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# RISK ASSESSMENT OF ALTERNATE BALLAST WATER EXCHANGE ZONES FOR VESSEL TRAFFIC TO THE EASTERN CANADIAN ARCTIC



Figure 1. Recommended Alternate Ballast water exchange zones for the eastern Canadian Arctic.

#### Context

Transport Canada Marine Safety (TCMS) is tasked with managing a regulatory program to set ships' procedures to reduce the risk of ship-mediated transfer of invasive species. TCMS has requested scientifically defensible advice as the basis for national ballast water regulations regarding Alternate Ballast Water Exchange Zones (ABWEZs) for ships in ballast destined for ports in waters of the eastern Canadian Arctic. Under current regulations, ABWEZs have been designated in the Hudson Strait and Lancaster Sound regions of the eastern Canadian Arctic for foreign vessels travelling to the Hudson Bay complex or the Northwest Passage, respectively, in the event that foreign vessels bound for Arctic ports need to conduct emergency ballast water exchange within the Canadian Exclusive Economic Zone (EEZ). Hudson Strait receives the largest volume of shipping activity in the eastern Canadian Arctic and was assessed by Fisheries and Oceans Canada (DFO) in 2009. Several recommendations resulted from the 2009 assessment including the need to assess a broader geographical area of the Labrador Sea to the east of Hudson Strait and to incorporate oceanographic modeling of dispersion patterns. The



Lancaster Sound ABWEZ was not considered in the 2009 review.

DFO responded to these recommendations by evaluating the relative risks of ballast exchange along major shipping routes within the eastern Canadian Arctic, including both the Hudson Strait and Lancaster Sound ABWEZs. This assessment is based on oceanographic modeling of particle dispersion in relation to climate, depth, and areas of ecological significance. This assessment will be considered by TCMS to determine whether and how a regulatory program needs to be modified to reduce the risk of ship-mediated transfer of invasive species in the eastern Canadian Arctic.

This Science Advisory Report is from the November 20-21, 2013 Risk assessment of Alternate Ballast Water Exchange Zones for vessel traffic to the eastern Canadian Arctic. Additional publications from this meeting will be posted on the <u>DFO Science Advisory Schedule</u> as they become available.

### SUMMARY

- Transport Canada asked DFO for advice on current and potential exchange zones for ballast water in the eastern Canadian Arctic.
- Scientifically defensible advice was based on modeling the relative risks of ballast exchange at different locations along major shipping routes in the eastern Arctic. Dispersion model results were robust to variation in the weighting of the physical and chemical environmental characteristics of receiving habitats and consistently identified the same regions as having higher relative risk.
- The existing ABWEZs in Lancaster Sound and Hudson Strait are among the areas of highest relative overall risk associated with ballast water-mediated aquatic nonindigenous species (NIS). It is recommended that these zones be removed from current regulations and replaced with more appropriate ones.
- It is recommended that ABWEZs within the eastern Arctic be situated offshore of the 1000 m depth contour in waters between latitudes 57 and 75°N, and longitudes 56 and 73°W (Figure 1).
- To further mitigate risks from organisms in the ballast sediment, it is recommended that vessels entering the Canadian eastern Arctic from beyond the EEZ not in ballast flush their residuals from the ballast tanks prior to entering waters under Canadian jurisdiction. An ABWEZ should be used as a last resort.
- There are currently no regulations for ballast water exchange for vessels operating within the EEZ. Given the potential for transfer of both indigenous and established NIS from southern Canada (and northeastern United States) by these vessels, the recommended ABWEZs would also be appropriate for ballast water exchange and flushing for vessels arriving from southern Canada regardless of whether they have taken on fresh- or marine ballast water. Recognizing operational constraints of vessels coming from southern Canada, further research is needed to assess options for exchange zones closer to shore.
- Under the current regulations Canada does not require reporting of the origin of ballast water for vessels operating within the EEZ. Such knowledge would improve our abilities to understand ballast mediated NIS introductions. It is recommended that these data be acquired.

