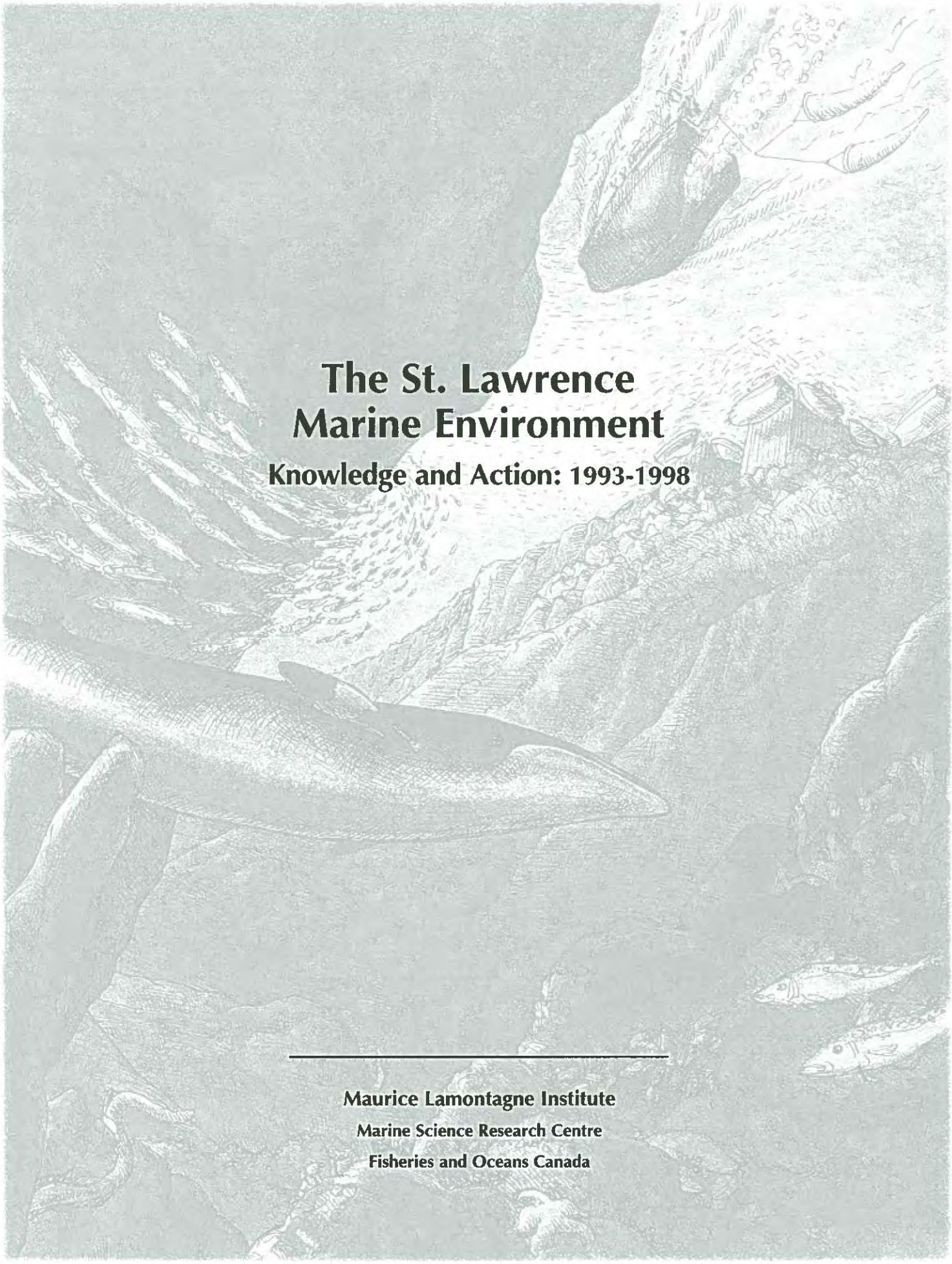

The St. Lawrence Marine Environment

Knowledge and Action: 1993-1998

Maurice Lamontagne Institute
Marine Science Research Centre
Fisheries and Oceans Canada

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The studies and activities described in this document were made possible through the participation of many partners and collaborators of the Maurice Lamontagne Institute. These participants come from several sectors within the Department of Fisheries and Oceans, Laurentian Region, other federal and provincial departments, Canadian and foreign universities, research institutes, non-governmental organizations, local associations, regional county municipalities, various groups, and numerous individuals. We thank them all for their contributions.

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FOREWORD

The rich diversity and beauty of the enclosed sea formed by the Estuary and Gulf of St. Lawrence have always fascinated the people living along its shores. For many years now, scientists have been striving to uncover the secrets of this marine environment; however, despite the many research studies conducted in the St. Lawrence marine environment during the 20th century, a great deal still remains to be learned. Just ten years ago, the scientific information available on the marine part of the St. Lawrence was still very sketchy. Since then, the work done by scientists and managers of the marine environment, combined with the traditional knowledge accumulated by users of the St. Lawrence, has gradually increased our understanding of the complexity of this ecosystem. By pooling all knowledge concerning the Estuary and Gulf of St. Lawrence, we will be able to protect the ecosystem more effectively, thus ensuring the preservation of its diverse resources for the benefit of future generations.

The *St. Lawrence Marine Environment–Knowledge and Action: 1993-1998* presents the results of activities conducted during a period when the Maurice Lamontagne Institute (MLI) of the Department of Fisheries and Oceans (DFO) participated in several special programs on the marine environment, over and above its regular scientific programs. The *St. Lawrence Vision 2000 Action Plan*, which is dedicated to reclaiming the St. Lawrence for all citizens through the conservation and protection of its ecosystem, has permitted the acquisition of considerable knowledge on little known aspects of the St. Lawrence marine environment. In parallel with the research projects implemented under the *St. Lawrence Action Plan*, coastal communities have undertaken many conservation, restoration and enhancement initiatives focussing on specific habitats, with the support of Fisheries and Oceans Canada. In addition, DFO's *Toxic Chemicals Program*, aimed at increasing our understanding of the distribution and biological effects of contaminants, has provided a clearer picture of the health of the St. Lawrence. Readers should be aware that this document does not cover MLI's research activities related to marine fish and invertebrate stocks or the assessment of their biomass. Information on those activities is provided in various other publications that can be obtained from MLI.

Many of the findings from MLI programs on the marine environment have also been published in the scientific literature; however, they are not very accessible to the lay reader. By compiling and presenting pertinent information in this popular science document, it was our aim to facilitate and broaden the dissemination of knowledge about the St. Lawrence marine environment. This publication is intended for the general public, for environment managers, and for all persons interested in various aspects of the marine environment. It gives an overview of DFO's participation in the key achievements of environmental programs related to the St. Lawrence marine environment between 1993 and 1998. Readers will also find information on the future directions established for DFO programs, particularly under the *Oceans Act*, and the Department's participation in Phase III of the *St. Lawrence Vision 2000 Action Plan*.

We hope you enjoy the reading!

Jean Boulva
Regional Director
Science

Jean Piuze
Regional Director
Oceans

Maurice Lamontagne Institute (MLI) is one of the ten research centres operated by Fisheries and Oceans Canada. This facility, which opened in 1987, is located in Mont-Joli, Quebec. Its programs and activities encompass many spheres of scientific research: fisheries research, oceanography, studies of the marine environment, hydrography, along with fish habitat and coastal zone management.

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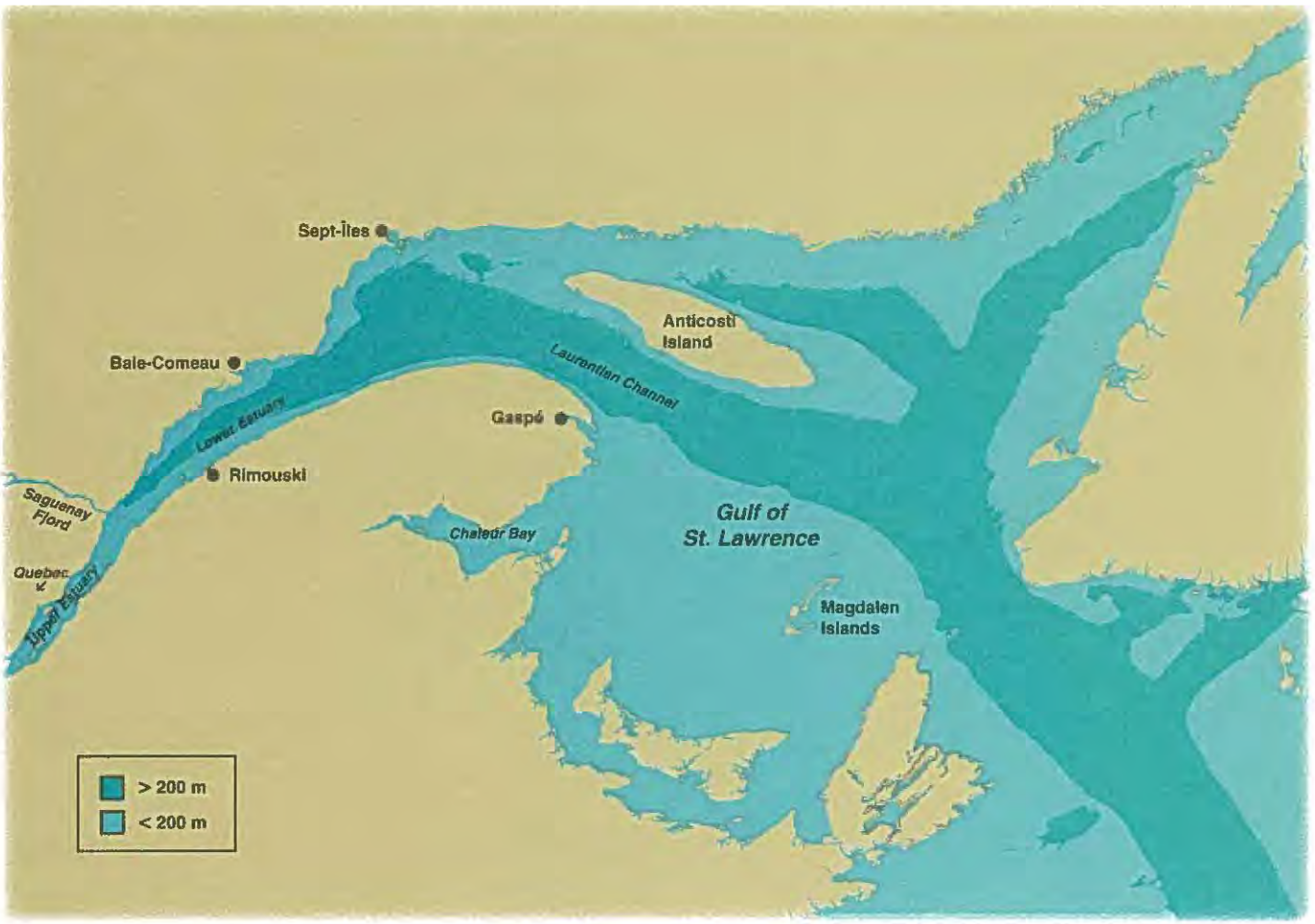
* The technical and scientific terms are defined at the end of each chapter.

INTRODUCTION

Between 1993 and 1998, in addition to carrying out its regular programs, the Maurice Lamontagne Institute (MLI) of the Department of Fisheries and Oceans (DFO), Laurentian Region, participated in various special programs, including the *St. Lawrence Vision 2000 Action Plan* (SLV 2000), the DFO's *Toxic Chemicals Program* and the *Program of Energy Research and Development.* The work done by MLI scientists has expanded the existing knowledge and understanding of the marine environment of the St. Lawrence. The Institute has also been involved in many environment-related activities through its active partnership in SLV 2000 or collaboration in community initiatives. All of these environmental programs have generated a large quantity of scientific information which DFO wishes to make more accessible to environment managers and the public at large.

This publication provides an overview of DFO's contributions, between 1993 and 1998, to species and habitat conservation and protection, initiatives undertaken by community stakeholders and efforts to increase knowledge of the St. Lawrence marine environment. The document also presents the results of ongoing research programs and management activities related to the marine ecosystem and highlights the importance of pursuing the development of environmental tools and technologies. Finally, the future directions established for environmental programs are described, including the initiatives arising from the *Oceans Act*, DFO's *Toxic Chemicals Program* and Phase III of the *St. Lawrence Action Plan.* This wide-ranging information is set out in six chapters entitled Coastal Habitats, Community Involvement, Marine Environment, Marine Mammals, Contaminants and Management of Marine Ecosystems.



Upper Estuary, Lower Estuary and the Gulf of St. Lawrence.

coastal habitats

highlights

Characterization studies and activities carried out in the St. Lawrence marine environment

The Gaspé Peninsula's ecologically rich habitats

Will the Havre aux Basques lagoon become a freshwater environment?

New discoveries about North Shore habitats

Rehabilitation plan for the New Carlisle barachois

Restoration of the Bonaventure barachois

Creation of an eelgrass bed at Baie-Comeau

Seeking an ecological solution: the case of Rivière-du-Loup Bay

WHAT ARE COASTAL HABITATS?

Shorelines, rocky and sandy bottoms, seagrass beds and the waters that wash over these environments represent coastal habitats. Such a mosaic of habitats supports a wealth of marine plant and animal life. These habitats are often subject to considerable pressure from human activity, which explains why many have become severely degraded. More and more people are concerned about conserving, restoring and enhancing coastal habitats. Knowledge is the key to achieving this goal. Scientific research provides the tools needed to document the characteristics and the ecological importance of habitats. As well, techniques have been developed to restore degraded habitats and develop new ones.

From 1993 to 1998, characterization studies were conducted on a large number of coastal habitats (see Figure 1-1 and Table 1-1). Generally, such studies may involve acquiring information on various aspects such as changes in the coastal environment (analysis of aerial photos); the hydrodynamic conditions (currents, tides); the sedimentary regime; the physio-chemistry of the water (temperature, salinity, dissolved oxygen, nutrients); the contamination of sediments and organisms; the shoreline and aquatic vegetation; the fish; the plant and animal plankton; and the history of uses and human pressures. It is a little bit like a doctor giving a patient a checkup by putting him through a series of tests. Just as a doctor makes a diagnosis and proposes the appropriate course of treatment, biologists use the results of studies to evaluate the state of health of a habitat and propose solutions. Studies can also focus on specific questions that cover less ground but look at certain aspects in depth. The subjects and areas studied vary according to the interests of researchers, but also according to the concerns of local organizations which have proposed projects to Fisheries and Oceans Canada. To illustrate the wide range of knowledge acquired, some examples of completed projects are described below.

FIGURE 1-1 *The various locations where characterization studies where conducted and action was taken.*

SITE	KNOWLEDGE ACQUIRED ON											FINDINGS	ACTION[1]
	Physical Environment				Biological Environment								
	Geomorphology	Hydrodynamics	Physical chemistry	Sediments	Vegetation	Plankton	Benthos	Fish	Marine mammals	Birds	Uses of the habitat	Environmental Stress	
GASPÉ PENINSULA AND THE MAGDALEN ISLANDS													
Havre aux Basques Lagoon	x	x	x	x	x	x	x	x		√	x	x	Re-opening the lagoon would be costly	RP
L'Île-du-Havre-Aubert														
Le bassin (bays)														CL
Harbour														CL
Ruisseau de la Grande Rivière	x	x						x			x	x	Obstacles to the smelt run	CL + developments
New Richmond Barachois	x	x	x	x	x	x	x	x		√	x	x	Needs protection	PEP
Bonaventure Barachois	x	x	x	x	x	x	x	x			x	x	North western basin is partially closed	R+Environ. monitoring
Grand Pabos Barachois		x	x	x	x	x	x	x			x	x	Bacterial contamination of softshell clams	C of wastewater + CL
Malbaie Barachois	x	x	x	x	x	x	x	x			x	x	Rich and diverse habitats	PEP + STE
Paspébiac Barachois	x	x	x	x	x		x	x		√	x	x	Western basin is partially closed	PEP + R
New Carlisle Barachois	x	x	x	x	x		x	x		√	x	x	Western basin is partially closed, contamination	RP
Carleton Barachois	x		x		x	x		x					Little used for herring spawning	
Baie des Capucins	x	x	x	x	x	x	x	x		√	x	x	Unique salt marsh in this sector	PEP
Baie de Gaspé	√	√	√	√	√	√	√	√	√	√	x	x	Important habitats to protect	PEP
Pointe Verte	x	x	x	x	x	x	x	x		x	x	x	Rich and diverse habitats	PEP
Baie de Cascapédia	√	√	x	x	x	√	x	x		√	x	x	Potential for increased diversity	AR + MP
NORTH SHORE AND ANTICOSTI														
Pointe-aux-Outardes	x	x	x	x	x	x	x	x		√		x	Rich and diverse habitats, erosion	PEP + erosion C
Baie des Sept Îles			x		x			x			x	x	Eelgrass bed, herring and smelt spawning grounds	PEP
Banc de Portneuf	x		x		x	x	x	x		x	x	x	Pressures: ATVs, wastewater, dumptsites	PEP
Baie Laval	x		x		x	x	x	x		x	x	x	Rich and diverse habitats	PEP
Baie Comeau	x	x	x	x	x			√		√	x	x	Disturbance of fish habitat	EG
Manicouagan Estuary	x	x	√	x	x	√	√	√	x	x	x	x	Great habitat and species diversity	PEP
ZIP 18 tributaries		x	x	x				x			x	x	2 smelt spawning grounds inventoried	PEP
Les Escoumins to Betsiamites	√	√	√	√	√	√	√	√	√	√	x	x	Integrated management potential	MP
Baie Ellis (Anticosti)	x		x	x	x		x	x			x	x	Healthy habitat	PEP
SAGUENAY AND THE LOWER ST. LAWRENCE REGION														
Saguenay								x			x		Spawning grounds, fishing pressure	PEP
Île aux Lièvres Channel								x	x	x			High diversity of fauna	Recommended for PEP
L'Isle-Verte			x		x			x					Potential herring spawning ground	Incubation trials
Rivière-du-Loup	x	x		x	x						x		Marsh eroding	Sediment confinement
Spartina marsh (guide)	√	√			√			√		√	√	√	Development potential	Future restoration?

√: Literature Information
x: Field Work Information
ATV: All Terrain Vehicle
ZIP 18: Lower Estuary Priority Intervention Zone

[1] Legend

AR: Artificial Reefs
C: Control
CL: Bank Clean-up
EG: Eelgrass Planting
MP: Management Plan
PEP: Protection and Enhancement Plan
R: Restoration
RP: Restoration Plan
STE: Private or Public Stewardship

TABLE 1-1 *Summary of characterization studies conducted and actions taken in the St. Lawrence marine environment from 1993 to 1998.*

THE GASPÉ PENINSULA: ECOLOGICALLY RICH HABITATS

Chaleur Bay, on the southern shore of the Gaspé Peninsula, is unusual in that it is dotted with barachois (coastal ponds partly cut off from the sea by long sandbars and connected to it by a breach, varying in width, called a pass or inlet). Barachois favour the development of salt marshes and beds of eelgrass (a saltwater plant) and are unique, ecologically rich and in constant evolution. With such characteristics, it is not surprising that these environments have been much studied. The findings have confirmed that many species of fish and other forms of marine life use the barachois to feed, reproduce, live and grow. Some of these habitats support large mollusc beds. They are also much frequented by waterfowl, wading birds and shorebirds. Since these sheltered waters provide natural harbours suitable for fishing boats and sites for development projects, they have also attracted people. Over time, the barachois have been altered, with more or less harmful effects, the most common alterations being diking, domestic and industrial wastewater discharges, domestic garbage dumping, and filling. These days, the barachois are increasingly recognized for their ecological value and many local groups are active in preserving, restoring and enhancing them. Examples of projects are given in this chapter.

HAVRE AUX BASQUES: A LAGOON... A ROAD

In 1956, construction of Highway 199 in the Magdalen Islands blocked the exchange of water between the sea and the eastern end of Havre aux Basques Lagoon. As soon as the road was built, it was recognized that cutting off the lagoon was perhaps a mistake. The characterization studies conducted on Havre aux Basques Lagoon are some of the most extensive done since the late 1980s. They have shown the impact of the diminished water exchange between the lagoon and the sea on fish habitat characteristics. The most striking effects are greater differences in water temperature, reduced salinity, higher water level and the lack of a tide. Havre aux Basques Lagoon is therefore less and less like a saltwater environment. The spartina (a salt-loving plant) marshes may in time recede and be replaced by freshwater or terrestrial plants. As well, since the water temperature in the lagoon can now reach 23-25 °C in summer, it no longer offers optimal conditions for the growth of eelgrass.

In the long term, given the potential threat to key habitats for marine aquatic organisms, the conversion of this lagoon into fresh or brackish water is not seen as desirable. However, the high cost of the required restoration work is the main impediment to re-opening the lagoon to the sea.

Photo: K. Walsh-Moleski

Mouth of the Rivière des Rapides in Baie des Sept Îles.

NEW DISCOVERIES ABOUT NORTH SHORE HABITATS

Several North Shore bays, sheltered from the wind and waves, can be excellent habitats. For example, Baie des Sept Îles, heavily used by fish, was found to contain a 4 km^2 eelgrass bed. Significantly, eelgrass beds are some of the most valuable marine habitats for fish, offering shelter, food and sometimes spawning grounds. As well, four smelt spawning sites located in four different tributaries that drain into the bay were characterized. Even though Baie des Sept Îles has been considerably altered by surrounding industrial and harbour development, the characterization studies revealed the quality and diversity of its habitats.

Farther west, in Baie Laval, near Forestville, a surprising diversity of habitats was inventoried, notably marshes, an eelgrass bed, a kelp bed, a salmon river, and a heronry. The largest softshell clam bed on the North Shore and a notable abundance of the anadromous brook trout, commonly called sea trout, are also found in this area. This habitat diversity illustrates the ecological richness of Baie Laval.

KNOWLEDGE GUIDES ACTION

In short, characterization studies have sometimes brought the richness of certain habitats to light, and have sometimes pinpointed situations calling for further action. Better knowledge leads to a better understanding of the ecological and economic value of coastal habitats, prompting governments and local stakeholders to take on their protection or restoration. Increasingly, habitat enhancement plans take into account the need for habitat and natural landscape protection, while allowing local communities to develop the recreation and tourism potential of sites.

Where habitats have been subject to significant disturbance but still offer good potential for marine species, restoration should be considered. The first step is to eliminate pollutant sources that can place stress on these habitats. Then, if further measures are needed, technical and socio-economic feasibility studies are done to determine the type of rehabilitation work required, as well as the costs involved. The actual work conducted to restore a habitat is the step that requires community support, the intervention of various experts, and often the search for financial partners. Below are presented four examples of restoration or experimentation projects.

A REHABILITATION PLAN FOR THE NEW CARLISLE BARACHOIS

Various features make a barachois a good habitat for marine species. One very important factor is the quality of the exchange of water with the sea. It was this quality that was affected by human activity in the New Carlisle barachois and which reduced its carrying capacity for marine organisms. To remedy the situation, a proposal has been made to remove the embankment that separates the barachois in two and inhibits tidal flushing.

During the characterization work, for this barachois, sediment analyses showed significant organic (petroleum hydrocarbons, PCBs) and inorganic (copper, mercury, arsenic, lead) contamination at certain sites.

Photo: M.-F. Dalcourt

Sampling sediments in the New Carlisle barachois.

Since removing the embankment could modify the hydrodynamic conditions of the environment, the contaminated sediments could potentially migrate toward the uncontaminated or less contaminated areas. To avoid this, the sediments should be treated or removed from the environment before any of the planned work to restore the barachois is done.

