1	Social well-being
Sociocultural impacts of the transportation of hydrocarbon -Northern Sea – small communities		1	Social well-being

Photo: Pixabay

THE BOOMTOWN EFFECT AND THE DISRUPTIONS OF THE SOCIAL EQUILIBRIUM

In the literature on the social impacts of the exploitation of the natural resources on land, especially the non-renewable ones, the boomtown effect is widely documented (Brisson *et al.*, 2014; CIRAIG, 2015; Bouchard-Bastien & Gervais, 2016). Such a phenomenon is described as a set of processes of rapid changes that could arise from the implantation of an extractive industry that is capable of destabilizing certain communities (CIRAIG, 2015). The most vulnerable communities would be the small municipalities with low density and rural populations. These would include aboriginal communities. In fact, the rapid growth of the population would have a more pronounced effect on the infrastructures, on the availability and the price of the goods and services as well as on the social fabric related to the maintaining of the public order, the sociocultural dynamics and to the culture (Bouchard-Bastien & Gervais, 2016; Meschtyb *et al.*, 2005).

However, very few studies have focussed on the different social impacts linked to this phenomenon in the context of the exploration, the exploitation and the transportation of hydrocarbons in a marine environment. Written documentation first leads one to foreshadow a boomtown effect in the construction phase, with the important, albeit ephemeral, arrival of workers in small communities (Bouchard-Bastien & Gervais, 2016, citing Bouvier de Candia *et al.*, 2008). Hence, when building the *Hibernia* drilling platform, off the coast of St, John's, Newfoundland, a camp of workers isolated from neighboring communities was created to attenuate the possible negative impacts associated with the rapid demographic changes (Bouchard-Bastien &

[The boomtown effect] is described as a set of processes of rapid changes that could arise from the implantation of an extractive industry that is capable of destabilizing certain communities. [...] In fact, the rapid growth of the population would have a more pronounced effect on the infrastructures, on the availability and the price of the goods and services as well as on the social fabric related to the maintaining of the public order, the sociocultural dynamics and to the culture.

Photo Nenets Farmer:
Steve Morgan /
stevemorganphoto.co.uk

Gervais, 2016, citing Bouvier de Candia *et al.*, 2008).

Furthermore, a qualitative study aiming at evaluating the social impacts of the maritime transportation of oil was done in the small communities of the autonomous district of Nenetsia (extreme northwest of Russia), on the littoral of the Barents Sea (Meschtyb *et al.*, 2005). It emphasized concerns amongst the members of these communities as to the future of their environment should there be spills, as well as the important development of port activities. These activities encroach on their traditional territories. Concerns were raised as to the restoration of that environment once the oil exploitation and transportation is over. Excerpts from the notes obtained by Nina Meschtyb, the field researcher, go back to August 2001 and illustrate quite well these concerns.

" We should think about our heritage and be concerned about the future, which we don't know yet. We have experienced how political and economic changes are reflected on our life. OK. I can earn money today, buy something, and let my land be destroyed, but, what if the internal and external policy of Russia were to be change tomorrow when the oil price falls? What if all oil workers abandon the oil-site without restoration? We Nenets will remain here anyway but will face our degraded environment. My son and his descendants woulnd't [be able to] feed themselves from nature anymore, nor would they have anything in the outside world. We have to have this in mind. „

(Meschtyb *et al.*, 2005, p. 326)

Finally, the boomtown effect would come about when clean-up, decontamination and remediation efforts would be underway as required after major spills. This work often requires a substantial manpower, made of both volunteers and salaried workers. For instance, following the incident of the BP company in the Gulf of Mexico, approximately 55,000 workers[1] from local communities and from other regions participated in the clean-up. In the case of the sinking of the *Hebei Spirit*, in 2007, close to Taean, South Korea, nearly a million people participated in the clean-up activities, six months after the incident (Ha *et al.*, 2012). Major accidental spills would therefore be susceptible to bring about a sudden increase of the population, which could create pressure on the infrastructures and on the local and regional services (Bouchard-Bastien & Gervais, 2016, citing Picou *et al.*, 2009). The lack of housing was mentioned in one study documenting the effects of the sinking of the *Exxon Valdez* oil tanker (Gill *et al.*, 2012). Nevertheless, more studies are necessary to document the expansion and swift slowdown effects of the development of communities linked to the exploitation of hydrocarbons in a marine environment, particularly those deriving from oil platforms, transportation of the hydrocarbon and the infrastructures of ports (CIRAIG, 2015; Forsyth *et al.*, 2007). /

Photo: New Zealand
Defence Force / Wikimedia

[1] Numbers vary according to consulted articles.

Photo: Deepwater Horizon Response / FlickR

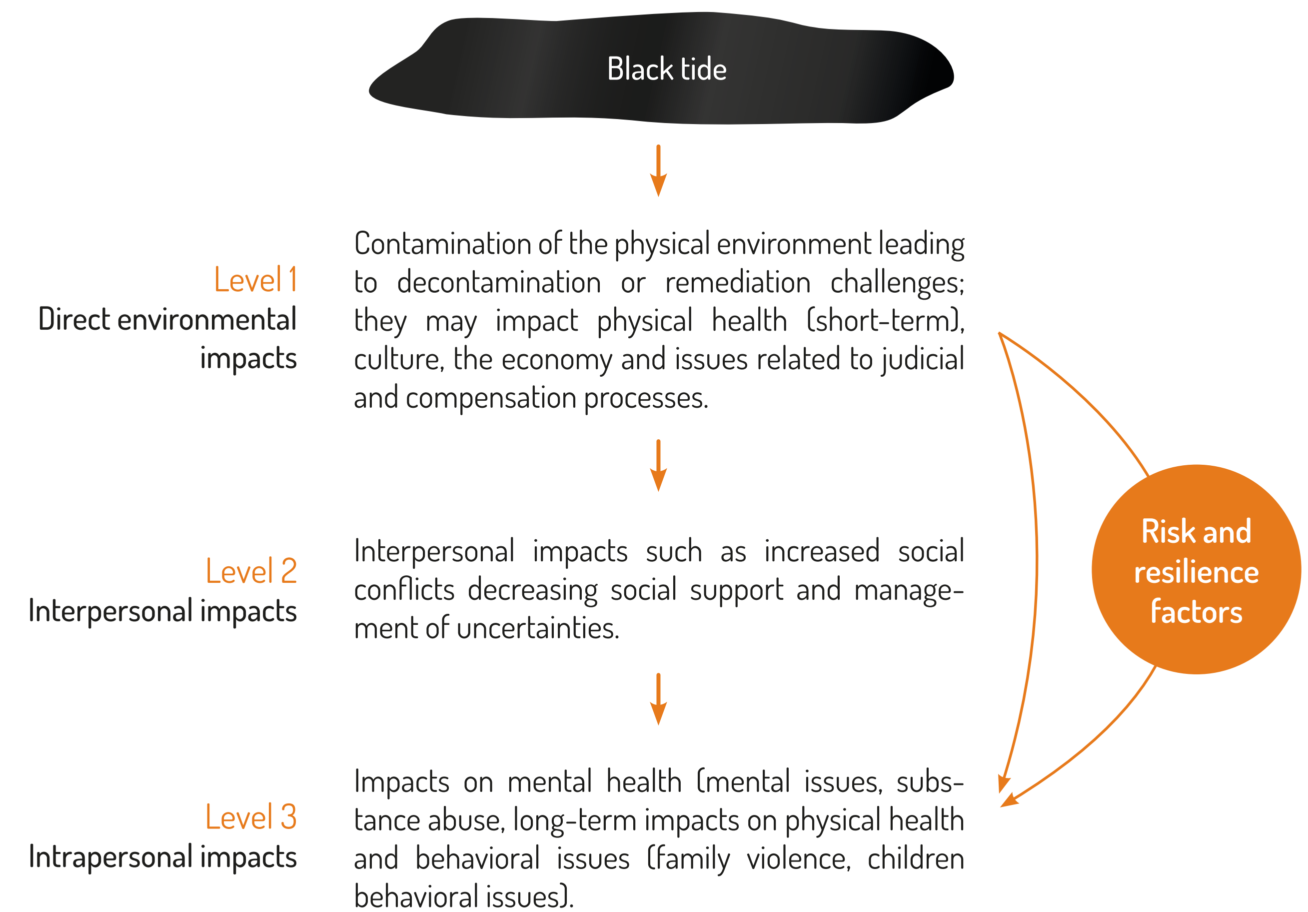
SPILLS AND BLACK TIDES: A CASCADE OF IMPACTS ON THE PHYSICAL AND MENTAL HEALTH OF INDIVIDUALS AND THE WELL-BEING OF COASTAL COMMUNITIES

The consulted literature largely addresses several incidents which occurred in a marine environment, on drilling platforms or when important spills were the result of the sinking of oil tankers, bulk carriers and barges (Chevalier *et al.*, 2015, citing O'Rourke & Connelly, 2003, Eykelbosh, 2014 and D'Andrea & Reddy, 2014). The two main documented cases, in the written documents (41 of the 51 used articles), deal with the spill following the explosion of the *Deepwater Horizon* drilling platform belonging to the BP company in the Gulf of Mexico, in 2010, and the black tide produced by the sinking of the *Exxon Valdez* oil tanker, off the coast of Alaska, in 1989. The authors of a scientific review that focussed on spills caused by oil tankers and published in 2010, indicated that, out of the 38 accidents that had occurred on the planet in the past 50 years, only seven had been the object of a study that was published and documented the impacts on the physical and mental health of the coastal populations (Aguilera *et al.*, 2010).

Oil spills in a marine environment are different from other disasters [...] due to the lengthy duration of the first phase, i.e. the dispersion of the hydrocarbon.

Oil spills in a marine environment are different from other disasters (natural or technological) due to the lengthy duration of the first phase, i.e. the dispersion of the hydrocarbon. This phase, also called "acute phase" might last weeks, months even. Besides, the longer this phase lasts, the more important the consequences on the well-being of the coastal communities and on the physical and mental health of individuals. These consequences are added to the direct effects on the ecosystems and on the economic activities, such as fisheries and tourism (Palinkas, 2012). Palinkas (2012) suggests a conceptual framework that would allow for a better understanding of the social impacts associated with extreme situations of spills of crude oil (and other oil products), to determine the risk or resilience factors liable to increase or decrease these effects. The framework was tested in the context of a literature review on the sinking of the *Exxon Valdez*. It referred to three levels of impacts associated with the unfolding of the events (see Figure 5.2). Therefore, an oil spill in a marine environment with the scope of the *Exxon Valdez* will, first of all, affect the environment and the short-term physical health of the populations touched directly by the spill (level 1). It will then give rise to social impacts in the involved communities (level 2). These impacts at levels 1 and 2 will bring about, on a long-term basis, impacts on the

Figure 5.2
Conceptual Framework – Impact of black tides on coastal populations.
(Adapted from Palinkas, 2012.)



intrapersonal plan, including effects on the mental health of individuals (level 3) when protection factors are insufficient. Even if such a mode is likely to evolve with the development of knowledge, some authors believe that shedding a light on those links, as Palinkas did in 2012, contributes in a significant way to the understanding of the impacts on the health and on the psychosocial well-being of the coastal populations following a black tide (Bonanno, 2012; Osofsky *et al.*, 2012; Galea, 2012).

An epidemiological study, led by the U.S. federal government, after the black tide caused by the explosion of the *Deepwater Horizon* platform (the Gulf States Population Survey), outlines 4 types of exposure based on:

1) the location of the residence;
2) the direct contact with the oil;
3) the implication in the clean-up activities;
4) the impacts of the black tide on employment or income (Fan *et al.*, 2015).

The exposure is deemed direct in the case of the first three criteria and indirect as to the fourth one. The authors indicate that, at the moment of intervention, one must consider that direct exposure to oil products is a more important health determinant as it is associated with the worst effects in terms of physical and mental health. However, the indirect exposure is not insignificant as it touches the greatest number of people. These results are in line with those that are seen in studies on the preceding spills (Fan *et al.*, 2015, citing Palinkas, 2009, 2012) along with the results from studies addressing the exposure to disasters in general (Fan *et al.*, 2015, citing Norris *et al.*, 2002a, 2002b and Yzermans *et al.*, 2009; Palinkas, 2012).

Photo Explosion of the *Deepwater Horizon* platform: Wikimedia

IMPACTS ON PHYSICAL HEALTH

The written documents focus on several possible impacts of black tides on the physical health (Chevalier *et al.*, 2015; Goldstein *et al.*, 2011; Lyons *et al.*, 1999; Aguilera *et al.*, 2010; Ha *et al.*, 2012; Woodward, 2010; D'Andrea & Reddy, 2013, 2014; Meo *et al.*, 2009). The accidental spills of hydrocarbons would induce the release of many contaminants which could represent a threat to human health. However, the nature of these contaminants varies as per the context of each accidental spill. Today, oil products and other composites associated with cases of population contamination are:

1) mixtures of heavy hydrocarbons that are not really volatile, such as crude oil;
2) light volatile hydrocarbon (for example, BTEX [benzene, toluene, ethylbenzene and xylenes], VOCs [volatile organic compounds] and PAHs [polycyclic aromatic hydrocarbon]);
3) non-organic such as cadmium and zinc (Chevalier *et al.*, 2015).

Other composites associated with remediation activities could also constitute elements of risk on the health of populations, such as dispersants that are usually made of surfactants, emulsifiers, surface-active agents, stabilizers and organic solvents. The conclusions of studies on these dispersing agents are, however, based on toxicological data relating specifically to some constituents, without necessarily taking into account their synergic effects (Chevalier *et al.*, 2015, citing Alo *et al.*, 2011). The main populations exposed to these contaminants are:

1) local residents living near the contaminated sites or involved in them;
2) vacationers, tourists and local users of the contaminated resorts;
3) the residents, the workers and the volunteers who have participated in the clean-up of contaminated littorals (Chevalier *et al.*, 2015).

The latter are those who experience the largest exposure with the most important impacts on the physical health (Chevalier *et al.*, 2015; Aguilera *et al.*, 2010).

The ways in which individuals are exposed are essentially inhalation and cutaneous absorption. The exposure via inhalation would mainly occur when one is in contact with volatile compounds (essentially VOCs and HAPs) with low molecular weight deriving from crude or degraded oil products. As to the cutaneous exposure, it is associated with different manipulations of oil products and soiled objects, such as tools used when cleaning banks, animals, plants and minerals touched by the black tide (Chevalier *et al.*, 2015, citing Alo *et al.*, 2011). The contamination of the food chain from the fauna living in the sediments and sea floor is also being raised in the literature as a risk factor on the health when these marine organisms are consumed by human beings (Chevalier *et al.*, 2015). This contamination of the sediments by oil products would not only be associated with accidental spills, but also with the leaks from drilling pools or the rejecting at sea of lubricating muds used during these drilling activities (Goldstein *et al.*, 2011). The impacts of these diverse types of exposure on the physical health are divided into short-term and long-term effects.

The short-term clinical manifestations arising from inhalation, cutaneous contact, ingestion of contaminated water or food, or the contact with sand on contaminated beaches during the clean-up activities following spills affect especially individuals involve in clean-up activities (Goldstein *et al.*, 2011; Aguilera *et al.*, 2010). The short-term physical manifestations recorded after a direct exposure to oil or contaminated water are summarized in Table 5.2. The gravity and the persistence of the injuries seem to be linked to the type of exposure and its scope, to the fact of wearing (or not) adequate individual protective equipment when cleaning-up (for instance, clothing, gloves, masks) and to the presence of comorbidity in the studied individuals (for example, respiratory issues are more important amongst smokers). Most of the time, these acute conditions are reversible.

The current data is insufficient to draw potential chronic consequences, as the available studies do not report any long-term follow-up on the exposure to oil products (Chevalier *et al.*, 2015). Yet, certain biological markers, measured amongst people exposed to crude oil, have shown the presence of enzymatic and cellular disruptions along with chromosome mutations. These changes indicate possible consequences on the longer-term, although it is not possible to associate them with a type of composite, with some concentrations or a precise duration of exposure (Chevalier *et al.*, 2015). Now, although crude oil is not considered carcinogenic, certain products deriving from its refining or its fractioning, that could come from spills (such as some PAHs), would so be to animals, even at a low dose (Wilk *et al.*, 2013). Consequently, should these products be accidentally spilled, this type of effect could not be excluded. Regarding workers involved in the clean-up activities following the sinking of the *Exxon Valdez*, the level of exposure would have been significantly associated with a decline of the declared and observed health status after the spill (Palinkas, 2012). The chronic clinical manifestations perceived or reported are as follows: heart disease, hypertension, diabetes, thyroid problems, cancers, asthma, ulcers, bronchitis, chronic cough and prolonged cutaneous irritations (Palinkas, 2012, citing Impact Assessment, 1990 and Palinkas *et al.*, 1993; Meo *et al.*, 2009). Nevertheless, there is a need to proceed with some biomonitoring of the people who have been exposed to oil spills, especially those individuals involved in the clean-up activities, in order to better assess short- and long-term consequences on physical health, and to formu-

Photo: Deepwater Horizon Response / FlickR late recommendations in terms of protection measures to be taken (Aguilera *et al.*, 2010; Ha *et al.*, 2012; Diaz, 2011).

Presently, the lack of comparative and longitudinal studies that would allow the identification of the long-term impacts of hydrocarbon spills in a marine environment on physical health could be explained by the difficulties in determining, defining and sampling targeted populations (Goldstein *et al.*, 2011, citing Galea *et al.*, 2008). Also, the difficulties to detect long-term effects arise from comparing heterogenous studies data, such as different levels of exposure, target populations, and research proposals (Goldstein *et al.*, 2011, citing Raphael, 2008). The sometime prolonged delays between the events and the beginning of the studies can also compromise the documentation of these effects since the capacity of interviewed individuals, asked to recall their experiences, can be distorted and the measured biological markers may lack validity (Goldstein *et al.*, 2011).

Table 5.2
Inventory of possible physical manifestations on the short-term as a result of a direct exposure to oil or contaminated water (Chevalier *et al.*, 2015; Goldstein *et al.*, 2011; Lyons *et al.*, 1999; Ha *et al.*, 2012; Woodward, 2010; D'Andrea et Reddy, 2013, 2014; Meo *et al.*, 2009).

SYSTEMS AFFECTED	CLINICAL MANIFESTATIONS
Integumentary/mucous	Irritation • Pruritus/Itch • Redness • Cuts • Eye irritation
Respiratory	Nose, sinus or throat irritation • Breathing difficulties, reduction of lung capacity • Cough
Cardiovascular	Palpitations
Hematological	Alteration of hematological profiles
Hepatic	Alteration of hepatic profiles and liver dysfunction
Neurological	Cephalgia • Vertigo and ailments • Dizziness • Cognitive troubles (memory problems) • Fatigue • Heat stroke*
Gastro-intestinal	Nauseas • Vomiting • Abdominal pain
Musculoskeletal	Back pain and injury, joint pain*

** Associated with clean-up activities*

SOCIAL IMPACTS ON THE COASTAL COMMUNITIES

Photo:
É. Pelletier

The contamination of ecosystems, as a result of a spill, might particularly affect those local communities that economically, socially and culturally depend on natural resources (Bouchard-Bastien & Gervais, 2016).

Local economic activities which could be affected by a spill revolve mainly around sectors, such as fisheries, aquaculture, seal hunting, tourism and the oil industry (Gill *et al.*, 2012; Osofsky *et al.*, 2011; Bouchard-Bastien & Gervais, 2016, citing Schmidt, 2014, Picou *et al.*, 2009, Innovation maritime, 2014 and Carrier Sekani Tribal Council, 2006; Buttke *et al.*, 2012a, 2012b). Some researches emphasize that, for fishers, the loss of revenue resulting from large spills of hydrocarbons can last way beyond the decontamination period as the negative perception of consumers regarding the quality of sea products coming from an affected area persists over time (Bouchard-Bastien & Gervais, 2016; CIRAIG, 2015). The value chain of any fishery can be affected by large spills because, as it was also the case of the *Deepwater Horizon*, since this perception also hindered fishers from regions located outside the contaminated zones (CIRAIG, 2015). In the case of the *Exxon Valdez*, some individuals left the region affected by the oil disaster because of the reduction of their revenues which was attributed to the suspension of some commercial activities, such as fisheries and tourism. These movements can increase the demographic and economic decline of a region (Gill *et al.*, 2012; Bouchard-Bastien & Gervais, 2016, citing Schmidt, 2011, Picou *et al.*, 2009, Innovation maritime, 2014 and Van Hinte, 2005).

The effects of spills of hydrocarbons on the social fabric of the affected communities are associated with the generalised disorganisation of services related to lodging, food, leisure and transportation (Bouchard-Bastien & Gervais, 2016). It is also known that natural disasters bring an accrued pressure on the local psychosocial services (Laurendeau *et al.*, 2007; Malenfant, 2013), which can rapidly run out of resources to respond to the needs of the residents (Gill *et al.*, 2012; Bouchard-Bastien & Gervais, 2016, citing Picou *et al.*, 2009 and Trépanier *et al.*, 2015). This disorganisation creates, in the process, social disruptions, such as the fragmentation of the social cohesion and the loss of the recognized, assistance and mutual help network (Gill *et al.*, 2012; Osofsky *et al.*, 2011; Bouchard-Bastien & Gervais, 2016, citing Picou *et al.*, 2009; Fan *et al.*, 2015). As observed in the cases of the *Exxon Valdez* and the *Deepwater Horizon*, these disruptions also seem to derive from economic and environmental consequences of the spills as well as by the tensions deriving from the management of the accident by the authori-

This disorganisation creates, in the process, social disruptions, such as the fragmentation of the social cohesion and the loss of the recognized, assistance and mutual help network .

Photo: Deepwater Horizon Response / FlickR

ties (Gill *et al.*, 2012; Osofsky *et al.*, 2011; Bouchard-Bastien & Gervais, 2016, citing Picou *et al.*, 2009 and CIRAIG, 2015). It would seem that, in comparison with other disasters, the *Exxon Valdez* oil spill produced more disruptions in the social relations. The studied communities in the context of that event showed several attributes of the corrosive or toxic communities, as they are called (Freudenberg, 1997). They were also touched by “the conflicts and the competition over the limited resources (Kreps, 1985), the disputes and the search of compensation for the damages (Picou *et al.*, 2004), the loss of social connection and the feeling of being cut off from the world (Erikson, 1976), the increased uncertainty in terms of the long-term impacts (Baum and Fleming, 1993) and the decrease confidence in the capacity of the public authorities to limit the impacts and to prevent disasters (Couch, 1996; Erikson, 1994; Freudenberg, 1993) » (Palinkas, 2012, p. 205, free translation). Some authors also mentioned the existence of conflicts linked to decontamination activities occurring after the spill of the *Exxon Valdez* between the local residents and the new arrivals (Bouchard-Bastien & Gervais, 2016, citing Picou *et al.*, 2009), but also amidst the local community, especially around the unequal distribution of jobs associated with the decontamination (Palinkas, 2012). Some negative effects on households have also been documented; one notes the presence of family conflicts, an increase of spousal and family violence, the decrease of time spent with the family and a reduction in the number of exchanges amongst family members (Palinkas, 2012; Gill *et al.*, 2012).

Finally, culturally speaking, the impacts of the spills can induce a transformation of a community identity when this one is associated with the sea (Bouchard-Bastien & Gervais, 2016, citing Lee & Blanchard, 2012, Gill *et al.*, 2012, Osofsky *et al.*, 2011, Picou *et al.*, 2009 and CIRAIG 2015). Especially, the literature focussing on native communities identified sociocultural impacts resulting from a major accidental spill of hydrocarbons. As it was observed in the case of the *Exxon Valdez*, a loss of fishing territory has affected spiritual and traditional subsistence activities (Bouchard-Bastien & Gervais, 2016, citing Gill & Ritchie, 2015, Desbiens *et al.*, 2015, Innovation maritime, 2014, Johnson, 2011 and Carrier Sekani Tribal Council, 2006).

[...] culturally speaking, the impacts of the spills can induce a transformation of a community identity when this one is associated with the sea .

IMPACTS ON THE MENTAL HEALTH OF INDIVIDUALS

Several studies focussing on the spills (*Exxon Valdez, Tasman Spirit, Sea Empress* and *Deepwater Horizon*) indicate a correlation between those incidents and the increase of psychological disruptions, of distress and of other symptoms related to mental health disorders amongst people who have been involved in the clean-up and those from the touched communities (Bouchard-Bastien & Gervais, 2016, citing Gill & Ritchie, 2015, Gill *et al.*, 2012, Lee & Blanchard, 2012, Osofsky *et al.*, 2011, Picou *et al.*, 2009, CIRAIG, 2015, Trépanier *et al.*, 2015 and Innovation maritime, 2014; Drescher *et al.*, 2014; Gallacher *et al.*, 2007; Goldstein *et al.*, 2011). The long duration of the acute phase of the disaster associated with the dispersion of the oil over a period of several weeks, leads to a prolonged period of acute psychological stress in some of the individuals exposed, which creates a risk of bringing about more consequences on their mental health than other types of disaster would (Palinkas, 2012; Shultz *et al.*, 2015). Furthermore, it is acknowledged that technological disasters, out of which some are major oil spills, generate more important stress than natural disasters do (CIRAIG, 2015). This would be due to the fact that technological disasters cause uncertainty as to the effects on health, on economic impacts, on environmental damages, on the fair and equitable reparation and, on the return to sociocultural normalcy (Gill *et al.*, 2012). Moreover, the perception of an accrued and uncontrolled risk contributes to the chronic uncertainty and adds to anxiety and psychological stress (Gill *et al.*, 2012; Palinkas, 2012). Thus, in the case of the explosion of the *Deepwater Horizon* platform, the effects on mental health linked to the disaster are more important and are being felt for a longer period of time than those associated with hurricane Katrina that hit those regions in 2005 (Devi, 2010).

The perception of an accrued and uncontrolled risk contributes to the chronic uncertainty and adds to anxiety and psychological stress.

The psychological effects of the oil spills have also been associated with disruptions of social relations, changes of lifestyle, and stress created by the accident and the risks linked to the accidental spill. Other factors, such as the loss of confidence in the future and in the institutions and the organisations in charge,

the fear, the anger and the powerlessness, would also be associated with psychological disruptions (Fan *et al.*, 2015; Gill *et al.*, 2012; Palinkas, 2012; Bouchard-Bastien & Gervais, 2016). Researchers have also noticed, as they were looking into the cases of the *Exxon Valdez* and the *Deepwater Horizon*, that these effects are likely to last for many years after the accident (Schultz *et al.*, 2015, citing Palinkas et al., 2004 and Picou *et al.*, 2009; CIRAIG, 2015). As to the *Exxon Valdez*, a study has demonstrated important stresses linked to disputes and compensation procedures, as the latter went on for over 15 years (Gill *et al.*, 2012). These data indicate that, in this case, the stress associated with the dispute would have brought on more important psychosocial consequences than the accident did (CIRAIG, 2015, citing Picou & Martin, 2007).

Psychological disruptions, in touched individuals, are varied in nature. Some case studies and literature review on the major spills (*Sea Empress, Exxon Valdez* and *Deepwater Horizon*) mention manifestations of stress, anxiety, depression and post-traumatic syndrome in some residents (Bouchard-Bastien & Gervais, 2016, citing Gill *et al.*, 2015, Gill *et al.*, 2012, Lee & Blanchard, 2012, Osofsky *et al.*, 2011, Picou *et al.*, 2009, CIRAIG, 2015, Trépanier *et al.*, 2015 and Innovation maritime, 2014; Lyons *et al.*, 1999; Fan *et al.*, 2015). An increase in deviant behavior and an abusive use of alcohol and drugs have also been observed in the communities affected by the oil disasters i.e. the *Exxon Valdez* and the *Deepwater Horizon* (Palinkas, 2012, citing Palinkas *et al.*, 1993, Russell *et al.*, 1996 and Osofsky *et al.*, 2010; Gill *et al.*, 2012; Bouchard-Bastien & Gervais, 2016, citing Osfosky *et al.*, 2011 and Picou *et al.*, 2009). Some impacts would have been observed in children, in the case of the *Exxon Valdez*, such as increased behavioral and developmental problems (Palinkas, 2012, citing McLees-Palinkas, 1994).

The groups described as being the most vulnerable to psychological impacts, as a result of oil spills, would be:

- workers whose economic activities are linked to natural resources, such as fishers who, as reported by some studies, did not tend to look for professional help (Bouchard-Bastien et Gervais, 2016; Gill *et al.*, 2012; Arata *et al.*, 2000);
- individuals who experienced life, work, family and social involvement disruptions (Gill *et al.*, 2012; Bouchard-Bastien et Gervais, 2016, citant Lee et Blanchard, 2012 et Osofsky *et al.*, 2011);
- individuals with addiction problems or mental health issues (Fan *et al.*, 2015; Teich et Pemberton, 2015).

As it is in the case for the physical health, methodological constrains in the documentation on social impacts and mental health are regularly mentioned in the literature. There would be a lack of comparative and longitudinal studies on the psychological health and on the social dynamics associated with large spills of hydrocarbons in a marine environment (Bouchard-Bastien & Gervais, 2016). Some variations in the thoroughness with which stressors and symptoms of mental health are measured, the lack of data on the conditions prior to the event and the lack of validated instruments to measure are also observed (Goldstein *et al.*, 2011, citing Savitz *et al.*, 2008 and Kessler *et al.*, 2008; Teich & Pemberton, 2015). /

CONCLUSION

What is to be learned from this overview of the literature for the coastal populations of the Gulf of St. Lawrence? Such an exercise reveals that the exposure of coastal populations to large quantities of hydrocarbons, as a result of an accidental spill, could generate a cascade of effects on the physical and mental health of individuals and a social disruption in the involved populations, particularly amidst small coastal communities. It is therefore important to consider that, in Quebec, several coastal communities of the Gulf of St. Lawrence are already showing social factors of vulnerability, partially because they are located in regions where the economy is hardly diversified and driven by the exploitation of natural resources (fisheries, forestry, mining and wind energy), and where unemployment is more severe than elsewhere in the province (ISQ, 2015). One must also remember that the communities of the Gaspésie-Îles-de-la-Madeleine and Côte-Nord regions are rural, that their populations are aging due to the demographic decline, which has been going on for several years, and that they maintain special relation with the sea, whether the latter involve economic development or identity (CIRAIG, 2015; Duhaime & Godmaire, 2002). In fact, a strong link with the natural environment can be seen within the populations of these regions (CIRAIG, 2015), especially within the Innu and Mi'gmaq First Nations. These characteristics make the social and psychological impacts likely to occur in the case of a major spill for these communities.

Photo: P. Archambault

It is important to examine all the aspects of a given situation and to draw lessons from previous accidents in the debate on the exploitation of hydrocarbons in the Gulf of St. Lawrence (GENIVAR, 2013). Actual knowledge on the health and social impacts related to the boomtown effect and oil spills must therefore guide the reflective thinking in Québec and must be taken into consideration in decision-making. This knowledge should evolve with the advancement of research, which will help to better understand the complexity of their impacts on human life and the particularities of the context in which they occur (Galea, 2012). /

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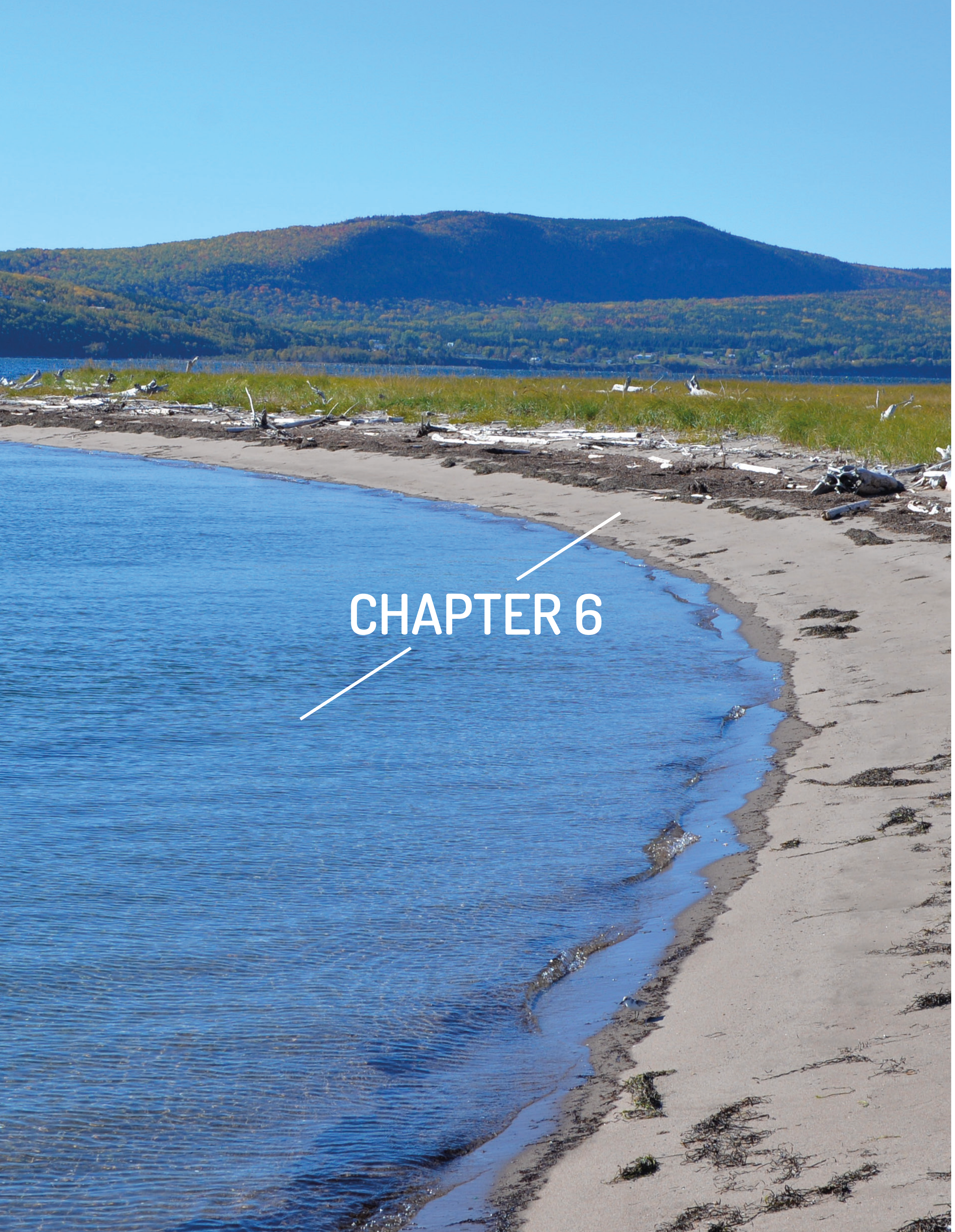

Projects and claims of the organisations of the Quebec civil society and the exploration and the exploitation of hydrocarbon in the gulf of St. Lawrence

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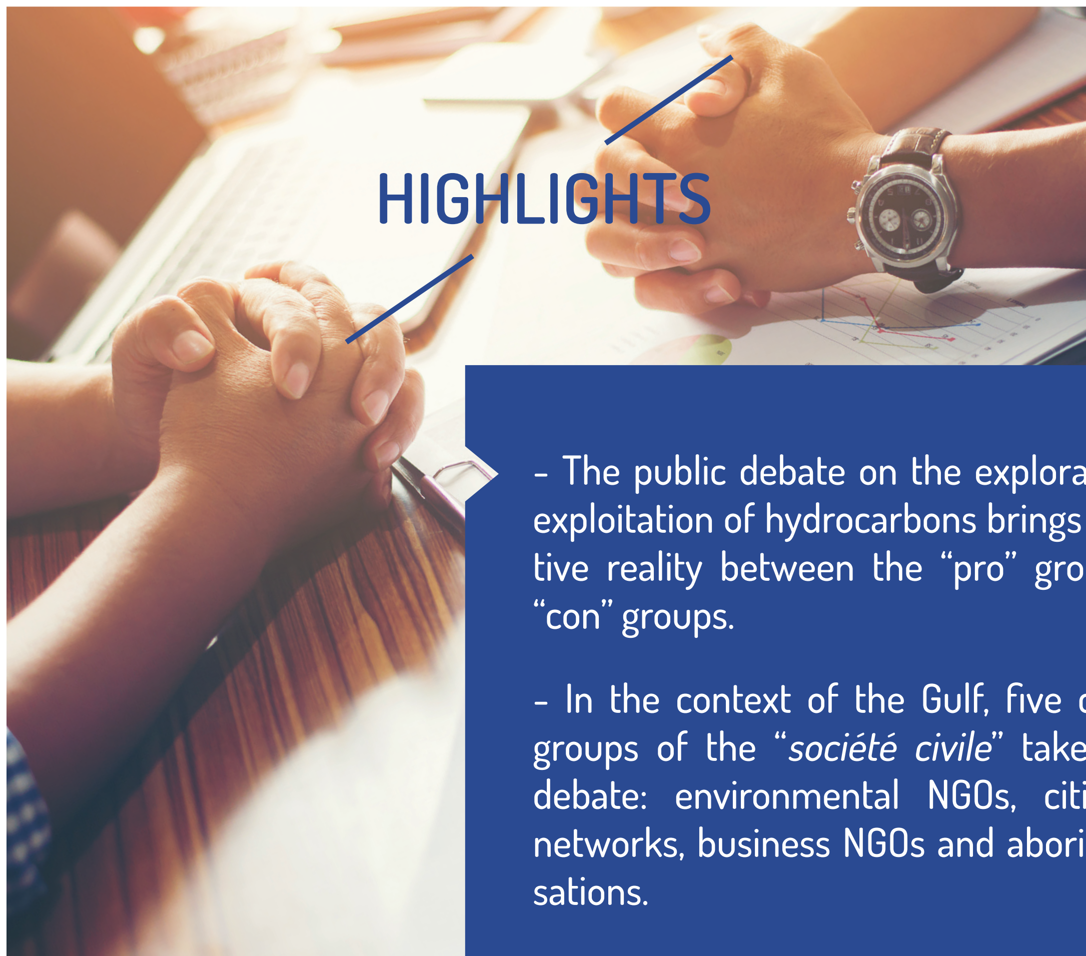
Photo: É. Pelletier

The controversy over the exploration and the exploitation of hydrocarbons in the Gulf of St. Lawrence can be found at the heart of the news, but there is no systematic reporting about the actors taking part in it, nor of their claims. Therefore, the question asked in this chapter is the following one: How do the exploration and the eventual exploitation of hydrocarbons in the gulf fit in the project of the groups of the "*Société civile du Québec*"? Our objective is to list all the actors of the debate and their main positions, that to develop a descriptive background to understand the controversy around the development of hydrocarbons in the Gulf. We are proposing two typologies that will contribute to enhance the understanding. The first typology focuses on the actors of the Quebec civil society involved in the debate on hydrocarbons in Quebec. It is based on a differentiation of these actors against three criteria: those sectors of the civil society to which they belong, the organisational types they adopt and their level of involvement in the debate. The second typology addresses the claims of the actors (pro or against the exploitation), but also the issues with respect to the consultation, the moratorium, the conservation and the energy transition. Combined, these two typologies help better contain the specificities of the controversy on the exploitation of hydrocarbons in the gulf, while informing on the discursive and organisational identity of the groups that are being heard within it.



