Risk assessment procedure: development of tools and application in the capelin spawning / larval retention area

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This pilot project is linked to current national work and applies the theoretical notions of a risk analysis in the context of a real situation: capelin conservation in the Estuary and Gulf of St. Lawrence. While phase I resulted in the identification and the formulation of the problem through the development of Pathways of Effects (PoE) models, phase II, presented in this report, focusses on the development of a proposed risk assessment procedure and associated tools to be applied. The procedure is composed of four types of analysis: analyses of predicted conditions, measured conditions, and desired conditions, and a comparative analysis of conditions. The human activities and stressors identified in PoE models that potentially affect the capelin spawning / larval retention area were used to develop and apply the tools. To do this, Gallix beach, located in the region of Sept-Îles (Quebec, Canada), was selected as the ecological unit of reference. The proposed risk assessment procedure contributed to the development of a tool to analyze the predicted conditions. To carry out the three remaining types of analysis, other avenues were explored. All in all, the second phase of the pilot project demonstrated that tools can be developed to be versatile, flexible, and to perform well when used in a real context. Lastly, the work confirmed that risk assessment within a risk analysis process can help decision makers define priorities and subsequently focus their efforts on the management and regulation of activities that have greater potential social, cultural, or economic impacts.

RÉSUMÉ

Giguère, N., Nellis, P., Tremblay, G.H., Giangioppi, M., Ellefsen, H.-F., Magassouba, A., Comtois, S., Savenkoff, C. et Dufour R. 2011. Démarche d’évaluation du risque : développement d’outils et application à la zone de fraie et d’alevinage du capelan. Rapp. tech. can. sci. halieut. aquat. 2947 : vii + 37 p.

Le présent projet pilote s’annexe aux travaux nationaux en cours et vise à appliquer les concepts théoriques d’une approche d’analyse de risque aux particularités d’une situation réelle, la conservation du capelan de l’estuaire et du golfe du Saint-Laurent. Alors que la phase I a conduit à l’identification et à la formulation de la problématique par l’élaboration de modèles de séquence des effets (SdE), la phase II présentée dans ce document a ciblé l’élaboration d’une démarche d’évaluation du risque par le développement d’outils et par leur application. La démarche proposée se compose de quatre blocs d’analyses : les analyses des conditions prédites, des conditions mesurées et des conditions désirées, de même que l’analyse comparative de ces conditions. Afin de réaliser les exercices de développement et d’application des outils, les activités humaines et les facteurs de stress identifiés par les SdE pour leur potentiel d’altération de la zone côtière, donc ayant un effet probable sur la zone de fraie et d’alevinage du capelan, ont été retenus. À cet effet, la plage de Gallix, située dans la région de Sept-Îles (Québec,

Canada), a été identifiée comme unité écologique de référence. La démarche d'évaluation du risque proposée a permis de développer un outil d'analyse des conditions prédites et d'explorer, par la réalisation d'ébauche d'outils, certaines avenues possibles pour les trois autres blocs d'analyses. Dans l'ensemble, cette deuxième phase du projet pilote a permis de démontrer qu'il est possible de développer des outils d'évaluation du risque de façon à ce qu'ils soient polyvalents, flexibles et performants lorsqu'utilisés dans le contexte d'une situation réelle. Enfin, ces travaux ont permis de valider que l'évaluation du risque, à l'intérieur d'un cadre d'analyse de risque, a le potentiel de permettre aux décideurs de dégager les priorités et, subséquemment, de concentrer leurs efforts sur la gestion et la réglementation des activités qui ont un plus grand potentiel d'impact environnemental, social, culturel ou économique.

1.0 INTRODUCTION

The Department of Fisheries and Oceans (DFO), under the *Oceans Act,* promotes sustainable development and the protection of oceans in order to sustain healthy and productive ecosystems for present and future generations. From this perspective, risk-based decision-making approaches are recognized by DFO as a key to effective management. Efforts are now underway to develop risk analysis guidelines to aid oceans planners and environmental managers in implementing integrated oceans management and ecosystem-based management within Canada's coasts and oceans. These guidelines may also be useful to others interested in identifying, assessing, and managing potential impacts of human activities on aquatic ecosystems and their resources. The scope of the guidance will apply to all social, cultural, and economic activities taking place on land or in oceans that may affect Canada's estuarine, coastal, and marine waters ecosystems (DFO 2010, DFO in prep.[1]). Risk analysis is an approach used by several national and international institutions (e.g., Queensland Environmental Protection Agency in Australia, United States Environmental Protection Agency, Canadian Food Inspection Agency, and Food and Agriculture Organization of the United Nations). It generally includes the phases of *identification and problem formulation*, *risk assessment,* and *risk management* (Figure 1).

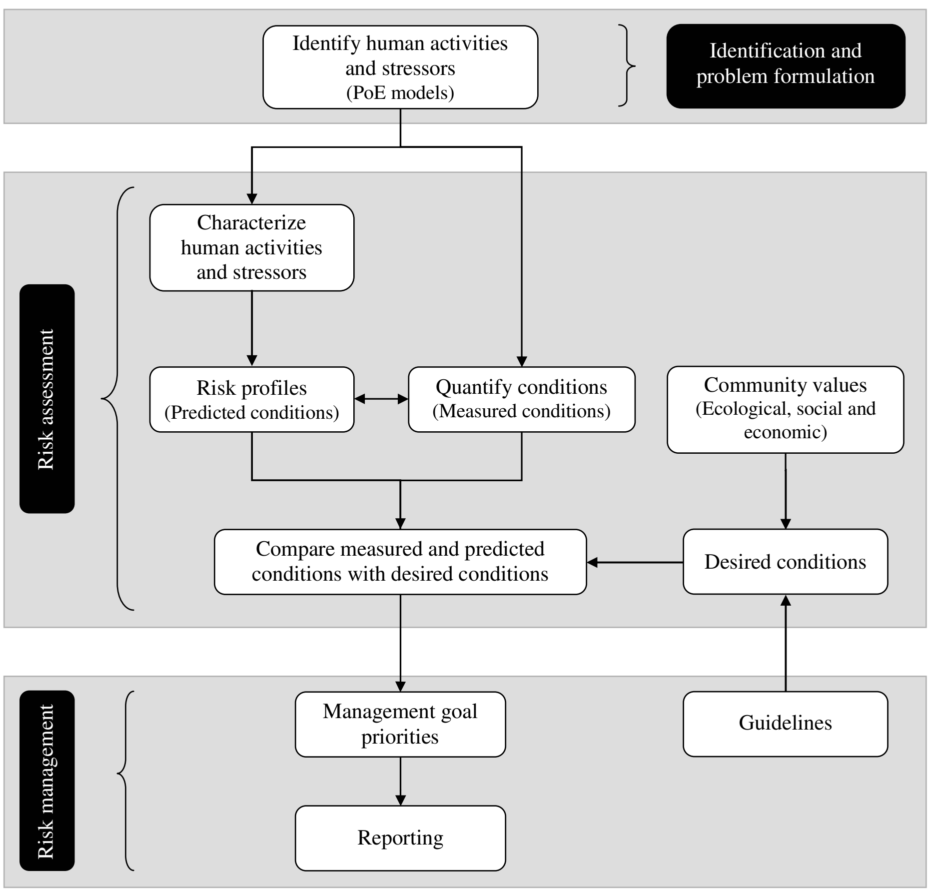

Figure 1. Steps in the risk analysis process (adapted from Moss et al. 2006).

[1] DFO (Department of Fisheries and Oceans). In preparation. Draft Pathways of Effects National Guidelines: January 25th.

The objective of this pilot project, which was carried out using a risk-analysis approach, is to develop and apply simple, effective, and versatile management tools to a real situation in order to establish a comprehensive portrait of an environmental problem and to support managers in the decision-making process. While phase I of the project, through the development of Pathways of Effects (PoE) models, made it possible to conclude the steps of identifying and formulating the risk-analysis problem (Giguère et al. 2011), phase II focusses on the risk assessment stage. PoE models establish potential causal linkages between human activities, stressors, and potential impacts on ecological components and/or functions. Phase II aims to propose a procedure and develop tools to assess and describe the risk these linkages represent. The application of this risk assessment process in a real context makes it possible to validate its capacity to define and prioritize the issues required for carrying out the final stage of risk analysis, i.e., risk management.

"Capelin conservation in the Estuary and Gulf of St. Lawrence" was selected by the working group (Appendix 1) as the subject for all phases of the pilot project. Capelin (*Mallotus villosus*), was selected because of its ecological significance (Savenkoff et al. 2007a, 2007b) and its distribution throughout the entire St. Lawrence ecosystem (Grégoire et al. 2008). In phase I, capelin conservation was the endpoint[2] (central element) of the PoE models. However, in order to proceed with a risk assessment (phase II), clear measurable endpoints (glossary, Appendix 2) have to be defined. They provide direction for the assessment and are the basis for the development of questions, predictions, models, and analyses (DFO in prep.). For the purpose of this project, "Quantity and quality of capelin spawning / larval retention habitat"[3] was chosen as the measurable endpoint (Giguère et al. 2011), and Gallix beach, located in the municipality of Sept-Îles (Quebec, Canada) was selected as the ecological unit in which the assessment was undertaken.

The proposed procedure includes four distinct types of analysis: the analyses of predicted conditions, measured conditions, and desired conditions as well as the comparative analysis of these conditions. This report presents the major steps of the procedure and the details of the predicted conditions analysis in order to assess the ecological risks associated with stressors in the ecological unit. Through draft tools, the report also presents ways that should be considered for conducting the other three types of analysis in the future. These tools can be used to pave the way to conduct a comprehensive risk assessment, which includes the social, economic, and cultural aspects tied to the ecological components.

2.0 METHODOLOGY

Two of the PoE models developed in phase I (Appendix 3) were used to guide the methodology. The proposed risk assessment procedure was elaborated based on a review of various existing methods. Sections 2.1 to 2.3 present the steps used to define the proposed procedure.

[2] The term endpoint was chosen during phase I (Giguère et al. 2011) as a substitute for the term "valued ecological component." A more detailed definition is provided in the glossary in Appendix 2.
[3] Measurable endpoint "Quantity and quality of capelin spawning / larval retention habitat" will be simplified by "Spawning / larval retention area." A more detailed definition is provided in the glossary in Appendix 2.

2.1 LITERATURE REVIEW AND CHOSEN METHODOLOGY

The risk assessment method was guided by the characteristics that the entire procedure and all the tools should possess and which fit the purposes of this project: simplicity of use, effective communication of results, high integration capacity, flexibility, and versatility. The established procedure is mainly the result of the combination of two different existing methods, i.e., the *"Risk profiler: Ecosystem Risk Characterisation and Decision-Making Support Tool"* (M. Hardy, DFO, Gulf Fisheries Centre, unpublished data) and the *"Integrated estuary assessment framework"* (Moss et al. 2006).

2.1.1 "*Risk profiler*" method

The *"Risk profiler*" method (M. Hardy, DFO, unpublished data) was selected as the main reference method for the Excel tool development. It provides a procedure for assessing the risk level associated with the potential impacts of human activities on the endpoint or one of the measurable endpoints. This simple semi-quantitative procedure makes it possible to characterize the human activities and stressors specific to an ecological unit in terms of the severity and likelihood of the impacts they may generate. The risk profiler can thus assign a level of risk to human activities and stressors and ultimately produce an ecological risk profile in the form of a graph or table.

This method is an effective tool providing decision makers, professionals, and managers with scenarios on which to base their decision making. The tool identifies management priorities based on the vulnerabilities of the ecological unit (M. Hardy, DFO, unpublished data).