# BACKGROUND

The discharge of ballast water by ships provides a mechanism for the transfer of biota from one region to another, with potentially damaging effects to the receiving ecosystem. Historically, ballast water has been the predominant ship-mediated vector for aquatic nonindigenous species (NIS) introductions to Canada (Ricciardi 2001; de Lafontaine and Constan 2002). Current

Ballast Water Control and Management regulations (SOR/2011-137), registered on 2011-10-27 under the *Canada Shipping Act*, 2001 (2001, c. 26), require transoceanic and coastal vessels that travel outside Canada's Exclusive Economic Zone (EEZ) to exchange their ballast water and to flush tanks that contain residual sediment and ballast water with saltwater before entering Canadian waters (Figure 1). The objectives of this exchange are:

- 1) to release foreign coastal biota where they are least likely to colonize Canadian coastal waters, and
- 2) to replace them with oceanic species that are less likely to survive when the vessels discharge their ballast into Canadian coastal waters.

Current ballast water regulations apply to ships entering Canadian waters from outside the EEZ. Ships that operate exclusively in waters under Canadian jurisdiction are exempt from regulations on ballast water exchange nor are these vessels covered by any other regulations. Their ballast water poses an unknown but potentially significant pathway for the transfer of NIS within Canadian waters. (e.g., Ruiz and Reid 2007; Casas-Monroy et al. 2014).

Ballast water exchange is considered an interim solution to the ballast water problem (Bailey et al. 2007; Ruiz and Reid 2007). Once the International Convention for the Control and Management of Ships' Ballast Water and Sediments that was adopted by the <u>International Maritime Organization (IMO)</u> in 2004 has been fully ratified, vessels originating from outside Canada's EEZ will be required to treat their ballast water prior to release (IMO 2013). In the future, some Arctic-bound vessels may opt to conduct mid-ocean ballast water exchange and then treat their ballast tanks to further reduce the risk of species introductions ((BIMC 2012, v.10, app.10D-10, s.4.2 & app. 6; see also <u>BIMC FEIS response to QIA-IR-D-02, p. 49 of 55</u>).

The effectiveness of ballast water exchange as a means of reducing the risk of species introductions depends upon the exchange being complete, and on maximizing differences between intake and discharge environments. Optimally, water and biota loaded from shallow, warm, brackish coastal waters during ballasting is released into deep, cold, marine offshore waters during exchange. Ballast water exchange is an effective method for reducing the initial coastal and freshwater plankton assemblages in ballast tanks (by an average of 80-99%) (Gray et al. 2007; Ruiz and Reid 2007). However, when natural mortality observed in control tanks is considered, the efficacy of exchange alone can be much lower (29-40% for microplankton, 23-54% for zooplankton) (Simard et al. 2011). Little is known about the survival rates of the coastal biota that are discharged during exchange.

The fate of biota released during ballast water exchange becomes increasingly important when ships are unable to exchange their ballast outside the EEZ and do so within Canadian waters. This can occur when inclement weather or other safety concerns prevent exchange outside the EEZ. In such cases ships are authorized by the Minister to conduct their exchange in an alternate ballast water exchange zone (ABWEZ) within Canadian waters. Two such zones have been designated for use by vessels from outside the EEZ travelling westbound to ports in the Canadian eastern Arctic including the Hudson Bay complex, one in Lancaster Sound and the other in Hudson Strait. Neither zone was established on the basis of a scientific assessment. An assessment of the Hudson Strait ABWEZ by Fisheries and Oceans Canada (DFO) in 2009 recommended a broader geographic area to the east of Hudson Strait, including the Labrador Sea, be assessed and that it should incorporate oceanographic modeling of dispersion patterns (DFO 2010). The Lancaster Sound ABWEZ was not considered in the 2009 review.

