Appendix X

Quantification of Risks of Alien Species Introductions Associated with Alternative Area for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence

RNT Consulting Report 108

Submitted March 22, 2002

TABLE OF CONTENTS

Quantification of Risks of Alien Species Introductions Associated with Alternative Area for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence

Executive Summary

Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping is important to the Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world (Gauthier & Steel 1966). Millions of tonnes of ballast water are discharged into the Estuary and Gulf of St.Lawrence each year. Ballast water has been identified as one of the pathways by which alien aquatic species are introduced outside of their normal range. Under the current Canadian voluntary guidelines, all ships entering Canadian Waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). The 2001, Transport Canada survey has shown that 77% of all ships entering the Gulf of St.Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5 % are ships, which declared that as they are coming up the North American coastline they are exempt from the need to exchange. Additional 13% do not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange.

The current guidelines make provisions for ballast water exchange in “back-up areas”, if exchange is not feasible offshore for safety reasons. Incoming foreign ships may exchange their ballast waters within the Gulf of St. Lawrence, in the Laurentian Channel southeast of Anticosti Island, where depth exceeds 300 m. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St.Lawrence was evaluated using a Probabilistic Risk assessment model. The risk was measure in terms of quantity of alien species introduced into various parts of the Gulf, including the Laurentian Channel, giving current shipping patterns and practices.

The relative risk to the Laurentian Channel is 0.5% of the quantity of alien species introduced in the Gulf and Estuary as a whole (including the Laurentian Channel). The model also calculates the quantity of alien species introduced into Area I, II,III,IV of the Gulf, the river stretch(RS) and the Fresh Water Estuary. It is clear that with current shipping patterns and practices the area of the Gulf with greatest risk of alien introductions is Area I (relative risk of over 51%), followed by the River Stretch (38.5%). The discharges to the Laurentian Channel represent negligible risk compared to discharges done in these areas. Even when the number of ships discharging in the Laurentian channel was assumed to be three times the number used in the model, the relative risk in the channel rose to just 1.79%.

Further, the model shows that the greatest potential for introductions comes from the North Atlantic Coast (FAO Region A), followed by FAO Region B which includes the European and Scandinavian coast of the North Atlantic.

The model as constructed is capable of simulating a number of “what if scenarios”. This can be very useful in testing the impacts of any new shipping guideline or regulations on the risk of alien introduction into the Gulf of St.Lawrence.

At this time, the model is restricted to predicting the risk of introductions. It does not incorporate the potential for survival of the alien species introduced. This refinement should be added if additional data can be obtained. Further, the possibility of introducing alien species into the Gulf of St.Lawrence on the hulls of incoming ships represents an additional risk to the one estimated by the model. In order to obtain a complete picture of the possibility of alien introductions by shipping, this component of the risk must be quantified.

1.0 Introduction

Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping plays an important role in Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world, compared to the 121 Mt, 69 Mt, > 43 Mt, and 5 Mt received respectively by Australia, the United States, the United Kingdom, and New Zealand (Gauthier & Steel 1966). In addition to this, the domestic and coastal shipping are responsible for the translocation of large quantities of ballast water.

Aquatic alien species invasions through ballast water discharges are now recognized as a serious problem threatening global biological diversity and human health worldwide. On November 27, 1997, the IMO (International Maritime Organization) Marine Environmental Protection Committee (MEPC) adopted Resolution A.868(20), "Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens" The IMO recommends that all maritime nations of the world adopt and use these voluntary guidelines. This international initiative was preceded in Canada, by voluntary Guidelines introduced in May 1989 for the control of ballast water discharges from ships entering the Great Lakes and St. Lawrence Seaway. These guidelines were in turn prompted by a number of highly visible introductions of non-native fish, other aquatic species and pathogens, which have caused extensive environmental harm and economic hardship. On September 1, 2000, the guidelines introduced for the Great Lakes were extended as national Guidelines for all waters in Canada.

Currently, all ships entering Canadian Waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). Those that are coming up the North American coastline frequently consider themselves exempted from the need to exchange.
The current guidelines make provisions for ballast water exchange in “back-up areas”, if ballast water exchange is not feasible offshore for safety reasons. The suitability of these areas for exchanges has yet to be fully assessed. Incoming foreign ships may exchange their ballast waters within the Gulf of St. Lawrence, in the Laurentian Channel southeast of Anticosti Island where depth exceeds 300 m (located east of 63°W longitude). This situation changes the risk for ballast water mediated introductions in this ecosystem. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St.Lawrence is the subject of the following report.

2.0 Review of Available Data

As of now, there is no evidence, or official reports, of successful ballast-water-mediated introductions of non-indigenous species to the Estuary or the Gulf of St.Lawrence (Gilbert 2002, pers.comm.). No non-indigenous species has been reported which would have environmental or socio-economic impacts comparable to those observed in the Great Lakes or elsewhere in the world. The apparent absence of successful ballast water-mediated introductions in the Estuary and Gulf may be a reflection of the harsh marine climate in this region or of the sparse biological monitoring in the last decade.

Available reports and databases were reviewed for data that could be used to construct the model. Number of personal interviews were conducted with leading scientists in the region. List of resources collected is included in Appendix A.

2.1 Summary of findings from the review of literature and personal interviews

Millions of tonnes of ballast water are discharged into the Estuary and into the Gulf each year (Gauthier and Steel 1996, Bourgeois et.al. 2001). The precise volume of discharge is difficult to establish for two main reasons:

1. The data acquisition system to document the origins and volumes of the ballast water relies on the voluntary response of ship officers. There is no verification.

2. The database of ballast water forms collected following the September 2000 extension of the voluntary guidelines has only been in existence since June 2001.

The 2001, Transport Canada survey (Appendix D) shows that 77% of all ships entering the Gulf of St.Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5 % are ships which declared that as they are coming up the North American coastline they are exempt from the need to exchange. Additional 13% do not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange.

The only vessels which could be confirmed to have exchanged in the Laurentian Channel are those proceeding to the Great Lakes. Appendix B contains the details of those ships obtained from the U.S.Coast Guard in Massena. Dominique Tapin, Director Marine Administration & Technology, Shipping Federation of Canada was contacted as were other shipping representatives and Transport Canada. No additional ships were identified as having conducted ballast water exchange in the Laurentian Channel until March 2002.

In mid-March 2002, Transport Canada forwarded an analysis of the ECAREG (Eastern Canada Region – Vessel Traffic Service) database done by G.Herbert from DFO. Data collected in 1997 shows 56 ships using the Laurentian Channel for ballast adjustment or discharge and 43 ships in the year 2000. Comparing the data collected for year 2000 (Appendix C) with the data received from the U.S. Coast Guard in Messina (Appendix B), shows an overlap of only 3 ships.

The other 9 vessels reported by Massina are not captured by the ECAREG database. Further examination of the year 2000 ECAREG Data shows some ships claiming to have no ballast on board (NOBOB), some which show partial ballast water discharge, some registering their intention to exchange but no confirmation that they have done so. Given the deadline for this report, a decision was made to base the model on the verified information from U.S.Coast Guard. The possibility of additional ships using the Laurentian Channel and the impact it would have on the relative risk of introducing alien species in this region was incorporated into a sensitivity analysis presented in Section 5.0, Discussion of Results.

What percentage of water actually exchanged when ships report "full" mid-ocean exchange is the subject of much discussion. Harvey et.al 1999 document that the percentage exchanged varied from 0 to 100% in a sample of 61 ships. The U.S.Coast Guard considers "full" exchange to mean that 80% of the ballast water was exchanged. In the absence of definitive data, this was the value used in the model.

All relevant reports examined reported high densities of live phytoplankton and zooplankton present in the ballast water being discharged in the Gulf. All studies found species in the ballast water are not currently present in the Gulf. Encysted life forms were found in the sediments of ballast water tanks. Taxonomy and population density information is sparse (Locke et.al 1991, 1993, Harvey et.al. 1999, Mallet 2001, Rao et.al 1994) The data gave values as to the possible densities of different species (within an order of magnitude) Origin of ballast water will influence the number of individuals present and the species composition. However, ballast water remnants and sediment are present in the ballast water tanks as ships travel from port to port. Therefore the biota of the last port of call does not necessarily corresponds entirely to the species present in the ballast water tank. This results in no two ships, even if coming from the same destination, having the same species composition or densities of individuals.
We did not feel the data was extensive enough to incorporate into the model in a meaningful way.

Very little information is available on possible presence and density of pathogens. However, the threat of introduction of toxic phytoplankton to local mussel farming industries prompted the Canadian Coast Guard (CCG) in 1982 to issue the Notice to Mariners #995. This yearly renewed notice prohibits ships bound for the Mines Seleine's pier, situated in the Grande Entrée Lagoon of the Îles-de-la-Madeleine, Gulf of St. Lawrence, from discharging their ballast waters within 10 nautical miles of the islands unless the water was taken on in a well-defined area off Canada's east coast, at a distance of 5 miles or greater from the shoreline (Gosselin et.al.1995).

The length of the voyage may affect the number of individuals present in the ballast water. The longer the voyage, the fewer species and individuals (M. Gilbert 2002 pers.com, J.Martin 2002pers.comm., Mallet 2001, MacIsaac 2002). Not enough information is available to correlate length of voyage with an exact decrease in population density of various taxa, but there is a significant decrease in both the number of species and a number of individual after 5 days in the ballast water tanks. After 10 days 75% decrease was observed (Gilbert 2002 pers.com).

2.2 Workshop with Stakeholders

A meeting was held on November 8th, 2001 in concert with the CMAC meetings in Ottawa. The list of participants and Minutes of the Meeting are included in Appendix E.

The stakeholders were identified by Transport Canada and Fisheries and Oceans Canada. Presentation was given by Mr. Ravishankar on the proposed Risk Methodology and the model under consideration. Ms. Claudi summarized the data available and the assumptions made in the construction of the model. Input was solicited from the 37 participants present. Valuable additional data was made available from several sources. Support was offered by the Shipping Federation of Canada. This support was gladly accepted.

The workshop was invaluable as the data and input received was used to improve the model.

3.0 Probabilistic Risk Model

The objective of the risk assessment undertaken was two fold:

1. To estimate the risk to the Gulf and Estuary, which includes the Laurentian Channel, from exchange and discharge of ballast water therein. The risk is measured in terms of the quantity of alien species introduced. The quantity is expressed as a fraction, in percentage, of the quantity of any alien species present in the ballast at origin. By definition, all alien species are considered undesirable. The introduction alone was considered, survival post-introduction was beyond the scope of this model.

2. To estimate the relative risk to the Larentian Channel. This is estimated as a fraction, expressed in percentage, of the risk to the Gulf and Estuary including the Larentian Channel.

