ST. LAWRENCE CENTRE

THE UNFOLDING STORY OF THE ZEBRA MUSSEL IN THE ST. LAWRENCE RIVER

Is the St. Lawrence River a hospitable environment for this exotic species?
Is this newcomer likely to cause serious problems?

These concerns have been at the heart of the Zebra Mussel research and monitoring program since the species first appeared in the St. Lawrence River. A research team from the St. Lawrence Centre of Environment Canada has attempted to find the answers to these questions, and to come up with some general findings.

An Invasive Mussel

The most striking characteristics of the zebra mussel are its tendency to congregate by the tens, even hundreds, of thousands per square metre, and its extraordinary capacity for invading aquatic habitat. A European migrant, this little freshwater mollusc (see photo opposite) was accidentally introduced into the Great Lakes in discharged ballast water in 1986, where it has achieved densities of 300 000 per m^2 in places (1). Its presence in the fluvial stretch of the St. Lawrence River, the northernmost extent of its range, was confirmed three years later. The mussel spread as far as the Montmagny Islands before the salinity of the water acted as a natural barrier to its further downstream expansion. In 1996, scientists of the

Photo: B. Cusson and D. Labonté

St. Lawrence Centre (SLC) of Environment Canada confirmed the presence of the zebra mussel in the Richelieu River, a tributary of the St. Lawrence and the northern outlet of Lake Champlain, which connects to the Great Lakes (2).

Already tagged with a reputation as a nuisance species, the zebra mussel is a cause for concern because the

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problems it engenders are serious. It fouls and blocks conduits (water intakes, pipelines, tunnels), corrodes ship hulls, covers wrecks, causes loss of habitat, and changes the structure and functioning of ecosystems. Unfortunately, solutions to these problems are few and not very effective, so that the cost of the invasion runs into millions of dollars every year, chiefly for cleaning and control measures (3). It is not surprising, then, that SLC researchers wanted to take a closer look at this exotic invader.

Growing Abundance

In an attempt to answer the questions posed earlier, SLC researchers analysed the abundance and examined the dispersion and colonization dynamics of the zebra mussel in the river. Zebra mussel density data for the river (Table 1), for all age classes, agree with the data reported in the scientific literature. Thus, average densities ranging from 1500 to 4000 per m^2 were observed in the St. Lawrence River in 1994 and 1995 (4), reaching a peak of about 20 000 per m^2 in the Soulanges Canal (5). Our own data show the same range of values, peaking at 20 620 mussels per m^2 at the Bassin Louise marina in 1992, and reflect the mussel's increasing abundance over time, particularly striking at the Beauharnois, Bécancour, and Île d'Orléans stations.

As to whether the zebra mussel population in the river will grow to achieve the densities observed in the Great Lakes, consider the following: a) the zebra mussel has been in the river for ten years now, b) population densities are comparable to those of other species in the river, like the gastropod *Bithynia tentaculata*, another foreign species introduced over 100 years ago (6,7), and c) the zebra mussel can reach densities of hundreds of thousand per m^2 less than five years after its introduction into a favourable environment such as the Great Lakes (1). We have to acknowledge that the St. Lawrence River, with the exception of certain habitats, is not the most favourable environment for the zebra mussel. Thus, it can be assumed that the zebra mussel will not thrive in the St. Lawrence to the extent that it has in the Great Lakes.

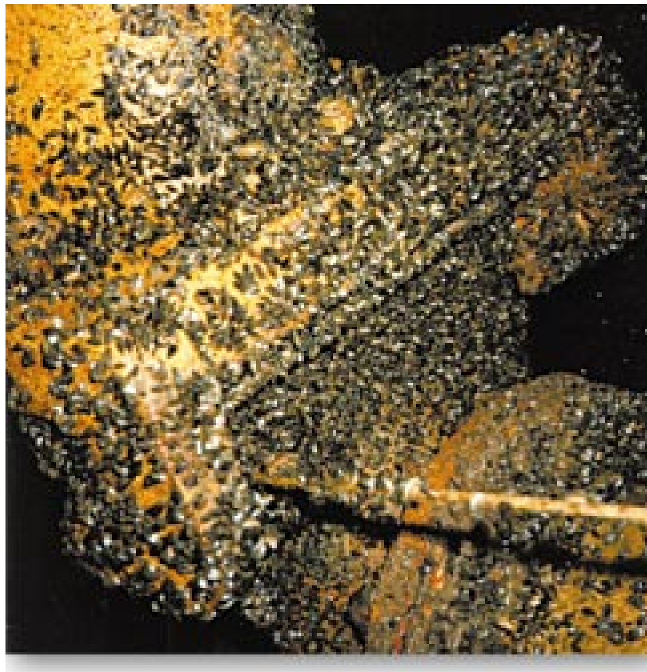

PHOTO: B. CUSSON
AN UNDERWATER CONDUIT INFESTED WITH ZEBRA MUSSELS IN THE ST. LAWRENCE RIVER JUST OFF MONTREAL, QUEBEC.