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HIGHLIGHTS

- The public debate on the exploration and the exploitation of hydrocarbons brings out a reductive reality between the "pro" groups and the "con" groups.

- In the context of the Gulf, five categories of groups of the "*société civile*" take part in the debate: environmental NGOs, citizen groups, networks, business NGOs and aboriginal organisations.

- These groups adopt a diversity of projects and claims: pro exploitation, against exploitation; pro consultation, pro moratorium, pro conservation and pro energy transition.

INTRODUCTION

The controversy over the development of hydrocarbon file in Quebec is constantly showing up at the top of the news. Through their repetitive media confrontations, the "pros" and the "cons" seem to have crystalized a bipolar discourse which the Quebec society has to look into as a collectivity to decide on a strategy, its guidelines or its alternative solutions. There is no doubt that the clearest manifestation of this duality was the almost simultaneous publishing of two manifestos, in January 2014, on the development of the hydrocarbon file. First of all, on January 8th, a group of 11 personalities, close to the business world, launched the *Manifeste pour tirer profit collectivement de notre pétrole*, which fosters a conversation basically driven by the public finances and the commercial balance of the Province of Quebec, the demographic curve and the current trends regarding the use of oil. It proposes the exploitation of fossil resources to build a "common wealth", while reducing our dependency on foreign oil, (*Collectif pétrole Québec*, 2014). The response from the opponents to the development of the file was not long in the coming. On January 20th, a collective of personalities from the involved fields answered with the *Manifeste pour sortir de la dépendance au pétrole*, which put forward the notion that "our lifestyle has major impacts on our natural resources and our regional and global ecosystems", (*Collectif pour sortir du pétrole*, 2014), and the necessity to eliminate not only our dependency on foreign oil, but our dependency on oil, period.

The duality between the "pro" and "con" groups finds, in these two manifestos, a storyline that deeply characterises the discourse on the development of hydrocarbons in Quebec. Yet, one must realize that a more complex look on the positions of the Quebecois actors is called for. First, one must address the hydrocarbon "file" using the plural form as today's news on hydrocarbons are presented through many controversial topics: resource development (alleged or real) of the Gulf of St. Lawrence and its surrounding (especially in the Gaspésie and at Île d'Anticosti), shale gas in the St. Lawrence Valley, especially the development; and all those subjects with respect to modes of transportation i.e. maritime, rail and pipeline. One more element contributes to the complexity of the question – and it barely touches on the exchange between the two manifestos mentioned above – and sends one back to the multiple angles that could possibly be adopted in the realm of these debates, especially the consumption, the production, the transportation, the ecological risks, the climate change, the economic development model, etc. Moreover, the many controversies over hydrocarbon cover both common stakes, including some others, which are more specific. This contributes to making the debate even more complex. In any case, beyond the arguments, the positions and the campaigns in the media, one should really wonder as to "who" is really speaking in the debates on the development of hydrocarbon. This question must incite the examination of the profiles of the speakers in order to situate the arguments within the realm of concrete socioeconomic and political realities.

> The many controversies over hydrocarbon cover both common stakes, including some others, which are more specific. This contributes to making the debate even more complex.

This is the canvas on which it is appropriate to draw the main lines of the controversy, which is of interest to us at this point: the exploration and the exploitation of hydrocarbons in the Gulf of St. Lawrence. In this chapter, the question asked is as follows: how do the exploration and the eventual exploitation of hydrocarbons fit into the project of the main groups of the Quebec civil society? Our objective, which, *a priori*, remains of a descriptive nature, is to list the actors of the debate and their main positions to create a descriptive background to understand the controversy around the development of hydrocarbons in the gulf. We suggest two typologies that will contribute to the improvement of our understanding. The first typology focusses on the actors of the Quebec civil society involved in the debate on hydrocarbons in Quebec. It is based on a differentiation of these actors against three criteria: those sectors of the civil society to which they belong, the organisational types they have chosen and their level of involvement in the debate on the hydrocarbon file in the gulf against the other controversies listed above. The second typology focuses on the claims of the actors who intervene directly, the most, in the debate on hydrocarbons in the gulf. Combined, these two typologies help better describe the specificities of the controversy on the exploitation of hydrocarbons in the gulf, while informing on the identity -not only discursive, but organisational as well – of the groups that speak up.

Our objective [...] is to list the actors of the debate and their main positions to create a descriptive background to understand the controversy around the development of hydrocarbons in the gulf.

The nature of this study is both exploratory and descriptive. Thus, the methodological strategy, adopted to identify the groups of the Québec civil society involved in the debate on hydrocarbons, is not entirely systematic. This strategy rests on a research of written and "online" documents widely aiming at the so-called snowball method, which is used to identify and list units (herein groups) using aggregation, i.e. using networks of known relationships of certain groups and organisations to discover new groups to be added to the list. Such a strategy is facilitated by the fact that the groups of the Quebec civil society, intervening on the hydrocarbon question, gather around several coalitions and networks, especially Web pages (such as Facebook pages) and supply information on the members or other "sites of interest". Hence, we have followed these links to identify groups and organisations to the saturation point, that where there no longer was anything new showing up. Moreover, in order to list the widest possible diversity of groups and organisations, we sifted through the *Registre des lobbyistes du Québec* using the following keywords "*hydrocarbures*" and "*forage pétrolier*". Last of all, we reviewed the documentation derived from the recent public consultations and from the environmental strategic evaluations on themes touching hydrocarbons in the gulf, (BAPE, 2004; GENIVAR, 2013; C NLOPB, 2011, 2014). Hence, we could identify other networks of organisations that could be considered in the study. /

Photo: Pixabay

GROUPS OF THE QUEBEC CIVIL SOCIETY AND THE HYDROCARBON FILE

We propose to present the projects and the claims regarding the exploration and the exploitation of hydrocarbons in the Gulf of St. Lawrence, in terms of a typology of groups from the Quebec civil society involved in this debate. The civil society concept offers an advantage as it provides fairly clear boundaries, first amongst the large institutional fields of modern societies, and second, between their many components. In other words, the concept of a "civil society" allows for a descriptive approach and facilitates the development of typologies – two attributes we will exploit in this chapter in order to list the actors, their projects and their claims with respect to the stake we are interested in. Our first typology focusses on the groups, and it is built around three main segmentations: belonging to the civil society, the legal status of the groups, and the degree to which these groups are involved in the debate on hydrocarbons in the Gulf of St. Lawrence.

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FIRST SEGMENTATION: SECTORS OF THE CIVIL SOCIETY

Outstandingly modern – in the sense that it is a product of the philosophical debates that have contributed to the rise of the political modernity –, the concept of a "civil society" has evolved with the flow of deep transformations in western societies up until today. And now, we are referring to a "global civil society", (Keane 2003; Glasuis *et al.*, 2002). Therefore, as civil society could have been referred to as an industrious bourgeoisie with Hegel and Marx, it has eventually managed to trans-

From the “civic associations” of Tocqueville and from Gramsci’s “organisms commonly qualified as private”, civil society has progressively become a place called “non-governmental organisations-(NGOs),” as we know them today.

late the idea of a private sphere maintaining an ambivalent relationship with the state that describes both the separation of these two spheres, but also their interdependence, (Cohen and Arato, 1994). For example, to Tocqueville, a civil society is considered to be the place for the exercise of liberty, in the context of democracy and equality, which the state allows it to undertake, but it is also threatened by the authoritarian power of that state. Throughout the 20th century, several events – especially the rediscovery of Gramsci’s writings, (Bobbio, 1988), the struggles for emancipation of the former Soviet Republics, (Mastnak, 2005; Pelczynski, 1988) and the beginning of the discourse on world governance, (Duchastel et Audet, 2008) – have made it so that civil society is now located in a frame of three poles starring the three large institutional fields, namely the state, the market and the civil society.

The intellectual and historical approach, which led to this triangularization, had the concept of civil society move from a highly “ideal-normative” status, which attributed to it an intrinsic mission of emancipation, to a status that was more “analytical-descriptive”, that makes it possible to use the concept to cease upon the empirical realities, (Keane, 2003). This passage was especially achieved through the increased attention given to organisations that constitute civil society. Therefore, from the “civic associations” of Tocqueville and from Gramsci’s “organisms commonly qualified as private”, civil society has progressively become a place called “non-governmental organisations-(NGOs),” as we know them today.

The best example of this mutation of the concept is likely found in the definition given by the United Nations Organisation:

> “Civil society is the “third sector” of society, along with government and business. It comprises civil society organizations and non-governmental organizations. The UN recognizes the importance of partnering with civil society, because it advances the Organization’s ideals, and helps support its work”[1].
>
> (ONU, s. d. 1)

The consequences of this triangularization of the large institutional spheres and the emphasis put on the NGOs are important. First, the qualificative “non-governmental” doubles up with the implicit attribute “non-merchant”, thus excluding not only the governmental sphere, but also the enterprises. However, those NGOs that represent a group of enterprises or an industrial sector can be considered as civil society. This is what pushes some people to differentiate the “civic” sector from the “corporate” sector of the civil society, (Duchastel et Audet, 2008): on one hand, groups who pretend to be speaking on behalf of the general interest and, on the other hand, those who represent the sectorial and economic interest. Other typologies go even farther. Hence, in the frame of the negotiations on climate change, the United Nations Framework on climate change (UNFCCC) proposes nine “constituents” to the civil society: the corporate NGOs (or BINGO), the environmental NGOs (or ENGO), local and municipal governments, Aboriginal Nations organisations, research organisations (or RINGO), Trade Union organisations (or TUNGO), farmers and producers organisations, Women’s organisations and the likes, and Youth organisations (or YOUNGO).

[1] Translator’s note: http://www.un.org/en/sections/resources-different-audiences/civil-society/index.html as of April 11th , 2018

Photo:
S. Weissenberger

This typology of the UNFCCC seemed useful to us, as it makes it possible to organize a first classification of the listed groups when we researched documents. Our typology of the groups of the Quebec civil society involved in the debate on hydrocarbons in the Gulf of St. Lawrence (Table 6.2) presents the following categories: environmental NGOs, corporate and aboriginal nations organisations NGOs. The research document helped us identify two aboriginal organisations (the Idle No More movement, which, per se, is not an organisation, and the MMAFMA), five corporate NGOs (*l’Association pétrolière et gazière du Québec, l’Association québécoise des fournisseurs de services pétroliers et gaziers, le Conseil du patronat du Québec, la Fédération des chambres de commerce du Québec, les Manufacturiers et exportateurs du Québec*) as well as a large number of environmental organisations.

SECOND SEGMENTATION: ORGANISATIONAL FORMS OF THE ENVIRONMENTAL GROUPS

However, the sectors of the civil society represent very large categories whose composition may be heterogenous. Which is the case of the environmental NGOs sector, whose large diversity has been known for a long time, (Vaillancourt, 1981). Such a diversity exists in the midst of the organisational forms of these groups, and they are not limited to the typical NGOs. More often than not, environmental groups use informal and specific forms of organisation that do not meet legal and administrative parameters which would make them NGOs. This diversity in organisational forms, in the composition of the civil society, might have consequences in the capacity for the social actors to speak up, as long as the official classifications of the members of the civil society – such as the UNFCCC

ZIP COMMITTEES AND THE CHIEFS OF THE FIRST NATIONS – ACTORS OF THE CIVIL SOCIETY?

The boundaries between the civil society and the other two institutional fields (governmental and merchant) are not always very clear. Some organisations or initiatives often overlap in these areas. Therefore, it is not always easy to determine what is really part of the civil society. We dealt with this situation using two cases.

The First case refers to the ZIP[2] committees. The program, *Zones d'intervention prioritaire* (ZIP), derives from a collaboration between governmental institutions and groups from the Quebec civil society. In 1988, Environment Canada undertook the creation of local structures of consultation to deal with zoning of "both the ecological and social banks of the St. Lawrence" (*Plan d'action Saint-Laurent*, 2016), while, at the same time, Quebec environmental groups were developing *Stratégies Saint-Laurent*, with a similar objective: the consultation and the participation of the many actors concerned in the public decisions with respects to the St. Lawrence River. Such a double process lead to the creation of the *Programme ZIP*, in 1993. As ZIP committees include actors from the federal and provincial governments and municipal authorities, we chose to exclude them from our analysis. Moreover, even though some ZIP committees took part in the debate on the exploration and the exploitation of hydrocarbons in the gulf, groups from the civil society participating in these committees are already considered in the study. Lastly, we have integrated to the analysis the *Stratégies Saint-Laurent* organisation whose mandate is to represent the ZIP committees.

The second case is that of the coastal First Nations of the Gulf. Several organisations representing these First Nations have filed memoranda at strategic environmental assessments held in the last few years on the stakes with respect to the exploration and exploitation of hydrocarbons in the gulf, or that have publicly spoken against these activities. Such is the case of the Council of the Ekuanitshit Innu Nation and of the Mi'gmawei Mawiomi Secretariat in the course of the consultations in Newfoundland and Labrador where the topic was the *Old Harry* project, and also the case of the Quebec Assembly of First Nations and that of Labrador. Be that as it may, these organisations, as structures of governance of the First Nations, may be considered as part of the governmental sphere as opposed to civil society. And, quite to the contrary, the Mi'gmaq Maliseet Aboriginal Fisheries Management Association (MMAFMA) is more clearly part of what we intend to mean by the term "civil society". We have included this in the study.

[2] Translator's note: Primary Intervention Zones - (unofficial translation)

or the one proposed by the integrated system of the Civil Society of the United Nations (UN, s. d. 2) – have become institutionalised and operational. This is why we deemed it necessary to create sub-categories within the environmental groups involved in the debate on hydrocarbons in the Gulf of St. Lawrence, and to differentiate the different organisational forms of environmental groups.

The organisational forms of the interveners, on the matter of the exploitation of hydrocarbons in the gulf, are multiple. Some of them are legally recognized as "corporate entities" and regulated by federal laws. Such is the case of the non-profit organisations (NPOs). These organisational forms are easy to locate as they are listed in the records of the Canadian and Québec governments, for instance, the charities listed at the Canada Revenue Agency (CRA)[3] or in the *Registre des entreprises du Québec* (REQ)[4]. Other ones are "citizen groups" or networks or organisations that, as such, are not legal entities.

So, we submitted the names of all the environmental groups listed in the debate on hydrocarbons in the gulf to the research tools provided by the REQ and the list of charities of the CRA. The shaded areas of Table 6.1 indicate the organisations registered as NPOs and as charities with at REQ and the CRA.

This investigation emphasizes the many profiles of those groups with or without an official legal status. Amongst the environmental groups, three sub-categories appear.

Firstly, groups that bare the title of Association or Foundation, and NGOs known for their interventions in the environmental debates, are all registered as NPOS. As a matter of fact, most of the groups with a charity number at CRA are also those groups that are part of the history of the environmental mobilisations in Quebec, most notably Greenpeace, *Nature Québec, la Fondation David Suzuki, le Sierra Club, le RQGE, la SVP, les AmiEs of the Terre de Québec*, etc., (Vaillancourt, 2015). These groups are defined through their involvement over the years in a large number of environmental debates. Hence, the stakes linked to hydrocarbons do not constitute, in their mission, an exclusive pole. Quite to the contrary, these organisations have a more generalist mission reaching a larger field. The term **environmental NGO** applies rather well to this sub-category of more generalist and institutionalised groups.

> More often than not, environmental groups use informal and specific forms of organisation that do not meet legal and administrative parameters which would make them NGOs.

Secondly, most of the groups for whom the question of hydrocarbons is at the heart of their mission – as their name says (*Alerte Pétrole Rive-Sud, Non à une marée noire dans le Golfe du Saint-Laurent, Stop oléoducs* and *Tache d'huile*) – do not have, in most cases, the official NPO status. It is the same for the groups who claim to be "citizens" (*Convoi citoyen* and *Les citoyens au courant*). Therefore, as opposed to environmental NGOs, the field of action of the "non-registered" environmental groups revolves mainly around the issues dealing with energy and hydrocarbons, and it is part of the citizen and associative fabric with territorial boundaries. Albeit the exceptions and the fact that some of these groups are in fact registered

[3] www.cra-arc.gc.ca/chrts-gvng/lstngs/menu-fra.html
[4] www.registreentreprises.gouv.qc.ca/fr/consulter/rechercher/default.aspx

Table 6.1
Legal status of the environmental groups on the *Répertoire des entreprises du Québec (REQ)* and the list of charities of the Canada Revenue Agency (CRA)

● = *Registered through a Parent organization working at federal or provincial level.*

NAME OF THE GROUP	REQ	CRA
Alerte Pétrole Rive-Sud		
AmiEs de la Terre de Québec		
Association madelinienne pour la sécurité énergétique et environnementale		
Association québécoise de lutte contre la pollution atmosphérique		
Attention FragÎles		
Coalition Saint-Laurent		
Collectif Moratoire Alternatives Vigilance Intervention		
Collectif scientifique sur la question du gaz de schiste		
Convoi citoyen		
Conseil régional de l'environnement Gaspésie–Îles-de-la-Madeleine		
Eau secours! Coalition québécoise pour une gestion responsable de l'eau		
Éco-Vigilance Baie-des-Chaleurs		
Élan global		
Énergie alternative		
Ensemble pour l'avenir durable du Grand Gaspé!		
Environnement Vert Plus		
Équiterre		
Fondation David Suzuki		●
Front commun pour la transition énergétique		
Greenpeace Québec	●	
Justice climatique Montréal		
Les citoyens au courant		
Nature Québec		
Non à une marée noire dans le golfe du Saint-Laurent		
Regroupement vigilance hydrocarbures		
Réseau québécois des groupes écologistes (RQGE)		
Sierra Club Québec		●
Société pour la nature et les parcs du Canada (SNAP) – Section Québec		●
Société pour vaincre la pollution (SVP)		
Stop oléoducs		
Stratégies Saint-Laurent		
Tache d'huile		

with the *REQ* (for instance, *l'Association madelinienne pour la sécurité énergétique et environnementale* and *le Collectif Moratoire Alternatives Vigilance Intervention*), one must note that none of them has a charity number. The sub-category of the groups who fit that profile can be designated as **citizen groups**.

There is a third sub-category and it overlaps the last two; it is mainly different because its function is to link the different groups -networks, coalitions and common fronts-. When they unite several groups involved on the question of hydrocarbons, they create bridges between environmental NGOs and citizen groups. The *Coalition Saint-Laurent, le Front commun pour la transition énergétique, Élan global, Eau secours!, le Regroupement vigilance hydrocarbures, le RQGE* and *Stratégies Saint-Laurent* are found in this category. No doubt, the most active and representative of these networks is *la Coalition Saint-Laurent.* Founded in 2010, by *Nature Québec, Attention FragÎles, la Fondation David Suzuki* and *SNAP – Section Québec*, the *Coalition Saint-Laurent* got involved in the strategic environment evaluation process in the *Old Harry* dossier, most notably in the exercises held in Newfoundland, (C-NLOPB, 2011, 2014) and the one held in the Quebec section of the gulf by GENIVAR (GENIVAR, 2013). As a source of information for the other groups involved in the dossier on exploration around the gulf, an advisory resource to the actors (groups or citizens) wishing to write memorandum in the consultation process, and popular writers in exploration and exploitation of hydrocarbon dossiers in the context of the gulf (*Coalition Saint-Laurent*, 2014), the *Coalition Saint-Laurent* typically represents what we mean by the linkage function which characterises the **networks of groups** sub-category.

This brief analysis of the legal status and the organisational forms of the environmental groups helps us determine three sub-categories of environmental group interveners in the debate on hydrocarbons in Quebec:

1) environmental NGOs with a more generalist mandate and some history in terms of environmental struggles in Quebec;
2) citizen groups, more specialized on stakes such as energy and hydrocarbons and more solidly footed in local contexts;
3) networks of groups, which overlap these two sub-categories by ensuring some coordination amongst them.

These three sub-categories act near the corporate NGOs and the aboriginal organisations in the typology of the groups of the civil society involved in the debate on hydrocarbons in the Gulf of St. Lawrence. It is now possible to apply one last seg-

Environmental NGOs' exemple

David Suzuki Foundation

Citizen groups' exemple

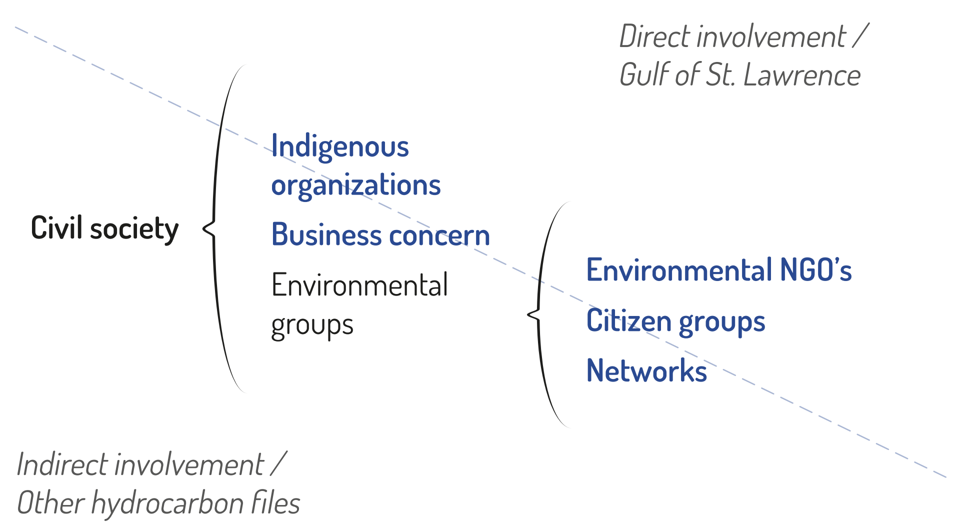
TACHE D'HUILE
PROTÉGEONS L'EAU POTABLE, PRÉVENONS L'IRRÉPARABLE...

Networks groups' exemple

ST-LAWRENCE COALITION SAINT-LAURENT

mentation to this typology by differentiating those groups that are directly involved in the debate on the exploration and the exploitation of hydrocarbon in the gulf from those interested in the hydrocarbon file in a more general manner, (Figure 6.1). We will study this third segmentation in the next sub-section.

Figure 6.1
Segmentations of the typology of the groups of the Quebec civil society involved in the debates on hydrocarbons. Elements in blue represent those retained for the analysis.



THIRD SEGMENTATION: THE POSITIONING AND THE EXPLOITATION OF HYDROCARBONS IN THE GULF

The first two segmentations developed above apply with no difference to the groups of the Quebec civil society that position themselves in either one of the controversies on hydrocarbons. However, not all of these actors take an explicit position on the file we are interested herein, i.e. the exploration and the exploitation in the Gulf of St. Lawrence. Some groups, having started off with the struggle against shale gas or pipelines, have developed a discourse on the whole of the hydrocarbons, for example, when they approached them from the point of view of the exploitation process (such as hydraulic fracking) or their transportation via railroad or pipeline. However, as the object of this chapter deals with the controversy around the exploration and the exploitation of hydrocarbons in the gulf, it is appropriate to identify more specifically those groups that foster projects and claims with respect to this file. So, the third segmentation of our typology makes a distinction between the groups that are *directly involved* in the debate on hydrocarbon in the gulf and those that are *indirectly involved*. The former adopts one or several explicit and documented positions with respect to hydrocarbons in the gulf, whereas the latter are mainly involved in the other controversies; and, if they can raise the question of the gulf, they have not developed specific arguments dealing with it (see Table 6.2).

Table 6.2
Typology of the groups of the civil society involved in the debate on hydrocarbons in the Gulf of St. Lawrence.

GROUPS DIRECTLY INVOLVED IN THE FILE OF THE GULF	
Citizens Groups	Association madelinienne pour la sécurité énergétique et environnementale Ensemble pour l'avenir durable du Grand Gaspé! Non à une marée noire dans le golfe du Saint-Laurent Tache d'huile
Environmental NGOs	AmiEs de la Terre de Québec Attention FragÎles Conseil régional de l'environnement Gaspésie–Îles-de-la-Madeleine Fondation David Suzuki Greenpeace Québec Nature Québec Société pour la nature et les parcs du Canada – Section Québec Sierra Club Québec
Corporate NGOs	Association pétrolière et gazière du Québec Association québécoise des fournisseurs de services pétroliers et gaziers
Network Groups	Coalition Saint-Laurent Stratégies Saint-Laurent
Aboriginal Organisations	Association de gestion halieutique autochtone Mi'gmaq et Malécite
GROUPS INVOLVED IN OTHER FILES	
Citizens Groups	Alerte Pétrole Rive-Sud Collectif Moratoire Alternatives Vigilance Intervention Collectif scientifique sur la question du gaz de schiste Convoi citoyen Justice climatique Montréal Les citoyens au courant Stop oléoducs
Environmental NGOs	Association québécoise de lutte contre la pollution atmosphérique Environnement Vert Plus Équiterre Société pour vaincre la pollution
Corporate NGOs	Conseil du patronat du Québec Fédération des chambres de commerce du Québec Manufacturiers et exportateurs du Québec
Network Groups	Front commun pour la transition énergétique Eau secours! Coalition québécoise pour une gestion responsable de l'eau Élan global Regroupement vigilance hydrocarbures Réseau québécois des groupes écologistes
Aboriginal Organisations	Idle No More

The main interest of this typology is to enrich the analysis of the projects and claims of the groups of the civil society in a context where the media discourse tends to portray a duality between of the "pros" and the "cons". The truth is that there is a certain series of more nuanced positions and arguments which should be emphasized. Some of these arguments, projects and claims could very well characterize some categories of groups of the Québec civil society. This feeds the interest for both the development of the knowledge on the subject and the more serene unfolding of the debate on the hydrocarbon file in the Gulf of St. Lawrence. One must therefore, from this point on, get interested in the projects and claims of the groups directly involved in the debate on this file. /

Photo: Pixabay

PROJECTS AND CLAIMS

Hence, we have documented the projects and the claims of the groups directly involved in the controversy on the exploitation of hydrocarbons in the Gulf of St. Lawrence. Let's emphasize that, on the methodological side, our approach does not constitute a true analysis of the systematic content as it remains exploratory and does not pretend to be exhaustive. We proceeded with the review of the available documentation on the webpages of these groups and in the classification of the main projects and claims of the groups against six categories:

1) pro exploitation in the gulf;
2) against exploitation in the gulf;
3) pro consultation;
4) pro moratorium;
5) pro conservation;
6) pro energy transition.

Table 6.3 illustrates the contribution of the citizen groups i.e. the environmental NGOs, the corporate NGO, the networks of groups and the aboriginal organisations, to these six categories of projects and claims. Most of the groups take positions in at least two categories, which indicates that the arguments are built by creating a balance between several claims, sometimes stacking them one against the others. The following sub-sections will help better understand both the arguments and claims mobilised by the groups; it will also help link the different categories and the types of groups at their source.

PRO EXPLOITATION

With no surprise, the corporate NGOs (APGQ and AFSPG) openly favor the development of the file. However, they occupy different positions in this industrial sector. The APGQ is first and foremost a lobby for the advancement of the oil projects in Quebec, and they promote the development of methods of so-called "sustainable" non-conventional exploitation, for instance the one foreseen for Île d'Anticosti. As to the AFSPG, its mission is to promote the offer of services to its members for the exploitation of hydrocarbons. Their arguments emphasize the economic benefits of the exploitation by projecting them on the overall file, upstream and downstream; for example, at the exploration and transportation phases. At every step, these organisations predict the spin-offs for the many Quebec

Table 6.3
Distribution of the actors of the groups of the civil society involved in the debate on hydrocarbons in the Gulf of St. Lawrence against their claims.

	PRO EXPLOITATION	CON EXPLOITATION	PRO CONSULTATION	PRO MORATORIUM	PRO CONSERVATION	PRO TRANSITION
CITIZEN GROUPS						
Association madelinienne pour la sécurité énergétique et environnementale			■	■		■
Ensemble pour l'avenir durable du Grand Gaspé!		■	■	■		
Non à une marée noire dans le golfe du Saint-Laurent		■	■		■	■
Tache d'huile		■	■	■		■
ENVIRONMENTAL NON-GOVERNMENTAL ORGANISATIONS						
AmiEs de la Terre de Québec		■		■		■
Attention FragÎles			■	■	■	■
Conseil régional de l'environnement Gaspésie–Îles-de-la-Madeleine			■	■	■	■
Fondation David Suzuki		■	■	■		■
Greenpeace Québec		■	■		■	■
Nature Québec			■	■	■	
Société pour la nature et les parcs du Canada (SNAP) – Section Québec			■	■	■	
Sierra Club Québec		■	■		■	■
CORPORATE NON-GOVERNMENTAL ORGANISATIONS						
Association pétrolière et gazière du Québec (APGQ)	■		■			
Association québécoise des fournisseurs de services pétroliers et gaziers (AFSPG)	■					
NETWORK GROUPS						
Coalition Saint-Laurent			■	■		
Stratégies Saint-Laurent			■	■		
ABORIGINAL ORGANISATIONS						
The Mi'gmaq Maliseet Aboriginal Fisheries Management Association (MMAFMA)			■	■	■	

communities, especially the creation of several jobs. Citing, as an example, the economic spin-offs (jobs and growth) from the exploitation of natural gas in Alberta, the AFSPG encourages Quebecois to take that step. That is why, as the APGQ asserts, "Quebec can and must produce a part of the oil and gas it consumes", (APGQ, 2017a).

AGAINST EXPLOITATION

The position opposite to the first one is that oil should stay under ground, and that no oil file should be developed in Quebec. This obviously means that the hydrocarbon file has to be taken off the board, including exploration and transportation. A large part of the antiexploitation argument rests on the environmental concerns and puts forward the limited aspect of the resources, the decline of certain populations of animals, the increase of greenhouse effects and the acidification of the oceans, to justify their opposition to oil. The fragility of the ecosystems of the Gulf of St. Lawrence and the need to protect them are explicitly mentioned by *Les AmiEs de la Terre, la Fondation David Suzuki* and *la SNAP – Section Québec*. The risks of catastrophe and spills are also bundled in the argument of several groups who emphasize that a black tide in the St. Lawrence could have a devastating economic impact on the economic activities of the islandic and coastal communities, especially those where the economy rests mainly on the fisheries and tourism.

If several environmental NGOs and certain citizen groups talk openly against exploration and exploitation of hydrocarbons in the gulf, many groups are not explicitly or categorically opposed to it. The following four claims show a nuanced argumentation on of the more detailed elements of an eventual creation of a hydrocarbon file in the gulf.

If several environmental NGOs and certain citizen groups talk openly against exploration and exploitation of hydrocarbons in the gulf, many groups are not explicitly or categorically opposed to it.

PRO CONSULTATION

Claiming that public consultation indicates a willingness to participate in a decision that is not yet cemented. So, the groups categorically refusing the exploitation of hydrocarbons in the gulf do not have a tendency to ask for more consultation, and most of the groups asking for a consultation do not refuse up front the exploitation projects. The former are mainly from the environmental NGOs and their networks, while the latter are mainly citizen groups, with the notable contribution from the MMAFMA. The former demands first and foremost to be consulted on any question with respect to the management of the marine aquatic resource and, even though it does not take a position -pro or con- the exploitation of hydrocarbon in Quebec, the activities it wants to protect could be affected. *L'Association madelinienne pour la sécurité énergétique et environnementale* grants a lot of emphasis on the necessity to consult populations concerned by the projects in this file, just like the *Tache d'huile* organisation. *La Coalition Saint-Laurent* and its many partners prefer a vast federal-provincial commission on the development of the file in the gulf: the only way to deal with the question in its entirety as five provinces and a large number of First Nations are coastal to the Gulf of St. Lawrence, (*Coalition Saint-Laurent*, 2014).

The *APGQ*, a Quebec lobby group involved in the hydrocarbons file, does not really claim any consultation, but commits, in its declaration on social acceptability, to contributing "in a proactive manner to an open and honest consultation with the interveners directly affected by the project", (APGQ, 2017b). This commitment must however be envisaged in terms of certain constraints which are not the responsibility of the Corporate NGOs, one of the most significant, being in no doubt the constitutional obligation -recognized by the Supreme Court of Canada, for the Crown- to consult and accommodate the First Nations as to the type of industrial development, especially that which is in question herein. So, the acknowledgement of this obligation is at the heart of the interventions of the coalition of the Chiefs of the Innu, the Mi'gmaq and the Maliseet First Nations, as they intend to make sure the hydrocarbon file does not go against their ancestral rights, (Desbiens *et al.*, 2015).

Photo Chiefs of the Innu, the Mi'gmaq and the Maliseet First Nations:
Groupe CNW/Nation Mi'gmaq de Gespeg / gespeg.ca
and Première Nation Malecite de Viger / malecites.ca/fr

PRO MORATORIUM

As those groups that claim a moratorium on the development of the hydrocarbon file in Quebec do not all share their opposition to the exploitation of hydrocarbon in the gulf, the argument involving the project of a moratorium is diversified. Whereas several groups claim a moratorium on the basis of their pure and simple opposition to the development of the file, while other ones, such as *la Coalition Saint-Laurent*, ask for a moratorium on the exploitation of hydrocarbon in the whole of the Gulf of St. Lawrence, while they specify that, being pro moratorium is not necessarily the equivalent of being against the exploitation of hydrocarbon. Instead, *la Coalition Saint-Laurent* promotes a process of reflective thinking and analysis bringing together all the provinces, the governments of the First Nations and concerned groups before making a decision that could turn out to be difficult to reverse. *La Fondation David Suzuki* favors a moratorium that would block exploration and exploitation of hydrocarbon projects in the whole of the Gulf of St. Lawrence. As to *Stratégies Saint-Laurent*, they also suggest a moratorium on the exploration and the exploitation of hydrocarbons in the gulf as long as the proof will have been shown that there will not be any consequences on its ecosystems.

As a matter of fact, the claim for a moratorium helps introduce, in the discourse of the groups, a series of conditionalities with respect to the exploitation of hydrocarbons, from the consultation to the analysis of the risks, with the conservation of large territories of the gulf and energy transition in the middle of it all. The moratorium, overall, takes an easy place in terms of other complementary claims in the discourse of the groups of the Quebec civil society. Potentially, it can reach all the groups that do not necessarily share the same degree of opposition to the file, except for the Corporate NGOs. Hence, claiming a moratorium has strategic ramifications towards the creation of a common approach, as the position of *la Coalition Saint-Laurent* shows.

As a matter of fact, the claim for a moratorium helps introduce, in the discourse of the groups, a series of conditionalities with respect to the exploitation of hydrocarbons, from the consultation to the analysis of the risks, with the conservation of large territories of the gulf and energy transition in the middle of it all.

PRO CONSERVATION

In the conservationist tradition, there are certain positions, more or less radical, which generate varied propositions for solutions; from the preservation of natural spaces, from any or all human activities, to the instauration of zones with restriction on the use of spaces and resources, especially those whose degree of constraint vary, (Yvard-Djahansouz, 2010). The most demanding position in this matter, within the realm of the Gulf of St. Lawrence, comes, we believe, from the Canadian Parks and Wilderness Society–Section Quebec. Their claim is to protect green spaces and marine areas via the creation of a large network of protected spaces, up to reaching the objective which would aim at protecting 50% of the natural public spaces remaining in Canada. Other organisations, such as *Nature Québec* and *Sierra Club Québec*, also have a mission: to conserve large natural spaces, especially marine areas, which could be instituted in the gulf. The Mi'gmaq Maliseet Aboriginal Fisheries Management Association also has a mission: to conserve the aquatic resources over all its territory but, its position, as we have said, consists in marrying conservation and economic activities, such as fisheries.

PRO ENERGY TRANSITION

Claiming an energy transition transcends all other arguments, except for those favoring exploitation. It is characteristic to both the citizen groups and the environmental NGOs. In fact, this is a claim that goes largely beyond the context of the debate on hydrocarbons, but that, nevertheless, has systematically mobilised more and more actors of the environmental movement, (Audet, 2016). However, this new discourse is not uniform: the transition can cover a slate of varied ideologies. In the course of the debate on hydrocarbons in the gulf, two main tendencies come to the front: an approach inspired by the political ecology and the technocentric approach.

