ST. LAWRENCE
Action Plan 2011-2026

FIVE-YEAR REPORT 2016-2021

St. Lawrence Action Plan Achievements and Overview

Canada

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Québec

Coordination and writing
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List of Acronyms

AAFC: Agriculture and Agri-Food Canada
ACRD: Aquatic Contaminants Research Division
AIS: Aquatic invasive species
CaPA: Canadian Precipitation Analysis
CCAC: Climate Change Advisory Committee
CCAP: Climate Change Action Plan
CCIMDS: Coordination Committee on the Integrated Management of Dredging and Sediments
CIP: Community Interaction Program
CSA: Canadian Space Agency
DFO: Fisheries and Oceans Canada
ECCC: Environment and Climate Change Canada
eDNA: Environmental DNA
HC: Health Canada
IC: Issue committee
IAAC: Impact Assessment Agency of Canada
IMSL: Integrated management of the St. Lawrence
INSPQ: Institut National de la Santé Publique du Québec (Quebec national public health institute)
LSP: Lake Saint-Pierre
MAPAQ: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (Quebec Department of Agriculture, Fisheries and Food)
MELCC: Ministère de l'Environnement et de la Lutte contre les changements climatiques (Quebec Department of Environment and the Fight Against Climate Change)
MFFP: Ministère des Forêts, de la Faune et des Parcs (Quebec Department of Forests, Wildlife and Parks)
MSP: Ministère de la sécurité publique (Quebec Department of Public Safety)
MSSS: Ministère de la Santé et des Services sociaux du Québec (Quebec Department of Health and Social Services)
MTO: Ministère du Tourisme du Québec (Quebec Department of Tourism)
MTQ: Ministère des Transports du Québec (Quebec Department of Transport)
NCC: Navigation Coordination Committee
NGO: Non-governmental organization
OSSL: Overview of the State of the St. Lawrence
PBDEs: Polybrominated diphenyl ethers
PCA: Parks Canada Agency
PCBs: Polychlorinated biphenyls
PHAC: Public Health Agency of Canada
PSC: Public Safety Canada
PSPC: Public Services and Procurement Canada
RARP: Regional Action and Rehabilitation Plan
RRT: Regional round table
SLAP: St. Lawrence Action Plan
SLGO: St. Lawrence Global Observatory
SLL: St. Lawrence Lowlands

SSLMP: State of the St. Lawrence Monitoring Program
TC: Transport Canada
UPA: Union des producteurs agricoles (Quebec farmers' union)
WG: Working group
WGNEP: Working Group on Numerical Environmental Prediction
WGSSLM: Working Group on the State of the St. Lawrence Monitoring
WO: Watershed organization
ZIP: Zone d'intervention prioritaire (area of prime concern)

Message from the Federal Minister

Canada is a country committed to conserving its freshwater. This valuable resource is facing significant and intensifying challenges, such as drought, flooding, and deteriorating water quality, largely brought on by climate change.

The St. Lawrence River originates in the Great Lakes, which were formed at the end of the last ice age, and becomes a large estuary in the area of Île d'Orléans, where its freshwater mixes with the ocean's salt water. The St. Lawrence River lies at the heart of the social, economic and cultural life of Quebecers and Indigenous peoples. Since it is also their main source of drinking water, it is important to ensure that the St. Lawrence River is protected and that its resources are used responsibly and sustainably.

This document summarizes the activities of the St. Lawrence River Action Plan between 2016 and 2021, including 43 interdepartmental projects focused on biodiversity conservation, sustainability of uses and water quality improvement. These achievements include the restoration of shorelines affected by floods in recent years and initiatives to address the warming of deeper waters where there is a persistent risk of harmful algae blooms. Also noteworthy is the development of a representative and resilient network of protected areas. There is no doubt that in addition to climate change, agriculture, shoreline urbanization and shoreline encroachment are also intensifying existing stresses on aquatic grass beds in the river and its tributaries.

As a result of collaborative efforts by St. Lawrence Action Plan partners, organizations dedicated to the conservation, protection and rehabilitation of biodiversity and natural habitats now have access to two important reference tools: the Atlas of Sites of Conservation Interest in the St. Lawrence Lowlands, and the Atlas of sites of conservation interest in the Estuary and Gulf of St. Lawrence coastal regions.

Cleaning up, protecting and restoring our waterways are some of the greatest challenges of our time. I applaud the tremendous work of the scientists involved in the St. Lawrence Action Plan, which reflects an unwavering commitment to ensuring that we can leave a healthy river for our children. None of the results presented in this document could have been reported without this collaboration between governments and our partners.

The Honourable Jonathan Wilkinson
Minister of Environment and Climate Change

Message from the Provincial Minister

In April 2019, on his 134th day in orbit above the Earth, Quebec astronaut, astrophysicist, physician and engineer David Saint-Jacques tweeted a photo of the St. Lawrence as seen from space, which he entitled "the majestic St. Lawrence." The photo was reposted by a number of journalists in the media, one describing it as "breathtaking" and, presto, hundreds of proud Quebecers responded with the comment of "magnificent."

The massive St. Lawrence not only carves a groove through Quebec's landscape, but is an extremely challenging and intriguing research subject, making the collaboration established under the Canada–Quebec Agreement on the St. Lawrence *all the more crucial.*

Quebecers rely on their elected officials, scientists and all water users to protect the St. Lawrence, and ultimately to ensure its sustainability. They want to understand its realities and to make sure that its shorelines and coasts, as well as its aquatic fauna and flora, are safeguarded. Finally, they want to have water of sufficient quality and quantity.

The 2016–2021 phase of the St. Lawrence Action Plan (SLAP) has been a formidable tool in recent years for ensuring crucial cooperation and mobilization. It is now coming to an end, leaving behind a wealth of achievements of which Quebec can be proud. Thanks to the pooling of the expertise of specialists from 18 government agencies and departments, SLAP 2016–2021 has allowed 43 interdepartmental and intergovernmental initiatives to be completed, centred on three priority issues: biodiversity conservation, sustainable use, and improved water quality.

This just-published summary of the SLAP 2016–2021 results allows us to monitor changes in the St. Lawrence and to gauge the magnitude of the efforts made by both the scientific community and water stakeholders to preserve this great river. It will inspire the next five years of Quebec-Canada cooperation.

On behalf of the Government of Quebec, I would like to thank all those who are studying the St. Lawrence and working to keep it healthy. We can indeed rely on these committed guardians of the river. Thanks to them, we have a better understanding of its health, which is particularly critical in this time of climate change, the impacts of which are already clearly perceptible in many of our communities.

Seen from space, the St. Lawrence seems intact, a veritable corridor of life flowing into the sea. However, this macro view must not obscure the many challenges that we face in its conservation and protection. The St. Lawrence remains a fragile, highly complex ecosystem, with living components that fluctuate widely over the years.

We must continue to rigorously protect the St. Lawrence.

Benoit Charette
Quebec Minister of Environment and the Fight Against Climate Change and
Minister Responsible for the Laval Region

Message from the Agreement Co-Chairs

We are pleased to submit this report on the achievements in the 2016–2021 phase of the St. Lawrence Action Plan (SLAP). The governments of Canada and Quebec, together with numerous stakeholders, have invested in a multitude of projects aimed at conserving, restoring, protecting and enhancing the rich diversity of the St. Lawrence. This action plan, the sixth since 1988, has given rise to some remarkable initiatives to protect and enhance the St. Lawrence River.

Owing to the efforts of experts from 18 government agencies and departments, 43 projects have been carried out under the 2016–2021 phase of SLAP, centred on three priority issues: biodiversity conservation, sustainable use, and improved water quality.

Furthermore, the efforts by the government partners in the State of the St. Lawrence Monitoring Program (SSLMP) have allowed us to better understand the factors influencing the health of the river and to predict future changes in its ecosystems, owing to the indicators monitored under this program. These efforts have also included the publication of a dozen fact sheets and the report entitled Overview of the State of the St. Lawrence 2019*, as well as the organization of the Rendez-vous Saint-Laurent event to facilitate the sharing of recent discoveries.*

In addition, since 2011, the integrated management of the St. Lawrence has been implemented under SLAP through the establishment of regional round tables (RRTs), the holding of the St. Lawrence Forum, and the continuation of the ZIP (area of prime concern) program. The goal is to inform, raise awareness among, and mobilize local stakeholders through collaborative projects involving one of SLAP's three priority issues. The Community Interaction Program (CIP), a funding initiative, also encourages mobilization by riverside communities.

Consequently, we are pleased to present this report on the 2016–2021 phase of the St. Lawrence Action Plan, which outlines numerous examples of notable achievements under the plan. Many challenges remain, and others will inevitably arise in the years ahead. To rise to these challenges, we can count on the collaboration of all those who have a heartfelt commitment to the St. Lawrence's future.

Jean Pruneau
Environment and Climate Change Canada

Marc Leduc
Quebec Department of Environment and the Fight Against Climate Change

1. BACKGROUND

Since 1998, the Canadian and Quebec governments have collaborated in the St. Lawrence Action Plan (SLAP) under the *Canada–Quebec Agreement on the St. Lawrence*. Their actions have contributed to the following outcomes, among others:

- Documenting and reducing sources of pollution
- Conserving, rehabilitating and enhancing habitats for plants and animals
- Broadening knowledge and equipping decision makers to make more informed decisions
- Encouraging sustainable navigation practices
- Promoting collaboration among users of the St. Lawrence on resource management and sustainable use
- Raising awareness among, and mobilizing, communities.

Building on their past achievements, both governments have renewed their commitments for the 2016–2021 period by investing $56 million in the Agreement's implementation. Through the pooled expertise of specialists from 18 government agencies and departments, SLAP 2016–2021 has led to many interdepartmental projects and activities, including 43 projects focusing on the three priority issues of biodiversity conservation, sustainable use, and improved water quality.

Since 2013, under the State of the St. Lawrence Monitoring Program (SSLMP), government participants have worked to increase our knowledge of the St. Lawrence by providing information on over 20 indicators, in such areas as water quality, sediments and the health of biological components. The *Overview of the State of the St. Lawrence 2019* provides a summary of the results for these indicators.

Furthermore, under the **Numerical Environmental Prediction Program,** the partners have pooled their expertise to provide reliable, up-to-date data that allow the development of decision support tools such as hydrological forecasting models. This program enables governments to adapt their policies, and funding and other forms of support, in order to respond to new environmental realities.

In addition, since 2011, to encourage participation by communities tied to the St. Lawrence by their uses, activities and recreation, SLAP has supported the **integrated management of the St. Lawrence** (IMSL) by establishing regional round tables (RRTs), holding the St. Lawrence Forum and continuing the ZIP (areas of prime concern) program. Additional funding from the **ZIP program** and **regional round tables** has encouraged community cooperation and action.

In addition, SLAP 2016–2021 includes an integrated funding program, the **Community Interaction Program** (CIP), which invites riverside communities to undertake projects that tackle SLAP's three priority issues. Under this program, 35 projects were funded by Environment and Climate Change Canada (ECCC) and 24 projects, by the Quebec Department of Environment and the Fight Against Climate Change (MELCC).

For more information, visit the SLAP website at https://www.planstlaurent.qc.ca/en/ for detailed descriptions of the projects and work completed.

2. PRIORITY ISSUES

2.1 Biodiversity conservation

A number of governmental authorities and regional stakeholders have responded to the challenge of conserving biodiversity, an issue that is at the core of the Agreement. The two major orientations that guided the Biodiversity Conservation Issue Committee during the 2016–2021 period were:

- Identify, protect, restore and enhance environments of ecological importance
- Prevent the introduction and control the spread of invasive alien species.

In this context, the conservation of the biodiversity of the St. Lawrence ecosystem was focused on five main objectives, leading to the completion of 11 projects on this theme, three examples of which are presented below.

Examples of projects

Project 1: Complete, disseminate and promote the integrated plan for conserving natural areas of the St. Lawrence

Project objectives

This project began during the 2011–2016 phase of SLAP and continued in the 2016–2021 phase. To carry out the project, various tools were developed to support local communities working to conserve the St. Lawrence's natural environments. This toolbox allows governments and the various stakeholders involved to determine the most appropriate and effective conservation measures for restoring and conserving natural environments.

Project context

The natural environments in southern Quebec support a highly diverse fauna and flora. However, human activities in this region (urbanization, agriculture and industry) contribute to reducing the ecological integrity of these environments or even lead to the extirpation of certain plant and animal species. Numerous species at risk occur in the natural environments of the St. Lawrence Lowlands (SLL) and conservation measures are required to preserve this rich biodiversity.

Similarly, key ecosystems to be preserved, which have very high conservation value, such as coastal marshes, are located in the coastal regions of the estuary and Gulf of St. Lawrence. These natural environments do not experience the same impacts from human activities that are observed in the SLL but are affected by other conservation issues, such as coastal erosion and flooding and the presence of invasive alien plant species.

This project was the result of close collaboration between the many stakeholders involved in conserving natural areas in southern Quebec (federal and provincial governments, conservation organizations and consultants), supported by experts and consultants from academia and conservation stakeholders active at various phases of the project.

Project results and deliverables

Several products were delivered:

- Two atlases were produced to identify sites of interest where the most glaring conservation needs exist, one for the SLL and the other for coastal habitats in the estuary and Gulf of St. Lawrence.
- Dissemination tools were designed so that users could access the atlas data and results.
- Strategies were devised to determine the conservation measures to be implemented.

Atlas of Sites of Conservation Interest in the St. Lawrence Lowlands
(SLL atlas)

Based on detailed land use mapping in the SLL carried out from 2011 to 2016, the SLL atlas identifies the areas where conservation measures are required to maintain functional ecosystems and biodiversity in this huge region. The conservation targets retained include forested areas, wetlands, open habitats (old fields and perennial crops), and aquatic environments (Figure 1). For each of these ecosystem types, the sites to be considered for conservation were determined by first selecting areas with very high conservation value, i.e., those that host priority occurrences or critical habitat of species at risk, protected areas, exceptional forested ecosystems or sites with unique ecological features. Multicriteria prioritization analyses were then performed to locate additional sites deemed important for conserving biodiversity, i.e., scientifically recognized wildlife habitats or occurrences not considered in the analysis of conservation targets, including such things as spawning sites, alvars and colonial bird nesting sites.

The SLL atlas also allows the results of other biodiversity conservation projects undertaken under SLAP to be integrated. Consequently, the list of privately owned protected areas and important fish habitats in the St. Lawrence were important inputs that guided the production of the atlas.