3.1 Assumptions

The following assumptions were made either because of paucity of data available or to streamline the model:

1) Due to a paucity of data, there is no distinction made between different types of alien species. Consequently, all alien species, once introduced, are considered to have the same potential for adverse effect. Only the quantity of alien species introduced is considered as a measure of risk.

2) The effects of differences in salinity in the ballast water at the point of origin and the point of discharge in the Gulf are not considered due to lack of data. The difference affects survival once introduced but not the actual introduction.

3) The effects of the season when the exchange or discharge in the Gulf and Estuary takes place are not considered. This factor affects survival not the actual introduction and it was not pursued at this stage of the model.

4) The duration of a ship's voyage has an effect on the mortality of the alien species contained in the ballast. The longer is the voyage, the higher is the mortality rate. Based

on the limited data available, it is considered that any transit time that is less than 5 days has no mitigation effect, i.e., mortality rate in the ballast water tank is zero. The mortality rate for any transit time that is greater than five days is assumed to be 50%. This means, an exchange or discharge of ballast from a ship with a transit time of more than five (5) days would introduce only 50% of the amount of alien species that were present at origin. This assumption allows for taking into account the transit time and its effects while keeping the model relatively simple)considering the wide ranging transit time of the ships coming into the Gulf).

5) Ports of origin and destinations are of significance only in terms of transit time. The differences in climate and salinity are not considered.

6) It is assumed ships that exchange ballast either in mid-ocean or in the Laurentian Channel do a “full” exchange. In practical terms this means that on average a mid-ocean exchange replaces 80% of the ballast water taken on in the port of origin. That is, the fraction of alien species remaining in the ballast after a mid-ocean exchange is 20% of the amount that was present at origin. We assume that no mid-ocean species taken on during the exchange poses a threat to the coastal areas of the Gulf and, therefore, is not considered in this model.

7) An exchange in the Laurentian Channel is considered to replace 80% of the ballast water taken on in the port of origin. That is, the fraction of alien species remaining in the ballast after the exchange is 20% of the amount that was present at origin.

8) No distinction is made between different taxa. All species in all taxa are considered to pose an equal threat.

9) On the average, only 13 ships bound for the Great Lakes exchange ballast water in the Laurentian Channel. It is assumed that the remaining ships bound for the Great Lakes either exchange in mid-ocean or are NOBOB ships.

3.2 Model Description

Using the assumptions made in Section 3.1, the risk model was developed to calculate the risk to the Gulf and Estuary (including the Laurentian Channel) and to calculate the relative risk to the Laurentian Channel alone.

Briefly, the steps involved in the development of the model were as follows:

a) Enumerate the possible ways by which a discharge at ports in the Gulf and Estuary can occur.

b) Enumerate the possible ways by which an exchange in the Laurentian Channel can occur.

c) Determine for each possible way and thus in total, the quantity of alien species discharged at port, as a fraction of the quantity of alien species present at origin. This is the risk from discharge at port.

d) Determine for each possible way and thus in total, the quantity of alien species discharged in the Laurentian Channel, as a fraction of the quantity of alien species present at origin. This is the risk from exchange in the Laurentian Channel.

e) Determine also for each possible way and thus in total, the quantity of alien species discharged at port, as a fraction of the quantity of alien species present at origin in all ships from all FAO regions travelling to the Gulf and Estuary. This is the risk from discharge at port.

f) Determine for each possible way and thus in total, the quantity of alien species exchanged in the Laurentian Channel, as a fraction of the quantity of alien species present at origin in all ships from all FAO regions travelling to the Gulf and Estuary. This is the risk from exchange in the Laurentian Channel.

g) Using the above information, determine the total risk to the Gulf and Estuary and the relative risk to the Laurentian Channel.

The possible means of discharge or exchange is developed for a typical ship from originating region “i” to destination “j”. For the purposes of this study, the originating regions are the FAO regions of origin A, B, C, G and all other regions that are collectively referred to herein as region O (Fig.2). The destination zones in the Gulf and Estuary are categorized as I, II, III, IV, 4, RS (River Stretch), FWE (Freshwater Estuary), and GL-LC. Destination GL-LC, which represents the Laurential Channel, is not really a destination zone but is considered as one for modelling purposes (Fig.3).

The many ways in which a discharge or an exchange can occur is enumerated using a method known as the Event Tree method. This method involves identifying the possible ways in which the amount of alien species introduced into the Gulf and Estuary (including the Laurentian Channel) could be mitigated. Then, for a typical ship going from region “i” to destination “j”, considering the applicability and success and failures of each mitigation, the different paths or sequences are developed such that each path culminates in an introduction of alien species.

In this study, for each ship, there are three possible mitigating processes with respect to discharge in port. These are: the transit time being greater than five (5) days, mid-ocean exchange, and Laurentian Channel exchange. With respect to discharge in the Laurentian Channel, only the transit time is a possible mitigating process. This is because, only ships that did not exchange ballast in mid-ocean would possibly exchange in the Laurentian Channel.

Each mitigation process or system is modelled using a binary model for outcome. That is, each is considered either to be a success or a failure. So, if all combinations of N mitigation processes were possible, then there would be 2^N sequences. This means, given that we are considering three (3) possible mitigation processes, the maximum number of sequences possible would be $2^3 = 8$. However, as only ships that did not exchange in mid-ocean might exchange in the Laurentian Channel the possible sequences reduce to a total of six (6).

This is process is illustrated in the following figure which represents the event tree for a ship going from region “i” to destination “j”.

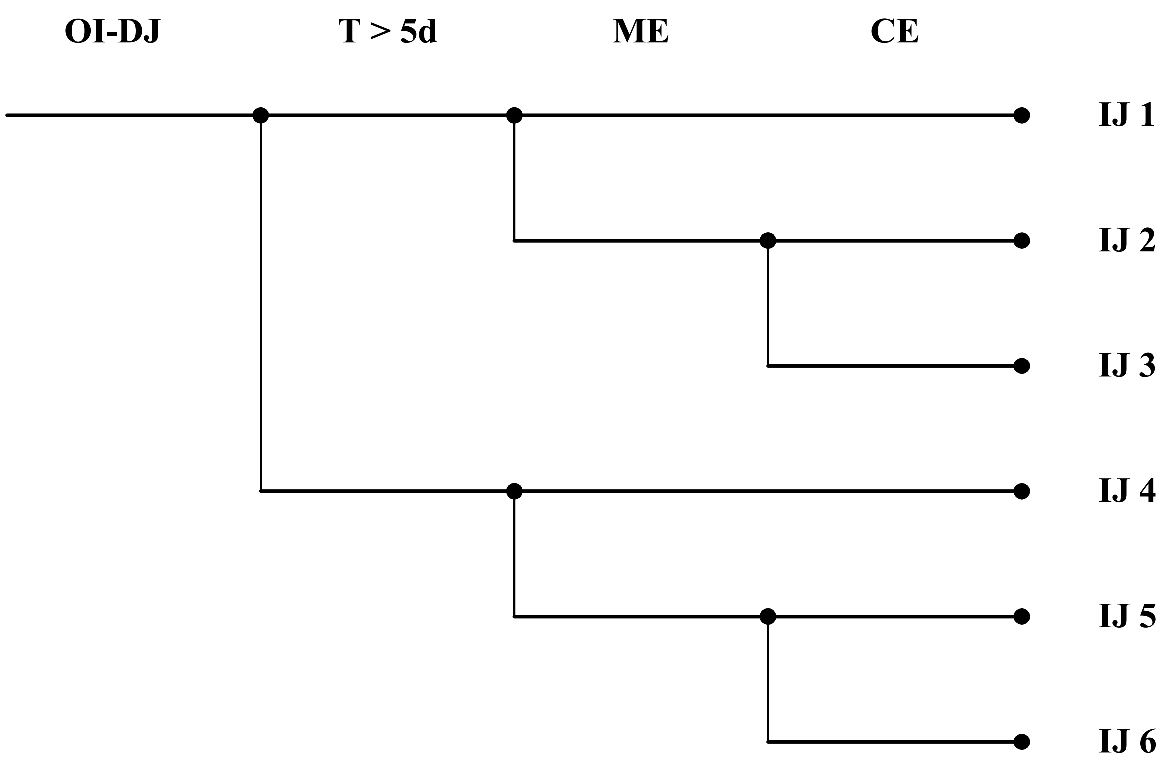


Figure 1: Event Tree for Region of Region I and Destination J – Discharge in Port

Top Line

OI-DJ	Ship from region “i” going to destination “j”
T > 5d	Transit time of the ship is greater than five (5) days
ME	Mitigation through mid-ocean exchange
CE	Mitigation through exchange in the Laurentian Channel

Right Column

IJ N	Sequence number N for a ship from origin “i” going to destination “j”

As described above, each mitigation process has two possible outcomes; corresponding to each mitigating process. Success is depicted by the top horizontal branch and failure by the bottom branch. The six sequences depict the following possibilities:

Sequence Number	Transit Time > 5days?	Mid-Ocean Exchange	Channel Exchange
IJ 1	Yes	Yes	Not Done
IJ 2	Yes	No	Yes
IJ 3	Yes	No	No
IJ 4	No	Yes	Not Done
IJ 5	No	No	Yes
IJ 6	No	No	No

Sequence IJ 1 represents the possibility that the transit time is greater than five (5) days and the ship exchanges ballast in mid-ocean. Therefore, it will not exchange ballast in the Laurentian Channel. Similarly, sequence IJ 6 can be interpreted to represent the possibility that the transit time is no more than five (5) days and the ship does not exchange ballast either in mid-ocean or in the Laurentian Channel.

Figure 1 depicts the model for risk from discharge at the ports. The same model with some modification can be used to obtain the risk from exchange in the Laurentian Channel. Only two of the six sequences, viz., sequences IJ 2 and IJ 5 represent the possibility of exchange in the Laurentian Channel. Based on this fact, quantity of alien species introduced in the Laurentian Channel can be calculated.

Appendix F presents the mathematical model that was used for calculating the risk estimates. Due to resource constraints, only mean estimates are provided, and uncertainty analysis was not performed. An uncertainty analysis is usually performed to quantify uncertainties in the input data and hence the results, which are point estimates. Where input data vary and could be considered to be random variables, their true values can only be estimated to a degree of certainty that depends on the sample used for estimation. The input data are usually mean values and, therefore, the results are also mean values. Quantifying the uncertainty will provide limits for the mean value. The limits are called confidence limits, as it can be stated with a defined level confidence that the true mean value of the result would fall within these limits.

Appendix G describes the sensitivity analyses that were done as a means of verifying the logic of the model.

3.3 Input Data

The input data on which the risk estimates are based, are given in Tables 1 to 4.