Pollution sources, notably municipal wastewater discharges, have been controlled. Contaminated sediments are confined to the western sector of the barachois and do not pose any imminent public health hazard. The extent of sediment contamination, both in terms of surface area and

depth, has been well documented and different scenarios for treatment have been examined.

Future action will depend upon various technical and economic constraints. For example, disposing of the sediments in a regulation landfill site could be a costly solution, due to pre-treatment, storage and transportation costs. A decontamination process has also been considered and preliminary tests have been performed; however, costs and method reliability must be evaluated more closely. DFO intends to continue to support local organizations, and there are plans to explore other avenues to restore the New Carlisle barachois in co-operation with private sector and government partners.

In short, the case of the New Carlisle barachois shows how complex environmental issues can be as well as how important it is to study all the facets of a situation before taking action.

BAIE-COMEAU: A PARK FOR PEOPLE AND FISH

Baie des Écorces, located in Baie Comeau in the Lower Estuary, was used to store bark by a pulp and paper mill for a long time. In 1995, the municipality of Baie-Comeau decided to convert this site into a waterside park and began site restoration work. Thanks to a financial contribution from DFO, the city was able to integrate fish habitat considerations into the development scheme. As an example, an experiment to plant eelgrass was carried out in a section of the bay. This was a particularly interesting initiative as only a few such attempts have been made in Quebec. The plants were taken from a natural eelgrass bed without detriment to it. The outcome seems to be very positive. The eelgrass plants transplanted in June 1997 have practically all survived and grown well. Given the ecological importance of eelgrass, it is hoped that this new habitat will attract many species of fish and marine organisms.

BONAVENTURE: ALLOWING THE TIDE TO BRING SALT WATER BACK

The Bonaventure barachois, in the Gaspé Peninsula, has also been subject to human modification. This barachois is fed by the waters of both Rivière Bonaventure and Chaleur Bay. Following the construction of Highway 132 and a municipal road in the 1970s, salt water could no longer circulate freely in the northwestern section of the barachois. Reduced water salinity had led to a gradual decrease in marine species diversity in this sector. As well, the discharge of municipal wastewater from 1908 to 1994 caused a significant decline in water quality. In an attempt to remedy the situation, a restoration plan was drawn up.

Photo: S. Villeneuve

View of the culvert under Highway 132.

The first step, in 1995-1996, aimed to re-establish saltwater circulation: an 8 m wide culvert was installed under Highway 132 and the municipal road was relocated. The results of environmental monitoring in the fall of 1996 showed that the influx of fresh water, from an artificial canal linking the Rivière Bonaventure and the basin under restoration, was still too great compared to the saltwater influx. Additional work was undertaken in 1998 to close this canal and create a marine environment in the basin. Biological and physical monitoring will then be done to check whether these modifications have produced the expected results.

Photo: M.-F. Dalcourt

Eelgrass at the Bonaventure marina.

RIVIÈRE-DU-LOUP: WHEN THE SEA ENCROACHES UPON THE LAND

From Jean Lesage Highway (Highway 20) along Rivière-du-Loup Bay, cement arcs can be seen in the intertidal zone at low tide, while at high tide the water is nearly up to the road. At this rate, it may be only a question of time before the St. Lawrence floods the highway. The marsh is eroding! Various experts have seen this as an opportunity to attempt a sediment confinement experiment based on the principle of penning up suspended sediments inside cement structures. Sediment then builds up on the bottom, allowing the marsh to regenerate. The cement arcs are part of a small-scale pilot project. This project has shown that it is possible to induce sediment accumulation. However, significant problems remains. Building a structure to enclose and protect the entire zone would be very costly. Finding financial partners and initiating joint action involving the local population and governments, could be part of a solution.

Photo: ARGUS inc.

Sediment confinement structure, Rivière-du-Loup Bay.

GLOSSARY *

Anadromous: refers to fish that migrate from salt water to fresh water to spawn.

Carrying capacity: maximum natural capacity of a habitat to produce and support living organisms.

Enhancement plan: plan that sets out the actions needed to enhance a natural environment.

Photo: R. Tremblay

Aerial view of the Carleton barachois.

These actions can be at the habitat level (for example, the establishment of spawning grounds and artificial reefs, and revegetation) or at the recreation and tourism level (for example, the development of paths and lookouts).

Environmental monitoring: study of the physical, chemical and biological characteristics of a habitat following a restoration or enhancement project, to assess environmental benefits and whether project goals were reached.

Habitat: the environment in which an organism, species, population, or a group of species lives, and on which their survival depends, directly or indirectly.

Heronry: colony where herons nest.

Intertidal zone: section of the littoral zone between the highest and lowest tides.

Kelp: brown marine algae with long flat ribbon-like blades.

Management plan: planning tool which expresses stakeholder interests (environmental and socio-economic) and concerns, within a given area, in the form of actions needed to ensure the best possible combination of conservation measures, sustainable resource utilization and economic development.

Protection plan: plan that sets out the measures needed to protect a natural habitat (federal, provincial or municipal protected status, stewardship projects, or other appropriate measures).

Restoration plan: plan that sets out the actions needed to re-establish the natural characteristics (chemical, physical or biological) of a habitat which has been altered by human activity entailing a loss of productivity or biodiversity.

Seagrass bed: large underwater grassland or aquatic environment dominated by floating vegetation, algal vegetation or submerged vegetation.

Spartina: aquatic plant from the grass family which grows in salt marshes.

Spawning ground: place where the female fish releases its eggs and where the male fertilizes them.

Stewardship: voluntary commitment by owners of private or public property to manage their lands in such a way as to protect, develop and enhance natural environments and the species they support. This commitment usually takes the form of agreements between the landowner and a conservation organization.

** Terms are defined according to their use in the text.*

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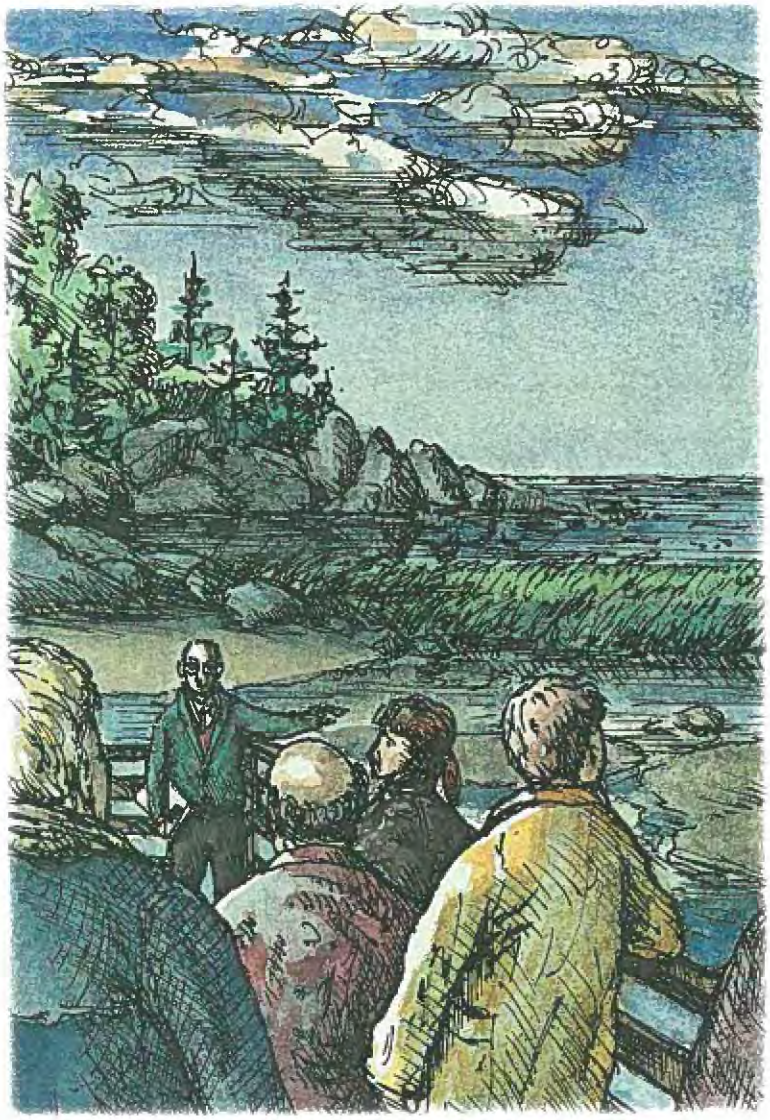
Photo: Fisheries and Oceans Canada

Caen Road, embankment of the New Carlisle barachois.

community involvement



highlights

Priority Intervention Zones (ZIP) program accepts the challenge of co-operative action

Clean-up projects undertaken by local communities

Integrated Coastal Zone Management: a pilot project on the Upper North Shore

A marine garden in Baie de Cascapédia

COMMUNITIES ARE BEING CONSULTED

Traditionally, coastal zone resources and activities have been managed mainly by the different levels of government, according to their specific mandates. Times have changed, however, bringing new ways of doing things. Among these is community involvement. Even though community groups have always existed, it is only recently that they have become the preferred partners of government in environmental matters. A major step in recognizing community action has been taken under the federal–provincial agreement, *St. Lawrence Vision 2000*. Under the joint action plan, government partners have supported the establishment of committees representing the various areas of prime concern (*Priority Intervention Zones*–ZIP) of the St. Lawrence, and set up a financial support program for community-driven projects. This program is designed chiefly to support action projects, but funding has also been provided where necessary for studies to define the action required.

ZIP COMMITTEES

The *Priority Intervention Zones* (ZIP) program was set up and implemented under the *St. Lawrence Vision 2000 Action Plan*. Under the aegis of *Stratégies Saint-Laurent Inc.*, a non-governmental organization devoted to the protection, rehabilitation and enhancement of the St. Lawrence, various ZIP committees have been established in the fluvial and marine sectors of the St. Lawrence (see Figure 2-1). These committees are made up of residents and representatives from industry, municipal sector and non-governmental organizations (NGOs), united by the common goal of rehabilitating the natural environment. The 23 ZIPs, divided into 13 study sectors, have been delimited on the basis of biogeographic regions, hydrological regime, biological resources, socio-economic characteristics and future restoration potential.

The ZIP program, which is founded on co-operative action among the federal and provincial governments and shoreline communities, comprises three main stages.

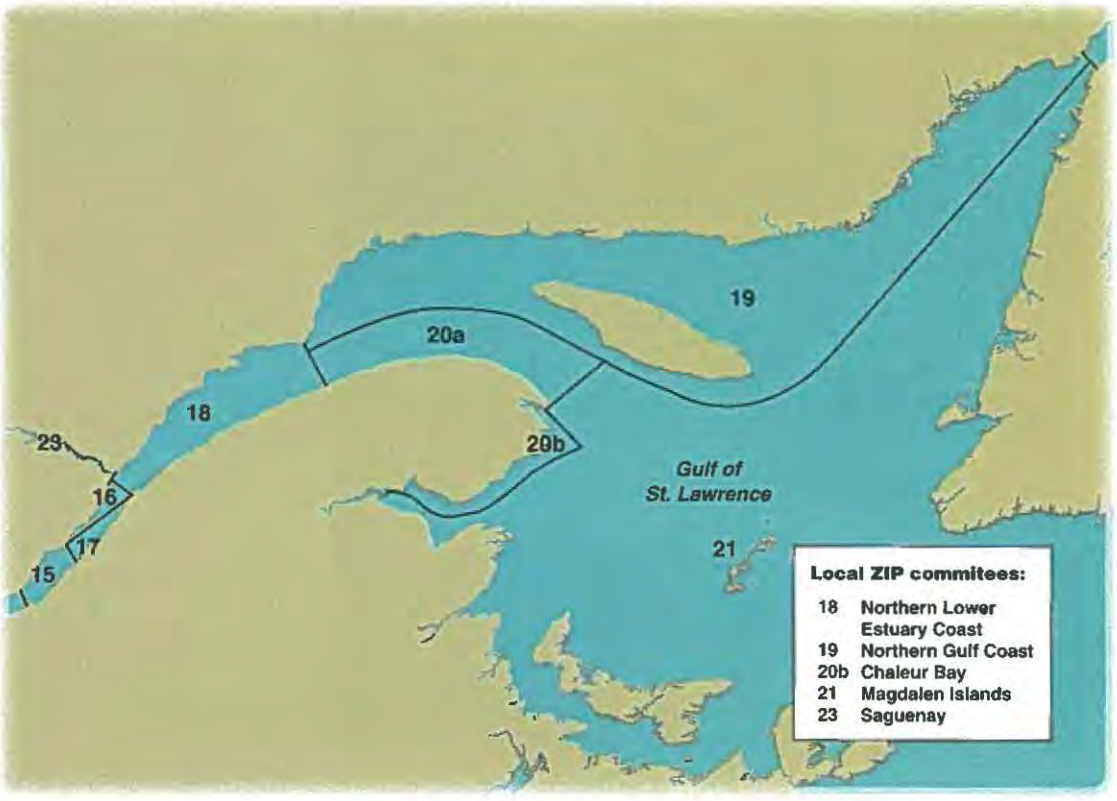


FIGURE 2-1 *Map showing the Priority Intervention Zones (ZIP) in the St. Lawrence marine environment and identifying the ZIP committees operating in 1998. The other ZIP committees should be formed during Phase III of the St. Lawrence Action Plan.*

Stage 1: Environmental assessments

First, an environmental assessment is prepared by the departments concerned for each study sector in the fluvial and marine sectors of the St. Lawrence. These assessments consist of a series of technical reports and a comprehensive regional assessment, and are distributed to shoreline stakeholders. ZIP reports are unique in that they bring together, in a single document, all the environmental information, both published and unpublished, on a local scale. Community stakeholders, in particular the ZIP committees, can use these documents to find out about the physical characteristics of their coastal aquatic environment, the contamination sources in their sectors, the extent of contamination of the water, sediment and living organisms, the habitats and plant and animal species found locally, the socio-economic profile, the uses of the environment and the human health risks associated with the different uses of the St. Lawrence.

Stage 2: Public consultation

Next, the ZIP committees organize a public consultation to enable citizens and local stakeholders to find out about the results of the environmental assessment and express their opinions. Four public consultations have been held so far in the St. Lawrence marine environment: in Chicoutimi (Alma–Jonquière ZIP and Saguenay ZIP jointly), in Baie-Comeau (Northern Lower Estuary Coast ZIP), in Carleton (Chaleur Bay ZIP) and in Sept-Îles (Northern Gulf Coast ZIP). During these consultations, residents are invited to participate in identifying the priorities for action to protect, restore and enhance their regions.

Stage 3: Ecological Rehabilitation Action Plan (ERAP)

Lastly, based on the discussions held during the public consultation process, the local ZIP committees group the stated priorities and draw up an Ecological Rehabilitation Action Plan (ERAP). The purpose of this multisectoral plan is to identify, in collaboration with the stakeholders concerned and regional authorities, the actions required to protect the sector's natural resources, consistent with sustainable use of the environment.

COMMUNITIES ARE LEARNING AND ACTING TO PRESERVE THE ENVIRONMENT

Several organizations have seized the opportunity offered by the *St. Lawrence Vision 2000* agreement to increase their knowledge of habitats they considered important or at risk, and to develop protection or enhancement plans. Figure 1-1 and Table 1-1 of the *Coastal Habitats* chapter show the many projects that have been carried out by community organizations. In addition to the direct benefits they produce, these initiatives catalyze action in local communities. It is apparent that when local populations become aware of the richness of their natural environment, they are more determined to conserve and develop these resources in an environmentally sound and sustainable way. The following examples attest to the vitality of shoreline communities.

Photo: Logiqest Services - conseils

Grand Pabos barachois clean-up project.

CLEAN-UP TIME!

Four clean-up projects have led to the rehabilitation of productive marine habitats and the beautification of areas frequented by the local population and tourists.

Photo: Logigest Services - conseils

Clean-up project at Chandler and Pabos Mills.

- In the Magdalen Islands, the *Aquarium des Îles* initiated a clean-up project in the natural harbour of L'Île-du-Havre-Aubert, a very busy resort area. Four tonnes of various types of waste were picked up.

- Under another project in the Magdalen Islands, this one directed by the *Centre nautique de l'Istorlet* and assisted by owners of adjacent land, the banks and intertidal zones of Baie du Bassin and Baie de Grande-Rivière on L'Île-du-Havre-Aubert were cleaned. In this case, more than six tonnes of waste were collected.

- On the North Shore, the *Corporation de protection de l'environnement de Sept-Îles* cleared four metric tons of waste from the marsh in Baie des Sept Îles and its tributaries, thereby improving the quality of spawning grounds for rainbow smelt and other fish species.

- Around the Gaspé Peninsula, 31 kilometres of shoreline bordering the municipalities of Chandler and Pabos Mills, including the shores and bottom of the Grand Pabos barachois were cleared of 311 cubic metres of household waste. Here, too, a local organization, the *Association pour la valorisation du barachois de Grand Pabos*, directed the undertaking and ensured its success.

Shoreline clean-up efforts require the involvement of more than just a few people. The entire community participates in one way or another, by lending equipment, by volunteering to collect, sort and transport waste, by co-ordinating work, or simply by allowing children to take part with their teachers. Dozens or even hundreds of people take part. Local communities set to work tirelessly, often discovering that there is a lot more waste than previously anticipated. The clean-up work thus gives the participants a sense of satisfaction, because they are helping to make the natural environment healthier.

COMMUNITY INVOLVEMENT IN INTEGRATED COASTAL ZONE MANAGEMENT

Integrated Coastal Zone Management refers to the management of all natural resources and activities that take place in coastal zones. The current practice is to involve local communities in various decision-making processes and to consider the various uses of a given coastal zone in preparing guidelines for specific activities. In other words, rather than managing activities one by one and consulting the interest groups concerned separately, integrated management encompasses a group of activities and users of a given area. This can result in an integrated management plan for a coastal zone.

Consulting all the stakeholders produces a wealth of ideas which can give rise to innovative projects, but can also create problems because of naturally diverging interests among individuals and user groups. The consultation process is worthwhile since management measures that are developed with the participation of the interested parties and adopted by consensus are more likely to be implemented. Such a management plan is more in keeping with local needs and concerns, and becomes a source of empowerment for shoreline communities. Given that this represents a new approach within the context of coastal zone management in Quebec, operating methods need to be developed that will suit all those concerned.

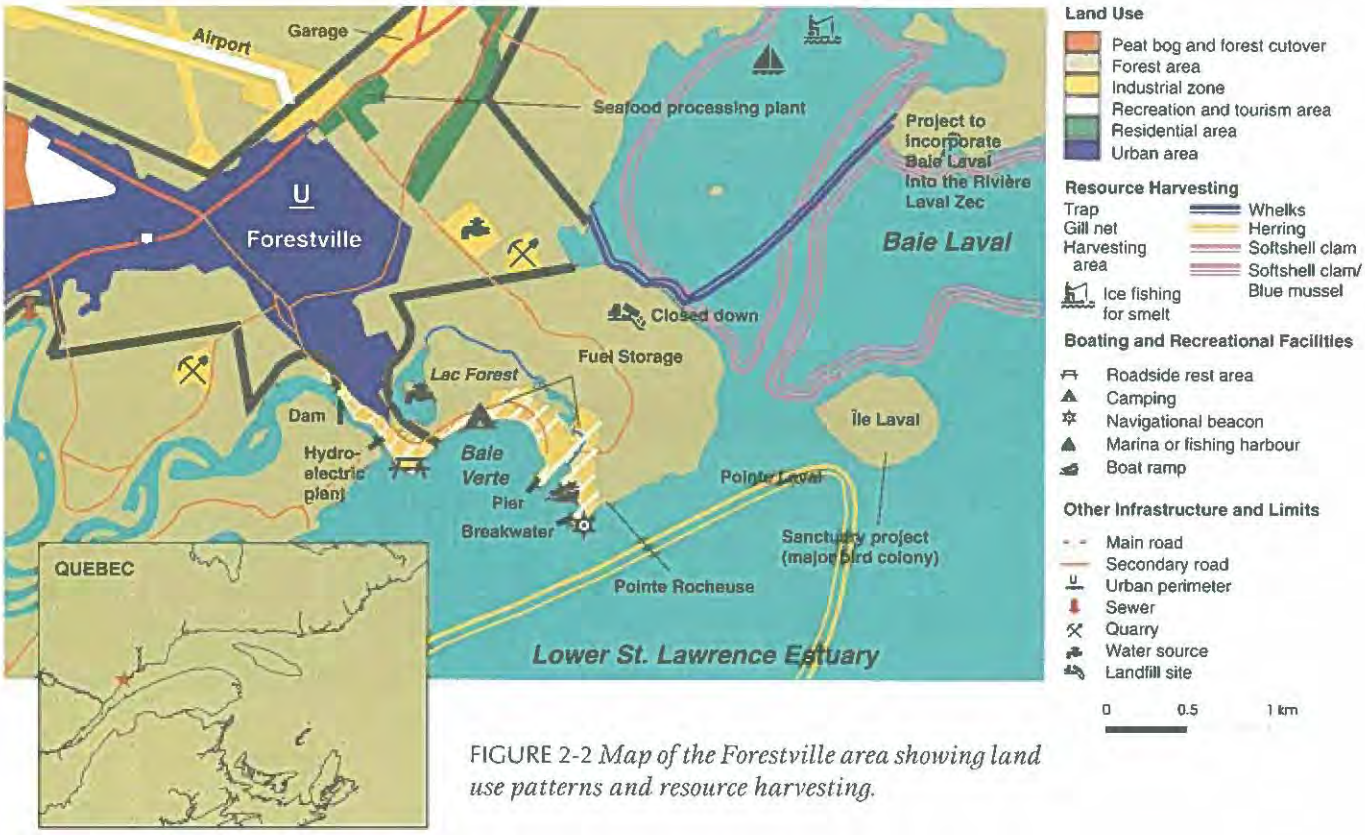


FIGURE 2-2 *Map of the Forestville area showing land use patterns and resource harvesting.*

PILOT PROJECT ON THE UPPER NORTH SHORE

A pilot project has been launched on the Upper North Shore, in the Lower St. Lawrence Estuary, to develop an integrated coastal zone management approach. This project, initiated by local organizations and Fisheries and Oceans Canada, encompasses the coastal zone between Les Escoumins and the Rivière Betsiamites (85 km).

The first stage began in 1996 with the mapping of coastal habitats and uses of the environment. This gave rise to a comprehensive and visual tool which can be made available to all those interested (see the example in Figure 2-2). In the second stage, which took place in 1997-1998, 18 stakeholders were brought together from various sectors of activity, including the municipalities, regional county municipalities (RCMs), the fishing industry, environmental protection and enhancement groups and the tourist industry. The group divided the territory into 14 coherent management units based on ecological, geographical, administrative and use characteristics. Next, these stakeholders determined the priority to be assigned to the units with reference to various characteristics such as use, ecological value, sensitivity and accessibility. In the third stage, the participants identified 34 activities that take place in the coastal zone and ranked them in order of importance. Finally, a similar method was used to analyse 55 concerns (identification, location in relation to the units and prioritization).

During 1998-1999, the multistakeholder group plans to establish a real management plan comprising concrete measures. Other government departments and levels of government will have to be brought into the process should any issues arise that exceed the jurisdiction of local and regional authorities and of DFO.

For DFO, the Upper North Shore pilot project could provide answers to broader questions related to the concept of Integrated Coastal Zone Management. For example, what is the ideal size of a management area? What are the most effective tools and mechanisms for co-operation? What are the limitations of this concept? Finally, the Upper North Shore initiative could serve as an example for other regions located in the St. Lawrence marine environment.