Vessels that require ABWEZs will release ballast water from coastal ports into the upper 20 m of the Arctic water layer, where it will be diluted and dispersed. Biota in the released water should be small, with limited mobility relative to their transport by currents. Their fates following

discharge mid-ocean or into ABWEZs are poorly known. Some organisms will suffer osmotic or thermal shock and die at or shortly after release. Others may descend in the water column, where their survival will be determined by their ability to withstand deep water conditions characterized by higher salinity, lower temperature, and lower light conditions than are common in coastal ports. The remainder will survive following release and be transported by surface currents. It is the latter that are most likely to reach more favourable coastal environments and have the potential to establish reproducing populations.

The impact of introduced species on the receiving ecosystem can be severe and widespread. These species can affect native species by competing with them for resources or space, preying upon them, poisoning them, disrupting their habitats, altering their gene pool through hybridization, introducing parasites or diseases to which they have little resistance, and/or the uncoupling of important biological linkages (e.g., Hallegraeff 1998; Sax et al. 2007). Lacking natural predators, the introduced populations may expand quickly into adjacent areas and their rate of population increase may be high. This can lead to dramatic changes in community structure and function.

The potential for introductions will increase as ship traffic into the eastern Canadian Arctic, including the Hudson Bay complex, increases in response to the growing demand for resources, and to improvements in access related to climate change (e.g., Smith and Stephenson 2013). Little is known about what species might be introduced, their ability to establish, or potential impacts to indigenous species. Consequently, the ABWEZs must be situated in areas where the conditions are least likely to favour the survival and establishment of organisms released in ballast. Optimally, exchange should take place where organisms released with ballast water are swept offshore into deep-water environments, rather than into shallow coastal areas that might provide more hospitable habitat for establishment of NIS entrained with ballast water from foreign ports.

This study evaluates the suitability of existing ABWEZs in Lancaster Sound and Hudson Strait using a semi-quantitative model to assess relative risk from ballast water dispersion along major vessel tracks into the Canadian eastern Arctic. Recommendations are made regarding the suitability of the existing ABWEZs and preferred locations for ABWEZs. The objective is to identify areas where ballast water exchange is least likely to introduce foreign species and thereby avoid ecological damage. This Science Advisory Report summarizes the main conclusions and advice from the science peer review. The research document (Stewart et al. in prep.) provides an in-depth account and the full list of references for information summarized in this report. The proceedings report summarizes the key discussions of the meeting.

# ASSESSMENT

Risk is typically determined based on the likelihood (probability) of an event occurring and the magnitude of potential consequences (impacts) should that event occur (Mandrak et al. 2012). In the case of this study, quantitative assessment of risks associated with ballast water exchange requires knowledge of:

- 1) the likelihood of exposure of receiving habitats to NIS;
- 2) the likelihood of these NIS surviving and establishing reproducing populations; and
- 3) the potential impact of introduced NIS on the receiving ecosystem.

Since this quantitative information is mostly lacking for the eastern Canadian Arctic, the relative risks from exchange at different locations along major shipping routes in the eastern Arctic were considered using mathematical modelling. To assess potential for exposure of receiving habitats to foreign biota, Brickman's (2006) semi-quantitative risk assessment model for

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dispersion of ballast water in shelf seas was adapted for use in the eastern Canadian Arctic. This primarily involved using the Canadian East Coast Ocean Model (CECOM), a coupled iceocean model with the ocean component based on the Princeton Ocean Model (POM). The Canadian Meteorological Centre (CMC) Global Environmental Multiscale (GEM) model provided meteorological forcing, and a version of the 3D Generalized Bottom Boundary Layer Transport Model (BBLT3D) was adapted for particle tracking.

Relative risk was modelled along four shipping routes:

- 1) Labrador Sea to Lancaster Sound via central Baffin Bay (deep route);
- 2) Labrador Sea to Lancaster Sound via western Baffin Bay over depths >300 m (coastal route);
- 3) eastern Hudson Strait; and
- 4) Cumberland Sound.