Table 1 gives the average number of ships from different FAO regions to the different parts of the Gulf. The data used is from Bourgeois et.al.2001. Their report covers the period 1978-1996. Although there are a total of 13 FAO regions, regions other than A, B, C, and G are combined together to form the so-called region "O" (for other) in their report. The average annual traffic from the different regions of the Gulf was also based on Bourgeois et.al 2001.
Of the average 13 ships bound for the Great Lakes (Appendix B), 11 are assumed to come from

FAO region A, one (1) from region G, and the rest are equally distributed among regions B, C and O. The Laurentian Channel is treated as a virtual port and is designated as GL-LC.

Table 1: Average Number of Ships Discharging or Exchanging in the Gulf Per Year
After Bourgeois et.al.2001

From Origin	Arriving At Destination						
	I	II	III	IV	RS	FEW	GL-LC
A	62.0	22.0	9.0	12.0	35.0	47.0	11.0
B	267.0	21.0	20.0	25.0	446.0	93.0	0.3
C	54.0	4.0	5.0	2.0	88.0	27.0	0.3
G	40.0	35.0	32.0	32.0	145.0	41.0	1.0
O	9.0	5.0	1.0	1.0	72.0	23.0	0.3

Table 2 gives the average ballast capacity of ships.

Table 2: Average Volume of Ballast, Tonnes Per Ship
After Bourgeois et.al.2001

From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	14.40	0.70	0.20	0.30	7.3	3.5	2.30
B	14.40	0.70	0.20	0.30	7.3	3.5	2.30
C	14.40	0.70	0.20	0.30	7.3	3.5	2.30
G	14.40	0.70	0.20	0.30	7.3	3.5	2.30
O	14.40	0.70	0.20	0.30	7.3	3.5	2.30

Table 3 gives the likelihood of average transit time being greater than 5 days, the likelihood of mid-ocean exchange and the conditional likelihood of an exchange in the Laurentian Channel given there was no mid-ocean exchange. Ships from region A have an average transit time that is less than five days (D.Tapin pers.comm. 2002). Based on the distances, it is considered that all ships from regions B, C and O have an average transit time greater then five days. Again, based on distances, half of the ships from region G are considered to have an average transit time greater than five days. Recently communicated information indicates that on the whole about 78% of the ships that travel to the Gulf exchange ballast in mid-ocean Appendix D). For simplicity 75% average was used. Only a small percentage of ships from FAO region A exchange in mid-ocean. It is considered reasonable to expect that a much greater percentage of ships from FAO region G would exchange ballast in mid-ocean. Thus, allowing for the possibility that a small percentage of ships from FAO regions B, C and O might not exchange ballast in mid-ocean, a 90% probability of exchange in mid-ocean is assigned to these ships. The probability of mid-ocean exchange for ships from FAO regions A and G were derived assuming that the likelihood for ships from region G is four (4) times that of ships from region A. This leads to probabilities of 15% and 60% respectively for ships from regions A and G.

Currently, only ships that are bound for the Great Lakes exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. This means the conditional probability of a ballast exchange in the Laurentian Channel is one for these ships bound for the Great Lakes (destination GL-LC in Table 3) and zero for all other ships.

Table 3: Probability of Ballast Exchange or Treatment

(a): Probability of Average Transit Time > 5 days, $p_{T,\ ij}$							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	1.00	1.00	1.00	1.00	1.00	1.00	1.00
G	0.50	0.50	0.50	0.50	0.50	0.50	0.50
O	1.00	1.00	1.00	1.00	1.00	1.00	1.00

(b): Probability of Mid-Ocean Exchange, $p_{ME,\ ij}$							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.15	0.15	0.15	0.15	0.15	0.15	0.15
B	0.90	0.90	0.90	0.90	0.90	0.90	0.90
C	0.90	0.90	0.90	0.90	0.90	0.90	0.90
G	0.60	0.60	0.60	0.60	0.60	0.60	0.60
O	0.90	0.90	0.90	0.90	0.90	0.90	0.90

(c): Probability of Channel Exchange (given no mid-ocean exchange), $p_{CE,\ ij}$ %							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.00	0.00	0.00	0.00	0.00	0.00	1.00
B	0.00	0.00	0.00	0.00	0.00	0.00	1.00
C	0.00	0.00	0.00	0.00	0.00	0.00	1.00
G	0.00	0.00	0.00	0.00	0.00	0.00	1.00
O	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 4 gives the effectiveness of mitigation resulting from transit time being greater than five days, and exchange of ballast in mid-ocean and the Laurentian Channel. While not much data are available on the effect of transit time, there is evidence to suggest a 50% mortality rate for ship with a transit time greater than five days. The effectiveness of exchange in both mid-ocean and the Laurentian Channel is assumed to be 80%. That is, the quantity of alien species remaining in the ballast after an exchange is 20% of the quantity that was present in the ballast before the exchange. For the purposes of the model this is called the residual fraction.

Table 4: Mitigation Effectiveness

(a): Mitigation Effectiveness of Transit Time > 5 days – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.50	0.50	0.50	0.50	0.50	0.50	0.50
B	0.50	0.50	0.50	0.50	0.50	0.50	0.50
C	0.50	0.50	0.50	0.50	0.50	0.50	0.50
G	0.50	0.50	0.50	0.50	0.50	0.50	0.50
O	0.50	0.50	0.50	0.50	0.50	0.50	0.50

(b): Mid-Ocean Exchange Effectiveness – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.20	0.20	0.20	0.20	0.20	0.20	0.20
B	0.20	0.20	0.20	0.20	0.20	0.20	0.20
C	0.20	0.20	0.20	0.20	0.20	0.20	0.20
G	0.20	0.20	0.20	0.20	0.20	0.20	0.20
O	0.20	0.20	0.20	0.20	0.20	0.20	0.20

(c): Channel Exchange Mitigation Effectiveness – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.20	0.20	0.20	0.20	0.20	0.20	0.20
B	0.20	0.20	0.20	0.20	0.20	0.20	0.20
C	0.20	0.20	0.20	0.20	0.20	0.20	0.20
G	0.20	0.20	0.20	0.20	0.20	0.20	0.20
O	0.20	0.20	0.20	0.20	0.20	0.20	0.20

4.0 Results

The results corresponding to the current situation where the only ships exchanging in the Laurentian Channel are those bound to the Great Lakes are provided in Tables 5 and 6. Both tables provide results for each possible combination of region of origin and destination zone, as well as marginal aggregates and the total aggregate.

Table 5(a) provides risk of introduction at port, Table 5(b) provides risk of introduction in the Laurentian Channel, and Table 5(c) and Table 5(d) provide total risk of introduction in the Gulf and Estuary including the Laurentian Channel. Table 5(c) provides the risk from region "i" to zone "j" as well as the marginal risk from each of region "i" and at each of zone "j". The risk from region "i" to zone "j" is given as a fraction of the ballast from region "i" that is exchanged or discharged in zone "j". The marginal aggregate risk is given as a fraction of ballast that is exchanged or discharged from region "i" or at zone "j". Table 5(d) provides the risk from region “i” to zone “j”, the marginal aggregate risk from each of region “i” and zone “j”, and the total risk to the Gulf and Estuary including the Laurentian Channel, all as a fraction of all the ballast from all regions that is exchanged or discharged in the Gulf and Estuary.

Referring to Table 5(a), the results in the table are to be interpreted as follows. They provide an estimate of risk of introduction resulting from discharge of ballast at port. The risk estimate for ships going from origin, say, region A to destination, say, zone II, is 88%. What this means is that the ballast discharged in zone II by a ship from region A would contain 88% of the quantity of alien species that were present in the ballast at origin. Similarly, the ballast discharged in zone IV by a ship from region C would contain 14% of the quantity of alien species that were present in the ballast at origin. Of course, GL-LC being the Channel and only a virtual port, the figures under the column GL-LC are all zero.

The estimate of marginal aggregate risk from ships originating in, say, region A, is 86.4%. This means that the sum total of the ballast discharged at ports in the Gulf and the Estuary by ships from region A would contain 86.4% of the quantity of alien species that were contained in the ballast of all the ships from region A at origin. The estimate of marginal aggregate risk from ships originating in, say, region B, is 14.0%, the same as the risk estimate at individual zones (except GL-LC).

Similarly, the estimate of marginal aggregate risk in a destination, say, zone II, is 42.8%. This means that the sum total of the ballast discharged at ports in zone II by ships from all the FAO regions would contain 42.8% of the quantity of alien species that were contained in the ballast of all the ships travelling to zone II from all the FAO regions.

Table 5(b) shows the risk of introduction in the Laurentian Channel. The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the ballast discharged in the Laurentian Channel by a ship from region A would contain 68% of the quantity of alien species that were contained in the ballast at origin. As mentioned previously, only ships that are bound for the Great Lakes currently exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. Thus, non-zero values are shown only under the column GL-LC. That is, only ships that are bound to the Great Lakes and that exchange in the Laurentian Channel are included here.

Table 5(c) shows the total risk to different parts of the Gulf and Estuary including the Laurentian Channel. As mentioned previously, this table provides the risk from region “i” to zone “j” as well as the marginal risk from each of region “i” and at each of zone “j”. The risk from region “i” to zone “j” is given as a fraction of the quantity of alien species present at origin in the ballast of ships from region “i” that is exchanged or discharged in zone “j”. The marginal aggregate risk for region “i” is the quantity of alien species discharged in the Gulf and Estuary, given as a fraction of the quantity of alien species present at origin in the ballast of ships from region “i”. Similarly, marginal aggregate risk for zone “j” is the quantity of alien species discharged in zone “j”, given as a fraction of the quantity of alien species present at origin in the ballast of all ships from all FAO regions travelling to zone “j”.The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the ballast discharged in the Gulf and Estuary including the Laurentian Channel by a ship from region B is estimated to contain 14% of the quantity of alien species contained in the ballast at origin. Similarly, the ballast discharged in zone II is estimated to contain 42.8% of the quantity of alien species contained in the ballast of all the ships travelling to zone II from all the FAO regions. Other results are to be similarly interpreted.

Table 5(d) shows the total risk to the Gulf and Estuary including the Laurentian Channel but as a fraction of all the ballast from all regions that is exchanged or discharged in the Gulf and Estuary. In addition to providing the risk from region "i" to zone "j" and the marginal aggregate risk from each of region "i" and zone "j", it provides the total risk to the Gulf and Estuary including the Laurentian Channel. The marginal risk can be obtained by a summation of the appropriate row or column, and the total risk can be obtained by a summation of either the row or column of marginal aggregate risk. The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the quantity of alien species discharged in the Gulf and Estuary by a ship from region B would be 8.09% of the quantity of alien species contained in the ballast of all the ships from all FAO regions at origin. Similarly, the quantity of alien species discharged in the Gulf and Estuary by a ship arriving in zone I would be 13% of the quantity of alien species that were contained in the ballast of all the ships from all FAO regions at origin. Other results are to be similarly interpreted.

