



## Efficacy of open-ocean ballast water exchange as a means of preventing invertebrate invasions between freshwater ports

Gray, Derek K., Thomas H. Johengen, David F. Reid, Hugh J. MacIsaac

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**ABSTRACT:** Ballast water is a major vector of nonindigenous species invasion globally. Mandatory ballast water exchange (BWE) was implemented for vessels carrying ballast water into the Great Lakes in 1993. Despite the implementation of this policy, few data are available on its effectiveness, and invasions have continued to be reported in the Great Lakes. In this study, we conducted experiments to assess the efficacy of BWE on six operational transoceanic vessels traveling from the Great Lakes to European ports. Each vessel had paired ballast tanks, one of which was designated as a control that remained filled with Great Lakes water, while the other was exchanged with mid-ocean water. Community composition was assessed immediately after tanks were filled and again prior to water discharge in European ports. BWE was verified by ship records and, in two cases, by in situ water quality sensors. BWE was highly effective (>99% loss) for reducing concentrations of freshwater zooplankton. Live sentinel amphipods and oligochaetes deployed in incubator chambers sustained nearly universal mortality in tanks that experienced BWE, but not in unexchanged tanks. Finally, BWE reduced in situ recruitment of zooplankton from diapausing eggs present in ballast sediments in additional incubator chambers deployed in these tanks. Collectively, these studies support the contention that BWE by transoceanic vessels traveling between freshwater ports results in ballast water that would exceed proposed International Maritime Organization (2004) ballast water performance standards if these standards were applied to freshwater species only. Thus, BWE provides strong protection to freshwater ecosystems against invasions by both pelagic and benthic freshwater species.

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