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Ballast water management in Canada: A historical perspective and implications for the future

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ABSTRACT

Non-indigenous species (NIS) can create significant risks when introduced to foreign ecosystems. One of the many vectors facilitating the global transport of NIS is ballast water, and as commercial shipping increases so does the threat of ballast water-mediated introductions. Despite Canadian regulations, consistent with international guidelines put forth by the International Maritime Organization in the early 1990s, ballast water remains a potential vector for the introduction of many NIS to Canadian marine ecosystems: there have been no new introductions in the Laurentian Great Lakes Region since 2006, yet marine ecosystems continue to see the introduction and establishment of NIS. This paper details and analyzes the development of Canadian ballast water management (BWM), in the context of marine ecosystems, and identifies issues therein. BWM in Canada has a number of management gaps that have persisted since large-scale BWM began in the late 1980s. These include BWM exemptions for vessels not exiting the North American continental shelf, and limitations of effectiveness of mid-ocean exchange as the predominant management method in marine ecosystems. In addition, ballast water regulations for the Canadian Arctic may require additional consideration as the Arctic will likely continue to see an increase in both warming and commercial shipping in the future, thereby increasing the potential risk of NIS. In order to adequately protect all Canadian marine ecosystems, it is recommended that the current BWM regime: fill gaps in management to help prevent further introduction and spread of NIS; focus equally on both marine and freshwater regions, and; look to other aggressive BWM strategies such as those being developed by the state of California.

1. Introduction

Non-indigenous species (NIS) are species anthropogenically introduced outside their natural range, which if established (i.e., survive and reproduce), may or may not cause harm to native ecosystems [18]. A subset of NIS may be classified as aquatic invasive species (AIS) if they cause irreversible economic or environmental damage. Worldwide, invasive species are one of the leading causes of animal extinctions, and are a significant threat to marine biodiversity [54,68].

Thousands of NIS have been transported globally by a number of anthropogenically-mediated vectors [65,67], several of which have facilitated the spread of NIS in aquatic environments, including: ship-mediated vectors (e.g., ballast water, hull-fouling), recreational boating, live bait, aquarium trade, live food fish, and unauthorized introductions [12]. Ballast water is one of the leading vectors for transporting and introducing species, both in Canada and around the world [25,67], and has led to the transfer and introduction of at least one third of all documented marine invasions [32,84].

Ballast water is used to control a ship's stability and trim, but vessels typically take up water and release it in different locations thereby facilitating the rapid movement of species between those locations. Many national and international management strategies have been developed to address the problem of NIS transport via ballast water, including in Canada, where ballast water management (BWM) began in the early 1980s. However, because ballast water-mediated introductions still occur today, especially in Canada's marine coastal regions, current management strategies have not been wholly effective.

This paper details the development of BWM strategies in Canada and demonstrates limitations of current regulations in meeting the unique challenges associated with BWM in Canadian

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marine regions. This paper also evaluates the implementation of BWM strategies in marine ecosystems in relation to the development of relevant international strategies and policies. By analyzing the history of Canadian BWM in conjunction with studies on aquatic invasions in Canadian marine ecosystems, the effectiveness of current BWM policies in protecting Canada's marine ecosystems are examined, and possible mitigation strategies are considered.

2. A historical perspective of Canadian ballast water management

An analysis of the historically published NIS literature indicates that the Laurentian Great Lakes Region (GLR) is far more studied from a NIS perspective than any of Canada's marine ecosystems. Based on the invasion history of the GLR (see [53]), it is logical that national policies regarding NIS and BWM were initially targeted at the GLR, as 55–70% of invasions in the GLR since 1959 were attributed to the release of ballast water [63,21]. In addition to considerable ecological impacts, NIS in the GLR have caused upwards of $138 million USD per year in damage to human infrastructure alone [66]. However, in the 25 years that have passed since Canadian BWM began [53,62], BWM protocols still emphasize the GLR with limited emphasis on coastal marine systems (discussed below). A detailed timeline of Canadian, relevant USA, and International Maritime Organization (IMO) BWM policies can be found in Appendix A of this paper.

Canadian BWM initially began at a local scale in marine waters. In 1982, the Canadian Coast Guard (CCG) issued Notice to Mariners #995, which sought to prevent ships bound for the Grande Entrée Lagoon in the Magdalen Islands from discharging ballast water obtained in high risk areas [59,31]. Notice to Mariners #995 prohibited ballast water discharge within 10 nautical miles of the islands, and was issued to help prevent the introduction and exposure of toxic phytoplankton to mussel aquaculture farms in the Grande Entrée Lagoon [31].