Table 5: Risk of Introduction - Current Scenario

(a): Risk of Introduction at Port - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	88.0	88.0	88.0	88.0	88.0	88.0	0.0	**86.4**
B	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
C	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
G	39.0	39.0	39.0	39.0	39.0	39.0	0.0	**39.0**
O	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
Risk At Destination, %	**26.9**	**42.8**	**35.9**	**37.4**	**21.9**	**33.5**	**0.0**	

(b): Risk of Introduction in Laurentian Channel - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	0.0	0.0	0.0	0.0	0.0	0.0	68.0	**1.27**
B	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
C	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
G	0.0	0.0	0.0	0.0	0.0	0.0	24.0	**0.03**
O	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
Risk from Ships to Destination, %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**59.7**	

Table 5 (Continued): Risk of Introduction – Current Scenario

(c): Total Risk of Introduction in Gulf and Estuary - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	88.0	88.0	88.0	88.0	88.0	88.0	68.0	**87.6**
B	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
C	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
G	39.0	39.0	39.0	39.0	39.0	39.0	24.0	**39.0**
O	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
Risk from Ships to Destination, %	**26.9**	**42.8**	**35.9**	**37.4**	**21.9**	**33.5**	**59.7**	

(d): Total Risk of Introduction in Gulf and Estuary - Fraction of Total Quantity in Ballast From All Origins								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	6.09	0.11	0.01	0.02	1.74	1.12	0.13	**9.24**
B	4.17	0.02	0.00	0.01	3.54	0.35	0.00	**8.09**
C	0.84	0.00	0.00	0.00	0.70	0.10	0.00	**1.65**
G	1.74	0.07	0.02	0.03	3.20	0.43	0.00	**5.51**
O	0.14	0.00	0.00	0.00	0.57	0.09	0.00	**0.80**
Risk At Destination	**13.00**	**0.20**	**0.04**	**0.06**	**9.75**	**2.10**	**0.14**	**25.29**

Table 6 provides risk of introduction in the Laurentian Channel relative to the total introduction in the Gulf and Estuary including the Laurentian Channel. As mentioned above, it is a very small 0.5%. This means that the quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel.

Table 6: Relative Risk of Introduction in the Laurentian Channel

Relative Risk of Introduction in Laurentian Channel, Fraction of Total Risk of Introduction in Gulf and Estuary								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	1	**2**	**3**	**4**	**RS**	**FWE**	**GL-LC**	
A	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**1.4**
B	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
C	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
G	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.1**
O	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
Risk from Ships to Destination, %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**100.0**	**0.5**

5.0 Discussion of Results

In Table 5(a), the estimate of marginal aggregate risk from ships originating in region A, is 86.4%. This means that the sum total of the ballast discharged at port by ships from region A would contain 86.4% of the quantity of alien species that were present at origin. It is slightly less than the 88% risk at individual zones (except GL-LC) because the aggregate is based on all ships originating from region A, which includes ships from region A that are bound for the Great Lakes and that exchange in the Laurentian Channel. The estimate of marginal aggregate risk from ships originating in region B is 14.0%, the same as the risk estimate at individual zones (except GL-LC). This is because, very few ships from region B exchange in the Laurentian Channel and, therefore, do not significantly affect the aggregate estimate. Similar reasoning applies to other regions.

The estimate of marginal aggregate risk at zone II, is 42.8%. Risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin of all ships arriving in zone II. This estimate is influenced by the distribution of ships arriving in the zone from different regions. Referring to Table 1, a vast majority of ships arriving in zone I are from region B, which have a transit time greater than five days, and 90% of these ships exchange ballast in mid-ocean. On the other hand, a vast majority of ships arriving in zone II are from regions A and G, and the transit time of all the ships from region A and 50% of the ships from region G are less than five days. Also, only 15% of the ships from region A and 60% of ships from region G would exchange in mid-ocean. This explains why the marginal aggregate risk in zone II is significantly higher than that in zone I. Similar reasoning explains the results for other zones.

From Table 5(b), the risk of introduction into the Laurentian Channel is the greatest from ships originating in region A and G. Again, risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin of all ships exchanging in the Laurentian Channel. This is because, most of the ships that exchange in the Laurentian Channel come from these regions. Also, as mentioned above, the transit time of all the ships from region A and 50% of the ships from region G are less than five days; and, only 15% of ships from region A and 60% of ships from region G are considered to exchange ballast in mid-ocean. The marginal aggregate risk in the Laurentian Channel is 59.7%, i.e., the quantity of alien species discharged into the

Laurentian Channel is estimated as 59.7% of the quantity of alien species contained in the ballast of the 13 ships that exchange in the Laurentian Channel in a year. However, as explained below, the total risk to the Laurentian Channel is two orders of magnitude less than this.

From Table 5(c), ships that originate in region B are estimated to introduce 14% of the quantity of alien species contained in their ballast at origin. This low value is to be expected as their transit time is greater than five days and 90% of them exchange ballast in mid-ocean, both of which are significant mitigating factors. Ships that discharge in zone II introduce 42.8% of the quantity of alien species contained in the ballast of ships from all FAO regions at their origin. Again, risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin. As mentioned in the previous paragraph, the ships that exchange in the Laurentian Channel introduce 59.7% of the quantity of alien species present in these (13) ships at origin. However, as the total ballast carried by these ships is very small compared to the total ballast of all other ships destined to a port in the Gulf and Estuary, the risk from exchange in the Channel is much smaller than what the 59.7% estimate might suggest. This is seen Table 6 which shows that the relative risk of introduction in the Laurentian Channel is 0.5%. This in itself is an overestimate of the true risk, as the model does not take into account the effect of survival aspect on introductions. From Appendix B it appears that about 50% of ships exchanging in the Laurentian Channel have fresh water or brackish ballast, making the survival of any introduced species unlikely. Further, Gilbert 2000 has shown that any particle discharged in the Laurentian Channel is either flushed out or takes days before it impinges on shore which mitigates its threat to coastal regions.

In Table 5(d), the total risk to the Gulf and Estuary including the Laurentian Channel is estimated to be 25.3%. That is, the quantity of alien species introduced into the Gulf and Estuary is estimated as 25.3% of the quantity of alien species contained in the ballast of the ships from all FAO regions at their origin. Ships from region A going to zone I constitute the single highest risk at 6.1% or about 25% of the total risk. The ships from region B going to zone II constitute the second highest risk at 4.2% or about 20% of the total risk. This is explained as follows. A vast majority of ships from region A do not exchange ballast in mid-ocean and about 30% of these ships discharge their ballast in zone I. About 40% of the ships from region B discharge their ballast in zone I, although a significant number of these ships exchange their ballast in mid-ocean. Ships arriving in zone I carry the most ballast on the average – 14.4 tonnes per ship.

The marginal aggregate total risk at zone I is the highest at 13%, or 50% of the total risk to the Gulf and the Estuary. The reason for this is as explained above. The second highest is the risk to the River Stretch at 9.8% or 38% of the total risk to the Gulf and Estuary. This stems from the fact that 54% of all the ships entering the Gulf travel to the River Stretch ports and they carry an average 7.3 tonnes of ballast per ship. The marginal aggregate risk in the Laurentian Channel is 0.14%, which is only 0.55% of the total risk to Gulf and Estuary including the Laurentian Channel (see below).

The marginal aggregate total risk from ships from region A is the highest at 9.2% followed closely by ships from region B at 8.1%. This is explained by the reasons given above.

In Table 6, the risk of introduction in the Laurentian Channel comes only from those ships that

are bound for the Great Lakes. The model considers that only ships that are bound for the Great Lakes exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. However, the marginal aggregate risk from each region is very small or nil. The quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel. This means that the quantity that is introduced at port is 99.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel.
As there is a possibility that additional ships may be using the Laurentian Channel for ballast water exchange, sensitivity analysis was performed to examine the possible impact of this situation. The sensitivity analysis involved increasing the number of ships that discharge in the Laurentian Channel. The relative proportion of ships from different origins was kept the same as in Table 3, but the total number was increased to 43. This number was chosen based on information obtained in mid-March 2002 (Appendix C), which indicated that in the recent past as many as 43 ships on the average might have exchanged ballast in the Laurentian Channel. The results from this sensitivity analysis showed that:

- Risk of introduction at port = 25.0%
- Risk of introduction in the Laurentian Channel = 0.46%
- Total Risk = 25.5%
- Relative risk of introduction in the Laurentian Channel = 1.79%

Compared to the current situation, the risk at port is slightly less. This is because, while the quantity discharged at port remains the same, there are more ships exchanging in the Laurentian Channel and hence the total amount discharged or exchanged in the Gulf and Estuary increases. As ships that exchange ballast in the Laurentian Channel carry smaller ballast, this increase is small.

As can be expected, the risk of introduction in the Laurentian Channel increases. This increase is proportional to the increase in the number of ships exchanging in the Laurentian Channel and is still very small compared to the risks in other parts of the Gulf. In addition, the model is a simplified representation of reality in that it does not account for factors such as survival, dispersal and differences in seasons and salinity.

The results in Tables 5 and 6 provide estimates of the average risk. This is the outcome of using average values for the input data. Uncertainty analysis has not been performed at this time. It is not uncommon to perform uncertainty analysis, and it is recommended that it be part of any future analysis. As explained previously, an uncertainty analysis is usually performed to quantify uncertainties in the input data and hence the results, which are point estimates. Quantifying the uncertainty will provide limits for the mean value. The limits are called confidence limits, as it can be stated with a defined level confidence that the true mean value of the result would fall within these limits.

6.0 Conclusion

The risk from discharge and exchange of ballast water in the Gulf and Estuary including the Laurentian Channel was estimated. The over all risk to the Gulf and Estuary including the Laurentian Channel, as measured in this study, is estimated as 25.3%. The relative risk to the Laurentian Channel is estimated as 0.5%, i.e., the quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity of alien species introduced in the Gulf and Estuary as a whole (including the Laurentian Channel). Ships from region A going to zone I constitute the single highest risk at 6.1% or about 25% of the total risk. The ships from region B going to zone II constitute the second highest risk at 4.2% or about 20% of the total risk. The marginal aggregate total risk at zone I is the highest at 13%, or 50% of the total risk to the Gulf and the Estuary, followed by a risk of 9.8% or 38% at the River Stretch. The marginal aggregate total risk from ships from region A is the highest at 9.2% followed closely by ships from region B at 8.1%.