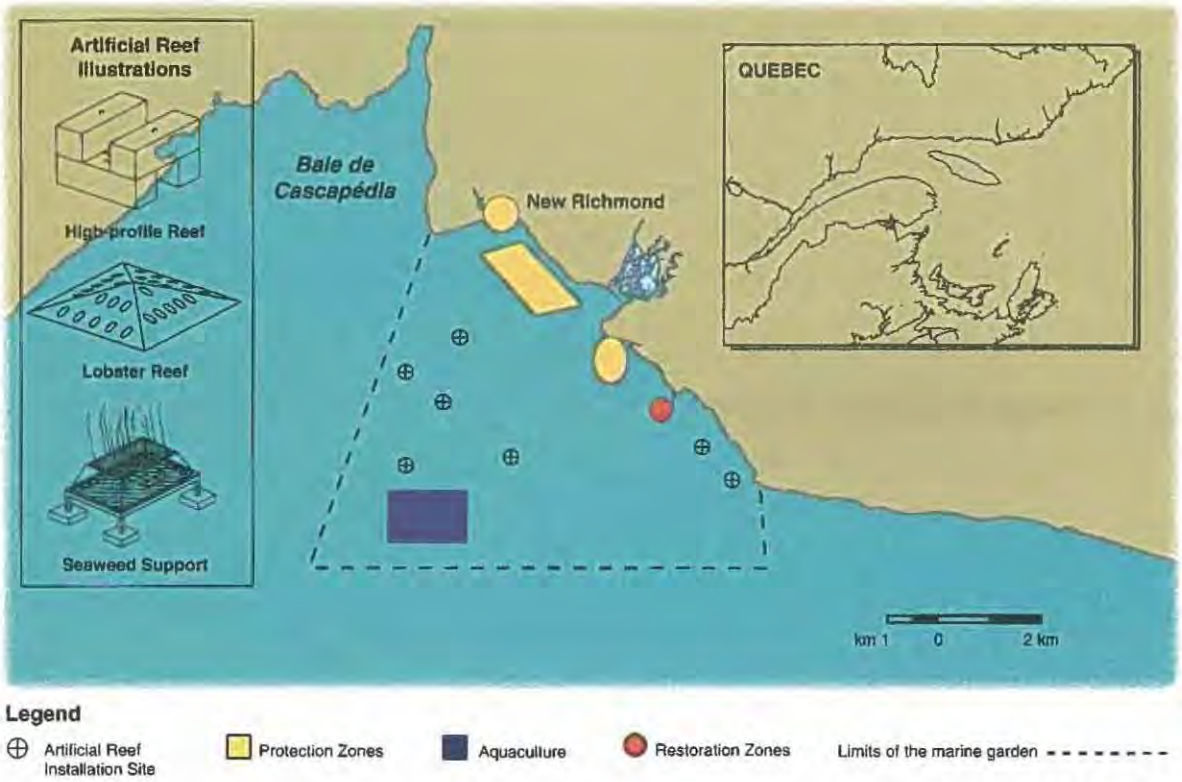


FIGURE 2-3 *Map of Baie de Cascapédia and illustrations of artificial reefs. The low-profile reefs (less than 1.5 m high) and seaweed supports favour colonization by benthic organisms and macrophytic algae. Some of the structures were designed especially for lobster. The high-profile reefs (more than 1.5 m high) offer suitable shelter and protection for a number of fish species. In all, 20 low-profile reefs, 17 high-profile reefs and 5 seaweed supports are located at seven sites within the bay, at depths varying between 5 and 22 metres.*

COASTAL ZONE ENHANCEMENT IN BAIE DE CASCAPÉDIA

A multipartite management committee, composed of representatives of all users of Baie de Cascapédia, has been formed in the Gaspé Peninsula to oversee a project called *Hortus: creation of a marine garden in Baie de Cascapédia*. This project is aimed at developing and providing for the enhancement of a 50 km^2 area in Baie de Cascapédia which has traditionally been used by the New Richmond community for numerous activities, such as commercial and sport fishing, boating activities and mussel farming. Since the turn of the century, however, the bay has been subject to considerable human disturbance. For example, it has received discharges of untreated effluents and industrial wastes from municipal wastewaters and from a pulp and paper mill. These discharges have had a negative impact on water quality, the abundance and diversity of marine fauna and flora, as well as use of the water body by residents. Since the late 1980s, efforts have been directed at treating municipal and industrial wastewaters as a means of controlling these pollution sources.

This step was not enough for New Richmond residents. They wanted to do even more for the environment, and so the *Hortus* project multipartite committee came into being in 1997. Its mandate is to develop a management plan detailing the actions to be implemented to conserve sensitive habitats, harmonize commercial and recreational activities, restore disturbed sites and enhance the area. Under the enhancement component, the priority is to install artificial reefs and seaweed support structures (see Figure 2-3), with the aim of diversifying available habitats and providing additional shelter for the marine resources found in the targeted sector of Baie de Cascapédia. Meanwhile, the committee is examining other priorities identified in the management plan and possible ways of implementing them. The management plan will be periodically reviewed to incorporate new knowledge and take stock of the measures required in order to achieve the community's objectives.

WORKSHOP ON COMMUNITY INVOLVEMENT HELD AT GASPÉ

A workshop on community involvement in coastal habitat management was held at Gaspé in March 1997. The goal was to bring together DFO representatives and NGOs that work in partnership with DFO to discuss issues related to coastal zone management. Twenty-two NGO representatives from the Gaspé, Magdalen Islands and North Shore regions participated in this workshop which consisted of presentations and round table discussions. Participants had the opportunity to familiarize themselves with various coastal zone management approaches, study various ways of implementing them and, finally, ensure more effective co-ordination of the activities of local stakeholders and DFO, in keeping with their respective objectives. Not only did the NGOs have the chance to exchange ideas and views with DFO representatives, they also found out about other projects—some of them similar to their own—taking place elsewhere in Quebec.

Photo: R. Patterson

Round table discussion at the community involvement

The following topics were covered at the workshop:

- The *Oceans Act*;
- Coastal Zone Management;
- The progress of the Integrated Coastal Zone Management pilot project on the Upper North Shore;
- Conservation of the Malbaie barachois;
- The *Hortus* project;
- Conservation of natural habitats on privately owned land;
- Stewardship, a tool for coastal habitat management;
- Private stewardship in the Magdalen Islands;
- Public stewardship.

Community involvement continues to be an important concern under Phase III of the *St. Lawrence Action Plan* and Canada's *Oceans Act*.

GLOSSARY*

Benthic organism: aquatic organism that lives in contact with bottom sediments.

Coastal zone: zone of interaction between the land and the marine environment. The land and sea boundaries of the coastal zone vary widely from one location to another. On land, it encompasses the sector containing the majority of shoreline uses that have a direct influence on coastal habitats and resources. Away from shore, the coastal zone should be limited to the area where the majority of uses occur, such as inshore fishing, coastal navigation and aquaculture.

Enhancement plan: plan that sets out the actions needed to enhance a natural environment. These actions can be at the habitat level (e.g. the establishment of spawning grounds and artificial reefs, and revegetation) or at the recreation and tourism level (e.g. the development of paths and lookouts).

Intertidal zone: section of the littoral zone between the highest and lowest tides.

Macrophytic algae: large algal species.

Management plan: planning tool which expresses stakeholder interests (environmental and socio-economic) and concerns, within a given area, in the form of actions needed to ensure the best possible combination of conservation measures, sustainable resource utilization and economic development.

Protection plan: plan that sets out the measures needed to protect a natural environment (federal, provincial or municipal protected status, stewardship projects, or other appropriate measures).

Stewardship: voluntary commitment by private or public property owners to manage their lands in such a way as to protect, develop and enhance natural environments and the species they support. This commitment usually takes the form of agreements between the landowner and a conservation organization.

** Terms are defined according to their use in the text.*

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marine environment

highlights

The St. Lawrence "weather prediction system"

The new Atlas of Tidal Currents

Tonnes of carbon trapped in the deep ocean

Abnormally cold water temperatures in the Gulf of St. Lawrence

Effects of ultraviolet radiation on marine organisms

Inshore fish species of the St. Lawrence Estuary

THE ST. LAWRENCE "WEATHER PREDICTION SYSTEM"

Physical oceanographers and hydrographers work together to develop hydrodynamic models of the Estuary and Gulf of St. Lawrence. Just as various models are used in forecasting weather, hydrodynamic models are used in predicting changes in the physical state of the St. Lawrence. These models generate a number of products and services of benefit to various users of the St. Lawrence.

- Water level forecasts for the St. Lawrence, covering time periods ranging from 48 hours to 30 days, provide information used by mariners and can forewarn shoreline dwellers in the event of flooding.

- Forty-eight hour predictions of ice conditions and movement in the Gulf of St. Lawrence are prepared daily and distributed to the persons in charge of icebreaking services.

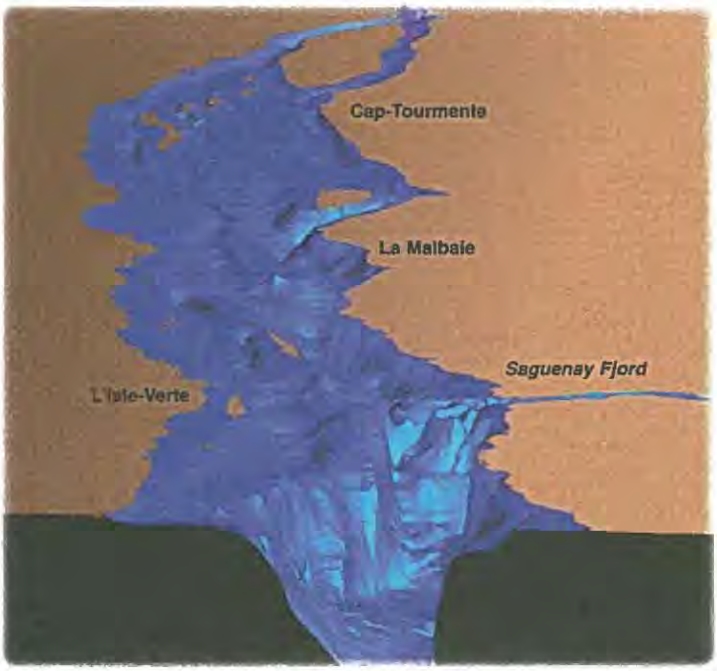

Illustration: MLI's modelisation laboratory

Three-dimensional map of the seabed showing the area from the head of the Laurentian Channel, near the mouth of the Saguenay, to Île d'Orléans.

- Forty-eight hour forecasts of surface currents are produced daily for the entire St. Lawrence. When a ship sinks, these predictions can be used to calculate the probable trajectory of survivors and can assist in deploying search and rescue teams. Surface current forecasts can also be employed in environmental emergency response operations to predict the movement of an oil slick and plan clean-up efforts (see Figure 3-1).

- Surface current predictions were also used in preparing the new *Atlas of Tidal Currents*, which covers the sector from Cap de Bon-Désir to Trois-Rivières, and is a valuable tool for all vessels that navigate the St. Lawrence.

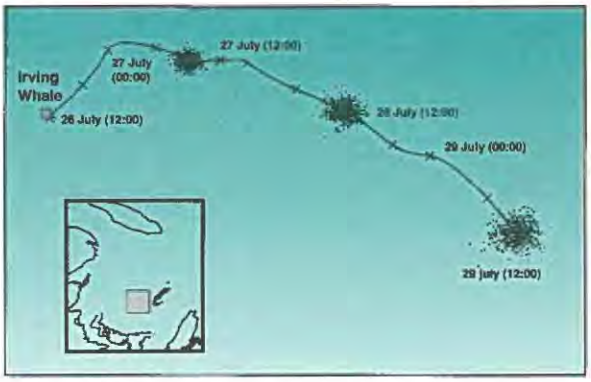

FIGURE 3-1 *Predicted path of a hypothetical oil spill resulting from the Irving Whale salvage operations in 1996. This prediction was established by the joint modelling team of Fisheries and Oceans Canada and Environment Canada using numerical models and drifting buoy data. The solid line depicts the mean trajectory of the hypothetical spill. Each cluster of points depicts the size of the hypothetical spill after 24 hours.*

NEW ATLAS OF TIDAL CURRENTS FOR THE ST. LAWRENCE ESTUARY, FROM CAP DE BON-DÉSIR TO TROIS-RIVIÈRES

Mariners are well aware of how strong and variable the tidal currents are in the St. Lawrence. For example, in the Upper Estuary, upstream from Trois-Pistoles, current speed is generally four knots and sometimes exceeds eight knots (a knot is approximately equal to 1.8 km/h). What is more, the currents reverse direction about four times a day, and the timing of this reversal varies from one location to another. These powerful currents pose a risk to human safety as well as for the marine environment. A new *Atlas of Tidal Currents* was published in 1997, replacing a publication dating back to 1939 (see Figure 3-2). The new atlas contains detailed charts of the surface currents at hourly intervals during the semi-diurnal tidal cycle in the St. Lawrence between Cap de Bon-Désir and Trois-Rivières. Users can estimate the current by simply marking their position on the charts and calculating the time that separates them from slack tide at the appropriate reference port. Collectively, the 108 charts in the new atlas feature some 110 000 current arrows which can be used for this purpose.

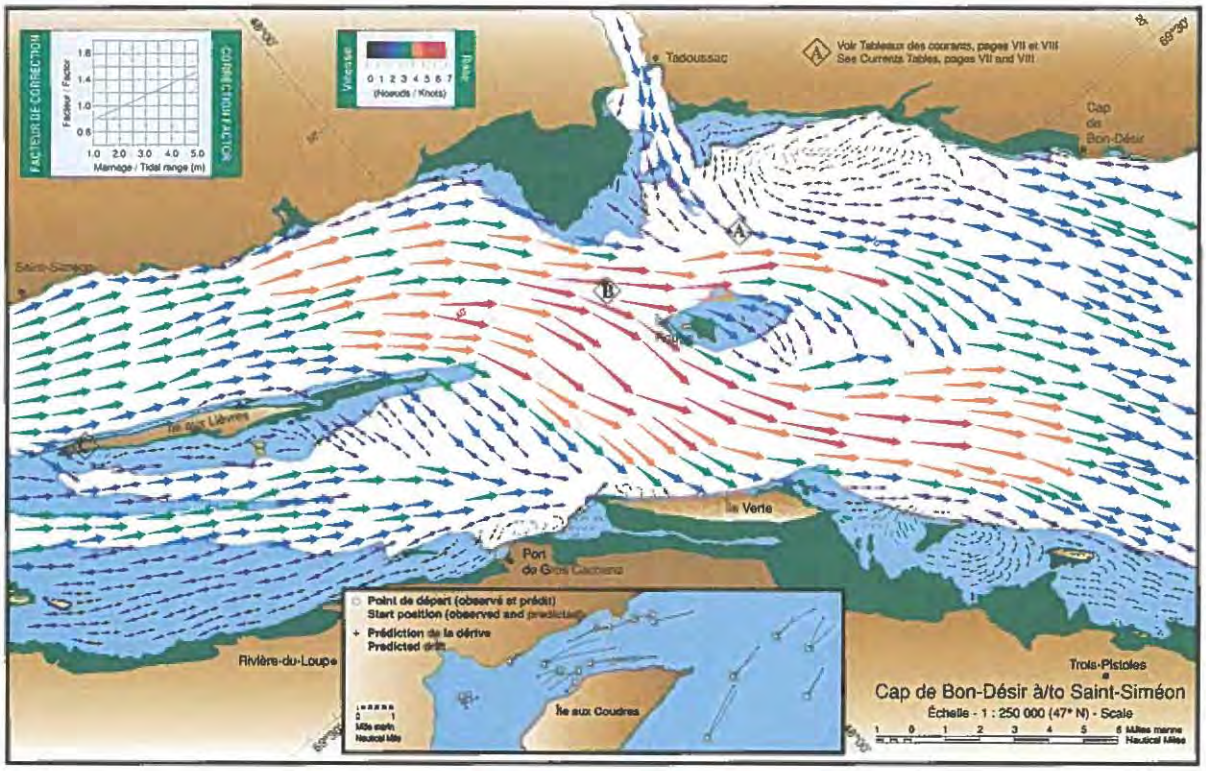

FIGURE 3-2
One of the 108 charts in the new Atlas of Tidal Currents.

CARBON FLUX IN THE OCEANS

Carbon is the basic element of all life on Earth. Approximately seven billion tonnes of carbon generated by human activities is released into the atmosphere each year in the form of carbon dioxide gas (CO_2). There is a general consensus among scientists that this human disturbance is increasing the amount of heat trapped in the atmosphere, thereby contributing to the greenhouse effect and global warming. Nevertheless, a major portion of this CO_2 becomes trapped in the deep ocean and hence cannot contribute to the greenhouse effect. It is believed that the carbon may remain in this deep sea reservoir for periods on a scale of 1000 years. However, scientists do not know exactly how the carbon travels from the atmosphere to the ocean depths.

Modelling activities have revealed the possibility of a new pathway for carbon transfer to the deep ocean—the transport of dissolved organic carbon (DOC). Dissolved organic carbon, which comes mainly from dead marine plants and animals, can be used as an energy source by marine bacteria. Until 1995, DOC was considered a negligible factor in the vertical transport of carbon in the water column; however, a growing number of studies indicate that this is not the case (see Figure 3-3).

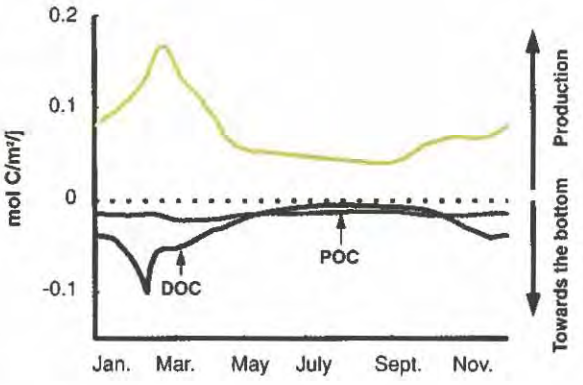

FIGURE 3-3 *Numerical model simulation of three types of carbon transport in the water column of the Gulf of St. Lawrence. Organic carbon is produced by photosynthesis in the surface layer (0-50 m) (yellow line). Note that light and carbon dioxide (CO_2) are necessary for photosynthesis. Part of this organic carbon can escape from the surface layer in particulate form by sinking due to gravity. This is particulate organic carbon, or POC (red line). And some of it can escape in dissolved form when the surface layer undergoes mixing with the underlying water. This is dissolved organic carbon, or DOC (blue line).*

According to this simulation, the flux of dissolved organic carbon (DOC) into deeper water is often greater than that of particulate organic carbon (POC). In other words, most of the carbon stored in the deep sea originated as dissolved organic carbon. This situation can be explained by the fact that in cold environments, like the Gulf of St. Lawrence, bacteria break down DOC more slowly. Some scientists believe that where the rate of bacterial decomposition of DOC is slower than the rate at which the water column is mixed, DOC could accumulate on the sea bottom. This hypothesis is very controversial, however, and it has not yet been field tested.

WATER TEMPERATURE VARIATIONS IN THE GULF OF ST. LAWRENCE

Scientists are also keenly interested in the water temperature changes that have occurred in the Gulf of St. Lawrence. An analysis of the temperature data for 1985 to 1995 shows that the 30-100 m layer of water (as measured from the surface of the water column) was abnormally cold throughout this entire period (see Figure 3-4).

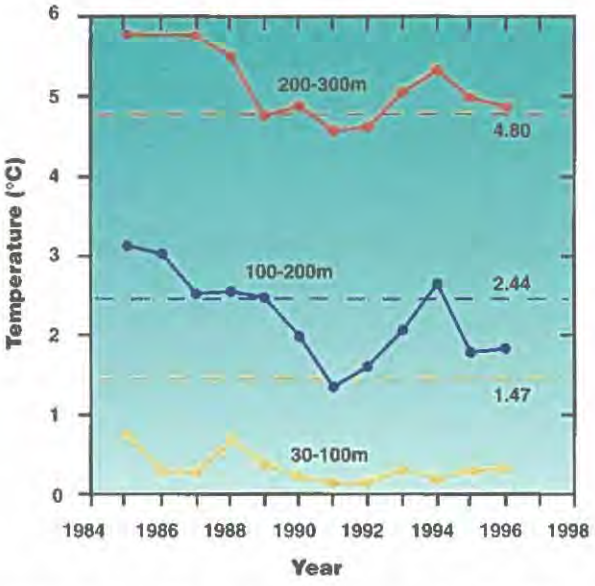

FIGURE 3-4 *Water temperature in the 30-100 m (yellow), 100-200 m (blue) and 200-300 m (red) layers (based on depth measured from the water surface) in the Gulf of St. Lawrence. The dotted lines represent normal water temperatures for each of these layers; they were calculated using available historical data.*

However, the deeper water layers (100-200 m and 200-300 m) had more variable temperatures, ranging from warmer than normal in the mid-1980s to colder than normal in the early 1990s, followed by a warming trend.

Some scientists believe that the abnormally cold temperatures in the 30-100 m layer may have had harmful effects on some marine species, possibly contributing to the collapse of certain fish stocks.

IS ULTRAVIOLET RADIATION HARMFUL FOR MARINE ORGANISMS?

Since 1980, the stratospheric ozone layer, which protects us from the harmful effects of ultraviolet rays (UV), has generally thinned by 3 to 6% in the summer and 7 to 12% in the winter. Chlorofluorocarbon (CFC) emissions to the atmosphere caused by various human activities are largely to blame for this depletion. Despite the implementation of the *Montreal Protocol*, an international accord aimed at phasing out the production of ozone-depleting substances, the thinning of the ozone layer is expected to continue for about 50 years. As a result of this decrease in the Earth's natural protection from UV rays, there will be a significant increase in the solar radiation reaching the ground, particularly the most harmful wavelengths, or UV-B (280-320 nanometres).