Inspired by the political ecology school of thought, the first one brings back into question the same bases found in the capitalist system and insists on the necessity to transform not only the reality of energy but also the politico-economic system. To *Les AmiEs de la Terre de Québec*, for example, it is important to come out of the current extractivist paradigm, which generates exploration projects such as those touching the gulf. Hence, the transition should be done through a decentralisation of the energy systems so that each community could opt for the type of energy it wishes to prioritize. The network of groups *Élan global* proposes a similar argument as it presents the energy transition as a socioeconomic matter that takes into consideration the "humanisation of the economy". In the same line of thought, the citizen group *Tache d'huile* foresees an ecological transition associated with the idea of a cut in working hours, a reorientation of the economic objectives or the reduction of consumption.

Poster: elanglobal.org

The other transition approach can be qualified as technocentrist. The *Front commun pour la transition énergétique* and *l'Association madelinienne pour la sécurité énergétique et environnementale*, and the big environmental NGOs, such as Greenpeace, *la Fondation David Suzuki* and *Équiterre*, foster a vision of a transition driven by technology and energy substitution solutions – local and renewable energies that will create jobs. Here, we are not criticizing the established order as much as we are proposing solutions that are credible and relatively easy to implement, and that would overthrow the pretensions of reaching an "autonomous energy" in the hydrocarbon industry. /

CONCLUSION

This chapter aimed to explore the projects and the claims, of the groups of the Quebec civil society, with respect to the stakes involved in the exploitation of hydrocarbons in the Gulf of St. Lawrence. In order to deliver our most systematic report, we opted for an "analytical - descriptive" definition of the civil society, which consisted in the development of a segmentation of the different types of groups of the civil society involved in the controversy on hydrocarbons in Quebec: to identify projects and claims which characterize them and make them different one from the other. The citizen groups, the environmental NGOs, the networks of groups, the corporate NGOs and the aboriginal organisations, as we then demonstrated, have, at the same time, shared claims and positions that make them stand apart. These projects and these claims are sometimes complementary – which is the case, for instance, of the claims pro consultation and pro moratorium –, while others are incompatible – a critical approach of the energy transition bans a pro exploration and pro exploitation position. This, which we could call "the discourse space" of the Gulf of St. Lawrence, is therefore clearly more complex than the duality between the "pro" and "con" groups which transpires in the public debate on hydrocarbons. /

Photo: Jannoon028 / Freepik

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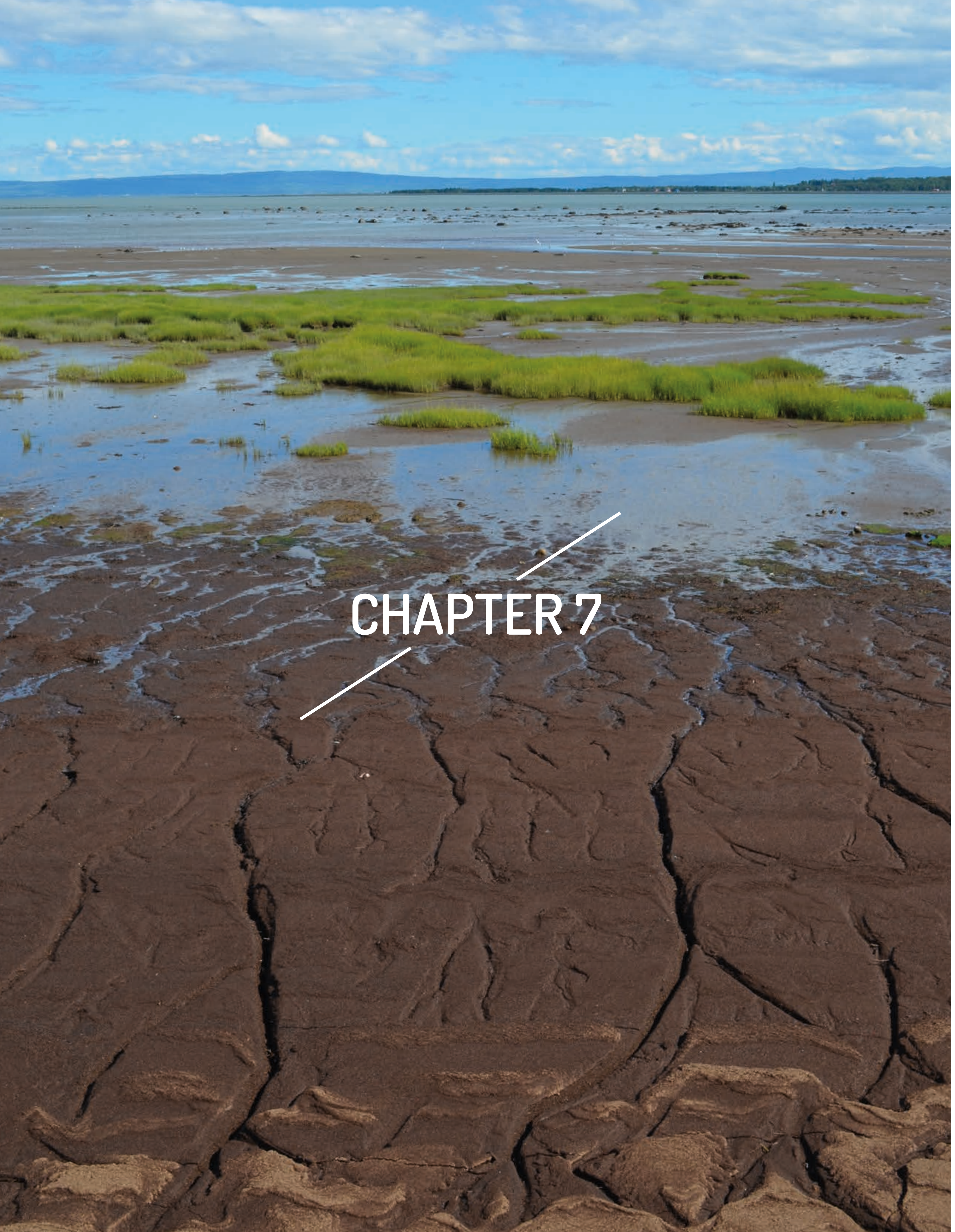

Impact of the fragmentation of the laws on the development of hydrocarbons in the gulf of St. Lawrence

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Seen through the prism of the law, the Gulf of St. Lawrence constitutes a fragmented space among (more than 2 plans) management plans, with a still imperfect framework. The legal order is divided into a slew of topics and legal sources, spanning from the international law to local norms; which also includes states such as the First Nations, via a myriad of regulating local communities and agencies. The dichotomy between the physical and ecosystemic unity of the Gulf, on one hand, and the mosaic of laws that apply to it, on the other, complicates – perhaps "impedes" at certain points – the development of hydrocarbons in a marine environment. This text presents a few of the most significant interfaces in the legal systems in order to illustrate the principles that structure and influence the normative framework of the management of the natural resources in the Gulf.

Photo:
C. Petetin

HIGHLIGHTS

- Because legal systems are not sufficiently structured and their interactions remain partly occult or implicit, laws fragment the management of the Gulf of St. Lawrence, complicating the management of hydrocarbons in a marine environment.

- It is necessary to ensure a more coherent structure, an enlightened decision-making process and the creation of adequate normative standards with respect to the development of hydrocarbons in the Gulf of St. Lawrence.

- The creation of an organisation or of a permanent pole of research dedicated to the study of questions relative to the eventual exploitation of hydrocarbons in the Gulf would favor the orderly and secure development of this energy file.

INTRODUCTION

The Gulf of St. Lawrence constitutes a singular space, an indivisible and distinct unit due to both its physical geography and its endemic ecosystem. This unicity is not reflected in the legal sphere. Seen through the prism of the law, the Gulf of St. Lawrence constitutes a fragmented space between management plans with an imperfect framework. The normative fractures all over the Gulf divide this space into multiple jurisdictions and dissociates the regulatory fields from many activities taking place in it. The legal order is divided in a slew of topics and legal sources, spanning from the Convention on the Law to local norms; which also includes states such as the First Nations via a myriad of regulating local communities and agencies.

The dichotomy between the physical and ecosystemic unity of the Gulf, on one hand, and the mosaic of laws that apply to it, on the other, complicates – perhaps "impedes" on certain points – the development of hydrocarbons in a marine environment. This text presents a few of the most significant interfaces within the legal system to illustrate the principles that structure and influence the normative framework of the management of the natural resources in the Gulf[1].

The first part of this text touches on the spatial fragmentation of the Gulf through the combined action of the international law, the constitutional law and the territorial distribution of the different jurisdictions. The second part illustrates some intersections between the legal systems which have rather significant repercussions with respect to natural resources. Those are the interactions between the mirror-laws of a co-management zone to another, the protection of foreign investments and the rights of the First Nations. The repercussions among these legal systems remain largely occult because they have not yet been the object of many judgements or extensive research or exhaustive studies with respect to the development of hydrocarbons in the Gulf. /

The Gulf of St. Lawrence constitutes a singular space, an indivisible and distinct unit due to both its physical geography and its endemic ecosystem.
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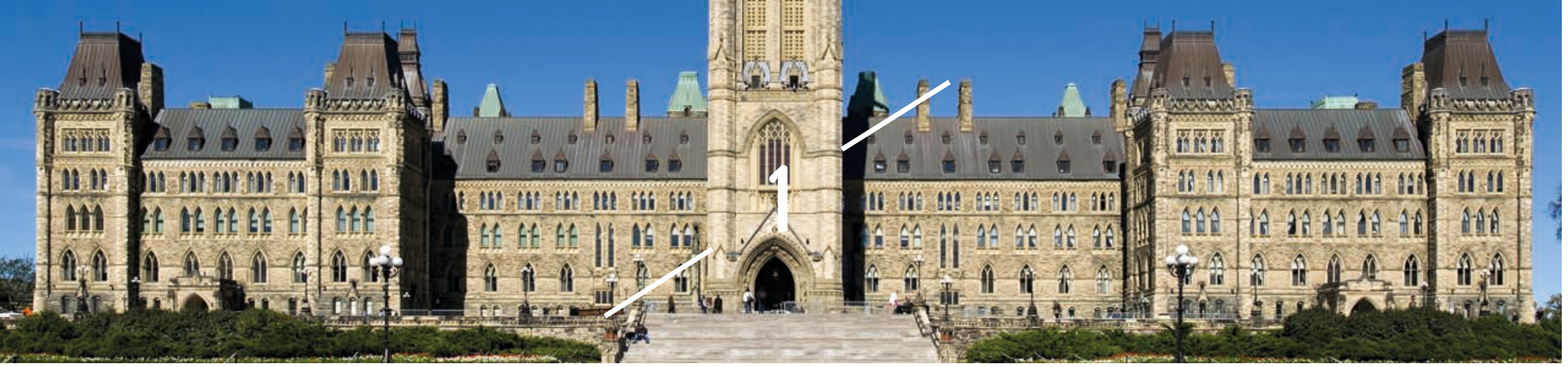
[1] This text does not include some details regarding the legal issues mentioned in order to present a global and intelligible picture without the background of a legal expert. For example, the difference between inland waters and internal waters is not herein established, neither is the possibility to establish a difference between the situation of the Gulf of St. Lawrence and principles developed by the Supreme Court with respect to the jurisdiction over natural resources off the Pacific and Atlantic coasts.



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JURISDICTIONS IN THE GULF OF ST. LAWRENCE

The laws do not clearly attribute jurisdictions in the Gulf of St. Lawrence. Such a matter leads to significant uncertainty. It is imperative that one studies this question as it partly dictates the forms of the legislative and regulatory framework applicable to the management of the natural resources in the Gulf.

THE PRINCIPLES OF CONSTITUTIONAL LAWS

The Constitutional Act of 1867 (Constitution) distributes legislative powers to both federal and provincial governments. In general, powers are shared in order to reflect the federal jurisdiction over Pan-Canadian topics or those bearing a national interest while the provincial jurisdiction applies to a specific territory and deals with topics of a local nature.

The Constitution grants specific powers based on two lists of topics given to the federal and provincial governments. On one hand, Section 91 of the Constitution expressly gives the federal government the power to legislate in many pertinent spheres regarding the Gulf of St. Lawrence. These spheres cover such things as navigation and marine facilities, federal public property, regulations over traffic and commerce, fisheries at sea or in land, aboriginal affairs and works and undertakings spanning beyond any provincial boundaries or linking provinces amongst themselves. To this, one will add "residual jurisdiction", under which the federal government administers jurisdictions in other spheres other than those which are not expressly assigned to provinces.

On the other hand, provincial jurisdiction, with respect to the development of hydrocarbons, can be linked to several constitutional provisions. Section 92 grants them jurisdiction over ownership, civil rights, provincial crown lands and all matters of a purely local or private nature. Section 92A gives the provinces jurisdiction in legislating the following matters:

- **prospection** of non-renewable natural resources in the province;
- **exploitation**, conservation and management of non-renewable natural resources, including the pace of their primary production;
- **export**, outside the province and bound to another part of Canada, of the primary production drawn from non-renewable natural resources.

And, Section 109 grants provinces the ownership of "lands, mines, minerals", i.e. natural resources found on their territory, such as, hydrocarbons. To that effect, provinces can enact regulations to manage the use of their property, as any owner can when looking after what he/she owns.

Therefore, the Constitution seems to grant legislative jurisdictions, to the two levels of government, the possibility to intervene in the matter concerning the development of hydrocarbons. The provinces can regulate the exploitation of natural resources: they can deliver permits for the exploitation of oil or gas found on their territory or grant rights to emit greenhouse gases in the fossil energy sector. The federal government can regulate the navigation of oil tankers sailing on the St. Lawrence or the export of hydrocarbons via trans-border pipelines.

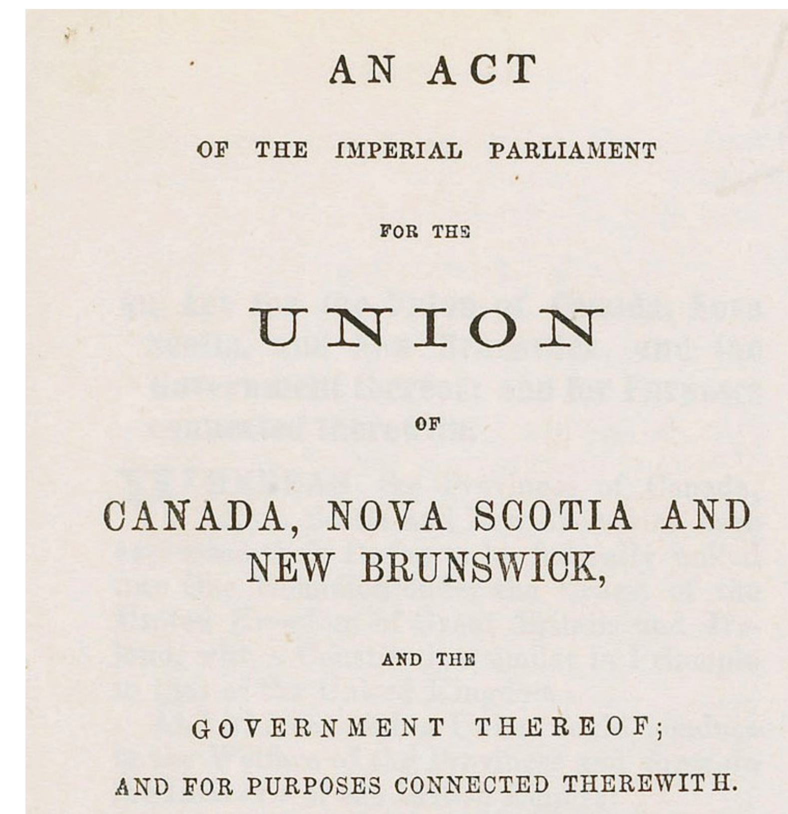
The Constitution seems to grant legislative jurisdictions, to the two levels of government, the possibility to intervene in the matter concerning the development of hydrocarbons.

To begin with, it is possible to imagine an intergovernmental management of the development of hydrocarbons in the Gulf of St. Lawrence, where provincial and federal legislative managers would cohabit harmoniously within a perspective of cooperative federalism. Yet, the situation is not that simple. Several factors, of a legal nature, complicate the structuring of federal and provincial legislative interventions in the gulf.

First of all, the text of the Constitution goes back one and a half centuries. It is hardly detailed and not adapted to framing activities that did not exist back in the days of Confederation. Thus, the tribunals must interpret the constitutional provisions against complex and detailed principles and rules using an abundant jurisprudence to determine which level of government has the power to frame the many aspects of the energy sector in the Gulf. In some cases, it is impossible to know, with certainty, if a given legislative provision is valid and in accordance with the Constitution before the Supreme Court makes a pronouncement on the matter.

The text of the Constitution goes back one and a half centuries. It is hardly detailed and not adapted to framing activities that did not exist back in the days of Confederation.

For instance, environmental questions are crucial for the development of natural resources. Yet, the Constitution does not expressly assign any jurisdiction over environmental matters, (Becklumb, 2013; Halley and Trudeau, 2012).



AN ACT

OF THE IMPERIAL PARLIAMENT

FOR THE

UNION

OF

CANADA, NOVA SCOTIA AND NEW BRUNSWICK,

AND THE

GOVERNMENT THEREOF;

AND FOR PURPOSES CONNECTED THEREWITH.

In 1867, the protection of the environment was not a significant issue. Traditionally, modifications to the environment caused by extraction of natural resource projects were seen as a local matter of provincial jurisdiction affecting the civil rights of citizencorporations. However, in 1997, the Supreme Court rendered a judgement which established, for the first time, that the federal parliament can rely on its criminal jurisdiction to put in place measures to manage substances that are toxic to the environment, (R. v. Hydro-Québec, 1997; Brun, 1993). At the same time, the legality of a set of provisions was confirmed, which increased the federal power of intervention in environmental matters.

Environmental questions are crucial for the development of natural resources. Yet, the Constitution does not expressly assign any jurisdiction over environmental matters.

Second, jurisdictions assigned to the federal parliament and to the provinces are generally considered as exclusive. An order from a government – federal or provincial – cannot encroach the jurisdiction of another order. For instance, Québec cannot affect the navigation of oil tankers, sailing on the St. Lawrence and in the Gulf, when the province takes measures to preserve the environment, as the federal government is empowered with an exclusive jurisdiction over navigation. An overlap of provincial and federal norms remains possible, but the exclusivity of the jurisdictions can stop a level of government to put in place an exhaustive legislative framework that integrates all the aspects of a sector of activity. As a matter of fact, the ensuing fragmentation is increased by the doctrine of the federal preponderance which applies in overlap cases. This doctrine makes inoperative the provincial norms contrary to the federal ones. A valid provincial norm can therefore be deprived of effects even if it finds itself within the realm of a provincial jurisdiction.

Third, the legislative jurisdictions of the provinces are confined to their respective territory. The principle of territoriality keeps a province from adopting laws to regulate activities outside its borders. Theoretically speaking, the exclusive powers of the provinces, as recognized by the Constitution, only address the "land territory", which includes inland waters. Nevertheless, only the federal government has the jurisdiction over the natural resources in a "maritime territory" and the ownership of its resources. Even though it seems to be clear at first glance, the rule of territoriality is still subjected to disputes. Some provinces stretch their jurisdiction beyond their land territory, (see *Personal Property Security Act*, section 4(1)b) of Nova Scotia). Furthermore, the span and the location of the provincial borders can be confusing, which keeps the two levels of government from clearly determining where exclusive jurisdictions begin and end, (Newman, 2013; Dorion et Lacasse, 2011).

Photo: Benson Kua / Wikimedia

On the legal stand point, these three factors generate several uncertainties, which can incite tensions or conflicts doomed to end in disputes. Hence, the management of the natural resources in the Gulf of St. Lawrence has become complicated. The problem linked to the territoriality principle is especially acute in terms of the development of hydrocarbons. Due to its importance, this question deserves distinct attention.

THE PRINCIPLES OF THE CONVENTION ON THE LAW OF THE SEA

The sharing of the rights and jurisdictions in the marine space pursuant to Canadian law is based, in a rather important portion, on concepts and principles of international law. The Convention on the Law of the Sea divides the maritime territory of any state into several "zones" as per the 1958 Geneva Convention on the Law of the Sea and the 1982 United Nations Conference on the Law of the Sea. Canada took part in the Convention of 1982 and transposed it into federal law through the Oceans Act. Furthermore, the principles developed in international law are applied by the Supreme Court of Canada to determine to which level of government resources in these maritime zones belong. Before venturing into the jurisprudence of the Supreme Court, we must proceed with an overview of the principles and concepts of international law, to facilitate the understanding of the legal situation:

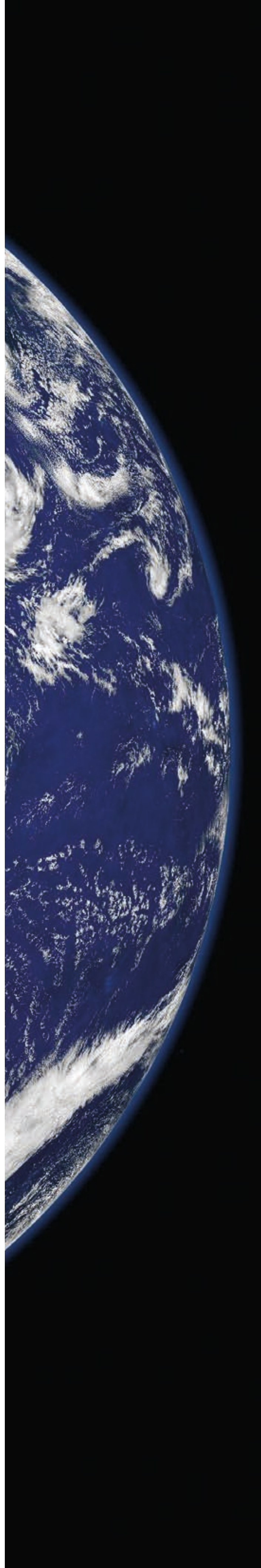
- **Baseline:** The baseline generally refers to the "low tide water mark" i.e. the line marked by the lowest point of the ebbing tides. The baseline sets the end of the land territory of a state and the beginning of its maritime territory, (Rigaldies, 2001). In other words, land and maritime territories are separated from each other by the baseline. The states regularly claim several exceptions pursuant to international law to draw the baselines off the shores from the low tide water marks to enclose bays, the mouth of a body of water, archipelagos or other recesses along the coasts in their land territory and to push farther their maritime territory;

- **Inland waters:** Inland waters are located between the land and the baseline. Generally, freshwater and the maritime littoral are found in the inland waters. International law says that inland waters are part of the land territory of the coastal state, which is the sovereign party;

- **Territorial sea:** The territorial sea, also referred to as "territorial waters" spans from the e43 base to the high sea over a line of 12 marine miles. The marine mile, or nautical mile, is the equivalent of 1,852 meters. In international law, the sovereignty of the coastal state also applies to the territorial sea and the marine bottoms and sub-soils. The sovereignty confers to the state an exclusive right to exploit natural resources;

- **Special Economic Zone:** The Special Economic Zone (SEZ) stretches from the external limit of the territorial sea to a line located 200 marine miles off shore, away from the baseline. The state does not apply full sovereignty but benefits from exclusive rights as it has "the sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters suprajacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone"[2];

- **Contiguous Zones and the Continental Shelf:** Other notions, such as contiguous zone and the continental shelf, extend the influence of a state beyond its territory pursuant to international law. For instance, the continental shelf prolongs the exclusive rights of a state all the way to the external edge of the continental margin. The continental margin consti-



[2] Article 56(1)a) of the Oceans Law of the sea, United Nations, signed in Montego Bay on the 10th of December 10, 1982, online http://www.un.org/Depts/los/convention_agreements/texts/unclos/part5.htm on April 13th, 2018.

tutes the submerged extension of the land mass of the coastal state all the way to the continental slope, which excludes the large oceanic floors. The continental plate can stretch – more or less- far from the SEZ, depending on the local geological particulars. In the Atlantic, off the coasts of Newfoundland-and-Labrador, the continental shelf extends beyond the SEZ. Be that as it may, the notions of contiguous zone and continental plate do not confer any more rights than the zones already targeted for the purpose of the development of hydrocarbons in the Gulf.

Hence, conforming with international law, Canada has rights of exploration and exploitation of the natural resources in the Gulf of St. Lawrence. The SEZ extends far away from the shores of each coastal province to cover the entire Gulf. The exclusive rights thus conferred to Canada mean that no other state can proceed with the development of the resources of hydrocarbons in the Gulf of St. Lawrence.

These principles do not resolve all the ambiguities. The exact status of the Gulf of St. Lawrence, in terms of international law, is not perfectly clear. Are we talking about internal waters on which the full-fledged sovereignty applies, or is it a space surrounded by a crown of territorial sea located in a Canadian SEZ?

In international law, the extend of the rights, with which Canada is empowered, varies when the Gulf happens to be in one or the other one of those situations. In principle, the Convention of 1982 comprises mechanisms from which Canada could draw straight baselines to close the entrances of the Gulf at both straits, i.e. Cabot and Belle Isle. Even though these baselines have not been officially drawn, in 1971, Canada created fishery closure lines in these two straits; it acts as if the Gulf was part of its national jurisdiction. Even if the rights and the actions of Canada in the Gulf did not justify a historical title, it is highly likely that the slew of unilateral actions taken by Canada and accepted by the other states would establish the full Canadian sovereignty over the Gulf in international law, (Rigaldies, 2001).

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THE JURISPRUDENCE OF THE SUPREME COURT

The application of the rules of international law percolate in Canadian national law. It also influences the sharing of jurisdictions and rights in the gulf. All along, the second half of the 20th century, the Supreme Court of Canada determined which level of government (federal or provincial) has priority over the oil and gas resources located off the coasts, and the jurisdiction over their exploration and exploitation. The answer of the Court, developed throughout the development of three References in Principle, merges the legal analysis to an historical perspective[3]. The Court applies the Convention on the Law of the Sea to the context of the Canadian Federation to reach its conclusions.

› 1967 REFERENCE: MARINE MINING RIGHTS OF THE OFFSHORE SUB-SOILS OF THE COASTS OF BRITISH COLUMBIA

In this matter, British Columbia argued that it owns the property rights and the legislative jurisdiction over the territorial sea and the continental shelf off its coasts. The Province claimed it has the exclusive jurisdiction over the exploration and the exploitation of the mineral resources.

First of all, the Court established that British Columbia has no right over the territorial sea. Canada is the sovereign state and owner of the territorial sea bed. Canada has the right to explore and exploit the seabed pursuant to its constitutional jurisdiction over federal public property or over its residual jurisdiction as this is a matter affecting the country as a whole. Furthermore, the rights of Canada over the territorial sea come from international law and are recognized by the other sovereign states. And, Canada has the jurisdiction to enter into international accords with respect to the rights in the territorial sea.

Second, British Columbia does not have any rights over the continental shelf either, because it has no historical, legal or constitutional base to back them up. The continental shelf is beyond the borders of British Columbia. Canada is the sovereign state recognized as the owner of the powers granted by international law, and it is up to the Canadian provinces to push back claims from other members of the international community in that zone.

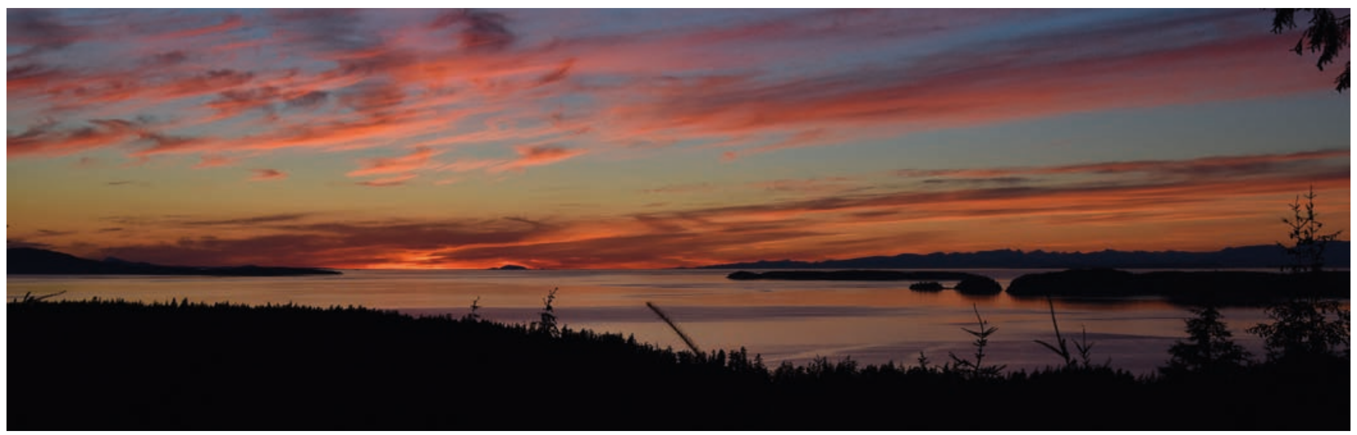
Carte: IBCAO 2017 / Google Earth

[3] The status of the Chaleur Bay is settled by: *An act for the settlement of boundaries between the provinces of Canada and New Brunswick*, 1851, 15-16 Victoriæ Reginæ, c. 63 (R.-U.); Mowat v. McPhee, (1880) 5 RCS 66. Chaleur Bay is entirely situated in a provincial territory and divided between Québec and New Brunswick.

› 1984 REFERENCE: OWNERSHIP OF THE SEABED OF THE GEORGIA STRAIT

In that matter, British Columbia asked the same question as to its ownership and its exclusive jurisdiction over the exploration and the exploitation of the mineral resources, not in the territorial sea nor the continental shelf, but in the Strait of Georgia, between the continent and Vancouver Island. The Court went back to the same test it applied in the reference of 1967: Did submerged lands in question belong to the province when it joined the Confederation? The decision of the Court rested on the interpretation of the terms "Pacific Ocean" found in an 1866 British imperial law and the terms "territory of the United States" found in a treaty dating back to 1848 between the United States and Great Britain. The treaty and the imperial law granted sovereignty over the seas between the coasts and the Pacific Ocean before it joined the Confederation, making the province the owner of the resources in the inland waters of the Georgia Strait and the exclusive legislative jurisdiction over the area.

Photo: Xucy / Wikimedia



› 1984 REFERENCE: CONTINENTAL SHELF OF NEWFOUNDLAND

In this matter, Newfoundland and Ottawa argued over the ownership and the jurisdiction over the resources of the *Hibernia* oil field, a gas pool located on the Atlantic continental shelf. The failure of the political negotiations lead to a dispute taken before the tribunals in 1983. The Supreme Court rendered its judgement in 1984 and decided that the federal government has the rights of exploration and exploitation and the jurisdiction to legislate in that zone pursuant to its residual jurisdiction. The Court kept the same test as was used in the previous references: this was mainly a question of determining if the submerged lands in this matter belonged to the province when it entered the Confederation. However, the Court added to the test the following:

1) international law must have recognized the right to explore and exploit the continental shelf before Newfoundland joined the Confederation on March 31st, 1949;
2) Newfoundland must have effectively acquired these rights;
3) Newfoundland must not have lost these rights pursuant to the conditions of the union with Canada.

That said, the answer to all these questions was negative, therefore, Newfoundland has no right and no power whatsoever.

Basically, the jurisprudence of the Supreme Court globally establishes the legislative jurisdiction of the provinces and their rights to explore and exploit

natural resources off their coasts can always proceed up to the baseline, which indicates the beginning of the marine territory and of the territorial sea. As to the federal government, it has exclusive jurisdiction and rights from the baseline away from the coasts whether in the territorial sea, in SEZ or on the continental shelf, (Roy, 2009). Ottawa has rights, agreed to in international law, over these maritime zones and is the only entity responsible *vis-à-vis* its neighboring states and the international community.

Carte: IBCAO 2017 / Google Earth

Once more, this situation is, *a priori*, clearly wrought with uncertainties. The jurisprudence of the Supreme Court shows that international law percolates in national law and determines, to a degree, the jurisdictions and the rights of the federal and provincial governments in marine zones. It is possible the international law does consider the Gulf of St. Lawrence as inland waters subjected to full Canadian sovereignty. Such a status would push the coastal provinces to claim jurisdiction over the Gulf: the inland waters belong in the land territory; hence the constitutional jurisdiction of the provinces would apply over them, (see Calderbank *and al.*, 2006; Charney, 1992a, 1992b). This reasoning could, in part, explain why Canada has not drawn any straight baselines for the two straits closing the Gulf. Despite a slew of legal arguments in favor of Ottawa, these residual uncertainties feed the provincial claims with respect to the Gulf.

PROVINCIAL CLAIMS

Ever since 1960, Canadian provinces have claimed jurisdiction over the natural resources in marine zones. As to the Gulf of St. Lawrence, such a claim came in September 1964 via an agreement set out by Newfoundland, Nova Scotia, Prince-Edward-Island and New Brunswick (*Arbitration between Newfoundland and Labrador and Nova Scotia*, 1st phase, 2001, p. 38-39). This agreement, which Québec joined, divided the Gulf into zones attributed to each coastal province. The borders of the respective zones and their marking was essentially done in accordance with the strict equidistance method, (Smith, 1997). This method limits zones by drawing a median line to each point which is at an equal distance to the baselines bordering the opposite and adjacent coasts of the coastal provinces in the Gulf. Inside one's specific zone, each province would benefit from all the rights and jurisdictions required for the development of oil and gas resources in a marine environment, including the power to grant deeds and deliver permits.

The maneuvering, that took place before and after the Agreement of 1964, indicates that such an accord is aimed at establishing a common front to have the federal government accept the claims of the provinces. The provinces only wanted to convince Ottawa to modify their respective territory, with the help of the jurisdiction the accord granted the federal parliament, pursuant to section 3 of the Constitutional Act of 1871. Thus,

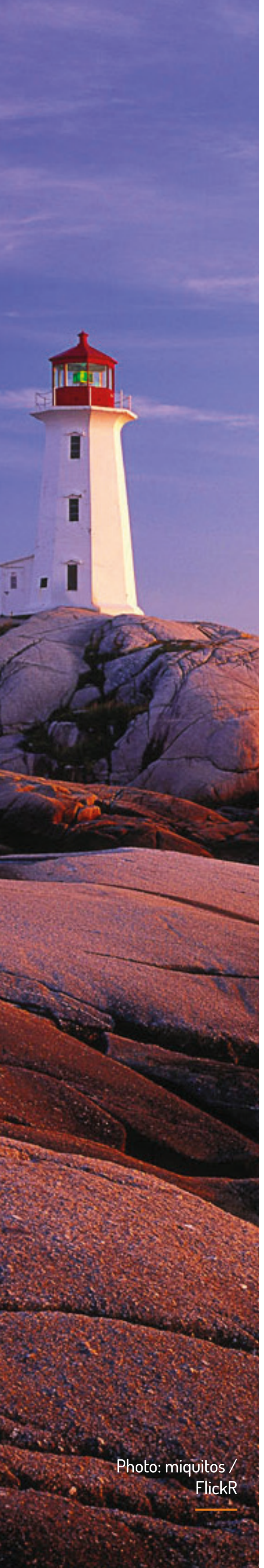


Photo: miquitos / FlickR

the Agreement had political implications. Nevertheless, the position of the provinces also called for legal arguments and relied on legal opinions.

Be that as it may, the 1967 reference regarding the rights of under-sea mining, off the coasts of British Columbia, weakened the position of the provinces of the Gulf. In 1969, a new initiative, lead by Québec, aimed at confirming the distribution of the Gulf according to a variant of the 1964 Agreement using laws that the government of each coastal province would adopt. In 1972, the initiative led to a common communiqué from the five provinces that reiterated the sharing of the Gulf and asserts their ownership over the natural resources therein. The federal government rejected the communiqué on the spot. The provincial consensus unravelled shortly as Newfoundland undertook a review of its marine policy, which lead it to adopt a unilateral approach.

In 1974, the federal government initiated a process of negotiation with the provinces. Newfoundland did not participate, while Quebec quickly removed itself. The negotiations reached a high in 1977 as Ottawa offered New-Brunswick, Nova Scotia and Prince-Edward Island an Agreement, (Clancy, 2011; Harrison, 1977). Such an offer aimed to end the provincial territorial claims in exchange for a consistent intergovernmental management on one hand, and the dividing of the Atlantic continental shelf amongst the provinces, based on the borders drawn in 1964, on the other hand, allocating the jurisdictions between the federal and provincial governments. The agreement failed following the withdrawal of Nova Scotia, as it preferred returning to its initial position and claiming exclusive rights over offshore natural resources.

Despite this failure, Ottawa and the provinces began a turn-around in their policies with respect to the Gulf to privilege an intergovernmental management based upon bilateral agreements. In 1982, the federal government entered into an agreement with Nova Scotia that established the Canada – Nova Scotia Office on offshore hydrocarbons, becoming responsible for the development of exploitation projects and for of the sharing of the offshore revenues of the province. The agreement deliberately removes the issue with respect to the jurisdiction over the continental shelf.

That said, the 1984 reference relating to the continental shelf of the Atlantic put an end to the pretenses of Newfoundland with respect to its offshore hydrocarbons, while the federal government was softening its position relating to the majority of revenues from the exploitation of sub-sea pools. In 1985, Ottawa and St. John's, Newfoundland, entered into the Atlantic Agreement, which oversaw to the mutual management of energy resources in a marine environment, the sharing of ensuing revenues and the creation of the Canada – Newfoundland Offshore Hydrocarbons Office.