Due to a paucity of data and resource limitations, the risk model that was developed was simplified and does not account for such factors as survival, migration, and differences in salinity and season. The model was verified through a sensitivity analysis, but the verification is limited to the model logic and not the input data. Risk is measured in terms of the quantity of alien species introduced, expressed as a fraction of the quantity present in the ballast at origin. This does not account for the actual quantity of ballast discharged or exchanged, or distinguish between the taxa of alien species. Survival and transport of introduced species was not taken into account. While these factors lead to a conservative estimate, they should be addressed in future studies.

Despite the limitations of the current model, it does provide consistent methodology for evaluating risks of alien introductions from ballast water discharges. It shows that the greatest danger to the Gulf of St.Lawrence is posed by coastal shipping from Region A discharging in the ports of Zone I. Therefore, remedying this situation first would provide the greatest return on investment in terms of the environmental health of the Gulf.

The methodology used can be applied to different scenarios of shipping patterns and regulation to help in evaluation of the different options. Again, it provides for a consistent, science based approach to decision making.

Appendix A

Balaban, M. 2001. **Vessel traffic/vessel shipping patterns on the east coast of Canada, 2000 shipping season.**

Bourgeois, M.; Gilbert M.; Cusson B. 2001 **Evolution du traffic maritime en provenance de l'etranger dans le Saint-Laurent de 1978 a 1996 et implications pour les risques d'introduction d'especes aquatiques non indigenes. Rapp.tech.can.sci.halieut.aquat.2338:viii +34p.**

Gauthier D., Steel, D.A. 1996**. A synopsis of the situation regarding the introduction of nonindigenous species by ship-transported ballast water in Canada and selected countries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2380:1-57**

Gilbert M.; Saucier, F.J. 2000. **Suitability of the Gulf of St. Lawrence as backup zone for ballast water exchanges by foreign ship proceeding up to the St. Lawrence Seaway. 10th International Conference on Aquatic Invasive Species, Toronto, February 2000.**

Gosselin, S.; Levasseur, M.; Gauthier, D. 1995. **Transport and deballasting of toxic dinoflagellates via ships in the Grande Entrée Lagoon of the Îles-de-la-Madeleine (Gulf of St. Lawrence, Canada). In Lassus P.,G.Arzul,E.Erard,P.Gentien & C.Marcaillou(eds.) Harmful Marine Algal Blooms pg.591-596**

Harvey M.; Gilbert, M.; Gauthier, D.; Reid, D.M. 1999. **A preliminary assessment of risks for the ballast water-mediated introduction of nonindigenous marine organisms in the Estuary and Gulf of St. Lawrence. Can.Tech.Rep.Fish.Aquat.Sci.,2268:x+56p.**

Lewis, D. 1994. **Canadian coast guard assessment of the potential for introduction of exotic species through exchange of industrial shipping ballast water. Aquatic Sciences Inc., St. Catharines, ON.**

Locke, A.; Reid, D.M. ; Sprules, W.G.; Carlton; J.T. ; van Leeuwen, H.C. 1991. **Effectiveness of mid-ocean exchange in controlling freshwater and coastal zooplankton ballast water. Can.Tech.Rep.Fish.Aquat.Sci.1822**

Locke, A.; Reid, D.M.; van Leeuwen; H.C.; Sprules; W.G.; Carlton, J.T. 1993. **Ballast water exchange as a means of controlling dispersal of freshwater organisms by ships. Can.J.Fish.Aquat.Sci.50:2086-2093**

Mallet Research Services 2001; **A preliminary assessment of the risks of ballast water mediated introduction of non-indigenous phytoplankton and zooplankton species into Nova Scotia waters. Report to Transport Canada Marine Safety Section.**

MacIsaac, H.J.; Robbins T.C; Lewis M.A. 2002 **Modeling Ships' Ballast Water as Invasion Threats to the Great Lakes. Presented at the 11th International Conference on Aquatic Invasive Species, Washington D.C. February 2002.**

Roy, S. 1994. **Analyse d'échantillons de sédiments provenant de réservoirs d'eau de ballast.**

Smith, T.E.; Kerr, S.R. 1992. **Introductions of species transported in ships' ballast waters: the risk to Canada's marine resources. Can.Tech.Rep.Fish.Aquat.Sci.1867:1-16**

Subba Rao, D.V.; Sprules, W.G.; Locke, A.; Carlton, J.T. 1994. **Exotic phytoplankton species from ships' ballast waters: risk of potential spread to mariculture on Canada's east coast. Can. Data Rep. Fish. Aquat. Sci. 937: iv + 51 p.**

Appendix B – Known Ballast water Exchange in the Laurentian Channel provided by U.S.Coast Guard in Messina

Vessel Name	Last Port of Call	Total Volume m3	Ballast water – most likely salinity
	1999		
Marinette	Sept Isles, Canada	530	Marine
Dora	Brayton Pt., MA	14105	Freshwater
Concord	Baltimore, MD	1079	Brackish/FW
Caro	Newark, DE	4666.5	Variable/mostly brackish
Cheremkhovo	Boston, MA	1127	Brackish
Santiago	St. Johns, Canada	1489.76	Marine
Clipper Antares	New London, CT	4770.1	Marine
Federal Saguenay	Baltimore, MD	15856.1	Brackish/FW
Hilal II	New York, NY	11289	Variable/mostly brackish
Finikas	Searsport, ME	3163	Marine
Argus	Wilmington, NC	2769	Freshawater
		2000	
Olympic Mentor	Baltimore, MD	1686	Brackish/FW
Lamda	Sheet Harbor,N. Scotia	1134	Marine
Daviken	Baltimore, MD	9594	Brackish/FW
Spring Laker	New Haven, CT	1662.36	Marine
Malene	Copenhagen, Denmark	238	Brackish/FW
Goviken	New Haven, CT	1632	Brackish/FW
Marilis T	Baltimore, MD	1152.08	Brackish/FW
Federal Bergen	Baltimore, MD	2576.1	Brackish/FW
Fullnes	Baltimore, MD	3919	Brackish/FW
Federal Asahi	New Haven, CT	1057	Brackish/FW
Dobrush	Norfolk, VA	8574	Brackish/Estuarine
Spring Laker	Philadelphia, PA	4841.94	Freshwater
		2001	
Federal Hunter	Camden, NJ	4436	Freswater
Spar Opal	New Haven, CT	940	Brackish/FW
Happy River	Providence, RI	3520	Brackish/Marine
Spar Jade	Philadelphia, PA	1610	Freshwater
NST Challenge	Providence, RI	5110	Freshwater
Federal Kivalina	Baltimore, MD	12233	Brackish/FW
Dimitris Y	Boston, MA	3913.2	Brackish
Adimon	Norfolk, VA	5430	Brackish/Estuarine
Mathile Oldendorf	Gaspe, Canada	4511.6	Marine?
Lucky Lady	Baltimore, MD	1164	Brackish/FW
Sylvia	Belledune, Canada	3907	Marine
Coral Trader	St. John, NB	1325	Marine

[1] Donor harbour salinities provided by M.Gilbert Fisheries and Oceans Canada

Appendix C

Record of Vessel Trips Using Laurentian Channel for Ballast Water Exchange – Summary from ECAREG Database for year 2000, provided by Glen Herbert, Oceans and Coastal Management Division, Fisheries and Oceans Canada (Maritimes Region), Bedford Institute of Oceanography

Stat_Report	TripNum2	Vess_Name	GrosTon	VesTyp
	553724	STAR STRONEN	12768	MG
	553724	STAR STRONEN	12768	MG
	553724	STAR STRONEN	12768	MG
(L)XCHD BAL WATER COMPLETED	553724	STAR STRONEN	12768	MG
(M) WILL EXCHANGE IN LAURENTIAN CHANNEL	553724	STAR STRONEN	12768	MG
(M)IOPPC EXP. 9 JUNE 2000	534062	MARINETTE	9261	MG
	534062	MARINETTE	9261	MG
(M)VESSEL WILL EXCHANGE BALLAST BETWEEN 61W-63W	534062	MARINETTE	9261	MG
(M) BAL EXCH COMPLETE POSN 4855N 06250W	534062	MARINETTE	9261	MG
	534062	MARINETTE	9261	MG
IOPPC EXP: 09 FEB 2001	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
(M) Q1 ANSWERED TO SATISFACTION	532657	EMMAGRACHT	8448	MG
BALLAST EXCHANGED BETWEEN 61-63W.	532657	EMMAGRACHT	8448	MG
(M) JIGS 1 YES 2 YES	533786	PIETRO BARBARO	9383	TL
4916.5N 6352.7W CO 300 SPD 13KTS OPEN WATER	533786	PIETRO BARBARO	9383	TL
(M)WILLEXCHANCE IN LAURENTIEN CHANNE	533786	PIETRO BARBARO	9383	TL
EXCH BALLAST FM 4831N 6155W TILL 4857N 6300W	533786	PIETRO BARBARO	9383	TL
(M) COF EXPIRES JULY 30TH 2002	533786	PIETRO BARBARO	9383	TL
(M)IOPP-30/06/02,ISM-22/01/03,DOC-22/03/02	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
4850.3N 6243.8W CO 300 SPD 13 KTS OPEN WATER	533786	PIETRO BARBARO	9383	TL
(L) CFM BAL XCHD BN 61/63W	535159	NELVANA	44340	MB
(M) BALLAST TO BE EXCHANGED IN LAURENTIAN CHANNEL	535159	NELVANA	44340	MB
	535159	NELVANA	44340	MB
	535159	NELVANA	44340	MB
BALLAST EXCHANGED IN LANRENTIAN CHANNEL	549915	NAVA MARIA	18604	MB
	549915	NAVA MARIA	18604	MB
(M) INTEND CHANGING BST LAURENTIAN CHANNEL	549915	NAVA MARIA	18604	MB
	549915	NAVA MARIA	18604	MB
(M) BAL WILL BE CHANGED BETWEEN 61/63W WILL ADVISE	538360	LAMDA *	9529	MB
	538360	LAMDA *	9529	MB