To meet the needs of potential atlas users, all the project's products (reports, geospatial data, maps, etc.) are available online from the data catalogue of the St. Lawrence Global Observatory (SLGO). Users can obtain more details on the spatial distribution and conservation value of sites of interest and thus adapt the analysis of these data to their specific local conditions, based on their specific objectives. Owing to the widespread dissemination of this information to conservation organizations in southern Quebec, the SLL atlas is now widely used for such activities as land-use planning (regional wetland and water bodies and natural environment conservation plans), preparing funding applications, or serving as an educational or instructional tool. Conservation strategies are currently being developed to determine the most appropriate measures for reconciling sustainable land development and natural habitat conservation in this region, the most highly populated one in Quebec. It should be noted that an updated version of the SLL atlas is planned in the coming years to integrate new knowledge from ecological connectivity analyses conducted under another SLAP project, as well as progress made with respect to knowledge of the distribution of species at risk and the designation of new protected areas.

Figure 1. Sites of conservation interest in the Saint-Amable area (Montérégie region)

The Lavallière Bay and Sorel islands region has many wetlands of conservation interest. © Christine Lepage, ECCC

Atlas of Sites of Conservation Interest in the Estuary and Gulf of St. Lawrence Coastal Regions

The *Atlas of Sites of Conservation Interest in the Estuary and Gulf of St. Lawrence Coastal Regions* (Estuary / Gulf atlas) was produced using the same process as the SLL atlas. Ecosystems of conservation importance were identified, including forested areas, inland wetlands, coastal marshes and sandy environments, to which were added sites to be preserved on an individual basis such as breeding bird colonies. Regional workshops bringing together regional organizations (ZIP committees, conservation NGOs, government representatives, etc.) were organized in the spring of 2019 to validate the results of the Estuary / Gulf atlas and to consider conservation strategies and actions to be implemented to address regional conservation issues.

To meet users' needs, the atlas data and results are also available from the SLGO data catalogue. Tangible benefits have already been obtained under projects implementing measures proposed during these workshops, notably the mapping of invasive alien plant species in coastal marshes in the southern estuary and Chaleur Bay.

Black Guillemots (*Cepphys grylle*) nest along rocky coastlines of the estuary and Gulf of St. Lawrence. © Christian Marcotte, ECCC

Saint-Omer Migratory Bird Sanctuary, in the Gaspé region. © Benoît Jobin, ECCC

Project 2: Restore the Lake Saint-Pierre shoreline

Project objectives
The objectives of the project include:

- Identifying sites suitable for habitat restoration efforts
- Supporting partners in carrying out restoration projects in areas of high wildlife potential
- Conducting wildlife surveys at restored sites.

Project context
The Lake Saint-Pierre (LSP) floodplain is the largest in Quebec. Supporting a rich biodiversity (over 280 resident and migratory bird species and 78 fish species), LSP contains exceptional habitats for the reproduction, feeding and nesting of many species. For example, nearly half the fish species in the St. Lawrence plain, including Northern Pike (*Esox lucius*) and Yellow Perch (*Perca flavescens*) use the floodplain's still-water habitats for spawning and feeding. These vast riparian wetlands also provide nesting and foraging habitats for numerous species of ducks, geese and marsh birds, including the Black Tern (*Chlidonias niger*).

A sizeable portion of the LSP shoreline is used for agriculture, mostly field crops (corn and soybeans). Current farming practices leave little vegetation cover in spring that could serve as wildlife habitat and, moreover, increase soil erosion, particularly during the spring freshet, resulting in altered water quality. The agricultural use of the shoreline is one of the factors contributing to the decline in the Yellow Perch population in Lake Saint-Pierre, a phenomenon observed for over 20 years. A moratorium was imposed on the Yellow Perch commercial and sport fishery in 2012 and renewed in 2017 for another five years. Furthermore, the recent conversion of perennial crops to annual crops in the LSP region, as well as in southern Quebec as a whole, has resulted in declining populations of grassland birds that depend on pastures and forage crops for nesting. Several of these species, such as the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*), are designated at risk in Canada.

Although the state of the LSP ecosystem is worrisome, the wildlife populations there can recover if they have access to quality habitats where they can complete their life cycles. In 2013, to take action to counter the main causes of this ecosystem's deterioration, the Quebec government launched its intervention strategy for the future of Lake Saint-Pierre. Since 2018, various measures have been implemented under this strategy to restore the lake's ecological functions. In parallel, the Lake Saint-Pierre regional round table (LSPRRT) has made recommendations, mainly involving the identification of the most appropriate areas for restoration, based on maximizing wildlife gains. On the basis of the knowledge that has been acquired since SLAP 2011–2016 on the habitat alterations in the 0–2 year flood risk zone[1], over 5,000 hectares (ha) have been targeted for restoration efforts and changes to agricultural practices along the shoreline.[2]

Project summary and scope

The project has allowed concrete restoration and conservation measures to be undertaken along strategic portions of the LSP shoreline to maximize benefits to wildlife habitats, biodiversity, and the overall ecosystem. For example, a permanent vegetation cover has been established on certain pieces of land previously used for intensive agriculture and a partnership has been created between conservation organizations and the agricultural sector. Lastly, wildlife surveys were conducted at certain sites to establish a baseline and will be useful in assessing the benefits of restoration after the completion of work.

Aerial view of the vast wetlands on the south shore of Lake Saint-Pierre. © Christine Lepage, ECCC

Development of riparian strips along a watercourse. © Lake Saint-Pierre ZIP Committee

Project results and deliverables

Several products were delivered:

- Mapping of priority sites for restoration efforts, established in collaboration with LSPRRT partners
- Recommendations on integrating wildlife habitat enhancements in projects to maintain agricultural watercourses along the shoreline
- Restoration of 385 ha of habitats since 2016. In addition, work was done on an additional 307 ha to optimize existing enhancements, improve connectivity, and integrate wildlife enhancements in watercourse maintenance work (Figure 2).
- Wildlife surveys (fish, birds, anurans) carried out jointly by the Quebec Department of Forests, Wildlife and Parks (MFFP), ECCC and their partners
- Restoration projects are being developed in partnership with community stakeholders, including watershed organizations (WO), ZIP committees and the Union des producteurs agricoles (UPA).

Among the 5,000 ha on the LSP shoreline where efforts are needed, 800 ha have been prioritized for habitat restoration work due to their conservation status and high wildlife potential.[3]

In areas with intensive agriculture (corn, soybeans), habitat restoration may involve establishing a permanent vegetation cover that respects natural plant succession in Lake Saint-Pierre, in order to provide habitats suitable for the recovery of fish and grassland bird populations, as well as to improve water quality and biodiversity. Since 2016, habitat restoration measures have been carried out on 385 ha, 367 ha of which are considered a priority (Figure 2). Projects to re-establish connectivity or optimize existing wildlife enhancements were carried out on 301 ha, 137 ha of which are considered a priority (Figure 2). Watercourses in the Sainte-Geneviève-de-Berthier area and in the Berthier-Sorel Islands[4] have also been enhanced by reducing slope angles and establishing expanded riparian buffer strips (i.e., at least five metres in width), increasing the area and quality of habitats on 6 ha of agricultural land.

Wildlife surveys and inventories (fish, birds and anurans) were conducted at eight sites to document the presence and abundance of animal communities under the conditions preceding the restoration work.[5]These data will provide a baseline for documenting, in future surveys, the response of these species to efforts to restore and improve habitat quality. In addition, inventories were conducted at four sites five years after restoration. The sampling of fish larvae was also carried out at certain restored sites on the north shore of LSP in order to establish an indicator of the quality of, and changes in, restored habitats.[6] These surveys confirm the use of the restored habitats as spawning and nursery areas by fish, including Yellow Perch.

In conclusion, this project has led to close collaboration between citizens, local communities, the scientific community, and governments to restore part of LSP's ecological integrity, long altered by various human activities.

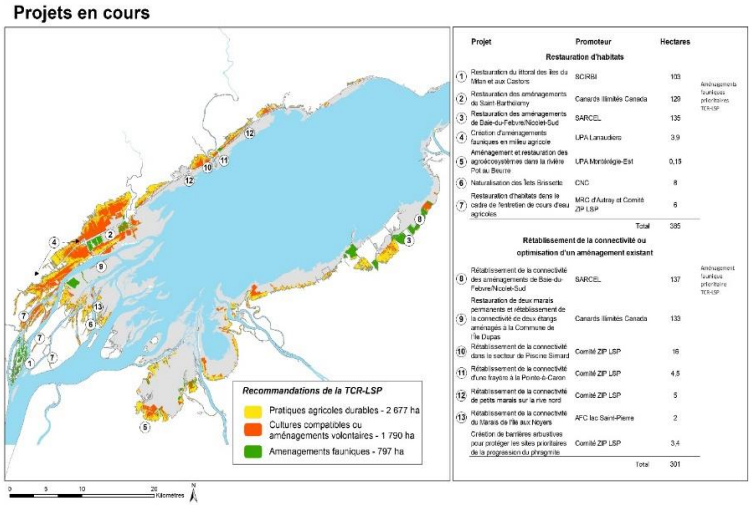

Figure 2. Location of habitat restoration projects in the Lake Saint-Pierre floodplain

Young-of-the-year Northern Pike (*Esox lucium*). © MFFP

Seine fishing in an agricultural watercourse on the Lake Saint-Pierre shoreline during the spring floods. © MFFP

External collaborators

- Lake Saint-Pierre ZIP Committee
- Ducks Unlimited Canada
- Société d'aménagement récréatif pour la conservation de l'environnement du lac Saint-Pierre (SARCEL) (LSP wildlife habitat conservation and management organization)
- Aire faunique communautaire du lac Saint-Pierre (LSP community wildlife area)
- Société de conservation, d'interprétation et de recherche de Berthier et de ses îles (society for the conservation, interpretation and study of Berthier and its islands)
- Fondation de la faune du Québec (Quebec wildlife foundation)
- UPA, Lanaudière and Eastern Montérégie branch
- Organisme de bassin versant de la rivière Yamaska (Yamaska River watershed organization)
- Autray Regional County Municipality
- Lake Saint-Pierre Regional Round Table (LSPRRT)
- Université du Québec à Trois-Rivières.

Project 3: Continue to coordinate and harmonize aquatic invasive species (AIS) detection and monitoring programs and activities

Project objectives

This project has the following objectives:

- Increase AIS monitoring in Lake Saint-François, Lake Saint-Louis, Lake Saint-Pierre and port areas
- Continue to develop environmental DNA (eDNA) analysis protocols and implement them in targeted priority areas.

Project context

The early detection of aquatic invasive species (AIS) can pose a challenge in terms of human and financial resources. Detection programs based on traditional methods (such as nets) can be insufficient to detect these species at an early stage of their introduction. Integrated detection programs, which combine traditional detection methods with citizen surveillance and more sensitive techniques, are being increasingly adopted worldwide by AIS managers as strategies to increase their detection capabilities. Among these leading-edge techniques, the use of eDNA is emerging as an indispensable tool.

Project summary

To broaden the scope of monitoring activities and encourage the adoption of new harmonized detection techniques, this project aims to coordinate detection activities and increase the use of eDNA in departmental AIS monitoring programs. This will be achieved by developing an eDNA toolbox, mainly by establishing protocols and detection networks and developing specific tests.

Project scope

Before 2015, the use of eDNA in wildlife management in Quebec was basically limited to the university research community. The objective of this project was to make this technique accessible to managers of aquatic wildlife in the St. Lawrence. The ultimate goal was for departments to be able to implement a common set of good practices in sampling, laboratory analysis and result delivery.

Project results and deliverables

Several products were delivered:

- Specific tests for the target aquatic invasive species
- Improved sampling protocols.

The eDNA technique used to identify AIS involves the detection of one or more DNA molecules of the target species through the development of a specific test for that species, called a primer, based on the species' genetic code. Dr. Louis Bernatchez's lab at Université Laval and various teams at MFFP are working in collaboration to facilitate the increased adoption of eDNA.

Thanks to the funding available from MFFP, SLAP and the Climate Change Action Plan (CCAP), 60 tests were developed during this project, covering invasive, commercial and threatened species of fish, crustaceans, and molluscs. [7] A vast annual detection network, now composed of over 500 water sampling stations in the St. Lawrence River (from Lake Saint-François to Lake Saint-Pierre) and in certain key tributaries (such as the Richelieu River), has been in place since 2015. These efforts have led to the detection of the Grass Carp (*Ctenopharyngodon idella)* in the St. Lawrence and are used to guide MFFP's annual monitoring activities (electrofishing). To improve its sampling protocols, MFFP organized two knowledge transfer activities in the field with a team from the Whitney Genetic Laboratory (United States Fish and Wildlife Service). These activities have been greatly beneficial, given the Whitney team's extensive experience in detecting Asian carps using eDNA. The Whitney lab processes over 8,000 water samples a year.

These eDNA tests have also been used in specific detection efforts, like that targeting the Tench (*Tinca tinca*). Some of this testing has occurred outside the St. Lawrence system, for example, in the detection network for invasive water fleas (Spiny Water Flea [*Bythotrephes longimanus*] and Fishhook Water Flea [*Cercopagis pengoi*]), as well as in other aquatic wildlife management and knowledge acquisition efforts.[8] In 2019, Fisheries and Oceans Canada (DFO) joined the project, using the eDNA method developed to detect Chinese Mitten Crab (*Eriocheir sinensis*) in the St. Lawrence River (Figure 3). The advances made in the use of eDNA have also paved the way for the adoption of a broad-spectrum approach (metagenomic sequencing) to eDNA analysis, which aims to detect all species in a given group (e.g., fish or invertebrates) from a single water sample. This technique has proven particularly useful in analyzing the fish communities present in port areas and in shipping lanes in the St. Lawrence.[9]

This project has also enabled the departments to strengthen their expertise in the technical and analytic aspects of eDNA. However, further research is needed on the potential factors influencing the interpretation of eDNA analysis results, such as DNA production, degradation and transport in aquatic environments.