2.1.2 *"Integrated estuary assessment framework"* method

The significance of the *"Integrated estuary assessment framework*" method (Moss et al. 2006) stems mainly from the fact that it bases the prioritization of impacts on the biophysical conditions of the environment and on the value assigned to the endpoint by the human communities concerned. This particularity makes it possible to integrate socio-economic and cultural aspects as well as scientific data into the risk assessment process. Several elements of this method hold particular significance, namely to structure the entire procedure (see Section 2.3). These include the use of a summary table of studied conditions (see Section 2.3) that facilitates the reading and the reporting of obtained results; this is a critical step in risk assessment.

2.1.3 Elements of interest and complementary methods

The following elements of interest were retained among other approaches to risk assessment.

Several methods introduce the concept of uncertainty. According to Fletcher (2008), risk assessment consists of making the most informed decision possible based on available information and necessarily involves uncertainty. N. Mandrak (DFO, Great Lakes Laboratory for Fisheries and Aquatic Sciences, unpublished data) defines uncertainty as an element that "considers the quality and quantity of available data to rank likelihood and magnitude [severity] and provide risk managers with an indication of the inherent strengths and weaknesses in the assessment of risk."

Also, some methods use assessment criteria with a multi-level scales to allow for a more refined classification or risk ranking. For example, specific DFO's methods (N. Mandrak, DFO, unpublished data; G. Olivier, DFO, Central administration, pers. comm.) define risk based on the probability or likelihood of an event occurring and the magnitude or severity of its potential impacts. Each of these aspects is associated with a scale of several levels that better quantifies the associated risks (e.g., five levels from "negligible" to "extreme" to characterize the magnitude of the risk). Furthermore, categories of criteria can be established on the basis of various aspects of a problem (e.g., socioeconomic, human, ecological criteria). The procedure developed for the purposes of the project draws on these principles.

Other tools developed for working with Ecological and Biological Significant Areas (EBSA) and Candidate Ecological and Significant Species (CESS) included a significant element that increases the transparency of the risk assessment process (Hardy et al., in prep.[4]). To ensure this transparency, a "justification" section enables one to support the choice of risk level by presenting the information utilized for the selection.

Lastly, the use of these risk analysis methods in a real case, such as the ecosystem of the Yukon North Slope (Stephenson and Hartwig 2009), also indicates the benefits of compiling results in the form of maps. This visual summary geographically illustrates the various risk levels assessed in the targeted study area.

2.2 STUDY AREA

Gallix beach, located in baie Sainte-Marguerite near Sept-Îles, possesses the characteristics required for the application of tools in a real situation: 1) it is used by capelin as a spawning / larval retention area (DFO 2011; F. Grégoire, DFO, Maurice Lamontagne Institute, pers. comm.), 2) many human activities and stressors are present at the periphery of the beach, and 3) research work to identify the biophysical characteristics of a good capelin beach is currently underway (F. Grégoire, DFO, pers. comm.).

Figure 2 shows the study area: Galix beach as the ecological unit and its immediate anthropogenic context.[5] The ecological unit includes the beach, from the highest high water large tide to the 5 m isobath. The lower limit, set at a depth of 5 m, considers the general use of the beach by capelin as a spawning / larval retention area (F, Grégoire, DFO, pers. comm.).

[4] Hardy, M., Ferron, C., Mullins, C., Trottier, J., and Joseph, V. In preparation. Vulnerabilities of ecosystem components to human activities within the Gulf of St. Lawrence. Gulf Region Oceans Management Series 201/XX.

[5] The immediate anthropogenic context is a summary representation of the main human activities in baie Sainte-Marguerite. During risk assessment, human activities and stressors having an influence on the ecological unit will be considered as a whole and according to their significance even if they are located outside the area represented here.

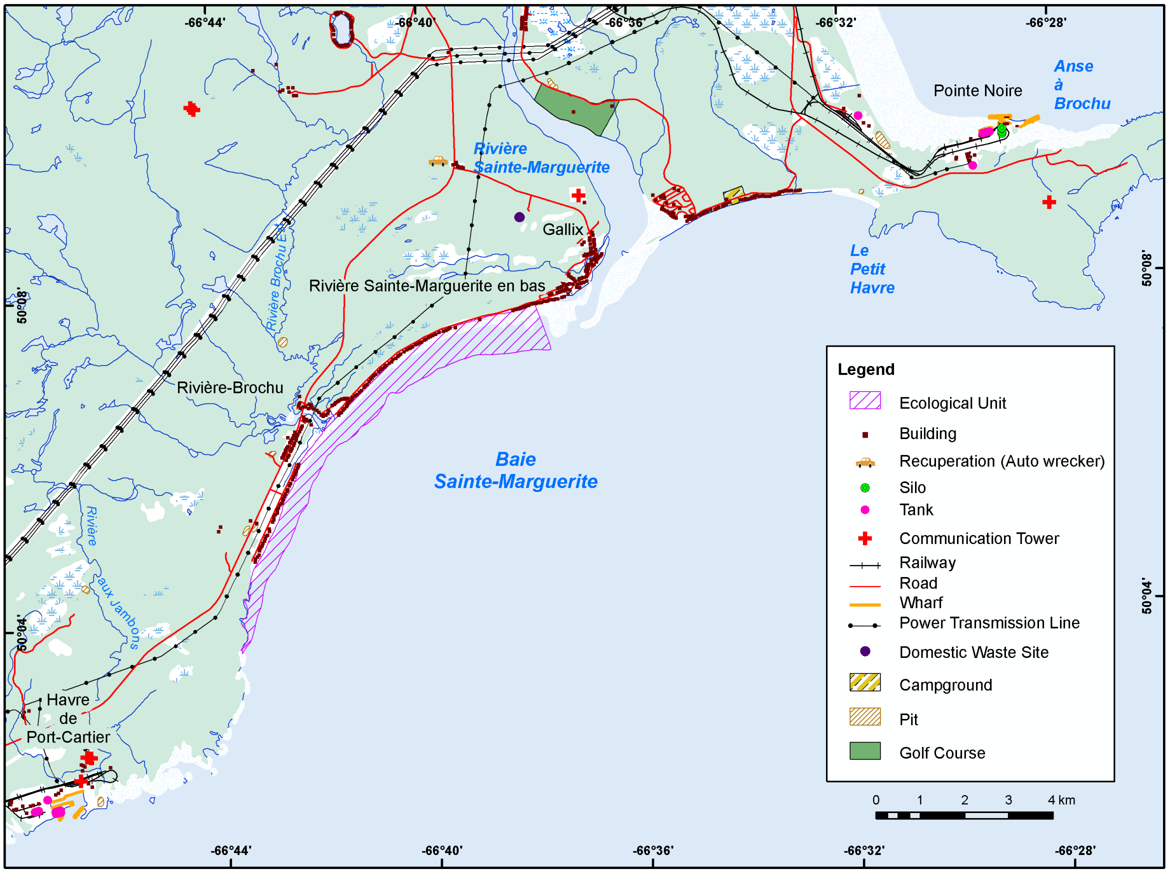

Figure 2. Ecological unit and area of immediate anthropogenic context (Source: Fish Habitat Management Information System – FHAMIS, DFO).

2.3 FORMULATION OF THE RISK ASSESSMENT PROCEDURE AND GUIDELINES FOR TOOL DEVELOPMENT

The proposed procedure for risk assessment and tool development is based on the framework suggested by Moss et al. (2006) (Figure 1). The analyses to be achieved were grouped into types according to their specific objectives. The four resulting types of analysis are 1) analysis of predicted conditions, 2) analysis of measured conditions, 3) analysis of desired conditions, and 4) comparative analysis of conditions (Figure 3). For the purposes of the project, Type 1 is based on the risk profiler method described above (Section 2.1.1). Types 2 to 4 complete the procedure and are inspired by the work of Moss et al. (2006) (Section 2.1.2).

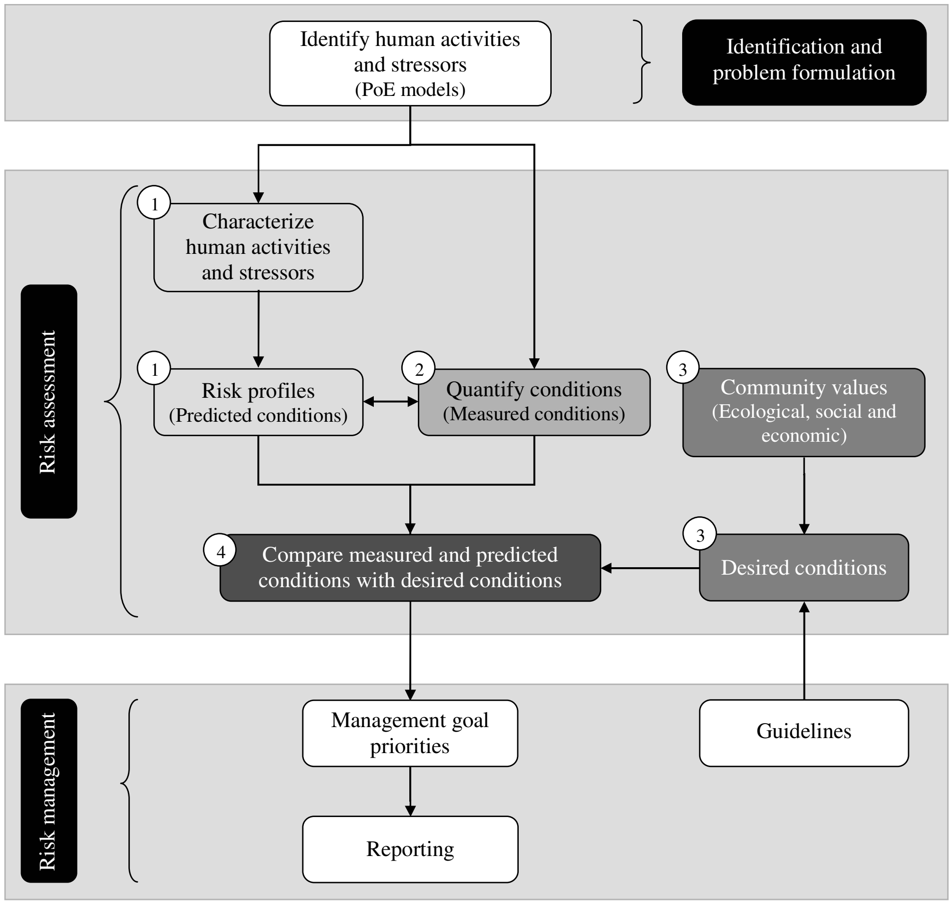

Figure 3. Distinction of the four types of analysis for the proposed risk assessment procedure: 1) the analysis of predicted conditions, 2) analysis of measured conditions, 3) analysis of desired conditions, and 4) comparative analysis of conditions.

2.3.1 Analysis of predicted conditions

The predicted conditions analysis (Type 1) aims to characterize the risk associated with human activities and stressors present in the ecological unit that can potentially impact the selected measurable endpoint. The tool to be developed will be adapted from the "*Risk profiler*" method mentioned in Section 2.1.3 and will be adjusted based on different tests and validation processes. It aims to determine risk in three stages, i.e., 1) by defining the ecological unit, 2) by characterizing the activities and stressors present, and 3) by producing risk profiles.

2.3.2 Analysis of measured conditions

While the analysis of predicted conditions makes it possible to estimate the level of risk that the various uses may represent for the ecological unit, the analysis of measured conditions (Type 2) presents an indication of the current state of the unit. This indicator stems from the processing and interpretation of scientific data on the biophysical characteristics of the environment and in connection with the same stressors as those considered during the analysis of Type 1.