	538360	LAMDA *	9529	MB
BALLAST WAS EXCHANGED BETWEEN 61W & 63W.	538360	LAMDA *	9529	MB
	549544	DOBRUSH	17989	MB
	549544	DOBRUSH	17989	MB
(M)WILL BE EXCHANGED IN LAURENTIAN CHANNEL BTWN 61W+63W	549544	DOBRUSH	17989	MB
	552094	SHOU CHANG HAI	27766	MB
(M) COMMENCE EXCH BALLAST	552094	SHOU CHANG HAI	27766	MB
(M)VSL ADVSD AS PROC TO PORT WEST OF 63W-BAL TO BEEXCHANGED	552094	SHOU CHANG HAI	27766	MB
	552094	SHOU CHANG HAI	27766	MB
	552094	SHOU CHANG HAI	27766	MB
(M) EXP IOPPC 17 MAR 2004, ISM 20 MAR 2002, DOC 30 JAN 2002	552094	SHOU CHANG HAI	27766	MB
	534655	WELLINGTON KENT	7001	TT
	534655	WELLINGTON KENT	7001	TT
(M) EXCH BAL TANKS LAUR CHNL CGO TANKS EXCH ASHORE DESTN	534655	WELLINGTON KENT	7001	TT
	534655	WELLINGTON KENT	7001	TT
EXCHANGE BALLAST BETWEEN 4705N05956W AND 4855N06254W.	550236	BERNHARD OLDENDORFF	43332	MB
	550236	BERNHARD OLDENDORFF	43332	MB
	550236	BERNHARD OLDENDORFF	43332	MB
	548132	THORNHILL	22354	MB
(M) COMPLETED BST EXCHN IN LAURENTIAN CHANNEL	548132	THORNHILL	22354	MB
	548132	THORNHILL	22354	MB
	542300	DOUG MCKEIL	292	HT
BALLAST EXCHANGED BTWN 6130W AND 6230W	542300	DOUG MCKEIL	292	HT
(M) MASTER INFORMS ECAREG BALLAST DRAWN IN 15' BOSTON HBR	542300	DOUG MCKEIL	292	HT
(M) COMPLETED BAL EXCH BTN 4854.7N/6255.9W AT 11/2200Z	547436	DEVOLAN *	14558	MB
(M) EX IOPP 2000/NOV/07 ISMC 2003/03/28 ISM/D 2002/03/07	547436	DEVOLAN *	14558	MB
	547436	DEVOLAN *	14558	MB
(M) BALLAST WILL BE EXCHANGED LAURENTIAN CHNL 61W-63W	547436	DEVOLAN *	14558	MB
IN CONFORMITY.	547436	DEVOLAN *	14558	MB
	547436	DEVOLAN *	14558	MB
	551617	SPRING LAKER	17997	MB
	551617	SPRING LAKER	17997	MB
(M) BAL WILL BE EXCHNGD BTWN 61W-63W IN LAUREN. CHNL	551617	SPRING LAKER	17997	MB
WATER BAL. HAS BEEN EXCHG AS REQUIRED	551617	SPRING LAKER	17997	MB
	538053	KAPITAN VAGA	6030	MG
(M)WILL BE EXCHANGED IN LAURENTIAN CHANNEL	538053	KAPITAN VAGA	6030	MG
EXCHNG COMPLTD AT 1945LT PSN 4820N 6127W.	538053	KAPITAN VAGA	6030	MG
	538053	KAPITAN VAGA	6030	MG
	547568	STAR DRIVANGER *	27735	MG
COMPLIES - WILL EXCHANGE IN LAURENTIAN CHANNEL BTW 61/63W	547568	STAR DRIVANGER *	27735	MG
	547568	STAR DRIVANGER *	27735	MG
(N)UNABLE TO PUMP #5 TANK DUE STABILITY. NON COMP RPT SENT	547568	STAR DRIVANGER *	27735	MG
	543140	FOREST ENTERPRISE	10199	MG
	543140	FOREST ENTERPRISE	10199	MG
(M) CALLED CUSTOMS&IMMIGRATION RE ROGUE	543140	FOREST ENTERPRISE	10199	MG
(M) 1700MT BAL TAKEN IN US PORTS/XCHANGE IN LAURENTN CH.	543140	FOREST ENTERPRISE	10199	MG
(M) EXCH POSN 4854N 06255W	543140	FOREST ENTERPRISE	10199	MG

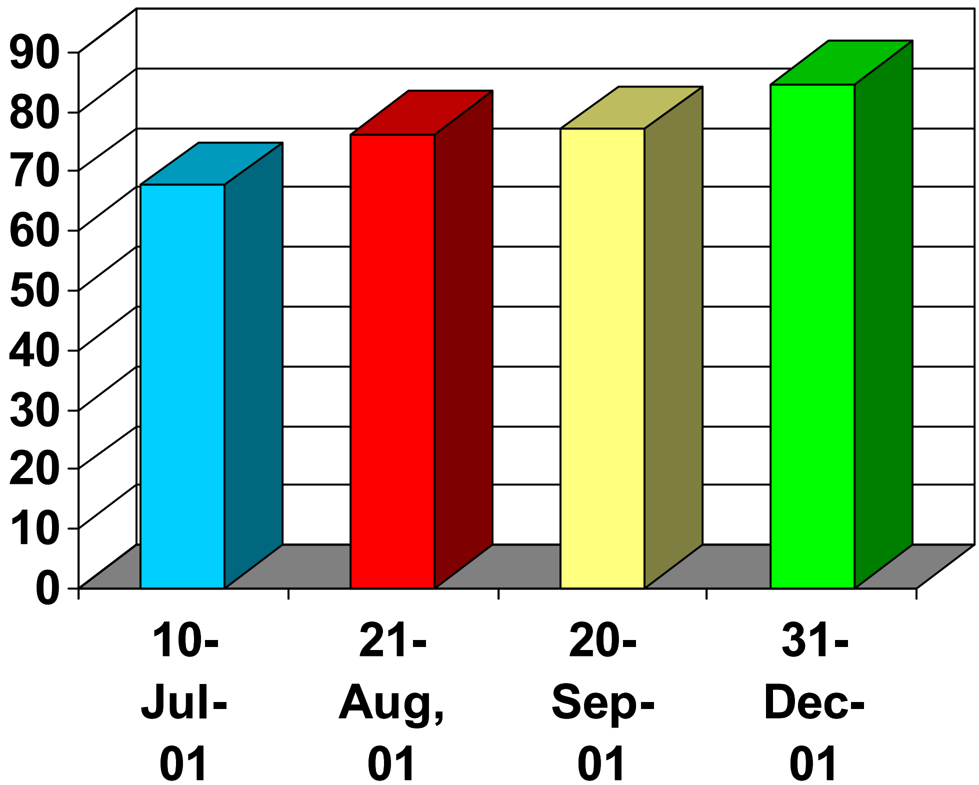
(M) 1800MT EXCH 3730N 06700W; WILL DISCH 600MT LAUR. CHNL	536878 VOLA	13834	MB
	536878 VOLA	13834	MB
	536878 VOLA	13834	MB
BALLAST EXCHANGED IN LAURENTIAN CHANNEL>300M 6103/6253.	553053 MILLENIUM EAGLE	17822	MB
BALLAST TO BE EXCHANGED IN LAURENTIAN CHANNEL >300M 61/63W	553053 MILLENIUM EAGLE	17822	MB
	553053 MILLENIUM EAGLE	17822	MB
	553053 MILLENIUM EAGLE	17822	MB
START TO EXCHG BALLAST PASSING 61W WILL TAKE 24HRS	531370 HENG SHAN	86192	MB
	531370 HENG SHAN	86192	MB
IOPPC EXP AUG 10/2004 ISM-DOC FEB 26/2003 SMC FEB 09/2000	531370 HENG SHAN	86192	MB
NO EXCHANGE OF BAL THIS TRIP - WILL CHANGE BTW 61/63W	531370 HENG SHAN	86192	MB
	531370 HENG SHAN	86192	MB
(M) WILL EXCHANGE BST IN LAURENTIAN CHANNEL	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531788 BREMER SATURN	2854	MG
IOPPC 10.05.2000	531788 BREMER SATURN	2854	MG
WILL EXCHANGE 470TONS BALLAST IN LAURENTIAN CHANNEL	531788 BREMER SATURN	2854	MG
COMPLETED BALLAST EXCHANGE AT 4829N 06152W	531788 BREMER SATURN	2854	MG
	531788 BREMER SATURN	2854	MG
NEW ICE RECOMMENDED ROUTE #3 SENT VIA VCG	531788 BREMER SATURN	2854	MG
(L) ADVISED NEW ICE ROUTE NO. 4	531788 BREMER SATURN	2854	MG
	532457 MICHIGANBORG	6540	MG
	532457 MICHIGANBORG	6540	MG
IOPPC EXP 09 SEPT 2004 COC EXP 17.06.2002	532457 MICHIGANBORG	6540	MG
BALLAST TO BE EXCHANGED IN THE LAURENTIAN CHANNEL.	532457 MICHIGANBORG	6540	MG
ISM EXP 21-03-2005 ISM DOC 17-06-2002	532457 MICHIGANBORG	6540	MG
(M) EXCH LAURENTIAN CHANNEL	544659 VOORNEBORG	6130	MG
	544659 VOORNEBORG	6130	MG
ISM EXP JUNE 17 2002	544659 VOORNEBORG	6130	MG
	544659 VOORNEBORG	6130	MG
(M) IOPPC 2000/JUL/15 ISMC 2000/AUG/15 ISMD 2000/OCT/04	534891 BOW DE SILVER	6294	TT
(M) BST TAKEN IN PORT AM, WILL EXCH ACCORDING INSTRUCTIONS	534891 BOW DE SILVER	6294	TT
(M) TANKER TYPE OIL/MOLASSES/CHEMICAL II/III	534891 BOW DE SILVER	6294	TT
	534891 BOW DE SILVER	6294	TT
(M) BAL XCHD 4527/06014 TO 4818/06122 300630Z	534891 BOW DE SILVER	6294	TT
	534891 BOW DE SILVER	6294	TT
(M) COF 2000/JUL/15	534891 BOW DE SILVER	6294	TT
(M) IOPPC 09/01/2001 ISM 28/03/2003 DOC 16/02/2003	535224 EMMA OLDENDORFF	18220	MB
(M) EXCHANGED >2000M	535224 EMMA OLDENDORFF	18220	MB
(M) COMPLETED BAL XCHANG 1600Z 48.32N/062.01W	535224 EMMA OLDENDORFF	18220	MB
	535224 EMMA OLDENDORFF	18220	MB
	535224 EMMA OLDENDORFF	18220	MB
COMPLETED BALLAST EXCHANGE IN PX 4856N 06259W.	535415 YUAN ZHI	21392	MB
	535415 YUAN ZHI	21392	MB
	535415 YUAN ZHI	21392	MB