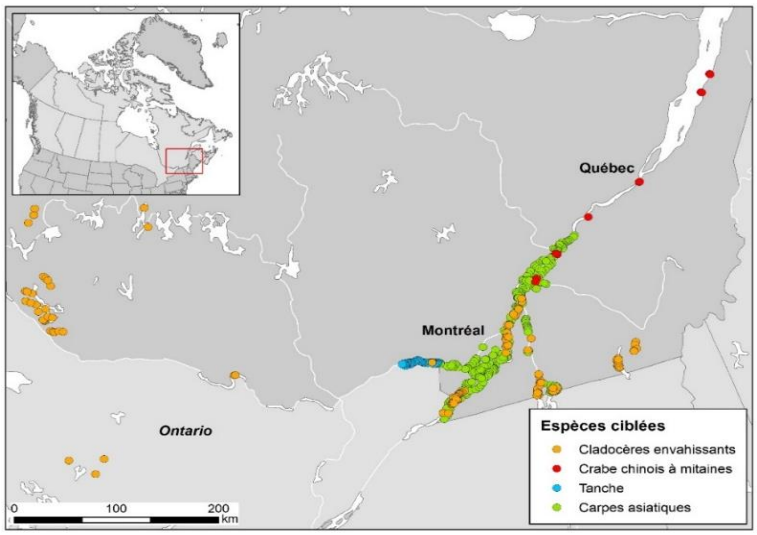

Figure 3. Distribution of eDNA water sampling stations for detecting AIS in the St. Lawrence, 2015–2020

External collaborators

- Université Laval (Dr. Louis Bernatchez's lab)
- Whitney Genetic Laboratory (United States Fish and Wildlife Service).

2.2 Sustainable use

The work of the Sustainable Use Issue Committee was structured around four orientations:

- Promote sustainable management of fishery resources
- Maintain and promote sustainable navigation
- Promote sustainable management of water levels and flows in a context of climate change
- Improve the knowledge on hydrocarbons in the St. Lawrence system.

During the 2016–2021 period, 12 projects involving federal-provincial cooperation were conducted on the sustainable use issue. Their results can be consulted on the SLAP website. Three of them are presented in greater detail below. In addition, four projects, described in the table below, integrate the aspects of collaboration, knowledge sharing, and the determination of common issues shared by a number of stakeholders.

Coordination Committee / Knowledge Exchange Group	Roles and Objectives
Navigation Coordination Committee (NCC)	– The NCC has roughly 20 member organizations representing the shipping industry, pleasure boating sector, social and environmental groups, and federal and provincial government bodies. – Its objective is to harmonize commercial and recreational navigation practices with the protection of ecosystems, in accordance with the principles of sustainable development. – The purpose of its work is to strengthen good practices, assess the impacts of climate change on marine transportation, ensure public and ship safety, develop commercial and recreational navigation activities, harmonize uses, and encourage the participation of riverside communities. – Committee members reaffirmed the importance and relevance of their actions by updating the *Sustainable Navigation Strategy for the St. Lawrence: 2012–2017 Action Plan*, to demonstrate their strong commitment to sustainable navigation for the well-being of St. Lawrence ecosystems and users.
Climate Change Advisory Committee (CCAC)	– The CCAC advises the issue committees and working groups to ensure climate change is taken into account across the board in SLAP projects. – It organizes virtual knowledge transfer activities according to the needs expressed, ensuring that the riverside community organizations concerned also benefit. Information sessions help to maintain links with the community of practice and facilitate networking among stakeholders.
Coordination Committee on Integrated Management of Dredging and Sediment (CCIMDS)	– The CCIMDS is composed mainly of federal and provincial government representatives concerned with dredging and sediment management issues. – Its objective is to develop various shared tools for overseeing dredging and sediment management activities in Quebec and to provide a forum for discussion and the exchange of information among the various stakeholders involved. – The committee's current activities are organized around the sharing of information on the various dredging projects approved or under evaluation, the determination of new issues related to the development of commercial navigation in the St. Lawrence, and sediment remediation.
Knowledge Exchange Group on Ecological Risk Management Related to Marine Transportation of Hydrocarbons	– This group works to promote the exchange of information and to strengthen collaboration between federal and provincial departments and agencies active in managing the potential impacts of marine incidents on aquatic ecosystems. – Its objective is to improve knowledge to support decision making. – To date, the exchange of information has led to the sharing of information on activities underway in the departments and on work to establish cartographic integrative indices.

Examples of projects

Project 1: Promote and implement incentive measures for sport fishing in the St. Lawrence

Sport fishing for Striped Bass in the Restigouche River. © David LeBlanc, Restigouche River Watershed Management Council

Beach seine sampling for the annual survey of young-of-the-year Striped Bass. © Dominique Lapointe, MFFP

Background

The St. Lawrence offers exceptional fishing opportunities for those wishing to try sport fishing for the first time or to take it up again. However, efforts are needed to develop this activity sustainably. The arrival of Striped Bass (*Morone saxatilis*) in the Gaspé region (southern Gulf of St. Lawrence population) has led to the development of a booming sport fishery in this part of Quebec. Monitoring this fishery will allow its impact on the southern Gulf of St. Lawrence population of Striped Bass and on the quality of the fishery to be assessed, as well as more detailed knowledge to be acquired on users.

In addition, the status of the Striped Bass population reintroduced in the St. Lawrence River must be characterized and monitored to assess the progress of its recovery and to define the conditions supporting a sustainable sport fishery. Knowledge acquisition efforts and the monitoring of the species' status are being carried out for this purpose. Meanwhile, the information gathered has been useful to both MFFP and DFO in implementing measures benefitting the species and assessing its recovery.

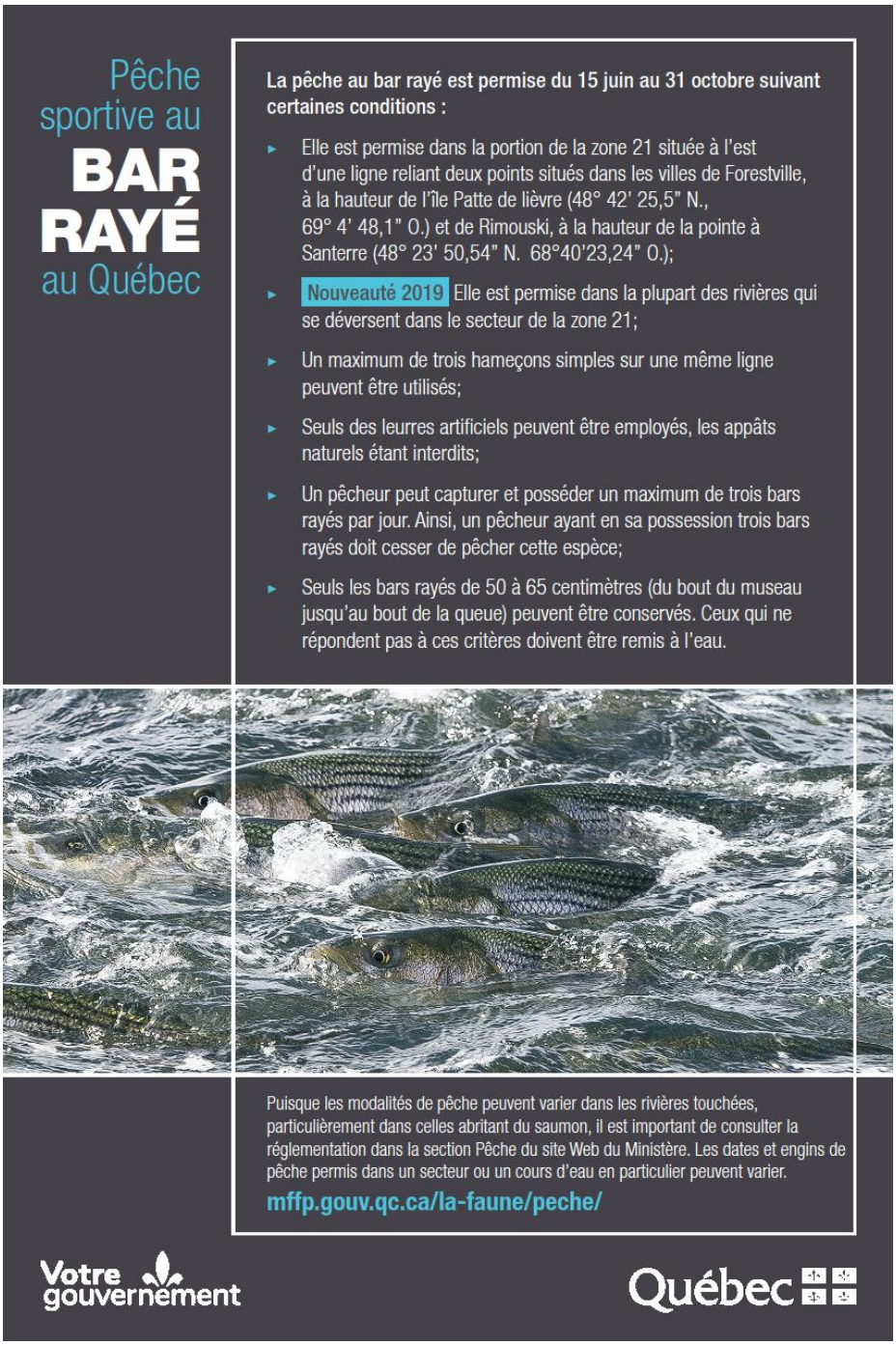

Figure 4. Poster summarizing Striped Bass fishing regulations

In Quebec, MFFP is responsible for managing the recreational Striped Bass fishery, but it is critical that it work with partners like DFO to ensure the consistent, sound and sustainable management of the Striped Bass fishery (southern Gulf of St. Lawrence population) in conjunction with the Maritime provinces. Collaboration with DFO also facilitates the implementation of recovery measures so that the Striped Bass returns to areas where it was previously extirpated (St. Lawrence River population protected under the *Species at Risk Act* since 2011).

General objective

Develop and showcase sustainable sport fishing in Quebec.

Specific objectives

1. Continue and improve knowledge acquisition on the sport fishes of the St. Lawrence.
2. Develop the Striped Bass sport fishery in the southern Gaspé region (southern Gulf of St. Lawrence population).
3. Establish a sustainable threshold exploitation rate for the Striped Bass sport fishery (St. Lawrence River population).
4. Establish and disseminate an index of the quality of the sport fishery.
5. Encourage and facilitate sport fishing in the St. Lawrence.
6. Acquire a better knowledge of users.

Results

Development of the Striped Bass sport fishery in the southern Gaspé region (southern Gulf of St. Lawrence population)

Tracking the changes in the Striped Bass sport fishery allows the impact of harvesting on this population and on the quality of the fishery to be assessed. This information, combined with the species' abundance and its use of Quebec waters (estimated by telemetry), provides a clear picture of the status of the Striped Bass in Quebec. Consequently, access to the Striped Bass sport fishery has been expanded over the years by adjusting the harvesting conditions and authorizing this activity in a larger number of regions and rivers (Figure 5).

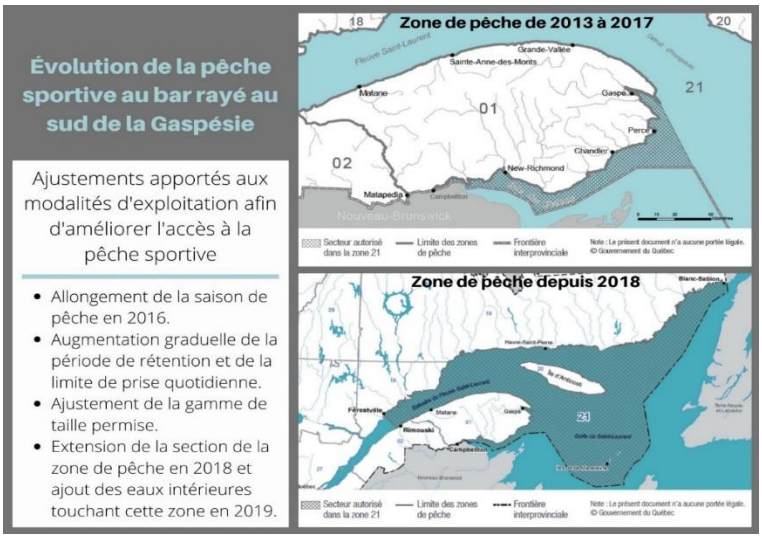

Figure 5. Changes to the Striped Bass sport fishing regulations in Quebec

Establishing a sustainable threshold exploitation rate for the Striped Bass sport fishery (St. Lawrence River population)

Lucie Vanalderweireldt's doctoral dissertation on the return of the Striped Bass to the St. Lawrence estuary, including the ecology of the early life stages and the features of critical habitats, has allowed the habitats used by larval and young-of-the-year Striped Bass to be characterized.[10] The highlights of this dissertation include:

- The determination of the species' nursery areas in the St. Lawrence River, which are located mainly along the edges of the salinity front (upstream in fresh water and downstream in oligohaline water [low salinity])
- The habitat in the oligohaline zone of the middle estuary has the best conditions for larval feeding and reduced larval mortality.
- Beginning in July, Striped Bass disperse throughout all estuarine habitats, where they stay close to the shore, and show a drastic change in their diet.
- From June to September, the most favourable conditions for the growth of Striped Bass in terms of the physical environment and prey availability were found in oligohaline habitat in the middle estuary.

The results of this research and various MFFP surveys have provided a better understanding of the reintroduced population and allowed its status to be assessed (Figure 6). In particular, the standardized young-of-the-year survey, conducted in fall since 2013, allows the species' abundance and distribution to be tracked. Biological data from subadult and adult bass have allowed a specific growth curve for the St. Lawrence River population to be established.

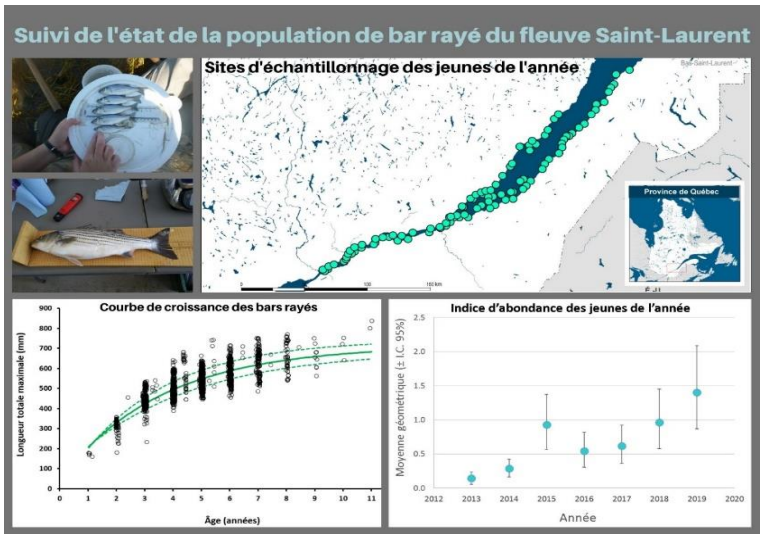

Figure 6. Monitoring the status of the St. Lawrence River population of Striped Bass

Deliverables

- Development of the Striped Bass sport fishery in Quebec
- Doctoral dissertation on the subject
- Monitoring of indicators for the Striped Bass sport fishery in the southern Gaspé region.