How far does this increased UV radiation penetrate into surface waters and what are the dynamics involved? And what are the repercussions on marine organisms of this change in their environment? In an effort to answer these questions, DFO scientists first measured UV radiation penetration in the waters of the Estuary and Gulf of St. Lawrence, with a particular focus on areas and periods of intense biological productivity. They determined that at certain locations in the Gulf, 10% of UV-B rays penetrated the surface layer to a depth of 3-4 metres: this is where the majority of eggs and larvae from commercially valuable fish and crustaceans are found. Furthermore, in experiments performed in outdoor basins, cod eggs that were exposed to natural sunlight during their development (between egg release and hatching) showed

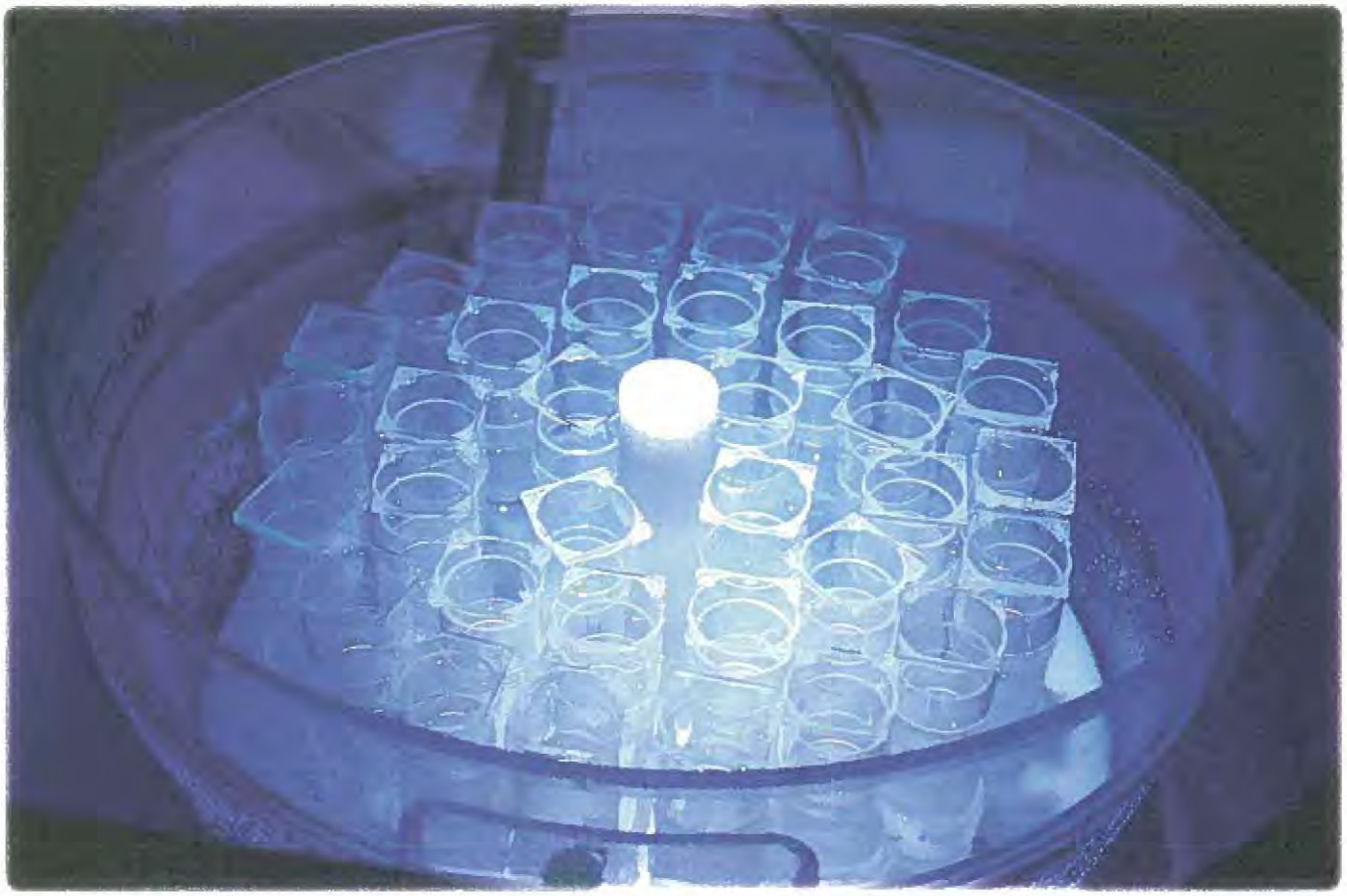

Photo: J.-F. St-Pierre

Cod eggs in quartz tubes subjected to radiation from a solar simulator.

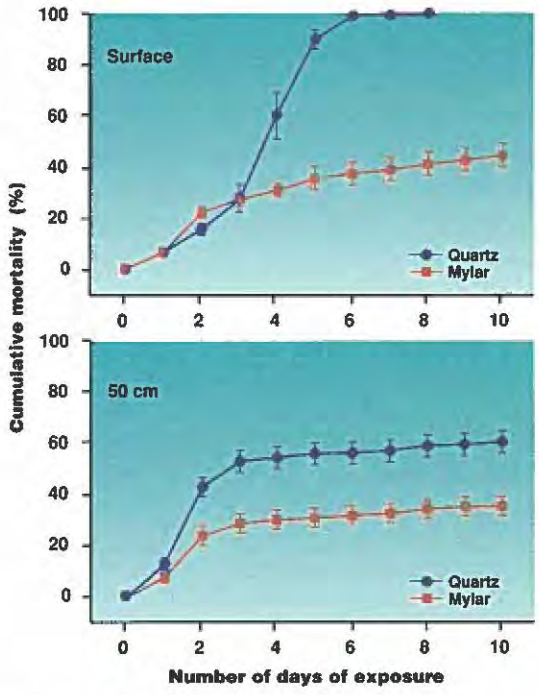

FIGURE 3-5 *Comparison of the mortality of cod eggs exposed to natural UV rays (quartz) and of eggs not exposed to UV-B radiation (mylar filter). Whereas the quartz is transparent to UV-B, the mylar filter blocks them. Natural mortality was about 40%.*

mortalities of up to 60% in shallow water (50 cm) and 100% at the surface (see Figure 3-5). To determine which wavelengths in the UV spectrum are most likely to affect marine organisms, laboratory experiments were conducted using solar simulators and a series of filters that block UV radiation to a varying extent. With the help of mathematical models, scientists can predict the UV radiation environment that will exist with continued depletion of the ozone layer. The simulation results for the Gulf of St. Lawrence showed that if cod eggs in the surface layer were exposed to the midday sun (based on the present thickness of the stratospheric ozone layer) for a total of 42 hours, the mortality rate would be 50%. With a 20% decrease in total ozone, this level of mortality would be reached in just 32 hours.

These results must, however, be considered in context, by taking into account cloud cover, water transparency, and the vertical distribution of eggs and larvae of marine organisms. All the same, the experimental findings are sufficient cause for concern.

Photo: S. Bérubé

Weir at Métis-sur-Mer.

WEIR FISHERS HELP SCIENTISTS

Thanks to information provided by an ichthyological diversity monitoring network, researchers now have better knowledge of the status of the fish populations along the shores of the St. Lawrence Estuary. There is rich diversity of both freshwater and saltwater fish species in the Estuary. Five commercial fishers from Île-aux-Coudres, Saint-Irénée, Cacouna, Sainte-Luce and Métis-sur-Mer respectively, who use weirs as fishing gear, allowed scientists to compile their catches for the period 1986 to 1997. During these fishing seasons, a total of 23 different fish species were captured in the five weirs. The main species caught were Atlantic herring, capelin, rainbow smelt and American eel. Among the less abundant species observed were Atlantic sturgeon, Atlantic halibut, whitefish and American shad.

Between 1986 and 1997, year-to-year fluctuations were generally noted in the abundance, diversity, and seasonal and spatial distribution of the different fish species caught in the weirs. This is illustrated by the graph below, which shows the variation in the number of species and their abundance, expressed in the form of a species diversity index (see Figure 3-6). The observed variability may have been caused by natural fluctuations in the populations or in the environment, or by human disturbances over the past few decades, such as dredging, pollution or intensive fishing.

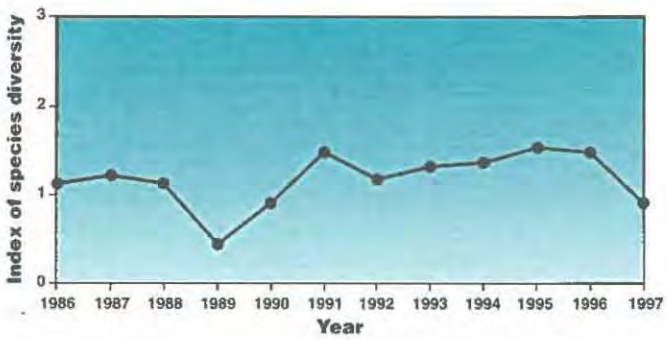

FIGURE 3-6 *Species diversity index for fish caught in five weirs in the St. Lawrence Estuary between 1986 and 1997.*

GLOSSARY

Chlorofluorocarbon (CFC): molecule composed of atoms of carbon, chlorine, and fluorine. CFCs are known for their ability to destroy ozone and their role in climatic warming.

Drifting buoy: floating device designed for recording parameters such as water and air temperature, barometric pressure, wind direction and speed, and water salinity.

Flux: transfer of a substance between two environments.

Hydrodynamic: having to do with the movement of liquids, or with fluid mechanics (study of the circulation of liquids and the forces exerted by liquids).

Knot: unit for measuring current speed which corresponds to 1.8 km/hour.

Model: simplified representation of a process or system.

Nanometre (nm): unit of length equal to a billionth of a metre (or 10^{-9} metres), which is used to measure radiation wavelengths.

Ozone: molecule made up of three atoms of oxygen.

Photosynthesis: production of organic matter by plants and algae using carbon dioxide from air or water as source of carbon. Plants and algae that contain chlorophyll (pigment) have the ability to fix CO_2 using light as a source of energy.

Salvage: the act or process of recovering a ship that has sunk or run aground.

Semi-diurnal tide: tidal cycle with two high tides and two low tides in the same day.

Simulation: method of representing physical phenomena, using a computer or a model.

Slack tide: time during the tidal cycle when the sea level is stabilized; also called slack water.

Stratosphere: layer in the atmosphere between the troposphere (altitude of 6 to 17 km) and the mesosphere (extending to an altitude of 50 km).

Ultraviolet radiation (UV): radiation in the wavelength range 280-400 nanometres.

Upstream: section of a watercourse between a point of interest and the source.

Water column: vertical section of water from the sea surface to the bottom.

Wavelength: distance between two successive crests of a wave.

Illustration: J. Bégin

Capelin.

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Photo: F.-J. Saucier

Scientist preparing to deploy an instrument for measuring water temperature, salinity and density between the surface and the bottom.

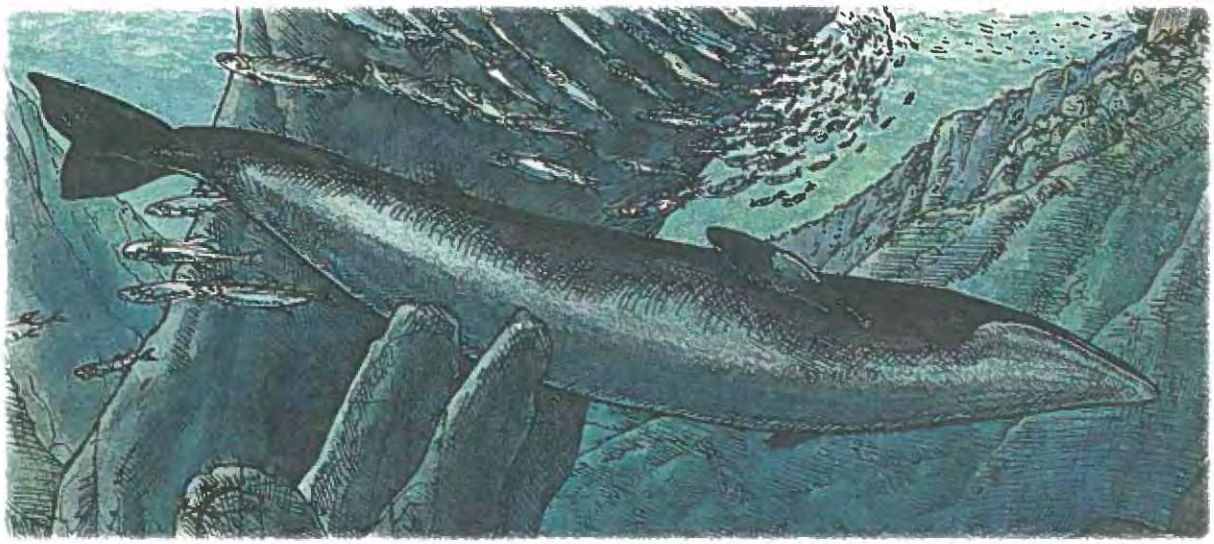
marine mammals

highlights

1997 aerial survey of the St. Lawrence beluga population

The Beluga Recovery Plan and the implementation plan

Cetaceans of the Gulf of St. Lawrence



The harbour seal: a year-round resident

Hydroacoustics: tools for learning more about whales

Monitoring strandings of marine mammals

Health of marine mammals

HOW ARE THE ST. LAWRENCE BELUGAS DOING?

Aerial population survey

An aerial survey of the St. Lawrence beluga population was carried out in 1997. In the sector between Île aux Coudres and Île du Bic, visible belugas were counted using aerial photos taken from aboard two aircraft. The aircraft, each equipped with a metric mapping camera, flew over the study area by following a grid of transects (see Figure 4-1). Meanwhile, an observer performed a visual count of belugas in the Saguenay Fjord from aboard another airplane. A population index estimate, which reflects changes in population size but does not give the actual number of individuals, indicated that there were 700 belugas, give or take 46. Since an unknown portion of the population is under the water surface when the aerial photos are taken, this number does not constitute a precise population count. That is why it is called an index. However, to compensate for the submerged belugas, the index estimate was calculated by applying a correction factor of 15% to the photographic counts. As this correction factor is considered conservative, the index estimate of 700 belugas should underestimate the actual population size. According to the trend shown by the index estimates computed from 1982 to 1997, the size of the population may be increasing. However, this cannot be confirmed for several years, until three or four additional surveys have been done.

Encouraging news

The possible increase in the population index for belugas is an encouraging sign because it indicates that the population is no longer declining and that it may in fact be rebuilding. Both the adult survival rate (computed from statistics on belugas that have become stranded or have died of natural causes) and the birth rate seem to be normal. As well, there appears to be a low rate of mortality from predation, stranding, entrapment in ice, and fishing gear. With regard to changes in the extent of contamination of beluga habitats, the concentrations of most contaminants measured in sediments and in a number of aquatic organisms have decreased since the 1970s. This situation suggests that the contaminant levels in belugas may eventually decline. On the other hand, the limited genetic variation within the population, the contaminants still present in their environment, and the large and growing volume of vessel traffic are all worrisome aspects which could affect the population's recovery.

Belugas.

Photo: R. Michaud / GREMM

STATUS OF THE ST. LAWRENCE BELUGA POPULATION

Near the end of the 19th century, the St. Lawrence beluga population was estimated at 5000 individuals. The drastic decrease in beluga numbers has been attributed to intensive hunting of these whales for their blubber and skin. In those days, the authorities even offered bounties for the capture of belugas, believing that they were harmful to fish stocks. In the St. Lawrence, hunting was banned in 1979 under the *Fisheries Act*. In 1983, due to the small population size and concern that beluga numbers would keep dwindling, the *Committee on the Status of Endangered Wildlife in Canada* (COSEWIC) designated the St. Lawrence Estuary belugas as an *endangered population*. In 1997, the status of the St. Lawrence belugas was re-evaluated. As there was not a clear majority in favour of changing the population's status from *endangered* to *threatened*, the status has remained unchanged.

FIGURE 4-1 *Map of the study area showing the flight lines followed during the 1997 aerial photographic survey of belugas in the St. Lawrence Estuary.*

THE ST. LAWRENCE BELUGA RECOVERY PLAN

The *St. Lawrence Beluga Recovery Plan*, the first of its kind for a marine mammal species in Canada, was made public in February 1996. The plan was developed by a group of independent scientific experts from the public and private sectors and commissioned by the Department of Fisheries and Oceans (DFO) and the World Wildlife Fund Canada (WWF Canada).

This team of experts began by reviewing all available pertinent information on the beluga's situation and then identified known and potential factors which pose a threat to the St. Lawrence belugas and may hinder the population's recovery. As a result of this exercise, 56 recommendations were drafted and grouped under five strategies for action.

The five strategies for action proposed by the Beluga Recovery Team are as follows:

- Achieve, in the St. Lawrence ecosystem, an overall reduction in toxic contaminants believed to be having a negative impact on belugas;
- Reduce disturbance caused by human activities in areas frequented by belugas;
- Prevent ecological catastrophes and ensure emergency preparedness;
- Monitor the state of the population;
- Investigate other possible obstacles to beluga recovery.

The goal of this recovery plan is to improve the population's situation to the point where its official status can justifiably be modified from *endangered* to *threatened*, and then to *vulnerable*. *Vulnerable* is the best possible status at present given the population's isolation, its marginal existence and the presence of humans in the ecosystem, all of which are factors that can affect the belugas in the St. Lawrence.

Three of the categories established by the Committee on the Status of Endangered Wildlife in Canada:

Endangered: a species facing imminent extirpation or extinction.

Threatened: a species likely to become endangered if limiting factors are not reversed.

Vulnerable: a species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.

IMPLEMENTATION OF THE RECOVERY PLAN

In July 1996, further to the *St. Lawrence Beluga Recovery Plan*, Fisheries and Oceans Canada, Environment Canada, Canadian Heritage (Parks Canada) and Environnement et Faune Québec published a plan for implementing the recommendations related to their respective jurisdictions. During a review of the 56 recommendations formulated by the group of experts, it was determined that, in nearly 75 % of cases, actions had already been planned, were in progress or had already been carried out in some instances. Nonetheless, many new initiatives intended specifically to address objectives set out in the Recovery Plan were also put forward. Like the team of experts, the two levels of government felt that the beluga population's high level of contamination, its small size and isolation, along with the intense pressures from human activity, were all factors justifying the continuation of protection and monitoring efforts.

The main initiative related to implementing the Recovery Plan involved establishing, in collaboration with WWF, a committee mandated to oversee and promote implementation of the plan by the different departments concerned, the industry and non-governmental organizations.

In short, the *St. Lawrence Beluga Recovery Plan* and the implementation plan have provided an opportunity to take stock of the current situation, the progress achieved and the objectives that have not yet been attained. They have also revealed that the issues related to the beluga need to be considered in the much broader context of the environmental quality of the St. Lawrence.The success of the plan hinges on the willingness of government, non-governmental organizations, industry and the general public to assist in protecting the belugas and restoring the St. Lawrence. Such actions will not only be favourable for the belugas, they will benefit the ecosystem as a whole and human health in particular.

AERIAL SURVEYS OF CETACEANS IN THE GULF OF ST. LAWRENCE

Aerial surveys of cetaceans in the Gulf of St. Lawrence were conducted in 1995 (late August - early September) and in 1996 (late July - early August). The visual counts were performed from aboard an aircraft which flew over a grid of transects. The Gulf was subdivided into three sectors: the north, the centre and the south. Whereas in 1995, the grid of transects covered the entire Gulf, in 1996 efforts were concentrated in the northern sector and part of the central sector. Of the 10 cetacean species observed, 7 were present in large enough numbers to permit quantitative analyses.

- Minke whales were ubiquitous in the Gulf of St. Lawrence, with more frequent observations in the northern part of the Gulf. Scientists estimated that there were 1 000 minke whales in the Gulf as a whole in 1995, and 600 in the northern sector in 1996.

- In 1995, there were an estimated 12 000 white-sided dolphins in the Gulf of St. Lawrence. However, in 1996 almost none were observed. This situation may be due to the fact that the survey was carried out a month earlier in 1996.

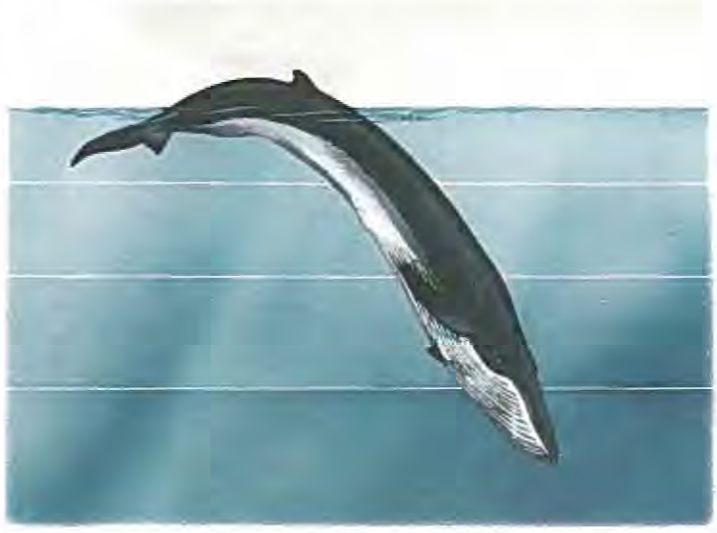


Illustration: J.-C. Campet

Fin whale.

- The estimate for fin whales was a few hundred individuals compared with one hundred for humpback whales. Most of these whales were observed in the northeastern sector of the Gulf.

- White-beaked dolphins were observed only in the Strait of Belle Isle and at the northeastern edge of the Gulf. The estimate was 2500 for each of the two years of the survey flights.

- Harbour porpoises were more abundant in the northern Gulf. They were also present in the central and southern sectors of the Gulf, albeit at lower densities. In 1995, the number of porpoises in the entire Gulf was estimated at 12 000, while in 1996 the estimate was 21 000 for the northern Gulf alone.

- Pilot whales were observed in the southeastern Gulf, which was surveyed in 1995 only. At that time, their number was estimated at 1500.

- Blue whales and belugas were observed too seldom to produce reliable analyses. The tenth species that was observed could not be identified.

SEALS OF THE ST. LAWRENCE ESTUARY

The four species of seals most commonly observed in the St. Lawrence Estuary are the grey seal, the harp seal, the hooded seal and the harbour seal.

- Grey seals spend the winter in the Gulf of St. Lawrence and off the coast of Nova Scotia; however, they are present in the Estuary from May to November.

- Harp seals and hooded seals generally spend the summer in the Arctic and use the Estuary only during winter and spring, from December to May. However, growing numbers of harp seals are now frequently observed in the Estuary over the summer.

- Harbour seals are the only year-round residents of the Estuary.

Photo: F. Bélanger

Grey seal (male).

Photo: J.-F. Gosselin

Harp seal (female and pup).

Photo: J.-F. Gosselin

Hooded seal (female, pup, and male).

HARBOUR SEAL

Aerial population survey

Little information is available on the harbour seals of the St. Lawrence Estuary. A review of the existing data on this species reveals striking similarities with the beluga in terms of recent history. For example, the harbour seal population, like that of the belugas, was the object of bounty hunting, which reduced its numbers considerably. Based on the initial population estimates dating from the 1970s, there were some 13 000 harbour seals in Eastern Canada, including 700 in the Estuary.

From 1995 to 1997, aerial surveys were conducted along the north and south shores of the Estuary by counting the number of seals that could be seen on haul-out sites. A haul-out is a coastal site, often consisting of large rocks, where seals go to rest. Between 500 and 600 harbour seals were counted on haul-out sites located between Sainte-Anne-des-Monts and Saint-Jean-Port-Joli (see Figure 4-2). These figures have not, however, been corrected to account for animals absent from haul-out sites at the time of survey flights. They do suggest nonetheless that the harbour seal population has changed little since the 1970s.

Movement and diving activities

Researchers have used satellite telemetry and other long-distance tracking devices to learn more about the harbour seal's movements and migration patterns, along with the animals' diving activities. In addition to providing diving depths and swimming speeds (Figure 4-3), the data compiled indicate that harbour seals are fairly sedentary. Most of the tagged seals (with satellite transmitters attached to their fur) spent the winter in the Estuary, between Bic and Métis-sur-Mer. Exchanges between haul-out sites appear to be limited, that is, the animals usually return to the same sites.

FIGURE 4-2 *Location of the main harbour seal haul-out sites in the St. Lawrence Estuary between 1995 and 1997.*

Photo: V. Lesage

Harbour seals.

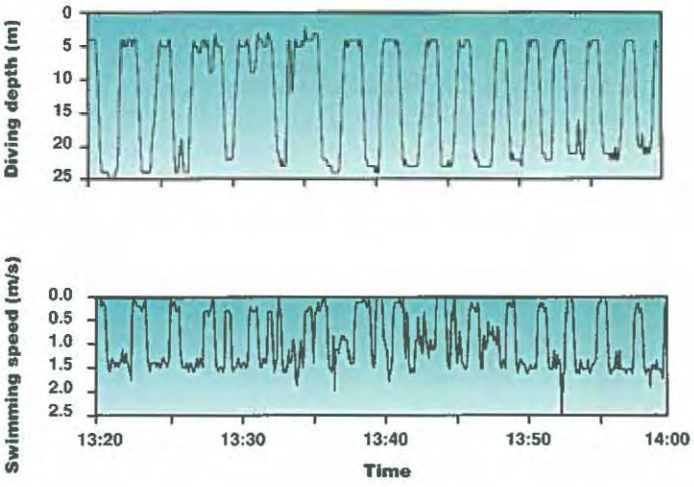


FIGURE 4-3 *Diving depths and swimming speeds of a harbour seal recorded in the Bic area in August, 1996, during a 40-minute period of activity.*

CONTAMINANTS

Contaminant studies have also been conducted on harbour seals. Average polychlorinated biphenyl (PCB) concentrations measured in the blubber of live harbour seals (43.2 µg/g of lipids) were similar to those found in stranded belugas (39.8 µg/g of lipids), but much higher than those measured in other pinnipeds like grey seals (5.6 µg/g of lipids) and harp seals (1.5 µg/g of lipids), which are not year-round residents of the St. Lawrence Estuary. The effect of these contaminant levels on the animals has not yet been determined.

