NOBOB-S: Salinity/Brine Exposure as a Biocide for Application to NOBOB Residuals

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This project is completed

Overview

The largest freshwater port system in the North America is located in the Great Lakes region. It has been estimated that over 180 nonindigenous species have become established in the Great Lakes ecosystem since 1810 (Ricciardi, 2006). Environmental and economic losses due to these species have been estimated at a few billion dollars since about 1990 (O'Neill, pers. comm.). Commercial shipping has accounted for the majority of the nonindigenous species established in these areas (Holeck et al., 2004). Due to ship traffic to the Great Lakes from low salinity ports of the North Sea and Baltic Sea, environmentally tolerant species from these ports are often classified as 'high invasion risk' taxa (Wonham et al., 2005).

The entry of NOBOB (No Ballast on Board) vessels has become a priority nonindigenous species management issue in the Great Lakes. Over 90% of vessels entering the Great Lakes in recent years are NOBOB ships (Johengen et al., 2005). However, these ships often contain adults, larvae, eggs and spores of many taxa within the sediments and residual water of their ballast tanks (Niimi and Reid, 2003; Johengen et al, 2005). NOBOB ships are not covered by ballast water management regulations (mid-ocean ballast water exchange) implemented in 1993 that are designed to reduce the likelihood of new aquatic species introductions. While off-loading and reloading cargo in the Great Lakes, many NOBOB ships take on new freshwater ballast and often discharge this ballast water back into the Great Lakes. This creates a potential invasion risk for the Great Lakes especially if the ballast tank taxa originate from distant ports of similar environmental conditions (Drake et al., 2005; Duggan et al., 2005; Wonham et al., 2005).

In August 2005 the U.S. Coast Guard implemented a policy change that established a voluntary "best management practices" approach for residual ballast water and sediment for NOBOB vessels entering the Great Lakes system. The new policy states "For vessels unable to conduct midocean ballast water exchange, conduct saltwater flushing of their empty ballast water tanks in an area 200 nautical miles from any shore, whenever possible." However, many ships entering the St. Lawrence Seaway are unable to follow this saltwater exchange or flush policy because of load line restrictions and seaway draft constraints. Johengen et al (2005) reported that of 103 vessels surveyed entering the Great Lakes between 2000 and 2003, 49 had last ballasted in fresh or low-salinity water. Of these 49 ships, two had treated their tanks with chlorine, 16 had performed a saltwater flush or a ballast water exchange since the last ballasting, but 31 were entering with fresh or low salinity residual ballast material in their tanks.

Objectives

Increase number of invasive species populations eradicated, contained, or mitigated.

Transition of two tools or best practices to prevent introduction of invasive species into coastal environments from other than “no-ballast-on-board” ships in the Great Lakes.

Proposed Work

Completed field sampling and brine exposure experiments on at least 10 Great Lakes organisms.

Complete brine exposure experiments on at least 10 fresh and brackish water halotolerant organisms from the Chesapeake Bay, San Francisco Bay, and/or the Baltic Sea.

Scientific Rationale

This project will test the effectiveness (concentration-time-mortality) of high concentration salt solutions (sodium chloride brines) as a back-up to saltwater flushing of ballast tanks. Brine solutions are potentially available at many, if not most ports and could be delivered to ships in tank trucks and pumped directly into ballast tanks (Jenkins, pers. comm.). Brines have long been used for preservation of food and few organisms (halophiles) are adapted to highly saline environments. Those that are likely would not survive in the freshwater environment of the Great Lakes.

A ship entering the Great Lakes with residual ballast water of salinity less than the desired 30 ppt could add relatively small amounts of sodium chloride brine at the first port of call. Residual water is generally only a few centimeters deep and thus the typical volume of brine needed to flood a ballast tank with enough brine to raise the effective salinity to ›30 ppt is also relatively small. However, NOBOB ships generally offload cargo at their initial ports of call in the Great Lakes and then must ballast with local Great Lakes water. This can make the window of opportunity for exposure (time from addition to brine until ballast tank is flooded with freshwater, thus diluting the salinity) as short as a few hours. This project will explore the use of brines as a quick-acting biocide suitable for use as part of a back-up strategy to open-ocean saltwater flushing that could be applied to ships not able to safely conduct the open-ocean flushing management practice at sea.

In order for informed recommendations to be made about the best strategy for brine exposures, experimental data will be obtained on the salinity tolerance of planktonic and benthic taxa typically found at in coastal waters or ports of the Great Lakes, the North Sea, and the Baltic Sea.

Experimental Approach

To determine the minimum exposure time and sodium chloride concentration required to kill representative freshwater benthic invertebrates and zooplankton species using organisms commonly found in low salinity ports of the United States (Great Lakes, Chesapeake Bay, San Francisco Bay) and the Baltic Sea.

