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Cumulative Effects of Marine Vessel Activities in the St. Lawrence River and the Saguenay River – Pilot Project

Presentation of Mandate and Methodological Approach

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1 Background

Transport Canada develops and administers policies and regulations to advance the safety and security of Canada's marine transportation system. It promotes an efficient and sustainable system that protects the marine environment and contributes to economic development.

In November 2016, the Government of Canada announced the $1.5-billion Oceans Protection Plan (OPP) with the objective of improving marine safety and responsible shipping, protecting Canada's marine environment and offering new opportunities to Canadians.

Through the OPP, the Government of Canada is committed to preserving and restoring coastal marine ecosystems that are vulnerable to increased marine shipping, while reducing the impact of day-to-day vessel traffic. Many concerns have been expressed about the increase in marine transportation and the impact of other marine activities (a sector of industry that can be a major source of human impact) on coastal and marine ecosystems and on the way of life of Indigenous communities.

To address these concerns, Transport Canada has been working with First Nations, marine industry stakeholders and coastal communities since 2017, and organizing collaborative workshops to ensure that all parties are equally involved throughout the project.

Meanwhile, a project on the development of a common framework to assess the cumulative effects of marine activities on the St. Lawrence was launched under the St. Lawrence Action Plan in 2018. One of the aims of this project is to ensure coordination between the Government of Canada (Transport Canada, Fisheries and Oceans Canada, Canadian Coast Guard and Impact Assessment Agency of Canada) and the Government of Quebec (Ministère de la Sécurité publique [Department of Public Security]; Ministère des Forêts, de la Faune et des Parcs [Department of Forests, Wildlife and Parks]; and Ministère de l'Environnement et de la Lutte contre les changements climatiques [Department of Environment and the Fight Against Climate Change) in collecting and aggregating existing data required for the study, while encouraging close cooperation with First Nations, marine stakeholders and coastal communities.

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Mandate

Transport Canada has retained the services of a team from Laval University to develop a methodology and assess the cumulative effects of marine vessel activities in the St. Lawrence River (fluvial and estuary section) and the Saguenay River (deep-water section) in Quebec.

For this cumulative effects project, the approach adopted is a sectoral one that explores the environmental issues and effects pertaining to a particular sector (that is, a framework based on the assessment of a single sector of industry), given that the objective is to manage the way in which the effects of marine vessel activities, in particular, act cumulatively on the human and biophysical environment. Marine vessel activities include not only commercial vessels, but also cruise ships, ferries, fishing boats and pleasure craft. Port infrastructure is not included in this project. The location, intensity and/or movement of these various types of craft can generate one or more stressors for ecosystems.

This contract will support the Government of Canada and the Government of Quebec in the design of a common framework to assess the cumulative effects of marine vessel activities and will help identify mitigation tools and strategies that can be applied to current vessel movements and the development of future projects. This will be done in a collaborative manner with First Nations, scientists from various backgrounds and managers in order to support evidence-based decision making.

2.1 Description of requirements

The Laval University team will develop a methodology to assess the cumulative effects of marine vessel activities, which will be presented to the various collaborators. Using this methodology, the team will assess the cumulative effects of marine vessel activities on the valued components identified by all participants involved in the project for the St. Lawrence (fluvial and estuary section) and the Saguenay River (deep-water section).

Based on this assessment, the Laval University team will produce a report summarizing the methodology used, the analysis performed, the results and the conclusions, which will be presented to the various collaborators.

The team will participate in workshops and discussions with all the participants involved in the project to fully incorporate everyone's comments and contributions.

2.2 Development of methodology

The analysis methodology used must be capable of:

- integrating the Indigenous and traditional knowledge compiled;
- using different types of data, including geospatial and tabular (non-georeferenced) data;
- considering multiple stressors arising from marine vessel activities;
- comprehensively assessing the cumulative effects of various stressors on the valued components identified during the workshops, including biological, environmental, cultural and socio-economic components.

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Laval University work team

Philippe Archambault will be the project manager. With a PhD in biology (1998), he began as a researcher at Fisheries and Oceans Canada (2000–2007) before becoming a professor at the Institut des sciences de la mer of the University of Quebec at Rimouski (2007–2017). Since 2017, he has been a professor at Laval University. Combining fundamental and theoretical research, Philippe has been studying the effects of various disturbances (of natural and human origin) on ecosystems for over 20 years. He has co-led or participated in many research programs focused on benthic biodiversity in Canada and abroad. The findings of his work have been used to develop protected marine areas, among others. He has also either authored or co-authored over 120 peer-reviewed scientific articles.