2.3.3 Analysis of desired conditions

The analysis of desired conditions (Type 3) provides explanations about the social, economic, and cultural aspects by quantifying the value that affected communities assign to the ecological unit. This type of analysis is complex, and several methods can be used to carry it out (e.g., work sessions with focus groups, large-scale surveys, cooperation, consultation with community stakeholders). For example, a survey was administered to over 800 residents of Queensland (Australia) to determine the economic value the population assigned to various types of use of waterways in that region (Lockie and Jennings 2003).

The analysis of desired conditions is preferably carried out after the first two analyses presented above. The analysis methodology can then be adapted to the major issues targeted by the two previous analyses and thereby assess the value and the risk specifically assigned to these elements by the communities concerned.

2.3.4 Comparative analysis of conditions

The fourth type of analysis consists of a comparison of the various results from the previous three types. It can be outlined in a synthesis table that managers can examine in order to make decisions in the subsequent stage of risk management. A comparative analysis tool can take various forms according to the managers and decision makers' needs or to the previous analysis results.

3.0 RESULTS

The principal product of phase II of the project is a tool to perform a predicted conditions analysis (Type 1) which was entirely developed and validated. However, although the proposed risk assessment procedure is comprehensive, not all of the accompanying tools for the entire procedure reached the stage of validation in a real context. The approach followed for the development of the draft tools for the other analyses (Types 2 to 4) are in Appendix 4.

The Results section presents details of the predicted conditions analysis tool, which is a spreadsheet that is in Appendix 5. This analysis tool was designed to be adapted to different situations, including a change in study area or a change of endpoint. It has been tested with biophysical data and the anthropogenic context available for Gallix beach.

The following sections describe the tool and its use by presenting the pre-established steps and the steps for the predicted conditions analysis that lead to risk characterization and risk profile charts creation. Each section corresponds to one tab of the spreadsheet, and the tool presentation take form of a courseware supported by examples taken from the exercise carried out for Gallix beach. Two copies of the tool are available on the CD placed in Appendix 5: one blank copy ready for use (predicted-conditions-analysis_original.xls) and one copy presenting the results for the Gallix exercise (predicted-conditions-analysis_gallix.xls). It is strongly recommended that the tool courseware be read along with one of these copies.

3.1 PRE-ESTABLISHED STEPS FOR THE PREDICTED CONDITIONS ANALYSIS

3.1.1 Definition of the ecological unit

The "Ecological unit" tab makes it possible to correctly define the unit subject to the predited conditions analysis and, accordingly, all of the subsequent risk analyses. It is important to define this area according to the targeted parameter (here the endpoint "spawning / larval retention area"), so that the analysis focusses on the selected subject. The tab displays a descriptive map of the area to which a written description can be added.

For the exercise with Gallix beach, the descriptive map shows the ecological unit and its immediate anthropogenic context as described in Section 2.2. A description of the principal biophysical features of the unit has also been added.

3.1.2 Drafting the portrait

The "Portrait" tab allows the tool to incorporate all of the information describing human activities and potential stressors (identified in Appendix 3, Pathways of Effects models) that can potentially impact the ecological unit. For each of the identified anthropogenic elements, the portrait is broken down according to the various assessment criteria, which are presented subsequently.

The portrait must be as comprehensive as possible and based on literature. In this respect, the portrait has a source identification column. It can also be supplemented with descriptive maps of the region surrounding the ecological unit including the current human activities, which gives a better representation of the potential stressors. Appendix 5 contains a general template ("drafting-portrait_template.doc") to guide the gathering of data required to draft the portrait.

3.1.3 Inventory of relevant definitions

Relevant definitions can be included in this tool tab as a reference when conducting the characterization. For the Gallix beach exercise, the definitions included are those describing human activities and stressors as formulated in phase I of the project (Giguère et al. 2011).

3.1.4 Description of probability and uncertainty

The "Probability and uncertainty" tab displays two elements of significance from Section 2.1.3. The criteria for ranking risk probability (G. Olivier, DFO, pers. comm.) have been used in the development of certain assessment criteria associated with human activities (Section 3.2.2). This probability scale allows for the addition of a concept of proportion (%) to certain criteria (e.g., the geographical extent of an activity) and thereby facilitates the risk characterization process. As for criteria for ranking uncertainty, the scale proposed by N. Mandrak (DFO, unpublished data) is used as a reference to illustrate the degree of certainty that can be assigned to the sources on which the risk characterization is based. This scale is the basis for the rank of uncertainty that will be assigned during the completion of Steps 2 and 3 of the predicted conditions analysis (Sections 3.2.2 and 3.2.3).

3.2 STEPS FOR THE PREDICTED CONDITIONS ANALYSIS

3.2.1 Step 1 – Identification of human activities and stressors

The first step of the predicted conditions analysis is performed in the tab "1-Identification Activities/Stressors." As for all of the steps to follow, the basic data on which this operation is based are taken and adapted from PoE models produced during phase I (Appendix 3). Figure 4 displays a PoE model mainly adapted for the purpose of phase II. This adapted PoE model illustrates human activities and potential stressors specific to the capelin spawning / larval retention area (Giguère et al. 2011).

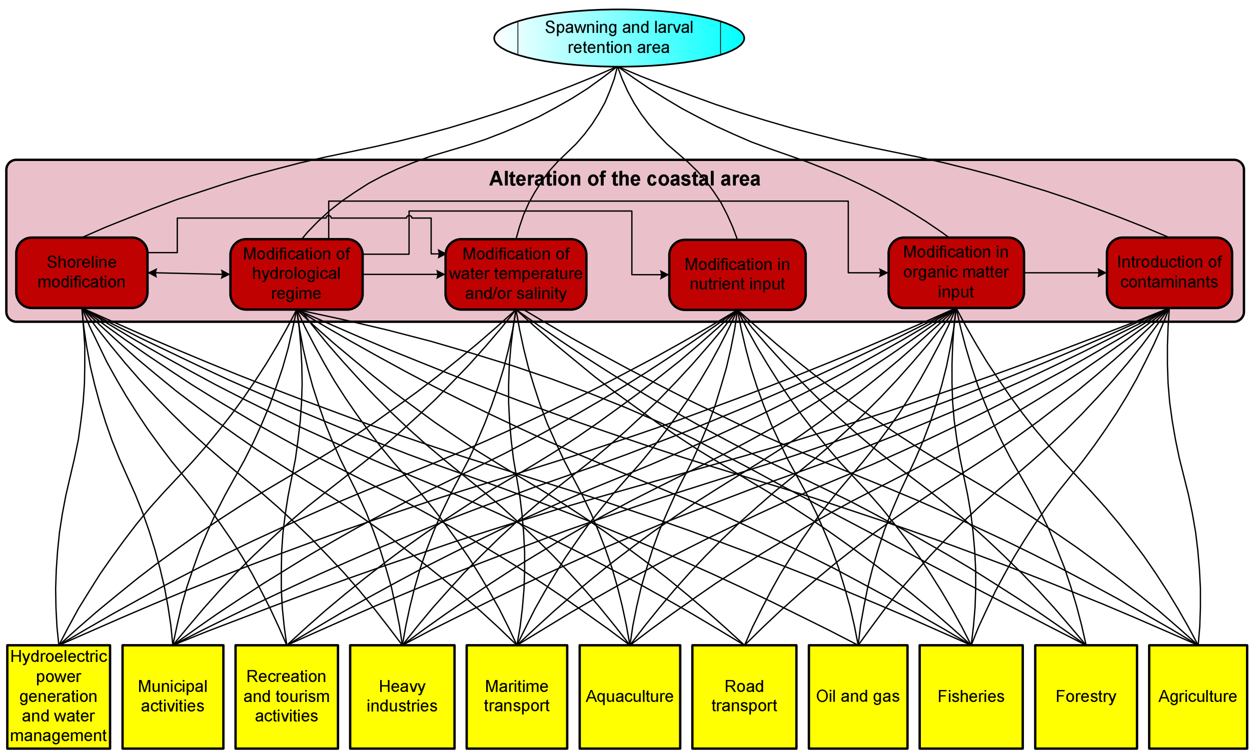

Figure 4. Adaptation of the holistic Pathways of Effects model for capelin conservation in the Estuary and Gulf of St. Lawrence in the specific case of alteration of the coastal area.

This tab contains an interactive table to be completed (Figure 5)[6] that allows the user to indicate the presence or absence of a human activity in the ecological unit or in the area of influence (glossary, Appendix 2). The tool offers the "yes/no" choice in a drop-down menu. For Gallix beach, the Figure 5 shows that aquaculture as well as oil and gas industry activities are absent from the area.

[6] For the courseware, the term *Figure* was chosen even though the element referred to is sometimes a table: in all, the "figures" are images directly taken from the tool.

Human activities	Presence (Yes/No)
Hydroelectric power generation and water management	Yes
Municipal activities	Yes
Recreation and tourism activities	Yes
Heavy industries	Yes
Maritime transport	Yes
Aquaculture	No
Road transport	Yes
Oil and gas	No
Fisheries	Yes
Forestry	Yes
Agriculture	Yes

Figure 5. Identifier for the presence of human activities in the ecological unit.

A second table located on this tab (Figure 6) supplements the information by presenting options for possible human activity / stressor pairs. In this tool, the black boxes correspond to options considered impossible, regardless of the type of ecological unit being studied. This feature stems from the PoE models (Figures 4 and Giguère et al. 2011).

The information entered in the interactive table and that contained in the pairs table is automatically compiled and posted to the second-to-last tab of the spreadsheet, called "Identification." This tab only indicates the pairs composed of the activities present in the ecological unit and the stressors that are triggered by these activities. Only these pairs will be considered and represented in the final risk profiles.

Human activity/ Stressor	Shoreline	Hydrological regime	Temperature & salinity	Nutrients	Organic Matter	Contaminants
Hydroelect.	Hydroelect. / Shoreline	Hydroelect. / Hydrological regime	Hydroelect. / Temperature & salinity	Hydroelect. / Nutrients	Hydroelect. / Organic Matter	
Municipal act.	Municipal act. / Shoreline	Municipal act. / Hydrological regime	Municipal act. / Temperature & salinity	Municipal act. / Nutrients	Municipal act. / Organic Matter	Municipal act. / Contaminants
Recreation & tourism	Recreation & tourism / Shoreline	Recreation & tourism / Hydrological regime		Recreation & tourism / Nutrients	Recreation & tourism / Organic Matter	Recreation & tourism / Contaminants
Heavy ind.	Heavy ind. / Shoreline	Heavy ind. / Hydrological regime	Heavy ind. / Temperature & salinity	Heavy ind. / Nutrients	Heavy ind. / Organic Matter	Heavy ind. / Contaminants
Maritime transp.	Maritime transp. / Shoreline	Maritime transp. / Hydrological regime	Maritime transp. / Temperature & salinity	Maritime transp. / Nutrients	Maritime transp. / Organic Matter	Maritime transp. / Contaminants
Aquaculture	Aquaculture / Shoreline	Aquaculture / Hydrological regime	Aquaculture / Temperature & salinity	Aquaculture / Nutrients	Aquaculture / Organic Matter	Aquaculture / Contaminants
Road transp.	Road transp. / Shoreline	Road transp. / Hydrological regime			Road transp. / Organic Matter	Road transp. / Contaminants
Oil and gas	Oil and gas / Shoreline			Oil and gas / Nutrients	Oil and gas / Organic Matter	Oil and gas / Contaminants
Fisheries	Fisheries / Shoreline	Fisheries / Hydrological regime	Fisheries / Temperature & salinity	Fisheries / Nutrients	Fisheries / Organic Matter	Fisheries / Contaminants
Forestry		Forestry / Hydrological regime	Forestry / Temperature & salinity	Forestry / Nutrients	Forestry / Organic Matter	
Agriculture		Agriculture / Hydrological regime	Agriculture / Temperature & salinity	Agriculture / Nutrients	Agriculture / Organic Matter	Agriculture / Contaminants

Figure 6. Possible human activity / stressor pairs for the capelin spawning / larval retention area. Black boxes identify impossible pairs in any ecological unit.