Table 1 Zebra mussel abundance on rocks and dock walls at various sites in the St. Lawrence River between 1991 and 1998

STATIONS	1991	1992	1996	1998
Cornwall	0		841	
South Lancaster		41	110	
Beauharnois	9	22	1 131	
Pointe à Péladeau	0	805		
Boucherville	1		21	
Tracy	6		173	
Île Lapierre	1		4	
Île aux Sternes	0		3	
Bécancour harbour	18	1 631	10 035	
Portneuf	0		14	34
Bassin Louise (Quebec City)		20 620	2 486	9 512
Lévis dock	6		224	157
Île d'Orléans		287	454	1 091

Note: Values represent average numbers of mussels per square metre, based on 9 to 12 study quadrats at each station (see map for locations).

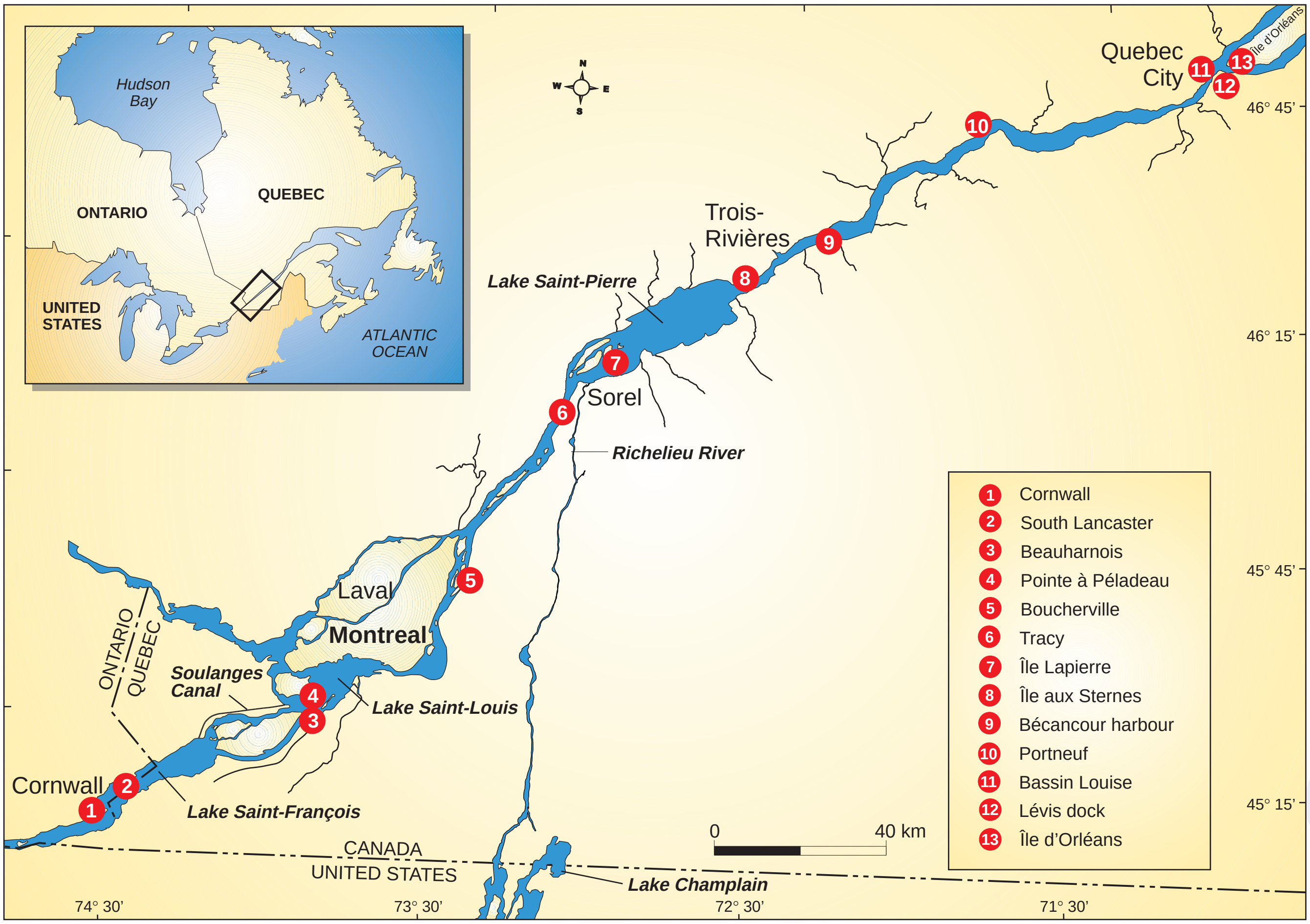

Figure 1 Freshwater fluvial stretch of the St. Lawrence River

Understanding to Improve Monitoring

Young Drifters

Females can produce from 30 000 to 40 000 eggs each per year, thus yielding great numbers of larvae. At that rate, fertilization necessarily takes place externally in the ambient water. Once hatched, zebra mussel larvae drift with the current for anywhere from 7 to 21 days, going through several metamorphoses before settling on a hard substrate. Four stages of larval development have been identified:

a) Stage D, in which the larva sports a thin, unadorned shell.

b) The Umbonal stage, in which the first ornamental markings appear on the hardening shell.

c) The Pediveliger stage, when the swimming organ, or foot appears.

d) The Plantigrade stage, when the larva, like those of marine mussels, develops filaments (byssus) to anchor itself to the substrate.

Photo: F. Delisle

The Umbonal stage of a Zebra Mussel larva. The presence of the first two stages at a given station confirms that reproduction occurs in the river.