LEARNING MORE ABOUT WHALES THANKS TO HYDROACOUSTICS

The upstream end of the Laurentian Channel, situated in the Tadoussac area, is the part of the Lower Estuary used most during the summer by whales, particularly minke whales and fin whales. These large marine mammals come to the area to feed on the high concentrations of fish and tiny crustaceans (commonly called krill) found there. This location has the richest aggregations of krill ever recorded in the Northwest Atlantic. It is believed that whales actively seek concentrations of krill and fish in order to increase their feeding efficiency. Gaining insight into the feeding habits of whales first requires an understanding of the mechanisms behind the accumulation of food sources in this region.

With the help of hydroacoustics, researchers have observed a relationship between the presence of physical gradients (fronts) and the presence of accumulations of living organisms. For example, they have shown that capelin, an important food source for both minke whales and fin whales, frequently congregate in frontal zones (Figure 4-4). Aggregations of young capelin have been found in more than 72% of observed frontal zones. Scientists believe that whales may use fronts and thermal barriers to devise capture strategies and optimize their feeding success. Hence, frontal zones would have an effect on the distribution of whales through their influence on the distribution of capelin.

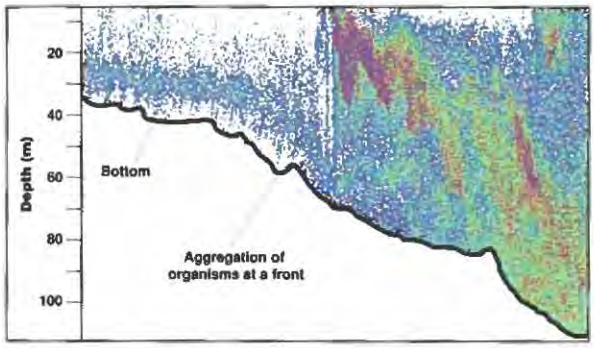


FIGURE 4-4 *Acoustic image showing a large accumulation of living organisms at the location of a front (red). There are two water masses at the front: the warmer, less saline waters of the Saguenay Fjord on the right side, and the colder, more saline waters of the Lower St. Lawrence Estuary on the left side.*

WHAT IS A FRONT?

The Lower St. Lawrence Estuary is characterized by the presence of the Laurentian Channel, which is between 300 and 350 metres deep. Cold, saline waters from the Gulf of St. Lawrence and the Atlantic Ocean flow up the Lower Estuary towards the upstream end of the Laurentian Channel, which is situated at the mouth of the Saguenay Fjord. In this part of the Channel, the bottom rises from 300 m to 50 m over a distance of only 20 km. The sudden rise in the sea bottom causes an acceleration in currents toward the surface and in an upstream direction at the spot where the Laurentian Channel waters meet the waters of the Saguenay Fjord and those of the Upper Estuary, which flow in the opposite direction. The meeting of these water masses, which have different temperatures, salinities and densities, causes intense mixing and creates zones of abrupt change called fronts. Fronts can occur on a variety of spatial and temporal scales, sometimes with the phenomenon of convergence, which can be recognized from the accumulation of foam, living organisms and floating debris on the water surface.

Photo: S. Cadieux

Aerial photo of a front (at flood tide) at the mouth of the Saguenay Fjord caused by the meeting of waters from the Laurentian Channel, the Saguenay Fjord and the Upper Estuary.

USING HYDROACOUSTICS FOR A CLEARER PICTURE OF THE SEA

Biologists employ hydroacoustic technology in locating and estimating the size of aggregations of fish, zooplankton or other organisms throughout the water column or on the sea bottom. The findings are used for various purposes, including stock assessments of certain fish species. Hydroacoustic techniques basically involve using an echosounder to emit sound pulses in the water and record the energy that is reflected when the pulses hit targets such as fish. The time between the emission and reception of the pulses, together with the intensity and direction of the return signal, make it possible to determine the target's distance, its size and its position in the water column. Every target has unique reflecting properties, called an acoustic signature, which are used in order to differentiate schools of various fish species, such as cod, redfish and capelin, as well as clouds of copepods and euphausiids (krill). To validate the acoustic signatures, a sample is taken with nets or trawls. The return signals from the zooplankton or the fish are then converted to biomass values or numbers of fish.

Photo: M. Plamondon

Scientific team performing a post-mortem examination on a male beaked whale stranded at Sept-Îles, on September 8, 1997. The animal weighed 4.2 tonnes and measured 6.6 metres.

Photo R. Michaud / GREMM

Blue whale feeding.

STRANDING OF MARINE MAMMALS IN THE ST. LAWRENCE

Every year, a number of marine mammal strandings occur in the St. Lawrence. The term "stranding" refers to the situation of an animal that has become trapped on shore and is unable to return to the water on its own, because it is sick or weak or it is merely lost. Shoreline residents are often the first people to witness strandings, and many of them report the incidents to DFO. A broad-based communications network is operated which can receive calls from the general public in every region of Quebec. All stranding incidents reported to the Maurice Lamontagne Institute (MLI) are recorded with as many details as possible. When a dead animal is found which meets the selection criteria (good state of preservation, accessibility and reasonable distance from MLI) and in the case of unusual incidents, a team of scientists is sent to the stranding site. The team performs a necropsy (post-mortem examination) right on the shoreline or transports the carcass to MLI so that samples can be taken. Beluga carcasses are transported to the Faculty of Veterinary Medicine at Saint-Hyacinthe, where a complete necropsy is done.

Scientists gather a variety of data on stranded marine mammals which allow them to gain insight into their

distribution, population dynamics, anatomy, diet and reproduction. In addition, organ and tissue samples can be used for genetic, toxicology, pathology, parasitology and microbiology studies.

In 1996, 108 marine mammal strandings were reported in Quebec by the public (Figure 4-5). Since 1990, seven cetacean species and five seal species have been involved in strandings. Potential causes include disease, malnutrition, trauma, navigational errors, accidents and encounters with human activities. It is often difficult to determine the exact cause of the stranding, even after a post-mortem examination.

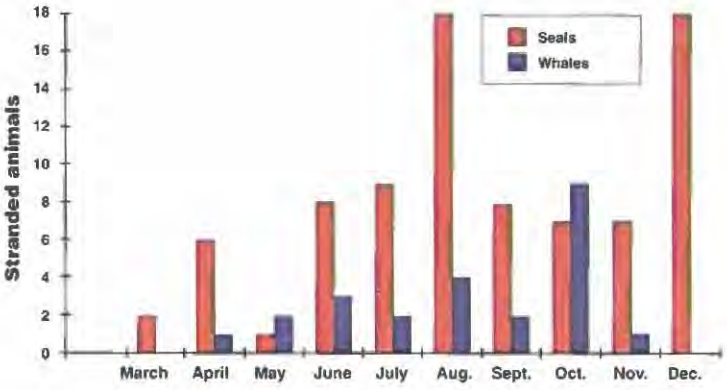


FIGURE 4-5 *Number of seal and whale strandings reported in 1996. The seal species included the harbour seal, grey seal, harp seal and hooded seal. Stranded whale species included the minke whale, fin whale, beluga, harbour porpoise and white-sided dolphin.*

THE HEALTH OF MARINE MAMMALS

In the Estuary and Gulf of St. Lawrence, new data on disease-causing agents (pathogens) have been obtained from the examination of live or dead marine mammals that became stranded, had been hunted or drowned in nets. Serum analysis results have shown that seals in the region are exposed to various disease agents, including seal morbillivirus (which killed more than 17 000 European seals between 1988 and 1989), distemper virus and two bacteria which can cause spontaneous abortions in animals and humans. However, the St. Lawrence belugas do not appear to be exposed to dolphin and porpoise morbillivirus, two other viruses which have killed hundreds of cetaceans in Europe. In certain seal species, scientists have also observed the presence of a micro-organism that is part of the normal oral flora of seals (it is found in 80% of grey seals, for example). This micro-organism can cause both lung disease in these animals and a human disease called *seal-finger*. This disease presents a health risk for people who handle seals, such as sealers, scientists who study seals, and employees of aquaria and rehabilitation facilities.

Various types of parasitic worms (roundworms, tapeworms, acanthocephalans and flukes) and pathogenic protozoa infect both seals and whales. A number of these are of little significance for the animals' health, unless present in large numbers. Nonetheless, lungworms can cause severe respiratory problems in seals and whales, leading to illness or even death. Some worms can be transmitted to humans. The whaleworm and the sealworm, for example, are transmitted to fish and can therefore be passed on to people who eat fish. However, human risks of infection are nil, provided the fish has been cooked fully, hot smoked, marinated properly, or frozen for four to five days at -20°C.

Contaminants can affect the immune system of certain animals, making them more susceptible to viral, bacterial and parasitic infections, including respiratory diseases which are particularly harmful for diving animals. Close to 90% of the belugas found stranded on the shores of the St. Lawrence Estuary were found to have lungworm infections in the lung parenchyma. Furthermore, histopathological examinations showed that seven of nine belugas stranded in the Estuary had a form of pneumonia (verminous pneumonia) associated with the presence of worms. Although the contaminant concentrations measured in the St. Lawrence beluga carcasses were high, the role that contaminants play in relation to the prevalence and intensity of such infections is not known.

GLOSSARY

Aggregation: congregation of many individuals.

Biomass: total mass of plants or animals in a biotype at a given time, expressed per unit area or volume.

Channel: generally the deepest part of a river or other body of water.

Distemper: acute infectious viral disease which causes fever and is highly contagious.

Gradient: rate of charge of a physical parameter with distance or time.

Histopathology: study of the microscopic anatomy of diseased tissues.

Necropsy (post-mortem examination): examination of a dead animal to study any existing lesions, take samples and attempt to determine the cause of death.

Parasite: animal or plant that lives on and draws nourishment from another living organism in a dependent relationship. A parasite harms but does not kill the host organism.

Parasitology: study of animal and plant parasites.

Parenchyma: organ or gland tissue that is essential to the organ's functioning, as opposed to the supporting connective tissue.

Pathogen: an organism that can cause lesions or disease.

Pathology: science concerned with the study of diseases, and their effects.

Population dynamics: study of changes in population structure.

Protozoan: unicellular organism, generally microscopic.

Seal-finger: bacterial infection of the finger or hand that occurs in humans following contact with an infected seal.

Serum: liquid component of the blood plasma.

Transect: narrow strip or line (real or virtual) in a given environment, used for analysis, description and mapping.

µg/g: microgram (one millionth of a gram = 10^{-6} gram) of a substance per gram of sediment or biomass.

Upstream: section of a water body between a given point and the source.

Water column: vertical section of water from the sea surface to the bottom.

Photo: R. Michaud / GREMM

Group of fin whales.

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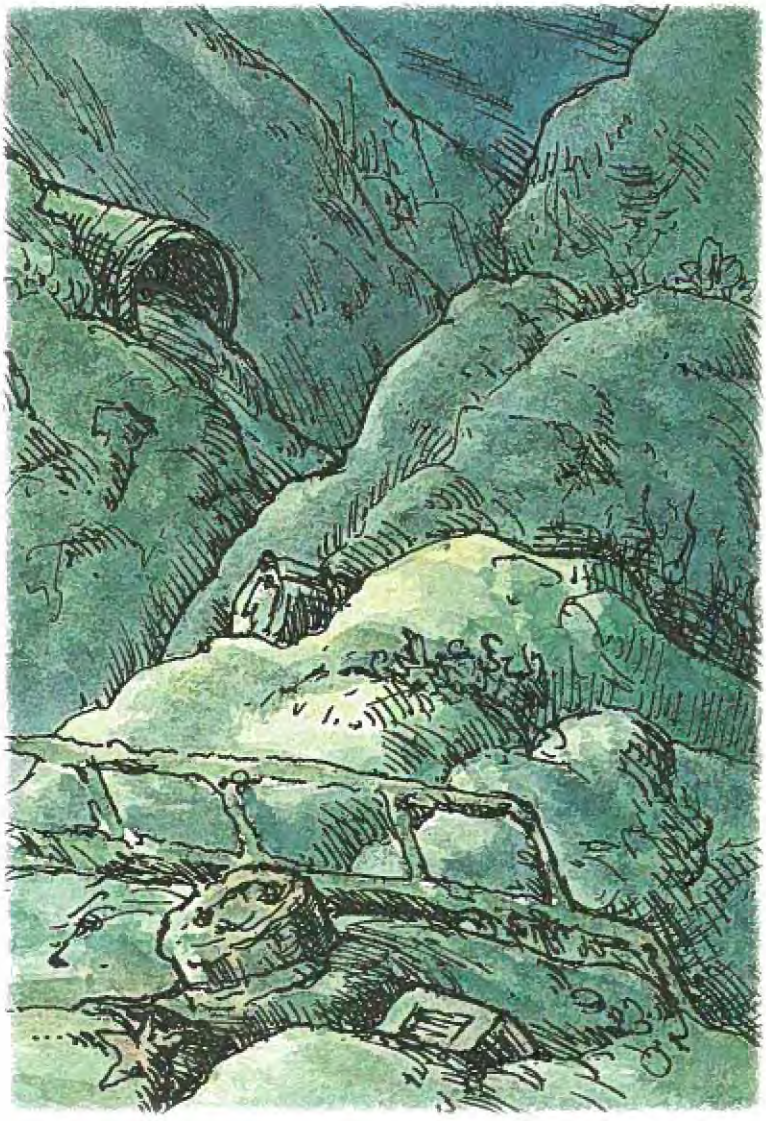
contaminants



highlights

Monitoring contaminant levels in sediments and marine organisms

Understanding pathways for the transfer of contaminants to living organisms

State of health of the American eel

Impacts of contaminants on the health of American plaice

Development of biological methods for enhancing environmental protection

The Irving Whale barge

MONITORING CONTAMINANT LEVELS IN MARINE SEDIMENTS OF THE ST. LAWRENCE

The Estuary and Gulf of St. Lawrence receive run-off waters from the Great Lakes – St. Lawrence basin, one of the most heavily urbanized and industrialized drainage basins in North America. Monitoring of contaminants in marine sediments of the St. Lawrence is conducted by taking sediment cores on a regular basis. A sediment core is composed of layers of sediments that have been laid down successively over time at a given site. Sediment core analysis provides information on the type and quantities of contaminants present, and can be used to trace the history of environmental contamination from the pre-industrial era to the present.

Photo: J. Munro

Photo: K. Côté

Sediment core sampling.

Contaminant concentrations measured in sediments are generally lower in the Estuary than in port areas and in riparian habitats affected by discharges of industrial and domestic effluents. Nevertheless, research conducted from 1993 to 1998 indicates that human activities have changed the chemical composition of marine sediments of the St. Lawrence. A number of observations can be made based on the research findings:

- Over the last century, the amount of **mercury** from industrial sources that has accumulated in sediments of the St. Lawrence Estuary is six times higher than the amount of mercury from natural sources. Chlor-alkali plants appear to be mainly responsible for the mercury contamination, particularly in the Saguenay Fjord. Since 1970, however, these facilities have reduced their discharges of mercury substantially.

- Estuary sediments contain some 13 000 metric tons of **lead** in excess of lead from natural sources. Much of this contamination stems from the use of alkyl lead compounds as anti-knock additives in gasoline between the 1920s and the 1970s. Mines and foundries are also a source of the lead detected in the marine environment.

- **Silver** is another contaminant that is widely distributed in sediments of the St. Lawrence Estuary. In some locations, the silver concentrations in sediment are five times higher than the background level. Municipal effluents are the main source of this contaminant in the St. Lawrence.

- **Arsenic** concentrations in Saguenay Fjord sediments can be as high as 60 mg/kg, which greatly exceeds the levels measured in Gulf of St. Lawrence sediments. This elevated level of arsenic can be explained by natural geochemical factors, however, and does not result from human activity.

- Researchers estimate that some twenty metric tons of **polychlorinated biphenyls** (PCBs) has accumulated in Lower Estuary sediments, and nearly ten tonnes in the Gulf of St. Lawrence, compared to 130 tonnes in Lake Ontario sediments.

PCBs are synthetic chemical compounds which are not naturally present in the environment. PCB congeners are highly persistent in the environment; some of them are virtually nonbiodegradable. PCBs have been around since about 1930, when they came into widespread use as hydraulic fluids, heat transfer fluids (heat transfer systems) and dielectric fluids (electrical transformers and capacitors) because of their physical and chemical properties. They were also formerly used in the manufacture of many everyday products (rubbers, paints, plastics, glues and textiles). Since July 1, 1980, however, the use of PCBs in new products has been prohibited in Canada.

- In 1995, the presence of **dioxins** and **furans** was detected for the first time in Lower St. Lawrence Estuary sediments. With the exception of Baie des Anglais, the concentrations measured in Lower Estuary sediment cores were indicative of a low level of contamination. The highest levels were two times lower than the maximum concentrations found in lakes Michigan and Superior and 10 times lower than those in Lake Ontario.

Estimates have also been made of the dioxin and furan load in sediment cores. This involves determining the total amount of these chemical compounds in sediment cores between the surface layer of sediment and the depth at which concentrations are no longer detectable. To calculate the dioxin and furan load, the sedimentation rate and sediment porosity at a given site must be taken into consideration, along with the contaminant levels in the different sediment layers. The results have shown that the dioxin and furan load per unit area of sediment is generally greater at the head of the Laurentian Channel (near Tadoussac) than in the Great Lakes, although the concentrations are higher in the Great Lakes. This situation can be explained by the higher rate of sedimentation in the Laurentian Channel, which has a diluting effect on dioxin and furan concentrations. With regard to these contaminants, only Lake Ontario shows a load per unit area of sediment that is three times higher than that measured in St. Lawrence Estuary sediments.

Although forest fires and volcanoes represent natural sources of dioxins and furans, human activity is the principal source. Dioxins and furans occur in wood preservatives (pentachlorophenol) as impurities, in emissions from municipal and industrial waste incinerators, and in the effluents of pulp and paper mills that use chlorine bleaching. Dioxins and furans may also occur as impurities in commercial PCBs, making them another potential source of these contaminants.

MONITORING CONTAMINANTS IN MARINE ORGANISMS

Scientists who monitor contaminants in marine organisms focussed their initial efforts on mercury, lead, and cadmium. These metals, albeit naturally occurring, can be toxic to living organisms (see box on next page). Mercury, lead, and cadmium concentrations have been measured in the muscle tissue of northern shrimp, in the

Illustration: L. Begin

Snow crab.

muscle tissue and digestive gland (hepatopancreas) of snow crab, and in the muscle, liver and gonads of a number of fish species from the Estuary and Gulf of St. Lawrence and the Saguenay Fjord. These species include Atlantic cod, Greenland halibut, deepwater redfish, American plaice, thorny skate, capelin, Atlantic herring and rainbow smelt.

- **Mercury** levels in the tissues of all species studied were 2 to 10 times lower than the standard set out in the *Canadian Guidelines for Contaminants in Fish and Fish Products*. The allowable level for human consumption has been set at 0.5 mg/kg by Health Canada. Northern shrimp and snow crab from the

Saguenay Fjord are exceptions, since they exhibited concentrations approaching the allowable limit. However, commercial and sport fishing for crustaceans is currently banned in the Saguenay Fjord.

Photo: G. Gaudreau

Sampling cod tissue for contaminant analyses.

- For all species studied, **lead** concentrations were found to be low, often below 0.05 mg/kg, with no marked difference observed between the Estuary, the Gulf and the Fjord.

- In the Estuary and Gulf of St. Lawrence as well as the Saguenay Fjord, **cadmium** levels in fish muscle and gonads and in crustacean muscle were low, often below the analytical detection limit of 0.002 mg/kg. However, as is often observed, cadmium levels were higher in the livers of fish and the hepatopancreas of snow crab.

In addition to metals, researchers are interested in tracking the levels of organic contaminants in living organisms.

- For example, concentrations of **polychlorinated biphenyls** (PCBs) and organochlorine pesticides, such as DDT, have been measured in the muscle and liver tissues of Atlantic cod, American plaice and Greenland halibut caught in the Estuary and Gulf of St. Lawrence and in the Saguenay Fjord. These compounds were detected in the tissues of almost all fish analysed, with the highest concentrations identified in cod livers and the lowest levels in the muscle of cod and American plaice. However, the detected concentrations have always been below the Canadian guidelines designed to protect human health.

POTENTIAL TOXIC EFFECTS ON LIVING ORGANISMS

Mercury
Inorganic mercury has a low toxicity. However, methylmercury, an organic form of this element, is the main type of mercury that accumulates in the tissues of aquatic organisms. Methylmercury is particularly toxic to aquatic organisms and humans because it damages the nervous system.

Lead
The most serious toxic effects of lead exposure are associated with the central nervous system. Individuals who are regularly exposed to high lead concentrations may exhibit serious kidney damage and blood disorders.

Cadmium
Elevated levels of cadmium can be toxic if ingested. Long term exposure to low cadmium concentrations can lead to chronic obstructive pulmonary disease, kidney disease or emphysema. The cardiovascular and skeletal systems may also be affected.

PCB
Some PCBs can impair the immune system, affect growth and reproduction, or cause certain types of cancer.

TRANSFER OF CONTAMINANTS TO BENTHIC ORGANISMS AND GROUNDFISH

Contamination from sediments

Persistent organic chemicals, such as polychlorinated biphenyls (PCBs), organochlorine pesticides and dioxins and furans, are ubiquitous in the aquatic environment. The fate of these compounds is closely linked to their association with suspended particles and with sediments in which they accumulate. Sediments, which act as a

sink for these contaminants, are also a component of the habitat of numerous benthic organisms and groundfish. While it is essential to evaluate and monitor contaminant levels in sediments, it is also important to study the bioavailability and bioaccumulation of these substances in living organisms.

This raises the question as to whether sediments represent an important pathway for the transfer of contaminants to benthic organisms. One study undertaken to examine this issue focussed on *Maldane sarsi*, a benthic worm found in the Lower St. Lawrence Estuary and the Saguenay Fjord. This species is situated at the bottom of the food chain and is eaten by many other benthic organisms and by groundfish.

The study results indicated that the benthic worms bioaccumulate the contaminants from their environment and hence constitute a route by which contaminants may be passed up the food web. In addition, there appears to be a simple relationship between the levels of toxic substances in benthic worms and those in sediment. Based on this, scientists should be able to predict the contaminant levels in worms from those detected in sediment.

The snow crab has also been studied in relation to its benthic habitat, that is, bottom sediments. The results showed that the contaminant levels in snow crabs sampled at several sites in the Estuary and the Saguenay Fjord were quite similar, despite the fact that the sediment concentrations of the substances varied widely. One possible explanation for this observation is that snow crabs may not be affected to any great extent by sediment contamination; instead they may absorb toxic substances from their food. In future laboratory studies on the transfer of contaminants, researchers will be able to gain a better understanding of the pathways of contamination in snow crab.