3.2.2 Step 2 – Risk characterization associated with human activities

The second step of the predicted conditions analysis, in the tabs identified by the number 2, makes it possible to characterize the risk associated with each of the human activities identified in the ecological unit in terms of five distinct criteria: intensity, duration, geographic extent, trend, and the regulatory response[7]. The first three criteria characterize the severity of the risk, while the other two are related to its likelihood.

The format of the characterization grid for human activities is presented in Figure 7. The criterion to be assessed and its general definition (grey box) are below the name of the concerned human activity. For each criterion, five levels of risk are established and defined according to the defined human activity. These descriptions are easily amended for the purposes of the ecological unit under study or according to the nature of the various activities present, which makes the tool more flexible and versatile.

To proceed with the characterization, the user enters an "X" to the right of the description of the criterion corresponding to the level of risk represented by the activity for the ecological unit. The level of risk of a human activity must be based on exhaustive research of information for each of the criteria.

[7] The criterion *Regulatory response* is based on the premise that an unregulated activity would present a higher risk for the ecological unit than an activity that is highly regulated (Stephenson and Hartwig 2009).

Activity: Hydroelectric power generation and water management

Results

5.0	5.0	4.0	3.0	1.0
0.5	0.1	0.5	0.3	0.1

INTENSITY			Uncertainty		
Level of Risk	Criterion				Justification: Intensity
	Intensity (level of activity) can be defined as the amplitude of a phenomenon caused by a human activity within the ecological unit and/or within the zone of influence of the ecological unit. It is expressed numerically in terms of frequency, level of effort, or strength.	Place an x		Place an x	There are three hydro-electric power plants on the Sainte-Marguerite River: SM-1, SM-2 and SM-3. Two power plants belonging to the private sector (Iron Ore Company of Canada or IOC), are located near the mouth: SM-1 (generation of 28.5 MW) and SM-2 (generation of 17.6 MW). In 1994, Hydro-Québec began construction of the Denis-Perron dam where the SM-3 power station is located; it has two turbine-generator units with an installed capacity of 882 MW (Hydro-Québec, 2002). Much of the total area of the drainage basin, specifically 76.5% or about 4,737 km^2, supplies the SM-3 dam. Nearly the entire area of the drainage basin of the Sainte-Marguerite River, or 6,168 km^2 (99.6%), drains into SM-2 (Therrien et al. 2001). The SM-3 dam is one of the four largest dams in Quebec. No information on periods of intense turbine use or on the management method used by dam operators.
Extreme	The level of activity or intensity associated with hydroelectric power generation and water management is **extreme** owing to the very high number, very high density and/or large size of the structures present in the ecological unit, the water volumes and frequency of discharge of water associated with dams, etc.	X	Very high certainty		
High	The level of activity or intensity associated with hydroelectric power generation and water management is **high** owing to the high number, high density and/or medium to large size of the structures present in the ecological unit, the water volumes and frequency of discharge of water associated with dams, etc.		High certainty		
Moderate	The level of activity or intensity associated with hydroelectric power generation and water management is **moderate** owing to the moderate number, density and/or size of the structures present in the ecological unit, the water volumes and frequency of discharge of water associated with dams, etc.		Moderate certainty	X	
Low	The level of activity or intensity associated with hydroelectric power generation and water management is **low** owing to the restricted number, low density and/or small to medium size of the structures present in the ecological unit, the water volumes and frequency of discharge of water associated with dams, etc.		Low certainty		
Negligible	The level of activity or intensity associated with hydroelectric power generation and water management is **negligible** owing to the very low number, the negligible density and/or small size of the structures present in the ecological unit, the water volumes and frequency of discharge of water associated with dams, etc.		Very low certainty		

Figure 7. Example of a risk characterization grid for a human activity: level of risk associated with the intensity criterion of hydroelectric power generation and water management for Gallix beach.

Two pieces of information are required to identify the level of risk: 1) the activity occurring in the ecological unit or in the area of influence (i.e., the information contained in the tabs “Ecological unit” and “Portrait”) and 2) the impacts of this activity or the stressors it generates, present for the endpoint or the measurable endpoint. This information may come from different sources, for example, from an expert’s advice or from the literature. In such information is lacking, the user’s judgement and experience is required.

In the example of Figure 7, the level of risk represented by hydroelectric power generation and water management for Gallix beach is deemed “Extreme” and the user enters the information providing the basis for this decision in the “Justification” box. The justification section is essential because it helps ensure that the characterization process is based on reliable and relevant information, thus ensuring transparency and better partner–stakeholder acceptability. It also allows for an easier reassessment of the risk level upon a subsequent assessment by listing the main sources and information used. Such a reassessment may be necessary following a change in an activity sector or when new information on the subject becomes available.

Following the risk characterization, the level of certainty of the information that formed the basis for the selected level of risk must be determined. Obviously the quantity and quality of the available information can be very uneven from one subject to the next, which implies a varying reliability of the results. To compensate for this situation, a scale of uncertainty, also comprising five levels (Figure 7), lends a degree of reliability to the sources used (on the basis of the ranking criteria for uncertainty in the tab “Probability and uncertainty”).

Also, the section “Results” located in the upper right part of Figure 7 summarizes the results of the activity characterization, here “Hydroelectric power generation and water management.” This kind of results summary is automatically created for each activity. The first line corresponds to the risk value (from 1 to 5) assigned to the activity for each of the five criteria (intensity, duration, geographic extent, tendency, and regulatory response). The second line is a compilation of the value assigned to uncertainty (varying among 0.1, 0.3, 0.5, 0.7, and 0.9). These results are transferred to a summary located in the “Calculation” tab (Figure 8) to be used in Step 5.

Lastly, it should be emphasized that the tool includes all of the activities presented by the PoEs, making it inclusive and integrative. However, the interactive table completed in Step 1 (Figure 5) makes it possible to discard human activities that are absent in the study area from the risk profile charts. In the results summary (Figure 8), these absent activities are represented by “False.”

	Severity			Uncertainty (Severity)			Likelihood		Uncertainty (Likelihood)	
Human activity	Intensity	Duration	Geographic extent	Intensity	Duration	Geographic extent	Tendency	Regulatory response	Tendency	Regulatory response
Hydroelectric power generation and water management	5	5	4	0.5	0.1	0.5	3	1	0.3	0.1
Municipal activities	3	5	4	0.3	0.1	0.3	3	2	0.5	0.3
Recreation and tourism activities	4	5	4	0.3	0.7	0.5	4	3	0.5	0.3
Heavy industries	4	5	2	0.1	0.1	0.3	5	1	0.3	0.1
Maritime transport	5	5	2	0.1	0.1	0.3	5	2	0.3	0.3
0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Road transport	2	5	1	0.1	0.1	0.1	3	1	0.3	0.1
0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Fisheries	2	2	2	0.3	0.5	0.5	3	2	0.3	0.3
Forestry	2	4	2	0.9	0.5	0.9	3	1	0.7	0.1
Agriculture	2	3	1	0.3	0.3	0.3	3	1	0.5	0.1

Figure 8. Summary of results of the risk characterization associated with human activities at Gallix beach.

3.2.3 Step 3 – Risk characterization associated with stressors

Step 3, comprised in tabs identified by the number 3, includes the risk characterization associated with each of the stressors. For each of the six stressors identified in PoE models (Figure 4 and Appendix 3), five criteria make it possible to characterize risk, i.e., magnitude, ecosystem sensitivity, reversibility (severity criteria), observed impacts in the past, and expected impacts in the future (likelihood criteria) (Appendix 2). The format in which the assessment criteria were formulated and the process of risk level determination is similar to the one presented for human activities (Section 3.2.2). The justification box is also present here.

Descriptions of the five risk levels for stressor characterization are based on the specific ecological model (PoE, Appendix 3). In fact, this PoE model made it possible to formulate descriptions specific to each of the stressors by including their respective impacts. Figure 9 shows an example of a description of a risk level for the criterion “Shoreline modification” that incorporates its specific impacts, i.e., reduction in size of the intertidal zone, erosion, silting, loss of substrate quality, and sediment accumulation.

REVERSIBILITY	
Level of Risk	**Criterion**
	Reversibility relates to the capacity to reverse the impacts induced by the stressor within the ecological unit. It is linked to resilience and the adaptation of species and habitats to damage. Reversibility may be contingent on the implementation of environmental management measures.
Extreme	Impacts caused by a shoreline modification, such as reduction in size of the intertidal zone, erosion, silting, loss of substrate quality or sediment accumulation, are **irreversible or nearly irreversible**. The species and habitats have a very low capacity to overcome or adapt to disturbances. Damage to the species, habitat or ecosystem is permanent or it may be reversible through a prolonged period of significant and sustained management efforts.
High	Impacts caused by a shoreline modification, such as reduction in size of the intertidal zone, erosion, silting, loss of substrate quality or sediment accumulation, **cannot be easily reversed**. The species and habitats have a limited capacity to overcome or adapt to disturbances. Damage to the species, habitat or ecosystem is almost permanent or may be reversible through a long period of natural recovery or, in the medium term, sustained environmental management efforts.
Moderate	Impacts caused by a shoreline modification, such as reduction in size of the intertidal zone, erosion, silting, loss of substrate quality or sediment accumulation are **reversible**. The species and habitats have the capacity to overcome or adapt to disturbances. Damage to the species, habitat or ecosystem range from temporary to semi-permanent or it may be reversible through a short period of environmental management efforts or a long period of natural recovery.
Low	Impacts caused by a shoreline modification, such as reduction in size of the intertidal zone, erosion, silting, loss of substrate quality or sediment accumulation, **can be easily reversed**. The species and habitats have a strong capacity to overcome or adapt to disturbances. Damage to the species, habitat or ecosystem is temporary or reversible through a short period of environmental management efforts or, in the medium term, natural recovery.
Negligible	Impacts caused by a shoreline modification, such as reduction in size of the intertidal zone, erosion, silting, loss of substrate quality or sediment accumulation, are **reversible through natural processes**. The species and habitats have a strong capacity to overcome and adapt to disturbances. Damage to species, habitats or the ecosystem is very temporary and completely reversible through natural processes.

Figure 9. Example of a description of a risk level: "reversibility" for the stressor "shoreline modification."

A results summary (Figure 10) is automatically produced in the "Calculation" tab during this step.

	Severity			Uncertainty (Severity)			Likelihood		Uncertainty (Likelihood)	
Stressor	Magnitude	Ecosystem sensitivity	Reversibility	Magnitude	Ecosystem sensitivity	Reversibility	Observed impacts in the past	Expected impacts in the future	Observed impacts in the past	Expected impacts in the future
Shoreline modification	5	4	3	0.1	0.3	0.7	4	3	0.3	0.5
Modification of hydrological regime	5	4	3	0.1	0.5	0.9	4	3	0.3	0.5
Modification of water temperature and/or salinity	2	4	3	0.7	0.3	0.7	3	2	0.7	0.7
Modification in nutrient input	2	2	2	0.3	0.7	0.7	3	3	0.5	0.5
Modification in organic matter input	3	4	3	0.3	0.5	0.5	3	3	0.7	0.5
Introduction of contaminants	5	4	4	0.3	0.3	0.3	2	2	0.7	0.5

Figure 10. Summary of the results of the risk characterization associated with stressors at Gallix beach.