To test for the presence of zebra mussels in a body of water and determine when colonization is most likely to occur, the simplest and quickest method is to monitor the abundance of larvae. An intensive study was conducted between June 1 and October 31, 1994, at various stations along the St. Lawrence River [8]. By way of example, Figure 2 shows the weekly variations in the average number of larvae per litre for each stage of development at the Les Cèdres hydro-electric plant located on the north shore of the river near Vaudreuil. Three main findings emerge from this study:

a) Eggs are laid and larvae are present from mid-June to mid-September, with a peak in abundance in early July. The same situation prevails in the Richelieu River [2].

b) Peaks in abundance for each stage are staggered, so that the Stage D and Plantigrade peaks are three weeks apart (July 4 to July 25). This corresponds quite closely with the larval development time suggested by other studies.

c) Numbers drop considerably as the larvae develop, from over 40 per litre in Stage D to 0.6/L in the Plantigrade stage. This suggests either that mortality is high or that large numbers of larvae drift downstream with the current.

All this information is invaluable to the application of measures to control colonization; of these, chlorination is among the most popular [1]. It is important to apply this method at the right time if larvae are to be eliminated, in the case of an initial colonization, or to inhibit larval recruitment and growth in established infestations, while at the same time respecting regulations for the type of chlorination and chlorine concentration limits. But what are the natural means by which this species is controlled in the river?