Lastly, a regain of interest in the hydrocarbons of the Gulf of St. Lawrence, in the 2000's, encouraged the federal and Quebec governments to let go of the territorial differences impeding the development of resources. In 2011, both parties signed an intergovernmental management agreement granting the province most of the benefits with respect to the eventual value-adding of hydrocarbons activities in the zone of the Gulf granted to the province in the 1964 Agreement, (Turmel, 2011).

Basically, the predominant force of the federal legal claims, with respect to the hydrocarbons of the Gulf, convinced the common front wishing to impose provincial claims. Nevertheless, the latter remained persistent enough to discourage an exclusive federal intervention in the

zone. At the end of the day, the privileged approach would see the suspension of the matter, with respect to the ownership of the resources, to establish bilateral common management frameworks, based on joint administrative structures, whose role is to control hydrocarbon development activities and distribute the revenues between the different federal and provincial levels. Such an approach constituted the anchor of all the agreements proposed to the provinces.

Whatever their legal value, some provincial claims over the Gulf remained; and that maintained a climate of uncertainty on the territorial question. Each provincial law that set forward the three management agreements presented provisions aiming at preserving all the rights, with respect to offshore hydrocarbons, of which the provinces might be the owner. In the case of Quebec, claims were transposed in the *Loi sur les terres du domaine de l'État*, which "applies to all the lands that are part of the sphere of the state, including the bed of bodies of water and lakes, and the parts of the beds of the St. Lawrence River and of the Gulf of St. Lawrence belonging to Quebec as acquired from their sovereignty right"[4](Smith, 1997; La Forest, 1970). Ottawa was opposed to that argument. The federal government relied on the limits fixed by the Royal Proclamation on the 7th of October, 1763 which limits the territory of Quebec to the St. Lawrence Estuary, west of a line that begins at Cap-des-Rosiers, in Gaspésie, that joins the western tip of Anticosti Island and, from there, goes to the mouth of the Rivière-Saint-Jean, on the North Shore, (Dorion and Lacasse, 2011). In fact, several federal laws, such as the Canada Shipping Act, refer to those lines. /

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[4] Section 1 - *Loi sur les terres du domaine de l'État*, RLRQ, chap. T-8.1.

Carte: IBCAO 2017 / Google Earth

INTERFERENCES AMONG THE LEGAL SYSTEMS

The partitioning of the Gulf of St. Lawrence, in terms of constitutional jurisdictions and geographical zones, granted to the provinces to impose in the Gulf, right at the start, a complex management structure. The accretion of legal systems within this marine space makes it hard to understand the law and renders its functioning burdensome. This present section features a few additional legal systems that affect the development of natural oil and gas in the Gulf and make them complicated. Besides, its reciprocal interactions remain by and large implicit or insufficiently integrated. Such is the case of the interactions between the mirror-laws from a co-management zone to the other, for the protection of foreign investments and the rights of First Nations.

GOVERNMENTAL INTERACTIONS

The agreements entered into between the federal government and the provinces for the management of hydrocarbons in the Gulf of St. Lawrence lead to mirror-laws. For each management zone, the Canadian Parliament and the provincial legislature in question adopt, each on their own side but in a tight collaboration, two acts that faithfully reproduce each other's provisions. In other words, in each management zone, the two laws that apply are basically identical; one is provincial, the other, federal. The Newfoundland co-management zone is governed by the *Canada-Newfoundland Atlantic Accord Implementation Act* (federal) and by the *Canada–Newfoundland and Labrador Atlantic Accord Implementation Act* (provincial); while the Nova Scotian co-management zone is controlled by the *Canada–Nova Scotia Offshore Petroleum Resources Accord Implementation Act* (federal) and by the *Canada–Nova Scotia Offshore Petroleum Resources Accord Implementation Act* (provincial). In the Quebec zone of co-management, the acts governing the implementation of the 2011 Agreement have yet to be sanctioned, although bills have been introduced in 2015: Bill n° C-47 at the federal level and Bill n° 49 at the provincial level[5].

The model of the mirror-laws duplicates the applicable legal instruments. Still, its advantage is that of keeping at bay disputes over the respective rights and jurisdictions of the two levels of government, while short-circuiting any possibility of contestation over the constitutional validity of the legislative provisions by the justiciable with a possible interest in it. Amongst others, the mirror-laws in each co-management zone aim at completely coordinating the many federal departments and agencies involved, and to integrate the administrative and the decisional action.

[5] Bill n° C-47 died on the order paper due to the 2015 fall elections.

The administrative structure and its terms vary from one co-management zone to the next but the example of Bills C-47 and 49 gives the opportunity to illustrate the type of coordination set in place. In the Quebec co-management zone, the administrative structure features three main aspects: joint management by the ministers, joint management by the *Régie de l'énergie du Québec*, by the National Energy Board and management by the *Comité des hydrocarbures dans un environnement marin*.

First of all, the federal Minister of Natural Resources and, in Quebec, *le ministre de l'Énergie et des Ressources naturelles* manage together the allocation and the development of hydrocarbons. They make joint decisions that are merged into one document. Thus, they deliver authorizations to value hydrocarbons, including exploration, important discovery and production permits. Neither can make regulations relating to the application of a mirror-law without the prior consultation and approval of the other party.

Further to that, the *Régie de l'énergie du Québec* and the National Energy Board, at the federal level, jointly govern the oil and gas activities along with the pipeline transportation. They supervise and deliver permits required for the activities of exploration, drilling, production and the transportation of hydrocarbons. The *Régie* and the Board make joint decisions in two steps: first, they render individual decisions which they communicate to one another; then, they agree on a joint decision that respects their individual decision. They also must put in place common services and ensure that they avoid duplication of work and activities. They can agree on the details of their collaboration and submit that agreement to the two ministers for approval.

National Energy Board

Last of all, the federal and provincial ministers may create the Hydrocarbons Committee in a marine environment, which undertakes consultative functions. The Committee may proceed with enquiries, hold public hearings and make any decision necessary to the accomplishment of the mandates it is given. The Committee is made of five members, with a maximum of three, who can be chosen from the Quebec or the federal Public Services. The remaining ones must be experts in the sphere of hydrocarbons.

Despite the coordination of the representatives from the federal and provincial states, and from administrative agencies ensured by the mirror-laws, the legal fragmentation of the Gulf influences the development of hydrocarbons. For instance, the mirror-laws govern the mechanisms required to come to unit agreements for the joint exploitation, by several operators and owners of royalties, when a pool goes beyond the boundaries of a one space unit, i.e. a sector that is attributed to the ends of drilling or production of hydrocarbons. The mechanisms related to the unit agreements apply when a pool overlap two or several space units in one and the same co-management zone. However, the mirror-laws do not mange explicit provisions that would allow for the creation of unit agreements for pools overlapping the border of a co-management zone.

The mirror-laws do not mange explicit provisions that would allow for the creation of unit agreements for pools overlapping the border of a co-management zone.

In the same breath, some mechanisms governing interactions between the governments involved in the Gulf are especially important as they aim for the spatial delimitation of the respective provincial jurisdictions. Indeed, every law on the development of agreements, on the intergovernmental management of hydrocarbons in the Gulf, include a resolution process in the case of disputes over the mapping of the maritime boundaries between two provinces. This process of dispute settlement requires one's attention for several reasons. On one hand, it deals with the fundamental question related to the territoriality which we laid out in the first part of this text. On the other hand, it reveals some significant uncertainties that persist due to the imperfect anchoring between several legal systems applicable to the Gulf.

Firstly, the boundaries of co-management granted by the mirror-laws in the Gulf are not all definitely drawn following a consensual plot approved by the coastal provinces and Ottawa. The Canada-Quebec and Canada–Nova Scotia mirror-laws create boundaries to the co-management zones, drawn following the strict equidistance method, which reflects provincial borders created by the 1964 Agreement. Nevertheless, an arbitrary sentence rendered in 2002 relating to a dispute with respect to the delimitation of co-management zones between Nova Scotia and Newfoundland-and-Labrador concluded that the 1964 Agreement has no constraining legal force. As a matter of fact, Newfoundland-and-Labrador no longer recognizes the plot of 1964 (Dorion and Lacasse, 2011). Both Canada–Newfoundland mirror-laws only define the boundary with the Nova Scotia co-management zone, but omit the delimitation of the border with the eventual Québec co-management zone.

Secondly, creating or moving boundaries in the Gulf could affect the distribution of the resources and revenues between the governments involved. The geological structure of *Old Harry*, Îles-de-la-Madeleine, illustrates the effect of plotting boundaries on the distribution of resources. Several assessments define *Old Harry* as the location with the greatest potential for oil and gas in the Gulf. However, this structure overlaps the boundary between Quebec and Newfoundland-and-Labrador as plotted with the 1964 Agreement. On one hand, Newfoundland-and-Labrador no longer recognize the plotting of that boundary. On the other hand, the geographical position marks used to determine its location can also be questioned. The delimitation from the 1964 Agreement rests on the equidistance between the eastern tip of the Îles-de-la-Madeleine and the Newfoundland coast. Otherwise, if Rocher-aux-Oiseaux was to be used as a position mark (this, being a small Quebec island sheltering a lighthouse and some buildings and located 32 km à to the east of the Îles-de-la-Madeleine), the boundary could be moved by a few kilometres towards Newfoundland-and-Labrador. The exploration permits for *Old Harry*, granted in the Newfoundland co-management zone, would then be located within the competency of another jurisdiction, the zone named by the Canada-Quebec agreement of 2011 (*Coalition Saint-Laurent*, 2014).

Thirdly, the beginning of some of the work of the exploration of hydrocarbons depends on the settlement of any eventual dispute between Quebec and Newfoundland-and-Labrador. Quebec has delivered research permits on hydrocarbons in 1996 and 1997 to exploration companies in the portion of the Gulf that the province is claiming, (Hydro-Québec, 2002). Since then, these permits have been subjected to a moratorium. The Canada-Quebec 2011 Agreement, and the mirror-laws projects that drive it, are depriving these permits of recognizance and operational character according to the co-management system, as an eventual interprovincial dispute remains unresolved, (Accord Canada-Quebec, 2011, paragr. 12.2; Project de loi n° 49, 2015, art. 479; Project de loi n° C-74, 2013-2015, art. 98).

Fourthly, the settlement of a dispute between two provinces would rest upon the application of the rules of international law related to the delimitation of the maritime boundaries. The boundaries of the 1964 Agreement rest upon the strict equidistance method. Even though international law recognizes this method of delimitation, this is not a prevailing rule.

To that effect, Labrecque says:

« In international law, there is a fundamental norm that says: the delimitation of a maritime boundary must be established

1) in accordance with the applicable law – international agreements, unilateral acts, customs, legal decisions, equitable principles, doctrine, resolutions of international organisations;

2) taking into account pertinent circumstances -they might be geographical, geomorphological, environmental, historical, economic and geopolitical;

3) using appropriate methods, such as the equidistance (or the median), the perpendicular to the general direction of the coasts, the trough line, the astronomic line (meridian, parallel, azimuth), the geometrical line (bisecting, arc of circle), the extension of the land boundary, the extension or the adoption of a pre-existing maritime boundary;

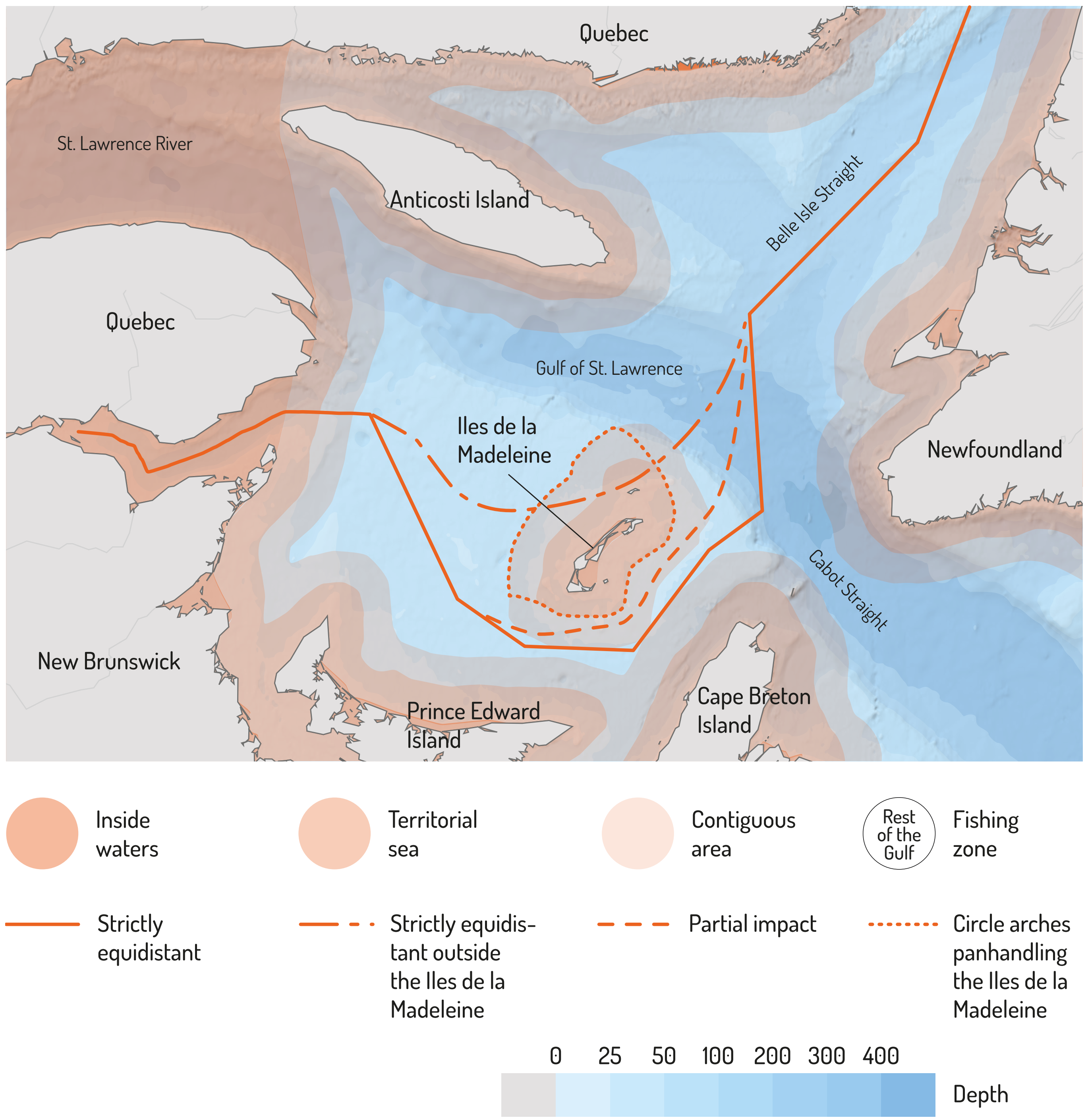
and 4) in a way that will result in an equitable outcome– which can be verified using proportionality tests aiming at the establishment of a relation between the respective lengths of the coasts of the two countries and the surface of the maritime zones that are vested in right on either side of the boundary »

(Labrecque, 1993, p. 195)

Hence, the rule of delimitation of maritime boundaries in international law aims, first and foremost, at obtaining an equitable result. The use of the strict equidistance method is subjected to that result. Should the current lines, plotted in accordance with the strict equidistance, create an inequitable situation, a panel of arbitration, applying international law could modify them. Without suggesting that such would be the case, the settlement of a dispute between Quebec and Newfoundland-and-Labrador could widen the boundaries established by the 1964 Agreement.

Figure 7.1

Methods of delimitation applied in the Gulf of St. Lawrence. *(From Labrecque, 1993.)*



To conclude, the dispute settlement processes are not uniform. On the one hand, the Nova Scotia and Newfoundland co-management zones plan the use of identical mechanisms. They give a central role to the federal government and grant it a large discretionary power to decide as to the process to be used. Firstly, the Canadian government tries, for a reasonable period of time, and through negotiations, to resolve the dispute between the two provinces. Should this fail, the federal government determines the body of dispute settlement which resolves said dispute and establishes the procedure and its rules of operation, this after consultations with the provinces involved. On the other hand, applicable mirror-laws in the Quebec co-management zone give a first line role to the provinces and plan the use of a much more detailed process. First, the provinces can try to settle the dispute through negotiations, then, mediation. Should these steps fail at resolving the dispute, the provinces can agree to submit themselves to an arbitration process to be done according to consensual modalities. Should the dispute remain unsettled, using the consensual approach, a province may unilaterally decide to submit the dispute to an arbitration process, the details of which are outlined in the list of provisions of these mirror-laws. Within this context, the odds of a dispute between Quebec and Newfoundland-and-Labrador could involve two dispute settlement processes without being able to determine up front which would prevail over the other.

THE PROTECTION OF FOREIGN INVESTMENTS

Other that the rules related to the delimitation of the maritime boundaries, other aspects of international law might influence the development of hydrocarbons in the Gulf. International law covering investments have significant repercussions on the national regulating systems for natural resources, such as the provisions concerning the preservation of the environment, (Dufour and Trudeau, 2012).

Photo: Dashu83 / Freepik.com

Several international free-trade agreements, in which Canada is part, plan measures of protection for investors and foreign investments. The NAFTA (North American Free Trade Agreement) is a preeminent example of such an agreement, though there are many more, including the Trans-Pacific-Partnership and the Canada–European Union (EU) the Comprehensive Economic and Trade Agreement, (Prince, 2015).

In that framework, any person, enterprise or asset of all kinds from a foreign country, that is a member of such an agreement and that is involved in commercial activities in Canada, is granted a set of rights. These rights include the benefits of a treatment that is as favorable as the treatment granted by Canada to Canadian investors and investments (national treatment), and to investors and investments from any third state (most-favored-nation). Furthermore, Canada must grant

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investors and foreign investments a fair and equitable treatment, which protects them against any form of discrimination, abuse and arbitration. Foreign investors also benefit from protection against direct or indirect expropriation, protection that gives them the possibility to receive an indemnity from Canada, even if the expropriation proceeds in accordance with the law, if it proceeds for the public interest and if Canadian investors, in a similar situation, are not entitled to an equivalent indemnity. Lastly, international agreements offering protection to foreign investors ban certain traditional practices to those states that impose duties to maximize the outcomes benefiting the national economy, including minimal local content clauses or preferences for Canadian goods and services. When any one of these rights is violated, the foreign investor can file a grievance to international arbitration without having to go through Canadian tribunals to get compensation for their losses and damages.

The decisions and doctrinal comments, with respect to the rights of foreign investors, put into question the capacity the state has, at its disposal, to proceed with some interventions, with respect to the natural resources value-added projects, (Elcombe, 2010). For instance, the protection granted to foreign investors would restrain the state's power to sovereignly establish and apply adequate environmental norms. In principle, administrative and regulatory authorities of a state could hesitate when intervening in an extraction project that would be contrary to the national environmental norms lest it would contravene the measures of protection designed for foreign investments in international law and, consequently, have to face exorbitant claims[6]. The three following examples of arbitrary sentences and claims pursuant to the NAFTA illustrate the effect that the protection of foreign investments could have towards the development of hydrocarbons in the Gulf.

› MOBIL INVESTMENTS CANADA INC. AND MURPHY OIL CORPORATION V. GOVERNMENT OF CANADA

Both Mobil and Murphy enterprises invested in the *Hibernia* and *Terra Nova* oil projects, located on the Atlantic continental shelf, off the coast of Newfoundland-and-Labrador. The mirror-laws governing the Newfoundland co-management zone require investors in offshore oil projects to get the approval for a plan of economic impact before authorization of their project. The dispute was born following the 2004 adoption of new guidelines by the Canada–Newfoundland-and-Labrador Offshore Petroleum Board. These would impose, in the economic impact plan, allocations towards research, education and training to the tune of a fixed percentage of annual revenue from exploration and production activities, (Genest, 2014).

The matter went before a court of arbitration which concluded that Canada had violated the protection measures of the foreign investments outlined in the NAFTA. The arbitrary sentence established that the expenses, required from investors in these plans of economic impact, were imposing *de facto* the purchase, the use, or the favoring of products or services produced or provided in the province. The requirement to invest a precise percentage of annual revenues towards research and development, education and training as well, is not an accessory element. Rather, it is a central element of the 2004 guidelines which must, consequently, be declared pursuant to the NAFTA.

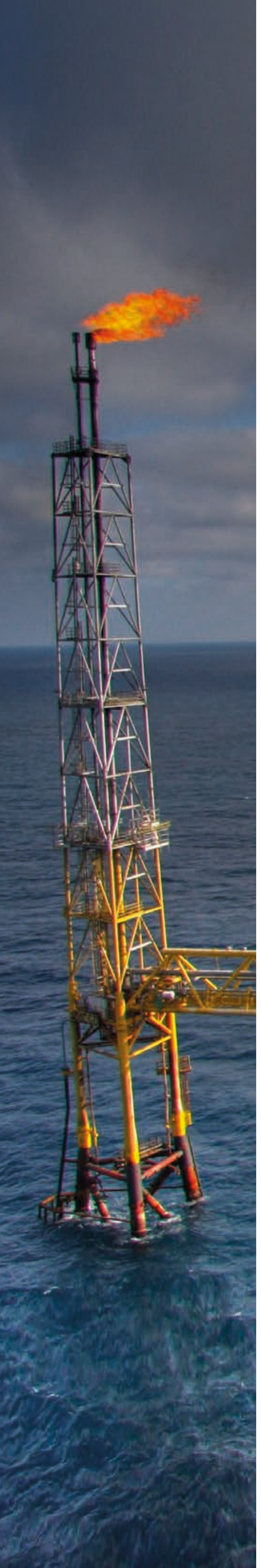
› CLAYTON AND BILCON OF DELAWARE INC. V. GOVERNMENT OF CANADA

Throughout the 2000's, American investors launched a project that included a quarry and a maritime terminal in Nova Scotia, as they wished to extract important volumes of rock aggregates and ship them to the United States to provide construction materials and to supply cement plants. The quarry was located close enough to a marine environment where whales are seen from time to time – less than one kilometer from the site where a series of explosions would allow for the extraction of the aggregate. Protection measures for fish habitat in the Fisheries Act applied while both provincial and federal laws imposed the assessment of environmental impacts on the project. The Joint Assessment Commission, responsible for leading the two processes of impact assessment, recommended to the federal and provincial authorities to refuse the requests for authorization of the project due to its considerable social and environmental impacts. The authorities followed this recommendation and rejected the project, which initiated a claim pursuant to the NAFTA.

The investors argued that the assessment process had been done in an arbitrary, inequitable and discriminatory manner. They felt that the refusal of the project was illegal because it was founded on the incompatibility of the project with "the fundamental values of the community", a rationale which is not part of the law. The investors also believed that the Joint Assessment Commission had not considered, nor proposed, measures to attenuate negative environmental effects to avoid the rejection of the project.

The court of arbitration ruled in favor of the investors. It concluded that Canada had violated the prescriptions of the NAFTA, with respect to the fair and equitable treatment, and the duty to treat

[6] The doctrine refers to a phenomenon called "regulatory chill".



foreign investors in the same manner they would national investors in similar situations. The arbitrators considered that the notion of "fundamental values of the community" was not part of Canadian law, and that neither the process of assessment of the environmental impacts nor the decision to authorize or to refuse the project should have been taken into account. The inclusion of an arbitrary criteria in the assessment process causes a discrimination against investors, who do not have the possibility to establish the conformity nor the merits of their project.

That decision was criticized many times over, as it emphasized the lack of knowledge of Canadian law with respect to the process of environmental assessment on the part of the arbitrators, (Bankes, 2015a; Doelle, 2015; McCarthy, 2015). Canada filed a request for a reversal of the arbitrary sentence before the Federal Court of Canada, in June, 2015[7].

› LONE PINE RESOURCES INC. V. GOVERNMENT OF CANADA

In 2006, an American enterprise committed -in a contract with a Canadian company that owned research permits granted under the Quebec *Loi sur les mines*- to proceed with exploratory drilling on the bed of the St. Lawrence River, near Bécancour. A few years later, Quebec committed to proceed with a strategic environmental assessment process on shale gas. Facing the controversy created by the development of fossil energies, the province decided to impose a moratorium on the exploration and the exploitation of hydrocarbons in the St. Lawrence River and adopted the *Loi limitant les activités pétrolières et gazières*, in 2011. From thereon in, research activities on hydrocarbons in the St. Lawrence River were banned pursuant to provincial law.

In 2013, an American investor initiated an arbitration process pursuant to the NAFTA against Canada and claimed $118 million. The arbitrary sentence has yet to be rendered, but the arguments on either side reflect what is at stake in this matter. On the one hand, Lone Pine Resources contests the revocation of the permits and alleges that Canada violated the norm, with respect to fair and equitable treatment, and the measures of protection against expropriation. The enterprise believes that the adoption of the moratorium is an arbitrary measure based on political motivations which constitutes an illegal expropriation of its investments.

On the other hand, Canada emphasizes that the moratorium was adopted following many environmental studies which concluded that the St. Lawrence River is not conducive to activities that would add value to hydrocarbons, and that the hydraulic fracking technique creates risks to the biophysical and human environment. The moratorium is motivated by the general interest and aims at a public policy objective which consists in protecting the river. Furthermore, the moratorium applies in a non-discriminatory manner to all research permit holders and cannot be considered as arbitrary, unfair nor inequitable. Lastly, Canada considers that Lone Pine Resources does not have a research permit nor any investment liable to be expropriated. The most it has is a contract signed with a Canadian company which has a research permit, and as such it does not offer any guarantee.

In this context, the protection of foreign investors, in terms of international economy law, raises a set of significant questions for the socioecological management of the Gulf of St. Lawrence. The three cases presented indicate that claims filed by foreign investors can affect decisions made by administrative and legislative authorities, or create obstacles to the protection of the environment, or to the local communities and the stimulation of the local economy, (Dufour, 2012; Bankes, 2013). The assessment process of the environmental impacts, of the projects for the development of the natural resources, becomes more complex and loses, in part, its operational character. The Canadian law confers to the administrative decider a discretion that is wide enough to take into account the social acceptability through the intermediary of the general interest, which justifies authorizing a project. Yet, it is in the discretion of the arbitrary panels to deny and grant damages to foreign investors whose projects are rejected administratively, if they are not accepted by the hosting communities. In the end, the system of protection of foreign investments adds an additional normative stratum whose repercussions increase the complexity and the fragmentation of the legal structure governing the Gulf.

THE RIGHTS OF THE FIRST NATIONS

The rights of the First Nations have often been described as the "sleeping giant" of the natural resources sector in Canada. Ever since the 1970's, aboriginal law has been developing major transformations through the decisions of the Supreme Court and the agreements between the governments and the First Nations. The repatriation of the Constitution played a crucial role by conferring a supralegislative scale and strength to the rights of the First Nations in their enshrinement to Section 35 of the Constitutional Act of 1982. From thereon in, most of the projects, for the development of the natural resources, include a component relative to aboriginal rights.

Section 35 of the Constitutional Act of 1982 recognizes and affirms the ancestral aboriginal rights, as well as the rights set out in a treaty, including the rights likely to be acquired in the future through agreements on the territorial claims. The text of that section gives an opportunity to identify several types of aboriginal rights. First, the rights set out in a treaty are easier to identify as they rest on a text. The treaties belong to two large families:

1) The historical treaties, generally formulated in noble, general and ambiguous terms state which tribunal takes recourse to the subjacent principles, such as the honor of the Crown, to remedy the weakness of the text in order to achieve equitable outcomes, (Beckman v. Little Salmon/Carmacks First Nation, 2010, paragr. 12);

2) The modern treaties, signed after 1970, show a detailed content which is subjected to complex negotiations by the parties empowered with important resources, and a wording that is being carefully studied by the courts, (Quebec [*Procureur général*] c. Moses, 2010, paragr. 7).

Besides that, the ancestral rights are more difficult to identify and define. In the absence of a textual incarnation, the great diversity of such rights leads to highly variable forms, which are tributary to the

From thereon in, most of the projects, for the development of the natural resources, include a component relative to aboriginal rights.

[7] www.italaw.com/sites/default/files/case-documents/italaw4362.pdf

context in which they fit. The definition of the ancestral rights is based on fundamental elements of the aboriginal societies before the arrival of the Europeans that determine the integrating customs, practices and traditions, (R. c. Van der Peet, 1996, paragr. 44-45). The ancestral rights must be evaluated in terms of the way they were exercised when first contact was made with the colonial powers, while recognizing their evolution from then on.

The ancestral deeds constitute a particularly important category of ancestral rights as it has been the object of recent developments in jurisprudence, and also because it can have marked impact on the management of the natural resources in the Gulf of St. Lawrence (generally, Bankes, 2015b). In a judgement rendered in 2014, the Supreme Court recognizes and affirms for the first time the existence of an aboriginal territorial deed, (Tsilhqot'in Nation v. British-Columbia, 2014). The demonstration of an ancestral deed requires that the occupation of a territory by an aboriginal group be sufficient, continuous, exclusive and prior to the affirmation of the sovereignty of the Crown. When an aboriginal group claims and manages to demonstrate an ancestral deed in court, it:

> « (...) confers ownership rights similar to those associated with fee simple, including: the right to decide how the land will be used; the right of enjoyment and occupancy of the land; the right to possess the land; the right to the economic benefits of the land; and the right to pro-actively use and manage the land.
>
> [...] The right to control the land granted by the ancestral right means that governments and other persons wising to use the lands must obtain the consent of the ancestral deed owners. Should the aboriginal group not consent to the use, the only recourse consists in establishing that the suggested use is justified pursuant to section. 35 of the Constitutional Act of 1982. »
>
> (Nation Tsilhqot'in v. British Columbia, 2014, paragr. 73 and 76)[8]

Whether one tries to justify the infringement of an ancestral deed, or more generally, as soon as the governments foresee a measure liable to have repercussions on an ancestral deed, whatever its nature, both the federal and provincial governments must abide by the duty to consult and accommodate the First Nations (Rio Tinto Alcan Inc. v. Carrier Sekani Tribal, 2010). The governmental measures which can initiate the duty to consult and accommodate include administrative

[8] Generally, see paragraphs 67 to 88.

gestures authorizing precise activities of extraction of the natural resources, just as the more general strategic decisions, such as the approval of management plans for a resource or the adoption of some laws. The directives with respect to carrying the duty of consultation and accommodation vary with the circumstances, but the intensity of the duty increases the clearer the aboriginal rights are and the higher the risk to breach them is, (Haïda Nation v. British Columbia, 2004).

An overview of the situation of the First Nations in the Gulf of St. Lawrence indicate that each type of aboriginal right could, in principle, be affected by the development of hydrocarbons in a marine environment, from the rights set out in ancestral treaties, to a slew of ancestral rights all the way to the right to consultation and accommodation, (Desbiens *et al.*, 2015). Three First Nations have been using the Gulf of St. Lawrence prior to the settlement of Europeans: the Innu, the Maliseet and the Mi'gmaq. These nations span over 20 communities in the coastal zones along the Gulf, on the territory of the five coastal provinces, (Dubé-Tourigny, 2014; GENIVAR, 2013). Some of them have agreed, with the mighty colonial powers, to some historical treaties conferring the First Nations the rights to subsistence and commercial fisheries for which the federal government had to create a framework in order to avoid creating a prejudice, (R. v. Marshall,1999; Gough, 2008). The conclusion of the treaties has certainly not extinguished other rights already recognized or untold, as of yet, amongst those which the First Nations may use in the Gulf.

The ancestral rights and the rights set out in the treaties can, in many ways, constrain action of the state with respect to the development of hydrocarbons in the Gulf of St. Lawrence. The ancestral rights can impose duties to consult and accommodate that are much more strict than negotiations between the Crown and the First Nations claiming an ancestral right over the Gulf, which have been ongoing for several years, (Aboriginal and Northern Affairs Canada, 2010). Amongst the measures subjected to constraints leading to aboriginal rights, one could find, as the case may be, the allocation of authorizations to exploratory drilling activities, the deliverance of exploitation permits, the creation of objectives for the development of hydrocarbons in a marine environment within a pluriannual policy, following a strategic environmental assessment, and even the adoption of a framework law that would govern the development of the resources in the Gulf or the modification of legislative provisions that would reduce the protection at the disposal of the aquatic ecosystem. The aboriginal rights could also interfere with the protection of foreign investments, (Tucker, 2013). All these measures are, in fact, liable to bring about many negative repercussions over the aboriginal rights in the Gulf of St. Lawrence, such as the sound impact of seismic surveys on the halieutic resources or the increase of the risk of a black tide. Nevertheless, it is just about impossible to determine ahead of time the ways with which aboriginal law will interact with the other systems of the ongoing development of the natural resources in the Gulf, keeping in mind the contextual character of the applicable rules, their low transposition within a legislative framework and the constant evolution of the jurisprudence. /

CONCLUSION

Laws fragment the Gulf of St. Lawrence where the legal systems insufficiently relate one to the other. Their interactions remain, in part, occult or implicit. Such a situation complicates the management of hydrocarbons in a marine environment. A constant effort towards studies and research, with respect to several unexplored aspects in terms of the legal framework in the Gulf, is necessary if one wants to ensure a more coherent structure and enlightened decisions, just as it is for the creation of adequate normative standards with respect to the development of oil and of gas. The creation of a permanent organisation or pole of research dedicated to the questions raised through the eventual exploitation of hydrocarbons in the Gulf would benefit the orderly and safe development of this new energy file. /

Photo:
É. Pelletier

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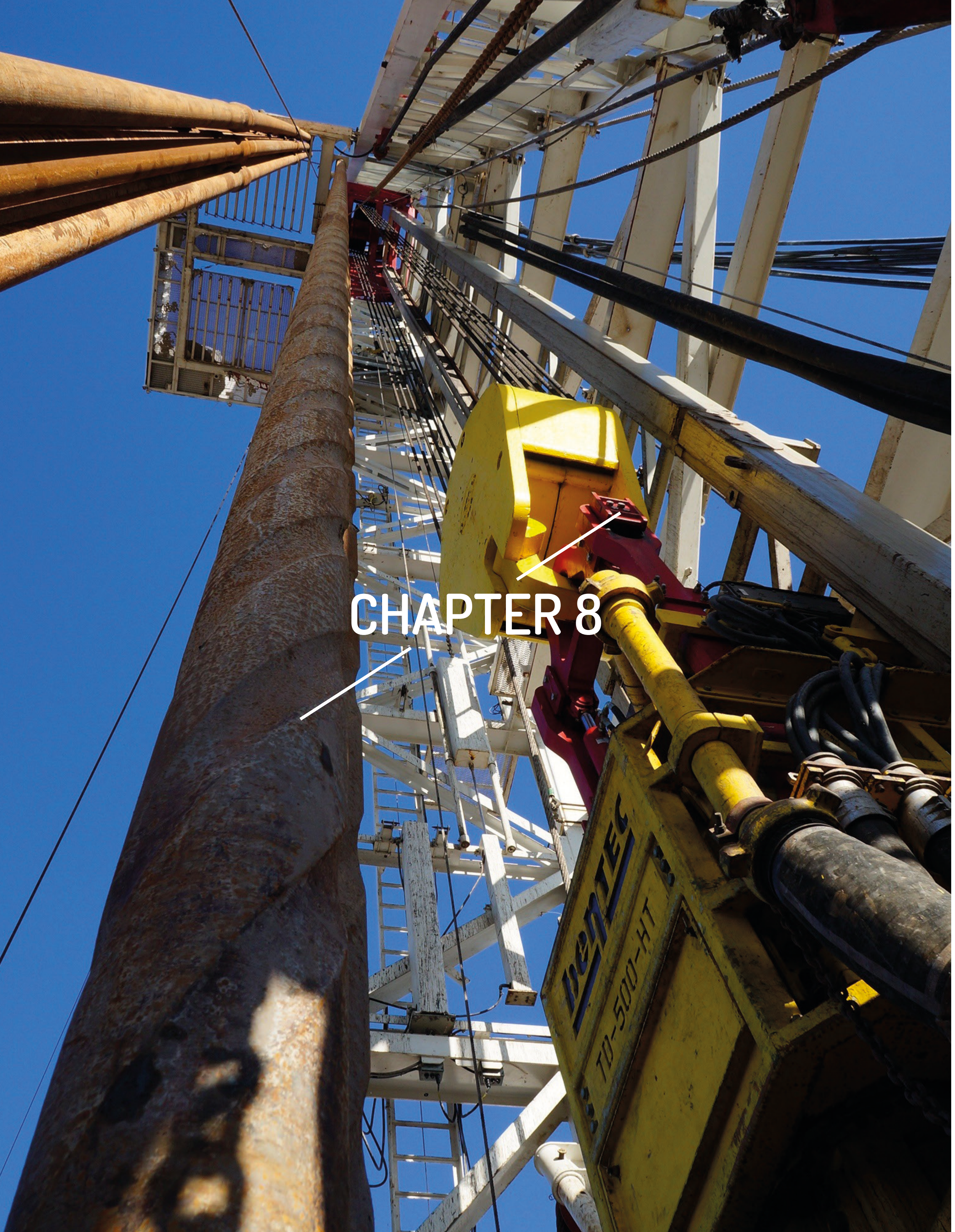

CHAPTER 8

Photo:
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Regulating offshore oil and gas exploitation

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Through the implementation of regulatory frameworks, the industry and the states have attempted, over the years, to maintain the risks associated with the exploration and the exploitation of hydrocarbons at negligible, acceptable, or, at least, tolerable levels. Yet, the exploitation of hydrocarbons, in offshore environments, involves a commitment to work on notions that are very much unknown, such as health and safety or environmental protection. It is for that reason that the Québec government insists on the adoption of the best practices, without defining them, however. What are those best practices? Do they exist? Studying the environmental and judicial characteristics of the Gulf of St. Lawrence in an international perspective gives us a possibility to shed some light on what those best practices might be. While studying the specific case of the Barents Seas, we are learning that technical standards to be applied to ensure an acceptable level of risk do not yet exist for an environment such as the Gulf. Furthermore, the development and implementation of those standards require not only the modernisation of the legislative and technical structures but over and above it all, the proactivity, the cooperation and the transparency of all the stakeholders, including the industry, from an international perspective.