3.2.4 Step 4 – Weighting of human activity / stressor pairs

Creating pairs by directly associating the values assigned in Steps 1 and 2 to the activities with those of the stressors can create unrealistic or nonrepresentative charts. For example, maritime transport was identified as an activity having a generally high risk for Gallix beach (Figure 8) because of the presence of large industrial ports on either side of the unit (at Port-Cartier and Sept-Îles). On the other hand, the stressor "Shoreline modification" represents a significant risk for capelin conservation because of the significance of its potential impacts on the spawning / larval retention area (Figure 10). However, the direct matching of these values in the human activity / stressor in the profile corresponds to a high risk level that is not representative of the situation observed in the ecological unit. In fact, it is not accurate to say that maritime transport activities, although significant in the periphery of Gallix beach, truly generate a shoreline modification. This example illustrates that, even if a human activity / stressor pair exists, it is still necessary to quantify and qualify the pair within its ecological unit.

Step 4 was formulated to resolve the above-mentioned issue by considering the pertinence of the human activity / stressor pairs in the ecological unit. This step makes it possible to weight the linkage between the components of each pair, using an interactive table (Figure 11[8]) comprised in tabs "4-Link". To fill the tables, the user must answer the following question: "In what order of importance does the activity induce the stressor in the ecological unit?" The rank assigned to the significance of linkages may be low (0.1), moderate (0.5), or strong (1.0)[9]. Each rank will then multiply the pair's value obtained in the previous risk characterization, and consequently will move the points in the profile.

Stressor
Shoreline modification

Pair	Link
Hydroelect./Shoreline	Moderate
Municipal act./Shoreline	Strong
Recreation & tourism/Shoreline	Moderate
Heavy ind./Shoreline	Low
Maritime transp./Shoreline	Low
Road transp./Shoreline	Low
Fisheries/Shoreline	Low

Low
Moderate
Strong

Figure 11. Example of weighting of the strength of the linkage of the human activity / shoreline modification stressor for Gallix beach.

[8] Figures 11 and 12 show empty boxes (or "0") that correspond to the activities that are absent in the unit, as established in Step 1 (Section 3.2.1). For Gallix beach, aquaculture and oil & gas activities are nonexistent.

[9] The choice of values was made by consensus based on the expertise of the working group. These values made it possible to move points according to Gallix beach purposes. The results obtained correspond to the reality.

Figure 12 presents the summary of the linkage weighting step, which is automatically created in the "Calculation" tab that will be used in Step 5.

Weighting	Shoreline modification	Modification of hydrological regime	Modification of water temperature and/or salinity	Modification in nutrient input	Modification in organic matter input	Introduction of contaminants
Hydroelectric power generation and water management	0.5	1	1	0.1	0.1	
Municipal activities	1	0.5	0.5	0.5	0.5	0.5
Recreation and tourim activities	0.5	0.1		0.1	0.1	0.1
Heavy industries	0.1	0.1	0.1	0.1	0.1	0.5
Maritime transport	0.1	0.1	0.1	0.1	0.1	0.5
0	0	0	0	0	0	0
Road transport	0.1	0.1			0.1	0.1
0	0			0	0	0
Fisheries	0.1	0.1	0.1	0.1	0.1	0.1
Forestry		0.1	0.1	0.1	0.1	
Agriculture		0.1	0.1	0.1	0.1	0.1

Figure 12. Summary of the weighting results concerning the linkage strength of the human activity / stressor pairs for Gallix beach.

3.2.5 Step 5 – Risk profile

The last step in the predicted conditions analysis is the creation of risk profiles for each of the stressors; these are found on the "5-Profile" tabs. The calculations required for locating points on the chart are made in the "Calculation" tab. The risk profile is based on two averages calculated from the risk level attributed to each component of a human activity / stressor pair: 1) to severity criteria (X axis) and 2) to likelihood criteria (Y axis) (Figures 8 and 10). Each mean is later multiplied by the weighting rank assigned to the pair in Step 4 (Figure 12). An example is available on the copy of the tool presenting the results for the Gallix exercise (Appendix 5).

The chart produced from these calculations makes it possible to visualize the level of risk of a human activity in terms of a stressor in the ecological unit. Figure 13 presents the risk profile of the identified activities that can generate the stressor "Shoreline modification" at Gallix beach. The profile shows that municipal activities can have a higher potential of impact, whereas activities linked to maritime and road transport, fishing, and heavy industry present a rather negligible potential risk.

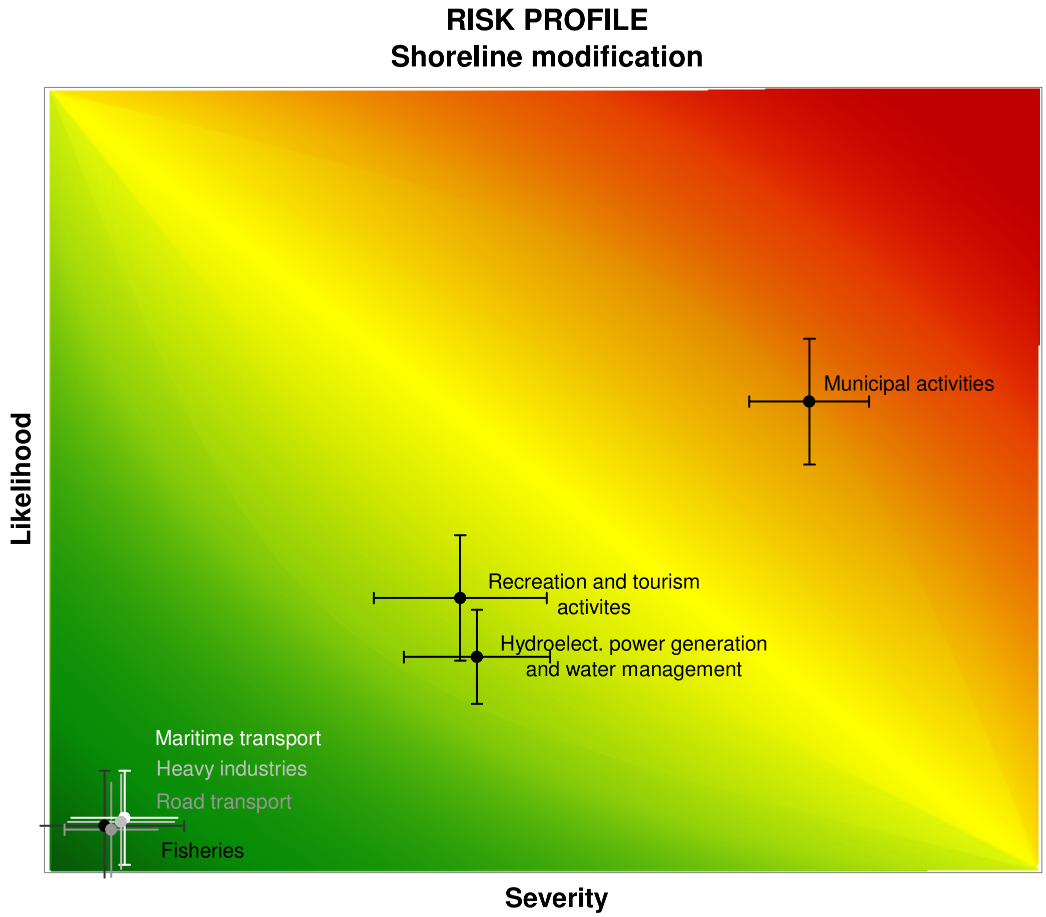

Figure 13. Risk profile for human activities present and having the potential to generate shoreline modification for Gallix beach.

To supplement the information presented by the risk profiles, the uncertainty values assigned during Steps 2 and 3 (Sections 3.2.2 and 3.2.3) are also represented in the form of uncertainty bars associated with each of the points. These bars provide an overview of the certainty of sources[10] that formed the basis for the risk characterization of a human activity / stressor pair. These uncertainty values correspond to two distinct means calculated from uncertainty values associated with severity and likelihood criteria (Figures 8 and 10), but with no weighting this time.

The five other risk profiles produced while assessing Gallix are presented in the "measured-conditions-analysis_gallix.xls" spreadsheet in Appendix 5.

[10] It is important to indicate that the uncertainty bars associated with activities in the risk profiles do not correspond to standard error values (as understood in statistics). These bars rather provide a visual representation of the quantity and quality of the information obtained which forms the basis for the risk assessment of a human activity / stressor pair.

4.0 DISCUSSION

4.1 INTERPRETATION OF RISK PROFILES

The predicted conditions analysis tool provides a visual representation of the results in the profiles produced, which makes it possible to quickly compare and rank the potential risk level of each of the pairs. However, the interpretation of these graphs involves a particularity that users and decision makers must keep in mind: activities likely to disrupt the environment represent a theoretical risk, but not necessarily a real and current impact on the environment. For example, the profile shown in Figure 13 identifies municipal activities as those presenting the greatest potential for generating a shoreline modification. However, in the specific case of Gallix beach, the community stakeholders are aware that municipal activities, and more particularly the installation of bank stabilization structures (e.g., riprap, spur), represent a high risk for the stability of the beach and the integrity of the residential grounds around it. Consequently, this awareness seems to be favourable for the conservation of this capelin spawning and larval retention area and, ultimately, for species conservation itself. The current management lines envisaged by territory managers already take the cost-advantage analysis of the various solutions into account to address shoreline erosion. For example, they anticipate moving housing located in the erosion zone rather than opting for the installation of hard structures that would reduce the size of the beach or eliminate it. In maintaining this approach, decision makers could thereby lessen the future impacts of municipal activities on Gallix beach.

This example of an approach shows that the proposed tool, through the estimation of potential ecological risk and the interpretation of risk profiles, allows community stakeholders and managers to effectively identify the aspects of risks that are most critical to a specific ecological unit and can thereby guide decision making, management lines, governance, and the investment of energies.

Table 1 groups together the information presented in all of the risk profiles produced during the risk characterization exercise for the Gallix beach ecological unit. This table is another option for a visual representation that synthesizes results to support interpretation and decision making during the risk management step. In addition, the geographical representation mentioned as a significant element in other methods (Section 2.1.3) could be used to improve visualization and communication of the results. However, such a risk representation requires a spatial processing of information, which has not been developed during the present exercise. It still is an avenue to keep in mind for this type of analysis.

Table 1. Summary of results of the predicted conditions analysis for Gallix beach. The colours correspond to those of the risk profile; grey = pair non-existent in the ecological unit; black = pairing impossible regardless of the ecological unit.