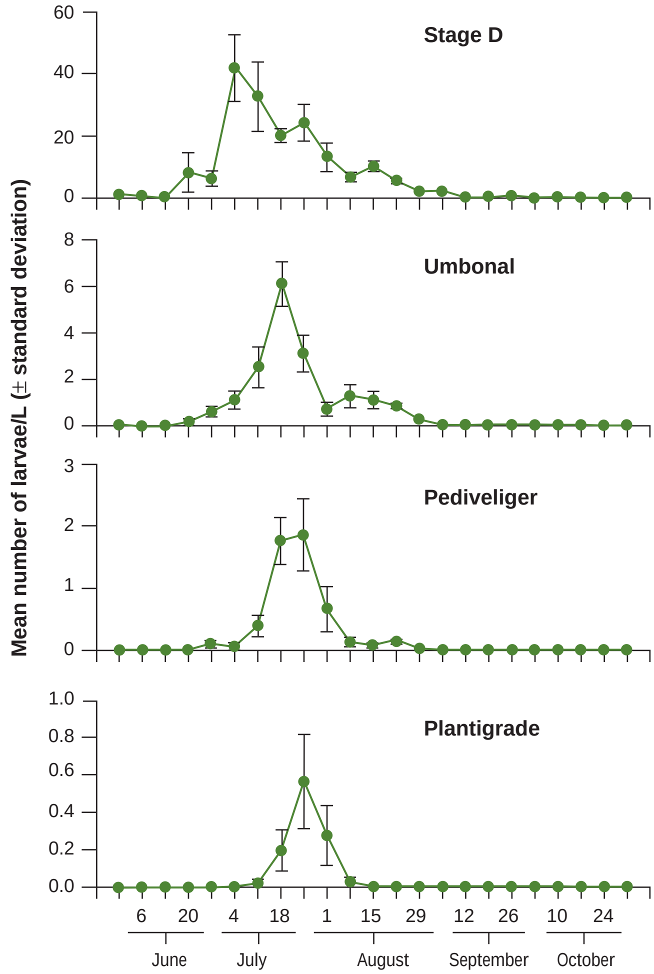

Figure 2 Seasonal variations in abundance of the different larval stages of zebra mussel in the St. Lawrence River

Natural Factors Controlling Zebra Mussel Abundance

All species are subject to natural control, either by competition for limited food resources or by natural enemies. The food resources available to the zebra mussel in the river (phytoplankton, protozoans and bacteria) are plentiful, and predators (birds, fish, crayfish, leeches) are not very effective. Under these conditions, and given its very high rate of larval production, a zebra mussel's infestation in the St. Lawrence would be expected. Yet we have just seen that observed abundance levels to date are relatively low. What accounts for this?

Chemically, the waters of the St. Lawrence meet the zebra mussel's needs for growth and survival, particularly in terms of calcium content (a highly significant parameter for the composition of mollusc shells), which exceeds the threshold value for the species (Table 2). Chemical considerations aside, then, we turn to physical parameters. It does indeed appear that the dispersal of large numbers of larvae on the current to the salt waters of the estuary constitutes a natural control mechanism for this nuisance species. During the larval abundance period, current speed becomes a key factor in zebra mussel population dynamics. There are sections of the river where the current is strong (> 1 m per second) — in rapids and the main channel, for example — and sections where the water moves more slowly, as it does along the shores of the fluvial lakes. These differing, sometimes alternating sections offer habitats of variable suitability for zebra mussel colonization. Moreover, with average current speeds ranging from 0.4 to 0.8 m/s (typical of the fluvial St. Lawrence lakes and the main channel, respectively), larvae could be drifting from 250 to 500 km in one week: the distance between Lake Ontario, the river's source, and the

Table 2 Physical and chemical conditions essential to mussel growth, and percentage of sites studied (n = 182) in the river meeting these requirements in summer

CONDITIONS	Zero growth	Percentage	Optimum growth	Percentage
Temperature (°C)	< 8 and > 30	0	17–24	100
Conductivity (µS/cm)	< 36	0	> 110	100
pH	< 7.4	3	7.9–8.0	13.3
Calcium (mg/L)	< 11	0	> 28	83
Current speed (m/s)	> 1.5	3	< 1.0	68

eastern end of Île d'Orléans, where salt water begins and zebra mussels meet their end, is about 400 km!

A colonization monitoring program set up in 1990, when the zebra mussel first appeared in the river, has demonstrated the effect of the current, using the navigational buoys set out along the fluvial stretch of the river between Cornwall and Île d'Orléans. The percentage of buoys colonized falls off sharply once current speed exceeds 0.75 m/s (Figure 3).

Thus, wide dispersal and delayed settling probably explain why the zebra mussel is less abundant in the river than its breeding potential might otherwise allow.

Given the current state of research, what we know about the species can be summarized as follows: the zebra mussel is established in the river and is likely to remain. There is no prospect of a crisis at present or in the near future, but caution remains the watchword. Too few studies have been done in fluvial environments to be able to pass judgment on the species' impact on either the environment or the economy, and further research is essential. Even though colonization in the river does not appear to be as serious today as it is in the Great Lakes, we would do well to remember that we are dealing with a species with a dread reputation as a pest. Abundance monitoring therefore remains imperative.