David Beauchesne is the post-doctoral student approached to carry out this project. With the experience he gained during his doctoral studies, David has all the qualifications required to carry out the work on the cumulative effects of marine activities.

Cindy Grant is a research professional on the Laval University team. Her diverse scientific and project management experience will be a major asset at all stages of the project leading to the assessment of the cumulative effects of marine activities.

An undergraduate student could take part in this project as a research assistant. This research assistant could be hired full-time during the summer or part-time during the school year. The candidate will be required to have geographical information system and programming experience.

4

Approach

4.1 Steps

A number of works from scientific and grey literature[1] detail the various steps of a cumulative impact assessment (*e.g.* Hegmann et al., 1999). Over the past few years, the Transport Canada team has worked with a number of Canadian and international experts on the approach to assessing the cumulative effects of marine vessel activities (*e.g.* Lerner, 2018; Pickard et al., 2019). A cumulative effects assessment typically includes, but is not limited to,

1. Identifying, involving and communicating with assessment stakeholders and Indigenous and non-Indigenous communities at all steps of the approach
2. Developing the scope of assessment
    - Setting assessment objectives
    - Defining the spatial and temporal limits of the study area
    - Identifying activities of concern and stressors that arise from them
    - Identifying and prioritizing valued components to which the assessment must relate
3. Establishing a profile of the study area

[1] Grey literature consists of documents produced by various public, business or industrial bodies subject to the rules of intellectual property and not controlled by a scientific peer review process.

  - Characterizing the intensity, extent and frequency of activities and stressors
  - Characterizing the valued components
  - Assessing the vulnerability of valued components to stressors

4. Cumulative effects assessment
5. Diagnosing the analysis

  - Determining the spatial distribution of the cumulative effects
  - Exploring the effect of stressors on the valued components in detail
  - Identifying sources of uncertainty and knowledge gaps

6. Implementing decision-making processes

  - Identifying and putting in place management measures
  - Identifying mitigation and compensation measures

7. Monitoring and adaptive management

The identification and involvement of First Nations and stakeholders (1) and the definition of the scope of assessment (2) have already been completed through a number of engagement sessions and workshops with experts in the field. In light of this process, we will now focus on the profile of the study area (3), the analysis of the cumulative effects (4) and the critical assessment of the analysis (5). Steps 6 and 7 are not part of this contract.

4.2 Scope

The assessment of the cumulative effects of marine vessel activities will be conducted for the ecosystems of the St. Lawrence (fluvial and estuary section, that is, from Montreal to Pointe-des-Monts) and the Saguenay (deep-water portion as far as Saint-Fulgence). The assessment process will help build a profile of the spatial distribution of the valued components and stressors arising from marine vessel activities in the study area targeted by the analysis. Marine vessel activities involve not only commercial vessels, but also cruise ships, ferries, fishing boats and pleasure craft. Port infrastructure is not included in this project. The vulnerability of the valued components to the various stressors will then be assessed. Lastly, the profile of the study area will be used to assess the cumulative effects of marine vessel activities on the valued components targeted. This study seeks a more proactive and holistic management of marine and freshwater ecosystems.

The cumulative effects assessment methodology and the steps of the approach will provide a present-day geographic profile of the study area, sources of pressure associated with marine traffic and the valued components deemed a priority. This profile will identify the knowledge available within the study area. This knowledge could, in another phase, enhance the pilot project and help with recurring analyses of cumulative effects, exploring new management issues, and expanding the study scope in order to include additional sectors of industry and increase the surface area of the study area.

Collaboration with First Nations and the integration of Indigenous knowledge will be given priority in the approach. Discussions and conclusions arising out of workshops with First Nations representatives and other stakeholders for the project's development will be major assets for the cumulative effects assessment. Indigenous knowledge, where available, will be used to detect changes in the environment and improve our understanding of the cumulative effects.

4.3 Study area

4.3.1 Activities and stressors

A characterization of the spatial distribution and intensity of stressors related to marine vessel activities in the study area is one of the most important elements in building a profile of the study area for a cumulative effects assessment. The marine vessel activities and stressors to be used for the pilot study are listed in Table 1. Available data used to characterize these stressors from these marine activities will be compiled.