Photo: D. Kalenitchenko

HIGHLIGHTS

- The legal and normative framework prevailing in the Gulf follows a provincial-federal intergovernmental pattern of offshore hydrocarbons, supervised by mechanisms of harmonisation of practices.

- The Quebec government has launched an initiative to regulate marine offshore oil and gas exploration and exploitation seeking the use of the generally recognized best practices.

- The context of the Barents Sea is substantially similar to that of the Gulf of St. Lawrence in terms environmental conditions, and the 2020 Barents project is an exemplary process for defining and the developing of best practices in terms of technical standardisation.

- This case demonstrates that the development and the implementation of standards not only require the modernisation of the legislative and technical framework but also the proactivity, cooperation and transparency of all stakeholders.

INTRODUCTION

The capacity to extract and use fossil fuels allowed an extraordinary development of human societies and defined the anthropocene era. It has contributed to sustain growth and globalize trade, but also had some ill effects. In order to draw socioeconomic benefits from it, the negative repercussions associated with exploration, extraction, storage, distribution and consumption of fossil fuels must be minimized. Such activities have progressively been optimized through the acquisition of a deeper knowledge, often deriving from a trial and error learning process, through technological development, and by setting-up regulatory frameworks.

In the 1960's, following the increased awareness of the general public to the negative impacts of industrial activities on the environment, private companies, governments and other independent institutions have gradually integrated its protection into their practices. Even though the exploitation of fossil fuels is a mature and well-structured industry, oil and gas exploration is proceeding in places where it is more expensive and more difficult to extract. On land, unconventional oil and gas from shale structures or tar sands require the use of industrial processes that are more expensive and more risky in many ways. In the offshore marine environment, exploration efforts are invested in increasingly deeper regions and in seasonally ice-covered seas. It is estimated that around 90 billion barrels of oil, 1669 tft^3 of natural gas and 44 billion barrels of liquid natural gas remain to be found in terms of technically exploitable resources in the Arctic, (USGS, 2008), out of which 84% would be located in offshore regions[1], (see also Weissenberger and Waaub, 2017, this document). In spite of a strict framework, the exploration in new environments and in conditions in which the industry is not familiar with means greater risks. The industry and the states involved also have to face new challenges. The civil society, through the actions of the citizens and non-governmental organisations, further participates in the legislative and decisional processes. Traditionally used technologies are no longer adequate and many projects often call for international and intersectoral cooperation. Lastly, in the marine environment, the working conditions are dangerous and still largely unknown. To progress constructively, organisations must therefore manoeuvre with prudence and diligence and carefully and adequately regulate the activities.

In Quebec, exploiting oil and gas, including those in the Gulf of St. Lawrence, is still on the political agenda and raises several questions, namely the one dealing with the possibility of exploiting offshore hydrocarbons in a way that would be profitable to society. In other words, can hydrocarbons be exploited while ensuring an acceptable level of risks and the safety of the persons and the environment? Much effort was invested and more is underway to find an answer to this fairly complex question. Some of these efforts consist in the strategic environmental assessments (*EES*, in Quebec) commissioned by the Quebec government (AECOM-Tecsult, 2010; GENIVAR, 2013) and reports produced in the framework of the *Plan d'acquisition de connaissances additionnelles* (PACA). Three documents are especially relevant to this chapter. The first one presents a comparative analysis of the legislations dealing with prevention, preparedness and intervention in major accidents, prepared by the *Chaire de recherche du Canada en droit de l'environnement* (CRCDE, 2015). This study focusses on legal frameworks in Newfoundland-and-Labrador, in the Canadian Arctic, in the United Kingdom (the North Sea) and in the United States (the Gulf of Mexico) and produced some enlightened findings. However, it does not cover Norway and the Barents Sea. The second document produced by *Innovation maritime* (2015), also studies prevention, preparedness and intervention measures in the case of major accidents, but more specifically those resulting from the maritime transportation of hydrocarbons. Lastly, the

Can hydrocarbons be exploited while ensuring an acceptable level of risks and the safety of the persons and the environment? Much effort was invested and more is underway to find an answer to this fairly complex question.

[1] tft^3 refers to trillion cubic feet.

report produced by *La Coalition Saint-Laurent* (2014) gives a complete and referenced picture on the matter of offshore hydrocarbons in the Gulf of St. Lawrence, including a description of the *Old Harry* prospect case.

The objective of this chapter is to define what is meant by *best practices* or the *highest standards*, as those terms are widely used in the public discourse as necessary conditions to be met before authorizing exploration and exploitation activities. Therefore, we will begin with a description of the legislative landscape of the Gulf of St. Lawrence in order to set it in a global context. Seeking for best practices leads us to examine the particular example of the Barents Sea, as it is an Arctic region whose features are similar to those of the Gulf of St. Lawrence in terms of exploitation conditions and as a practical case of an *ad hoc* elaboration of a technical regulation framework. Such an example will help us envisage what the quest for best practices, in terms of health, safety and protection of the environment, represents. /

Photo: P. Archambault

Photo: É. Pelletier

THE LEGAL CONTEXT IN THE GULF OF ST. LAWRENCE

The initial presentation of the legal context aims to shed light on the several types of regulations governing the oil and gas activity sector, and to emphasize the technical standards which constitute the structure in terms of safety, (to get a picture on the legal regime relevant to oil and gas, see Tremblay et Kolli, 2017, this document.)

A legal framework is first composed of **laws** that are discussed and voted by the assembly that holds the legislative power in a given jurisdiction. The implementation of laws is then given to an administrative **authority** with the power to adopt **rules**. The rules provide precision on the operational modalities of the law and set the concrete aspects of the activities subjected to it. Lastly, rules can refer to the administrative directives or to technical standards that give more precision on the enforcement of the law and its rules. These directives establish whether the provisions of the law are enforced or not, but their binding force with respect to the justiciable is variable. Contrary to laws and rules, **directives, norms and standards** are not directly binding as such, unless a legislative or regulatory provision says one must abide by it.

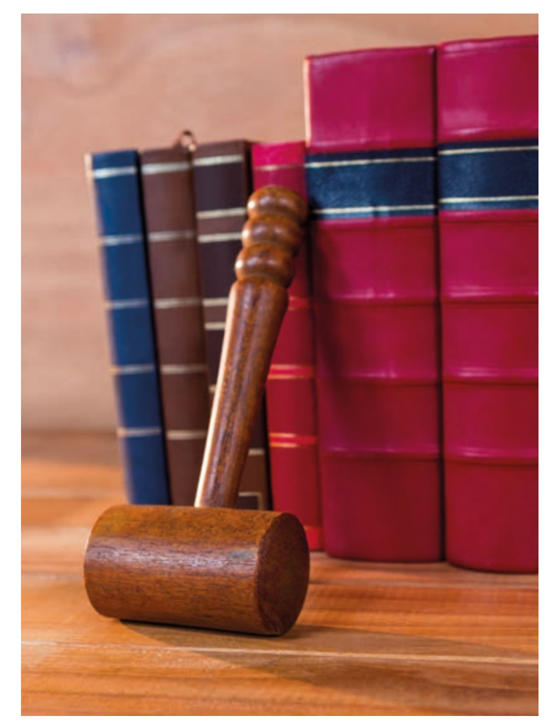


Photo: Awesomecontent / Freepik.com

There are notable differences in the way regulation frameworks are elaborated from a situation to another, from a country to another. They can be determined either by a pioneering industry, by an industry that bears a domineering position in the market, by a professional association, or by a consortium of industrial actors. The processes of standardisation or normalisation then aim at establishing a common referential in a given sector and harmonise the technical framework. Questions arise though on the efficiency, the relevance and the articulation of these technical frameworks in a particular legal context.

In the sector we are interested in, one must determine whether there are established technical standards and if they truly create safety, health and protection of the

In the sector we are interested in, one must determine whether there are established technical standards and if they truly create safety, health and protection of the environment.

environment. Another question, not studied in the present document, consists in knowing as to whether they meet the demands in terms of the law (laws on work, health, environment, etc.).

A legal regime features, most of the time, several laws and numerous rules governing each aspect of the targeted activities under the supervision of many responsible authorities. The legislative and regulatory regime around the management of oil and gas in the Gulf of St. Lawrence is particularly complex. Several jurisdictions overlap in the region, including the Canadian federal government, five provincial governments, tens of coastal municipalities, aboriginal territorial claims (for instance, Innu and Mi'gmaq Nations), national and provincial parks and international maritime traffic. The following sub-section will describe the Canadian legislative framework and the way it ensures a management of hydrocarbons as uniform as possible despite the regional peculiarities.

The legislative and regulatory regime around the management of oil and gas in the Gulf of St. Lawrence is particularly complex. Several jurisdictions overlap in the region, including the Canadian federal government, five provincial governments, tens of coastal municipalities, aboriginal territorial claims (for instance, Innu and Mi'gmaq Nations), national and provincial parks and international maritime traffic.

THE CANADIAN JUDICIAL FRAMEWORK AND THE ROLE OF THE NATIONAL ENERGY BOARD.

The National Energy Board (NEB) is the authority responsible for the regulation of operations subjected to the Canadian Petroleum Resources Act (L.R.C., 1985, chap. O-7) (see table 8.1 for a list of laws mentioned in this document). This law warrants that the subject operator will ensure the safety of workers and the protection of the environment, and see to the necessary requirements to get the required approvals. Hence, to get an approval, certain requirements must be met with respect to health and safety, pursuant to the Oil and Gas Occupational Safety and Health Regulations, (DORS/87-612), and with respect to the environment, pursuant to the Canadian Environment Protection Act, (L.C., 1999, chap. 33), the Canadian Environment Assessment Act, (L.C., 2012, chap. 19, art. 52), the Emergencies Act, (L.R.C., 1985, chap. 22, 4e suppl.) and the Emergency

Table 8.1
List of some of the federal and provincial laws and regulations relevant to oil and gas in Canada.

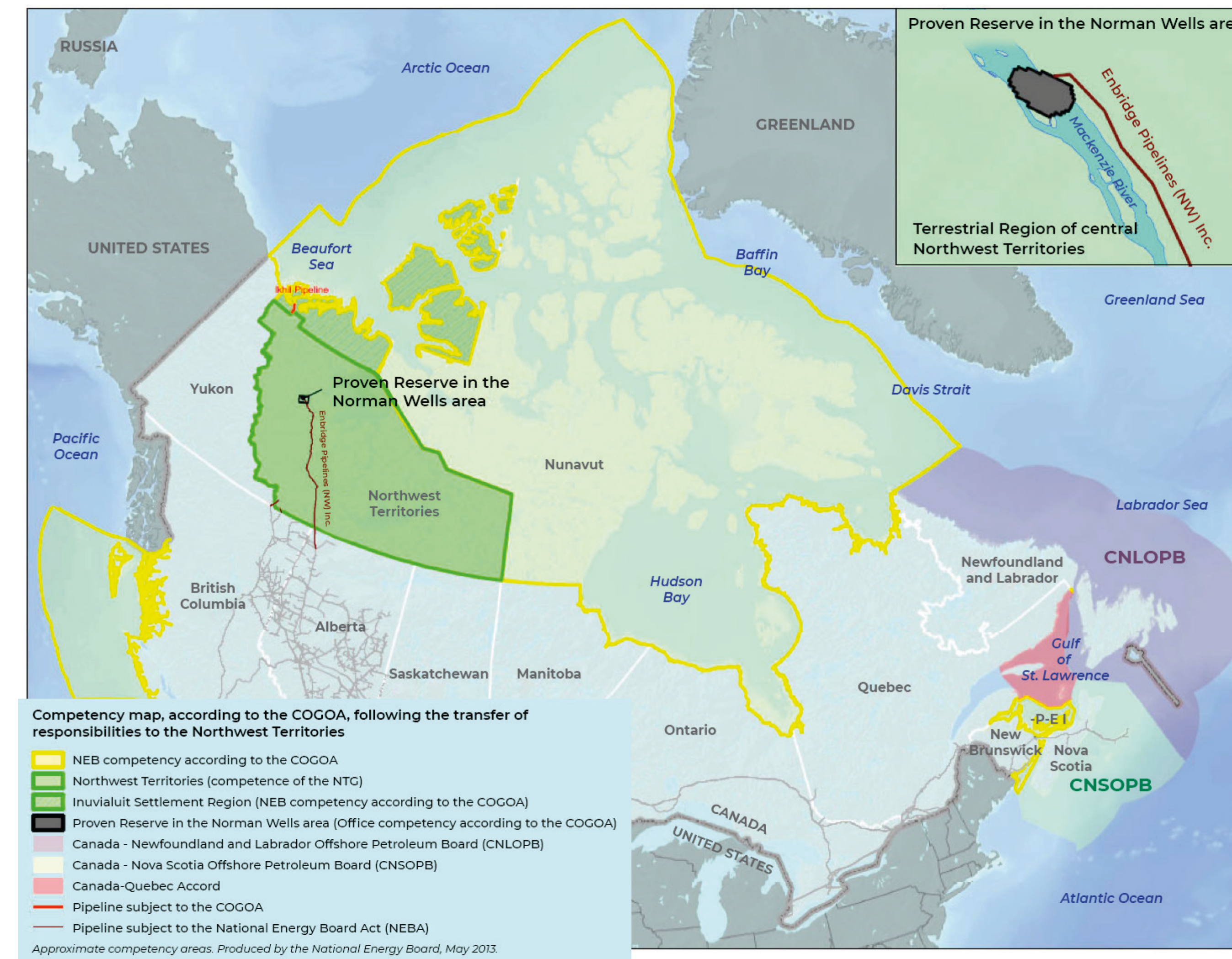
CANADA	
S.R.C., 1985, chap. 36	Canadian Petroleum Resources Act
L.C., 1987, chap. 3	Canada–Newfoundland and Labrador Atlantic Accord Implementation Act (see S.N.S., 1987, chap. 3)
L.C., 1988, chap. 28	Canada–Nova Scotia Offshore Petroleum Resources Accord Implementation Act (see R.S.N.L., 1990, chap. C-2)
Bill n° C-74, 41e legislature, 2e session	Act to implement the accord between the Government of Canada and the Government of Quebec for the joint management of petroleum resources in the Gulf of St. Lawrence * Bill died on the Order paper when elections were called on the 2nd of August 2015
L.R.C., 1985, chap. O-7	Canada Oil and Gas Operations Act
L.C., 1999, chap. 33	Canada Environmental Protection Act
L.C., 2012, chap. 19, art. 52	Canada Environmental Assessment Act
L.R.C., 1985, chap. 22, 4e suppl.	Canada Emergencies Act
L.R.C., 1985, chap. 6, 4e suppl.	Canada Civil Protection Act
DORS/87-612	The Canadian Oil and Gad Drilling and Production Regulations
DORS/96-114	Canada Oil and Gas Certificate of Fitness Regulations
DORS/2009-317	Nova Scotia Offshore Petroleum Drilling and Production Regulation
DORS/2009-316	Newfoundland Offshore Petroleum Drilling and Production Regulations
DORS/2009-315	Canada Oil and Gas Drilling and Production Regulations
QUÉBEC	
L. Q., 2011, chap. 13	Loi limitant les activités pétrolières et gazières
L. Q., 1998, chap. 24, art. 153	Loi modifiant la Loi sur les mines and Loi sur les terres du domaine public
RLRQ, chap. Q-2	Loi sur la qualité de l'environnement
Projet de loi n° 49, 41e législature, 1re session	Loi assurant la mise en œuvre de l'Accord entre le gouvernement du Canada et le gouvernement du Québec sur la gestion conjointe des hydrocarbures dans le golfe du Saint-Laurent
NEWFOUNDLAND-AND-LABRADOR	
R.S.N.L., 1990, chap. C-2	*Canada–Newfoundland and Labrador Atlantic Accord Implementation Act*
NEW-SCOTIA	
S.N.S., 1987, chap. 3	*Canada–Nova Scotia Offshore Petroleum Resources Accord Implementation Act*

Preparedness Act, (L.R.C., 1985, chap. 6, 4e suppl.). The enforcement of these laws is the responsibility of several organisations, including the NEB, Environment and Climate Change Canada (ECCC), Fisheries and Oceans Canada (DFO) and the Canadian Environment Assessment Agency. In 2010, following the accident of the *Deepwater Horizon* platform, the NEB proceeded with a vast consultation aiming to review safety and protection in terms of the environment, relating to the offshore drilling in the Canadian Arctic, (NEB, 2011). In 2014, the Agency published the requirements with respect to submissions relating to offshore drilling in the Canadian Arctic (NEB, 2014), which describes what an operator must submit in order to get the permission to drill.

The NEB regulates oil and gas exploration and production activities in Canadian waters, with the exception of the offshore regions of Nova Scotia, which are the responsibility of the Canada - Nova Scotia Offshore Petroleum Board (CNSOPB), and offshore regions of Newfoundland-and-Labrador, which are under the jurisdiction of the Canada – Newfoundland-and-Labrador Offshore Petroleum Board (CNLOPB). These two organisations, whose legal fields are shown at Figure 8.1, derive from the adoption of mirror-laws agreed to by Canada and each of the two provinces. They provide a frame for the shared management of offshore oil and gas resources and the sharing of revenues (L.C., 1987, chap. 3; R.S.N.L., 1990, chap. C-2; L.C., 1988, chap. 28; S.N.S., 1987, chap. 3). These laws also administer the process of arbitration that establishes the boundaries of offshore zones in case of disputes between provinces. As a matter of fact, a sentence has been rendered by an arbitration tribunal on the 26th of March, 2002. It established the boundary of the offshore zone between Newfoundland-and-Labrador and Nova Scotia. The NEB, the CNSOPB and the CNLOPB assess requests, give authorizations and act as first respondents by ensuring the coordination in case of a spill. Hence, the federal government is present, either through agreements with the provinces, or directly through the NEB, in all projects of oil and gas exploitation in the marine environment.

The Canada Oil and Gas Operations Act ensures that there is only one operator per facility (L.R.C., 1985, chap. O-7). This operator is also the holder of the license. In addition, there is only one **management system** per facility. The Canadian Oil and Gas Drilling and Production Regulations (DORS/2009-315) specify that the requestor of an authorisation bears the responsibility to develop and promote an efficient management system, a safety plan and a plan for the protection of the environment (EPP), and that such plans must be submitted to the respective boards for approval. Once approval has been granted, the operator has the responsibility to ensure the conformity with the management system. Dagg *et al.* (2011) define a management system as a set of processes and procedures that ensure that the requirements and objectives set in terms of health, safety and environmental protection are met by the operator.

Figure 8.1
Canadian coastal and offshore Zones regulated by the National Energy Board (NEB), the Canada - Nova Scotia Office on Petroleum Resources (CNSOPR) and by the Canada – Newfoundland-and-Labrador Office On Petroleum Board (CNLOPB). The red zone covers the Canada-Quebec Accord which led, in June 2015, to the presentation of mirror-laws bills. *(From the NEB, https://www.neb-one.gc.ca/nrth/index-fra.html.)*



THE LEGAL FRAMEWORK IN QUEBEC

At this point in time, two moratoria are in effect. The first one is permanent and bans oil and gas exploration and exploitation activities in the river, the estuary and the north-west portion of the St. Lawrence, pursuant to the *Loi limitant les activités pétrolières et gazières* (L. Q., 2011, chap. 13). The second one (L. Q., 1998, chap. 24, art. 153) bans oil and gas exploration and exploitation activities in the Quebec portion of the Gulf of St. Lawrence and *Baie des Chaleurs* up until an adequate management structure is created and all necessary conditions are assembled to protect the environment.

Photo *Baie des Chaleurs*: Gilles Douaire / FlickR

On the 24th of March, 2011, Quebec signed an agreement with the federal government on the intergovernmental management of offshore hydrocarbons (MERN, 2011). This agreement constituted the first step towards oil exploration in the Quebec portion of the Gulf; it will become effective with the adoption of mirror-laws, the projects of which were introduced in 2015. On the 11th of June, 2015, *Projet de loi 49: Loi assurant la mise en œuvre de l'Accord entre le gouvernement du Canada et le gouvernement du Québec sur la gestion conjointe des hydrocarbures dans le Golfe du Saint-Laurent, (Projet de loi n° 49, 41e législature, 1re session)* is adopted by the Quebec National Assembly. Shortly after, on 18th of June, 2015, *Projet de loi C-74: Loi portant sur la mise en œuvre de cet accord* (C-74, 41e législature, 2e session) is introduced in the Commons. Those two bills relate to mirror-laws that follow up on the previous agreement, which, as these words are being written, have yet to be translated into regulations. On the 2nd of August 2015, the federal Bill n° C-74 died on the Order Paper when federal elections were called. No other bill has been introduced since. The study of Bill n° 49 is now stalled as it must be examined in parallel with a federal bill. Be that as it may, the objective of these laws is to regulate oil and gas production in marine environments by fostering the use of the generally accepted best practices (Devost, 2015). This willingness is reiterated in 2014 through the *Plan d'action du gouvernement du Québec* aimed at adopting the best exploration and exploitation practices through the modernisation of the legislative and regulatory framework[2].

The Canada-Quebec Accord acknowledges that Quebec shall be the main beneficiary of the revenues from hydrocarbon production activities related to these resources. *La Régie de l'énergie du Québec* and the NEB must work together to use the power and functions granted to them by the law. The bills ask that oil and gas exploration, production and transportation activities in the designated zone require a permit to proceed with work and an authorisation for each activity. The authorizations of activities must, at a bare minimum, show conditions related to the responsibility in case of losses and damages, to the realisation of environmental assessments and to the payment of expenses incurred by the *Régie* and the NEB. The notice from the Quebec minister responsible for the *Loi sur la qualité de l'environnement* (RLRQ, chap. Q-2) and the one responsible for the Canada Environment Assessment Act (L.C., 2012, chap. 19, art. 52), will be compulsory to the end of the authorization of some activities at risk for an environmental incident. The regulations deriving from these two bills are not yet known and could feature new elements relating to the best practices relevant to offshore exploration and exploitation.

The *Politique énergétique 2030 du Québec*, made public on the 7th of April, 2016 (Quebec, 2016) mentions that the government is committed to developing the oil and gas sector, only if a transparent approach proceeding one step at a time is adopted. The revenues from that sector would be directed to the energy transition and, as a priority, to the development of renewable energies. To that end, a number of conditions must be met: safe transportation and responsible exploitation of oil and gas in Quebec, social acceptability within the hosting communities, and the application of the strictest technical and environmental standards.

The "best practices", the "highest standards" or the "exemplary practices" are omnipresent terms in public policies and on the lips of legislators. Best practices refer to a set of measures of governance and regulations in a given sector that are established by comparing different regions and countries. They may include measures on public policies or legislative, regulatory and technical measures. In terms of technical standards, CRCDE (2015) realizes that, following a series of major accidents that have occurred in several studied jurisdictions such as Newfoundland-and-Labrador, the United States and the United Kingdom, major restructuration was undertaken to progressively switch from a normative mode towards a performance-based or objective-based mode (see Box next page for a definition of "modes of regulation"). /

Best practices refer to a set of measures of governance and regulations in a given sector that are established by comparing different regions and countries.

Photo: Deepwater Horizon Response / FlickR

[2] http://hydrocarbures.gouv.qc.ca/demarche-plan-action-quebec.asp

There are two regulatory approaches to oil and gas exploration and exploitation in a marine environment: the **normative approach** and the **approach based on performance**. There is a general increase of the use of the performance-based approach in the United Kingdom, Greenland and Norway. The United States uses the normative approach, while Canada uses a hybrid of the two approaches.

Normative regulation defines the requirements or the procedures to which the regulated entities must comply. The regulation, in this case, aims at ensuring the conformity with the specified requirements. This approach is appropriate when a precise direction on procedures or technical standards is necessary, and it is particularly applicable when the best practices can be clearly defined. These practices are perceived as a reasonable balance between risks, mitigation and the costs related to the investment and the operations. However, it leaves very little room for innovation as the lack of flexibility can obstruct the introduction of new practices and technologies. This approach requires detailed inspections. Furthermore, it is the responsibility of the user to assess and manage the risks . Lastly, the normative regulation has very little transparency as it relies on the willingness of the stakeholders to share the information.

Performance-based regulation defines, for the regulated entities, the functions or the results to achieve, although it allows for an extensive flexibility in the procedure. The operator must select the solutions that satisfy the objectives and requirements for each specific case. Such an approach fosters innovation and proactivity in the enterprises as it is the operator's responsibility to find solutions and build on competencies with respect to technology, operations and the understanding of risks. The industry becomes completely responsible for its activities, though the efficiency of the approach is determined as per the dialogue and the confidence between the authorities and the industry. As a matter of fact, the task of the authorities within this regime is to conceive and develop the rules, and then, to oversee the work methods of the operators and the management systems. The operators enjoy a relatively high degree of freedom to develop their own solution, as long as they can demonstrate that they manage the risk associated with their activities and the objectives and requirements of the rule. The approach demands a high degree of knowledge and skills, but may lead to a lack of transparency in the public eye.

Mockup: C. Petetin

NORMS AND TECHNICAL STANDARDS IN THE OFFSHORE OIL AND GAS SECTOR

The International Organization for Standardization (ISO) plays a predominant role in the harmonization of technical standards and standardisation of activities deriving from the industries or actors within a given sector. It is the first creator of international standards of voluntary application in the world. These standards establish state-of-the-art specifications applicable to products, services and good practices, allowing for the growth of efficiency in all sectors of the economy. Elaborated as an international consensus, per sector, they help eliminating obstacles to international trade. The Canadian Standards Association (CSA) is an organisation that develops certification standards and whose activities meet the needs of the industry, the government, consumers and other interested parties in Canada as well as those in the global market. The goal of the international standards is to guarantee good quality, safe, reliable products and services. To private companies, they are strategic tools that bring prices down while increasing productivity and decreasing losses and errors. They open the access to new markets, establish equitable game rules for developing countries and facilitate free trade and equitable trade in the world. Experts from the whole world prepare the standards required by their sector.

In the petroleum industry, there are 174 ISO standards, out of which 123 deal with several aspects of offshore production: from general requirements for offshore structures (ISO 19900:2013), to requirements and guidelines with respect to emergency interventions (ISO 15544:2000), and requirements and guidelines to control and extinguish fires and to manage explosions in facilities offshore (ISO 13702:2015).

It is important to emphasize that the regions affected by extreme climates and under the influence of ice pose additional challenges to any oil and gas offshore exploration and exploitation activity. Some international efforts dealing with this matter have resulted in the creation of the standard for arctic offshore structures (ISO 19906:2010), which provides recommendations and guidelines for the design, the construction, the transportation, the installation and the dismantling of offshore structures related to activities of the oil and natural gas industries in cold and Arctic regions. The objective of this standard is to ensure that offshore facilities in arctic and subarctic environments provide an adequate level of reliability in terms of safety for the people and the protection of the environment. The guiding principles of the norm aim at completing, without duplicating, the series of ISO

19900 standards (Table 8.2) on precise questions with respect to structures in the presence of ice. The standards on pipelines, on port facilities and bridges are excluded from it and they do not cover the operation, the maintenance, the inspection, the servicing or the repair of arctic offshore structures. Even if the document is currently available for use, ISO 19906:2010 is being revised (ISO/AWI 19906)[3] by the sub-committee n°7 of the technical committee n°67 (ISO TC 67/SC 7). Updating standards is a long and tedious process, especially because it requires an impressive amount of research and consultation as well as the consensus of many parties. The improvements might consequently arrive late in terms of the real needs of the industry.

Table 8.2
Series of standards ISO 19900 applicable to structures offshore.

STANDARD	TITLE
ISO 19900	General requirements for offshore structures
ISO 19901-(1-7)	Specific requirements
ISO 19902	Fixed steel offshore structures
ISO 19903	Fixed concrete offshore structures
ISO 19904-(1-2)	Floating offshore structures
ISO 19905	Site-specific assessment of mobile offshore units
ISO 19906	Arctic offshore structures

The international standards are general and may apply to a number of geographical zones relative to the project development options. In the case of new situations, such as offshore projects in the Arctic, the rules and technical standards are not usually prepared or updated while taking into account its particular conditions. If one wishes to reach an acceptable level of safety in the context of a specific project or region, the general standards must be adapted by considering several aspects. These include the safety objectives of project, risk assessment methods from the design to the realisation of the project, site-specific environmental data acquisition, the definition of additional or modified operational needs, the definition of basic selection criteria for security factors for the project and the definition of the regulations in terms of new regulations for the targeted zone. Later o, in this document, we shall see how this adaptive work began in the concrete case of the Barents Sea, but first, let us take some time to characterize the level of risk that the industry would be facing in the Gulf of St. Lawrence. /

[3] The acronym AWI means "*approved working item*" and identifies the stage of development of the ISO standards. Six steps must be achieved before the approval and the publication of a standard. To get more details on this process, visit www.iso.org/iso/home/standards_development/resources-for-technical-work/stages_table.htm#s20.

Photo: C. Petetin

THE LEVEL OF RISK IN THE GULF OF ST. LAWRENCE

A DEFINITION OF RISK

The potential risk is a statistical concept broadly defined as the product of the probability or the frequency of an incident and its anticipated damages – let's call this the consequence. It may be represented using the following equation:

RISK = PROBABILITY × CONSEQUENCE

The consequences of accidents causing loss of human life, damages to the environment and/or financial loss may be more severe in places where the conditions of exploitation are more difficult. The isolation and the lack of infrastructures may slow down emergency interventions. Extreme temperatures, vagaries of the weather and the presence of sea ice might make rescue efforts more difficult and more perilous, if not impossible. The vulnerability of the affected environments might increase the costs related to the compensation of services provided by the ecosystem or to the recovery. The increased probability of a prolonged interruption of the activities after an accident due to seasonal access for repairs may cause a loss of profitability for the activity. Should the activities also become the object of an intense attention of the public that has a low tolerance for accidents, there is an increased probability of a loss of reputation for all involved parties. Therefore, the assessment of risks firstly requires the determination and the quantification of the consequences associated with the possible accidents and, second of all, the determination of the probability of occurrence.

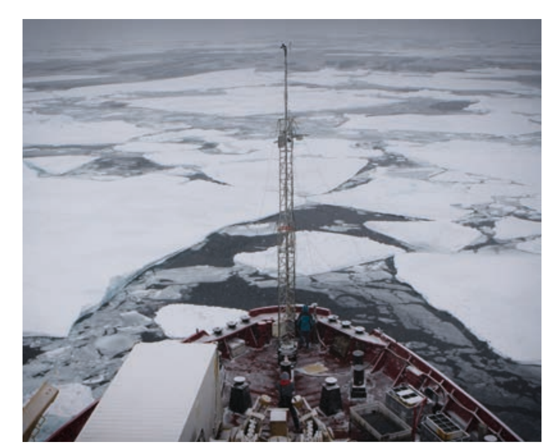


Photo: D. Kalenitchenko

The risk may be reduced by decreasing the probability of occurrence of incidents and/or in decreasing the consequences of eventual accidents. However, the consequences associated with certain factors, such as darkness, low temperatures, sea ice, isolation and the vulnerable environment can not be compensated. In order to maintain the same level of security in a context that aggravates the consequences, the only possible way consists in reducing the probability of the occurrence of incidents.


Photo: É. Pelletier

What about the risks related to offshore activities in the Gulf of St. Lawrence? Without answering in any exhaustive manner, we can however create a comparative picture of the oceanic/meteorological conditions to better situate the Gulf of St. Lawrence with respect to other targeted regions for the purpose of exploitation of hydrocarbons. Despite its southern position in relation to the Arctic Circle, the Gulf features winter conditions that, in some way, are similar to those conditions prevailing in certain areas in the Arctic. Air temperatures can reach extremes, around -30 °C. Consequently, the effect on the health and the safety of anybody working outside can be increased by the intense wind-chill when winter storms hit. Precipitation is sometimes heavy and abundant; ice storms, fog, strong and abrupt waves are part of the conditions in the Gulf. One of the most dreaded vagaries of the weather for offshore operators is a platform colliding with an iceberg. Even if icebergs are rarely seen in the Gulf, the probability of their presence is not zero, especially in the northeast portion of the Gulf, near the Strait of Belle Isle (Hill, 2000). A data base collated by the Canada Research Council reports several collisions between a ship and an iceberg in the waters of Eastern Canada, although these occurrences have been rarer in the last decades.

The distance between an eventual platform and coastal facilities is also a factor to take into consideration. Assuming that a platform was to be installed at the *Old Harry* prospect site, it would be approximately 80 km from the coast; a distance that is a whole lot less important than some other platforms off the coast of Newfoundland or in the North Sea. This could represent an advantage as it would reduce the time of intervention in case of an accident. Of course, it would be so if appropriate facilities were accessible at those locations. However, the proximity to the coast increases the risk that spills would reach sensitive and vulnerable coastal environments. Tables 8.3 and 8.4 feature a summary of the severity of the oceanic/meteorological conditions prevailing in 10 Arctic and sub-arctic regions. These regions are all inland or near the winter ice cover of the Northern Hemisphere, indicated with white spots in Table 8.2. /

Table 8.3
Comparative assessment of marine meteorological conditions prevailing in the main offshore oil zones of the Northern Hemisphere. The number indicates the level of severity of the hazard on a relative scale of 0 to 3, where 3 represents the highest level in all the regions presented, and 0 represents the absence or a negligible presence of the hazard (see Table 8.4 for definitions).

	SEA ICE	ICEBERGS	ICING	WIND CHILL	TIDES	WAVES	TOTAL
1. Gulf of St. Lawrence	2	1	2	2	1-3	2	**12**
2. Grand Banks of Newfoundland	1	3	2	2	1	3	**12**
3. Scotian Shelf	1	1	1-2	2	1-3	3	**12**
4. Beaufort Sea	3	2	3	3	1	1-2	**14**
5. Baffin Sea	2	3	3	3	1	1-2	**14**
6. Fram Strait (North-Eastern Greenland)	3	3	3	3	1	1	**14**
7. Barents Sea	1	2	3	3	1-2	2	**13**
8. Okhotsk Sea (Sakhalin Island, Russia)	2	0	2	2	1-2	2	**10**
9. North Sea	0	0	1	1	2	3	**7**
10. Caspian Sea	1	0	1	1	0-1	2	**6**

Table 8.4
Description of the scale of severity for each hazard presented at Table 8.3.

HAZARD	LEVEL 1	LEVEL 2	LEVEL 3
Sea ice	Sporadic presence of seasonal icee	Recurring presence of seasonal ice Ice pressure low to moderate	Presence of seasonal and perennial (pluriannual) ice for a major part of the year Ice pressure from moderate to strong
Icebergs	Occasional presence of small icebergs	Occasional presence of icebergs of all sizes	High probability of presence of icebergs of all sizes, including giant icebergs and ice islands
Icing	Rare precipitations	Occasional precipitations	Frequent precipitations
Wind chill	Occasional occurrence of wind periods and of intense cold	High probability of wind periods and of cold temperatures through part of the year	Persistent cold temperatures and wind over long periods
Tides	Low variations in the level of water and/or in currents linked to tides	Significant variations in the level of water and/or currents linked to tides	Important variations in the level of water and/or currents linked to tides
Waves	Extreme waves <5 m	Extreme waves 5-15 m	Extreme waves >15 m

Figure 8.2
Arctic and sub-arctic offshore zones where pools or prospects of hydrocarbons (oil and/or gas) are being developed or are being exploited. The oceanic/meteorological conditions in these regions are described in Tables 8.3 and 8.4. The white dots cover the average ice-covered area in ice in March 2015. We see:
1) the Gulf of St. Lawrence;
2) the Grand Banks of Newfoundland;
3) the Scotian Shelf;
4) the Beaufort Sea;
5) Baffin Bay;
6) the Strait of Fram;
7) the Barents Sea;
8) the Okhotsk Sea (Sakhalin Island, Russia);
9) the North Sea;
10) the Caspian Sea.