By the late 1980s, transoceanic and domestic vessels were pumping millions of tonnes of ballast water into the GLR [33,48], which facilitated the primary introduction and subsequent secondary spread of invasive zebra mussels (*Dreissena polymorpha*), spiny water fleas (*Bythotrephes longimanus*), and Eurasian ruffe (*Gymnocephalus cernuus*), among other NIS [53,83]. Canada recognized the socioeconomic and environmental damages being caused to the GLR by NIS, and along with the USA and Australia, formally approached the IMO's Marine Environmental Protection Committee (MEPC) in 1988 to raise the issue of BWM [83].

The Voluntary Guidelines for the Control of Ballast Water Discharges from Ships Proceeding to the St. Lawrence River and Great Lakes (hereafter Voluntary Guidelines), released on 1 May 1989, was Canada's first large-scale attempt at BWM. The objective of the guidelines was to protect the GLR from "non-native fish and other aquatic organisms that can be harmful to the balance of nature that now exists" ([48], p. 47). The Voluntary Guidelines applied to all transoceanic vessels (i.e., vessels that left the continental shelf of North America) destined to the GLR.

The *Voluntary Guidelines* were the first to promote mid-ocean ballast water exchange (MOE) for transoceanic vessels as a means to reduce the risk of introducing NIS. Specifically, these guidelines were the first to recommend that ballast water exchange (BWE) occur beyond the continental shelf or beyond the effects of freshwater currents. At the time, BWE was considered the most viable method for mitigating NIS introductions largely because the open ocean contained fewer organisms than coastal regions, and because marine organisms picked up mid-ocean were considered likely to have narrower salinity tolerance and therefore were unlikely to survive in freshwater systems following deballasting, compared to species picked up in coastal waters [61,23]. Canada's influence in the development of BWM guidelines is evidenced by the fact that early USA and IMO BWM strategies were based on Canada's newly instated 1989 *Voluntary Guidelines* [76]. However, from the onset of Canadian BWM there were gaps that persevered through time. For example, the *Voluntary Guidelines* introduced the idea of exemption zones: ships that did not leave the continental shelf of North America were not required to undergo BWE. This principle endures even in today's BWM regulations, despite well documented concerns about this aspect of the regulations [25,42,71].

In 1990, only the Great Lakes and St. Lawrence Seaway were protected by the *Voluntary Guidelines*: in 1991, however, the lower boundary moved to Quebec City [49]. Research indicated that some transoceanic vessels had not performed voluntary MOE and were still releasing ballast water potentially containing NIS in Montreal Harbour (primarily freshwater), which could mediate secondary introductions to the GLR [49]. The boundary change to Quebec City therefore extended protection to all freshwaters of the St. Lawrence River, further reducing the risk to the freshwater GLR from NIS introductions.

It was not until the late 1990s that marine ecosystems were considered for BWM outside of the Grande Entrée Lagoon. In 1997, the Vancouver Port Authority (VPA) developed a mandatory BWE program (hereafter *Standing Orders*) for all ballasted ships destined to arrive at the Port of Vancouver [44,46]. The *Standing Orders* stated that a ship's Captain must inform the VPA whether or not MOE had been performed. If MOE had not occurred, ships were required to return to sea to deballast if necessary [44]. Vessels traveling from north of Cape Mendocino, California, were exempt from performing BWE, because Cape Mendocino was considered to be a biogeographic barrier to the natural dispersal of species [71]. However, [44] suggested that the practice of exempting these vessels from performing BWE should be suspended as it "enhances the risk of moving NIS from ports in Oregon and the outer Washington coast to [Canadian] Pacific regions".

The VPA monitored MOE compliance by sampling ballast water dockside and assessing its salinity and biotic composition [44]. If ballast water had a salinity >25 psu or if ballast water samples contained more oceanic copepods (calanoids) than nearshore, bottom-dwelling copepods (harpacticoids), MOE was assumed to have occurred. The use of biological indicators for monitoring MOE was unique to the VPA, but its reliability was unknown since it had not been tested sufficiently [44]. The task of sorting, identifying, and counting copepods as indicators of MOE was onerous, and the VPA experienced significant difficulties implementing the procedures; for this reason, they reverted to relying only on salinity measurements instead of biotic indicators for assessing MOE compliance (C. Levings, pers. comm.). Nonetheless, it is important to recognize that the 1997 VPA *Standing Orders* were among the most advanced, though untested, policies for ballast water and NIS risk management of marine ecosystems at the time [44].

In 1998, Bill C-15 was passed to amend the *Canada Shipping Act* to give Canada the authority to implement statutory, nationwide BWM regulations [83]. On 4 November 1998, days after Bill C-15 was passed, a BWM working group was established under the Standing Committee on the Environment, a subsection of Canada's Marine Advisory Council (CMAC) [82,83]. This working group mapped out Canada's future BWM strategies and intended to provide a scientifically-based regulatory environment that would "prevent future introductions of aquatic alien species from the ballast water of ships" ([83], p. 238). Ultimately, the working group facilitated the creation of nationwide, non-statutory ballast water guidelines [74].