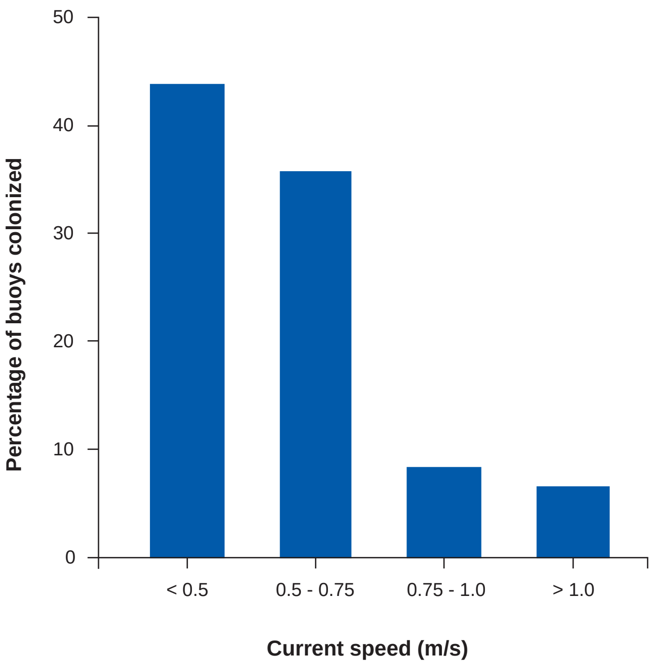

Figure 3 Colonization rate by zebra mussel as a function of current speed

The Zebra Mussel as Pollution Monitor

Given that the zebra mussel is now part of the aquatic life of the St. Lawrence River, perhaps some benefit can be drawn from its presence. Its abundance, longevity, sedentary lifestyle as an adult (anchored to a substrate), its high filtration rate (≈1 L/day/individual) and especially its ability to concentrate certain chemical contaminants (e.g. metals, PCBs, PAHs and organo-metallic compounds) make it an ideal choice for pollution monitoring programs in aquatic environments. Contaminant accumulations in the soft tissues of the zebra mussel reflect not just the local presence of these substances in the environment, but also their bioavailability — that is, their ability to adopt a chemical form that organisms can assimilate.

Metal contamination, especially by organic tin compounds like tributyltin (TBT), a particularly toxic compound for many molluscs and other marine and freshwater invader species, has been the subject of university research projects on which St. Lawrence Centre researchers have collaborated. These substances, which are ingredients of marine paints and many plastic polymers, such as PVC, have been strictly regulated since the 1980s, but their concentrations and bioavailability in the fluvial environment of the St. Lawrence were not understood. A recent study of TBT concentrations in the soft tissues of zebra mussels at various stations in the St. Lawrence [9] showed that the substance was present at 9 out of 11 of the stations tested (Figure 4). Concentrations (in nanograms of tin per gram wet weight), which were well above the detection threshold (1 ng/g), varied by two or three orders of magnitude (i.e. differences of 100 to 1000 times) between stations (note that the scale on the vertical axis of Figure 4 is logarithmic).

A research team from the SLC has achieved a first in the field of ecotoxicology by analysing a series of biochemical responses in the zebra mussel as indicators of contamination [10]. The results of these "biomarker" tests reflect disturbances in metabolism, which is an important physiological line of defence for organisms exposed to chemical contaminants (examples are rupture of genetic material, hormonal changes in reproductive functioning, and heavy energy investment in detoxification mechanisms). Five biomarkers, constituting a single index (see sidebar), revealed significant variations in potential toxicity along the fluvial stretch of the river (Figure 5).

Index values of the effects of contamination were highest at stations located in harbours (Cornwall, Bassin Louise, Lévis dock) or close to heavily industrialized sites (Beauharnois, Boucherville, Tracy), contaminated to varying degrees. Conversely, stations relatively far from known sources of contamination (Île aux Sternes, Portneuf) posted the lowest index values.

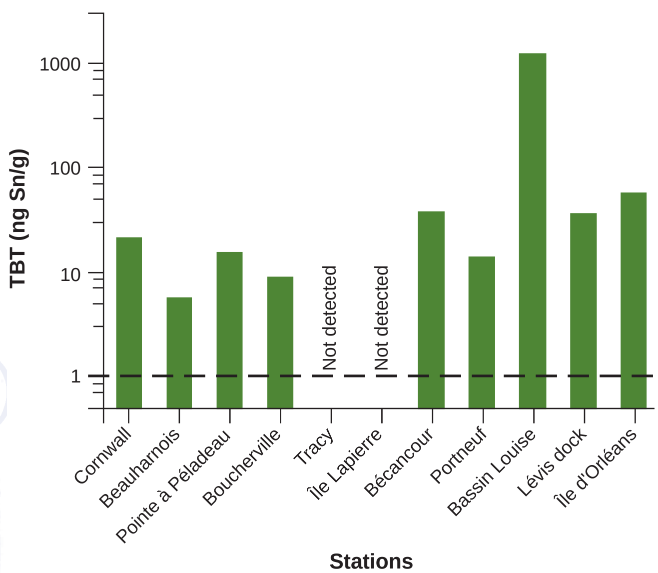

Figure 4 Accumulated tributyltin in the tissues of St. Lawrence zebra mussels in 1996