Activities/ Stressors	Shoreline	Hydrological regime	Temperature & salinity	Nutrients	Organic matter	Contaminants
Hydroelect.	Hydroelect. / Shoreline	Hydroelect. / Hydrological regime	Hydroelect. / Temperature & salinity	Hydroelect. / Nutrients	Hydroelect. / Organic matter	
Municipal act.	Municipal act. / Shoreline	Municipal act. / Hydrological regime	Municipal act. / Temperature & salinity	Municipal act. / Nutrients	Municipal act. / Organic matter	Municipal act. / Contaminants
Recreation & Tourism	Recreation & Tourism / Shoreline	Recreation & Tourism / Hydrological regime		Recreation & Tourism / Nutrients	Recreation & Tourism / Organic matter	Recreation & Tourism / Contaminants
Heavy ind.	Heavy ind. / Shoreline	Heavy ind. / Hydrological regime	Heavy ind. / Temperature & salinity	Heavy ind. / Nutrients	Heavy ind. / Organic matter	Heavy ind. / Contaminants
Maritime transp.	Maritime transp. / Shoreline	Maritime transp. / Hydrological regime	Maritime transp. / Temperature & salinity	Maritime transp. / Nutrients	Maritime transp. / Organic matter	Maritime transp. / Contaminants
Aquaculture	Aquaculture / Shoreline	Aquaculture / Hydrological regime	Aquaculture / Temperature & salinity	Aquaculture / Nutrients	Aquaculture / Organic matter	Aquaculture / Contaminants
Road Transp.	Road Transp. / Shoreline	Road Transp. / Hydrological regime			Road Transp. / Organic matter	Road Transp. / Contaminants
Oil & Gas	Oil & Gas / Shoreline			Oil & Gas / Nutrients	Oil & Gas / Organic matter	Oil & Gas / Contaminants
Fisheries	Fisheries / Shoreline	Fisheries / Hydrological regime	Fisheries / Temperature & salinity	Fisheries / Nutrients	Fisheries / Organic matter	Fisheries / Contaminants
Forestry		Forestry / Hydrological regime	Forestry / Temperature & salinity	Forestry / Nutrients	Forestry / Organic matter	
Agriculture		Agriculture / Hydrological regime	Agriculture / Temperature & salinity	Agriculture / Nutrients	Agriculture / Organic matter	Agriculture / Contaminants

4.2 PROCEEDING WITH THE PROPOSED PROCEDURE

According to the risk assessment procedure proposed in phase II, three other types of analysis follow the predicted conditions analysis. These analyses are inherent in carrying out a complete risk assessment that incorporates all of the aspects of a problem. From this perspective, analysis Types 2, 3, and 4 were also the focus of reflection, information research, and preliminary work to develop adapted tools. These subsequent analyses and the major conclusions drawn from this exercise are presented in Appendix 4.

To conduct the analysis of measured conditions (Type 2), an outline of the "Measured conditions analysis" tool is presented in Section A4.1 (Appendix 4). This outline consists of an Excel spreadsheet designed to visually resemble that of the predicted conditions analysis (Figure 7). The analysis of measured conditions makes it possible to assign a numerical value to the state of the environment—here the ecological unit—using indicators measuring specific biophysical parameters linked to the impacts resulting from the identified stressors.

Section A4.2 presents a proposed procedure for conducting the desired conditions analysis (Type 3). The proposed method would target the issues identified by conducting the predicted conditions and measured conditions analyses (Types 1 and 2) and would add a dimension of risk associated with social, economic, and cultural values.

Lastly, Section A4.3 deals with Type 4, i.e., the comparative analysis of conditions. This final step of the risk assessment provides an overall view of the results obtained from each of the preceding types of analysis and allows for their comparison. Although a portion of the proposed procedure is still in the draft stage, the suggestions and reflections presented in Appendix 4 show the range of possibilities offered by all of the analyses and tools envisaged.

These drafts demonstrated that this type of procedure requires time and resources to obtain a comprehensive, valid, and approved product covering the entire risk assessment process. For example, the process resulting in the assessment of cultural and social values involves consultation with the public using methods that may represent an investment of considerable time and resources. The development of indicators required for the "Measured conditions analysis" tool is another example of the investment essential to implementing the procedure undertaken here. The development of these indicators requires a comprehensive literature review and complete or partial characterization studies of the environment, a process that can take several months or even several years.

5.0 CONCLUSION

The objective of phase II of the project, i.e., to propose a procedure and to develop risk assessment tools to be applied to capelin conservation in the Estuary and Gulf of St. Lawrence (endpoint) as part of a risk analysis was achieved. To validate the procedure and the tools envisaged by applying them to a real context, Gallix beach was selected as an ecological unit that is representative of the capelin spawning / larval retention area (measurable endpoint), and the study subject was limited to the stressors that could alter the coastal area. The procedure, tools, and draft tools proposed were adapted using existing methods and were based on the information provided by the PoE models produced in phase I. Whether they are finalized or in draft form, the tools presented aim to obtain precise, complementary, and easily interpreted results. In addition, they demonstrate that it is possible to build risk assessment tools that are integrative, flexible, versatile, and easy to use, allowing for effective communication of the results. In the end, the entire risk assessment procedure envisaged is intended to provide a complete risk profile, including the ecological, social, economic, and cultural aspects associated with an ecological component within a specific unit. This profile will provide managers with concrete guidance, based on scientific information, when it is time to perform the last step in the risk analysis, i.e., decision making within the risk management framework.

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8.0 APPENDICES

Appendix 1. Composition of the DFO working group that collaborated in phase II of the pilot project.

Participant	Branch or Sector	Region
Arseneau, Cédric	Fisheries and Aquaculture	Québec
Comtois, Sophie	Ecosystem management	Québec
Dufour, Réjean	Science	Québec
Ellefsen, Hans-Frédéric	North Shore Sector	Québec
Giangioppi, Martine	Ocean Policy and Planning	Central administration
Giguère, Noémie	Ecosystem management	Québec
Grégoire, François	Science	Québec
Hazel, François	Ecosystem management	Québec
Magassouba, Ali	Policy and Economics	Québec
Massicotte, Éric	Policy and Economics	Québec
Nellis, Pierre	Ecosystem management	Québec
Savenkoff, Claude	Science	Québec
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Appendix 2. Glossary.

The following definitions are adapted to the needs of the document. Several come from the phase I report (Giguère et al. 2011) and are required to properly understand the text and the PoE models in Appendix 3. Main elements are in bold characters and sub-categories are underlined.

Endpoint: Component or ecological function that is to be protected.

Capelin conservation: Consists of preserving the integrity of capelin populations, subpopulations, or stocks.

Measurable endpoint: Measurable ecological component linked to the endpoint that is to be protected. Since it is measurable, this component establishes the relationship between the endpoint (in this case, capelin conservation) and the management objectives determined by managers.

Quantity and quality of capelin spawning / larval retention habitat (spawning / larval retention area): Quality of biophysical properties, number, and size of areas used by capelin for its reproduction activities (spawning ground) and early life stages (larval retention or nursery ground). It is important to point out that for the purposes of this project and given the available data, this measurable endpoint excludes the deepwater spawning component—a little known phenomenon—and instead focusses on the inshore spawning area.

Capelin abundance: Total number of individuals or number of individuals per unit of space (surface or volume) constituting a capelin population, subpopulation, or stock in a given region.

Ecological unit: area of particular biological and physical potential (e.g., specific groups of animal or plant species) and representative of the endpoint or of one its measurable endpoints.

Area of influence: area inside of which human activities can occur and potentially affect directly the ecological unit by generating one or several stressors. The area of influence is generally located next to the ecological unit, but its limits may change with the considered human activity (e.g., the area of influence of forestry activities corresponds to the watershed's territory that flows into the ecological unit or on its periphery).

Human activities: All human activities and actions that would be likely to affect the endpoint and measurable endpoints by inducing stressors. The human activities are elements to which management measures can apply.

Hydroelectric power generation and water management: **Hydroelectric power generation** relates to the conversion of the hydraulic energy generated by moving water (e.g., watercourses, waterfalls, waves, marine currents) to produce electricity. **Water management** concerns the regulation or artificial storage of a watercourse or water body by means of man-made infrastructure (e.g., hydroelectric dams, retaining dams, dikes) so the water can be reused for a variety of purposes (e.g. irrigation, industry, hydroelectricity, fish farming, potable water supply).

Municipal activities: Activities administered by municipalities, RCMs, and Aboriginal communities that can affect certain processes or elements of the natural environment. This activity sector is divided into two subcategories: the civil engineering and road network sector and the residential sector. The **civil engineering and road network sector** concerns activities connected to the development and management of a public area (e.g., deforestation, drainage, watercourse deviation), the construction and maintenance of public infrastructure (e.g., road system, waterworks, sewers), and public hygiene (e.g., wastewater and waste snow management, human waste management). The **residential activity sector** concerns activities connected to the development, management, construction, and maintenance of private land and infrastructure (e.g., shoreline modification, stabilization structures, land drainage, presence or absence of vegetation, and septic tanks).

Recreation and tourism activities: All the activities connected to the leisure and tourism sectors (e.g., hiking and nature outings, including the use of motorized vehicles, pleasure crafting, marine mammal observations). The definition also encompasses the facilities required for these activities (e.g., hotels, marinas, hiking trails, trails for motorized sports), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., armouring, clearing), and the waste or other effects generated by these activities (e.g., introduction of exotic species into the environment, trampling, anti-fouling paint).

Heavy industries: The economic sectors connected with the production and processing of raw material (e.g., mines, metallurgy, chemistry, paper mills). The definition also encompasses industrial facilities (e.g., plants, foundries, refineries), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., deforestation, fill work), and the waste or other effects generated by these activities (e.g., atmospheric emissions, wastewater, accidental spills).

Maritime transport: The transportation of merchandise or people by ship. The definition also encompasses maritime facilities (e.g., ports, wharves, navigational locks, breakwaters), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., dredging, reinforcing), and the waste or other effects generated by these activities (e.g., introduction of exotic species into the environment, atmospheric emissions, ballast water, grey water, accidental spills, anti-fouling paint).

Aquaculture: All animal or plant production activities taking place in natural or artificial aquatic environments. The definition also encompasses aquaculture facilities (e.g., tanks and raceways, collectors, cages), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., water intake, armouring, watercourse deviation), and the waste or other effects generated by these activities (e.g., escape of exotic species into the environment; spread of disease; use of nutrients, antibiotics, and disinfectants).

Road transport: Land transportation of merchandise and people by road. The definition also encompasses road infrastructure (e.g., road system, bridges, and culverts), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., deforestation, drainage, earthwork), and the waste or other effects generated by these activities (e.g., dust and aerosol production, noise, modification of the local climate, habitat fragmentation).

Oil and gas: All the activities connected to the exploration (e.g., seismic surveys) and extraction (e.g., drilling) of oil and gas resources in the marine environment. The definition also encompasses infrastructure (e.g., drilling platforms, pipelines), the activities associated with the development, construction and maintenance of this infrastructure (e.g., pile driving, blasting), and the waste or other effects generated by these activities (e.g., drilling waste, atmospheric emissions, accidental spills, light pollution).

Fisheries: All activities involving the capture of aquatic animals in their natural environment, whether as part of a targeted fishery (commercial, recreational, or subsistence fisheries) or otherwise (bycatch). The definition also encompasses primary and further processing activities where the organisms are prepared for market distribution.

Forestry: All activities connected to forestry. The definition also encompasses infrastructure (e.g., logging roads, culverts, fords), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., clearing, brush cutting, drainage, fill work), and the waste or other effects generated by these activities (e.g., changes in the structure of ecosystems, soil compaction, habitat fragmentation).

Agriculture: All activities connected with the development of a natural environment for the production of crops or rearing of animals to meet the needs of human societies. The definition also encompasses infrastructure (e.g., irrigation systems, silos), the activities associated with the development, construction, and maintenance of this infrastructure (e.g., deforestation, drainage, fill work), and the waste or other effects generated by these activities (e.g., spreading and spraying of fertilizers or pesticides, use of hormones in animal husbandry).

Stressor: Physical, biological, or chemical factors engendered by human activity that generate impacts (see definition) likely to affect endpoint and measurable endpoints (in this case the capelin spawning / larval retention area).