(M) EXP DATE IOPPC=25-03-2004,ISM=07-07-2003,DOC=14-10-2001	535415	YUAN ZHI	21392 MB
L)EXCHANGE OF BAL IN LAURENTION CHANEL COMPLETED 09/0100LT	535415	YUAN ZHI	21392 MB
(M)BAL TAKEN IN DELAWARE,WILL EXCH LAURENTIAN CH AND REPORT	535415	YUAN ZHI	21392 MB
(M) VESSEL TO PICK-UP CDN CHART FROM QBC-MTL AT DLES	535674	SILVER RIVER	8041 TT
(L)BAL OK.	535674	SILVER RIVER	8041 TT
(M) EXP IOPPC=25-06-2004, SMC=22-06-2000, DOC=11-06-2004	535674	SILVER RIVER	8041 TT
(M) NO BAL TO DISCHARGE BUT 426.8T TO EXCH IN LAURENTIAN CH	535674	SILVER RIVER	8041 TT
	535674	SILVER RIVER	8041 TT
	535674	SILVER RIVER	8041 TT
	535674	SILVER RIVER	8041 TT
	536724	HELLENIC CONFIDENCE	10984 MB
(M) NO BALLAST ON BOARD/WILL TAKE BALLAST IN CABOT STRAIT	536724	HELLENIC CONFIDENCE	10984 MB
	536724	HELLENIC CONFIDENCE	10984 MB
	540131	ARON	3410 MG
	540131	ARON	3410 MG
(L) 50 MT BALLAST WATER EXCHANGED 61W ET 63W.	540131	ARON	3410 MG
(M) 50 MTS WILL BE EXCHND IN LAUR. CH./WILL ADVISE	540131	ARON	3410 MG
IOPPC EXPIRY AUGUST 31/2000	540131	ARON	3410 MG
	541520	PANAM CRISTAL	5974 TT
(M)IOPPC 2001/01/17 ISM 2001/09/08 DOC 2002/05/28	541520	PANAM CRISTAL	5974 TT
(M) CERT. OF FITNESS 2001/01/17	541520	PANAM CRISTAL	5974 TT
(M) WILL COMPLY WITH BAL REG. AND ADVISE COMPLETED	541520	PANAM CRISTAL	5974 TT
COMPLETION OF BALLAST EXCHANGE 4810N/61W TO 4856/6259.	541520	PANAM CRISTAL	5974 TT
	541520	PANAM CRISTAL	5974 TT
	554171	MOEZELBORG	6540 MG
CHANGE WATER BALLAST ENTRE 4809N 6100W ET 4839N 6244W.	554171	MOEZELBORG	6540 MG
(M) WILL CHANGE BST IN LAURENTIAN CHANNEL	554171	MOEZELBORG	6540 MG
	554171	MOEZELBORG	6540 MG
(M) COMPLETED BALLASTING 4856N 06259.3W	542714	LAPPONIAN REEFER	7944 MR
(M) BAL TO BE EXCHANGED LAURENTIAN CHANNEL	542714	LAPPONIAN REEFER	7944 MR
	542714	LAPPONIAN REEFER	7944 MR
	542714	LAPPONIAN REEFER	7944 MR
(M) IOPPC EXPIRES JAN 23RD 2002	542714	LAPPONIAN REEFER	7944 MR
	543701	LYKES LEADER	13231 MG
	543701	LYKES LEADER	13231 MG
(L) VSL ADVD BALAST EXCHANGED IN LAURENTIAN CHANNEL.	543701	LYKES LEADER	13231 MG
(M) EX TOWER BRIDGE/C6KP4 UID 20023	543701	LYKES LEADER	13231 MG
(M) EXP IOPPC 14/OCT 2001	543701	LYKES LEADER	13231 MG
(M) IOPPC 2003/02/10	545193	FU AN CHENG	16801 MG
	545193	FU AN CHENG	16801 MG
	545193	FU AN CHENG	16801 MG
(M) WILL EXH LAURENTIAN CH. BST 1080MT BWTN 61W/63W	545193	FU AN CHENG	16801 MG
(L) BAL XCHDIN LAURENTIAN CHNL DEPTH EXCD 300 MTRS.	545193	FU AN CHENG	16801 MG
(M) SENT OVERDUE +4 HOUR MESSAGE VIA SYDNEY RADIO/VCO	545193	FU AN CHENG	16801 MG
	548229	TAIPAN	12758 TL
(M) NO BALLAST ON BOARD. INTENDS TAKING 150MT IN GULF.	548229	TAIPAN	12758 TL
	548229	TAIPAN	12758 TL

(M)IOPPC EXP: 31/10/01 COF:31/10/01 ISM:26/07/05	548229	TAIPAN	12758 TL
EXCHANGE BALAST FROM 4811N/06105W TO 4846N/06234W	548548	MARGARA	40705 TT
	548548	MARGARA	40705 TT
	548548	MARGARA	40705 TT
(M)IOPPC: 08/31/2004 ISM: 12/12/2004 DOC: 02/09/2003	548548	MARGARA	40705 TT
	552366	LING XIAN	31643 MB
(M)EXPY;IOPPC:30/11/2004.ISM:23/04/2002.DOC:28/08/2001	552366	LING XIAN	31643 MB
(M)INTEND TO EXCHANGE BALLAST TAKEN AT NEWARK BTWN 61 & 63W	552366	LING XIAN	31643 MB
	552366	LING XIAN	31643 MB
	553662	ATLANTIC SWAN	7285 TT
(L) XCGD COMPLETED IN LAURENTIAN CHANNEL	553662	ATLANTIC SWAN	7285 TT
(M) EXP IOPP 31 JUL 2005 ISM 16 JAN 2003 DOC 27 OCT 2002.	553662	ATLANTIC SWAN	7285 TT
(M) EXP INLS 31/07/05 COC 26/05/02 COF 31/07/05	553662	ATLANTIC SWAN	7285 TT
	553662	ATLANTIC SWAN	7285 TT
(L) VSL RQST CDN CHARTS FRM LES TO MTL (APL AVISE).	553662	ATLANTIC SWAN	7285 TT
(M) WILL EXCHNG BTWN 61-63W AND WILL RPRT PSN/TIME.	553662	ATLANTIC SWAN	7285 TT
	553746	EDEN	73016 MB
(M) EXCH BTWN 61W AND 63W.	553746	EDEN	73016 MB
	553746	EDEN	73016 MB
IOPPC 05/09 2001 ISM DOC 09/03 2004 SMC 12/09 2001	553746	EDEN	73016 MB
VSL TO EXCHANGE BALLAST BETWEEN 61W AND 63W	553746	EDEN	73016 MB
(M)WILL COMPLY& EXCH BAL IN LAURENTIAN CH BTWN 61W-63W...	554741	JING AN CHENG	16703 MG
(M)EXCH 3515N/7501W-3544N/7449W DEP 50M-1500M	554741	JING AN CHENG	16703 MG
(M)IOPPC 18/10/2002	554741	JING AN CHENG	16703 MG
	554741	JING AN CHENG	16703 MG
	554741	JING AN CHENG	16703 MG
(M) EX COMPLETED 4810.8/06102/4847.5/06236 IAW REGS	554741	JING AN CHENG	16703 MG
(M)ISMCERT/EXPIRY/OCT/05/2004 DOC/APR/08/2002	554741	JING AN CHENG	16703 MG
(M) SAFETY MANAGEMENT CERTIF EXP 23/06/2005.	547882	FEDERAL ASAHI	20659 MB
(M)BST ONBOARD TAKEN AT PHILADELPHIA, CHANGE LAURENTIANCHNL	547882	FEDERAL ASAHI	20659 MB
	547882	FEDERAL ASAHI	20659 MB
	547882	FEDERAL ASAHI	20659 MB

APPENDIX D -COMPLIANCE WITH CANADIAN BALLAST WATER GUIDELINES (%)

Provided by Marine Safety -Dartmouth



<u>Reasons for non-compliance</u>

409: total non-compliance reports (23%);
–108 did not comply but provided BW forms:
–151, on coastal voyages north-south route;
–138, no reason for not complying
–8, no BW exchange - bad weather;
–4, Safety/ hull stress

APPENDIX E

Minutes from the Workshop held in conjunction with the Canadian Marine Advisory Council, November 6, 2001 in Ottawa, Ontario

Laurentian Channel Workshop

Purpose:

- Consultation as part of CMAC, a binational forum, to obtain input for the development of a risk assessment assess the potential for introduction of alien species to the Gulf of St. Lawrence if the Laurentian Channel is an alternative ballast water exchange zone.

Workshop Overview:

- Explain the concept of probabilistic risk assessment (PRA).
- Obtain input to develop a risk analysis model for ballast water exchange in the Laurentian Channel.
- Discuss applicability to other geographic areas.
- Discuss Transport Canada's next regulatory step.
- Identify gaps in knowledge/data – What research is needed?

Outcomes:

- Agreed: The minimum volumes of ballast water exchanged in the Laurentian Channel will be based on the U Guard reports from Massena, NY.
- Agreed: For the purposes of developing the overall risk assessment model, there will be no separation of th Laurentian Channel from the Gulf or Estuary, although the risk posed by each area can be separated out.
- Agreed: Ports of origin for ballast water need to be considered.
- Agreed: Seasonal breakdown is a factor to be taken into consideration when developing the model.
- Agreed: Transit time is a factor to be taken into consideration when developing the model i.e., $\leq$ 5 days and
- Agreed: A risk assessment model will be constructed based on the best input data available. There will be a opportunity for fine tuning of the model when better data become available.

Other business following the workshop:

Janet Cavanagh introduced Brian Petrie, who provided an overview of the study that he has undertaken for Transp on circulation and dispersion patterns on the Continental Shelf off the coat of Nova Scotia.

Extensive discussion ensued over the request to the USCG for exemption from ballast water exchange for ships wi ballast water treatment systems.

APPENDIX F

Ballast Water Risk – Mathematical Model

The following describes the method of calculating risk. Refer to Figure 1 for the different sequences.

Let, for a ship originating in region "i" and destined for zone "j":

n_{ij} = number of ships per year

$p_{T,\,ij}$ = probability of transit time greater than 5days

$p_{ME,\,ij}$ = probability of mid-ocean exchange

$p_{CE,\,ij}$ = probability of channel exchange given no mid-ocean exchange

$q_{T,\,ij}$ = residual after being in transit for greater than 5 days as a fraction of the quantity in the ballast at origin, a voyage mitigation effectiveness

$q_{ME,\,ij}$ = residual after mid-ocean exchange

$q_{CE,\,ij}$ = residual after Channel exchange as a fraction of the quantity in the ballast prior to exchange, a measure exchange mitigation effectiveness

The various possibilities are represented in Figure 1.

Ships bound for the Great Lakes only pass through the Gulf and do not discharge at ports in the Gulf and Estuary. With the NOBOB ships, these ships would exchange ballast in the Laurentian Channel if they had not already exchanged ballast in The amount of alien species introduced in the Gulf and Estuary including the Lauentian Channel, therefore, is the sum of introduced at ports in the Gulf and Estuary and the amount introduced in the Laurentian Channel. Thus, the risk to the Gulf including the Laurentian Channel, as it is measured in this study, is the sum of the risk from discharge at ports and risk from the Laurentian Channel.