Table 1. List of marine activities identified for the pilot study on the cumulative effects of marine activities in the St. Lawrence.

Marine activities
Dredging
Anchorages
Groundings / wreckings
Operational discharges
Accidental spills
Movement underway
Fishing gear

The spatial distribution and intensity of each stressor will be characterized individually. For example, vessel movements could be characterized using navigation plots and vessel types, while dredging activities could be characterized according to the total quantity of sediment dredged (i.e. removed from one site or deposited at another). The specific data and approaches used will depend on the quality and availability of existing data. Once the individual characterization of stressors is complete, these will be input into a database that can be cross-referenced with the characterization of the valued components. These two databases will enable an analysis of the cumulative effects of stressors on valued components in the study area.

One example is an initiative taken from our research work called eDrivers (Beauchesne et al., 2020) and an interactive digital tool used to view an integrative database describing multiple stressors within the Estuary and Gulf of St. Lawrence:

4.3.2 Valued components

The valued components – *i.e.* elements to which the cumulative effects analysis pertains – were identified beforehand during engagement sessions and workshops with experts in the field, Indigenous representatives and multiple stakeholders. The valued components were selected separately for the fluvial (Montreal to the Saguenay River) and marine (Saguenay River and the Estuary) sectors of the St. Lawrence. The list of valued components identified will be used for this report. We will identify the available data that we can use for spatial characterization of these components (Table 2).

Table 2. List of valued components identified for the pilot study on the cumulative effects of marine vessel activities in the St. Lawrence

Valued component	**Example of sub-category**	**Freshwater environment**	**Marine environment**
Water quality	Water turbidity	X	X
Wildlife and plant habitats	Coastal habitats Benthic habitats Pelagic habitats	X	X
Significant sites	Indigenous heritage and cultural sites Archeological sites Tourist sites Protected areas	X	X

Valued component	Example of sub-category	Freshwater environ-ment	Marine environ-ment
	Diversity hotspots		
Bank integrity	Artificial banks Rate of erosion	X	
Marine mammals	Frequently observed species		X

Just like stressors, valued components will be characterized individually. For example, wildlife and plant habitats could be delineated based on knowledge about critical fish habitats in the study area and the known distribution of species at risk; marine mammals could be characterized according to the distribution of populations or based on areas of importance for their food supply. The specific data and approaches used will depend on the quality and availability of existing data. Once the individual characterization is complete, the valued components will be compiled in an integrative database that can be cross-referenced with the characterization of stressors, which will make it possible to study the cumulative effects in the study area.

4.3.3 Vulnerability

The vulnerability of the valued components to stressors caused by marine vessel activities will be evaluated for the cumulative effects assessment. This type of knowledge can be particularly difficult to obtain; entire research teams can be dedicated to examining the vulnerability of a single valued component to a single stressor, such as the vulnerability of marine mammals to underwater noise. While the vulnerability of some valued components to certain stressors is well documented and would allow for a robust assessment of individual environmental impacts, this type of knowledge is rarely – if ever – available for all "valued component–stressor" combinations. Yet, it is a necessity for a cumulative effects assessment.

A qualitative approach based on the opinion of experts and bibliographic research is therefore generally used to generate a vulnerability scoring matrix for all combinations of valued components and stressors (Figure 1). The use of a method through expert consultation thus adds value to expertise and knowledge that would not otherwise be available to support management and decision-making (Teck et al., 2010). According to the available knowledge, we will proceed with a bibliographic census to assess the vulnerability of the valued components to each stressor. This bibliographic research will be supplemented by knowledge from experts in the field to capture the known local particularities. The results of collaboration with all the participants involved in the project could, at this stage, make a particularly significant contribution to the cumulative effects assessment.

Various approaches can then be applied in order to use the qualitative information gathered to obtain the scoring matrix for the relative vulnerability of the valued components to the stressors. For example, the spatial scale of the stressors, their frequency, their functional effects (such as on the reproduction of species), or even the resistance or resilience of valued components could be used as criteria to assess the vulnerability of the valued components. These criteria will be selected according to the information gathered during the bibliographic research phase.