Laboratory studies in controlled environments can provide answers to certain questions much more readily than field observations, in which a number of factors or conditions may vary simultaneously. In a series of laboratory experiments spanning 84 days, American plaice were fed uncontaminated food but were kept in contact with PCB-contaminated sediments. At the end of this period, the fish showed a considerable buildup of PCBs in their tissues (see Figure 5-1). Clearly, therefore, sediment plays a fairly major role, either directly or indirectly, in the accumulation of organic contaminants in aquatic organisms.

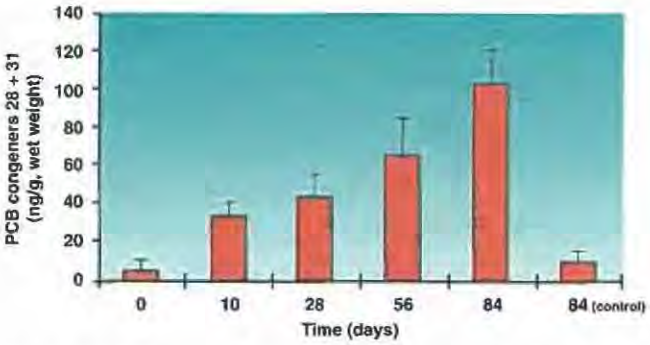


FIGURE 5-1 *Concentration of two compounds from the PCB family (28 + 31) in American plaice over time. In this experiment, the plaice were kept in tanks with a layer of PCB-laced sediments spread over the bottom. The fish were fed uncontaminated food. The control group was subjected to the same conditions, except that the bottom of the tank was covered with uncontaminated sediments. The error bars on top of the rectangular bars show the variability associated with the means.*

Contamination from food

To assess the extent to which an ecosystem is contaminated, representative samples of the biota and the physical environment must be gathered and analysed. However, to understand and be able to predict the effects of toxic substances on ecosystems, it is necessary to collect information on how fast marine organisms absorb and eliminate contaminants that are present in their environment. It is also crucial to learn more about the distribution of these substances in their tissues.

Laboratory experiments were conducted on the bioaccumulation of ingested metals in American plaice and snow crab fed a diet containing mercury, cadmium, and silver. In the plaice, the accumulation of the three metals was characterized initially by a very low retention rate. Only 10 to 15% of the ingested metal was stored in tissues, the rest being eliminated with the feces. Almost all the metals had concentrated in the gut lining of plaice, with only minimal quantities being transferred to other organs. In the case of snow crab, the retention rates for the same metals were higher, reaching 40% for cadmium and close to 100% for silver. The researchers also observed that cadmium and mercury had built up solely in the hepatopancreas while appreciable amounts of silver were observed in muscle.

Other experiments looked at the accumulation of methylmercury and tributyltin (TBT) in American plaice. The findings demonstrated that the two compounds were efficiently absorbed, with an initial retention rate varying from 40% for TBT to nearly 90% for methylmercury. Moreover, the substances were distributed throughout the organ systems (see Figure 5-2).

The next step will be to develop a quantitative model that can be used to predict the degree of accumulation of metal contaminants in both American plaice and snow crab, by looking at data on contaminant concentrations in certain benthic species on which they feed.

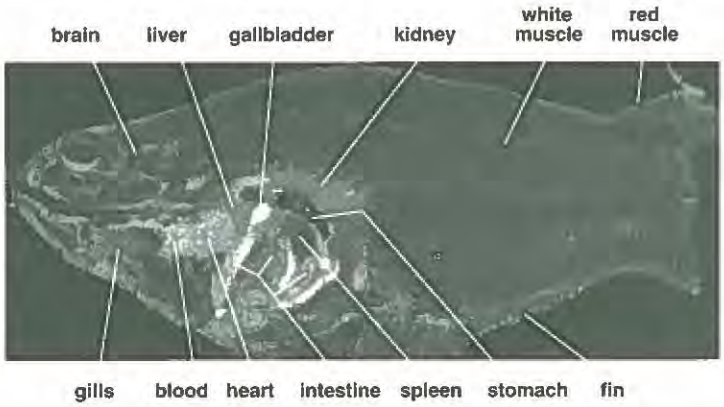


FIGURE 5-2 *Macro-autoradiogram of an American plaice. The macro-autoradiography technique, which uses radioactive substances that emit gamma rays, can be employed to determine the distribution of a contaminant in all the tissues and organs of a whole animal. The lightest zones in the image correspond to sites where TBT has accumulated.*

EFFECTS OF CONTAMINANTS ON FISH HEALTH

The American eel

From their birthplace in the Sargasso Sea, which lies in the western Atlantic some distance from the Florida coast, young American eels swim up the St. Lawrence and its tributaries, into freshwater zones, some travelling as far as Lake Ontario. The eels then live in freshwater until they reach maturity, at which point they swim back to the St. Lawrence and make their way back to the Sargasso Sea to breed. During their growing period in Lake Ontario and in the upstream section of the St. Lawrence River, the eels accumulate high levels of persistent chemical compounds. This makes migrating American eels a potential pathway for contaminant transfer to animals that feed on them, such as the St. Lawrence belugas. This is especially true of mirex, a chemical known to originate primarily in Lake Ontario. A relationship has been established between the mirex concentrations in eel tissues and their body weight. On this basis, the eels have been divided into two distinct groups, more contaminated ones and less contaminated ones. The proportion of eels deriving from the more contaminated sites (Lake Ontario and the upstream section of the St. Lawrence River) increases as the migration season progresses (see Figure 5-3c). Furthermore, eels have been sampled and found to have vertebral malformations and basophilic foci (precancerous lesions) in their livers (see Figure 5-3a, b).

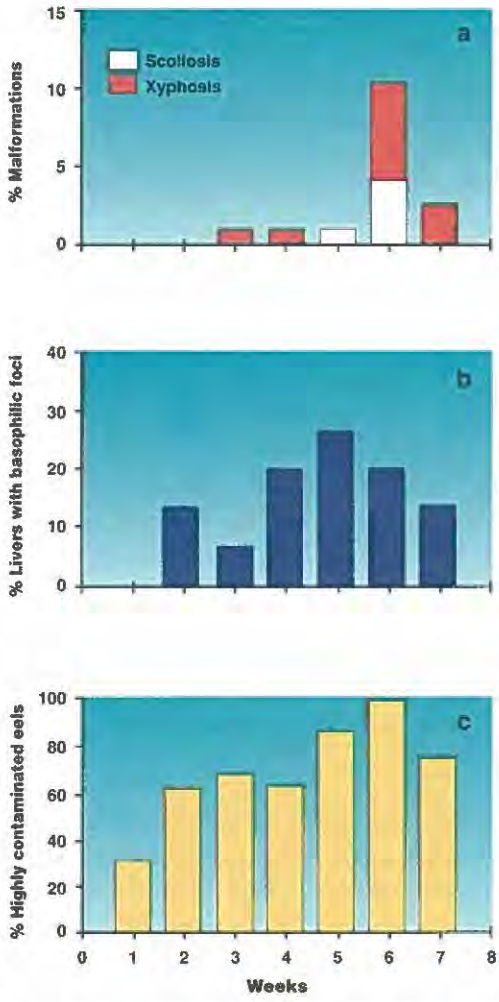


FIGURE 5-3 *Percentage of malformations (a), of basophilic foci in livers (b), and of highly contaminated eels (c), in relation to the migration season expressed in weeks.*

American eel.

Illustration: J. Bégin

These abnormalities were also observed to be more prevalent at the end of the migration season, a time when a larger percentage of eels exhibit a high level of contamination from organochlorine compounds. Whereas basophilic foci are fairly specific markers of contaminant exposure, vertebral malformations could be caused by other factors of human or natural origin. For example, they could result from the passage of eels through hydroelectric dam turbines. Alternatively, other factors might be involved, such as the size and age of the migrating eels.

This study represented the first time that precancerous liver lesions had been found in fish caught in the St. Lawrence Estuary. Since 1997, a team of researchers has been studying the prevalence of these lesions in resident species of the St. Lawrence Estuary, including the Atlantic tomcod and rainbow smelt.

Baie des Anglais, a research laboratory

The effects of mixtures of contaminants on fish health are often difficult to evaluate, owing to the complex repercussions on their various physiological systems. Such mixtures occur in coastal sediments, particularly near zones exposed to discharges of industrial effluent.

To shed some light on the problem, a laboratory study was done in which marine fish were exposed to contaminated sediments from Baie des Anglais. American plaice were used since they are relatively abundant in the St. Lawrence and they live in direct contact with the sediments. This bay situated near Baie-Comeau in the Lower St. Lawrence Estuary was chosen as experimental site because of the high levels of organic contaminants (PCBs, PAHs, dioxins and furans) found in the sediments there.

Effects on the reproductive system

Baie des Anglais sediments were sampled along a transect comprising three stations characterized by different levels of organic contaminants. Two of the stations were in the bay (contaminated sites), and the third was outside it (reference site). With increasing distance from the shore, the concentrations of contaminants were found to decrease by a factor of 10, so that the reference site was 100 times less contaminated than the first station on the transect. In the laboratory, male plaice were exposed to sediments from the three Baie des Anglais stations over a period of five months. At the end of the exposure period, spermatozoids were collected and used to fertilize eggs from females that had not been exposed to contaminated sediments. The results showed a significant reduction in the hatch rate of eggs fertilized with semen from males exposed to contaminated sediments (see Figure 5-4). What this indicates is that the contaminants present in Baie des Anglais sediments could have adverse effects on the spermatozoids of plaice and hence on their reproductive capacity.

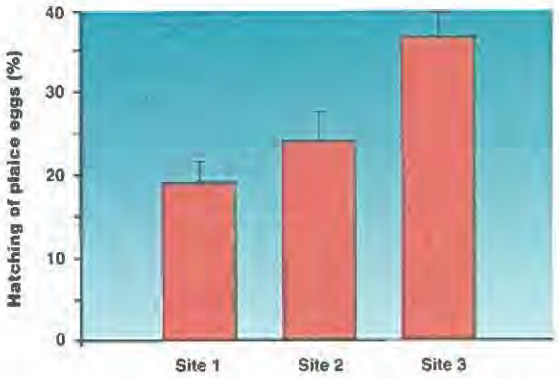


FIGURE 5-4 *Percent egg hatch for American plaice eggs fertilized with semen from males exposed during five months to contaminated sediments from two sites (Sites 1 and 2) in Baie des Anglais and from one site (Site 3) in the Estuary. The bars above the rectangular bars show the variability associated with the three means.*

Effects on the immune system

In two other experiments, scientists sought to evaluate the effects of contaminated sediment from Baie des Anglais on the immune system of American plaice. In the first experiment, some plaice were put in cages and kept at the above-

described stations for three weeks. In the second experiment, scientists studied PCB accumulation in American plaice in a controlled environment (laboratory), where marine sediments were the only possible source of PCBs.

The results, in both cases, showed that the contaminants present in Baie des Anglais sediments could alter the immune system of American plaice.

Effects on the endocrine system

It is known that some PCBs have a structure similar to that of thyroid hormones, for example, thyroxin. In fish, these hormones play a role in gonad maturation and body growth. Scientists were interested in studying PCB-contaminated sediment from Baie des Anglais to determine the effects of this contaminant on thyroxin metabolism. The findings showed that certain molecules of PCB had the same effect as thyroxin, while others seemed to inhibit its action.

No verdict yet

Although the observed effects of contaminants on the different systems of plaice point to potential problems, it should be kept in mind that the experimentation is still at an early stage, and that the experiments were performed on sediment samples from a bay whose contaminant levels do not reflect the concentrations generally observed in the marine part of the St. Lawrence. Moreover, a recent study has shown that the contamination does not extend beyond Baie des Anglais.

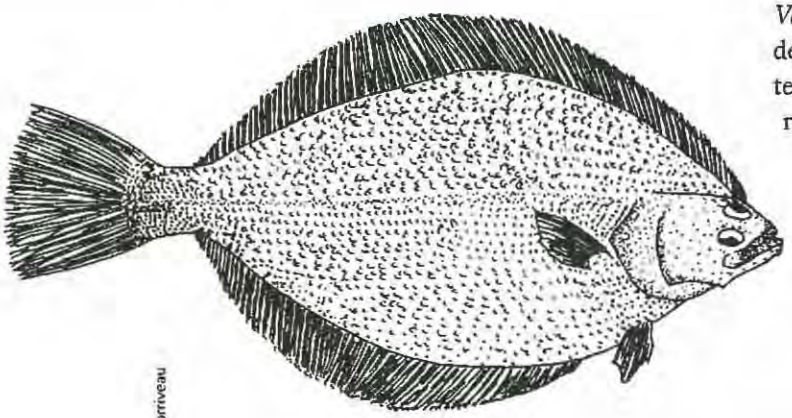


Illustration: L. Corriveau

American plaice.

DEVELOPMENT OF NEW TECHNIQUES

Accelerated oil biodegradation

In spite of safety precautions, accidental spills can occur during the exploration, production, and transportation of crude oil and refined oil products. Traditional clean-up methods following an oil spill involve removing and eliminating residues and contaminated sediments, and applying chemical dispersants. This type of approach is both costly and labour-intensive and may result in considerable environmental damage.

Scientists have embarked on a research program to develop bioremediation techniques as environmentally sound alternatives for treating oil-polluted sites. Bioremediation consists in releasing substances at contaminated sites to accelerate the natural process of biodegradation of contaminants. The substances used for this purpose are either oil-eating bacteria (bioaugmentation), or compounds such as phosphates that promote the growth of naturally occurring bacteria (biostimulation).

Field and laboratory studies have demonstrated conclusively the feasibility of using bioremediation procedures based on adding nutrients to enhance microbial degradation of oil on the sandy beaches and in the saltmarsh environments of the Canadian Atlantic Coast. The resulting methods have been employed successfully in the context of actual oil spills, such as the *Exxon Valdez* and the *Sea Empress*. Accelerated biodegradation offers a number of advantages as a technique for remediating oil spills: efficiency, reasonable cost, elimination of the need for waste disposal sites and minimal environmental impact.

Photo: S. Cobanli / BDR Research Limited

A sample of sediment contaminated by an oil spill is taken for analysis.

Clay-oil flocculation

Recent studies suggest that the dispersion of stranded oil in sheltered coastal environments may result from natural interactions between oil and fine mineral particles, such as clay, and sea water. These interactions (called clay-oil flocculation) provide a plausible explanation for the disappearance of residual oil from several sites, notably in the Arctic and in temperate coastal environments. It is believed that the adhesion of oil onto beach sediments is reduced when the oil forms droplets stabilized by fine mineral particles. These subsequently form micro-aggregates of a density low enough to be easily dispersed by tides and currents.

The use of natural flocculation has been envisaged as a countermeasure for facilitating the dispersal of oil from beach sediments following a spill. With this approach, interactions between the oil and mineral fines are augmented by mechanical agitation or the washing action of the surf. When the technique was applied on a pebble beach (Amroth Beach in the United Kingdom, which had been contaminated by an oil emulsion following the *Sea Empress* spill), it resulted in efficient oil removal by enhancing clay-oil interactions and by abrasion processes associated with strong waves and surf action.

Although spilled oil is successfully removed by these procedures, the use of this new technology still raises worries about whether the acceleration of clay-oil interactions does not simply move the residual oil from one environmental compartment (the beach) to another (the sea). To clarify this situation, scientists have undertaken a study to quantify the impact of clay-oil interactions on the biodegradation rate of oil released into the sea. The findings from laboratory experiments have corroborated field observations indicating that clay-oil interactions decrease the degree of adhesion of residual oil to solid surfaces. The residual oil is efficiently dispersed in the aqueous phase as small droplets stabilized by fine mineral particles. This prevents recoalescence of the oil and encourages the production of micro-aggregates. As a whole, the clay-oil interactions increase the area of contact between the oil, nutrients, oxygen, and indigenous oil-degrading bacteria, thereby enhancing the efficiency and speed at which the oil decomposes.

In short, this research has produced significant results which will support the development of efficient oil spill response techniques that are based on accelerating the natural process of clay-oil flocculation.

Using bacteria for marine environmental monitoring

In the natural environment, micro-organisms like bacteria play an important and well-known ecological role in chemical reactions such as the degradation of toxic organic compounds, nutrient recycling and trace metal transformation. Since micro-organisms respond rapidly to changes in environmental conditions, they can be used to evaluate the magnitude of the environmental effects of toxic chemicals.

A new method to measure sediment toxicity has been developed. It involves measuring the decrease in the activity of a specific enzyme in bacteria living in uncontaminated sediments, following contact with contaminated sediments.

Photo: D. St-Laurent / Environment Canada

Taking subsamples of sediment to apply the new toxicity evaluation method based on bacterial enzyme activity.

Since enzymes are proteins that facilitate and enhance various biochemical reactions, their importance at both the cellular level and the ecosystem level is widely recognized. Moreover, tests based on enzyme activity are generally more sensitive than those at the scale of a population. They are also faster and more reliable than measurements of the activity of whole organisms. The new analytical method, which uses indigenous bacteria as test organisms, is fast and inexpensive, and the results are easy to interpret. Moreover, the technique is fairly simple to use and can be implemented by most private laboratories with existing equipment. Use of this new test could boost reliability and predictive capacity in the context of future environmental risk assessments.

The new enzyme-based method has been used to measure the toxicity of contaminated sediments from the St. Lawrence Estuary (Baie des Anglais) and Chaleur Bay (Belledune Harbour). It has proven highly effective in detecting the presence of pollutants and holds promise as a tool for detecting the toxicity of waste material, such as dredge spoil, and supporting decision making about disposal options (e.g. ocean dumping or other type of disposal). Another possible application consists in tracking changes in the toxicity of a disturbed site or assessing the extent of contamination at such a site.

Measurement of bacterial enzyme activity in sediment also provides a means of monitoring the immediate and long-term impacts (other than toxicity) of ocean disposal of dredged material on the benthic environment. Enzyme activity was measured in sediments collected from a dredge spoil disposal site in Chaleur Bay (off L'Anse-à-Beaufils) and from two other sites in the Gulf of St. Lawrence (off Cap-aux-Meules and Grande Entrée, Magdalen Islands). When the results were compared with corresponding values obtained for the adjacent area and for some undisturbed sites, bacterial enzyme activity was always found to be lower at the disposal sites than in adjacent areas, despite the absence of chemical pollutants. This low level of enzyme activity was observed solely in sediment mounds, sometimes persisting for several years. The measurement of bacterial enzyme activity at disposal sites thus showed the potential that the approach offers for assessing other impacts, aside from toxicity, of dredge spoil disposal in the ocean, and for evaluating the extent and the persistence of those impacts.

THE IRVING WHALE BARGE

History

The *Irving Whale* barge sank on September 7, 1970 during a storm in the southern Gulf of St. Lawrence, about 100 km west of the Magdalen Islands. At the time, the barge was carrying about 4200 tonnes of heavy fuel oil, held at a temperature of 55-60 °C by a closed-circuit heating system containing about 7.5 tonnes of PCBs and 1.9 tonne of chlorobenzenes. The PCBs in the barge consisted of Arochlor 1242, a commercial mixture that is 42% chlorine by weight.

When the barge sank, 400 to 600 tonnes of oil were spilled and some washed ashore on the southwestern coast of the Magdalen Islands, soiling the beaches. During the ensuing 26 years, small quantities of oil periodically leaked out of the barge. It was not until June, 1995, during preparations for salvage operations, that the Canadian Coast Guard learned of the presence of PCBs in the *Irving Whale*'s heating system. During the summer of 1995, measurements of PCBs in sediments and living organisms taken around the wreck site confirmed that PCBs had escaped from the barge. However, the quantities of PCBs that had been released into the Gulf of St. Lawrence and the amounts still remaining on board could not be established prior to the recovery operation. Consequently, the environmental assessment of the project to raise the barge was conducted based on several spill scenarios involving different spill occurrences and quantities. Following a review of all possible scenarios, it was determined that the barge recovery operation was environmentally safe.

Salvage operation

The *Irving Whale* was successfully raised from the sea bottom on July 30, 1996. However, the subsequent barge clean-up and site remediation operations resulted in the recovery of only 1800 kg of the original 7500 kg of PCBs present in the heating system when the barge went down. Consequently, some 5700 kg of PCBs were released into the environment at the time of the sinking and over the following 26 years. In October, 1996, it was determined that a small proportion of this PCB material, roughly 150 kg, was still present in sediment in the area immediately adjacent to the sunken barge.

Photo: Environment Canada

The Irving Whale, right after it was raised on July 30, 1996.

Environmental monitoring

In October, 1996, a few months after the recovery operations, high PCB concentrations were detected in some snow crab specimens taken from the area near the wreck. PCB levels in 25% of the digestive gland (hepatopancreas) samples and in 5% of the muscle samples were either equal to or greater than the allowable limit of 2 mg/kg set by Health Canada for fish and seafood products destined for human consumption (*Canadian Guidelines for Contaminants in Fish and Fish Products*). Nonetheless, the PCB contamination of snow crab attributable to leakage from the barge appeared to be limited to the immediate vicinity of the wreck site.

Sampling surveys carried out in the spring of 1997 showed that appreciable changes had occurred over the previous winter in the contamination status of sediments and snow crabs at the wreck site. The sediment PCB concentrations in the heavily contaminated zones had declined significantly since October 1996, and the PCBs in sediments around this zone had spread somewhat. In addition, the PCB contamination in snow crabs from the area around the wreck site had decreased since the barge recovery, and none of the crabs captured in the spring of 1997 had PCB concentrations exceeding the Canadian guideline of 2 mg/kg applicable to seafood intended for human consumption. However, the fishing exclusion zone, a 9 x 9 km area established around the wreck site, has been maintained to prevent the sale of contaminated crabs and the resuspension of contaminated sediments.

It still remains to be discovered how and when the missing PCBs—more than 5500 kg—leaked out and were dispersed in the environment. Scientists have begun to examine this question. It seems that the PCBs from the *Irving Whale* have not contributed significantly to the present PCB load in the Gulf of St. Lawrence and that they have more likely become dispersed throughout the global terrestrial environment by oceanographic currents and the atmosphere. They therefore do not pose any threat to the quality of fishery products in the Gulf.

GLOSSARY

Analytical detection limit: the smallest concentration of a substance that can be detected with a given probality of accuracy. The detection limit varies with the subtances analysed and the analytical methods used.

Basophilic focus: site of cellular morphology alteration in the liver. This change is one of the first steps in the development of liver tumours.

Benthic: relating to benthos (see below).

Benthos: all the organisms living on the bottom of a natural aquatic environment.

Bioaccumulation: process whereby certain aquatic organisms absorb and accumulate chemicals from the environment directly or through consumption of food containing the chemicals.

Bioavailability: fraction of the total quantity of a chemical in the environment that can be assimilated by a living organism.

Biodegradable: describes a substance that can be decomposed or degraded by living organisms.

Bioremediation: remedial action using biological means to restore an environment. Examples of bioremediation include accelerating microbial degradation of oil by adding oil-eating bacteria (bioaugmentation) or compounds such as phosphates which stimulate the growth of bacteria that are already present in the environment to be remediated (biostimulation).

Biota: all of the living organisms (animals and plants) found in a given area.

Chlor-alkali plant: industrial facility that produces chlorine and caustic soda. From 1948 to 1976, most of the chlor-alkali plants in the Saguenay region employed a mercury cathode process.

Congener: each of the compounds belonging to the same chemical group and deriving from the same basic chemical structure. For example, the different molecules of PCB are congeners.

DDT (dichloro-diphenyl-trichloroethane): toxic organic insecticide. Its use has been banned in Canada since 1970.

Effluent: any run-off from a pollution source.

Enzyme: protein that facilitates biochemical reactions in living organisms.

