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Evaluating temperature effects on the efficacy of ballast water treatments to prevent non-indigenous introductions into the Canadian Arctic

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Summary
Ballast water is the primary vector for the transfer of non-indigenous species (NIS) among freshwater and marine ecosystems. Current strategies to reduce biological invasions are not 100% effective and additional measures are being developed to minimize the number of viable individuals discharged in ballast water. One of these measures is the use of ballast water treatment on board ships, however, effectiveness needs to be tested at the extreme edges of operational conditions (i.e., very low temperatures). We examine the effectiveness of ballast water treatments for eliminating plankton populations at different temperatures. Preliminary results showed that both treatments (chlorination and UV) have more than 60% efficacy eliminating two taxonomic groups (zooplankton and phytoplankton) at 2°C and 20 °C.

Introduction
The unintentional release of non-indigenous species (NIS) moved by ballast water from large ships constitutes a major threat to freshwater, estuarine and marine ecosystems (Drake et al 2007; Ruiz et al 2000). Climate change is also expected to enhance dispersal of NIS, especially in locations expected to receive greater shipping traffic, such as the Canadian Arctic Ocean. Currently, the most common strategy widely utilized is ballast water exchange (BWE), which replaces coastal water with open-ocean water in order to remove high-risk coastal organisms. Although BWE has been shown to reduce the number of coastal organisms in ballast discharges, it has some limitations (i.e., weather and sea conditions or geographic constraints) that may only allow 80% removal of coastal organisms. Given these limitations of BWE, several governments and agencies are transitioning toward a new framework, where ships will be required to meet numeric ballast water standards permitting discharge of a maximum density of viable organisms (IMO, 2004). To meet these standards, ships are expected to install a Ballast Water Management System to treat the ballast water using chemical, physical and/or mechanical treatments. Although a number of ballast water management systems have received Type Approval based on testing conducted in temperate locations (above 18°C), there is an absence of robust scientific information about the effectiveness of treatment systems operating at low temperatures (under 5°C). This information is crucial in order to protect aquatic ecosystems such as in the Arctic, therefore we aim to examine the biocidal effect of chemical (chlorine) and physical (combined filtration plus UV-c radiation) ballast water treatment processes at different temperatures.

Methodologies
Natural communities of phytoplankton and zooplankton were collected from Hamilton Harbor, Lake Ontario, Canada. For chlorine experiments, both taxa were treated with six different concentrations of chlorine up to 15 ppm at 10 C and 2°C. Experiments were carried out over 5 days. For filtration + UV radiation, tests thus far have been conducted at 20 °C, with additional tests planned at colder temperatures. Experiments were carried out over 5 days, with phytoplankton cultures conducted over 14 days to capture delayed physical response to UV radiation. On Day-0, water was filtered and treated with UV radiation, then kept in the dark for 5 days to simulate ballast tank conditions, then treated again with only UV radiation (replicating the multi-stage process used by shipboard treatment systems). Two types of samples were collected: zooplankton and phytoplankton samples without treatment (day 0 controls) and zooplankton and phytoplankton samples on day-5 (treated). For both chlorine and UV radiation experiments, zooplankton viability was verified by counting live organisms using a dissecting microscope. For tests using chlorine, phytoplankton viability was verified based on fluorescence readings, while for Filtration + UV radiation tests viability was verified based on the number of positive and negative tubes following the most probable number (MPN) method.

Results
Preliminary results show that a 2ppm chlorine concentration at 10°C killed 80% of zooplankton organisms, while at 2°C killed 70% of organisms using the same concentration. Differences were also observed in the EC50 (half maximal effective concentrations) for phytoplankton at both temperatures using the same chlorine concentrations. The chlorine treatment was very effective against most zooplankton groups, including planktonic copepods, Amphipoda, Bivalvia, and Rotifera. Physical treatment using filtration + UV ration seems to have high effectiveness at 20°C, meeting the concentration-based ballast water discharge limits for viable zooplankton and phytoplankton. Culture experiments also revealed that phytoplankton organisms greater than 10µm were not able to reproduce after UV treatment. Once additional tests filtration + UV are completed at lower temperatures, we will be able to assess the effect of temperature on treatment efficacy.

Figure 1. Left) Phytoplankton cultures with chlorine treatments; Right) Shore-side testing lab with filter + UV lamp.

Summary
Treating ballast water with chemical and physical treatments at uptake can be an effective strategy for eliminating potentially invasive species in many sea-going vessels. Our research constitutes the first step forward to markedly reduce invasion risk of zooplankton and phytoplankton NIS in ballast water discharged into cold-water ecosystems such as in the Arctic. While experiments are being conducted at bench scale, they provide valuable information on the response (immediate and delayed) of a variety of organisms to chlorine biocide and physical (filtration + UV) treatments. Additional tests are underway to more fully examine treatment efficacy at low temperatures, with final results expected in late 2015.

References:
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