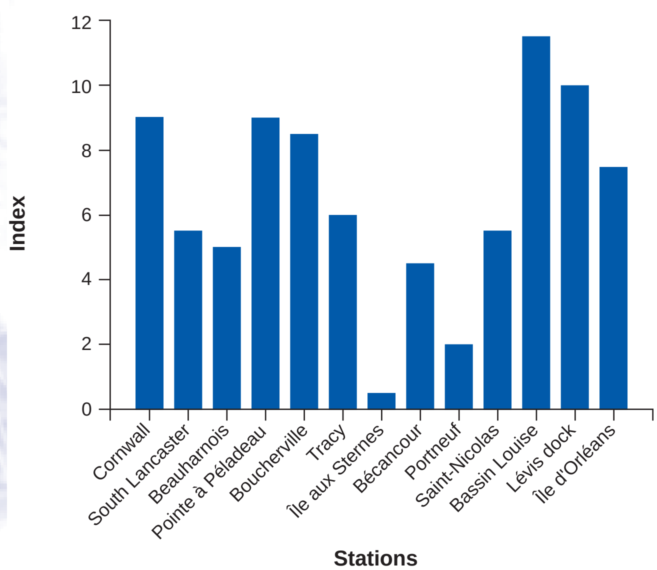

Figure 5 Biomarker index values at different stations in the St. Lawrence River

The Biomarker Index and the Zebra Mussel

The biomarker index is based on the responses to each of the biomarkers used in the study of the effects of contamination in the zebra mussel [10]. The index value is relative and is determined from a rating ascribed to each station significantly different ($p < 0.05$) from another. Thus, the first station in a list of significant pairings is rated 0. If the second station varies significantly from the first, it is assigned the rating 1; if the third varies significantly from both the second and first, it is rated 2, and so forth. When a station does not vary significantly from those following or preceding, it is assigned an average rating, calculated on the basis of its position in the list. This simple mathematical exercise is applied to each biomarker. The sum of the ratings for the five biomarkers for a given station constitutes the final index for that station. The lower limit of the index is zero, and the upper limit is determined by the number of stations and the number of biomarkers used. The lower the index value, the weaker is the response to the effects of contamination; in other words, the lower the toxicity potential. This means that the stations at Île aux Sternes and Portneuf are the least problematic. By comparison, those in the Bassin Louise marina and at the Lévis dock should be priorities for monitoring pollution effects.

The biomarker approach therefore is promising and ultimately may be integrated into a biological water quality monitoring program for the St. Lawrence. A great deal remains to be done, however, and work is continuing on both technical refinement of the biomarkers and on determining the usefulness of the zebra mussel as an indicator organism of the effects of pollution.

Other Introduced Species in the River

For at least the past century, 140 exotic species (algae, plants, molluscs, fish, etc.) have been introduced, either accidentally or deliberately, into the Great Lakes Basin of North America (11). How many of them are found at present in the St. Lawrence River? What are the risks of colonization and the adverse impacts on socio-economic activities and indigenous plant and animal communities? Our knowledge is still incomplete and too sketchy, particularly with respect to environmental impacts, to say whether the introduction of a species like the zebra mussel or its cousin the quagga mussel, or any other such nuisance species, is benign or not. Accordingly, a study program on the introduction of exotic species into the St. Lawrence River was included in the third five-year action plan developed by Environment Canada's St. Lawrence Centre. Future results should enrich our understanding of the biology of the St. Lawrence River and enhance our ability to manage environmental crises arising from the introduction of nuisance species, for this is a phenomenon whose scale will certainly keep pace with the unrelenting development of marine transportation.

Zebra vs. Quagga

The zebra mussel (*Dreissena polymorpha*) and the quagga mussel (*Dreissena bugensis*) are so alike that they might easily be thought to be a single species. We now know, however, that they are not one but two distinct species, both of which have invaded the waters of the St. Lawrence River. The quagga was first seen in the fall of 1992, but remains scarce in the river (less than 4% of the population) and has not yet turned up in the Richelieu River. This scarcity is associated with the near-total absence in the river of deep water (more than 20 m), its preferred habitat in the Great Lakes. The quagga thus seems to be a marginal threat, and research efforts continue to focus mainly on the zebra mussel.

PHOTO: B. CUSSON AND D. LABONTÉ
THE QUAGGA MUSSEL

For More Information

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