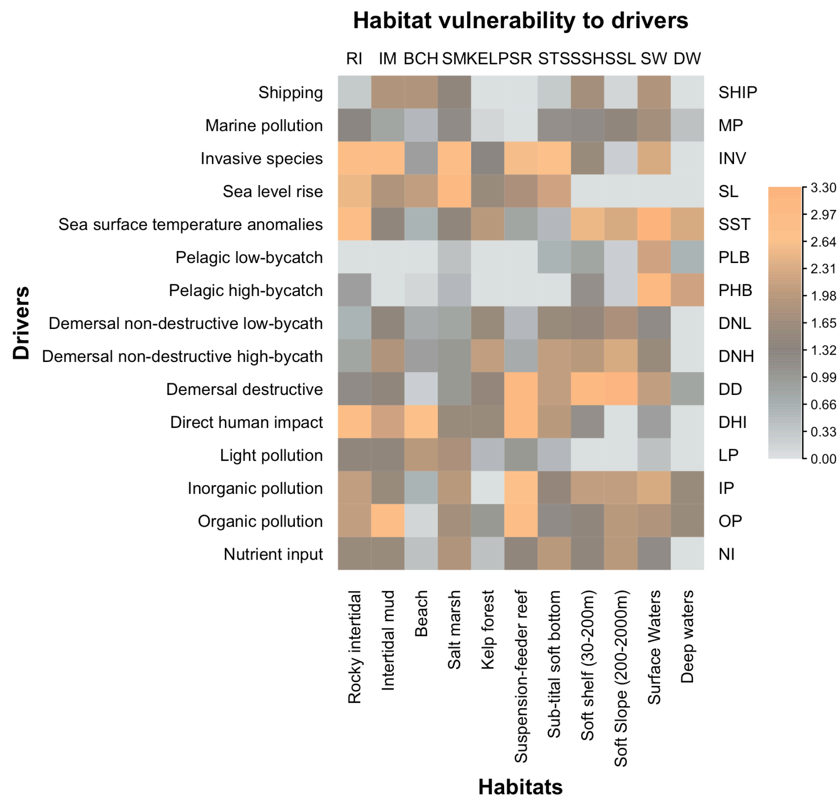

Figure 1. Example of a matrix of the vulnerability of various types of habitats to a number of stressors—called “drivers” in the figure—represented by the colour gradient (*i.e.* heat map; adapted from Halpern et al., 2019).

4.4 Cumulative effects assessment methodology

The cumulative effects of marine vessel activities will be assessed according to the methodology developed by Benjamin Halpern’s team at the University of California in Santa Barbara (Halpern et al., 2008, 2015, 2019). This method requires three types of data, which were outlined earlier for the study area profile: (1) the mapped presence or absence of valued components on which the cumulative impacts will be calculated (C_i), (2) the mapping of human impacts and their associated stressors (S_j) – *i.e.* stressors arising from marine vessel activities as part of this study – and (3) a matrix detailing the vulnerability of valued components to each stressor included in the analysis ($\mu_{i,j}$). These data are then added to a grid consisting of cells of uniform size characterizing the targeted study area. The cumulative impact predictions (I_C) are then calculated for each cell (x) of the grid using the following formula:

$$I_{C_x} = \sum_{i=1}^{n} \sum_{j=1}^{m} C_{i,x} * S_{j,x} * \mu_{i,j}.$$

The assessment of cumulative impacts is therefore obtained by adding all the individual effects of the stressors on all the valued components. This method proposes the calculation of a relative cumulative effects indicator. The term **relative** is central to understanding the assessment method proposed. An **absolute** indicator would reveal a change in the state of the valued components relative to the accumulation of stressors, such as a decrease in the population of belugas in the St. Lawrence Estuary in response to the accumulation of stressors. A relative indicator provides a comparison of the various stressors according to their intensity in the region studied and their effects on the valued components. Although it does not make it possible to assess the response of a valued component to one or more stressors, this approach offers more flexibility by enabling consideration of various types of data and knowledge that cannot normally be compared against one another.

This relative cumulative effects indicator can also be used to assess the relative share of a single stressor or a sub-group of stressors on the valued components. For example, a relative cumulative effects assessment could cover all marine mammal species in the study area. The index could be broken down to obtain the relative effect of all stressors on a single species, a single stressor on all species or any combination of stressors and valued components of interest. Figure 2 shows a fictitious example of various steps in the proposed method, from the study area profile to the relative cumulative effects assessment.