External collaborators

- Research chair on harvested aquatic species, Université du Québec à Chicoutimi (Pascal Sirois)
- Statistical consulting service, Université Laval (Gaétan Daigle).

Project 2: Establish a common framework for assessing the cumulative impacts of marine activities in the St. Lawrence and the Saguenay River

Background

In recent years, several projects involving marine activities have been proposed in Quebec. Although these projects have been or are currently the subject of environmental impact studies, including their cumulative effects, some concerns remain in the general public about these projects. A number of comments received from the public, including feedback from Indigenous communities, call for a more in-depth analysis of each of these projects' cumulative effects, particularly those related to marine traffic.

This pilot project on the cumulative effects of marine activities was proposed to respond to the growing concerns over an increase in marine transportation and other navigation activities, which have impacts on coastal and marine ecosystems as well as on Indigenous ways of life.

Project summary

The purpose of the project is to establish and implement a common framework for assessing the cumulative effects of marine activities, as well as encourage collaboration and coordination among government departments, organizations, Indigenous communities and other stakeholders. This collaboration involves the pooling of individual organizations' existing data, the sharing of expertise, the approval of methodology and its applications for the St. Lawrence and the Saguenay River and the dissemination of the results obtained. The project will provide a better understanding of the potential cumulative effects of marine activities and promote more consistent mitigation strategies for countering the cumulative effects identified. It will also stimulate and inform discussion and reflection surrounding government decisions in this area.

The pilot project covers the fluvial section of the St. Lawrence and the St. Lawrence estuary between Montreal and Pointe-des-Monts, as well as the Saguenay River upstream to Saint-Fulgence (Figure 7).

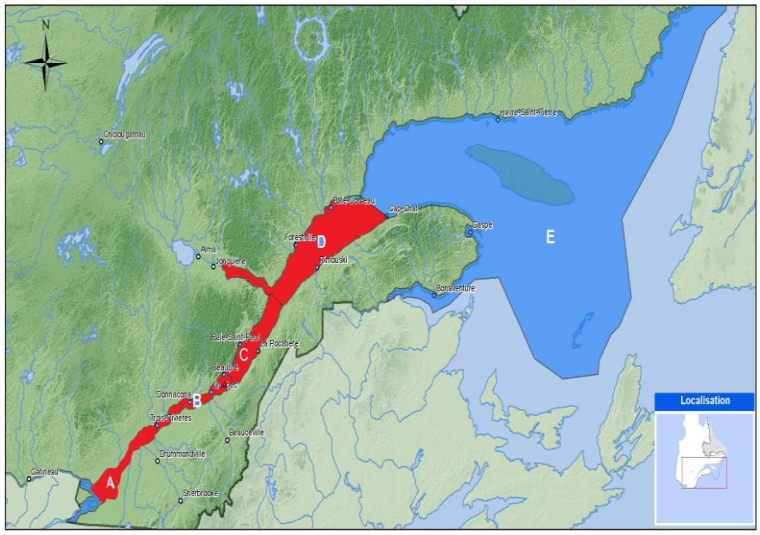

Figure 7. Area covered by the project

General objective

Determine common principles and concepts linked to the cumulative effects of marine activities on aquatic, coastal and marine ecosystems and Indigenous peoples' way of life, to be used in assessments, and ensure intergovernmental coordination.

Specific objectives

1. Collect and collate existing data on navigation, the environment, culture and traditional uses.
2. Assess the cumulative effects of marine activities.
3. Establish potential objectives for managing the cumulative effects of the marine activities identified.
4. Recommend strategies and tools to mitigate the potential cumulative effects of marine activities.

Results

A sector-based approach was adopted in this pilot project to examine environmental issues and effects associated with each specific sector (i.e., a framework based on the assessment of a single activity sector), since the objective is to manage how certain sources of stress generated by marine activities act cumulatively on valued components of the human and biophysical environments (components of the physical, biological or human environments deemed to have an ecosystem, scientific, social, cultural, economic, historical, archeological or aesthetic importance and likely to be affected by an activity or project).

Sources of marine stress identified by collaborators include dredging, anchorages, operational discharges, accidental spills, vessel stranding, ship movements and fishing gear. In the study, marine activities included all types of vessels, such as commercial shipping vessels, ferries, pleasure boats, tour boats and fishing boats.

The valued environmental and sociocultural components selected by collaborators included:

Fluvial Section	**Estuary / Saguenay**
Water quality (e.g., turbidity)	
Plant and animal habitats (coastal, benthic and pelagic habitats)	
Significant sites (places of interest): tourism, traditional, cultural, archeological, hunting, gathering and fishing sites; protected areas, etc.	
Shoreline / sediment integrity (related to the ship wake erosion stressor)	Marine mammals (whales, seals and in particular, belugas and their acoustic environment)

A contract was signed with Professor Philippe Archambault's team, at Université Laval, to develop and implement a methodology for assessing the cumulative effects of marine activities. A second contract was awarded to a social sciences researcher from Université Laval in January 2021 to develop and implement a methodology for assessing the cumulative socio-cultural effects of marine activities on Indigenous communities.

Deliverables

The project will generate the following deliverables:

- A proposed methodology developed by Université Laval and approved by the collaborators for assessing cumulative effects at the pilot site
- A presentation to collaborators for discussion purposes on the university's preliminary findings on the cumulative effects of marine activities
- A final report on the assessment of cumulative effects produced by Université Laval
- Recommended strategies and tools for mitigating the potential effects identified.

External collaborators

- First Nations representatives (Mohawks, Abenaki, Huron-Wendat, Innu, Malecite)
- University researchers, including those at Université Laval
- Shipping industry stakeholders, including Fednav, Desgagnés, the Shipping Federation of Canada, and Canada Steamship Lines
- Canada Port Authorities (Montreal, Quebec, Saguenay)
- Environmental non-governmental organizations (e.g., ZIP committees, Green Marine)

Project 3: Improve knowledge on the risks of oil spills in marine environments and develop operational tools to guide preparedness and response by marine incident managers

Background

In a marine incident, collaboration between the various responders and others involved has always been excellent. However, to improve the response to marine pollution incidents, formalizing all the processes and procedures in a single document is essential, as is developing a shared vision of responders' roles and responsibilities in an emergency. To this end, a task force was established to improve mutual understanding of the legislative framework governing the responses to marine incidents and to define a recommended management approach to be used by the Government of Quebec and various federal government bodies. Two tools were developed, an operational alert procedure for Quebec provincial authorities and the Collaboration Framework for Marine Incident Management.

In 2019, the Collaboration Framework for Marine Incident Management was completely reworked to take account of new operational realities and the creation of the Centre d'expertise en gestion des risques d'incidents maritimes (CEGRIM) (centre of expertise in marine incident management).

Project summary

The Framework describes how efforts by MELCC, the Canadian Coast Guard (CCG), and the Quebec Department of Public Safety (MSP) should be coordinated in the event of a marine incident. It takes into account the partners' different incident management systems and aims to improve the linkage between them. The main purpose of the Framework is to improve how responders are alerted and mobilized during marine incidents. It also helps to ensure a quick, coordinated and appropriate response to any marine incident that could jeopardize the health and safety of Quebec residents or that could adversely affect the environment.

This document is addressed mainly to responders from MELCC's environmental emergencies unit, CCG environmental response managers and responders in MSP's regional directorates. It specifies the roles and responsibilities of each organization to ensure that the actions taken by these different resources are fully effective.

General objective
The objective of the Collaboration Framework for Marine Incident Management is to streamline the process for alerting and mobilizing responders in the event of a marine pollution incident and for managing such incidents by clearly defining the roles and responsibilities of the various responders.

Specific objectives

1. Describe the approach for managing environmental emergencies related to marine incidents in Quebec.
2. Inform departmental authorities of the issues related to marine incident management.
3. Establish the way in which the CCG Environmental Response team and the provincial responders will function in the event of a marine incident.
4. Determine specific areas of provincial and federal jurisdiction in the event of marine incidents where there is either a risk, or the confirmed presence, of pollution.
5. Serve as a basis for discussion among MELCC, MSP and CCG responders.
6. Facilitate updates to the procedures of each of the organizations concerned.

Results
The Framework was distributed to most stakeholders involved in managing the emergency response to marine incidents. Different review phases are planned for the document to keep it up to date and to take account of comments. The task force is currently planning the next steps, which mainly involve developing popularization tools for municipal and regional stakeholders as well as holding meetings to serve as discussion forums for local stakeholders potentially affected by marine incidents. The collaborative approach used by the CCG, MSP and MELCC in managing marine incidents has been a success and is recognized across Canada. The Framework and particularly the tools that will result from it could serve as a reference for municipal and provincial authorities in developing specific plans consistent with the principles and approaches of Quebec's emergency management system and its response structures for major disasters.

2.3 Improved water quality

In efforts to improve the water quality in the St. Lawrence River, several positive changes can make a big difference. The orientations that guide the SLAP Water Quality Issue Committee in choosing research projects and activities to be undertaken include:

- The management of non-point source pollution, caused by such things as nutrient and pathogen inputs from the agricultural environment, as well as atmospheric inputs; this type of pollution is poorly documented.
- Contaminated sediment management
- Assessment of the presence of emerging contaminants (linked to wastewater discharges) and toxic substances. Their effects on the environment and human health are poorly understood.

In response to these three broad orientations, six objectives were established and have allowed 15 projects to improve water quality in the St. Lawrence to be completed during the 2016–2021 period.

Examples of projects

Project 1: Assess the contribution of dissolved and particulate organic matter to deep-water hypoxia and acidification in the St. Lawrence estuary

Background

Organic matter in the water is composed of a mixture of small organisms such as phytoplankton, zooplankton and bacteria, as well as detritus from the food chain. Organic matter is often divided into two fractions for research purposes, as well as operational reasons:

- **Particulate fraction**: organisms and detritus larger than 0.7 µm
- **Dissolved fraction**: elements smaller than 0.7 µm, such as viruses, macromolecules and particularly organic carbon (natural organic matter).

The St. Lawrence estuary receives substantial amounts of organic matter from the tributaries in its immense watershed (roughly 1 million km^2), with the St. Lawrence River alone contributing roughly 1.5 million tonnes of organic carbon a year to the estuary. [11] The organic load resulting from these inputs, as well as that generated by photosynthesis in the estuary itself, is transformed by different biological and physico-chemical processes that take place in the surface layer. A portion of this organic matter is exported to the deeper waters (> 250 m in depth), where its transformation may contribute to part of the oxygen deficit (hypoxia) and acidification observed at these depths.

General objective

Determine the role and importance of organic matter in the St. Lawrence estuary.

Specific objectives

1. Quantify and characterize this organic matter and explore its seasonal variations.
2. Improve the representation of organic matter in a three-dimensional biogeochemical model.
3. Analyze the seasonal dissolved oxygen cycle in the deep waters of the estuary.
4. Estimate the contribution of organic matter to deep-water hypoxia and acidification in the estuary.

Methods used to achieve the first objective

- *Tributaries*: For two years, 120 samples were taken in six tributaries of the estuary (St. Lawrence River, Rivière du Gouffre, Saguenay River, Manicouagan River, Ouelle River and Mitis River), and analyzed in three laboratories (Figure 8). The methods used to estimate organic matter in each of the three labs (DFO, MELCC and ECCC) were compared and calibrated. Organic matter measurements in these rivers were extrapolated using flow-based relations in order to cover all the estuary tributaries.
- *Estuary*: In 2016 and 2017, 322 samples were taken during two scientific surveys (Figure 8) to quantify organic matter in the St. Lawrence estuary (Figure 9).

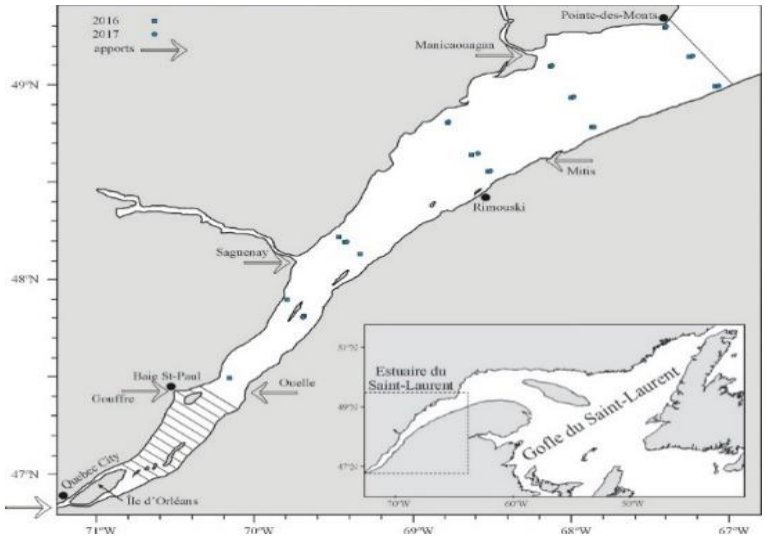

Figure 8. Sampling stations for scientific surveys in the estuary and location of the tributaries sampled

Results linked to the first objective

- *Tributaries*: The annual flux to the estuary from its tributaries is roughly **266,000 tonnes** of particulate organic matter (measured in the form of particulate organic carbon) and **2.158 million tonnes** of dissolved organic matter (measured in the form of dissolved organic carbon). The St. Lawrence River, by far the largest tributary of the estuary, contributes over 85% of the particulate organic matter and 60% of the dissolved organic matter.
- *Estuary*: The survey results show that, in summer, the load of suspended particulate matter (measured in the form of particulate organic carbon) in the estuary is around **106,000 tonnes** and that of dissolved organic material (measured in the form of dissolved organic carbon), roughly **1.699 million tonnes**.

The measurements taken can be used to improve the accuracy of the three-dimensional biogeochemical model (Objective 2) and inform the study of the dissolved oxygen cycle in deep water (Objective 3), in order to better understand the impacts of microbial organic matter transformation on deep-water hypoxia and acidification (Objective 4).