Disch

The expected frequency of each sequence weighted by associated mitigation effectiveness is estimated as follows:

$f_{ij,1} = (n_{ij}) \times (p_{T,\,ij}\ q_{T,\,ij}) \times (p_{ME,\,ij}\ q_{ME,\,ij})$

$f_{ij,2} = (n_{ij}) \times (p_{T,\,ij}\ q_{T,\,ij}) \times [(1\text{-}p_{ME,\,ij})\ p_{CE,\,ij}\ q_{CE,\,ij}]$

$f_{ij,3} = (n_{ij}) \times (p_{T,\,ij}\ q_{T,\,ij}) \times [(1\text{-}p_{ME,\,ij})\ (1\text{-}p_{CE,\,ij})]$

$f_{ij,4} = (n_{ij}) \times (1\text{-}p_{T,\,ij}) \times (p_{ME,\,ij}\ q_{ME,\,ij})$

$f_{ij,5} = (n_{ij}) \times (1\text{-}p_{T,\,ij}) \times [(1\text{-}p_{ME,\,ij})\ p_{CE,\,ij}\ q_{CE,\,ij}]$

$f_{ij,6} = (n_{ij}) \times (1\text{-}p_{T,\,ij}) \times [(1\text{-}p_{ME,\,ij})\ (1\text{-}p_{CE,\,ij})]$

Then, in terms of the *expected number* of ships weighted by mitigation effectiveness, the risk of introduction at port from a shi in region "i" and destined to zone "j" is given by:

$s_{ij} = \Sigma\, f_{ij,\,k}$ introductions per year, k = 1,6

Risk of introduction at port from ships originating from region "i" is estimated as:

$s_i = \Sigma s_{ij}$ introductions per year (summation over "j") [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from ships arriving at zone "j" is estimated as:

$s_j = \Sigma s_{ij}$ introductions per year (summation over "i") [i = A, B, C, G & O; j = I to FWE]

The total risk of introduction at port in the Gulf and Estuary is estimated as:

$s = \Sigma s_i = \Sigma s_j$ introductions per year

Let w_{ij} = the average quantity of ballast in a ship from origin "i" to destination "j".

Then, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, the risk of introduction at por originating from origin "i" and destined to region "j" is given by:

$$S_{ij} = (s_{ij}\ w_{ij})/(n_{ij}\ w_{ij})$$
$$= s_{ij}/n_{ij}$$

Risk of introduction at port from ships originating from origin "i" is estimated as:

$S_i = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over j) [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from ships arriving at zone "j" is estimated as:

$S_j = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over "i") [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$S = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to FWE)

<u>Exchange in the Channel</u>

Referring to Figure 1, for a ship from origin "i" destined to region "j", there are two sequences that would discharge in the Cha are sequences IJ2 and IJ5.

$$h_{ij,2} = (n_{ij}) \times (p_{T,\,ij}\ q_{T,\,ij}) \times [(1-p_{ME,\,ij})\ p_{CE,\,ij}\ (1-q_{CE,\,ij})]$$

$$h_{ij,6} = (n_{ij}) \times (1-p_{T,\,ij}) \times [(1-p_{ME,\,ij})\ p_{CE,\,ij}\ (1-q_{CE,\,ij})]$$

Then, in terms of the *expected number* of ships weighted by mitigation effectiveness, the risk of introduction in the Channel originating in region "i" and destined to zone "j" is given by:

$c_{ij} = h_{ij,2} + h_{ij,6}$ introductions per year

Risk of introduction at port from ships originating from region "i" is estimated as:

$c_i = \Sigma c_{ij}$ introductions per year (summation over "j") [i = A, B, C, G & O; j = I to GL-LC]

Risk of introduction in the Channel from ships arriving at zone "j" is estimated as:

$c_j = \Sigma c_{ij}$ introductions per year (summation over "i") [i = A, B, C, G & O; j = I to GL-LC]

The total risk of introduction in the Channel is estimated as:

$c = \Sigma c_i = \Sigma c_j$ introductions per year

Let w_{ij} = the average quantity of ballast in a ship from origin "i" to destination "j".

Then, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, the risk of introduction in the C ships originating from origin "i" and destined to region "j" is given by:

$$C_{ij} = (c_{ij}\, w_{ij})/(n_{ij}\, w_{ij}) = c_{ij}/n_{ij}$$

The marginal aggregate risk of introduction in the Channel from ships originating from origin "i" is estimated as:

$C_i = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over j) [i = A, B, C, G & O; j = I to GL-LC]

The marginal aggregate risk of introduction in the Channel from ships arriving at zone "j" is estimated as:

$C_j = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over "i")
(i = A, B, C, G & O; j = I to GL-LC)

Risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$C = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

<u>Total Risk</u>

The total risk to the Gulf and Estuary, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, from origin "i" destined to region "j" is given by:

$$g_{ij} = (s_{ij}\, w_{ij} + c_{ij}\, w_{ij})/\, n_{ij}\, w_{ij} = (s_{ij} + c_{ij})/n_{ij}$$

The marginal aggregate risk to the Gulf and Estuary from ships originating from origin "i" is estimated as:

$G_i = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The marginal aggregate risk to the Gulf and Estuary from ships arriving at zone "j" is estimated as:

$G_j = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over "i")
(i = A, B, C, G & O; j = I to GL-LC)

The total risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$G = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to FEW)

The total risk to the Gulf and the Estuary may also be estimated in terms of the fraction of the quantity of alien species cont ballast of all ships at origin travelling from all FAO regions to the Gulf and Estuary. This is calculated as follows:

Let,

$Q = (\Sigma n_{ij}\, w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

Risk from ships from region "i" travelling to zone "j" is estimated as:

$g'_{ij} = (s_{ij}\, w_{ij} + c_{ij}\, w_{ij})/ Q$

The marginal aggregate risk from all ships from region "i" is estimated as:

$G'_i = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/Q$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The marginal aggregate risk from all ships travelling to zone "j" is estimated as:

$G'_j = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/Q$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$G = \Sigma G'_i$ (summation over i = A, B, C, G & O)
$= \Sigma G'_j$ (summation over j = I to FEW)

<u>Relative Risk to the Channel</u>

The Risk to the Channel from exchanges in the Channel can be expressed relative to the total risk to the Gulf and Estuary fr This is the so-called Relative Risk and is estimated for a ship from origin "i" and destined to region "j" as:

$r_{ij} = c_{ij}/(s_{ij} + c_{ij})$

The total Relative Risk to the Channel from ships originating from origin "i" is estimated as:

$R_i = (\Sigma\, c_{ij}\, w_{ij})/(\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total Relative Risk to the Channel from ships arriving at zone "j" is estimated as:

$R_j = (\Sigma\, c_{ij}\, w_{ij})/(\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total Relative Risk to the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$R = (\Sigma\, c_{ij}\, w_{ij})/(\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

APPENDIX G

Risk Model Verification

In order to verify the risk model, sensitivity analysis was performed. This was done by changing some of the variables one at a keeping the rest at their values shown in Tables 3 to 6. The variable selected were mitigation effectiveness of the transit time, exchange and exchange in the Laurentian Channel. The results are presented in Table B-1. The highlighted rows are the res Tables 1 and 2. A discussion follows.

Table B-1: Sensitivity Analysis

Variable	Mitigation Effectiveness – Residual Fraction	Risk at Port, %	Risk in Channel, %	Total Risk, %	Channel – Relative Risk, %
Transit Time	0.00	12.8	0.14	12.9	1.06
	0.25	19.0	0.14	19.1	0.72
	0.50	**25.1**	**0.14**	**25.3**	**0.55**
	0.75	31.3	0.14	31.5	0.44
	1.00	37.5	0.14	37.7	0.37
Mid-Ocean Exchange	0.00	16.8	0.14	16.9	0.82
	0.20	**25.1**	**0.14**	**25.3**	**0.55**
	0.40	33.5	0.14	33.6	0.41
	0.60	41.9	0.14	42.0	0.33
	0.80	50.2	0.14	50.4	0.27
	1.00	58.6	0.14	58.7	0.24
Channel Exchange	0.00	25.1	0.17	25.3	0.68
	0.20	**25.1**	**0.14**	**25.3**	**0.55**
	0.40	25.1	0.10	25.3	0.41
	0.60	25.1	0.07	25.2	0.27
	0.80	25.1	0.03	25.2	0.14
	1.00	25.1	0.00	25.1	0.00

Note:Mitigation Effectiveness is expressed in terms of fraction of residual alien species in the ballast after the e For example, an effectiveness of 0.6 means that after an exchange the ballast would contain 60% of the quan prior to the exchange.

<u>Transit Time</u>

As the residual fraction increases, i.e., as the impact of the transit time on mortality decreases, the risk at port increases. T expected, as the ballast water discharged at port will contain a greater percentage of the alien species that were present at ori

The risk of introduction in the Laurentian Channel changes negligibly because the risk stems mostly from ships from region A, transit time of less than five days, and also the size of their ballast is small.

As the risk at port increases and the change in the risk to the Laurentian Channel is negligible, the relative risk of introdu Channel decreases as the residual fraction increases. This result is as expected.

Mid-Ocean Exchange

As the portion of ballast water exchanged in mid-ocean decreases, i.e., the residual fraction increases, the risk at port increa
as in the case of Transit Time, this is an expected result.

The risk of introduction in the Laurentian Channel changes negligibly because, as in the previous case, the risk stems mostl
from region A, which has a transit time of less than five days, and also the size of their ballast is small.

As the risk at port increases and the change in the risk to the Laurentian Channel is negligible, the relative risk of introdu
Channel decreases as the residual fraction increases. This result is also as expected.

Laurentian Channel Exchange

As the portion of ballast water exchanged in Laurentain Channel decreases, i.e., the residual fraction of original ballast wate
and the risk of introduction at port does not change. This is because, currently ships that discharge at port do not exch
Laurentian Channel. This is an expected result.

The risk of introduction in the Laurentian Channel decreases as the portion of ballast water exchanged in Laurentain Channe
i.e., the residual fraction increases. At first glance, this might seem counter intuitive. What this means, however, is that as
fraction increases an exchange introduces a smaller proportion of alien species and retains in the ballast a higher proportion
species that was present at origin.

As there is no impact on risk at port and the risk to the Laurentain Channel decreases, the relative risk of introduction in
decreases as the portion of ballast water exchanged in Laurentain Channel decreases, i.e., the residual fraction increases.
also as expected.

Canada

Sea Grant
National Sea Grant College Program

Massachusetts Institute of Technology
Sea Grant College Program, Pub. 04-02