Feces: solid waste matter resulting from digestion.

Geochemistry: science concerned with the processes governing the abundance and distribution of chemical elements in nature.

Gonad: organ that produces the sexual reproductive cells.

Groundfish: fish that inhabit and derive their food from the sea bottom, including cod, plaice, halibut, and redfish. By opposition, pelagic fish, such as capelin and herring, live in the water column.

Hepatopancreas: organ that plays the combined role of liver and pancreas in invertebrates.

Marine sediment: all of the natural particles (muds, clays, shells and dead organic matter) transported on the sea bottom.

Metabolism: sum of the chemical processes that come into play within a cell or in a whole living organism.

Methylmercury: organic form of mercury produced mainly by bacterial activity in anoxic layers (without oxygen) of sediments that are rich in organic matter.

mg/kg: milligram (one thousandth of a gram, or 10^{-3} gram) of a substance per kilogram of sediment or biomass.

ng/g: nanogram (one billionth of a gram, or 10^{-9} gram) of a substance per gram of sediment or biomass.

Organic: applies to chemical compounds with carbon as the basic element.

Organism: a living individual animal or plant.

Organochlorines: organic compounds containing chlorine atoms. Many of these compounds, such as dioxins, furans, numerous insecticides and PCBs, are toxic or even carcinogenic.

PAHs (polycyclic aromatic hydrocarbons): family of chemical compounds with a base structure of benzene rings. The PAH family is composed of dozens of substances which differ in the number and position of their benzene rings.

Persistence: length of time a chemical contaminant remains in the environment before decomposing into inert and generally harmless substances.

Pesticide: agent used against unwanted parasites, animals or plants.

Recoalescence: combining of suspended liquid particles into larger particles.

Scoliosis: lateral curvature of the spine.

Sediment core: vertical sample of sediment composed of many layers that have been laid down successively over time. The different layers can be analysed to determine the physical and chemical characteristics of the sediment (for example, contaminant concentrations).

Thyroid: gland situated at the base of the neck which produces hormones that regulate bodily processes, such as growth, metabolism and the functioning of the nervous system.

Toxicity: capacity or inherent potential of a substance to induce harmful effects in an exposed organism.

Tributyltin (TBT): active ingredient in paint that is used to prevent fouling organisms from attaching themselves to the hulls of ships.

Upstream: section of a water body that is between a point of interest and the source.

White muscle/red muscle: whereas white muscle functions without oxygen (anaerobically), red muscle is more vascularized and operates in the presence of oxygen (aerobically). Although white muscle makes up most of the body mass of fish, it is harnessed solely for urgent work (for example, predator avoidance).

Xyphosis: dorso-ventral curvature of the vertebral column.

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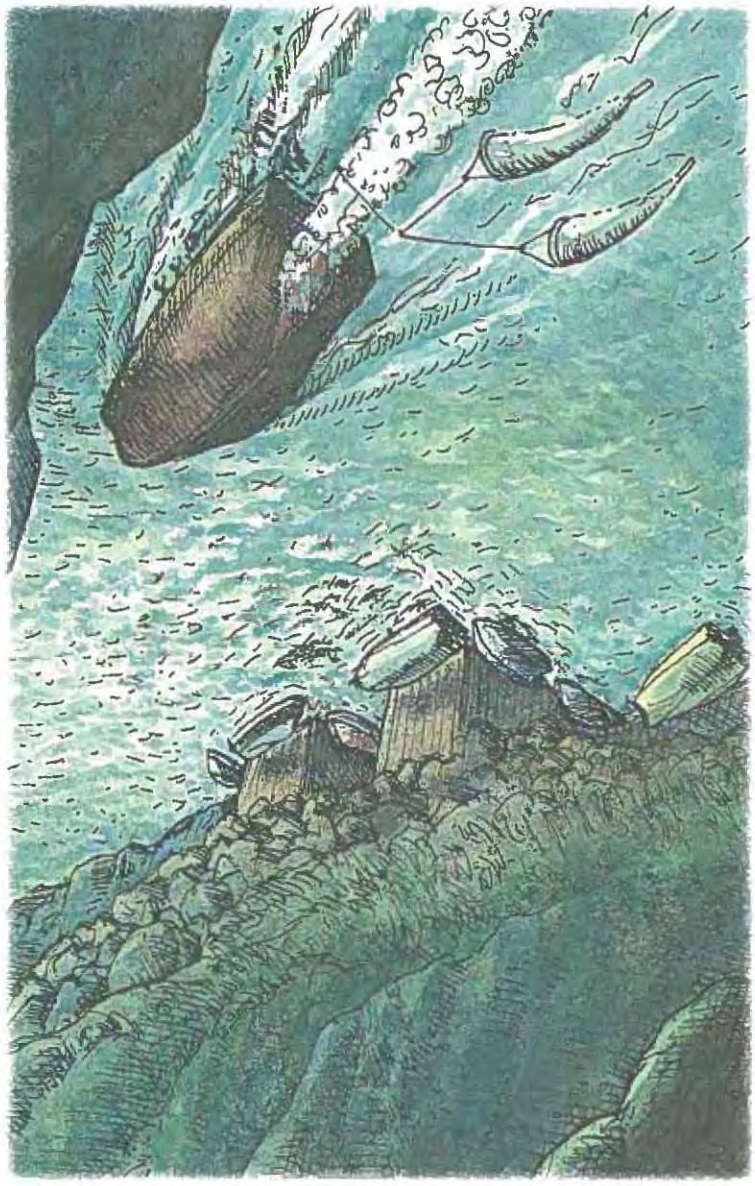
management of marine ecosystems



highlights

MANAGEMENT ACTIVITIES

Fish habitat protection

Environmental emergency response

Introduction of new species

Introduction and transfer of organisms

Impacts of dredge spoil disposal

Monitoring toxic algae

TOOLS

Fish Habitat Management Information System (FHAMIS)

National Contaminants Information System (NCIS)

Oceanographic Data Management System (ODMS)

Coastal and Ocean Water Level Information System (COWLIS)

Oceanographers and satellites

CURRENT AND FUTURE INITIATIVES

Toxic Chemicals Program

The Oceans Act

Phase III of the St. Lawrence Action Plan

The St. Lawrence Observatory

Management Activities

FISH HABITAT PROTECTION

There are many human activities that are potentially harmful to fish and their habitat. River diversions, dredging, land filling, mining and the construction of hydro-electric facilities, causeways, wharves, marinas, reservoirs and roads, as well as forestry and agricultural operations, are but a few examples.

Under the terms of the federal *Fisheries Act* and its *Policy for the Management of Fish Habitat*, DFO is required to ensure that all projects with potential effects on fish habitat are conducted in such a manner that there is no net loss of fish habitat.

The *Fisheries Act* is a powerful tool for the protection of fish habitat. Proposals for projects or activities to be carried out near or in the aquatic environment are analysed on a case-by-case basis, with a view to preventing the alteration, disruption or destruction of fish habitat. Further to this analysis, where applicable a notice is issued specifying the mitigation measures that need to be implemented to avert habitat loss. A mitigation measure might, for example, consist in not doing construction or other work during critical periods for fish such as spawning or migration.

Photo: D. Chamard

Wharf under construction.

When mitigation measures are insufficient to prevent habitat loss and the habitat is deemed non-critical, DFO can authorize the loss if the project proponent compensates for the loss through gains that are at least equivalent. This like-for-like compensation complies with the principle of no net loss set out in the *Policy for the Management of Fish Habitat*. Examples of compensation measures include the creation of spawning habitat or rehabilitation of disturbed habitats.

When habitat losses are deemed to be critical because the habitats affected are crucial or rare or they feature species at risk, DFO can refuse to authorize the habitat loss. The proponent may have to either make major modifications or abandon the project.

ENVIRONMENTAL EMERGENCIES RESPONSE

The Maurice Lamontagne Institute (MLI) is part of the environmental emergency response system dedicated to the marine environment. In the event of an incident that poses a threat to the environment, the Regional Environmental Emergencies Team (REET) is quickly deployed. REET includes both industry members and the government agencies concerned. MLI's role on this team is to provide scientific advice and recommendations for protecting the marine environment, fishery resources and fishing sites.

MLI also conducts research and development activities aimed at improving environmental emergency response. For example, as discussed in the *Marine Environment* chapter, hydrodynamic models are developed to provide tools for predicting the movement of survivors from a ship that has foundered or the trajectory of drifting objects, such as oil slicks on the water surface. As mentioned in the *Contaminants* chapter, MLI scientists have participated in various international research programs which have given rise to new techniques for remediating oil-contaminated shorelines. Finally, MLI can provide advice and participate in environmental sampling to assess habitat damage or monitor the recovery of a disturbed environment. Environmental monitoring of the *Irving Whale* wreck site, another topic covered in the *Contaminants* chapter, is a good example of this type of activity.

Photo: D. Chamard

Oil spill off Matane in the Lower St. Lawrence Estuary in December 1985. The oil slick has been contained by booms in the area adjacent to the ship.

BALLAST WATER DISCHARGES BY FOREIGN SHIPS MAY INTRODUCE EXOTIC SPECIES TO THE ST. LAWRENCE MARINE ENVIRONMENT

To maintain their stability, ships must hold water in their ballast tanks. This water is called ballast water. When ships fill their tanks with water, hundreds of species of organisms that are present in the water column and sediments can enter the tanks. When the ballast water is subsequently discharged in another port, exotic (non-indigenous) species may be released, with potentially adverse consequences for human health, fisheries, aquaculture and ecosystems.

In 1995, a study was conducted on the risk of new species being introduced to the Estuary and Gulf of St. Lawrence in ballast water discharges from foreign ships. The results showed that every year more than 700 ships from 30 different countries visit the main ports of the Estuary and Gulf. These ships carry 12.3 million metric tons of ballast water; they release nearly all of this water (11.7 million tonnes) into the St. Lawrence marine environment, primarily in the ports of Baie-Comeau, Port-Cartier and Sept-Îles, before departing for their return voyage laden with export cargoes.

Analyses of the water and sediment contained in the ballast tanks of some 100 ships led to the identification of 292 phytoplankton species and 98 zooplankton species in the water, and 65 phytoplankton and zooplankton species in the sediments. More than 66 % of the species found in the ballast water were not native to the Estuary or Gulf of St. Lawrence; some were present in densities as high as 100 000 individuals/m^3.

This study also showed that ships which completely exchange their ballast water at sea, as recommended in *Canadian Coast Guard guidelines*, carry far fewer phytoplankton and zooplankton organisms than ships that have not reballasted. Ballast exchange is a preventive

measure that appears to reduce the risk of exotic species introductions to the St. Lawrence Estuary and Gulf. However, the findings also indicated that some ships which reported that they had reballasted at sea had likely exchanged only part of their ballast water. This partial exchange could pose a threat to the marine ecosystems of the St. Lawrence.

A benthos survey is planned for some port areas in the marine part of the St. Lawrence. The goal is to determine whether exotic benthic species have already been introduced to the St. Lawrence system. The port areas were selected because ships regularly discharge their ballast water there. In addition, experiments will be performed to assess the viability of the phytoplankton found in the ballast water of a number of foreign ships.

RISK OF INTRODUCTION AND TRANSFER OF ORGANISMS THROUGH AQUACULTURE

The recent development of the aquaculture industry in Canada has caused an increase in the number of exotic species introductions and in transfers of species of specific organisms to areas outside their natural range. A certification program for fish farms was established in 1988, following the adoption of the *Fish Health Protection Regulations* under the *Fisheries Act*. Despite the substantial economic benefits that have accrued from certification to fish farm operators who export their products, the main purpose of the program is to protect the health of native fish species. For facilities that successfully undergo compulsory sanitary inspections, certification of fish health guarantees the absence of diseases and parasites that are deleterious to salmonids. The certificate issued to establishments that pass the inspection process entitles them to export eggs, juveniles or spawners to other Canadian provinces and promotes importation by foreign firms.

To handle the growing number of applications for permits to transfer organisms between provinces and to import marine organisms, DFO drew up a *National Policy on Introductions and Transfers of Aquatic Organisms* in 1997. This policy recognizes three types of risks: an ecological risk from the possible introduction of organisms which, by serving as predators, competitors or prey of native species, may upset the ecological balance; a health risk from the introduction of pathogenic or harmful organisms such as bacteria, parasites or toxic algae; and a genetic risk, that is, a potential imbalance in the phenotypes present in a local population.

This policy will be applied by regional committees, which will conduct formal reviews of requests to transfer or introduce species. Although the policy was originally instituted to address the issue of transfers of living organisms between the provinces or via imports to Canada, it could also be applied to proposals to transfer organisms within a given province.

OCEAN DISPOSAL

Dredging displaces huge quantities of sediment, with potentially adverse consequences for the aquatic fauna at the disposal site. DFO is responsible for providing Environment Canada with knowledge and scientific tools for enforcing the applicable regulations and for monitoring dredging operations at sea. In 1994, a study was conducted on the impact of this human activity on the benthic habitat at the disposal site used for dredged sediment from Anse-à-Beaufils. This site near Percé in the Gaspé Peninsula was selected as being representative of small craft harbours in Canada.

A survey of the benthic communities at that site revealed that, two years after disposal, the benthic fauna still had not returned to its original state. Four groups of benthic invertebrates that belong to different taxonomic families and that have different feeding strategies had recolonized the environment at differing rates. For example, whereas the abundance of crustaceans had declined dramatically, the number of polychaetes had increased following the release of dredge spoil.

With the ultimate goal of establishing more efficient and cost-effective monitoring methods, a study is currently in progress to determine whether the biomass–abundance ratio could be

employed to gauge the severity of impacts from the disposal of dredged material, and also the extent to which the site has been recolonized by the original biological community. The findings could affect the time period that is recommended for the use of a particular disposal site.

Photo: Fisheries and Oceans Canada

Barge containing sediment dredged near a wharf. If the sediment complies with Environment Canada guidelines related to contamination, it will be discharged in open water.

TOXIC ALGAE MONITORING NETWORK DEDICATED TO PROTECTING HUMAN HEALTH

In Canada, the summer growth of several species of toxic and harmful algae poses a potential threat to public health and to the commercial and recreational harvesting of certain marine species.

Of the hundreds of phytoplankton species present in the St. Lawrence, close to a dozen are harmful, or even toxic. The dinoflagellate *Alexandrium tamarense* is the best known toxic species in the St. Lawrence. It naturally produces neurotoxins which prevent the normal transmission of nervous impulses in mammals. Molluscs that feed on these algae can accumulate dangerous concentrations of the toxins. In humans, the first symptoms of poisoning are tingling in the lips and numbness of the arms and legs. This type of intoxication is called Paralytic Shellfish Poisoning (PSP).

FIGURE 6-1 *Network of stations operated to monitor harmful and toxic algae.*

Since 1989, DFO has been operating a program to monitor the toxicity of harmful algae in the Estuary and Gulf of St. Lawrence. A network of 11 inshore stations, covering all of eastern Quebec, is used to track the natural occurrence of these harmful algae in the waters of the St. Lawrence (see Figure 6-1).

Sampling

At all the monitoring stations, algae are sampled weekly from May to October. A number of bivalve shellfish harvesting areas are closed periodically—a situation which also impedes commercial harvesting—whenever it is determined that bivalves have bioaccumulated toxins from harmful algae.

Through the monitoring program, rapid warnings can be relayed to the *Canadian Food Inspection Agency* and to mussel farmers and fishers about the potential occurrence of blooms of harmful algae. The program also provides a means of increasing our knowledge of the ecology of these algae and reporting the appearance of new types of harmful algae in our waters. In the long run, monitoring program data will be used to gain a better understanding of the spatial and temporal distribution of toxic algae and the environmental conditions that are conducive to blooms.

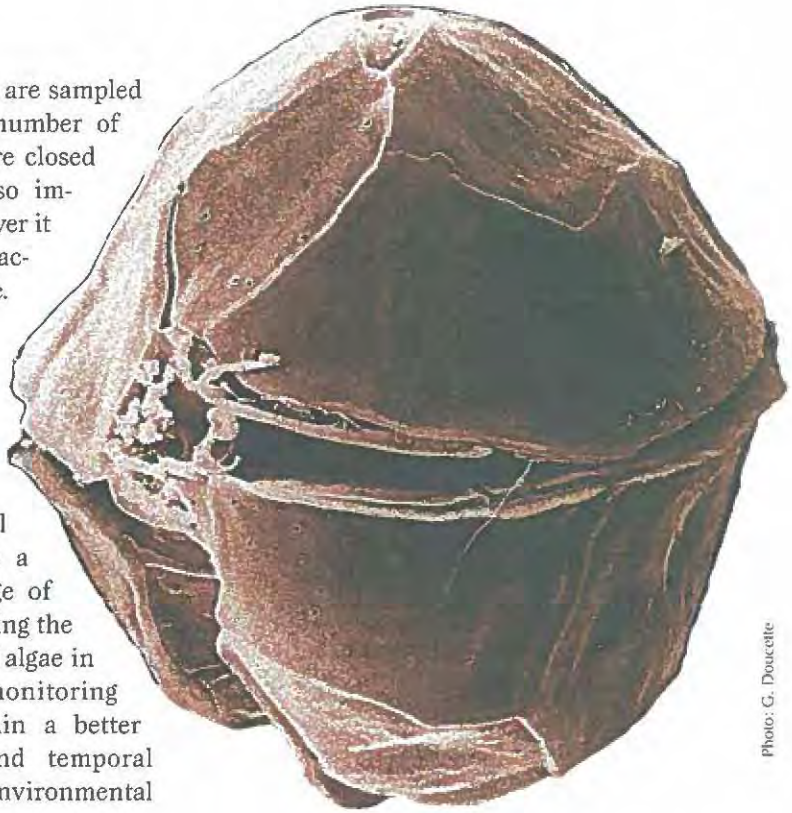


Photo: G. Doucette

Toxic alga Alexandrium tamarense *(Magnified 4000 x).*

Photo: M. Levasseur

In August 1996, exceptionally large concentrations of toxic algae were present in the St. Lawrence, giving the water a reddish colour. This phenomenon is known as a "red tide". The colour contrast of the photo has been enhanced.

Tools

FISH HABITAT MANAGEMENT INFORMATION SYSTEM

In 1993, DFO undertook the development of the *Fish Habitat Management Information System* (FHAMIS) to support its program to conserve and enhance coastal habitats of the St. Lawrence. The FHAMIS is a geographic information system which is used to manage and analyse available information on habitats, fishery resources and uses of the environment.

The marine environment of the St. Lawrence has been divided into eight coastal zones, extending from Île d'Orléans to the Gulf of St. Lawrence (see Figure 6-2). In all these sectors, research has been conducted on the existing knowledge of the environment and its use by aquatic organisms, by drawing on the scientific literature and conducting surveys of fishers. Field surveys have also been completed at given sites to obtain precise information for validating the data contained in the system.

The knowledge thus acquired has been grouped according to three broad themes: *Resource*, *Habitat* and *Use*. The *Resource* theme comprises information on the activities and life stages of aquatic organisms (both plants and animals). Information assembled under the *Habitat* theme can be used to provide a picture of the habitats suitable for resources in all zones studied. Finally, data on socio-economic activities are compiled under the *Use* theme.

The FHAMIS is particularly useful in the context of habitat impact assessments and environmental emergencies. It is designed not only to manage large volumes of marine environmental data, but also to perform analyses and produce output in cartographic format. For example, the system can produce maps indicating the vulnerability of coastal habitats to oil spills. It can also be harnessed to support habitat restoration and enhancement projects, along with the development of strategies for Integrated Coastal Zone Management.

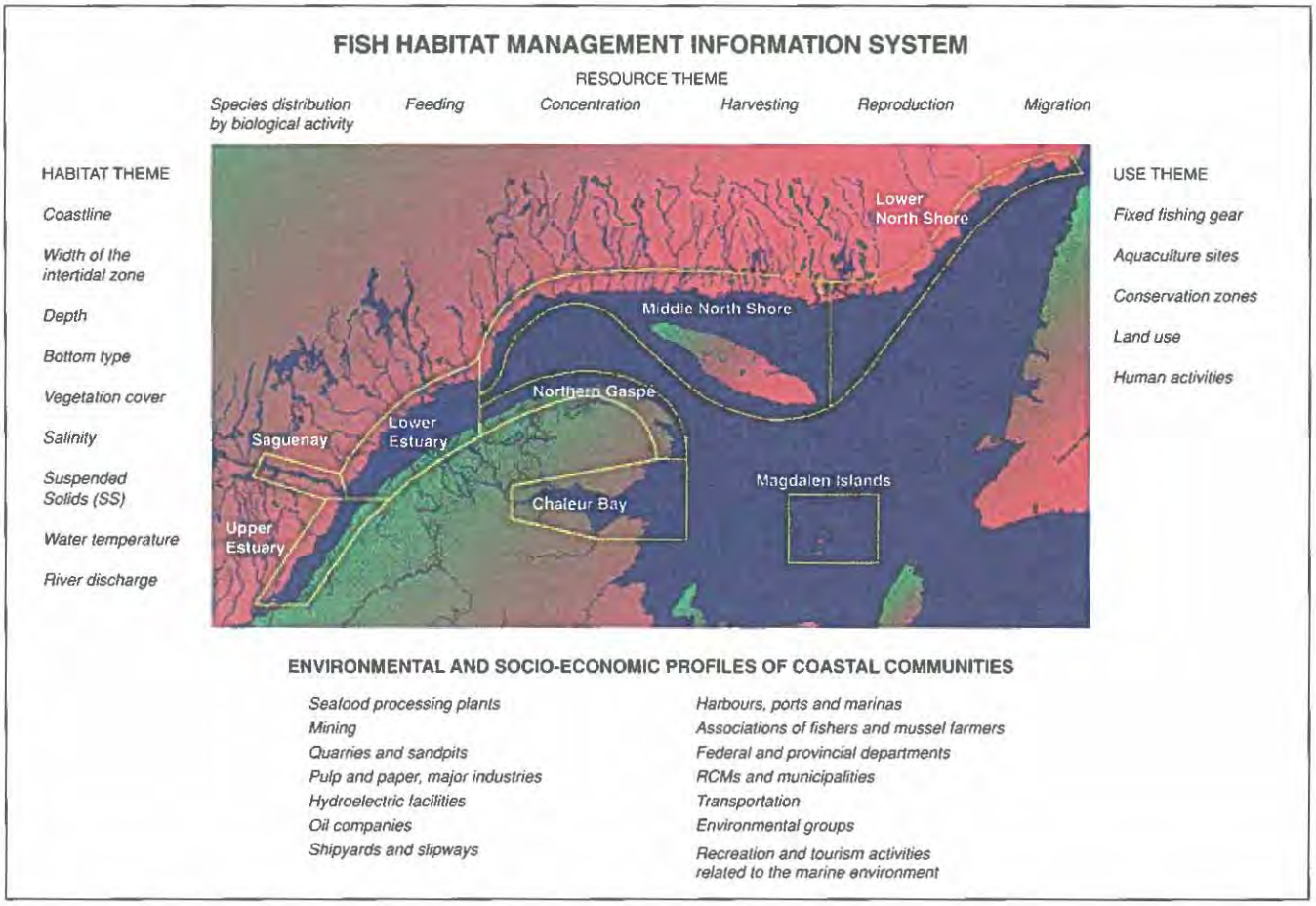


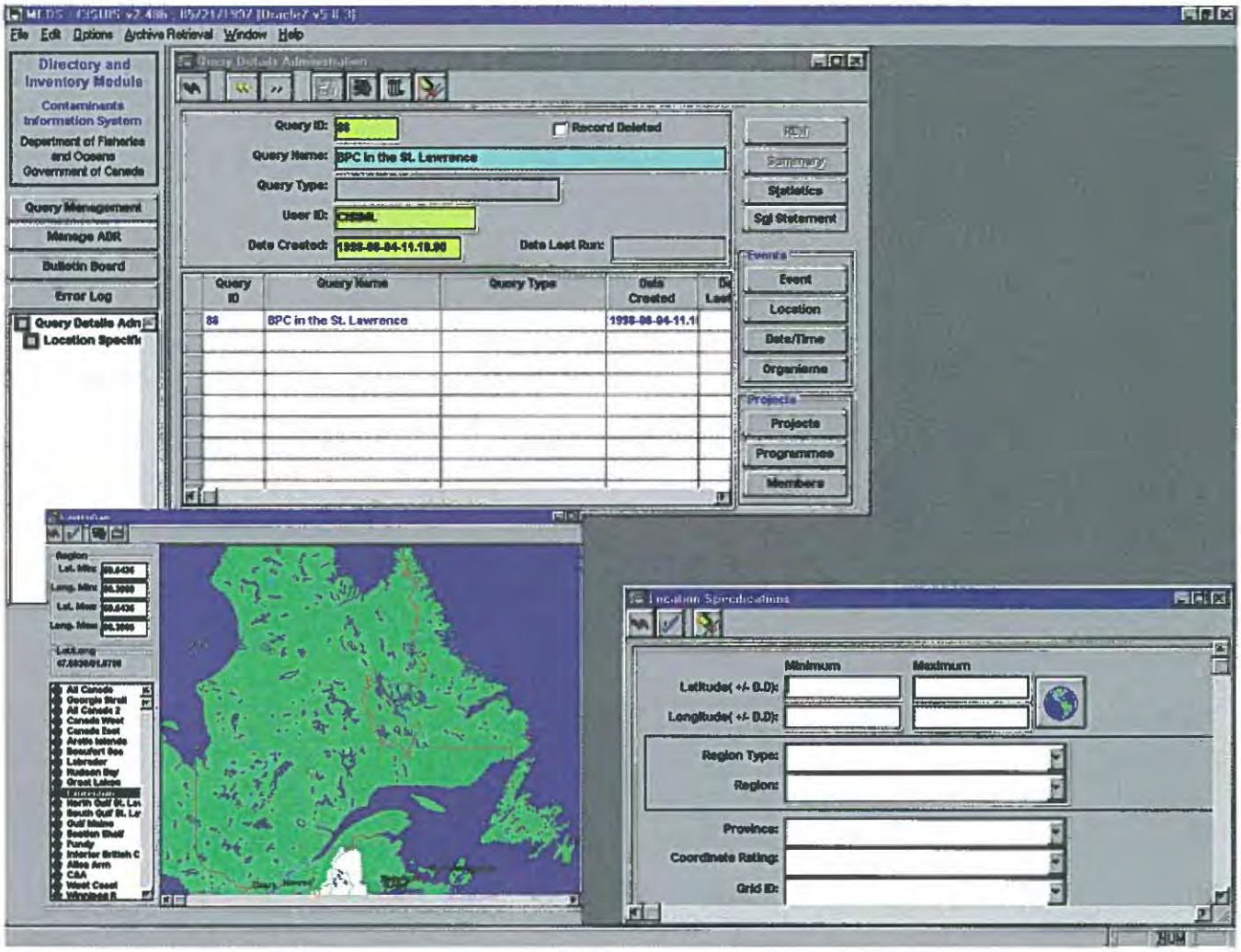
FIGURE 6-2 *Coastal zones and parameters covered in the Fish Habitat Management Information System.*