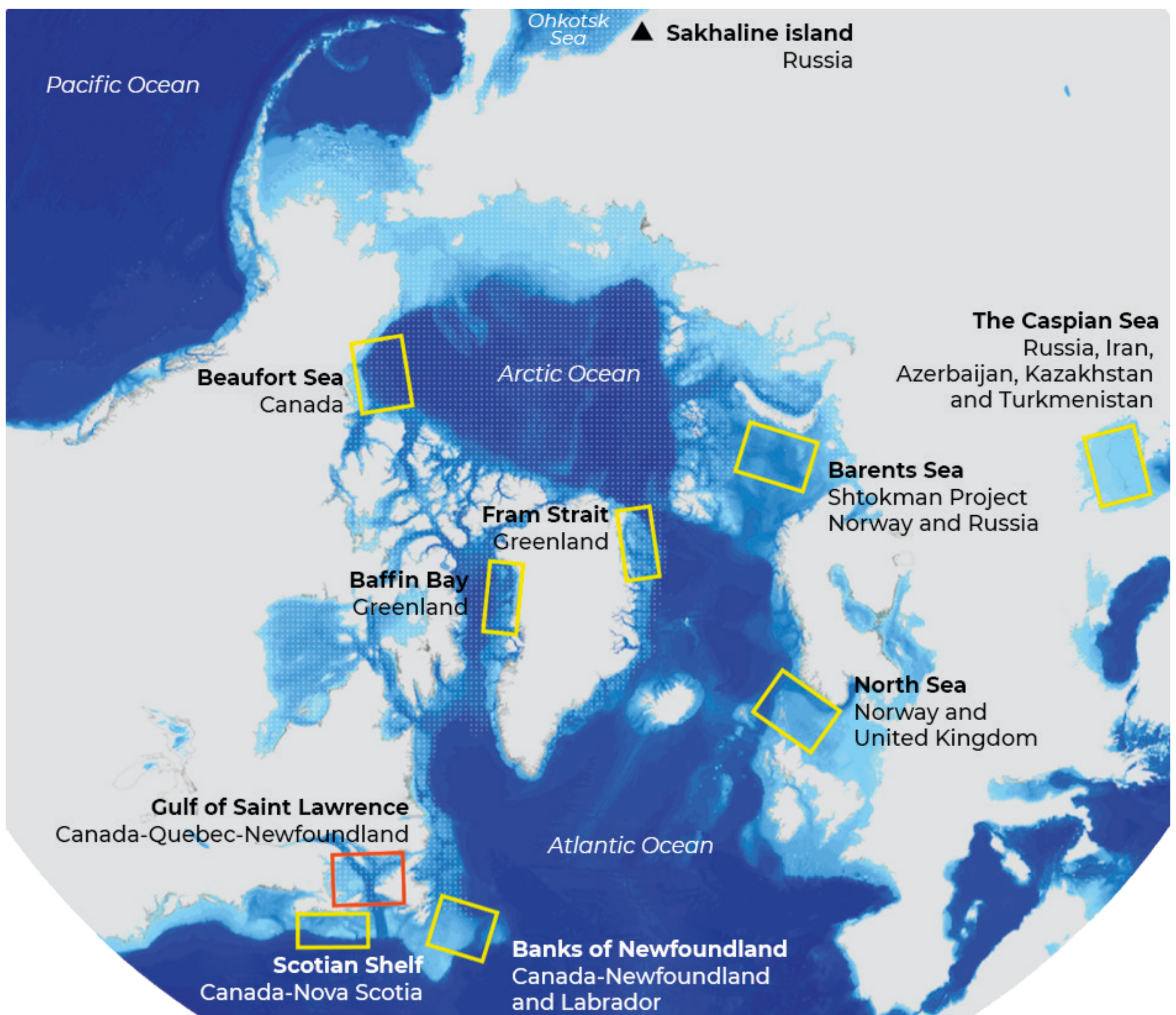


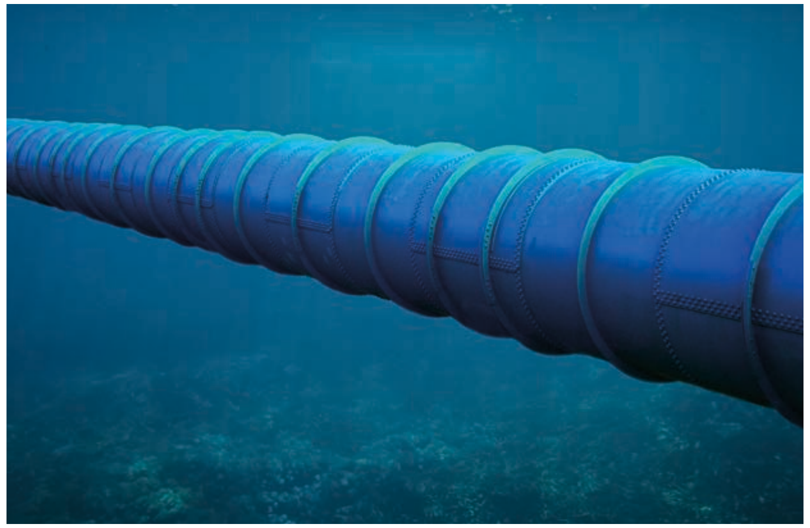
Photo: Pixabay

THE BARENTS SEA

Looking at Table 8.3, it seems obvious that Newfoundland-and-Labrador is the environment most similar to the Gulf of St. Lawrence, especially in terms of the existing associations on the legal and regulatory framework (CRCDE, 2015). However, in the quest for the best safety practices, the comparative approach calls for a study of what is being done elsewhere in the world. Norway is largely known as a nation championing offshore operations. This competence took root during the last century when Det Norske Veritas (DNV), a non-profit organisation founded in 1864, coordinated and supervised the development of the merchant marine. In 1970, after discovering oil in the North Sea, DNV relied on its competencies in the marine sphere to play a key role in developing practices of inspection, verification and management of offshore structures and operations. Today, the multinational DNV GL – a merger between DNV and with Germanischer Lloyd (GL) founded in 1868 in Hamburg – enjoys an international notoriety with respect to the regulating of the maritime industry and of hydrocarbons and energy.

However, prevailing conditions in the North Sea, where Norway has initiated and resumes offshore oil exploitation, can not be copared with those in the Gulf, especially because of the absence of sea ice and its more temperate climate. Instead, we need to look at the Barents Sea where Norway has undertaken projects exploiting natural gas (*Snøhvit*) and oil (*Goliat*). That is also where, in the Russian portion of the Sea, one of the largest reserves of natural gas in the world is found, *Shtokman*, named after its discoverer and around which a huge international project was undertaken in 2008. Defining and improving international standards began alongside the development of that project under the name Barents 2020, and constitutes a particular example that sheds light on our study.

Photo *Goliat* Plateforme: ENI NORGE



THE *SHTOKMAN* POOL

Shtokman is one of the largest known reserves of natural gas in the world. It is located in the Russian portion of the Barents Sea, 650 km north of the Kola Peninsula and west of Novaya Zemlya (Figure 8.2). Its reserves are estimated at 3,200 billion m^3, which represents 2% of the world reserves of conventional gas and more than twice the Canadian reserves, Canada being the third producing country. The pool is located at an average depth of 350 m. These reserves of natural gas were discovered in 1988, but the pool has yet to be exploited due to the difficult conditions of extraction, isolation, depth and also the context of the gas market made unfavorable by the shale gas production growth in the United States. Furthermore, the pool is located 500 km away from the coasts, which poses two serious problems. First, such a distance excludes the use of helicopters that would assure the rotation of the personnel and supplies. Second, a 500 km undersea gas pipeline must be built, which would be four times the length of the one used in the *Snøhvit* project, located in the Norway sector of the Barents Sea, and whose construction is facing several major issues. Once operational, the under-sea gas pipeline would be the longest in the world in a polar environment.

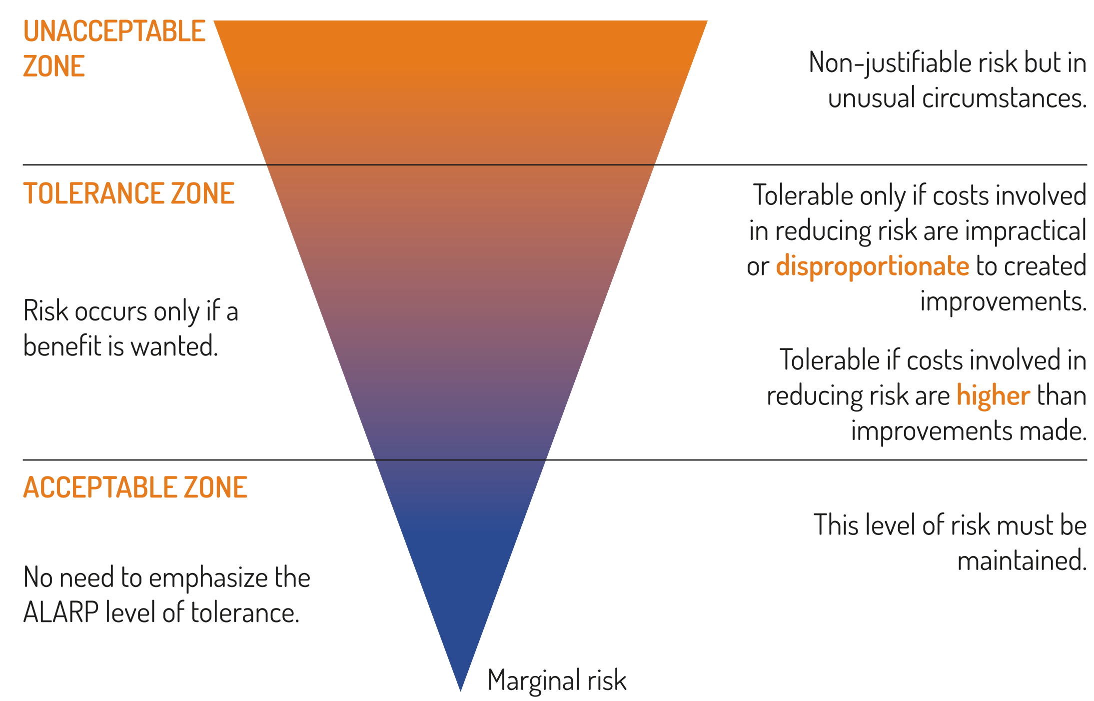
The Shtokman Development AG Company was founded in 2008 to undertake Phase 1 of the exploitation of the gas field and to bear the financial and technical risks associated with the extraction and the production of liquefied natural gas. In 2009, the company espoused a policy on health, safety and the environment (HSE)[4] which adopts the "as low as reasonably practicable" risk principle or ALARP, (see Box "The concept of ALARP"). Due to the recent drop in the price of oil, Total E&P, a French company, withdrew its participation in the consortium in 2015 (*Les Échos*, 2015), in the footsteps of Statoil, the Norwegian enterprise, which had also withdrawn one year earlier. At the very same time, two initiatives were launched to update the technical standards aiming at the exploitation of the resource with a minimum of risk, in an arctic environment: the production of an international technical norm for the offshore operations in the Arctic and the Barents 2020 project.

[4] www.shtokman.ru/f/1/about/policy/hse_policy.pdf

THE CONCEPT OF ALARP

ALARP refers to the level of risk "as low as reasonably practicable". This is a concept that defines criteria pertaining to the means of reducing risks and that derives from the precautionary principle. It is often illustrated in a carrot-like diagram, (see below); it is divided into three main sections. In the upper section, risks are classified as normally unacceptable, i.e. risks that must not occur, except in extraordinary circumstances. The risks at the base of the carrot are deemed minimal or negligible, i.e. generally acceptable and must not been subject to a cost-benefit analysis. However, the level of risk must be continuously monitored to ensure that it remains within the limit of tolerance. The zone of tolerance is in the center; it is often referred to as the ALARP Zone. That is where the risks can be tolerated if it has been demonstrated that mitigation measures have been set up and that costs associated with the reduction of the risks are superior, disproportionate even, to the expected benefits. The ALARP process means that the operator must analyze the pertinent costs and benefits -for instance, the increase of productivity, - associated with the reduction of the risk. The operator must also determine the minimum level of risk one can achieve with reasonable costs. Several factors influence this process: the perception of risk, the operator's policy on the management of risks, the social perception of the risk and the expectations of non-governmental organisations. The criteria for tolerance (acceptability, tolerance, unacceptability) of the risk to the personnel and the environment must be defined for all activities.

Figure 8.3
Carrot-like diagram of the ALARP concept. *(Modified from http://www.ep-consult.co.uk/service/hse-risk-assessment/safety-case-development.)*



Aware of the significant challenges that gas exploration and exploitation in the Barents Sea impose with respect to the HSE, the Department of Foreign Affairs of Norway gave to DNV (today, DNV GL) the mandate to lead an initiative involving the industry, in cooperation with Russia, aimed at harmonizing and defining standards to which the industry shall abide. Norway and Russia have some competency with respect to the exploitation of offshore oil and gas, although the update of the existing regional or national standards and their adaptation to the reality of the Barents Sea are essential. This project unfolded in four phases over a period of five years (2007-2012). Throughout **Phase 1** (October 2007 to October 2008), five articles were produced in order to provide guidance to the model of cooperation between Norway and Russia: DNV was selected as manager for the Norwegian and international portion of the project, whereas the technical committee 23 of Vniigas and Gasprom got the mandate to manage the Russian portion of the project, a structure of governance preserved until the very end.

In **Phase 2** (November 2008 to March 2009), the industrial stakeholders of the project selected seven key themes to be addressed by working groups made of specialists from different sectors: the common offshore standards; ice loads; risk management; the evacuation and the rescue; the work environment; ship loading, unloading and transportation, the operational emissions and the rejects in the air and in the water. The experts have agreed to use standards and practices used offshore, in the North Sea, as a point of reference for the Barents Sea. When considering the more difficult conditions of exploitation for intervention, for example for search and rescue or the spill clean-up, experts have concluded that an acceptable level of risk will have to be reached by decreasing the probability of occurrence of the incidents and accidents, which confirms the objective towards an improvement of the technical safety standards.

Throughout **Phase 3** (May 2009 to March 2010), seven working groups focussed on gathering the different aspects pertaining to the safety of the operations in the Barents Sea; they have developed a total of 130 standards applicable to the common practices, (Barents 2020, 2009). Out of those, 64 can apply as they are; the remaining 66 can apply conditionally, that is if modifications are made to address situations of low temperatures and ice loads. The defined standards can be classified as follows: International standards, such as ISO, UIT and IEC, Regional standards, such as CEN and ECES, National standards, such as GOST-R and industrial or associative standards, for example, Norsok, SNIP, API, IOGP and DNV (see the glossary for a definition of these acronyms).

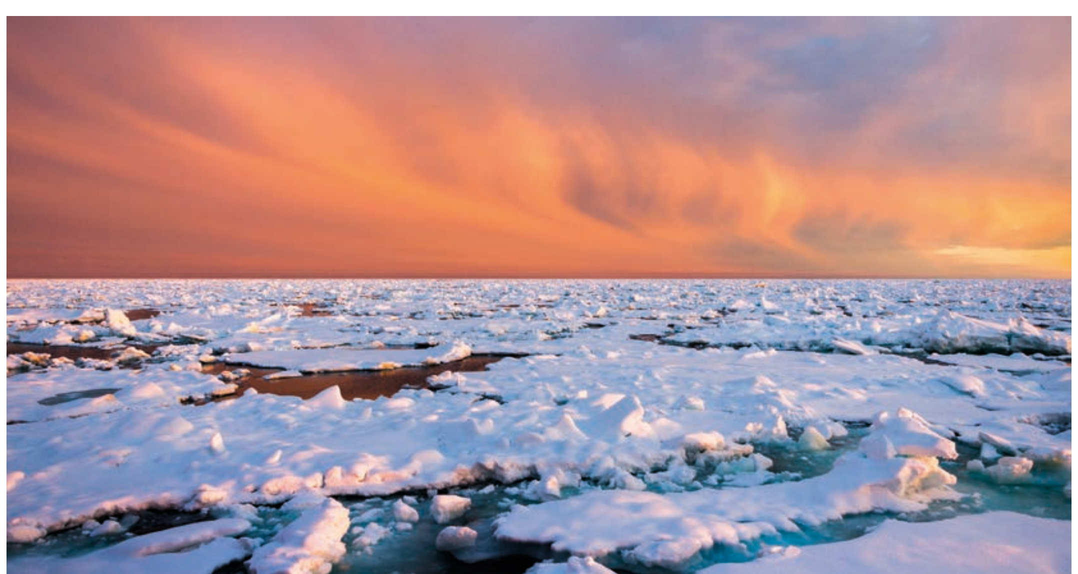


Photo: D. Kalenitchenko

The ultimate phase of the project, **Phase 4** (May 2010 to March 2012), had an objective: to provide concrete instructions to the industry in fields deemed critical and a priority with respect to the reduction of the probability of occurrence of incidents and accidents. The final report (Barents 2020, 2012) featured detailed recommendations from five of the working groups of Phase 3; they were submitted to competent normalisation organisations, mainly to sub-committee 8 responsible for arctic operations, which respond to the ISO TC 67. Here are some recommendations that appear in the final report:

- Standard ISO 19906 must be used as a basis for the design and the operation of fixed structures in the Barents Sea;
- Standard ISO 19906 must be put forward as a national standard as it has been approved at the international level;
- The working group has determined 10 items that should be modified, out of which four are a priority with respect to standard ISO 19906. Instructions have been identified as the best way to approach these matters. The document emphasizes the necessity to harmonize the understanding and the interpretation of ISO 19906.

To summarize, the Barents 2020 project is an exercise that proceeded before the installation and the operation of offshore structures, in an environment which, in many ways, is similar to the Gulf of St. Lawrence. It had a precise goal: to identify the best practices in terms of health, safety and environmental protection. The exercise mobilized over 100 international experts from institutions based in 40 countries and over five years, while the production of standard ISO 19906 required an effort from over 1,000,000 man-hours, spanned over seven years and done with an international working group that met 12 times. People involved in the working groups are researchers, engineers and specialists in the oil industry, volunteers from non-petroleum companies, entrepreneurs and university researchers from several countries. The final report of the Barents 2020 project outlines such topics as the very specific importance of a bi-jurisdictional and inter-sectorial approach, along with the participation of representatives who contributed to the success of the endeavor. They were from two countries: Norway and Russia. /

Photo: Freepik.com

CONCLUSION

Far from constituting an exhaustive review of the regulation practices governing the offshore oil and gas exploitation, this chapter attempted to draw a picture of the existing regulatory framework in the Gulf of St. Lawrence and to study the level of risk in terms of safety, while taking into account the specificities of the region. With that in mind, and in the perspective of defining the best practice framework, we focussed on a practical case pertaining to the development of norms and technical standards. We are noting, as it was reported by the CRCDE (2015), that the context of the Gulf of St. Lawrence is particularly complex and that any comparison remains arduous. Recent history has taught us that the legal and normative frameworks, as is the case of Newfoundland-and-Labrador and Nova Scotia, will be applied in the Gulf and will keep in line with a Canada-Quebec model of intergovernmental management of offshore oil and gas, supervised by mechanisms of harmonization. It is in such a context that Quebec and its partners shall define and adopt the best practices.

Photo: Håkon Thingstad / Wikimedia

The reputation and the experience acquired by Norway on offshore operations as much as on the development of performance regulatory mechanisms, led us to examine the specific case of the Barents Sea, not only as an environmental analogue, but potentially as an example to follow for defining and developing best practices of technical normalisation pertaining to safety. The examination of the Barents 2020 project initiated following the decision of several multinational oil companies to exploit the *Shtokman* field provided us with the possibility to identify a number of findings.

Firstly, the premises upon which the parties came to agree from the start did not exist prior to the standards applicable to offshore oil and gas exploitation in the Barents Sea. These parties took it upon themselves to identify and examine the existing standards and, as needed, to adjust them at the beginning with the objective of preserving a level of risk equivalent to the one prevailing in the North Sea. The standards to be applied must contribute to the minimisation of the probability of occurrence of the hazards, as the consequences associated to any one hazard is, in the Arctic, more severe.

In the definition of "best standards" applicable in a new situation, international standards are being considered simply because they derive from a rigorous process of harmonization aimed at reaching a consensus amongst the international experts. Yet, as they apply to general conditions, they must be adapted by the regional, national or industrial certification organisations. The Canada Oil and Gas Certificate of Fitness Regulation (DORS/96-114) identifies Det Norske Veritas and Germanischer Lloyd (DNV GL) as Authorities to deliver Certificates of Conformity pertaining to offshore structures, without explicitly determining which standards this authority must use for the purpose of certification. If we were to assume that DNV GL applies, for instance, the strictest standards in existence, those would be, at best, the ones that have been adjusted to the Barents Sea or another region that will have been defined as similar. If, to the contrary, the best practice consists, in fact, in adjusting the standards to the region in which operations will proceed, while taking into account the regional particularities, the foregone conclusion is that the applicable standards do not exist yet.

This takes us to another finding. The definition and the adoption of the best practices in the Barents Sea were produced in cooperation with, and in a completely transparent manner, amongst the stakeholders, i.e. the sovereign nations involved, the certification authorities, academics, and independent, international and industrial experts. If we were to transpose this exercise to Canada, we would have to invite to the table the five provinces neighboring the Gulf, the federal government and their involved authorities, the aboriginal nations, *la Société d'intervention maritime de l'Est du Canada* (SIMEC), the industry, the certification authorities (possibly DNV GL or others) and, potentially, some American organisations which could be asked to respond to certain situations, for instance the American Coast Guard in the case of a major spill.

In Canada, interprovincial or federal-provincial cooperation has always been difficult. Amongst the standards mentioned in *Directives des offices extracôtiers* and at the NEB, standard ISO 19906, which is applicable to offshore arctic structures, is not listed. To our knowledge, an initiative to study or review the standards applied regionally, in the Gulf of St. Lawrence, is not occurring. The *Deepwater Horizon* platform accident, which took place in 2010 in the Gulf of Mexico, has brought in the United States, in Canada and elsewhere, several reforms pertaining to the way to proceed in terms of creating frameworks for the offshore hydrocarbons, which would, once more, show that in the presence of structuring mechanisms, the industry progresses by trial and error. Lastly, industrial actors involved that are holding licenses in the Gulf of St. Lawrence do not have the experience nor the expertise of the players who have taken part in major projects, such as the *Shtokman* (e.g. Total E&P, Statoil and Gasprom).

Adopting the best practices does not only involve the modernisation of the legal and technical framework. It requires the proactivity from the authorities, the cooperation amongst all the stakeholders, including the industry, a great transparency as well as an international perspective. /

ACKNOWLEDGEMENTS

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ACRONYMS

API	American Petroleum Institute
ECS	European Committee for Standardisation
ECES	European Committee for Electrotechnical Standardization
DNV	Det Norsk Veritas
GOST-R	Organisation for the certification and standardisation of the Russian Federation
IEC	International Electrotechnical Commission
ISO	International Standard Organisation
NORSOK	Technical standards developed by the Norwegian oil industry
IOGP	International Association for Oil and Gas Producers
SNIP	Technical standards for Russia and Kazakhstan
UIT	International Telecommunications Union

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Photo: J. Descloitres, MODIS Land Rapid Response Team, NASA/GSFC

CHAPTER 9

“Commercially sensitive” environmental data: a study of a case in point pertaining to the asserations of oil seepage at *Old Harry*

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We, herein, are illustrating, with the help of a case, the difficulties encountered to get what could be pertinent from the environmental information industry, not to say crucial, to the impact studies and the decision-making process with respect to the exploration and the exploitation of hydrocarbons in the Gulf of St. Lawrence. The reported case addresses information, disseminated by Corridor Resources concerning persistent natural seepage of oil from the flanks of the *Old Harry* Prospect, in the Gulf of St. Lawrence. The seepages would rise up to the surface, appear just above the site and would form oil slicks visible with satellite imagery. Corridor interprets this as indications that the *Old Harry* Prospect holds oil. Although this information might be credible, we have not been able to verify its veracity as Corridor is apparently not in a position to divulge its sources, since the information is deemed to be commercially sensitive. We show the judicial, economic and political contexts in which the withholding of information can occur, and we critique the impact this can have on the ability to make societal decisions.

Scientia potentia est.

(Knowledge is power.)
Thomas Hobbes, 17th century

HIGHLIGHTS

- Corridor Resources is an enterprise that affirms it has observed surface slicks of hydrocarbons and interprets this phenomenon as revealing the occurrence of natural seepages from the *Old Harry* pool.

- It is impossible to make public an independent verification of that interpretation because the data is deemed to be commercially sensitive.

- The data represents a great scientific interest with respect to the understanding of the potential natural impact of hydrocarbons in the Gulf of St. Lawrence.

- In order to avoid any ambiguity, the conclusions of the technical studies made public should meet the standards of transparency, rigor and counter verification specific to scientific research.

INTRODUCTION

In Canada, scientific knowledge is considered to be the best way to shed light on important societal decisions which governments must make, whether they relate to matters such as health, education, environment or any other sphere of public life deemed important for the improvement of the collective good.

For instance, and with a direct link with the concerns of the *Notre Golf* network, this philosophy is being exposed, black on white, on the site of Environment and Climatic Change Canada, *Link with the development of policies and decision-making* where one can read:

« The direction of atmospheric science and research of Environment and Climate change Canada supports the policies of the federal government pertaining to air quality and regulatory initiatives. At the base of these activities, research and science provide [*sic*] solid scientific knowledge to support the Canadian environmental Protection Act [...], the foundation of the governing of the environmental legislation of Canada »

(Environment and Climate change Canada, 2016)[1]

This approach is also emphasized by the Canadian Department of Fisheries and Oceans (DFO) in a section called: *A framework for the future*, indicates that:

« As a science-based department, DFO relies on a vibrant Science program to provide qualitative and quantitative data and information combined with expert scientific analysis and advice to directly support decision-making as well as policy and program delivery for its operations across Canada and internationally »

(Fisheries and Oceans Canada, 2016)

Therefore, Canadian government institutions looking into environmental questions believe that this approach and the scientific knowledge are necessary to support the making of decisions in a clear and transparent manner. It is also in such a context that the network *Notre Golf* was born and is progressing, (Archambault *et al.*, 2016).

Yet, if this is a valued and used practice of the departments related to the environment, it does not jive with the industry. As a matter of fact, the industry will, sometimes, disseminate information it presents as scientifically rigorous, but which, in fact is scientifically non-receivable and, sometimes, misleading either due to conflicts of interest, to a lack of rigor or a lack of transparency. Some examples of such scientifically non-rigorous practices by Corridor Resources, an oil company that holds a permit of exploration in the Newfoundland part of the *Old Harry* Prospect, have already been exposed and criticized, Bourgault *et ses collaborateurs* (2014). We will not return to those examples but we are, herein, reporting a case which exposes the impasse that occurred when trying to verify assertions made by Corridor about possible oil seepage emanating from the *Old Harry* Prospect. We are also presenting the judicial context in which this type of information is circulating. /

Canadian government institutions looking into environmental questions believe that this approach and the scientific knowledge are necessary to support the making of decisions in a clear and transparent manner.

[1] Loose translation

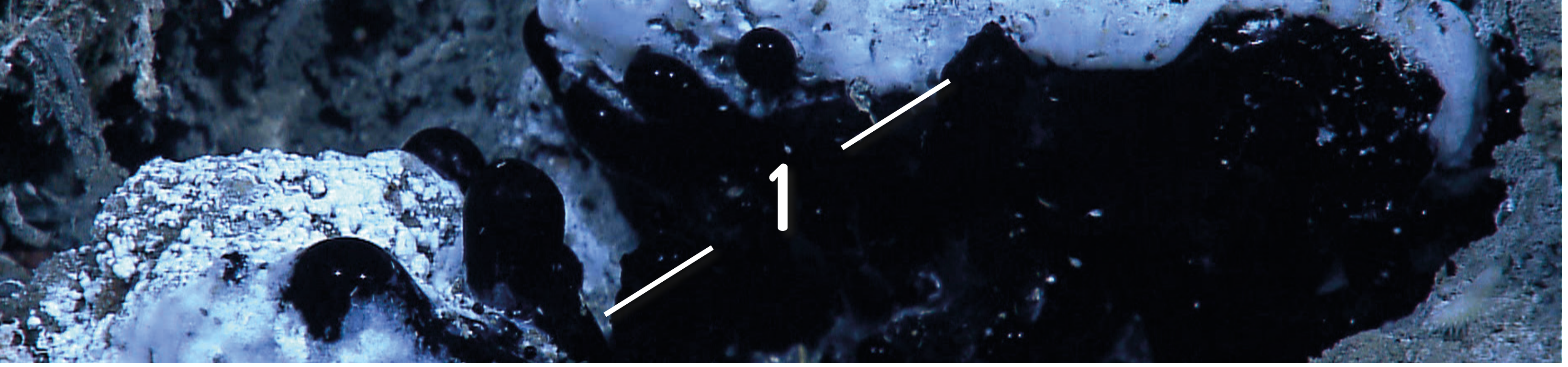


Photo: NOAA Okeanos Explorer Program, Gulf of Mexico 2012 Expedition / FlickR

OFFSHORE NATURAL SEEPAGE OF OIL

Nearly half of the oil that winds up in marine environments comes from natural seepage, (Kvenvolden and Cooper, 2003). These seepages are caused by the slow exfiltration of oil or gas from networks of veins and cracks naturally created in sediment rocks, from the pool deeply buried all the way to the marine beds. Once in contact with sea water, the fractioning of the oil, which is heavier than bottom water, can deposit on the sediment, near to the source of seepage, while lighter gas and oil can rise higher into the water column. Depending on the conditions of the stratification of the surrounding waters[2], the oil can rise until it inserts itself between two water layers at a balanced depth, i.e. the place where oil has the same density as that of the surrounding water, or even rise all the way up to the surface if the oil is light enough.

If the quantity of light oil released is large enough, this could create a slick visible at the surface; it may drift with the winds and currents. After awhile, the most volatile part of the slick of hydrocarbons will evaporate, leaving behind a heavier oil which could seep and wind up deposited, farther away, on the marine floor. This sequence is schematically illustrated on Figure 9.1. Even though the basic principles of this natural process are known, few studies focus on natural seepage as it remains misunderstood.

Under certain conditions, and following meticulous and deep analyses, these slicks generated by natural seepage can be detected with satellite imagery, (Hu *et al.*, 2009). These detections could indicate the presence of an oil or gas pool in the surrounding marine sub-soil, although it is still difficult to determine without ambiguity the real source of an oil slick that is only detected through satellite imagery. /

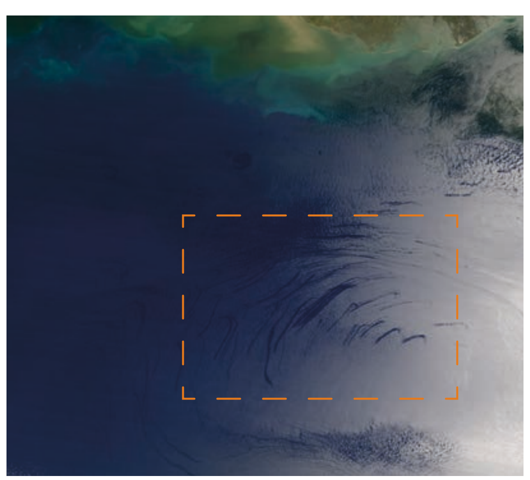


Photo Natural oil slick in the Gulf of Mexico: Jesse Allen / NASA *(using data obtained from the Goddard Level 1 and Atmospheric Archive and Distribution System (LAADS). Caption by Rebecca Lindsey.)*

[2] For more details on the hydrographic conditions characterizing the gulf, see Chapter 2 - Bourgault *et ses collaborateurs.*

Figure 9.1
Schematic representation of the trajectory of oil and gas released at sea through natural seepage. *(Modified from Woods Hole Oceanographic Institution, http://www.whoi.edu/oil/natural-oil-seeps.)*

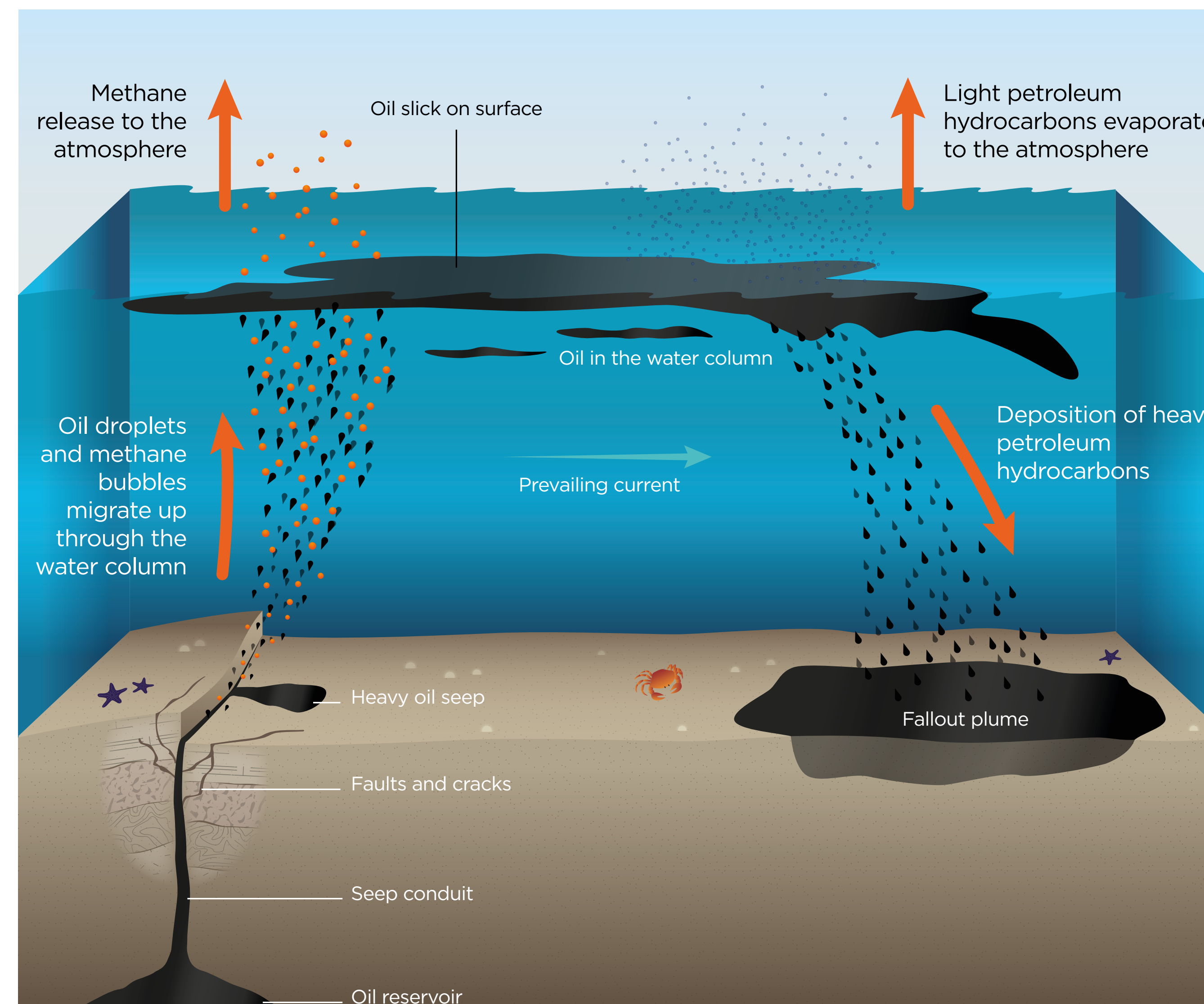


Photo: Pixabay

OIL SEEPAGE EVENTS IN THE *OLD HARRY* AREA?

The geological structures that could cause natural seepage are generally found in groups, in some precise areas around the globe, for instance, in the Gulf of Mexico (Hu *et al.*, 2009). Here, a question can be asked: could there be such occurrences of natural seepage in the Gulf of St. Lawrence, in general, and in the *Old Harry* area, more specifically, as they could betray the presence of a pool of hydrocarbons in the sub-soil of the gulf?

According to Corridor, the answer is affirmative as far as the *Old Harry* Prospect is concerned. As a matter of fact, the oil company has been asserting for around fifteen years that "six oil slick events, most likely emanating from the flanks of the *Old Harry* Prospect, have been detected at the surface of the gulf through satellite imagery", (Corridor Resources, 2000, p. 9; 2005, p. 13, loose translation). This affirmation was presented in its 2000 to 2005 annual reports, inclusively, (Corridor Resources, 2000, 2001, 2002, 2003, 2004, 2005) and it is still featured in its Annual Information Form, (for example: Corridor Resources, 2016). Some information was also given at public presentations, notably at the *Forum sur l'exploration et l'exploitation des hydrocarbures dans le Golfe du Saint-Laurent*, held at les Îles-de-la-Madeleine, in April, 2011, during which a map showing the position of the six large seepages in question was presented. Furthermore, at the same conference, the representative of Corridor Resources qualified these six seepages as "persistent", hence hinting that the *Old Harry* Prospect was naturally seeping oil in a continuous and permanent way. Therefore, this oil would be coming up in the 470-meter water column to appear just above the prospect, (Corridor Resources, 2011)[3]. The quantity of oil spilled would be large enough to be detectable at the surface using satellite imagery.

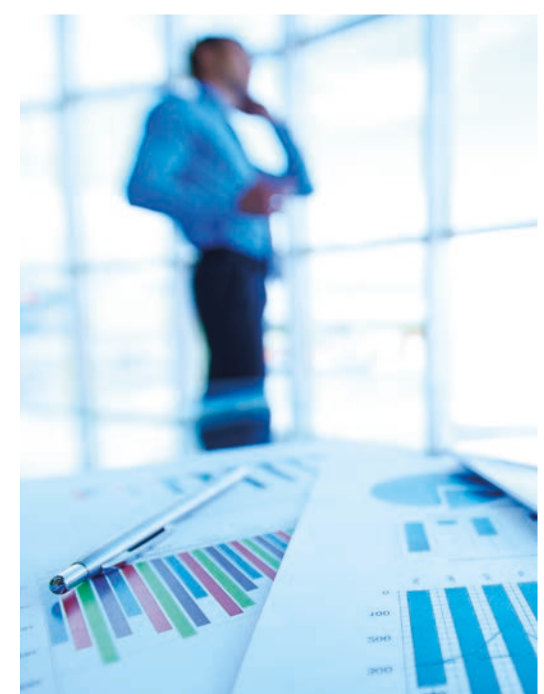
The representative of Corridor Resources qualified these six seepages as "persistent", hence hinting that the *Old Harry* Prospect was naturally seeping oil in a continuous and permanent way.

Yet, Corridor Resources provides no other information to support this assertion, hence, it is impossible to verify its veracity or to scientifically criticize it. Consequently, this information cannot be contradicted either. As we have shown in the preceding section, the natural advent of oil slicks at the surface from the seepage off of sub-marine pools is a possible phenomenon which can, sometimes, be observed via satellite imagery. For example, in the north-western portion of the Gulf of Mexico, (Hu *et al.*, 2009). Thus, information that is being disseminated by Corridor Resources becomes possibly credible. The Gulf of St. Lawrence seeps oil, around *Old Harry* or elsewhere. But, before we come to such a conclusion, this information must be counter-verified in a scientific, transparent and independent way.