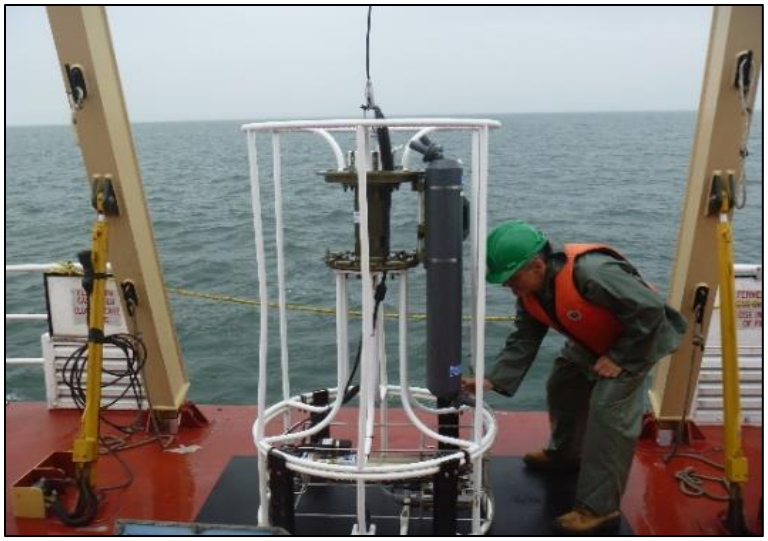

Figure 9. Taking a water sample using a rosette sampler and a Niskin bottle

Deliverables

- At least four scientific articles, two of which have already been published [11, 12]
- A master's thesis, currently in progress
- A database on organic matter in the estuary and its tributaries
- Two oral presentations at scientific conferences.

Project 2: Create retention ponds to capture pesticides and nutrients

Background

Runoff in agricultural environments is often laden with particles and contaminants, which can be transported to and alter nearby aquatic environments and their ecosystems. Retention ponds (Figure 10) are commonly used to prevent these environmental impacts. Built alongside a field, they create a wet area that retains agricultural runoff, which can then be treated with some water treatment methods.

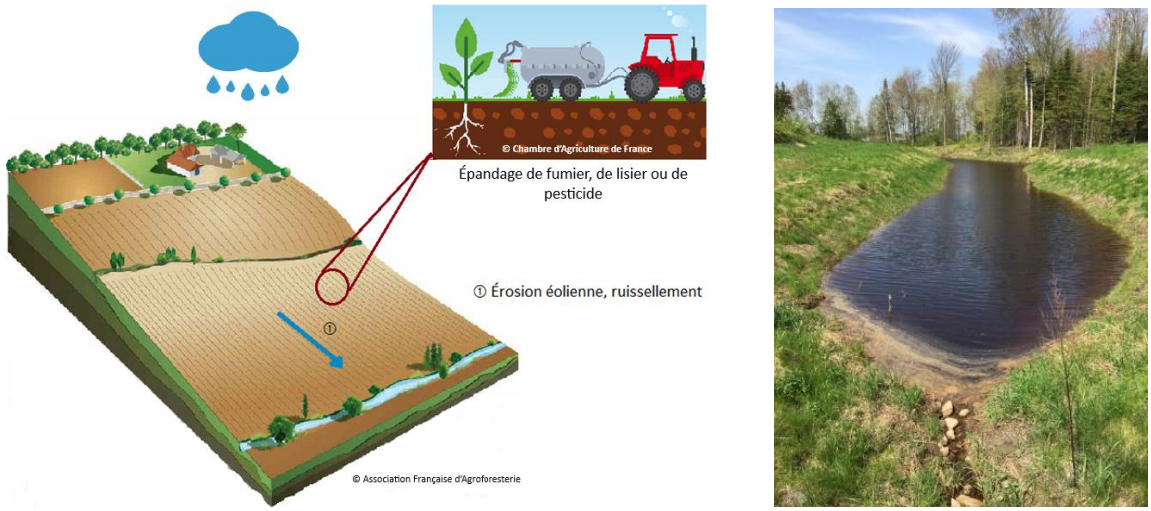

Figure 10. Runoff in the agricultural environment (left) and a retention pond (right)

Retention ponds are a simple, low-cost solution for retaining and treating potential agricultural contaminants in runoff, before they reach larger water bodies such as Lake Saint-Pierre. Therefore, evaluating the effectiveness of this measure is crucial before it is implemented on a large scale.

General objective
Evaluate the effectiveness of a retention pond in treating part of the runoff from crop fields.

Specific objectives
1. Evaluate the effectiveness of a retention pond in treating agricultural runoff.
2. Assess the retention pond's potential environmental impacts (potential toxicity of water and sediments in the pond, potential presence of antibiotic resistance genes, greenhouse gas emissions).

Results
Retention pond effectiveness
A reduction in nutrient and suspended solid (SS) concentrations was measured between the inlet and outlet of the retention pond, leading to the conclusion that the pond was effective in retaining these components of agricultural runoff. On the other hand, the elimination of pesticides varied depending on the type of pesticide and the year. The estimated removal efficiency for glyphosate and its degradation product aminomethylphosphonic acid (AMPA), based on the difference in concentrations measured at the inlet and outlet of the pond, can be explained by the tendency of these substances to bind to particles and therefore to occur in sediments after settling to the bottom. Thiamethoxam in the pond water was degraded quickly through hydrolysis and photolysis. However, a negative removal efficiency was observed for other pesticides (atrazine, metolachlor and clothianidin), indicating that they tend to persist in pond discharges.

Toxicity of retention pond water

The effects of the retention pond water on several organisms were assessed using toxicity tests. The pond water inhibited the growth of the alga *Raphidocelis subcapitata*, which could be associated with the significant quantities of suspended solids in the water, which considerably reduce the light penetration needed for algal growth. No toxicity was observed in the invertebrates *Daphnia magna* (Figure 11) and *Hyalella azteca*. However, American Toad (*Anaxyrus americanus*) tadpoles (Figure 12) exposed to pond water were much smaller than the control animals and the metamorphosis rate in tadpoles was altered after exposure to the pond water.

Figure 11. *Daphnia magna*

Figure 12. American Toad (*Anaxyrus americanus*) eggs

Greenhouse gases (GHG)
Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) saturation profiles were demonstrated in the pond water, sometimes even indicating supersaturation. The productivity of this environment (nutrients, phytoplankton biomass, presence of aquatic plants) provides ideal conditions for GHG production.

In summary, the results show that the retention pond is an effective solution for retaining nutrients, suspended solids, and certain pesticides (glyphosate and its degradation product AMPA, as well as thiamethoxam). However, the pond water had toxic effects on algal growth and the development of the American toad. In addition, it provides conditions that promote GHG production.

Deliverables
- The data generated by this project were used in a master's thesis and part of a doctoral dissertation.
- Ten oral presentations and six posters were presented during international or national conferences.
- At least two scientific articles are currently being drafted.

External collaborators
- Institut national de la recherche scientifique (INRS) / Centre Eau-Terre et Environnement (National Institute of Scientific Research, Water-Land and Environment Centre)
- Institut de recherche et de développement en agroenvironnement (IRDA) (Research and Development Institute for the Agri-Environment).

Project 3: Improve knowledge about pathogenic microorganisms from agricultural sources in the Lake Saint-Pierre tributaries

Background
The tributaries of Lake Saint-Pierre (LSP) and the St. Lawrence River support a range of recreational uses such as sport fishing and swimming, as well as providing a source of drinking water. The presence of fecal contamination indicators suggests that pathogenic microorganisms may be present, and furthermore may be resistant to antibiotics. The fecal contamination may come from livestock manure from one or more livestock operations in the watershed, from human sewage, from wildlife, or from several of these sources simultaneously. The nature and origin of this contamination were characterized in order to better determine measures for reducing it at the source.

General objective
Improve knowledge of the nature and sources of potential microbial pathogens in raw water in four drinking water intakes and in the LSP tributaries with a view to developing a decision support tool.

Specific objectives

1. **Component 1**: The presence of the protozoa (microorganisms) *Giardia* and *Cryptosporidium* and the bacterium *Campylobacter* was measured in raw water (before treatment) at four drinking water intakes (Figure 13) between 2011 and 2013. *Cryptosporidium* genotyping was performed to determine the source of this contamination. It should be noted that all the drinking water plants whose intakes were sampled use highly effective treatments to eliminate microorganisms before the drinking water is distributed.
2. **Component 2**: Measure concentrations of fecal contamination indicator bacteria (*E. coli* and enterococci) and their antibiotic resistance at 13 sampling stations in the main LSP tributaries and in the St. Lawrence River at the inlet and outlet of LSP (Figure 13) over a five-year period (2011–2016).
3. **Component 3**: Measure certain source tracking markers for fecal contamination in five LSP tributaries (Figure 13) over a three-year period (2016–2019) and improve the markers' analytic capacity.

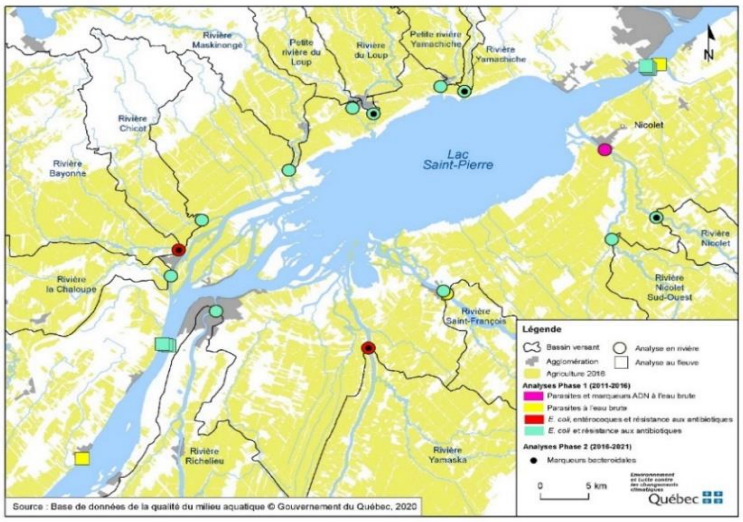

Figure 13. Location of sampling stations and types of surveys performed

Results

The highlights of the results are as follows:

- *Giardia* cysts and *Cryptosporidium* oocysts were detected in the raw water at four water intakes, with median concentrations of between 1 and 4 cysts per litre in the case of *Giardia* and between 0.1 and 0.5 oocysts per litre in the case of *Cryptosporidium*.[13]
- The raw water in three of the four intakes contained more than 150 CFU/100 mL of *E. coli* bacteria, an indication of degraded water quality.[13]
- The source of the genotyped *Cryptosporidium* oocysts was frequently agriculture and wildlife. Potentially human-infectious *Cryptosporidium* spp. and *Campylobacter* bacteria were also found.[14]
- An analysis of source tracking markers for contamination using mitochondrial DNA was carried out on raw water from one of the four water intakes. Human, porcine and bovine markers were detected in one half, one third and one tenth of samples respectively.[15]
- In eight LSP tributaries, *E. coli* concentrations exceeded the acceptable threshold of 150 CFU/100 mL (median) or 1,500 CFU/100 mL (95th percentile), indicating a high level of vulnerability to microorganisms in the water, which is used as a source of drinking water. In five other LSP tributaries, the thresholds of 15 CFU/100 mL (median) or 150 CFU/100 mL (95th percentile), which indicate a medium level of vulnerability, were exceeded. The 13 tributaries showed *E. coli* concentrations that often exceeded, depending on the site, the threshold of 200 CFU/100 mL, which indicates water unsafe for swimming.
- Overall, the proportion of antibiotic-resistant indicator bacteria ranged from 0% to 100% depending on the bacterial species, year and antibiotic tested. A strong link between *E. coli* resistance to tetracycline in the tributaries and hog density was also noted. [16]
- During the 2016–2019 period, progress was made in the capacity to analyze *Bacteroidales* source tracking markers for microbial contamination and five locations were monitored.

External collaborators

- INRS–Institut Armand-Frappier Research Centre

3. IMPLEMENTING INTEGRATED MANAGEMENT OF THE ST. LAWRENCE

3.1 Regional round tables

The mission of the permanent independent bodies referred to as regional round tables (RRTs) is to serve as forums where the various regional stakeholders involved in the management of resources and uses in their respective sections of the St. Lawrence can plan and harmonize their actions so as to contribute to the integrated management of the St. Lawrence. The mandate of the RRTs is to develop and implement, at their respective regional levels, a Regional Integrated Management Plan (RIMP) that represents regional stakeholders' priorities and their commitment to action.

During the 2016–2021 period, investments of $3.75 million were allocated to ensure the proper functioning of the RRTs. Six organizations (Jacques-Cartier ZIP Committee, Lac Saint-Pierre ZIP Committee, Les Deux Rives ZIP Committee, Quebec Metropolitan Community, Sud-de-l'Estuaire ZIP Committee and Îles-de-la-Madeleine ZIP Committee) coordinate the activities of the RRTs in the six St. Lawrence integrated management areas already established (Haut-Saint-Laurent and Greater Montreal, Lake Saint-Pierre, fluvial estuary, Quebec City, southern part of the middle estuary, and the Magdalen Islands).

During this five-year period, the six RRTs held 638 meetings and produced 645 publications, and RRT webpages were consulted more than 60,000 times. The six RRTs also submitted all the documents making up the Regional Integrated Management Plan (RIMP) for their respective management area to MELCC for approval.

ZIP (Area of Prime Concern) Program

The ZIP Program allows ZIP committees, as well as their umbrella organization Stratégies Saint-Laurent (SSL), to coordinate and implement collaborative activities by St. Lawrence stakeholders in order to respond to the priority issues set forth in the *Canada–Quebec Agreement on the St. Lawrence*. This collaboration helps local communities to become aware of and better understand the challenges involved in biodiversity conservation, sustainable use, and improved water quality. The ZIP committee network thus supports the implementation of the integrated management of the St. Lawrence (IMSL) through its activities, which complement those of the RRTs. For example, under the ZIP program, 12 ZIP committees up and down the St. Lawrence were able to continue their collaborative efforts, supported by their scientific knowledge and expertise. In addition, some committees developed or updated their regional ecological remedial action plans (ERAPs), based on new knowledge or participation by their partners, contributing to community discussion on, and mobilization around, new environmental issues.