Shoreline modification: Modification or alteration of the original conditions of shoreline or riparian area—the transition area between a natural water body and the vegetation in the dry area—in response to human activities or stressors of human origin (e.g., disappearance of vegetation, armouring, fill work, trampling).

Modification of hydrological regime: Modification or alteration of the original conditions of the water flow (e.g., run-off, infiltration, evaporation) in response to human activities or stressors of human origin (e.g., construction of dams, bridges, watercourse deviations, deforestation).

Modification of water temperature and/or salinity: Modification of the original conditions of the water's temperature and salinity in response to human activities or stressors of human origin (e.g., deforestation, dam construction, watercourse deviations).

Modification in organic matter or nutrient input: Modification of the original conditions of the input of organic matter (composed of dissolved or particulate carbons of plant or animal origin) and nutrients (organic or mineral substances that can be directly assimilated by the organism) in response to human activities or stressors of human origin (e.g., wastewater emissions, ballast water, deforestation, spreading of fertilizers).

Introduction of contaminants: The input of any foreign biological or chemical agent or any other agent in abnormal quantities (unnatural quantities) into the environment as a result of human activities or stressors of human origin (e.g., atmospheric emissions, use of anti-fouling paint, accidental spills) that can compromise the integrity of the environment or the organisms present there.

Criterion: Element upon which the risk characterization will be based that allows the selection of the level of risk for a particular human activity or stressor against the measurable endpoint represented by the ecological unit.

Intensity: Intensity (level of activity) can be defined as the amplitude of a phenomenon caused by a human activity within the ecological unit and/or within the area of influence of the ecological unit. It is expressed numerically in terms of frequency, level of effort, or strength.

Duration: Refers to the time period during which the human activity takes place within the ecological unit and/or its area of influence. Duration is expressed using a temporal expression, such as a year, or a period expressed as a proportion of the duration of a critical ecological period specific to the ecological unit.

Geographic extent: Relates to the area occupied by the human activity within the ecological unit and/or within the zone of influence. Extent is expressed in terms of surface area unit, surface area, length, width, etc.

Tendency: Is the general direction in which a human activity and/or a related activity sector tend to move and changes in the associated dynamics over time. The tendency may be increasing, stable, or decreasing. It can be expressed as a percentage per unit of time (often one or more years).

Regulatory response: Is the approach used to respond to discrepancies, to moderate, and to regulate a human activity. It encompasses all the existing processes, policies, mechanisms, practices, and actions that are applicable within the ecological unit and are aimed at reducing the environmental risks associated with the activity.

Magnitude: Relates to the amplitude of the impacts caused by the stressor within the ecological unit. It reflects the degree of change that may be induced by the advent of a new stressor or by a significant increase in a stressor whose effects were imperceptible until that point. The degree of change imposed on the initial environmental conditions may be expressed in terms of the abundance or strength (alteration potential) of the anticipated effects.

Ecosystem sensitivity: Relates to the ecosystem's ability to perceive and respond to changes in environmental conditions caused by stressors. It is generally described as a negative response that corresponds to vulnerability and is the opposite of tolerance. Sensitivity is closely linked to ecological significance and scarcity: the greater the ecological significance and the scarcity of the species and habitats making up an ecosystem, the more the ecosystem is sensitive and vulnerable.

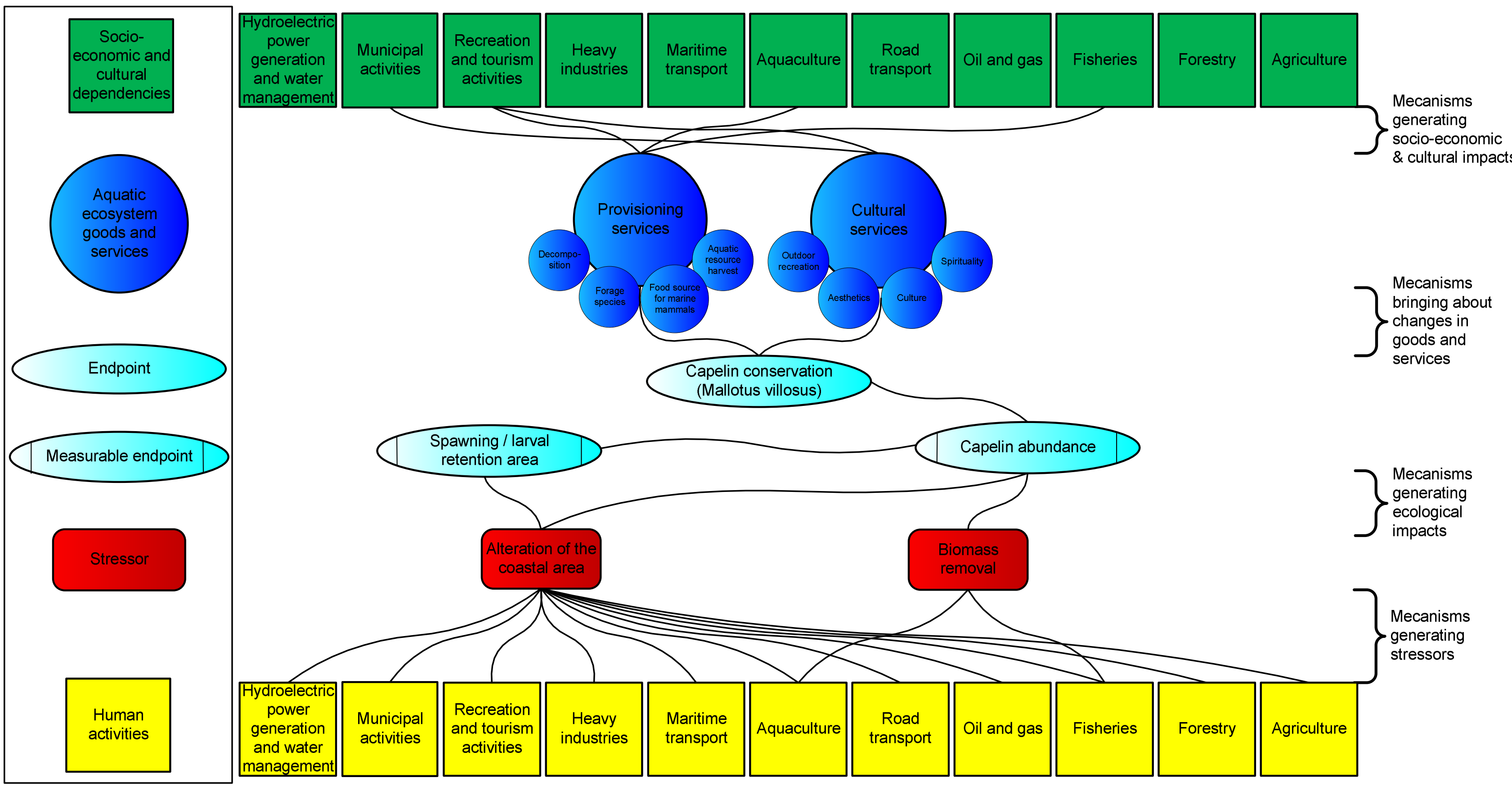
Reversibility: Relates to the capacity to reverse the impacts induced by the stressor within the ecological unit. It is linked to resilience and the adaptation of species and habitats to damage. Reversibility may be contingent on the implementation of environmental management measures.

Observed impacts in the past: Relate to effects and influence of the stressor that have occurred within the ecological unit or have been observed under similar conditions. These impacts can be described in terms of their chronic or sporadic nature.

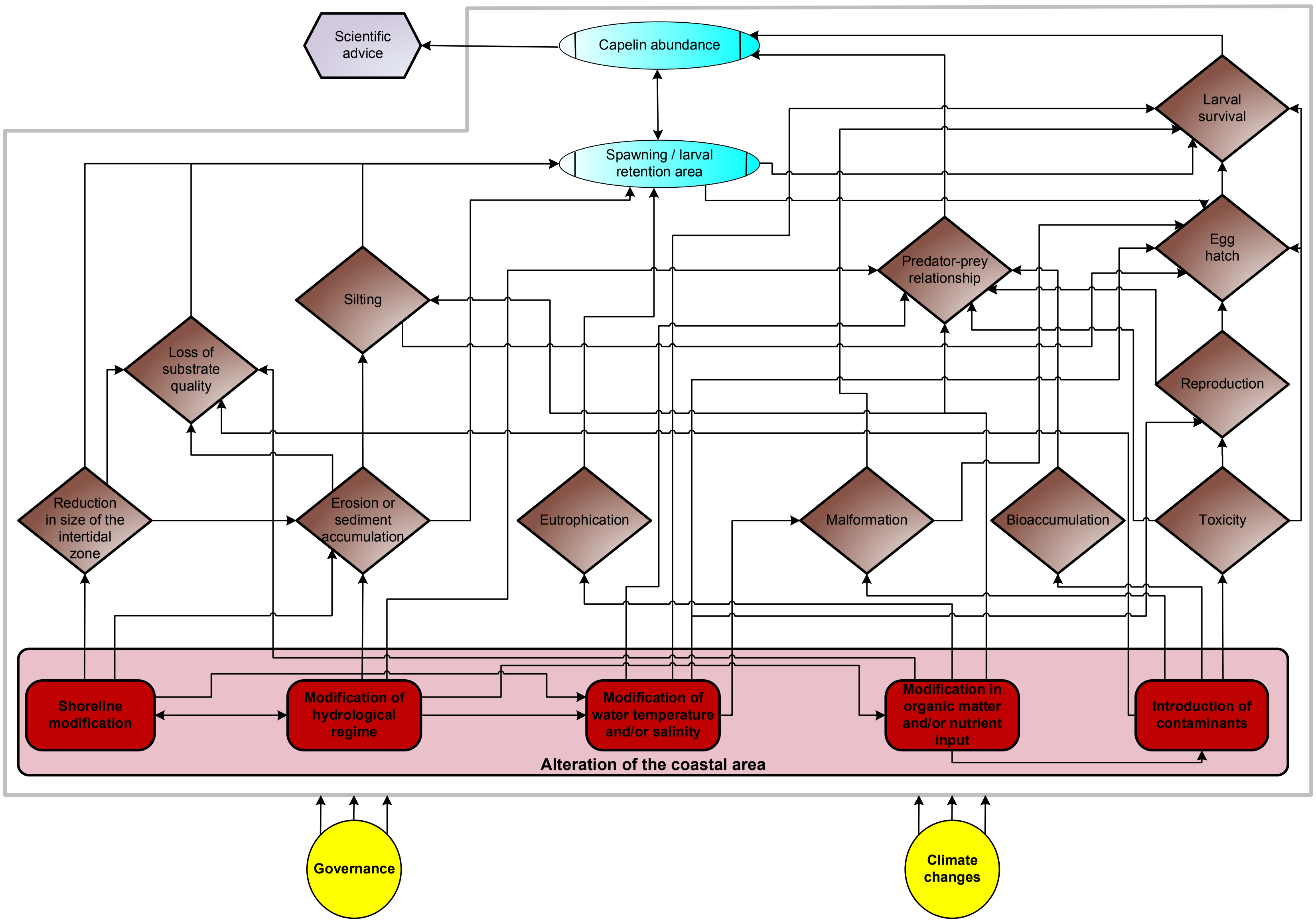
Expected impacts in the future: Means that the effects and influence of the stressor are anticipated or are likely to occur within the ecological unit.

Appendix 3. Pathways of Effects models.

Appendix 3a. Holistic Pathway of Effects model for capelin conservation in the Estuary and Gulf of St. Lawrence (completed during phase I of the pilot project; Giguère et al. 2011.).