We contacted the management of Corridor to get more information on these seepages they claim to have observed. Corridor answered by telling us that the company was no longer in a position to provide further details as it is constrained by an exclusivity contract with Airbus Defence and Space, which produced the said analyses. In fact, Airbus has set up data banks related to the seepages of hydrocarbons in the Gulf as part of a contract granted to Nalcor, an independant provincial Crown Corporation, (we will get back to this in the next section.)

[3] *« We hired a company that uses orbiting satellites to take pictures of the sea surface [...] and what they've noticed is that over the Old Harry site there are six persistent oil signatures on the surface. So there's an indicator from these satellite images that there's potential oil seeping out of Old Harry at the present day »* (Corridor Resources, 2011, 5:00-5:28).

Photo: Pressfoto / Freepik



The industry could therefore be holding crucial environment information of public interest, the details of which it apparently cannot share. The odd part in this case is that, evidently, Corridor feels it has the right to share publicly and quite freely the conclusions of the Airbus study. Yet, it does not feel it has the right to share the methodological details that would allow for the verification or the contradiction of the findings thereof. Without revealing sources and data, the information that is being disseminated cannot consequently be criticized and remains unreachable. Basically, Corridor says: "Do you take our word for it?" Yet, acting this way is scientifically unacceptable. To us, this type of information circulated by Corridor is irretrievable, scientifically and socially speaking, let alone that it is such an important environmental issue and is crucial information regarding the possible presence of offshore natural oil.

Yet, Corridor Resources provides no other information to support this assertion, hence, it is impossible to verify its veracity or to scientifically criticize it.

In terms of the environment, it would be crucial to verify this information and further it because, if the Gulf or *Old Harry* are persistently seeping oil, it would be imperative to coordinate research efforts, to take measurements and to monitor, to quantify the oil naturally surfacing in the Gulf, and to determine the sources before undertaking any attempt to proceed with exploration or exploitation. In fact, it is imperative to know the natural basic concentration of oil and its sources if we wish to eventually proceed with a comparative follow up and assess the environmental impacts of oil exploration and exploitation in the Gulf. If the industry withholds any unreleased information of such an importance, it should reveal its sources to better orient the research because that would contribute to better scientific knowledge. Otherwise, societal

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decisions cannot be made on the basis of such unverifiable information.

We then contacted Airbus to try and learn more about the source of the satellite images and the analyses. We asked them if we could buy the data and the analyses, at what cost, and under what conditions. There are, in the midst of the *Notre Golf* network, experts who could coordinate a second analysis and an interpretation of these images in a transparent, rigorous and scientific manner.

Airbus answered that the data was "commercially sensitive" and that, therefore, it could not be shared publicly. Airbus was open to selling us the data and the analyses, after a certain amount of negotiation, during which we explained what we wanted to do with the data. In principle, we could establish an exclusive contract that would give us the opportunity to access the data. However, as the data was classified as commercially sensitive by Airbus, we could not have divulged it publicly. Yet, in scientific research, exclusive data that cannot be shared publicly has no value as science must fundamentally show complete transparency and be submitted to criticism. Therefore, we have not invested any public funds to acquire this data, as it would only have satisfied our curiosity without having society at large benefit from it as well.

In scientific research, exclusive data that cannot be shared publicly has no value as science must fundamentally show complete transparency and be submitted to criticism.

As we mentioned before, a specific aspect of this case in point lies in the fact that the data are considered by Airbus as being commercially sensitive and that Corridor Resources is apparently constrained by a legal contract not to release the data, although the oil company releases the results publicly. Is this not a paradox? How come Corridor has the right to disclose the conclusions but cannot present the method of analysis nor the data? What is the meaning of the terms "commercially sensitive" in this context? Sensitive to whom and for what? Why are the conclusions of the study, the assertion of the presence of six persistent seepages around *Old Harry*, not being considered as commercially sensitive when the methodology is? The next question is about knowing why Corridor insists on disclosing the conclusions of this study deemed commercially sensitive. Is it to try to convince governments, investors and the population about an important reserve of hydrocarbons at *Old Harry*? This revelation seems to be the main reason, if we rely on the information presented by Corridor Resources at the Îles-de-la-Madeleine, (Corridor Resources, 2011). Then again, could it also be to minimize the impact these spills linked to exploitation activities could cause, the argument being that there is such a thing as natural seepage? Yet, there is natural seepage, so, what is the quantity released? The answer to this question must be known.

These assertions of natural seepage around *Old Harry*, disclosed with no details, raises many other questions. Do these detected seepages exist only around *Old Harry* or can they be located anywhere else in the whole of the Gulf? In other words, is Corridor choosing to disclose only the possible seepages detected in the *Old Harry* region, while ignoring other seepage events possibly detected elsewhere in the Gulf, or is the *Old Harry* region really at a hot point for such seepages? Based on the answer, the interpretation and the environmental follow-up of these seepages would be quite different. Also, Corridor Resources is not telling us if the satellite analyses were done around the *Old Harry* region only or over the entire Gulf. Yet again, if the analysis was done only at *Old Harry*, it would seem somewhat dangerous to generalise and to conclude that *Old Harry* is a hot point in the Gulf in terms of seepage. We asked those questions to Corridor Resources and got no answers. We also asked those questions to Airbus; they only gave us partial information. Based on the partial answers received, similar seepages would also have been observed in other sectors of the Gulf. Where? How many? We did not get any more details on those either. Furthermore, as we are aware of the strong currents of the Gulf and the properties of the water column, (see chapter 2), we are wondering how it is possible that oil seeping from *Old Harry*, in 470 meters of water, can thus appear at the surface, right above the prospect. We also asked Airbus how they could determine that these seepages come from the flanks of the *Old Harry* Prospect. Airbus answered by saying this conclusion did not derive from its analysis. Airbus indicated that it had only provided the surface position of the seepages it had observed. Hence, Corridor Resources concluded that these possible seepages detected at the surface, close to *Old Harry*, came from the prospect itself. The affirmation according to which seepages would likely emanate from the flanks of *Old Harry* is the interpretation given by Corridor Resources, though we have found no way to know how they came to this conclusion. /

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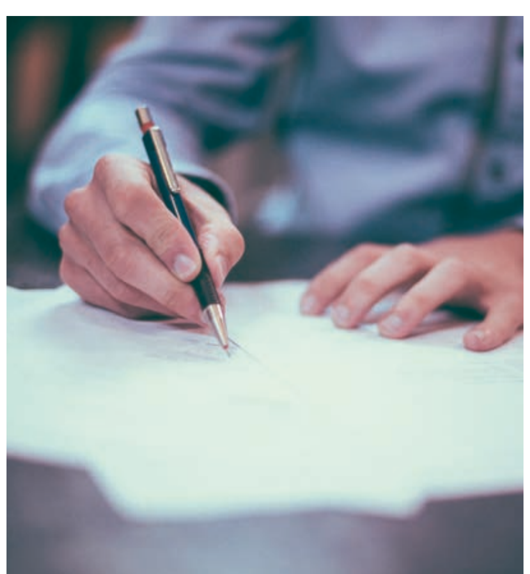
Photo: Awesomecontent / Freepik

THE JUDICIAL ASPECTS

The answers communicated by Nalcor, Airbus and Corridor Resources indicate that information on oil seepage is located in the commercial data banks of Airbus. Airbus can deliver permits to oil companies against a payment that would allow them to use the data to their own ends. Further to these elements, the judicial relations between Airbus, Corridor Resources and Nalcor, as to the data on seepage, remain opaque. The contracts that led to the permits delivered by Airbus to Corridor, and the creation of data banks at Airbus, thanks to the financing from Nalcor, are not available to the public. It is difficult to determine as to whether Nalcor has direct access to the data in question or the right to the data.

In that context, the opaque character of the contractual arrangements relating to the data on seepage renders uncertain the application of the legislative framework pertaining to the disclosure of information in the Newfoundland portion of the Atlantic littoral. The Energy Corporation Act (ECA) (2007) names Nalcor as an independent provincial crown corporation, which, at the outset, limits the duties to disclose that are normally imposed to the state and its representatives. The ECA also confers to Nalcor an important latitude to refuse the requests for communication or disclosure of commercially sensitive information it has access to, (see section 5.4 and sub-paragraph 2(b.1 where they define the expression commercially sensitive information). Insofar as Airbus has commercial rights on the data relative to the seepage of hydrocarbons in the Gulf, said data certainly bares a commercially sensitive character for Airbus, let alone Corridor, and that makes the information inaccessible. If it has access to the data or the rights to the data, Nalcor could decide to disclose it and make it available to the public as it is doing with respect to a series of geological data supplied in its disclosure policy. But, laws grant very little means to force Nalcor to disclose the information it considers commercially sensitive if it refuses access to it.



These uncertainties and difficulties of access must be understood in the context of the oil sector. The standards and practices in terms of the development of natural resources, such as in the hydrocarbons sector, generally grant a significant protection to privileged and confidential information linked to the discovery or the exploitation of a pool through the intermediary of commercial and industrial secrets, (Hardwicke-Brown, 1997). Such a protection is seen in the plan for the eventual development of oil and gas in the Gulf of St. Lawrence.

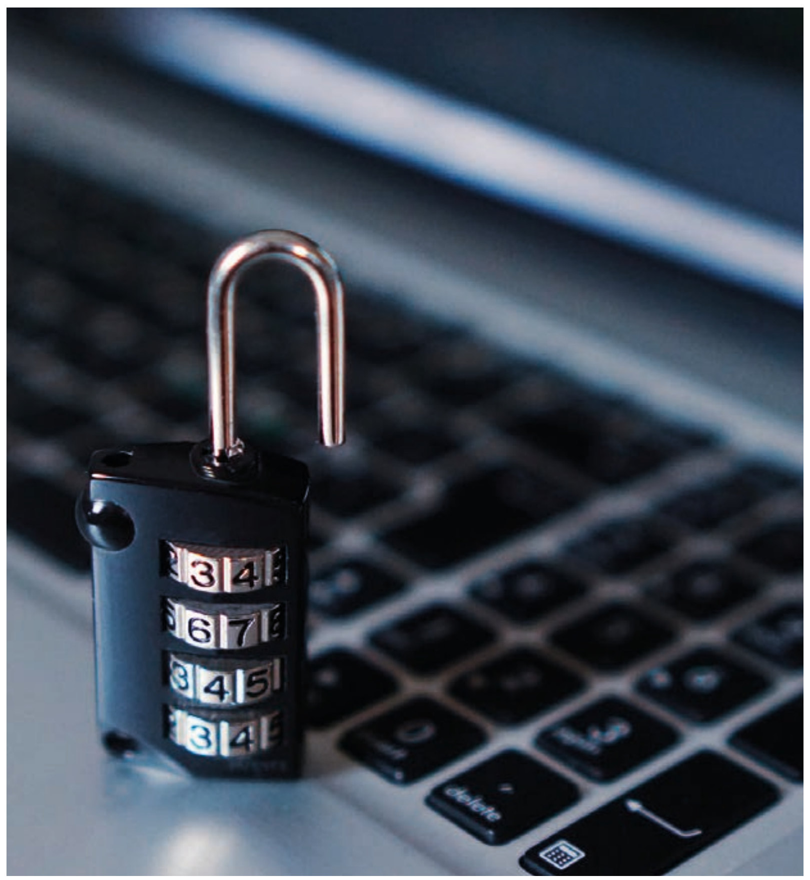
As with other similar agreements, agreed to by the federal government, and those of Newfoundland-and-Labrador and Nova Scotia, the Accord between the government of Canada and the government of Quebec, on the joint management of hydrocarbons in the Gulf of St. Lawrence, commits its signatories to treat the information received from oil or gas companies as privileged information not to be disclosed publicly without the written consent of the owner of the information, subject to federal and provincial applicable laws. This protection is transposed in a series of provisions in mirror-laws that make operational the bilateral management agreements between the federal government and the provinces bordering the Gulf. The provisions reflect the considerations our legislators and administrative decision makers keep in mind when they protect commercial and industrial secrets.

For instance, the National Energy Board and *la Régie de l'énergie du Québec* could, under certain conditions, stop the disclosure of information in the course of a public hearing with respect to a decision relating to the development of hydrocarbons in the Gulf. Such is the case if the disclosure likely risks causing losses of considerable profits to enterprises or to harm their competitiveness and if, the prejudice possibly resulting in the disclosure was to win over the importance of the disclosure in the interest of the public. The disclosure could also be stopped if confidential financial, commercial, scientific or technical information belonging to enterprises, and the interest of the enterprises, wishing to preserve the confidentiality of the information, wins over the importance of their disclosure in the interest of the public.

In the context of the hydrocarbons sector, these examples show a rather permissive approach with respect to the disclosure of information. In fact, transparency is often less important, as in the situation relating to the data on the seepage at *Old Harry*. As a matter of fact, federal law, just as much as provincial law, plans a multitude of provisions that restrain the dissemination of information of a technical or scientific nature, and protect the data available to the actors of the natural resources sector, (see Burns *et al.*, 2014). For instance, the safety and the security of the equipment, along with the loss of competitiveness or considerable financial profits, can justify the complete stop of the disclosure of information related to pipelines. Most of the time, applicable legislation ensures that geological information, pertaining to exploration activities or prospects, benefits from an accrued protection granted

Photo seepage of oil: NOAA Okeanos Explorer Program, Gulf of Mexico 2012 Expedition / FlickR

to privileged and confidential data belonging to the industry for a period of several years, to encourage those enterprises holding rights to develop resources, (Simms and Penick, 2007). In the latter case, theory has it that restrictions to the disclosure of information provide a competitive advantage to the enterprise that accesses it. In turn, that stimulates the extractive activity and the economy while increasing public coffers through the payment of taxes and royalties.



Generally, the access to information laws do not have efficient palliative clauses that would help to obtain the desired information. First of all, the access to information laws are aimed at government organisations and the agents of the state as opposed to the actors of the private sector, such as the oil and gas companies. Then, these laws play a role that is mainly completive and complementary. They will apply when the precise provisions governing the industry of hydrocarbons do not plan any precise solution. Furthermore, such laws enunciate numerous exceptions to the duty to disclose data held by administrative agencies that supervise the development of natural resources, (Baril, 2012, annual update)[4]. Hence, technical, industrial or financial data deemed confidential in the natural resources sector benefit from an exception that prevents disclosure. Such is the case for professional advice and data that could harm competitiveness of the company that supplies it.

Therefore, the many standards applicable here reflect a fluid equilibrium between diverse conceptions of the well-being of the public and the general interest. The traditional approach protects commercial and industrial secrets as indicatives to foster economic activity and to increase the material well-being of the individuals and the social value. In other words, the activity of the individual economic actor motivated by profit in the market place generates the common good by maximizing the overall wealth of society. On the other hand, the alternative perspective opposes private interest, which justifies confidentiality, to the general interest, which requires the disclosure for reasons linked to such things as health and public security. That point of view acknowledges the need for an intervention by public powers to remedy the weaknesses in the free market, which generate negative externalities of many forms, including environmental impacts, development of resource activities or the deficit of information from those who are not involved in the activities of the extractive sector. The *Code civil du Québec* illustrates the precarious balance between the two poles of the debate:

« A person may free himself from his liability for injury caused to another as a result of the disclosure of a trade secret by proving that considerations of general interest prevailed over keeping the secret and, particularly, that its disclosure was justified for reasons of public health or safety »[5]

(Civil Code of Quebec, 1991)

In this restrictive judicial context, how can one ensure that the information disseminated by the promoters (industry, consulting firm, government, etc.) is exact and pertinent in its common sense and in the scientific sense? Then one must question the bases of legitimacy upon which the research is fostered and financed when time comes to focus on matters touching, simultaneously, the interests of the industry and the public good and the environment. Would it be sound to introduce in the debate some notions with respect to the "environmentally sensitive" or "socially sensitive" data? /

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[4] See also *Nalcor Energy (Re)*, 2016 CanLII 37497 (NLIPC) re the interaction between, on one hand, section 5.4 of the *Energy Corporation Act*, which restrains access to commercially sensitive information, and, on the other hand, the *Access to Information and Protection of Privacy Act* (2015), which plan things such as restrictions to the disclosure of data by the State, its representatives when a third party could suffer economic damages form such.

[5] http://legisquebec.gouv.qc.ca/en/showdoc/cs/CCQ-1991 (translation found by the translator, on the 20th of April, 2018.

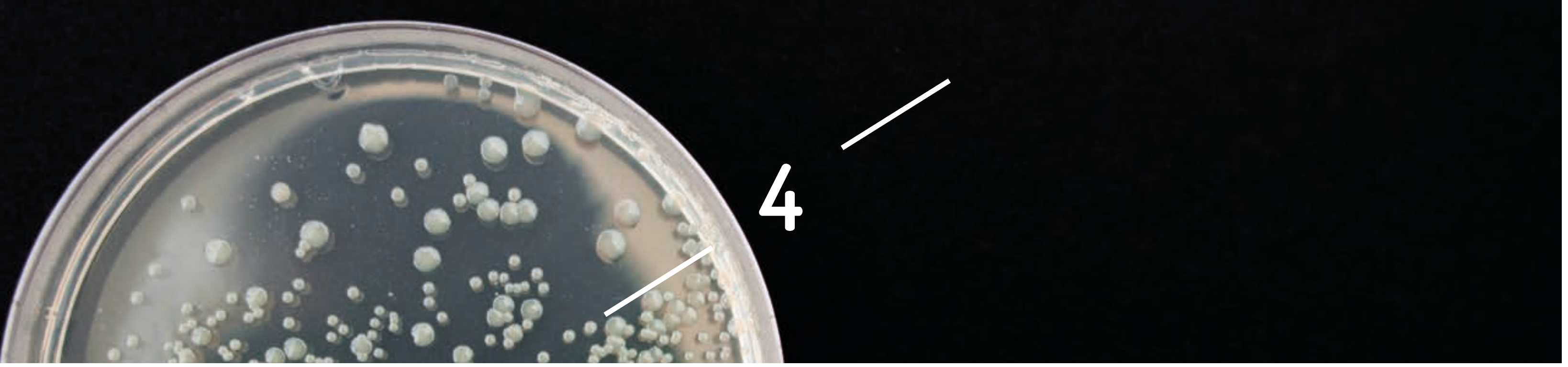

Photo: Pixabay

THE IMPACT ON DECISIONS BASED ON SCIENTIFIC KNOWLEDGE

Having no access to commercially sensitive data on possible oil seepage at *Old Harry* can have consequences for the coastal and islandic populations and the planning of research. It may generate a loss of resources (money from the taxpayer), a loss of time and favorable opportunities for the industry. In the following paragraphs, we will present an example that illustrates this issue.

Those marine organisms living in the environments where oil seepage exists are exposed to chronic oil contamination as opposed to acute contamination experienced when major spills, generally associated with accidents in the processes of exploration, exploitation or transportation of hydrocarbons, occur. This chronic exposition affects exposed organisms that, consequently, present unique adaptations that give them the possibility to inhabit these areas, and that, has most likely been the case for several generations. This phenomenon means that the adaptations are genetically coded, which gives the organisms the possibility to metabolise oil. Molecular tools would then allow for the understanding of the physiological mechanisms behind this tolerance. These organisms then become models for the impact study on oil and the adaptation over several generations in the environment in question. In the absence of more data on these possible seepages, scientific studies, whose objective is to characterize the state of the ecosystem before any perturbation generated by eventual activities of exploration or exploitation, would be biased. The effects of the chronic contamination of the ecosystems are not well known. Having the opportunity to study the Gulf of St. Lawrence to that effect would represent an important step in the understanding of the potential impact of hydrocarbons.

Furthermore, the organisms living around seepages, especially bacteria, probably have the capacity to degrade oil in the environment, (see chapter 2). In the case of accidents, their use could represent an asset in the limitation of the consequences of a spill. Yet, adequate conditions to have these organisms react should be studied. The fact that one may not be aware of their potential presence could signify a delayed answer to an environmental emergency; it might even slow down the emergence of an innovation or of a discovery in the sector. On the other hand, hydrocarbons oxidized by bacteria can be used as sources of food to benthic organisms; this is more the case in deeper waters, (Bauer *et al.*, 1990). Lastly, bacterial activity can generate a decrease in the concentration of oxygen in the sediments, while limiting the activity of the benthic organisms, (Steichen *et al.*, 1996), and this, in a system where hypoxia is a source of stress for organisms (see chapter 4). /

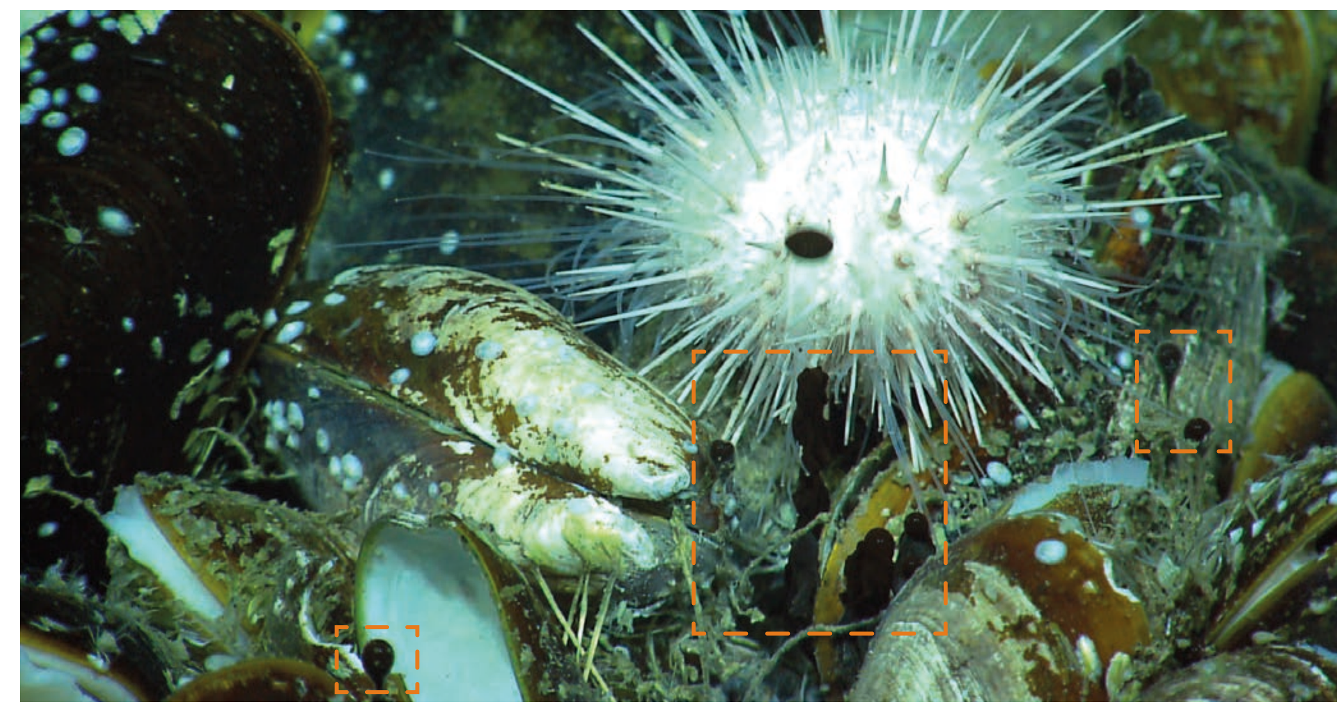

Photo of marine organisms living near oil seepages (boxes in orange): NOAA Okeanos Explorer Program, Gulf of Mexico 2014 Expedition / FlickR

CONCLUSION

The analysis of this situation illustrates the vigilance we must show with respect to the environmental information disseminated by the industry for this type of social issue. The fact that the industry presents the conclusions of an internal technical study -which would appear to be scientific- does not mean the information meets the standards of transparency, rigor and falsifiability emblematic of scientific research. Let us say that this does not apply only to the industry but also to any group that claims any position based on presented information of a scientific nature. Sometimes, science might be used to add or give credibility to information, but we must remain attentive when technical information is presented in this way. Scientifically speaking, at least in the field of natural sciences, any information that cannot be counter-verified nor submitted to criticism, because its sources cannot be revealed, has no value. Ethically speaking, neither the industry nor any other group should indulge in asserting anything publicly without having the possibility to reveal all the sources and analyses that led to the conclusions disseminated. No doubt, the industry can keep its own secrets but, in this case, it should keep them entirely to itself. The highest level of transparency must prevail from the very moment an industry or a group asserts anything publicly on an environmental issue that is closely related to a situation of such importance as that of the potential development of hydrocarbons in the Gulf of St. Lawrence.

Science very much rests on questions and the critical mind. We, herein, encourage any citizen, environmental, scientific, public or industrial group to remain critical of the information disseminated by any other group (citizen, environmental, scientific, public or industrial). There is no doubt, the first and simplest way to exercise one's critical mind is to ask questions, and that is what we are inviting you to do as much as possible. As a matter of fact, we end this conclusion by asking again a series of questions to Corridor Resources regarding possible persistent seepages it has detected as emanating from the flanks of the *Old Harry* Prospect:

1) Can you provide reports of the analysis and the data from the satellite images that led you to come to the conclusion to the effect that there would be six sites of natural and persistent seepage emanating from *Old Harry*?

2) How many images and over what period of time were these seepages detected? Does one image show six simultaneous occurrences of seepage? Is it from different images? Is this a synthesis of tens or hundreds of images? Basically, what is the statistical robustness of these analyses and conclusions?

3) How did you determine that these seepages were of a natural origin?

4) Out of all the analyzed images, how many show, with no ambiguity whatsoever, any sign of seepage? In other words, how did you determine that the seepages were persistent? Was it from several satellite images taken over many years that would have shown the systematic presence of these same six slicks above *Old Harry*?

5) How did you determine that the detected seepages came directly from the flanks of the *Old Harry* Prospect, and not from elsewhere?

6) Has the analysis of the satellite images covered all of the Gulf or only the *Old Harry* region?

a. If the analysis of the satellite images covered the entire Gulf, have other indications of actual seepage been detected elsewhere in the Gulf? If so, how many and where?

b. If not, if the analysis only covered a region around *Old Harry*, how did you come to the conclusion that the *Old Harry* region was seeping more oil than anywhere else in the Gulf?

The answers to these questions would certainly help government institutions make decisions based on real scientific knowledge. /

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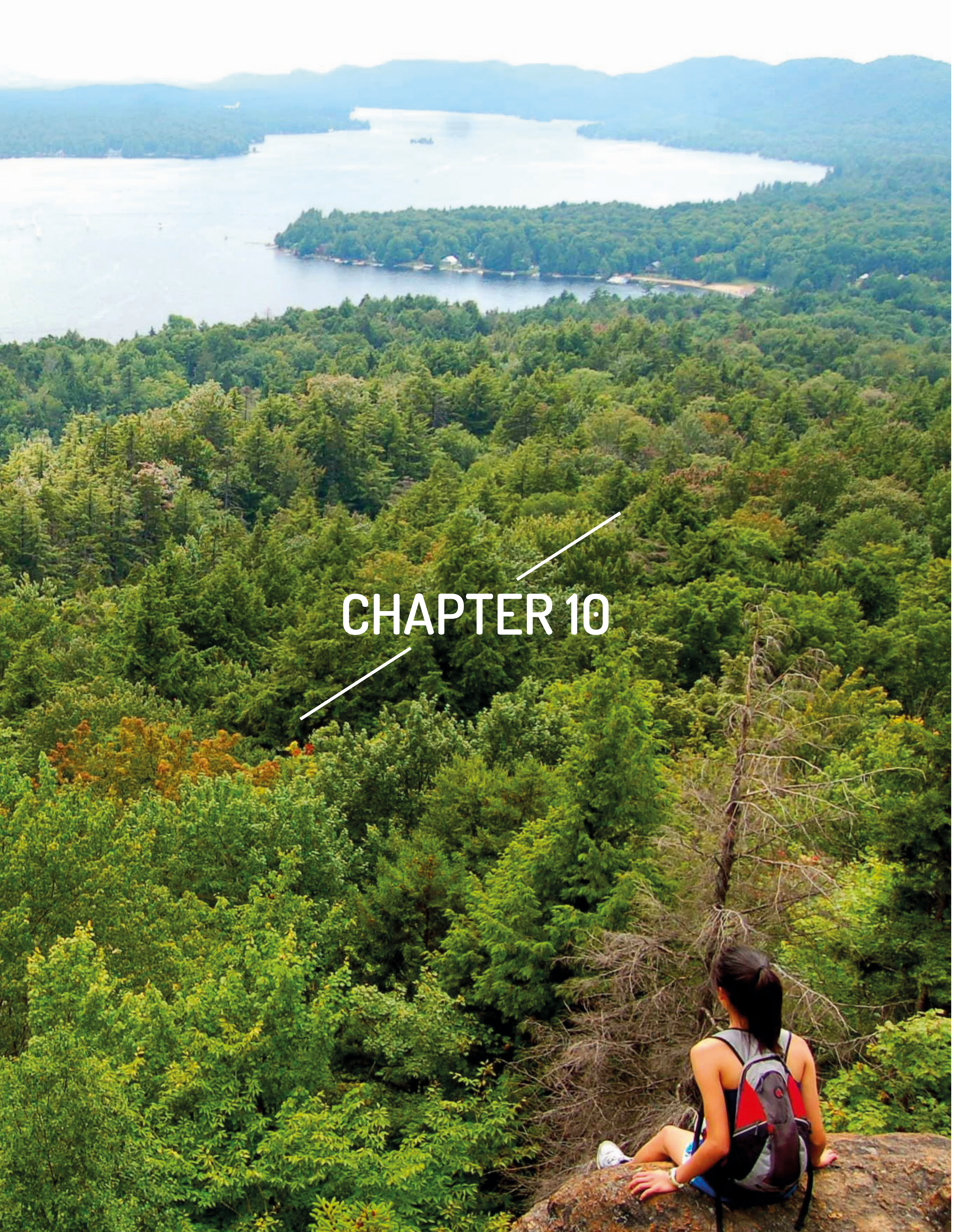

Environmental and sustainable development, education on the gulf of St. Lawrence: principles, educational approaches and types of engagement of youth citizen

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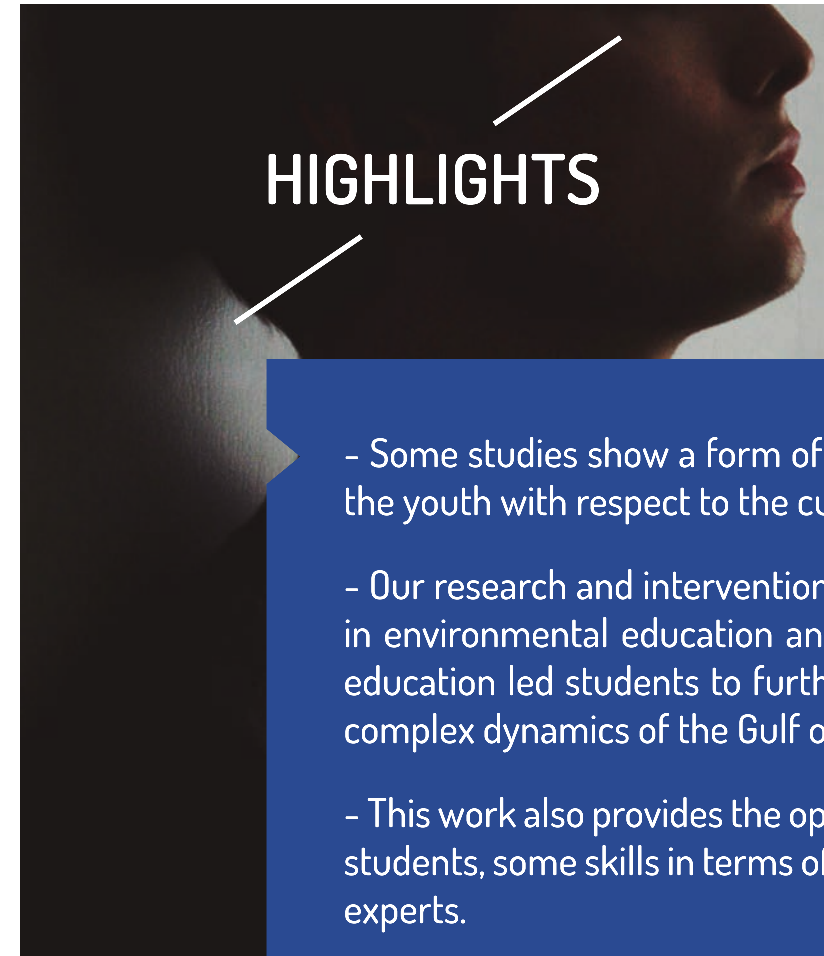
The theoretical foundations and the principles guiding our works on pedagogical innovation and research on education in science and the environmental and sustainable development education (ESDE) are presented in a brief manner, that to concretely illustrate -afterwards- how to put into practice a type of youth education that will initiate them to the current knowledge, to the research practices and to the complexity of the issues raised by the preservation and the sustainable development of the Gulf of St. Lawrence, which particularly apply in the case of the exploitation of hydrocarbons. Then, we will describe two educational approaches that we have developed and taught in classrooms. The first one was an interdisciplinary project on climate designed for two classes of students in their fourth year of high school in the Lower St. Lawrence region. It illustrates how we can lead students to further their understanding of this complex question in an interdisciplinary manner, to get documentation on certain current research practices and to dare exchange with an expert on a theme of their choice. The second educative approach, conducted amongst students of the 6th grade of an elementary school, had them learn the physical or geographical characteristics of the St. Lawrence, the evolution of the uses of the river, along with the vulnerability of the sea mammals to noise pollution from maritime traffic and the mining of marine beds. Furthermore, students became aware of the geographical origin of many objects they currently consume and that are shipped by boat. Then, they were initiated to different ways to engage in the protection of the St. Lawrence, either as a career choice or as citizens. Lastly, after our presentation on the way these two approaches work, we addressed the concept of eco-citizen engagement and emphasized what research is teaching us about the knowledge, attitudes and customs of youth pertaining to environmental issues. One of the principles that provided direction to our work consists in defining the characteristics of an education that would make more sense to students. We think we will thus be better at getting their direct attention, in school, by exploring ahead of time the manner with which one can engage as a citizen in environmental issues. This gives us the occasion to describe the teaching on the St. Lawrence that these students deem significant, on their analysis of the environmental crisis and on their way to react to it. Lastly, we will highlight possible ways to deal with education and research while taking into account these characteristics.

Photo:
S. Bonvalot

INTRODUCTION

As women involved in the research on education in the sciences and education in the environment and sustainable development (ESDE)[1], we are interested in the many educational issues raised by controversial environmental questions. In this chapter, we will address education for the citizen in the context of an eventual exploitation of hydrocarbons in the Gulf of St. Lawrence. We work, keeping in mind, that we are training the younger generation by inviting them to engage in the debates that concern them, in a well-documented, thorough and critical way, as they acquire the most accurate possible knowledge giving them the confidence in their capacity to change things, and inviting them to ask questions of experts and then, to take a position. To that effect, and in the footsteps of different researchers (Bencze et Alsop, 2014; Bader et Laberge, 2014), we believe in the importance of an ESDE that initiates students, at the end of elementary grades and at the high school level, to think critically about scientific research and to the several challenges that our western relationship with nature raises. We also believe that,



HIGHLIGHTS

- Some studies show a form of paralysis or fatalism amongst the youth with respect to the current environmental crisis.

- Our research and interventions in education in the sciences, in environmental education and in sustainable development education led students to further their understanding of the complex dynamics of the Gulf of St. Lawrence.

- This work also provides the opportunity to develop, amongst students, some skills in terms of research and interaction with experts.

- Different types of relationships which students entertain with scientific knowledge have been defined (practical, confident, critical), as they correspond to the different profiles of eco-citizen engagement.

- This research sheds a light on the importance of the approach on the identity and cultural dimensions of the relationship that the coastal communities of the Gulf have with nature, such as the aboriginal communities, to reflect upon its protection for future generations.

[1] We see two distinct educational currents:
1) environmental education;
2) education on sustainable development, as defined by UNESCO. In these two educational currents, we acknowledge the pertinence of certain research projects, approaches, theoretical or pedagogical practical thoughts. Therefore, we use in this chapter the expressions "environmental education" and "sustainable development" to emphasize the fact that we use both schools of thought, when the proposed approaches seemed pertinent, especially when they put forward the principles of critical pedagogy. We do not further develop these considerations in the framework of the present chapter, even though they are the object of several debates in the community of researchers in education related to the environment or education in sustainable development.

to pique the interest of young citizens, we must take into account their concerns and their projects, and aim at their emancipation, i.e. ensuring they become aware of the way some cultural codes, some standards and leading ideology orient their thought patterns and lifestyle, to create reflective thinking and a critical sense.