In their activities, the ZIP committees have been able to bring together dozens of stakeholders from different sectors, including Indigenous communities and the industrial, municipal, academic and community sectors. They have also been actively involved with the public, disseminating information and knowledge on environmental issues and the St. Lawrence ecosystem. The ZIP committees have helped to promote the conservation of the rivers' ecological wealth and sustainable uses, for the benefit of everyone,

as well as the protection of water quality. Lastly, they are involved at the local level in initiatives to fight illegal dumps and invasive plant species and to protect wetlands. ECCC has allocated $1.0 million annually to help fund these initiatives and support participation in the ZIP committee network.

3.2 St. Lawrence Forum

The St. Lawrence Forum (also known as the Forum on the St. Lawrence) is an invitational event which provides an opportunity for discussion and joint action, bringing together St. Lawrence stakeholders from the First Nations, municipal, economic, community, environmental, recreational, research and education sectors, as well as governments with responsibilities or interests related to the management of the river's ecosystems, resources and uses. The overall objective of the event is to share and pool together stakeholders' concerns, expertise, tools, resources, and possible solutions in order to encourage their joint action on issues affecting the St. Lawrence.

During the 2016–2021 period, the sixth and seventh forums were held:

- On November 28 and 29, 2018, with the theme "From Upstream to Downstream," 134 participants had the opportunity to broaden their knowledge, share their experiences and network with the various stakeholders present.
- On May 11, 13 and 18, 2021, with the theme "Science at the Service of Decision-Makers," the forum involved three webinars accessible to all, as well as discussion workshops. Over 350 participants had the opportunity to communicate their visions and needs to scientists in virtual presentations followed by discussion periods.

4. COMMUNITY PROJECTS AT THE HEART OF THE ACTION

4.1 Community Interaction Program (CIP)

The Community Interaction Program (CIP) is a funding program that supports community projects that strive to conserve, and improve the state of, the St. Lawrence ecosystem. ECCC and MELCC jointly administer and implement this program under SLAP 2011–2026.

Between 2016 and 2021, the two departments invested $3,290,233 to fund 59 projects carried out by 44 organizations. The projects have a total value of nearly $5 million, including investments from partners.

Table 1. Number of new projects funded during the 2016–2021 period (by category)

Biodiversity protection / restoration projects	Study / action projects	Public awareness projects	Study projects	Total
18	6	16	19	59

Examples of projects

Biodiversity protection / restoration project

Odanak Yellow Perch project: Restoration of a marsh by the Abenaki Council of Odanak

The purpose of this project was to facilitate fish movement in a section between a branch of the Saint-François River (Tardif channel) and a marsh in Odanak community territory, in order to support the spawning, maturation into adults and growth of Yellow Perch. The restoration (corrective measures for an inadequate slope and culvert), stabilization and revegetation work improved flow velocity and facilitated fish movements.

The project resulted in the restoration of roughly 4 ha of high-quality Yellow Perch habitat. Odanak community members participated in this wildlife project, as well as MFFP and the Fondation de la faune du Québec. The project, valued at around $85,000, received $39,126 in funding from the CIP.

Study / action project

Restoration of the spit of the Saint-Omer bank by the Gaspésie ZIP committee

The purpose of this study / action project was to protect the biodiversity of a salt marsh by restoring the spit of the Saint-Omer bank in Carleton-sur-Mer, in the Gaspé region, to preserve the ecological services it provides. A characterization study of the shoreline profile and a particle-size analysis were conducted, followed by sand replenishment and revegetation work. The project also led to the creation of a community awareness patrol to promote environmentally responsible behaviour in coastal environments.

This project resulted in the protection of an important 5-ha coastal marsh. Numerous partners participated: Ouranos; Université de Québec à Rimouski (UQAR); the birding group Club des ornithologues de la Gaspésie; and the City of Carleton-sur-Mer. The project, valued at around $158,081, received $99,890 in funding from the CIP.

Public awareness project

Défi Saint-Laurent (St. Lawrence Challenge) by Stratégies Saint-Laurent (SSL)

The aim of this project was to reduce the use of plastics and to clean up coastal environments where these materials accumulate by organizing clean-ups and a public awareness campaign on the impacts of plastics and microplastics on ocean biodiversity (habitats and species), particularly in the estuary and Gulf of St. Lawrence. The campaign, launched by SSL in partnership with the consulting firm M – Expertise Marine and with the participation of all the ZIP committees working in the marine environment, included collective clean-up efforts along the shoreline in the territories of all the ZIP committees involved, the development of a teaching kit and educational materials (including for conferences), commitment to behavioural change, and the publicizing of plastic clean-up campaigns.

The project, with a total value of over $222,000, received $97,213 in funding from the CIP and was implemented in cooperation with Aquaforum and CMONBAG.

Study project

Collective action plan for the sustainability of the Baie de Carillon by Abrinord

The degradation of the water quality in the Baie de Carillon is linked to threats to the integrity of aquatic and riparian ecosystems, which affect the biodiversity of the bay and river. The purpose of the project was to develop a collective action plan for the bay's area of influence, based on the characterization, profile and analysis of the study area. The action plan will make it possible to address community concerns, ensure sustainable use, and preserve the natural and cultural heritage of the Baie de Carillon, and thus reduce the vulnerability of the St. Lawrence ecosystem. Under the project, eight kilometres of shoreline were characterized.

The project, with a total value of over $40,000, received $24,500 in funding from the CIP and was implemented in cooperation with the Argenteuil Regional County Municipality, the environmental organization Conseil régional de l'environnement des Laurentides, the bird conservation organization Développement ornithologique Argenteuil and the conservation group Éco-corridors laurentiens.

5. INCREASING KNOWLEDGE TO IMPROVE DECISION MAKING

5.1 State of the St. Lawrence Monitoring Program

The State of the St. Lawrence Monitoring Program (SSLMP) was established in 2003 under the *Canada–Quebec Agreement on the St. Lawrence*. Since then, the partners have pooled their expertise to regularly report on the state and evolution of the St. Lawrence ecosystem. The results of environmental indicator monitoring (involving water, sediments, biological resources, uses and shorelines) are made available through a series of fact sheets, the Rendez-vous St. Lawrence event, and an overview report published every five years. The aims of the program are as follows:

- Pool the data collected and knowledge acquired by participants and collaborators during their ongoing environmental monitoring activities.
- Report on the state and evolution of the St. Lawrence using the scientific information generated.
- Regularly inform decision-makers and shoreline communities about the state of health and evolution of the St. Lawrence River, using dissemination tools that are tailored to their needs and that facilitate access to information.

Overview of the State of the St. Lawrence 2019

Thanks to the collaboration and expertise of the partners making up the Working Group on the State of the St. Lawrence Monitoring (WGSSLM), the fourth *Overview of the State of the St. Lawrence* (OSSL) was published. The 2019 OSSL describes the overall status of, and changes in, water quality in the St. Lawrence, as well as the major issues affecting the socio-ecological components of the St. Lawrence and the outlook for its short-, medium- and long-term health, notably:

- Excessive nutrient loads in Lake Saint-Pierre
- The acidification of the waters of the Gulf
- The impact of climate change on the river's tributaries.

An improvement, but a fragile balance

Figure 14 and Table 2 show the highlights of the overall findings (between 2013 and 2017) on the state of the St. Lawrence. In brief:

Overall status:

- 90% of indicators were ranked "good"
- 10% of indicators were "moderate-poor" or "poor"

Among the 14 indicators assessed in both the 2014 and 2019 overviews:

- 5 improved
- 9 remained stable

Among the six other indicators that were not assessed in both overviews or that were modified between the two reports:

- 1 improved
- 4 remained stable
- 1 deteriorated

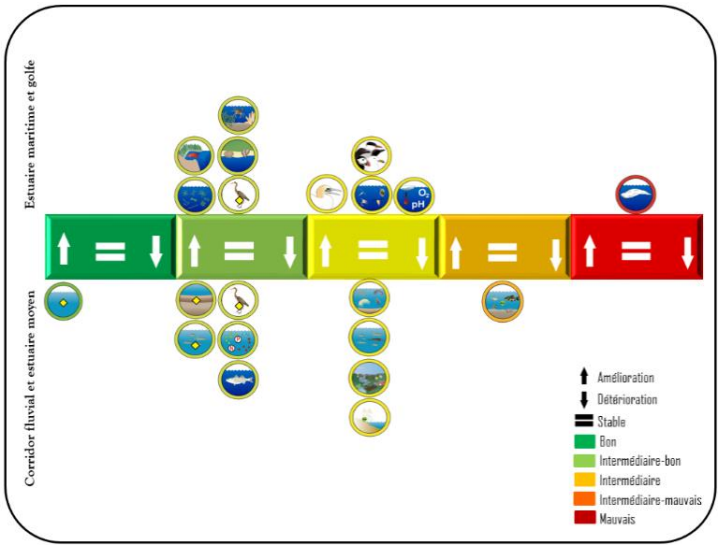

Figure 14. Distribution of the indicators assessed (most between 2013 and 2017) based on the findings on their status and trends

Table 2. Highlights of the 2019 Overview

Indicator	Highlights
Monitoring of land use	– "Moderate" status – Overall stable trend
Physicochemical and bacteriological parameters of St. Lawrence River water (index of bacteriological and physicochemical water quality, or IQBP5)	– Water quality "moderate-good" from 2015 to 2017 – Stable trend between the last two overviews (2014 and 2019)
Contamination of river water by toxic substances	Clear improvement in status of indicator (from "moderate" to "good") from the 2014 to the 2019 overviews
Contamination of sediments by toxic substances	Sediments at the sites monitored in the northern sector (Lake Saint-Louis, the fluvial section and Lake Saint-Pierre) are much less contaminated than those at the sites in the southern sector.
Contamination of freshwater fish by toxic substances	– Improving trend – Average mercury, polychlorinated biphenyl (PCB) and polybrominated diphenyl ether (PBDE) levels in the monitored species are often in line with the established recommendations, and most are declining or stable.
Contaminants measured in Great Blue Heron eggs	Overall downward trend in contaminant levels
Benthic macroinvertebrates	Community richness is lower in the fluvial section and Lake Saint-Louis than in Lake Saint-François and Lake Saint-Pierre.
Monitoring of invasive aquatic animal species (IAAS) in the St. Lawrence	The Round Goby is spreading quickly throughout the fluvial section, particularly in areas further upstream such as Lake Saint-François.
Fish communities in fresh and brackish waters	Stable overall since the 2014 Overview
Striped Bass	Spatial distribution and growth "good," but reproduction and abundance "moderate."
Invasive alien plant species	93% of study sites affected by at least one of the species monitored
Beluga population	Increased mortality in newborns and females in and around calving season
Monitoring of marine aquatic invasive species	Invasion index scores fairly low overall but worrisome in some sectors, mainly due to climate change
Phytoplankton community in the estuary and Gulf	Improving trend in recent years
Zooplankton community in the estuary and Gulf	Significant decline in zooplankton biomass
Toxic algae in the estuary and Gulf	– "Moderate-good" – Improving trend
Northern Gannet population	Signs of improvement since the 2014 Overview
Seabird populations	– The Atlantic Puffin population shows a slight increase; the Caspian Tern population has reappeared at very low levels, which is nonetheless encouraging. – Worrisome long-term downward trend in the Herring Gull population
Quality of shellfish growing waters	– The water quality is excellent in the shellfish waters around the Magdalen Islands and Lower North Shore, unlike those in the Gaspé and Lower St. Lawrence regions. – Water quality in the shellfish waters of the Middle North Shore and Upper North Shore / Charlevoix was rated moderate.
Oceanographic processes	Downward trend due to climate change

Rendez-vous Saint-Laurent

The Rendez-vous Saint-Laurent is one of the dissemination mechanisms for the State of the St. Lawrence Monitoring Program. This event, held periodically, brings together experts and stakeholders from communities, non-governmental organizations, industry, universities, and the municipal, provincial and federal governments.

The fifth Rendez-vous St. Lawrence was held in 2016, in Quebec City, on the theme "Meeting the Information Integration Challenge." The event attracted about 100 participants, including experts and representatives of communities, non-government organizations, industry, universities and government. Its objectives were as follows:

- Share the most recent results of the monitoring activities and the new elements of the State of the St. Lawrence Monitoring Program.
- Increase the knowledge of the St. Lawrence.
- Obtain input from users of SSLMP data and information.

The sixth edition of the event, from January 25 to 29, 2021, was held in the form of six webinars on various themes, with the objective of publicizing current initiatives to protect the St. Lawrence and the most recent results of the SSLMP.

Fact sheets

Fact sheets (also known as monitoring sheets) present and analyze the data gathered in the MSSL program for each environmental indicator. These sheets deal with subjects like river flows, water quality, biological resources, shorelines, sediments and uses. During the 2016–2021 phase of SLAP, 12 fact sheets were produced (St. Lawrence River Monitoring Sheets | St. Lawrence Action Plan (planstlaurent.qc.ca). The following are some of the fact sheets expected to be published by March 2021:

Government	Publication
Canada	– Contamination of water by toxic substances – Phytoplankton, toxic algae and zooplankton in the estuary and Gulf of St. Lawrence – Oceanographic processes: Temperatures, dissolved oxygen and acidification – Shellfish water quality in the estuary and Gulf of St. Lawrence – Northern gannet – population status – Beluga whale – population status – Changes in the levels and flows of the St. Lawrence River
Quebec	– Toxic Contamination of Freshwater Fish – Suivi des sites potentiels de baignade (monitoring of potential swimming sites) (in French only)

5.2 Numerical Environmental Prediction Program

The mandate of the Working Group on Numerical Environmental Prediction (WGNEP) is to develop numerical models to simulate changes in physical, biological or chemical processes in the St. Lawrence and its watershed, in order to predict the state of health of its terrestrial and aquatic environments. The objectives of the group are as follows:

- Improve predictions in order to better understand the St. Lawrence ecosystem and flow regime
- Provide a decision support and planning tool for integrated management of the St. Lawrence.

Many activities are carried out under the Numerical Environmental Prediction Program, including the following:

- Representing and predicting the dynamics and state of the ecosystem to help facilitate adaptation to future conditions and analyze the impact of climate change
- Supporting public safety responses to environmental emergencies: for example, during an accidental spill that could contaminate the water, during high-flow and low-flow periods, or during search and rescue operations
- Facilitating environmental assessments by analyzing the impacts of potential engineering works, particularly on erosion and sedimentation processes
- Supporting socio-economic activities: for example, by predicting clearances and channel depths required for commercial shipping under different climate change scenarios.