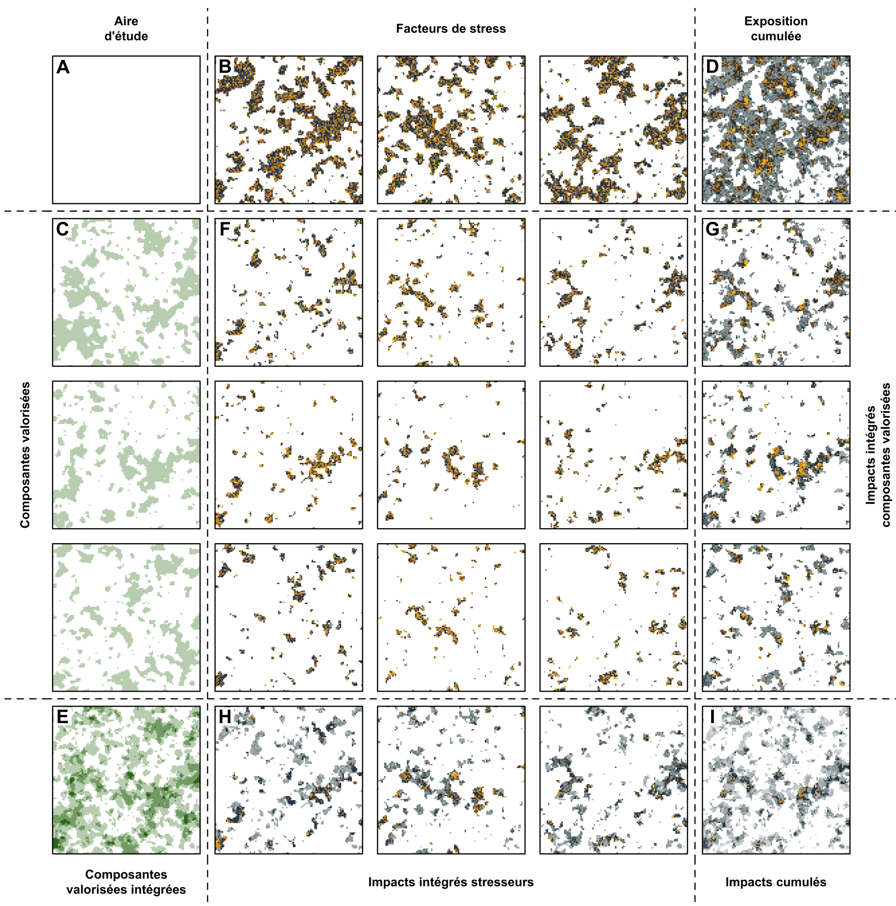

Figure 2. Fictitious example of a relative cumulative effects assessment according to the methodology proposed by Halpern et al. (2008). The study begins with delineating a study area of interest (**A**). A profile of the study area is then created by characterizing the distribution of stressors (**B**) and valued components (**C**) to achieve the assessment objectives. Adding all the stressors makes it possible to identify the environments most exposed to cumulative stress, that is, cumulative exposure (**D**). The sum of the valued components, meanwhile, helps identify environments in the study

area where a greater number of valued components overlap (**E**). By combining the distribution of stressors and valued components as well as the vulnerability of valued components to stressors, a relative assessment of the individual effects is obtained (**F**). The impact of all the stressors on a single valued component can be assessed (**G**), as can the impact of a single stressor on all the valued components (**H**). The addition of all the individual impacts provides a relative assessment of the cumulative effects, comprising all combinations of stressors and valued components (**I**).

4.5 Analysis results

4.5.1 Spatial distribution of cumulative effects

The relative cumulative effects assessment will help identify sites or regions most vulnerable to the accumulation of stressors in the study area. Figure 3 shows an example of a relative assessment of the cumulative effects of various stressors on habitats in the Estuary and Gulf of St. Lawrence (Beauchesne et al., 2018).