In this chapter, we first illustrate the principles that guide our pedagogical actions. In a general way, this means we will grant the importance to vigilance from citizens and to our management of nature and its consequences. We will emphasize the importance of teaching science in a way that will mobilize youth. Furthermore, we will, albeit very briefly, present the principles of critical pedagogy leading us to value the positions of the youth, in terms of identifying the functions at their base, whether it is their history, their culture, their familial context or the territory where they belong. To illustrate the implementation of these principles, we present two educational approaches carried out in classrooms. The first consists in teaching an interdisciplinary course on climate change to grade 11 students, while the second addresses the protection of the marine biodiversity of the St. Lawrence to 6th graders at an elementary school. The first example provides the possibility to identify not only the significant knowledge on the St. Lawrence achieved by students, but also their interest in science and research practices, and in furthering, in the classroom, the understanding of the complexity of climate change. We also talk about the types of eco-citizen engagement we have identified amongst those students who took part in this project. After presenting these two educational approaches, we will finally refine the educational and research perspectives which could be appropriately privileged with respect to the issues of exploitation of hydrocarbons in the Gulf of St. Lawrence. /

Photo: M. Teixeira

1 THE IMPORTANCE OF AN EDUCATION IN ENVIRONMENTAL AND SUSTAINABLE DEVELOPMENT OF THE ST. LAWRENCE THAT INITIATES SCIENTIFIC RESEARCH AND MOBILIZES YOUTH

In the *Stratégie gouvernementale de développement durable 2015-2020 du Québec* (MDDELCC, 2015), a work project that is dedicated to sustainable development education. Everywhere, the ESDE is becoming an important national issue, (UNESCO, 2015). Furthermore, in a context where, in 2015, the *Gouvernement du Québec* launched its *Stratégie maritime* (Quebec, 2015), sustainable development of the St. Lawrence is becoming a matter of great importance which will call upon youth, as they will have to live with the consequences of decisions made today.

Photo: M. Teixeira

Yet, environmental questions do not necessarily generate the needed interest and mobilisation. In fact, the majority of youth in Quebec or elsewhere do not seem to consider preservation of the environment as a priority, (Royer et de Grandpré, 2015). Amongst them, a large number act on an individual basis, sometimes more to conform than to follow personal conviction. For instance, youth recycle or reuse certain products, but without analyzing the consequence of their action, without looking in a deep and critical way at the structural causes of the environmental degradation. Their knowledge of standards and regulations and their participation in proceedings and the democratic processes, which guarantee the enforcement of current or bonified laws, remains minimal. Some authors go as far as talking about the depression of youth when it comes to the environmental crisis and to the catastrophe-filled discourse repeatedly served; they also stress a certain fatalism and, for a good number of them, that they do not have the power to change things, (Zeyer and Kelsey, 2013).

Photo:
M. Teixeira

Therefore, education has an important role to play, especially to bring confidence back to the youth and to concretely mobilize in an interesting manner. This is about enhancing the knowledge and developing, amongst the youth and the less young, different ways to become aware of attitudes, values, critical judgement and the creativity needed in citizen engagement that is discriminating and that respects nature and people, that cares about common wealth and that leads to targeting necessary transformations. In our perspective, this is about making sure youths and adults feel empowered to debate complex environmental questions such as the eventual risks relating to oil activity and feel competent to do so. Which means to be in a position where one can question experts on this topic and participate in public debates in an informed and thorough manner.

It is within this context that we propose to enhance scientific knowledge, to renew current concepts around science and to study forms of eco-citizen engagement of the Quebec youth, boys and girls, at the end of their high school years, about the sustainable development of St. Lawrence. Starting in 2008, our research team has collated different results regarding students in the 4th and 5th year of high school. The way with which these students conceive the meaning of the expression "to do sciences", their interest for that field of knowledge, along with their knowledge on climate change and their engagement, in school and as citizen in the context of this question, have particularly piqued our attention, (Bader *et al.*, 2013, 2014, 2015). In an exploratory way, we created links between certain types of relationships to certain types of scientific knowledge, to scholastic engagement and to eco-citizen engagement. We met a minority of students who were more critical about what their school is proposing to them and who often show their concern over environmental questions. They denounced the economic and political international situation with respect to the lack of social justice and structural action towards the preservation of the environment. However, they still did not know how to transpose their concerns into citizen actions that are sufficiently thorough, documented and designed to take advantage of current laws and regulations, (Morin *et al.*, 2015).

This is about enhancing the knowledge and developing, amongst the youth and the less young, different ways to become aware of attitudes, values, critical judgement and the creativity needed in citizen engagement that is discriminating and that respects nature and people, that cares about common wealth and that leads to targeting necessary transformations.

We base ourselves upon the principles of critical pedagogy to conceive the foundations and the practical modalities of the ESDE, (Bader, 2011; Bader et Laberge, 2014; Freire, 2013; Giroux, 2011). We are initiating students to research practices and to current scientific knowledge on environmental questions that they are concerned about: climate change, protection of the biodiversity, energy issues and exploitation of hydrocarbons. Then, we make them aware of the importance of their role as citizens by suggesting different ways to get engaged that have proven fruitful. We also subscribe to a prolongation of a scientific didactic based on Piaget's theory, (Piaget, 2012; Piaget et Inhelder, 2012) which pays attention to the development of the intelligence of students by taking into account their initial understanding, their logic, and their understanding of difficulties, and that consequently adapts the educational approaches, the proposed experiences and the courses. We also share the positions of authors such as Sadler *et ses collaborateurs* (2007), who promote the concept of opening the mind of students in their last high school years to the complexity of environmental questions, complexity relative to uncertainties and, often, to the absence of knowledge at play, but also to the interests, values, representations and prioritized issues in their analysis. To transpose these considerations in the classroom, we suggest a didactic of interdisciplinarity, (Fourez *et al.*, 2002; Bader *et al.*, 2013) and we frame it into a didactic of environmental questions, (Legardez et Simonneaux, 2006, 2011) which aims at the use of supervised debates in the classroom. All this led us to the validation of several educational activities and to glean the opinion of the students to identity their scope and limitations. /

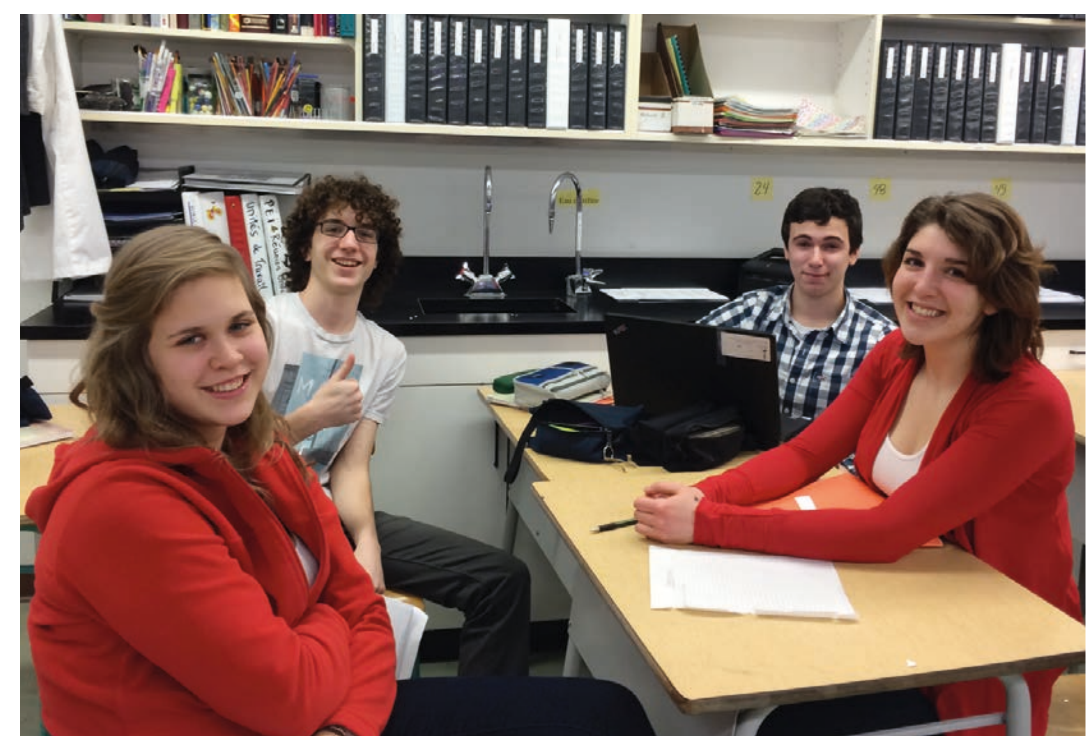


Photo:
G. Therriault

Photo: M. Teixeira

EDUCATING *IN TERMS OF* THE YOUTH AND *FOR* THE YOUTH, AND RENEWING THE SCHOLASTIC CONCEPT OF SCIENCE TO INTEREST THEM

One of the important principles in critical pedagogy consists in linking the pedagogical propositions to the concerns of the youth. This means working "in terms of" these youth, "with them" » and "for them", based on propositions made by Henry Giroux (2011), who believes that schooling has often lost its focus on the concerns of youth even when they are interested in science outside of school, (Osborne *et al.*, 2003). Also, several studies on the didactic of science illustrate that the teaching of science tends to reinforce a concept of the sciences that has little to do with the current research practices.

Photo: Collections École Polytechnique / Jérémy Barande

This idea that a researcher works alone, in a laboratory, is still widespread to the detriment of the one that includes team work, writing funding applications, participating in conventions, the debates of knowledge with colleagues and the explicit confrontation with numerous links between science and society. Facing this fictive concept, a second representation, a more socio-constructivist one, includes work on research in society, it defines actors who develop the knowledge, it sets them in real contexts, it refines certain social interactions that characterise scientific research and, consequently, it contributes to making science more accessible, (Latour, 2001; Fourez, 2002). All of this can also incite dialogues amongst citizens and experts. The distinction is important in education because these two representations of research practices do not lead to the same type of relationship to scientific knowledge.

Thus, an ESDE on the Gulf of St. Lawrence should reinforce the knowledge of the students, while trying to mobilise them and develop their critical judgement. Still, for knowledge that is taught to become interesting and exciting to students, one must know both the students and their interests; link the meaning of what is being taught to their identity and their culture; taking into account the social context and their territorial anchorage; and give special weight to pedagogical practices that give them their autonomy and make them responsible. Which is why cultural studies are important in ESDE, (Zeyer and Kelsey, 2013; Corcoran and Osano, 2009; Giroux, 2011), as they give the possibility to identify the ways with which youth from different cultural contexts understand environmental preservation, and sustainable development of their territory, and then to take such things into account in the classroom, (Martinez et Chamboredon, 2011; Schlosberg and Carruthers, 2010). This is also about us, as we have to give more meaning to what is taught in schools by linking the students to real issues and providing examples of successful eco-citizen engagement.

There are different pedagogical currents in ESDE (Scott and Oulton, 1999), going from the enhancing of knowledge on the environment in a interdisciplinary manner that draws from notions of biology, chemistry or physics, to approaches that, instead, foster interdisciplinary projects, (Fourez, 2001), and to approaches that aim at strengthening the affection link with nature. We can also work on bringing clarity to values and critical analysis of the neoliberal economic system. That way, critical pedagogy proposes to contribute by making codes and leading schools of thought more explicit and based on such things as individualism and the myth of technical progress. It also wants to remove the masks off the authoritarian and unequal rapports in school and, more widely so, their consequences on our relationship with nature and other people. Based on these principles, we must return to lifestyles that are simpler, more respectful of nature, pacifism and solidarity; develop those values in school; engage youth in constructive dialogues on the multiple dimensions of the environmental issues and concretely work in the analysis of complex issues, but remain in precise territories to identify the main elements to generate solutions.

Basically, we promote a reinforcement of the scientific culture in the youth by addressing social issues pertaining to the protection of the environment. We initiate them to some current research practices to enhance their conception of science. Then, we show examples of mobilisation for the environment, that proved successful, and of interesting careers, that can be taken as ways to engage oneself as citizen for environmental preservation. /

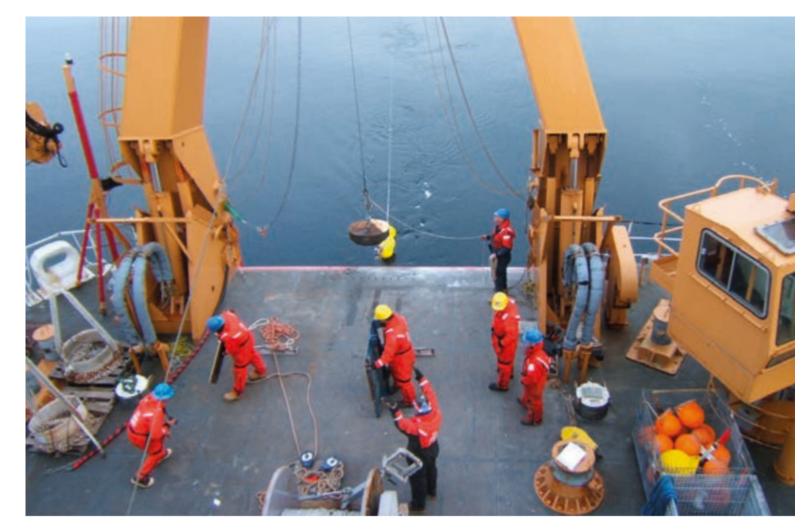
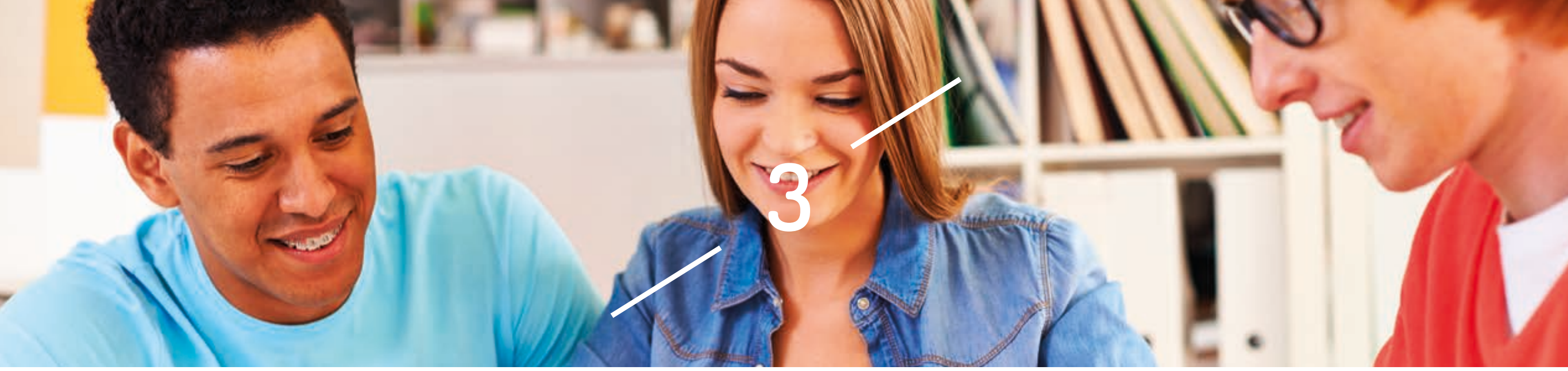


Photo: Collection of Dr. Pablo Clemente-Colon, Chief Scientist National Ice Center



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AN EXAMPLE OF AN EDUCATIONAL APPROACH ON CLIMATE CHANGE TO SECONDARY 4 LEVEL STUDENTS

Photo: D. Kalenitchenko

A specific project[2] led us to work jointly with three teachers of secondary level 4 history, science and ethics in a high school located in the Lower St. Lawrence region (see Box « The approach in the classroom » - next page).

Let us note here some elements on the knowledge about the St. Lawrence that students consider useful, pleasant and important. In the following lines, we will also refine what they told us as to their interest in science and research practices, how they address the complexity of the climate question and the types of eco-citizen engagement we identified.

[2] *Conseil de recherche en sciences humaines* (CRSH), Therriault et Bader, 2012-2015.
[3] Intermediary Education Program – (IEP) loose translation
[4] *Programme de l'organisme Baccalauréat International (IB)*: www.ibo.org/fr.
[5] We will not elaborate on our theoretical structures. Suffice it to say we are interested in the significance that youth give to scientific knowledge as it is taught in the classroom. We also wish to be more precise as to their way of engaging in school and to identify how they mobilize -or not- around and environmental questions. The first student/portraits we were able to draw in an exploratory way from this theoretical structure which helps identify some student-types differ, either on their conception of natural and social sciences or their attitude in school or as citizen in the light of the environmental issues. We present some of these elements in section 4.

THE APPROACH IN THE CLASSROOM

Two groups of students ($N = 45$) of the *Programme d'éducation intermédiaire*[3] (PEI)[4] were asked to document a topic of their choice on climate change. They were to proceed in an interdisciplinary fashion by raising four issues on the topic (issues that were either environmental, political, social or economic). They also were to target a controversy and a research practice, then meet an expert on the theme. Such a project unfolded over a period of five months during which seven periods of 75 minutes each were given to students to further their work. At the end of their research, each team wrote an essay as an answer to guiding questions that were meant to orient their reflective thinking:

1) What can we do to address the perspective of the climate change?
2) Can science tell us what to do?

The teams were to also present the important elements of their paper to other students in the classroom. Examples of the themes addressed were as follows:

- The impact of the delocalisation of enterprises on climate change;
- Oil spills;
- The impact of climate change in the waters of the North;
- The resilience of the communities facing climate change.

To better know the youth who participated in this study and to evaluate the scope of this approach of interdisciplinary teaching, we first created a written "knowledge profile" with the students, (Charlot *et al.*, 1992) using individual questionnaires. That gave us the opportunity to update their knowledge in science, they said they had acquired ever since their childhood, to verify the origin of the knowledge (school, family or other), to determine if they considered it as useful, pleasant and important, or not at all, and the reasons why, (Bader *et al.*, 2014). We also had several conversations on climate change with small groups of students at the end of the approach to refine the measure with which we had reached our objectives. Finally, we held a second individual conversation with 12 of them, the following spring, as they had then reached the secondary 5 level. We collected the data in several ways and at different moments within the approach.

In the framework of this interdisciplinary teaching approach, our interests of research addressed the relation of the engagement of the students[5] (Bader *et al.*, 2014) to scientific knowledge, school engagement and eco-citizen. The semi-directed conversations with the small groups of students, held at the end of the educational session, gave us the opportunity to refine the conversation with the students to enhance their conception of science, such as documenting a specific research practice, and determining if they considered the researched issue as complex.

THE LEARNINGS ON THE ST. LAWRENCE STUDENTS DEEMED SIGNIFICANT

Amongst the 68 students who, at the outset, were sent the "knowledge profile", 62 answered the first question demonstrating significant knowledge. Out of those, 79% referred to knowledge on the living universe (biology, ecology). A total of 95 significant facts referred to the living world over a total of 182 facts deemed to be useful, pleasant of important. Out of those, were the noteworthy occurrences of significant information related to tides, marine biomes, biodiversity, benthos and the pelagic zone, and objects of knowledge directly touching on the Gulf of the St. Lawrence. And amongst this knowledge, 58% came from family environments while only 26,4% of the other significant facts reported were from a family environment. This important proportion of home teachings, addressing the region of belonging, might be explained by a noteworthy concentration of specialists on the St. Lawrence in the region[6], -several are the parents of the students- but also by the strong significance the St. Lawrence Estuary has for the people living in the region where the study took place. These results shed light suggesting that it might be interesting to study the importance that students, from different regions of Quebec, grant to the knowledge of the Gulf of St. Lawrence and its sustainable development, taking into consideration things such as the potential exploitation of hydrocarbons.

Photo: P. Archambault

THE INTEREST IN SCIENCE AND IN RESEARCH PRACTICES

Although students, who answered questions, claim to be interested in science[7], a good majority (60,6%) say they know nothing or very little about the way scientists work to study climate change. Amongst the other students, 19 talked about it in very vague terms (28,8 %).

We asked students to document a research practice and to meet an expert (scientific or citizen) to validate their documentation, on the theme they had selected, in the framework of this teaching approach on climate change. Students documented almost as many research practices in the field of natural sciences as they did social sciences. At the outset, they seemed to entertain a representation of research practices in natural sciences that is not very precise and traditional; students talked about observations, experimentation, laboratories and surveys in the field. As to the social sciences, they had a much harder time explaining what researchers in economics, politics and regional development do compared to those they have met. In fact, they seemed to have very little vocabulary to that effect.

In a general way, students who took part in the approach learned that there were numerous and varied research practices and that researchers often work in teams, just like they do. They seemed awed to find out researchers are sociable people and that discussions with them is possible and fruitful. Generally, they did not doubt the validity of what the expert they met told them. In fact, those conversation with a researcher or an engaged citizen were decisive as to their interest in the proposed approach. Therefore, 10 teams out of 12 said the conversation with the expert constituted a central point in their approach, that such a meeting was motivating and interesting or that it gave them a chance to validate several documented elements.

On that point, it would be interesting to verify ahead of time what youth know about current research addressing the exploitation of hydrocarbons or, in a general way, the Gulf of the St. Lawrence, either in terms of natural sciences or social sciences. The progressive and systematic introduction of these considerations in the classroom, throughout the high school and college education years, would be formative whether it was to touch the initiation to research or current careers in science on the St. Lawrence.

Photo: S. Chayer

THE COMPLEX ISSUE THAT IS CLIMATE CHANGE

In the course of the conversations at the end of the project, several students said they understood that knowledge on one question, such as climate change, was wider than they thought in the first place. They also said that the approach gave them a chance to further several of its aspects with precision, which they said they never did in class even though the climate change theme was often talked about, but in a superficial way only more or less interesting to them. It is also interesting to note that several students became aware that a complex environmental issues would benefit from an analysis that uses several disciplines.

6 In the Lower St. Lawrence region, one will find the *Université du Québec à Rimouski* (UQAR). It houses many researchers in different disciplines interested to varying degrees in the St. Lawrence River. One will also find the *Institut des sciences de la mer de Rimouski (ISMER), l'Institut Maritime du Québec (IMQ), l'Institut Maurice-Lamontagne*, part of Fisheries and Oceans Canada, and several private companies linked to marine technologies.

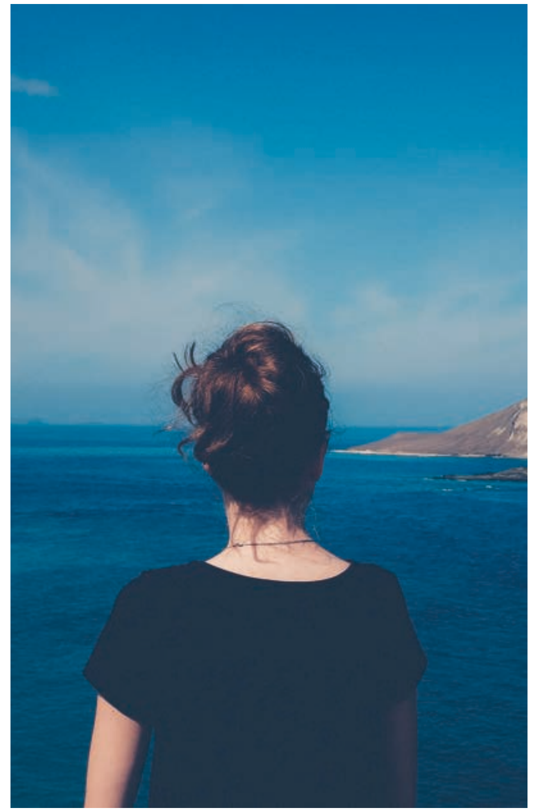
7 Out of the two groups participating in the project, 82.4 % of the students say they are very interested or quite interested in science classes.

THE TYPES OF ECO-CITIZEN ENGAGEMENT

Within the framework of this same study, our exploration of the eco-citizen engagement concept and of its different dimensions led us to characterize how youth define environmental questions, their causes, the possible solutions and their role as citizen with respect to these questions. Hence, we verified the extent to which these students felt concerned and interested by these questions, if they had knowledge and got information, and if they considered that they have the power to change things. We also listened to them talking about their desire to get involved and in which way they would; have any adults or projects on the environment affected them; do they go out in nature frequently; are they attached to it; do they participate in democratic life on these questions and are these experiences conclusive as far as they are concerned. Those are the many elements that might influence the way they will engage as citizens when it comes to matters addressing the environment.

Let us note that different studies in ESDE show a form of paralysis or fatalism amongst youth with respect to the current environmental crisis, considered as too catastrophic for solutions to still exist, (Zeyer and Kelsey, 2013; Connell *et al.*, 1999; Fielding and Head, 2011). When they act, youth would generally use actions that are relatively current, such as recycling, reusing items, using public transit, acting the conventional way because they were repeatedly told that it is important, (Bader *et al.*, 2013).

Some of them showed some cynicism. In a series of conversations held in a secondary school in the Quebec City area, with secondary level 4 students, during the course of prior study, (Bader *et al.*, 2013), over half of the students (27) met, and explained their frustration these problems are causing - problems for which



they did not feel they were responsible for in the first place. Instead, they feel that they have to face the consequences of the inaction of adults, these very adults who tell them what to do, without getting involved themselves. These students also said they considered these actions important for the protection of the environment, but that, if the large corporations and governments did not get involved any further, their efforts would be wasted.

Several elements are important to support the mobilisation of citizens, such as suggesting examples of successes that have a real impact and to walk alongside important adults who are really involved. It is also important to analyze the structural and ideological causes, the power plays and interests or values that provide direction in the decision-making process. Furthermore, according to Wals and Jickling (2009) amongst others, we must avoid getting youth involved in entirely predefined projects as this would contribute to reinforcing their disengagement.

Instead, it would be better to give them more power and autonomy to decide and to make them feel responsible, (Bader *et al.*, 2010). Let's emphasize that some high school graduating students are indeed aware of the political, structural and ideological causes of these societal questions, and that they could play a leading role in the classroom. Thus, it is important to look further into the logic behind the mobilisation of students and to better understand what causes their disengagement, and to propose educational projects and challenges that will attract their attention. Those are the considerations that led us to study the engagement of youth eco-citizens at the end of the high school years.

Through the analysis of 12 individual conversations that took place one year after the end of our educational approach, we have identified three types of eco-citizen engagement amongst these youth, (Morin *et al.*, 2015), in a most exploratory fashion. We must understand that the distinctions suggested herein need to be refined at a later date, as that will be part of a subsequent study amongst a larger number of topics. They are suggested as a way to demonstrate the eventual scope of this kind of study. These are the three types of engagement with respect to the environment we are currently suggesting:

› THE FIRST TYPE OF ENGAGEMENT: *A QUASI-ABSENCE OF ECO-CITIZEN ENGAGEMENT AND SOME PESSIMISM*

Some actions with a reputation to be good for the environment are being done without any conviction or analysis. This is an example: David[8] is a student who does not think he has the power to change things and who has no intention to "change the world". He recycles objects, avoids wasting and overconsuming but does not think these have an impact: to him, those are but "drops in an ocean". "If everybody did this, there might be a chance", but he says he is pessimistic. To him, most people do not want to change. The government leans to the right; therefore, the economic logic prevails and hold the power. He says the information would help him develop his critical sense. Nevertheless, David does not spontaneously get information on environmental matters. He does not feel he is engaged and delays such an engagement to a later place in time.

[8] The first name of all the students in this chapter are fictive.

› THE SECOND TYPE OF ENGAGEMENT: *SOME RESPONSIBILITY TAKING WITHOUT GOING TO A FULL PARTICIPATION IN CITIZEN ACTIONS*

The youth acts on a daily basis, solo, with respect to things he grants some importance to, but has no desire to get involved with the community. For example: Louis recycles, composts, limits his personal water consumption, bikes occasionally and is not inclined to overconsume. He acts rather easily but not systematically. Louis summarizes his engagement saying that: "It may be individualistic, but I do my part, so, don't bother me too much with that stuff!" Louis thinks that, if he felt more and if there is an emergency, it would be the only way to push him to get more involved. Marie-Hélène, acts occasionally as she feels concerned about the environment. She says she now shuts the tap when she brushes her teeth and she recycles, for instance. She knows what she could do to adopt a more respectful behavior toward the environment, such as not buying any new clothes, using a bike, participating in citizen movements, even taking a leading role in citizen actions, but will not do it.

› THIRD TYPE OF ENGAGEMENT: *A PARTICIPATIVE AND CRITICAL ENGAGEMENT TARGETING COLLECTIVE ACTION FOLLOWING THE CRITICAL ANALYSIS OF THE STRUCTURAL CAUSES OF THE ENVIRONMENTAL PROBLEMS*

This type of engagement israre. Alice is a good example. When we met with her, she told us she was learning from the classroom and was motivated by social conscientiousness. She prefers social sciences to understand why and how society evolves. She finds that sciences, such as those taught in school, do not go far enough. Her parents prefer home debates, which she appreciates. She often gets bored in school, as she finds it too rigid. There should be more room granted to creativity and the autonomy of the students, taking into account their concerns. Environmental questions pique her interest. To her, individualism is a problem. She mentions an obvious concern for the common good, for future generations and for sharing. She believes that, collectively, we hold a huge amount of power. As consumers, we approve the system. She does small things, but, to her, change will not happen that way. She also tries to convince other people. She knows an activist who takes the floor a lot of the time, which she sees as taking some of the power. She believes that speaking publicly is a way to influence others. To Alice, knowledge and power go together. Schools are currently failing, they must do more. The presentation of various points of view and issues would be a good start, just like undertaking constructive debates to help students showcase their opinion.

EDUCATIONAL POSSIBILITIES THAT WOULD TAKE INTO ACCOUNT THE OGIC OF THE ENGAGEMENT OF THE STUDENTS

No matter the profile of the students that were met, some important points need to be highlighted. First of all, it is necessary to have students increase and refine their understanding of the causes of the current environmental crisis by addressing, for instance, one or two case studies in an interdisciplinary way during the high school years. Several students mentioned that the approach on climate change led them to further understand the different sides of that question. When they put together all of these sides at the end of the project, the *exposés*, addressing each one of those aspects, made them aware of the complexity of the question, which according to them, had been approached, at the onset, too superficially in the classroom.

As to the students who say they are basically not that concerned over environmental questions, we are targeting an explanation on the action levers and those of social and environmental transformation. For instance, addressing causes and consequences of overconsumption is indispensable. This is also about illustrating, in a concrete fashion to these students, some well documented and known pollution misdeeds and some conclusive solutions that will reinforce their feeling that it is possible to change things. It is also appropriate to include, during classroom time, time to speak up and to make students responsible in the unfolding of school activities, and to propose to these students an inviting conception of scientific research. To strengthen the will of high school youth to get involved in a more participative and more collective way, we also illustrated processes and targeted real democratic instances along with standards, laws and rules, such as those that have allowed for the recovery of sites for nature preservation in Quebec. In the case of the ESDE module, designed for students at the end of the elementary school years, addressing the protection of the marine biodiversity of the St. Lawrence, we have also documented how the involved actors managed to create the Saguenay-St. Lawrence marine park. This concretely presented to the students how changes are possible starting with current laws and rules, while using democratic instances to a right end.

As we will define in the next section, we also presented to the students some examples of citizens who, using their profession or their conviction, get involved and successfully pressure to protect our environment. Let's add that another important element of our work was meant to value youth knowledge and scientific knowledge and to concretely illustrate the ways with which researchers find answers to their research questions, while giving value to the scope of the knowledge when it provides the opportunity to orient political choices for the better. Lastly, we promoted, as an approach to all the students, more training and support on critical and involved positions at school. This might mean that students who are capable to do this type of critical analysis should be further encouraged to participate more actively in the life of the classroom and act as a leader. /

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AN EDUCATIONAL APPROACH IN THE 6TH YEAR OF ELEMENTARY SCHOOL: ENHANCING THE KNOWLEDGE IN SCIENCE AND HISTORY OF THE ST. LAWRENCE AND MODELS OF ECO-CITIZEN ENGAGEMENT

In 2015, we were invited to design an ESDE module for two groups of 6th grade students in an elementary school of the Lower St. Lawrence[9]. To make them aware of some issues relating to the protection of the marine biodiversity of the Gulf of St. Lawrence, we developed a course on science and historical-geography, while the two teachers involved added their activities in French, Mathematics, English and Arts, as required. To remain coherent with the principles we previously enunciated, we emphasized content relating to the Lower St. Lawrence territory (content which could easily be transposed to other students in other regions).

This activity took place in six steps. First, following a discussion around the original knowledge of the students regarding the St. Lawrence, the main geographical and physical characteristics of the river (geographical situation, bathymetry, salinity, currents, etc.) were presented in an interactive way. To concretely illustrate some of these aspects, such as the watershed and the necessity to build locks so that boats can circulate, we preselected video and internet documents the teachers used in their classes. Demonstrations were also offered. For instance, we adapted a vat demonstration on salinity, and bulk density and oceanic circulation as designed by two researchers of the *Notre Golfe* network. The teachers also used a document featuring the evolution of the uses of the St. Lawrence designed by an educational designer of history at *Université de Laval*. In it, we find a map of New France, drawn by Samuel de Champlain, featuring the species of fish recorded at the time. Another example of the fishery was presented using the excerpt on the porpoise. in a movie called *Le beau Plaisir*, (Brault, Gosselin et Perrault, 1968).

[9] From the International Program: *Baccalauréat International* (IB), the equivalent of the IEP at high school level adapted to grade school.

The third step of the activity saw students getting involved in documentary research: they were to name species living in the St. Lawrence, while linking them to a specific zone, such as benthic, pelagic, etc. As the eventual creation of an oil port in Cacouna, in the midst of a beluga nursery, was all over the news in 2015, students had to research a specific aspect of the species. They selected topics such as acoustic telemetry, ships, belugas, food for belugas, and hunting belugas. Each team were to present their work to the classroom.

As a third step, we asked students to research the origin of current consumer products found in their midst and tell the classroom about them. We documented the intensification of maritime transport on the St. Lawrence. Works by Merchant *et ses collaborateurs* (2014) on noise from ships, to assess the impact of coastal development on marine mammals, helped us illustrate a research practice in a classroom. Therefore, students could become aware of this type of scientific research led by researchers on the question of the sounds ships produce and their impact on marine mammals. Students were asked to discuss the issues around maritime transportation in the Gulf of the St. Lawrence and to establish links with the consumption of material goods. The documentary called: *Navires et baleines de l'Atlantique Nord-Ouest* (ROMM, 2014) and the project *Trajectoires pétrolières* (Bourgault et Papillon, 2015) were emphasized. Lastly, the teachers highlighted the question with respect to eventual oil exploitation in the St. Lawrence, detailing the numerous products and activities currently depending on this type of energy and stressing the possible consequences (either positive or negative) of such an activity.

Fourth, in order not to reproduce a certain pessimism (current amongst youth, with their repetitive catastrophic discourse) and to address the concerns

of the high school students who, in fact, expressed their unease with respect to the very few possibilities of actions they can do to protect the environment, we suggested to the 6th graders some examples of engaged people dealing with environmental issues. Different profiles of actors were put on index cards for a role play to be conducted in the classroom. The profiles of a biologist who is also a member of the *Notre Golfe* network, of a citizen very much mobilized and well documented on the oil file, a deep-sea diver working on oil platforms, a naturalist with the *Comité ZIP du Sud-de-l'Estuaire*, the *Société de développement économique du Saint-Laurent (SODES)* and, finally, a professional lady researcher in physical oceanic research were used as examples, to name but a few.

Throughout the fifth step, students were asked to get documentation on the position of the actor they had to portray with respect to oil exploitation and the consequences on the biodiversity of the St. Lawrence. This was meant to have them suggest true inspiring examples that illustrate different dimensions of the question and with an objective to get schooling closer to "real life" and to confer more meaning to the learning. These examples were also meant to enhance the way in which students would wish to get involved on this question, at the end of the approach.

Finally, in the course of the last step, every student had to write down their position on the issue of hydrocarbon exploitation by describing and arguing their position and then, explaining how they thought they would get involved in the future. To proceed with the reflective thinking, students were pondering over several actions they could undertake to that effect: they were either to enhance one's knowledge on the topic, or to have more responsible consumption practices, and to create awareness at school or by participating in citizens movements. /

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CONCLUSION

The preliminary results we have highlighted in the present chapter point to a certain coherence in the way one engages in science at school, in the environment, and in society. They point to considerations that are already known in the work that focusses on the relationship to knowledge and youth, including the several ways to give meaning to school learning experiences, leading to a more or less important engagement that is participative and critical when environmental issues arise in the classroom or in the public space.

The conceptual framework presented in this item could lead to defining the profiles of young *Québécois* and *Québécoises*, at the end of high school years by crisscrossing the study on their relationship with scientific knowledge at school, with the environment and its preservation. Through the exploration -in a written form or via conversations – on the relationship of these youth with science, but also via their conception of schooling and matters of preservation and sustainable development of the St. Lawrence, we can identify the logic of school and eco-citizen engagement or disengagement of these students, while considering this logic to orient our educational and teachers' training practices. This research project will give us the opportunity to have a more accurate representation of the knowledge on the St Lawrence of 15 and 16-year-old youth and on the issues surrounding its sustainable development in the context of gas and oil exploitation. This will prove to be pertinent in the context of the activities pertaining to hydrocarbons in the Gulf and of the risks involved.

Two other elements are noteworthy at the conclusion of this chapter. As to the relationship with the territory and its consequences on the engagement of

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youth eco-citizens, it clearly dawned on us that the relationship with the St. Lawrence and the meaning of the knowledge about it are particularly emphasized in the Lower St. Lawrence region area where we collected the data. Hence, we intend to verify, in future research, the extent to which youth in urban or disadvantaged areas, even though they may live near the river, would mobilize the knowledge on the St. Lawrence as significant learning to them. We will then have to be *précis* in defining the knowledge they would value. Another angle of analysis addresses the identity and cultural dimension of the rapport with nature as we know for instance that, for coastal aboriginal communities of the Gulf of St. Lawrence, its protection is strongly linked to economic, social, environmental, and spiritual dimensions.

Lastly, the relationship youth entertain with scientific knowledge shows up in a most pregnant manner, along with -behind the scene- their rapport with the scientific or citizen expertise when the time comes to take a position on uncertain, risqué and controversial decisions. When investigating their rapport to scientific knowledge, we will be in a better position to understand the link between the interest in scientific knowledge, amongst youth, and their negotiating power in the context of the public debate on the exploitation of hydrocarbons. /

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