The WGNEP is able to integrate the following elements into its models:

- **Water**: currents, temperature, waves, levels, flows, quality and salinity
- **Ice and snow**: cover, thickness, temperature and density
- **Health of the ecosystem**
- **Precipitation**
- **Soil and vegetation conditions –** temperature and moisture content.

Examples of projects

Project 1: Enhance the use of meteorological data (precipitation analyses) from the St. Lawrence watershed

Background

Precipitation and snow depth observations are important inputs in a number of environmental prediction systems, including hydrological forecasting systems. These observations can include:

- Measurements by observers
- Automated ground measurements
- Remote sensing observations.

Since these observations are crucial but expensive to obtain, several federal, provincial and municipal organizations operate their own precipitation measurement programs. Both ECCC and MELCC have major facilities in the St. Lawrence watershed to measure precipitation. Owing to multiple constraints, not all the data generated are not shared between the departments. Improving data sharing and exchange mechanisms would allow better characterization of the spatial and temporal distribution of precipitation.

Specific objectives

To support specific SLAP projects, particularly those involving hydrological forecasting, this project aims to develop a common method for the measurement and spatialization of precipitation and snow depth data in the St. Lawrence Basin. Its objectives are as follows:

1. Compare current and historical techniques for measuring precipitation and develop best practices, particularly for solid precipitation and snow depth.
   The analysis of the data generated in the Canadian Solid Precipitation Inter-Comparison Experiment (C-SPICE) project, a parallel initiative in which ECCC and MELCC are partnering, will assist in this effort.
2. Establish a common database for precipitation observations from the recent past, including existing spatialized datasets for that period.
3. Compare current precipitation measurement and spatialization techniques and develop an optimal procedure for the spatialization of these data.

Results

1. ECCC's Canadian Precipitation Analysis (CaPA) system was installed at MELCC to assess the effect that adding MELCC data would have on the quality of precipitation analyses produced with the ECCC system. At the same time, a MELCC dataset was transferred to ECCC so that ECCC could perform the same assessment for the Richelieu watershed. In both cases, data pooling was demonstrated to improve the quality of precipitation analyses.
2. A solid precipitation intercomparison station was installed at the NEIGE site in Montmorency Forest. A report was prepared and submitted and is updated annually by Université Laval. Three international references to study precipitation undercatch processes were installed:

   2.1. **Reference 1**: A bush-type screen consisting of a precisely controlled arrangement of shrubs of a specific height and size. This windshield eliminates all wind turbulence, allowing all snow to be caught and eliminating bias. However, snow accumulation in southern Quebec is so great that it gradually buries the plants, almost reaching the height of the gauge and reducing the screen's effectiveness. Installation and maintenance related constraints also limit the usefulness of this type of windshield in our climate. A second arrangement, consisting of an opening in the middle of the forest, has been tested since the winter of 2020.
   2.2. **Reference 2**: A Double Fence Intercomparison Reference (DFIR) combined with a Tretyakov precipitation gauge (Figure 15)
   2.3. **Reference 3**: A Double Fence Automated Reference (DFAR), which minimizes the effect of the wind and is used to accurately measure wintertime precipitation every minute using a totalizer rain gauge.

   The DFIR had the best catch efficiency. The Nipher snow gauge (used by MELCC) was also demonstrated to provide accurate measurements, with a catch efficiency of 93%relative to the DFIR measurements. However, the DFIR and Nipher devices require the presence of an observer, which is not always possible, and do not take hourly measurements, which is preferred for hydrological forecasting. The reliability of the OTT totalizer rain gauge (used by MELCC) was also demonstrated, and the data generated by it were also better correlated with the DFIR data than those from the Geonor gauge (often used by ECCC). The catch efficiency obtained with the double Alter shield which is often used by ECCC (85%) does not justify it replacing a single Alter shield (86%, used at MELCC).

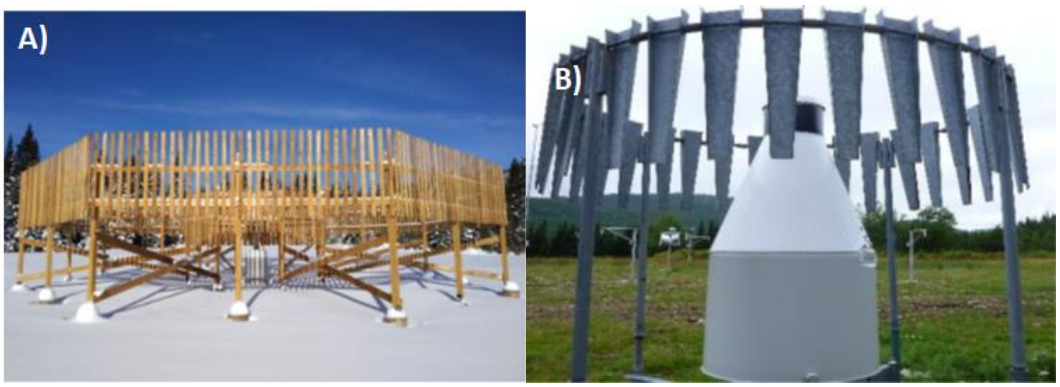

Figure 15. (A) DFAR-type shield, which is in fact identical to the DFIR; the difference between the two devices is the measurement instrument in the middle; (B) OTT Pluvio precipitation gauge [17] installed in a single Alter shield.[17]

Project 2: Establish linkages between hydrological models of the St. Lawrence watershed

Background

Hydrological forecasting, which is used to estimate the hydrological impacts of future meteorological events, is an important tool in:

- Flood warning systems
- The safe and effective management of public and private dams
- Navigation and environmental emergency response.

In the case of the St. Lawrence and its tributaries, a number of scientific and organizational issues limit the implementation of an optimal hydrological forecasting system. Technical capacities must be shared since both the federal and Quebec governments produce useful information for forecasting but neither partner can optimally fulfill its mandates by working in isolation. Consequently, developing tools and approaches for pooling forecasting capacities is helpful.

This project essentially involves carrying out different experiments on sharing hydrological forecasting tools. These experiments began during the first phase of SLAP (2011–2016) and have continued under the current phase (2016–2021). The main work has involved studying the benefits of merging numerical forecasting models to issue forecasts versus retaining separate numerical systems and merging the provisional results. Three SLAP-funded sub-projects carried out by university teams have tested several ideas. Certain efforts by the ECCC and MELCC teams have strengthened the results, paving the way for operational applications. These sub-projects included:

- **Sub-project 1 (Université Laval)**: Merge the CLASS model used by ECCC and the HYDROTEL model used by MELCC.
- **Sub-project 2 (Université Laval)**: Use different forecasting systems to create positive redundancy.
- **Sub-project 3 (Université Sherbrooke)**: Merge the results from ECCC's MESH and MELCC's FEWS-SPH systems.

These experiments have allowed certain guidelines to be developed for the potential pooling of ECCC and MELCC forecasts.

General objective
Improve the hydrological forecasting of water inflows into the St. Lawrence watershed.

Specific objectives
1. Harmonize ECCC's and MELCC's numerical atmospheric and hydrological modelling and data assimilation systems.
2. Assess the gains achieved in forecast quality from pooling data and numerical models.

Project results
The project allowed sufficient conclusions to be drawn to establish the following guidelines for the future pooling of ECCC and MELCC forecasts:

1. Merging numerical models is technically difficult and of limited interest in the future.
2. Each party's forecasting system has different strengths, and additional improvements can be made to these systems by leveraging these strengths. The MELCC system relies mainly on various scientific algorithms, whose results are improved daily by hydrological forecasters who take account of local conditions in the field. The ECCC system uses calculation and data management infrastructure, which can be deployed on an automated basis and are commensurate with its significant meteorological forecasting requirements.

3. The pooling of the results of the forecasting systems, each operating independently and with complementary strengths, looks highly promising since it generally leads to better results than those obtained from each system working independently.

Figure 16 illustrates the performance gains achieved in a specific example—forecasting the total amount of water transiting through 43 measurement stations located in the Quebec portion of the St. Lawrence Basin, predicted two days in advance, from February to April 2017. Figure 16A shows the results of the two systems considered independently, while Figure 16B shows the pooled results, which were calculated simply by averaging them. The pooled results generally correspond better to observations. It should be noted that an evaluation over a longer time period using more advanced pooling strategies than simply calculating the arithmetic mean is currently being studied under Sub-Project 3.

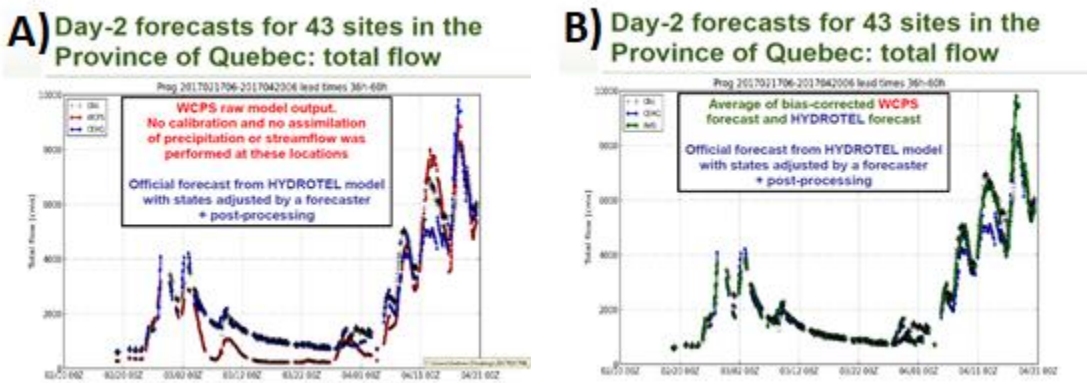

Figure 16. Day-2 numerical forecasts of the total flow at 43 measurement stations in the Quebec portion of the St. Lawrence Basin. In Figures (A) and (B), the hydrographs (black) correspond to the quantities of water observed, the forecasts by ECCC's MESH system (red), the forecasts by MELCC's FEWS-SPH system (blue) and the forecasts obtained by averaging the results of the two systems (green).[18]

CONCLUSION

Along with fostering community engagement as part of the integrated management of the St. Lawrence, the St. Lawrence Action Plan, which receives funding provided under the Community Interaction Program (CIP), is primarily concerned with issues related to biodiversity conservation, sustainable use, and improved water quality. Clearly, the results obtained in the different projects carried out under SLAP have supported knowledge acquisition, the advancement of science and decision making. Furthermore, obvious improvements have been made in the health of the St. Lawrence according to 90% of the indicators assessed in the 2019 Overview. However, the remaining 10% require special attention, primarily those related to nutrients, emerging contaminants, invasive alien species, and the beluga.

In the area of decision support tools, WGNEP projects have led to the installation of ECCC's Canadian Precipitation Analysis (CaPA) system at MELCC and, at the same time, the transfer of MELCC data to ECCC to assess the impact of this addition on the quality of precipitation analyses produced with the ECCC system. This pooling of data and models has helped to improve precipitation analyses. Furthermore, the establishment of linkages between the two departments' hydrological forecasting models for the St. Lawrence watershed shows promise for the future since overall, it leads to better results than those obtained from either system operating independently.

In renewing the *Canada–Quebec Agreement on the St. Lawrence* in 2021, the governments of Canada and Quebec have reaffirmed their mutual commitment to collaborate actively on the protection and enhancement of the St. Lawrence. This agreement allows the governments to pool their resources and expertise over the long term to achieve their objectives. A number of joint actions were completed during the 2016–2021 phase of the St. Lawrence Action Plan, while others will continue in the 2021–2026 phase. The new programming will also provide an opportunity to undertake new projects in order to examine emerging issues such as microplastics and their risks to the health of the St. Lawrence ecosystem, the impacts of pesticides and cyanotoxins in Lake Saint-Pierre, the health risks posed by poor bacteriological water quality at potential swimming sites in the river, the health and evolution of aquatic grass beds in the St. Lawrence River and the use of the river for sustainable commercial and recreational fisheries. A recent project on establishing a common framework to assess the cumulative impacts of marine activities on the St. Lawrence will continue in 2021–2026.

The two governments will also continue working to complete the roll-out of the integrated management of the St. Lawrence in the estuary and Gulf sectors.

Here are some key facts on the 2021–2026 phase:

- Nine federal departments and agencies and an equal number of Quebec departments and agencies will invest roughly $36 million and $25 million dollars respectively over the next five years to implement the measures specified in the St. Lawrence Action Plan.
- Activities under the State of the St. Lawrence Monitoring Program will continue. The implementation of this program will allow the health of the St. Lawrence to be monitored, thus fostering a better understanding of changes in the health of its waters and ecosystem, particularly in the context of climate change.
- The St. Lawrence Action Plan will continue to support participation by riverside communities through the CIP, which funds community projects that aim to conserve and improve the St. Lawrence ecosystem. This program will be renewed in the 2021–2026 phase of SLAP, with a $4.36 million investment.

Overall, despite noticeable improvements, the growing pressures on and vulnerability of the St. Lawrence ecosystem remain, along with an expanding range of socio-economic interests and ever more complex environmental issues. The challenges to be overcome are numerous and the participation and collaboration of all parties will be essential to take on these challenges.