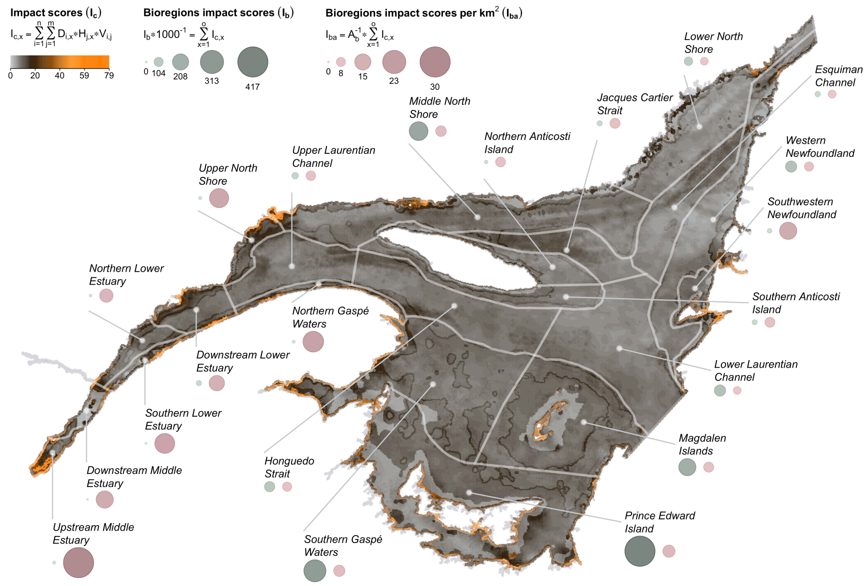

Figure 3. Relative assessment of the cumulative effects of 15 stressors on 11 habitats in the Estuary and Gulf of St. Lawrence

4.5.2 Detailed results

The cumulative effects assessment offers an integrative index that can be used to explore the accumulation of the effects of stressors in detail. A detailed exploration will be completed of the effects associated with each stressor on each valued component (Figure 2G, H). For example, we will explore the cumulative effects of marine vessel activities on plant and wildlife habitats separately from the cumulative effects on sites of significance in the study area. We will also explore the spatial distribution of the cumulative effects in two sectors of the study area separately. Cumulative exposure (Figure 2D) will also be analyzed to identify environments in the study area most exposed to stressors arising from marine vessel activities.

These analysis diagnostics will make it possible to, among other things, explore the cumulative effect indicator and identify the valued components most affected by the accumulation of the effects of stressors in the study area, the stressors of greatest concern and the areas most exposed to the accumulation of the effects of stressors. During these steps, we will also be able to identify the pathways of effects (DFO, 2020) that are most likely to impact the various valued components considered by the cumulative effects assessment. Pathways of effects establish the links between activities and their potential impacts on the various aspects of the ecosystems.

We will also identify exposure pathways of valued components to various stressors, that is, environments where the distribution of stressors overlaps with that of valued components. This index, which does not consider the vulnerability of valued components to stressors, will help identify stressors to which valued components are more frequently exposed in the study area. Considering the uncertainty and the difficulties in assessing the vulnerability of valued components, this relative index allows for the strict use of data that are typically more robust – characterization of stressors and valued components – to identify environments and valued components most at risk in the study area.

4.5.3 Uncertainties and gaps

The assessment results and conclusions will be limited by data availability. It is therefore important to properly document the uncertainty associated with each data source and all knowledge gaps identified during the cumulative effects assessment. This aspect is particularly important because this is a pilot study that will not be able to address all questions about the cumulative effects of marine vessel activities in the St. Lawrence.

4.5.4 Special considerations

- The proposed relative cumulative effects assessment is spatially explicit; it will provide a description of the spatial distribution and relative intensity of the cumulative effects in the study area.

This type of regional approach poses a few constraints, including the need to use mainly stressors and valued components that can have a spatial characterization completed, ideally for the entire study area. This makes the use of ad hoc studies difficult. For example, it would be difficult to include an assessment of fishery impacts on a common eel population at the mouth of a single river in the study area.

- As part of this pilot study, we will focus on a present-day cumulative effects assessment, that is, over the past 5 to 10 years according to available data. Historical data that help identify baselines will therefore not be used, unless a special need is identified. While relevant, the study context and data availability will not enable us to assess a baseline for all the stressors and valued components characterized, thus limiting the temporal conclusions we might draw.

- Data availability will guide the work we can accomplish for this pilot project. The study context does not enable the Laval University team to collect new data. The profile created will therefore be a compilation of current knowledge to characterize the stressors of marine vessel activities as well as the valued components identified. Should new data become available during the project, the Laval University team could take them into consideration, provided that their inclusion does not delay contract deliverables.