The deep-water and coastal routes through Baffin Bay were selected to bound potential ABWEZ exchange zones rather than follow specific ship tracks. The deep route should approximate the ballast water exchange track of least risk from a biological perspective, as it follows a central track through Davis Strait and Baffin Bay over deep water. The other three routes correspond approximately to the major shipping tracks identified by Transport Canada for the 2010 shipping season.

In the model, ballast water exchange was simulated as the release of 1000 randomly distributed particles in various segments (40 x 40 km each) of a given vessel track into the surface layer of circulation models for Baffin Bay – Labrador Sea and Lancaster Sound. The simulations were done for May, June, July, August and September (the ice-free season) of 2009 and 2010. Particles were released on the first day of the month and tracked for 30 days. The arrival time (time it took particles to reach a given area), and the frequency of occurrence (combined measure of abundance and residence time for particles in a given area) were computed and then combined to calculate the relative likelihood of exposure, which is the likelihood that a particular receiving habitat may be exposed to NIS released in ballast water.

To assess the relative risk for ballast-mediated introduction of NIS, the receiving habitats were weighted for modelling purposes based on relative likelihood of establishment and relative habitat sensitivity. Relative likelihood of establishment was based on a combination of physical and chemical environmental characteristics that are expected to affect the survival and establishment of self-sustaining populations of NIS in the event of introductions. These characteristics included water depth (coastal, shelf, deep-shelf, and deep offshore), mean annual sea surface temperature, mean annual sea surface salinity, and the seasonal duration of open-water (defined as <50% ice cover). Relative habitat sensitivity of receiving habitats was based on characteristics that reflect biological importance and provide the best available proxy for predicted magnitude of impact. These included biological importance (e.g., areas of high versus low congregation and/or biological diversity), risk intolerance (e.g., areas with populations that are more or less vulnerable to disturbances based on their numbers and/or their status), and importance as harvesting areas as a proxy for biological significance.

The final impact (relative risk) to receiving habitats from ballast water exchange along each ship track was calculated as the product of the likelihood of exposure, likelihood of establishment, and habitat sensitivity. Since the relationship between survival of NIS and various environmental characteristics has not been empirically demonstrated in this region, uncertainty was evaluated using model sensitivity analysis with different weighting schemes following the risk assessment

guidelines outlined in Mandrak et al. (2012). The model was robust to these different weightings and consistently identified the same regions as having higher relative risk.

Modelling results indicated the relative risk from releases along the ship tracks is very high to medium within the confines of Lancaster Sound, Cumberland Sound, and Hudson Strait (Figure 1). It is medium to low near the entrances of these areas and over the relatively shallow shelf southeast of Baffin Island, dropping to low or very low at the shelf edge and over the Canada-Greenland Ridge, and very low offshore of the shelf break. The areas of least risk are bounded approximately by the 1000 m depth contour (Figure 1). This depth is not far offshore from the 300 m depth contour in the western Labrador Sea and much of western Baffin Bay but would still allow ample distance (>400 km) for discharge to occur within the EEZ when approaching Hudson Strait from the Labrador Sea and Lancaster Sound from Baffin Bay.

For detailed information, rationale and formulae for each of the individual components of the risk assessment model as well as the approach that was used to test model sensitivity refer to Stewart et al. (in prep.).