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APPENDIX 1: LIST OF PROJECTS BY ISSUE COMMITTEE (IC) AND WORKING GROUP (WG)

Issue Committee: Biodiversity Conservation	
Orientation 1: Identify, protect, restore and enhance environments of ecological importance	
Objective 1.1: Develop common planning tools for identifying habitats of interest	
Complete and fine-tune the inventory of other conservation measures	MELCC
	ECCC
Identify important fish habitats and protect connectivity	MFFP
	ECCC
	DFO
Complete, disseminate and promote the integrated plan for conserving natural areas	MELCC
	MFFP
	ECCC
Implement the ecological surveillance and biodiversity monitoring program in the protected areas of the St. Lawrence and surrounding areas	MELCC
	MFFP
	ECCC
Assess and propose knowledge transfer actions and tools	MELCC
	MFFP
	MAPAQ
	ECCC
Take an inventory of conservation measures in the estuary and Gulf of St. Lawrence	MELCC
	DFO
Objective 1.3: Develop and restore areas of interest	
Restore the Lake Saint-Pierre shoreline	MFFP
	ECCC
Prepare a guide on restoring the degraded wetlands of the St. Lawrence	MELCC
	ECCC
Orientation 2: Prevent the introduction and control the spread of invasive alien species	
Objective 2.1: Establish prevention tools	
Develop common information and awareness tools	MELCC
	MFFP
	MAPAQ
	DFO
Objective 2.3: Detect the introduction and monitor the spread of aquatic invasive species (AIS)	
Continue to harmonize detection and monitoring programs and activities for aquatic invasive species (AIS)	MELCC
	MFFP
	DFO

Develop joint action and response plans in the event of detection	MELCC
	MFFP
	MAPAQ
	DFO
Evaluate the distribution and population dynamics of the Tench (*Tinca tinca*)	MFFP
	DFO
Objective 2.4: Gain a better understanding of the effects of invasive alien species	
Evaluate the effects of invasive alien fish species on freshwater mussels indigenous to the St. Lawrence (project completed)	MFFP
	ECCC
Determine the spread and assess the impacts of alien parasites	MFFP
	ECCC
Issue Committee: Sustainable Use	
Orientation 4: Promote sustainable management of fisheries resources	
Objective 4.3: Develop and promote sport fishing in the St. Lawrence	
Promote recreational fishing in the St. Lawrence	MFFP
	DFO
Orientation 6: Maintain and promote sustainable navigation	
Objective 6.1: Maintain and increase co-operation among St. Lawrence stakeholders, as well as with Great Lakes stakeholders, concerning navigation	
Participate actively in consensus-building forums on sustainable navigation issues	MELCC
	MTQ
	ECCC
	TC
Continue the activities of the Navigation Coordination Committee	MELCC
	MFFP
	MTQ
	MTO
	ECCC
	DFO
	TC
Establish a common framework for assessing the cumulative impacts of navigation activities on the St. Lawrence	MTQ
	MFFP
	MELCC
	MSP
	TC
	DFO
	IAAC

Objective 6.3: Implement and promote the integrated management of dredging, sediments and navigation	
Broaden the scope of the Dredging Activities Planning Registry and keep it updated on an ongoing basis	MELCC
	MTQ
	ECCC
	PSPC
Continue the activities of the Coordination Committee on the Integrated Management of Dredging and Sediments	MELCC
	MFFP
	ECCC
	DFO
	TC
	PSPC
Integrate wildlife and habitat-related issues in the potential development of marine transportation	MFFP
	ECCC
	DFO
Objective 6.4: Prevent the negative impact of vessel-generated wave action on bank erosion	
Continue monitoring vessel speed data	MTQ
	DFO
	TC
Orientation 7: Promote sustainable management of water levels and flows in a context of climate change	
Objective 7.2: Produce information and tools to support decision making related to water management	
Integrate earth observation technologies in emergency management operations	MSP
	CSA
	PSC
Establish the Climate Change Advisory Committee	MELCC
	ECCC
Orientation 12: Improve knowledge related to the transportation of dangerous goods within the St. Lawrence system	
Objective 12.1: Promote the sharing by government bodies of expertise on managing the ecological risks related to the marine transportation of hydrocarbons on the St. Lawrence	
Establish a knowledge exchange group on the management of ecological risks associated with the marine transportation of hydrocarbons on the St. Lawrence	MELCC
	MFFP
	MSP
	MTQ
	ECCC
	TC
Assess the impacts of hydrocarbons and the use of dispersants in the event of an oil spill	MELCC
	ECCC

Improve knowledge on the risks of oil spills in marine environments	MELCC
	MSP
	DFO
Issue Committee: Improved Water Quality	
Orientation 8: Reduce agricultural non-point source pollution	
Objective 8.1: Take, support and coordinate actions aimed at reducing agricultural non-point source pollution	
Align environmental prediction tools with tools for monitoring the state of the St. Lawrence (project completed)	MELCC
	ECCC
Evaluate the use of retention ponds to capture pesticides and nutrients in agricultural drainage and surface water in the Lake Saint-Pierre watershed	MELCC
	MFFP
	MAPAQ
	ECCC
	AAFC
Adopt sound agri-environmental and intervention practices in the Lake Saint-Pierre watershed: monitoring pesticides in surface water and assessing the health of aquatic organisms	MELCC
	ECCC
Establish the Agriculture Coordination Committee	MAPAQ
	MELCC
	AAFC
	ECCC
Objective 8.2: Determine the effects of agricultural non-point source pollution on aquatic ecosystems	
Improve the knowledge of pathogenic organisms from agricultural sources in the tributaries of Lake Saint-Pierre	MELCC-DIMAQ
	AAFC
	PHAC
Study the current health of, and changes in, the aquatic grass beds in Lake Saint-Pierre	MFFP
	ECCC
Prepare and hold a discussion workshop on Lake Saint-Pierre	MELCC
	ECCC-ACRD
Assess the effects of pesticides on aquatic organisms	MELCC
	MFFP
	ECCC
Orientation 9: Improve contaminated sediment management tools	
Objective 9.1: Improve risk assessment tools for contaminated sediment sites	
Assess the ecotoxicological and health risks of contaminated sediment sites in remediation projects	MELCC-CEAEQ
	MFFP
	MSSS-INSPQ
	ECCC
	HC

Determine the main environmental issues associated with areas of contaminated sediments in the St. Lawrence	MELCC
	MFFP
	ECCC
	DFO
	TC
	HC
Orientation 10: Assess the presence of emerging contaminants and toxic substances and their impact on the ecosystem	
Objective 10.1: Assess the presence and effects of toxic substances from municipal effluents	
Develop a project to assess the environmental and health risks associated with urban effluents in the Quebec City region	MELCC
	MFFP
	ECCC
Assess the effects of the dumping of the city of Montreal's wastewater treated by ozonation into the river	MELCC
	MFFP
	ECCC
Study the risks associated with the presence of cytostatic agents in the St. Lawrence	MELCC
	ECCC
Determine whether microplastics in the aquatic environment are an issue in the St. Lawrence by developing methodologies and assessing sources	MELCC
	ECCC
Objective 10.3: Assess the effects of toxic substances on the food chain	
Promote scientific exchanges by holding annual meetings on emerging contaminants of concern	MELCC
	MAPAQ
	MFFP
	MSSS-INSPQ
	ECCC
Orientation 11: Document the effects of riverine inputs	
Objective 11.1: Evaluate the contribution of riverine inputs to hypoxia, acidification and the appearance of toxic algae	
Assess the contribution of dissolved and particulate organic matter to deep-water hypoxia and acidification in the St. Lawrence estuary	MELCC
	DFO
	ECCC
	PCA
Community Interaction Program	
Support the implementation of community and environmental projects	MELCC
	ECCC

Working Group: State of the St. Lawrence Monitoring Program	
Objective 1: Report on the state and evolution of the St. Lawrence using the scientific information generated by the State of the St. Lawrence Monitoring Program	
Report on the state and evolution of the St. Lawrence using the scientific information generated by the State of the St. Lawrence Monitoring Program	MELCC
	MFFP
	ECCC
	DFO
	PCA
Objective 2: Regularly disseminate information to decision makers and riverside communities about the state and evolution of the St. Lawrence using means that are tailored to their needs and that facilitate access to information	
Regularly disseminate information to decision makers and riverside communities about the state and evolution of the St. Lawrence using means that are tailored to their needs and that facilitate access to information	MELCC
	MFFP
	ECCC
	PCA
	DFO
Objective 3: Provide leadership in integrated environmental monitoring program management	
Provide leadership in integrated environmental monitoring program management	MELCC
	MFFP
	ECCC
	DFO
	PCA
Working Group: Numerical Environmental Prediction	
Objective 1: Develop integrated, compatible tools to support water management planning and decision making with regard to the St. Lawrence and its watershed	
Establish linkages between hydrological models of the St. Lawrence watershed	MELCC
	ECCC
Enhance the use of meteorological data (precipitation analyses) from the St. Lawrence watershed	MELCC
	ECCC
Perform hydrological and hydraulic modelling of the Richelieu River watershed	MELCC
	MSP
	MFFP
	ECCC
Assess the impacts of climate change on St. Lawrence water levels and flows	MELCC
	ECCC
	DFO

Objective 2: Develop and implement scientific and technical mechanisms for coordinating numerical models	
Establish and maintain a computational cluster – organize meetings to coordinate research and development efforts	MELCC
	ECCC
	DFO
Objective 3: Support the Appendix E orientations, new objective added in 2013–2014	
Give presentations to publicize the work done in the working group (issue committees, universities, conferences, etc.).	MELCC
	ECCC
	DFO

For more details on these fact sheets, see the "Developing Knowledge" page on the St. Lawrence Action Plan website: Developing Knowledge | St. Lawrence Action Plan (planstlaurent.qc.ca)

APPENDIX 2: GOVERNMENT EXPENDITURES, 2016–2021, BY ISSUE COMMITTEE AND WORKING GROUP (in thousands of dollars)

	IMSL	Biodiversity	Sustainable Use	Water Quality	CIP	State of the St. Lawrence Monitoring Program	Numerical Environmental Prediction	Communications and Coordination	TOTAL
AAFC	0	0	0	178.4	0	0	0	0	**178.4**
IAAC	0	0	5.9	0	0	0	0	0	**5.9**
PCA	0	0	0	5	0	37.2	0	0	**42.2**
CSA	0	0	60	0	0	0	0	0	**60**
PHAC	0	0	0	26.73	0	0	0	0	**26.7**
ECCC	5,949.3	1,571.4	178.6	2,239.9	2,642.6	3,876.02	237.5	3,182.2	**19,877.5**
DFO	0	431.8	122.7	707	0	11,226.5	75	0	**12,563**
HC	0	0	0	6.8	0	0	0	0	**6.8**
PSPC	0	0	11	0	0	0	0	0	**11**
PSC	0	0	25	0	0	0	0	0	**25**
TC	0	0	343.2	0	0	0	0	0	**343.2**
Total Canada	**5,949.3**	**2,003.2**	**746.4**	**3,163.9**	**2,642.6**	**15,139.7**	**312.5**	**3,182.2**	**33,139.7**
MAPAQ	0	8	0	26	0	0	0	0	**34**
MELCC	6,792	595.9	164.1	659.6	1,157.7	2,175.3	236	906.5	**12,687.1**
MFFP	0	1,980	3,661	258.1	0	2,041.5	0	0	**7,940.6**
MSP	0	0	220.6	0	0	0	0	0	**220.6**
MSSS-INSPQ	0	0	0	0.3	0	0	0	0	**0.3**
MTQ	0	0	285.7	0	0	0	0	0	**285.7**
MTO	0	0	7.2	0	0	0	0	0	**7.2**
Total Quebec	**6,792**	**2,583.9**	**4,338.6**	**944**	**1,157.7**	**4,216.8**	**236**	**906.5**	**21,175.5**

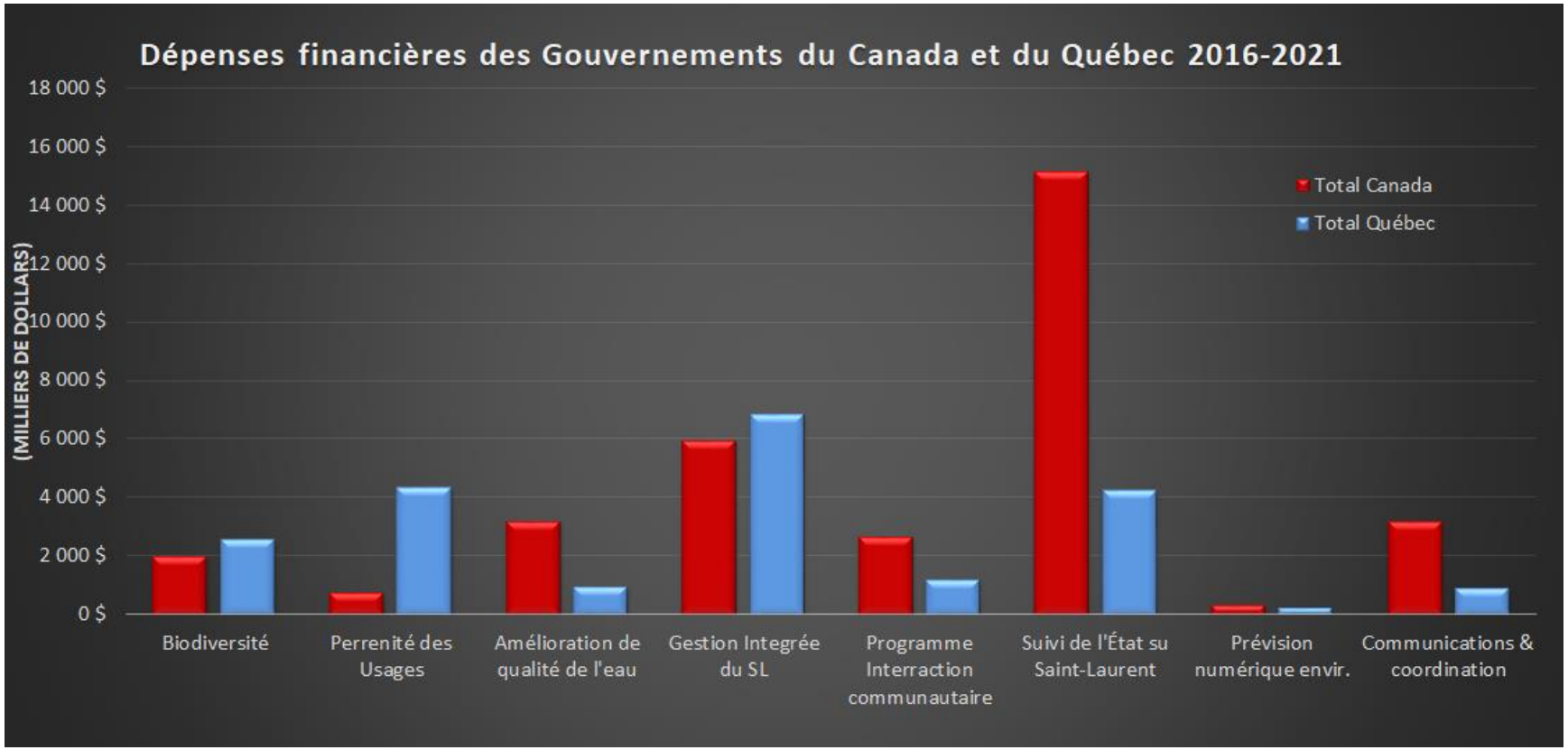

Figure 17. Government expenditures (Canada and Quebec) by issue committee and working group

Québec

Canada