- Lastly, a number of other human activities can be the source of environmental pressure in the study area. For example, water quality is certainly influenced by activities in the terrestrial environment and leaching from farmland through river mouths. However, this study will focus only on stressors arising from marine vessel activities.

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Data collection and management

Data will be collected in cooperation with various project collaborators and with the support of Transport Canada and members of the project led by the St. Lawrence Action Plan. No new data will be collected for this assessment. The entire study therefore relies on the availability of data that can be used to characterize the spatial distribution of valued components and stressors, as well as the vulnerability of valued components to stressors. Special attention will be paid to knowledge possessed by Indigenous and non-Indigenous communities. In that respect, we are planning meetings with First Nations representatives following the presentation of the methodological approach in order to put in place an appropriate strategy that will enable us to build on their knowledge and incorporate their concerns. The work approach adopted will result in an iterative, transparent process in which new considerations can be incorporated or previously shared considerations can be adjusted further to an engagement process. It should be noted that the concerns of First Nations, coastal communities and various project stakeholders were also considered ahead of this study through various engagement sessions organized by the Transport Canada team.

Databases will be managed by the Laval University work team with the aim of ensuring full transparency in the work carried out. To the extent possible, our team plans to fully share the code and data used for all steps in the cumulative effects assessment. Sensitive data could still be embargoed or be subject to stricter sharing agreements limiting or fully blocking access to some types of data. Nevertheless, this type of data can be incorporated into an open process through proper cataloguing so that a user can have an inkling as to the type and origin of the data used in the analyses as well as the relevant contacts for obtaining more information on the data. All suggestions, recommendations and requests from various partners as to the collection, management and sharing of data will be considered to ensure effective and respectful cooperation.

In addition to the meetings and engagement sessions planned in the contract seeking close cooperation with Transport Canada officials, we will adopt a transparent, replicable approach similar to the one we use for our initiative to characterize stressors in the Estuary and Gulf of St. Lawrence called eDrivers. We are basing our approach on the FAIR Data Principles, the purpose of which is to ensure that the data used are findable, accessible, interoperable and reusable. We are therefore using programming tools, including R language.[1] The use of programming tools, like software such as ArcGIS[2], offers a number of advantages. These tools provide a great deal of flexibility in incorporating changes or new considerations very quickly without having to repeat multiple steps in a complex process. This flexibility is not limited to analyses, since all steps in a project, from the integration of raw data to the production of reports, can be integrated and thus easily modified. It then becomes easy to add comments or new recommendations following engagement sessions, for example. We will also use GitHub[3], a version control tool that allows for documentation, quality control, and development and modification tracking of relevant programming elements for the entire project.

[1] R est un logiciel libre destiné aux statistiques, la science des données et les graphiques (https://www.r-project.org/)

[2] ArcGIS est une suite de logiciels d'information géographique (SIG) développés par la société américaine Esri (https://www.arcgis.com/index.html)

[3] GitHub est un service web d'hébergement et de gestion de développement de logiciels utilisé par plus de 40 millions d'utilisateurs partout à travers le monde (https://github.com/).

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Schedule

Deliverable	Date
Launch and preparation of schedule and work	Early February 2020
Document containing an overview of the method	May 2020
Creation of list of data needs and initiation of contact to obtain the necessary data	Mid-March – June 2020
Webinar with partners and collaborators	June 2020
Adjustment to approach based on collaborator comments	May – June 2020
Contacts and data collection	June 2020 – March 2021
Mapping of stressors and valued components	June 2020 – March 2021
Preliminary assessment of cumulative exposure of valued components to environmental stressors	November 2020 – February 2021
Preliminary assessment of vulnerabilities of valued components	November 2020 – February 2021
Summary report and presentation of preliminary findings for comment during a workshop, review and discussions on the vulnerability of valued components, and discussions on mapping of sources of stress and valued components	March 2021

Deliverable	Date
Adjustment to approach based on collaborator comments, integration of new considerations and incorporation of knowledge from collaborators and all participants involved in the project to assess the vulnerability of valued components	April – May 2021
Contacts and collection of missing data or data proposed during March 2021 workshop	April – May 2021
Final analyses and preparation of report	May 2021 – December 2021
Delivery of final report for translation and distribution	December 31, 2021
Presentation of final report at a workshop	Early February 2022

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