Task 1: Species from the Great Lakes Experiments

Brine exposures and controls will determine survivorship over time of animals abruptly exposed to sodium chloride salt solutions of 30 ppt, 60 ppt, and 120 ppt. Benthic invertebrates and zooplankton species from the Great Lakes will be tested, depending on their seasonal availability. At least three species of copepod, three species of cladoceran, two species of amphipods, two species of bivalves, and one species of oligochaete have been identified as likely candidates available from the Great Lakes. Additional species from the Great Lakes will be tested as appropriate and available. Field sites with easy access to western Lake Erie, Lake Michigan, and Lake Huron have been identified and are generally available with small boat support.

Task 2: Halotolerant Taxa

Prior experiments have identified at least 10 aquatic species from the Chesapeake Bay, San Francisco Bay, and the Baltic Sea as halotolerant, surviving exposures to salinity as high as 34 ppt. For these species, sodium chloride brine exposure experiments will also be conducted following the same experimental procedures as for Great Lakes species to determine the minimum exposure time and salt concentration (up to 120 ppt) to cause 100% mortality.

Expected Outcomes

a. Assessment of the usage of sodium chloride brine solutions to kill taxa in the ballast tanks of NOBOB vessels.
b. Information about the salinity tolerance of freshwater and euryhaline species that are typically available for uptake during ballasting from the Great Lakes, Chesapeake Bay, San Francisco Bay, and the Baltic Sea.

Governmental/Societal Relevance

The invasive-species risk posed by NOBOB vessel operations to the Great Lakes ecosystem resulted in rapid policy changes over the last two years. This outcome of this research is expected to strengthen the federal policy and regulatory-based protections by providing an addition on-the-ground tool that could be applied to ships entering the Lakes with low-salinity residual ballast water and claiming a safety exemption from the rules. Resolving the NOBOB loophole is a major recommendation of the Great Lakes Collaboration (Great Lakes Regional Collaboration, 2005. An Action Plan to Address Aquatic Invasive Species in the Great Lakes. Report of the Aquatic Invasive Species Strategy Team. October 14. 113 pp.):

Recommendation 1: Prevention of AIS Introduction and Spread through Maritime Commerce

Milestone 1.1: Immediately require, verify, and enforce that ocean-going vessels in the no ballast on board condition (NOBOB) implement practices that are an improvement over current practices

Relevance to Ecosystem Forecasting

In order to develop reliable forecast models for an ecosystem, the ecosystem must be relatively stable and the trophic dynamics well understood. When an invasive species becomes established in an ecosystem, it usually doesn't have local predators and often out-competes existing organisms for food web and habitat resources. It effectively destabilizes the ecosystem, with both primary and secondary impacts, making the possibility of reliable ecosystem forecasts unlikely. This project, if successful, will provide an additional tool to reduce the influx of new species, thus serving to enhance the protection and integrity of the Great Lakes ecosystem.

References

Drake, L. A., Jenkins, P. T., and Dobbs, F. C. (2005). Domestic and International Arrivals of Nobob (No Ballast on Board) Vessels to Lower Chesapeake Bay*. Marine Pollution Bulletin* 50, 560-565.

Duggan, I. C., Van Overdijk, C. D. A., Bailey, S. A., Jenkins, P. T., Limen, H., and MacIsaac, H. J. (2005). Invertebrates Associated With Residual Ballast Water and Sediments of Cargo-Carrying Ships Entering the Great Lakes. Canadian *Journal of Fisheries and Aquatic Sciences* 62, 2463-2474.

Holeck, K.T., Mills, E.L., Macisaac, H.J., Dochoda, M.R., Colautti, R.I., and Ricciardi, A. (2004). Bridging troubled waters: biological invasions, transoceanic shipping, and the Laurentian Great Lakes. *Bioscience* 54, 919-929.

Johengen, T., Reid, D.F., Fahnenstiel, G.L., MacIsaac, H.J., Dobbs, F.C., Doblin, M., Ruiz, G., and P. T Jenkins. (2005). *A Final Report for the Project Assessment of Transoceanic NOBOB Vessels and Low-Salinity Ballast Water as Vectors for Non-indigenous Species Introductions to the Great Lakes*. NOAA, Great Lakes Environmental Research Laboratory and University of Michigan, Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, Michigan, 287 pp.

Niimi, A.J. and D.M. Reid (2003). Low salinity residual ballast discharge and exotic species introductions to the North American Great Lakes. *Mar. Poll. Bull*. 46, 1334–1340.

Ricciardi, A. (2006). Patterns of invasion in the Laurentian Great Lakes in relation to changes in vector activity. *Diversity and Distributions*: In press.

Wonham, M. J., Bailey, S. A., Macisaac, H. J., and Lewis, M. A. (2005). Modelling the Invasion Risk of Diapausing Organisms Transported in Ballast Sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 62, 2386-2398.