## **Sources of Uncertainty**

- Data are limited for constructing temperature and salinity fields in the Arctic. So temperature and salinity fields used are smoothed in both space and time and are unlikely to capture annual salinity minimums. Variation in offshore salinity is unlikely to be biologically significant for this application. Of greater concern are the coastal areas where salinities may get low enough to be biologically relevant in the context of ballast-mediated NIS introductions. Mean annual salinity used in the modelling may underestimate the risk in coastal areas.
- Shipping is expected to increase and may operate year-round. The modelling of particle dispersion did not consider ballast release in the presence of ice cover (October to April) when particle dispersion is expected to be lower.
- There are limited data to inform the habitat sensitivity metric used in the assessment. Upper trophic level organisms including humans were used as proxies for habitat sensitivity in the absence of sufficient information on lower trophic organisms.
- Tidal range, bottom substrate, and coastal morphology are modifiers of invasion risk that were not included directly in the modelling.
- We have a limited understanding of the complexities of oceanography and ice dynamics and how these relate to invasion risks in the eastern Arctic.
- We have a limited understanding of the species found in the ballast of vessels travelling into the Arctic, their interactions with native fauna, their ability to establish in the Arctic, and their impacts.
- This study focused on the impacts of NIS to coastal species and not on deeper water species. Also, the review did not consider the potential harmful impacts from specific groups of NIS (e.g. phytoplankton, microalgae, zooplankton, and cysts from phytoplankton and algae) that could be introduced by ballast water. Certain species of phytoplankton, and algae in particular, that are known to be harmful to particular organisms may increase in abundance with temperature increases associated with climate change and this could lead to an increased rate of occurrence in species like shellfish that would then pose a risk to seabirds and walrus that consume them.

# CONCLUSIONS AND ADVICE

For vessels en route westward into the eastern Canadian Arctic, the existing ABWEZs in Lancaster Sound and Hudson Strait are among the areas of highest relative risk for introductions of NIS via ballast water. It is recommended that these zones be removed from current regulations and replaced with more appropriate ones.

To reduce risk, it is recommended that ABWEZs within the eastern Arctic be situated offshore of the 1000 m depth contour in waters between latitudes 57 and 75°N, and longitudes 56 and 73°W (Figure 1).

Vessels entering waters under Canadian jurisdiction from outside the EEZ should use an ABWEZ as a last resort.

To further mitigate risks from organisms in the ballast sediment (for further details see Stewart et al. in prep.), it is recommended that vessels entering the Canadian eastern Arctic from beyond the EEZ that are not in ballast flush their residuals from the ballast tanks prior to entering waters under Canadian jurisdiction. Again, an ABWEZ should be used only as a last resort.

There are currently no regulations for ballast water exchange for vessels operating within the EEZ. Given the potential for transfer of both indigenous and established NIS from southern Canada (and northeastern United States) by these vessels, the recommended ABWEZs would also be appropriate for ballast water exchange and flushing for vessels arriving from southern Canada regardless of whether they have taken on fresh- or marine ballast water. Recognizing operational constraints of vessels coming from southern Canada, further research is needed to assess options for exchange zones closer to shore that could be used by these vessels.

Under the current regulations Canada does not require reporting of the origin of ballast water for vessels operating within the EEZ. Such knowledge would improve our abilities to understand ballast mediated NIS introductions. It is recommended that reporting of these data be a mandatory requirement for vessels operating within the EEZ.

# **OTHER CONSIDERATIONS**

We have a limited understanding of the species found in the ballast of vessels travelling into the Arctic, their interactions with native fauna, their ability to establish in the Arctic and their impacts. Research regarding these knowledge gaps is needed to improve our abilities to understand ballast mediated NIS introductions.

Research on content of ballast water tanks prior to exchange and prior to release in port is needed to evaluate the potential for survival of NIS (species and numbers).

Research is needed to assess NIS pressures at release and the ability of live species to survive under conditions found in eastern Arctic waters.

Research is also needed to assess the effectiveness of ballast water treatment options under Arctic winter conditions to determine whether they offer a viable alternative to exchange.

Research is needed to test environmental effects of ballast water treatment options (discharge) on the Arctic environment.

## SOURCES OF INFORMATION

This Science Advisory Report is from the November 20-21, 2013 Risk Assessment of Alternate Ballast Water Exchange Zones for vessel traffic to the eastern Canadian Arctic. Additional publications from this meeting will be posted on the <u>DFO Science Advisory Schedule</u> as they become available.

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