NATIONAL CONTAMINANTS INFORMATION SYSTEM

DFO's *National Contaminants Information System* (NCIS) is a computerized bank of data and information on toxic chemicals found in fish, other aquatic life and their habitats in Canada.

System users can access the data bases through various personalized applications that simplify data input and extraction.

The system is founded on the premise that different people have different information needs. It is versatile and can handle queries for administrative information about projects and the people responsible for them, requests for summaries of archived data and requests to access raw data. The data bases in the system will eventually be accessible via the Internet, enabling all interested users to submit queries.



Standard screen in the National Contaminants Information System.

OCEANOGRAPHIC DATA MANAGEMENT SYSTEM

Why manage oceanographic data? Oceanographic data comprise all of the physical, chemical and biological parameters that scientists measure at sea during research cruises. The measurements they take include temperature, salinity, current speed and direction, as well as dissolved oxygen content and nutrient levels. Biological data such as the chlorophyll *a* concentration, which is routinely used as an index of phytoplankton biomass, are also compiled.

Oceanographic data must be carefully managed and safeguarded because they are highly valuable. The cost of acquiring this information at sea is very high, and lost data items cannot be replaced. In short, oceanographic data could be described as priceless.

That is why MLI has been working on developing an *Oceanographic Data Management System* (ODMS) since 1994. This system catalogues and archives data in a secure manner. Eventually all of the historical oceanographic data on the St. Lawrence will be contained in the system. In a system of this type, performing data searches is just like consulting a library catalogue. The system will also be accessible via the Internet.

Photo: J.-F. St-Pierre

Ship used by oceanographers.

Over time, the system contents will gradually be expanded and enriched, providing a highly valuable repository of oceanographic data. This will make it easy to obtain data series for such purposes as climatic and environmental studies.

COASTAL AND OCEAN WATER LEVEL INFORMATION SYSTEM

The *Coastal and Ocean Water Level Information System* (COWLIS) was jointly developed by DFO's Canadian Hydrographic Service and the company Services maritimes INFOMAR Inc. Since the early 1990s, this system has been providing information on water levels for the sector between Montreal and Sept-Îles.

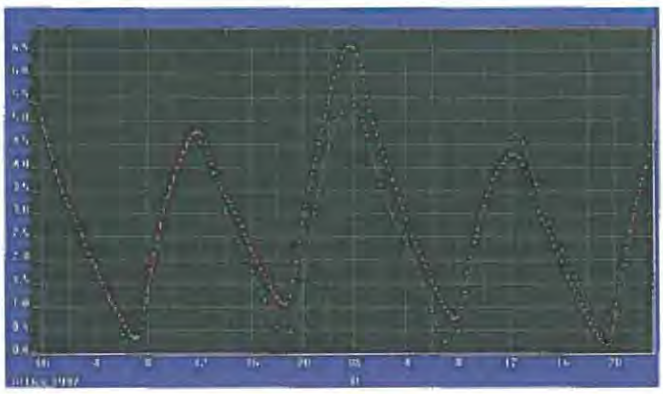
The network consists of 18 measurement stations that transmit observations by radio to five receiving stations scattered throughout the region. Each of these towers is linked to five micro-computers (local servers) which receive the data and send them to a central processing computer based at MLI. The data are then verified and forwarded to the Canadian Coast Guard's Marine Communications and Traffic Services and to St. Lawrence Seaway users who subscribe to the system, for example, commercial shippers. Information from this network helps to ensure marine transportation safety and optimize the cargoes carried by ships and ship transits. Given that for large ships every 2.5 cm increase in draft can represent a 150 tonnes increase in cargo (or 13 containers), worth approximately $26 000, it is easy to understand why ship owners would be keen to optimize their cargoes. That is why it is so important to obtain precise water level measurements.

WATER LEVELS

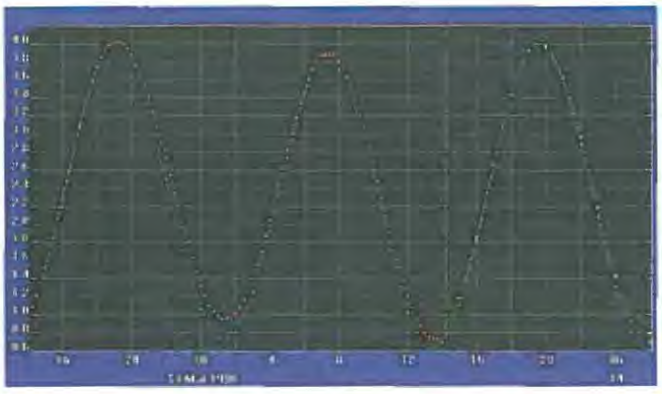
In these examples chosen to illustrate the type of data provided by the *Coastal and Ocean Water Level Information System*, the red lines represent the water level data recorded by the system, while the green lines are predictions based on tide tables. The turquoise lines correspond to forecasts computed by mathematical models incorporating the measurements recorded over the previous few hours.

Water level data recorded at the Quebec City station, December 30, 1997
December 30, 1997 is a memorable day for Quebec City residents. The unusual meteorological conditions that prevailed that day, coupled with the winds generated by the low pressure system (a low of 973 mbar was reached), caused an abnormal increase in water levels on the St. Lawrence and subsequent flooding of Dalhousie Street. The data recorded at the Quebec City station were more than 1.5 metres higher than the values predicted by the tide tables.

Water level data recorded at the Rimouski station, March 13, 1998
The data from the Rimouski station show what a user would see on screen, when consulting the system in real time. The vertical yellow line represents the actual time the image was captured. There are no values to the right of this vertical line because no data had been recorded yet. In addition to tide table predictions, mariners can access the results of water level forecast computations generated by the system.



Quebec City station, December 30, 1997.



Rimouski station, March 13, 1998.

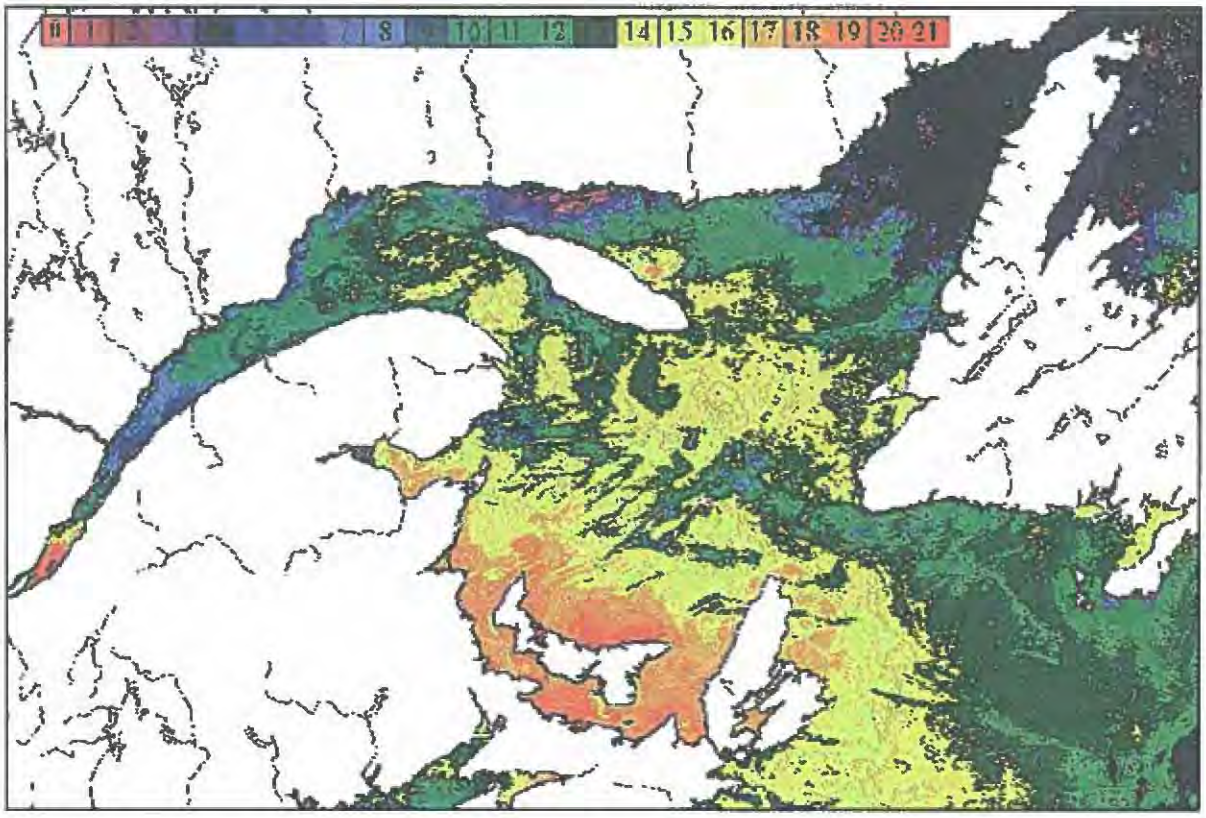


FIGURE 6-3 *Satellite image of sea surface temperatures in the Estuary and Gulf of St. Lawrence in July 1996. The temperature values associated with the different colours are shown in the scale in the upper part of the image.*

SATELLITES FOR A FAR-REACHING VIEW OF THE ST. LAWRENCE

In an ecosystem as vast as the St. Lawrence, major regional and temporal differences exist which result from interactions between the tides, the bathymetry, the wind and freshwater discharges, among other factors. The traditional tools of measurement used by oceanographers, including ships and drifting buoys equipped with measuring instruments, could not possibly capture the full complexity of the St. Lawrence environment. New measurement techniques are therefore required, including the use of images from Earth-observing satellites. From their vantage point more than 800 km above the Earth's surface, satellites can observe huge expanses of ocean in a time interval of just minutes. In addition, satellite overpasses provide imagery spanning a period of several hours to several days, thereby permitting frequent observations of the physical and biological processes occurring in the St. Lawrence for instance. Compilations of images over time can thus be employed in studying seasonal processes and, on a greater time scale, climate change.

A satellite-image receiving station was installed at MLI in 1994. Within an hour of every satellite overpass, sea surface temperature maps can be produced from the satellite-derived data (see Figure 6-3). These images, which can be used to observe spatial variations in sea surface temperature, are suitable for other applications as well, such as measuring surface currents. By analysing sequences of satellite images, experts can track changes in the meanders and eddies which frequently form in the Estuary and off the Gaspé Peninsula, and observe major cold water upwelling events caused by the wind along the North Shore of the Gulf and Chaleur Bay. MLI's receiving station can also capture images from another type of satellite which monitors changes in the colour of the sea associated with the presence of microscopic algae, thus permitting estimation of the quantity of phytoplankton drifting in the surface layer. The combined use of imagery from these two types of satellites enables scientists to investigate and increase present understanding of the impact of physical processes, notably temperature and currents, on the abundance of plankton organisms.

Current and Future Initiatives

DFO'S TOXIC CHEMICALS PROGRAM

It is increasingly being recognized that an ecosystem approach is critical for solving environmental problems in keeping with the principles of natural resource sustainability. Under DFO's *Toxic Chemicals Program*, initiated in 1997, special attention has been devoted to integrated approaches that promote multidisciplinary collaboration among scientific experts, clients and partners. More specifically, the focus has been on determining the fate of toxic chemicals in specific aquatic ecosystems, as well as their effects on fish and fish habitat.

The main research priorities of DFO's *Toxic Chemicals Program* are as follows:

- evaluate the biological effects of toxic chemicals;
- determine the fate of toxic chemicals;
- determine the spatial distribution and temporal trends;
- study the effects of industrial and municipal effluents and major industrial developments;
- identify the effects of pesticides, medical and agricultural products and previously unrecognized chemicals;
- manage data and information.

Photo: H. Welch

View of a coastal zone.

THE OCEANS ACT

Canada's *Oceans Act*, enacted in January 1997, establishes a new co-operative management approach for the conservation and protection of marine ecosystems. This approach is based on the premise that activities in the marine environment and management of those activities must be founded on collaboration among governments and stakeholders. To this end, in April 1997, DFO launched three key initiatives to support the management strategy for marine ecosystems: 1) the development of Integrated Coastal Zone Management plans; 2) the establishment of Marine Protected Areas and 3) the adoption and application of guidelines, criteria, and quality standards for the marine environment which are aimed at preserving and protecting the health of marine ecosystems.

Integrated Coastal Zone Management

Integrated Coastal Zone Management is an integral part of the management process for marine ecosystems, as defined in the *Oceans Act*. The emphasis in management is on the coastal zone, which is exposed to the greatest stresses and is an environment of concern for most stakeholders. Integrated Coastal Zone Management is first and foremost a process of co-ordination, consultation and planning aimed at consensus-based decision making. It encourages stakeholder participation in community decisions with support from the various levels of government and their agencies when needed.

In co-operation with all stakeholders concerned, particularly the partners of the *St. Lawrence Action Plan*, DFO will develop or play an active role in the development of integrated management plans for the coastal zone of the St. Lawrence marine environment. The Department will also devise management tools to enable local stakeholders to implement and follow up on such plans. Under this program, the Department will also harness the efforts of local collaborative groups, like the ZIP committees established in the Priority Intervention Zones along the St. Lawrence (see the *Community Involvement* chapter). These local committees will be called upon to play a critical role in

Photo: H. Welch

View of the sea bottom.

rallying support for the preparation and implementation of Integrated Coastal Zone Management plans. Over and beyond its involvement in the Integrated Coastal Zone Management initiative, the Department will participate directly in the implementation of Ecological Rehabilitation Action Plans (ERAPs) for marine ecosystems. DFO's intervention will be especially important in this regard, and may include coastal zone improvement projects, as well as fish habitat restoration and enhancement activities.

Establishment and management of Marine Protected Areas

A Marine Protected Area (MPA) is a marine territory which has been designated in order to conserve and protect one or more of the following marine components: commercial or non-commercial fishery resources, including marine mammals and their habitats; endangered or threatened marine species and their habitats; unique habitats; marine areas of high biodiversity or biological productivity; and any other marine resource or habitat as is necessary to fulfil the mandate of the Department of Fisheries and Oceans.

In the spring of 1997, an approach proposed by DFO for the creation of Marine Protected Areas was submitted to public review. Over the ensuing months, the Department drafted a policy and a national framework for the establishment and management of MPAs. A regional process document based on the national framework has also been drawn up and will serve as a reference tool for selecting areas of interest, and for nominating and designating MPAs. The participation of stakeholders and the general public is an integral part of all stages in the process. Implementation of DFO's *Marine Protected Areas Program* will begin with a learning phase consisting of pilot MPA projects which will be undertaken to test the national framework and the regional process. Likewise in the regional context, efforts are to be made to harmonize federal and provincial government initiatives for marine protected areas under the *St. Lawrence Action Plan*.

Marine Ecosystem Health

Marine Ecosystem Health is defined with respect to environmental standards designed to preserve and protect the integrity and quality of these ecosystems. This means that decisions related to planning and managing activities in estuarine, coastal and marine waters must take ecosystem health into consideration.

Tools for assessing Marine Ecosystem Health will be created to support the implementation of Integrated Coastal Zone Management plans and the establishment of MPAs. Assessments of the health of marine ecosystems must consider the contamination of resources and habitats, the status of harvested populations and temporal changes in the ecosystem being studied. Marine Ecosystem Health indicators and objectives incorporating these different aspects will be developed during the pilot projects, which will be started up gradually and will draw on various types of expertise.

THIRD PHASE OF THE ST. LAWRENCE ACTION PLAN

The *St. Lawrence Action Plan* is a joint federal–provincial program aimed at protecting, restoring and preserving the entire St. Lawrence system in order to reclaim it for the benefit of residents, in keeping with the principles of sustainable development. The Department of Fisheries and Oceans was actively involved in Phases I (1988-1993) and II (1993-1998) of the *St. Lawrence Action Plan.*

DFO will also participate in Phase III of the action plan, particularly the components related to the recovery of the St. Lawrence beluga population, the implementation of Integrated Coastal Zone Management projects and the establishment of Marine Protected Areas, the preservation and restoration of marine habitats, as well as the monitoring of marine ecosystems and chemical contaminants in those ecosystems. Various environmental aspects related to navigation on the St. Lawrence, notably integrated management of dredging operations, protection against shoreline erosion, introduction of non-indigenous species in ships' ballast water, and water level forecasts for the St. Lawrence, will be addressed as part of the Department's efforts to meet the objectives of the *St. Lawrence Action Plan*. At DFO, these activities will require the involvement of the Science, Oceans and Coast Guard sectors.

Sustained support will also be provided for local initiatives designed to protect, restore and enhance marine habitats and resources. DFO believes that the success of a program like the *St. Lawrence Action Plan* is greatly dependent on the direct involvement of local stakeholders, notably coastal communities.

THE ST. LAWRENCE OBSERVATORY

In 1997, DFO undertook to develop the *St. Lawrence Observatory*, a project intended to bring together the public (for example, federal and provincial departments, universities and municipalities) and private sector (for example, consulting firms, shipping companies and fishers) organizations involved in collecting environmental data on the St. Lawrence. The goal of this initiative is to set up an integrated information system of environmental data to permit the rapid and efficient utilization of data from all participating partners. The system will permit better understanding, prediction, analysis and modelling of changes occurring in the St. Lawrence. Although the *St. Lawrence Observatory* is a pilot project, the concept could eventually be adopted in other regions of Canada or Canada-wide.

Photo: J. Houle

Sampling with a bottom trawl.

GLOSSARY

Ballast water: water carried in a ship's ballast tanks which can be emptied and filled as needed to ensure the ship's buoyancy and stability.

Benthos: all the organisms living on the bottom of a natural aquatic environment.

Biodiversity: number of species present in a community or other unit and their relative abundance.

Biomass: total mass of plants or animals in a biotype at a given time, expressed per unit area or volume.

Chlorophyll *a*: pigment responsible for photosynthesis which gives plants their green colour.

Compensation for loss of habitat (according to the *Policy for the Management of Fish Habitat*): the replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production by artificial means in circumstances dictated by the social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitats for Canada's fisheries resources.

Competition: use of the same resource by two or more living organisms, when the resource is present in insufficient supply for the combined needs of the species.

Dinoflagellate: microscopic alga characterised by the presence of two whiplike flagella.

Effluent: generally applies to any run-off from a pollution source.

Fish (according to the *Fisheries Act*): includes fish, shellfish, crustaceans, marine animals and any parts of fish, shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.

Fish habitat (according to the *Fisheries Act*): spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

Fisheries resources (according to the *Policy for the Management of Fish Habitat*): fish (as defined in this glossary) stocks or populations that sustain commercial, recreational, or native fishing activities of benefit to Canadians.

Genotype: genetic composition of an individual that is determined by genes inherited from its parents.

Geographic Information System: group of principles, methods, instruments and georeferenced data used to capture, store, extract, measure, transform, analyse and map phenomena and processes in a given geographic area.

Marine sediment: all of the natural particles (muds, clays, shells and dead organic matter) transported on the sea bottom.

Mitigation (according to the *Policy for the Management of Fish Habitat*): actions taken during the planning, design, construction and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats.

Neurotoxin: toxin that specifically targets nerve tissue.

No net loss (according to the *Policy for the Management of Fish Habitat*): a working principle by which the department strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented.

Non-indigenous species: plant or animal species introduced from another area, i.e. that is not native to a particular ecosystem.

Pathogen: organism that can cause lesions or disease.

Phenotype: morphological and physiological features of a living organism which result from the interaction between its genotype and the environment in which it lives.

Phytoplankton: all plankton organisms belonging to the plant kingdom.

Plankton: all animal (zooplankton) and plant (phytoplankton) organisms, generally of very small size, which live suspended in the water column.

Proponent: person or organization who initiates a project and sees it through to completion.

Protection (of habitats) (according to the *Policy for the Management of Fish Habitat*): prescribing guidelines and conditions, and enforcing laws for the purpose of preventing the harmful alteration, destruction or disruption of fish habitat.

Spawning ground: place where the female fish lays its eggs and the male fertilizes them.

Taxon: any systematic unit (species, genus, family, etc.).

Upstream: section of a water body between a given point and the source.

Water column: vertical section of water from the sea surface to the bottom.

Zooplankton: group of plankton organisms belonging to the animal kingdom.

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