Appendix 3b. Specific ecological Pathways of Effects model for capelin spawning / larval retention area (completed during phase I of the pilot project; Giguère et al. 2011).



Appendix 4. Carrying out the proposed procedure.

Implementing the procedure targets analysis Types 2, 3, and 4 (Figure 3). The information of significance for building the subsequent tools required for conducting these analyses is shown in this appendix.

A4.1 Analysis of measured conditions

For the analysis of measured conditions, an Excel spreadsheet draft tool was produced (Appendix 5, measured-conditions-analysis_original.xls). Certain similarities exist between this draft tool and the predicted conditions analysis tool. The purpose of these similarities was to simplify the use of various tools by harmonizing the entire procedure.

The proposed draft tool is adapted to the case of the capelin spawning / larval retention area and could be applied to Gallix beach to conclude phase II. The underlying principles for the development of this tool, presented in Sections A4.1.1 to A4.1.3, may also serve as a guide for developing environmental assessment tools that are adapted to examine conditions for other species or study areas.

In its current state, the Excel spreadsheet is designed to visualize the final tool that could be produced. It is not designed to calculate, to link elements, or to produce results.

A4.1.1 Step 1 – List of environmental state indicators

In the first place, the analysis of measured conditions aims to establish a portrait of current environmental conditions by assigning a value to the prevailing conditions in the unit. In concrete terms, the analysis assesses the state of the environment with respect to the stressors that affect it on the basis of the most relevant scientific information.

The first step in this process consists of reviewing the existing environmental state indicators or those to be developed, in order to establish as complete a list as possible of parameters relevant to the assessment.

A table was devised for the capelin spawning / larval retention area following consultation of reference works (for example, Nakashima and Taggart 2002, Nakashima and Wheeler 2002, Moss et al. 2006), the Capelin Observers Network (CON), and experts[11]. This table presents examples of indicators that would make it possible to form a judgment of the state of the environment based on the impacts associated with each of the six stressors identified by the PoE models. This table is presented in the tab “List of indicators” in the draft tool presented in Appendix 5.

[11] François Hazel and François Grégoire, DFO, Québec Region.

A4.1.2 Step 2 – Definition of environmental state levels

After listing several indicators that allow the assessment of the environmental state, it may be necessary to carry out a selection among them. This step eliminates indicators that are less relevant, too costly, unrealistic, or absent. For example, the list established for the capelin spawning / larval retention area presents a total of 47 potential indicators allowing the assessment of the state of the ecological unit with respect to the stressors that can cause alteration to the coastal area. The number of indicators must be reduced before performing the assessment, mainly because of the costs and the complexity of data collection they would involve.

For this reason, the second step of the measured conditions analysis aims to select the indicators that will supply the most complete and relevant scientific information for each of the identified stressors and impacts. This step must be performed by users based on the characteristics of the ecological unit that they are working on.

Four indicator levels were developed, as an example, for Gallix beach. This example is located in the "Shoreline modification" tab of the draft tool (Appendix 5). The indicators "Development of the riparian area," "Dominant particle size," "Annual coastal retreat rate," and "Proportion of fine substrate ($\leq$ 0.125 mm) in the incubation substrate" were arbitrarily selected (Figure A4.1). Environmental state levels were developed for each indicator following a review of the literature. These levels (five should be assigned if possible, but this can vary depending on the information available, see Figure A4.1 c, d) make it possible to form a judgment of the state of the environment in the ecological unit by ranking conditions from "excellent" to "very poor." The exercise makes it possible to visualize the work required to continue developing the analysis tool.

Stressor	
	Shoreline modification

a)

Reduction in size of the intertidal zone		
Environmental state	Development of the riparian area	Place an X
Very poor conditions	More than 50% of the riparian area is developed	
Poor conditions	Between 26 and 50% of the riparian area is developed	
Good conditions	Between 11 and 25% of the riparian area is developed	
Very good conditions	Between 6 and 10% of the riparian area is developed	
Excellent conditions	Less than 5% of the riparian area is developed	

b)

Erosion or sediment accumulation		
Environmental state	Annual coastal retreat rate	Place an X
Very poor conditions	More than 4.7 m per year	
Poor conditions	Between 2 and 4.7 m per year	
Good conditions	Between 1 and 2 m per year	
Very good conditions	Between 0.2 and 1 m per year	
Excellent conditions	Less than 0.2 m per year	

c)

Loss of substrate quality		
Environmental state	Dominant particle size	Place an X
Very poor conditions	Very fine sand and silt (smaller than 2 mm) or particles larger than 25 mm	
Poor conditions		
Good conditions	Medium grain size sand (between 2 and 5 mm) or medium grain size gravel (between 20 and 25 mm)	
Very good conditions		
Excellent conditions	Very coarse-textured sand and fine-textured gravel (between 5 and 20 mm)	

d)

Silting		
Environmental state	Proportion of fine substrate (≤ 0.125 mm) in the incubation substrate	Place an X
Very poor conditions	More than 0.40% of fine substrate (≤ 0.125 mm)	
Poor conditions		
Good conditions	Between 0.20% and 0.40% of fine substrate (≤ 0.125 mm)	
Very good conditions		
Excellent conditions	Less than 0.20% of fine substrate (≤ 0.125 mm)	

Figure A4.1. Example of levels of environmental state indicators measuring impacts caused by the shoreline modification for Gallix beach. Levels developed for a) the indicator "Development of the riparian area" measuring the impact "Reduction in size of the intertidal zone," b) the indicator "Annual coastal retreat rate" measuring the impact "Erosion or sediment accumulation," c) the indicator "Dominant particle size" measuring the impact "Loss of substrate quality," and d) the indicator "Proportion of fine substrate (≤ 0.125 mm) in the incubation substrate" measuring the impact "Silting."

A4.1.3 Step 3 – Results of the analysis

The analysis of measured conditions made using the proposed tool aims to obtain a numerical value corresponding to the state of the environment. This value, ranging from 1 to 5, would be calculated for each of the stressors considered and will be used in the comparative analysis of conditions stage (Section A4.3).

A4.2 Analysis of desired conditions

A4.2.1 Objectives and challenges of the desired conditions analysis

While the principal objective of the analysis of predicted conditions is to determine the level of risk for human activities in the chosen ecological unit, the analysis of desired conditions is used to assign an economic value to these activities. This complementary information is important insofar as it should facilitate decision making when combined with the results of the predicted and measured conditions analyses. Even if a human activity represents a significant risk for an ecological unit, the decision makers could be reluctant to reduce or eliminate this activity if they are uncertain about its economic importance.

The challenge of this type of analysis is to assign an economic value to activities that often do not generate any monetary transactions. This is the case for several recreational activities. Yet these activities truly do have economic value because users are prepared to spend part of their leisure time on them and, in all likelihood, they would be willing to pay an amount of money if asked. Conversely, some human activities generate substantial revenues, but also negative externalities that are not considered. This would be the case for a polluting or noisy industry. In some cases, non-monetary economic values or negative externalities can have an effect on the value of property located nearby. Moreover, how can activities that create many jobs as opposed to those that create very few or none be assessed? What can be said about activities that have strategic importance that is not necessarily reflected in the only monetary revenues generated (e.g., maritime transport)?

A4.2.2 Example of the Lockie and Jennings survey on waterways in Central Queensland

These factors make it difficult, through simple calculations, to determine the economic value of human activities. In order to meet the challenge, some have instead opted for large-scale surveys among the population affected. This is the case for Lockie and Jennings who, in 2003, conducted a 20-minute telephone survey with 818 residents of Queensland (Australia). Using this questionnaire, the authors had to assign a value on scale of 1 to 10 to the activities having an impact on the waterways of the region. The results are presented in the Table A4.1.

Table A4.1. Values assigned to activities having an impact on waterways in Queensland.

Human activities	Value	Standard deviation
Town water supply	8.96	2.23
Agriculture	7.64	2.73
Tourism	7.54	2.43
Industrial water supply	7.51	2.83
Land-based recreational activities	7.18	2.41
Cultural and festival activities	7.17	2.40
Recreational activities on the water	6.64	2.87
Wastewater disposal	6.55	3.62
Commercial fishing	5.86	3.12
Sand and gravel extraction	5.73	3.32
Other commercial/industrial uses	5.71	3.34
Residential development	5.26	2.93
Passenger transportation	5.25	3.03

A4.2.3 Application of an analysis of desired conditions to the case of Gallix beach

If a survey of this type were conducted with the population living near Gallix beach, precautions should be taken so that the instructions and information provided to respondents are adequate to ensure meaningful results. For example, each individual surveyed could be given fact sheets about each of the human activities to be assessed. These fact sheets would present data on the number of jobs, revenues, taxes paid, strategic or cultural significance, the number of enthusiasts (when this involves a cultural activity) and, where applicable, relevant qualitative information. Instructions on how to take this information into account should also be provided to those surveyed. Lastly, the survey should also collect information on the respondents (e.g., sex, age, education, income) in order to better analyze the results.

Table A4.2 presents a possible summary table of results of a survey of the population on the economic value of human activities having an impact on Gallix beach.

Table A4.2. Values assigned to human activities having an impact on Gallix beach.

Human activities	Value (1 to 5)	Standard deviation
Hydroelectric power generation and water management		
Municipal activities		
Recreation and tourism activities		
Heavy industries		
Maritime transport		
Road transport		
Fisheries		
Forestry		
Agriculture		

The assessment of the economic value of human activities could also be assigned to experts. To assess the elements that are more difficult to quantify, experts could use surveys and other techniques or methodologies.

Combined with the results of the analysis of predicted conditions, the results of the desired conditions analysis might allow decision makers to prioritize the reduction or elimination of human activities having a significant negative impact on (or presenting a risk for) the ecological unit and a low economic value. Conversely, activities involving a low risk for the ecological unit, but of high economic value should not logically be priority targets.

A4.3 Comparative analysis of conditions

The comparative analysis step concludes the risk assessment procedure proposed in phase II of the project. This important step makes it possible to compare the values obtained during the three previous analysis types, i.e., the predicted (Type 1), measured (Type 2), and desired (Type 3) conditions analyses. The model presented in the Table A4.3 could, in part, be used for this purpose. In this example of a summary table of results, the stressors are identified. The numerical value entered in the "Risk" column corresponds to that obtained from the predicted conditions analysis. The value produced by the measured conditions analysis is entered in the "Condition" column. Once this part of the table is completed, the stressors having the highest values for risk and environmental conditions can be identified, and consequently the critical stressors can be highlighted. The values obtained from the analysis of desired conditions (socioeconomic and cultural values) thus established according to the priority issues highlighted through the analyses of Types 1 and 2 would be entered in the "Significance of values as rated by the community." The resulting comparative table would be a synthesis and decision support tool that is effective, easily interpreted, and used to begin the risk management stage.

Table A4.3. Example of reporting the results of a risk assessment for a specific system (Moss et al. 2006).

Stressor	Risk	Condition	Values assigned	Significance of values as rated by community
Acid runoff	5	4	Ecosystem	5
Nutrients	2	1	Ecosystem	5
Habitat loss	4	4	Ecosystem	5
Pathogens	5	5	Recreation	2

Appendix 5. Tools.

The CD contains three Excel spreadsheets and one Word document:

1) The "predicted-conditions-analysis_original.xls" spreadsheet contains a blank copy of the tool.

2) The "drafting-portrait_template.doc" document contains a comprehensive guide to draft the portrait of an ecological unit.

3) The "predicted-conditions-analysis_gallix.xls" spreadsheet contains a copy with the results for the Gallix exercise.

4) The "measured-conditions-analysis_original.xls" spreadsheet contains a blank copy of the tool.