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Review of current practices to reduce the risk of introducing non-indigenous species into the Pacific Region via ballast water

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Abstract

The contemporary solution used to minimize the risk of moving NIS (non-indigenous species) around the world's oceans in ballast water is mid-ocean exchange. In this procedure, if safety permits, the majority of the coastal water in a ship's ballast tanks is replaced with water from mid-ocean, containing organisms not adapted to coastal conditions, so that when a vessel arrives in an overseas port, the ballast water pumped into a harbour contains organisms that should not survive. Estimates of the efficiency of mid-ocean exchange vary widely, and are usually considerably less than 100 %.

Vancouver Port Authority (VPA) developed the mandatory ballast water program to reduce the risk of NIS arrival into waters under their jurisdiction. This protocol, established in 1997 under the VPA Harbourmaster's Standing Orders, is incorporated in the proposed Canadian national guidelines for ballast water management and has been adopted by port authorities in Fraser Port (New Westminster) and Nanaimo. Briefly, if a ship has not performed mid ocean ballast water exchange, with some exemptions, the vessel can be sent back out to sea to exchange ballast water at an alternate or backup site in Juan de Fuca Strait, subject to safety concerns. Initially the backup site specified was Race Rocks but more recently Sheringham Point is indicated. To date, no ships have been sent to an alternate location.

The decision to exempt ships that have taken on ballast water from north of Cape Mendocino in California from the VPA Standing Orders should be re-examined as this enhances the risk of moving NIS from ports in Oregon and the outer Washington coast to Pacific region. Ships with ballast water amounts of <1000 tonnes are also exempted. This should also be re-examined since only a few individuals or spores in the residual water and mud in a tank can establish a NIS population. VPA has a program to determine compliance rate for mid-ocean exchange. If ballast water is found to have salinity of > 25 psu or a preponderance of oceanic copepods (calanoids) over bottom dwelling coastal copepods (harpacticoids), the vessel has complied. An assessment is required to determine the statistical power and biological validity of the sampling program. Other B.C. ports (e.g. Prince Rupert and Victoria) should become involved in efforts to reduce the risk of introducing NIS to Pacific region.

Résumé

L'échange des eaux de ballast en haute mer est la solution moderne adoptée pour minimiser le risque de déplacer des espèces non indigènes d'un océan vers un autre. De cette façon, lorsque que les conditions sont sécuritaires, l'eau de ballast des navires est remplacée par de l'eau puisée en haute mer, qui contient des organismes non adaptés aux conditions côtières, de sorte qu'à l'arrivée au port, l'eau vidangée ne contient que des organismes incapables d'y survivre. Les estimations de l'efficacité de cette approche sont très variables mais généralement inférieures à 100 %.

Les autorités responsables du port de Vancouver ont élaboré un programme de vidange obligatoire des eaux de ballast afin de réduire les risques d'introduction d'espèces non indigènes dans les eaux relevant de leur compétence. La marche à suivre, imposée en 1997 en vertu d'un ordre permanent du capitaine du port, est incluse aux lignes directrices canadiennes proposées pour la gestion de l'eau et a été adoptée par les autorités portuaires du port Fraser (New Westminster) et de Nanaimo. En résumé et à quelques exceptions près, lorsqu'un navire n'a pas procédé à une vidange de son eau de ballast en haute mer, il peut être redirigé vers la mer pour procéder à un échange d'eau de ballast à un site situé dans le détroit de Juan de Fuca, sous réserve de questions de sécurité. Au début, le site choisi était Race Rocks mais il a récemment été changé pour Sheringham Point. Aucun navire n'a encore été redirigé vers un tel site.

La décision d'exempter les navires qui ont rempli leurs ballasts au nord de cap Mendocino en Californie des ordres permanents devrait être réexaminée car cela accroît le risque de déplacer des espèces non indigènes de ports de l'Orégon et de la côte externe du Washington vers la région du Pacifique. Les bateaux dont la quantité d'eau de ballast est inférieure à 1000 tonnes sont aussi exemptés. Cette décision devrait aussi être réexaminée car seulement quelques organismes ou spores présents dans l'eau résiduelle ou la boue des réservoirs peuvent donner lieu à l'établissement d'une population. Les autorités du port de Vancouver disposent d'un programme de vérification de la conformité pour l'échange d'eau de ballast en haute mer. Lorsque l'eau de ballast présente une salinité supérieure à 25 psu ou la prédominance de copépodes océaniques (calanoïdes) par rapport aux copépodes des fonds côtiers (harpacticoïdes), le navire est jugé conforme. L'évaluation est nécessaire pour déterminer la validité statistique et biologique du programme d'échantillonnage. D'autres ports de la Colombie-Britannique (Prince Rupert, Victoria, etc.) devraient participer à ces mesures de réduction du risque d'introduction d'espèces non indigènes dans la région du Pacifique.

A: Introduction and Background

The maintenance of natural communities and ecosystems is a key goal for marine environmental health, as specified by the Oceans Act. However, numerous introductions of exotic species are known for the coast of British Columbia and some of them have likely arrived via ballast water carried by deep-sea ships. There are about 20 ports in the Pacific region where deep sea ships regularly or occasionally visit. However, available data suggest that Vancouver harbour (includes Roberts Bank, English Bay, and Burrard Inlet) is where the majority of the ballast water is discharged. Ballast water disposal is a complex ecological problem with international shipping and safety concerns which must be considered in any pragmatic solution to NIS risk management. The ecological problems relating to NIS and ways to try and minimize risk of introductions via ballast water have been reviewed in recent papers (e.g. NRC, 1996; Ruiz et al. 1997). As noted by NRC (1996) a ship is a biological island - ballast water is only one habitat for NIS on a ship. Fouling organisms on the hull, sediment in tanks and anchors, and organisms in sea chests are others issues which need consideration. Other potential vectors for NIS, not related to shipping, include intentional introductions, accidental releases of live seafood or research organisms, and the aquarium trade.

Non-indigenous species continue to arrive by ships ballast water in British Columbia, as shown by the only work on this topic in the Pacific region, conducted in 1995-1997 (Levings et al., 1998), and recent work that showed phytoplankton can be grown from mud in the bottom of ballast tanks (Sutherland 1999, unpublished). The recent arrivals of the Japanese varnish clam (*Nuttallia obscurata*) (Merilees and Gillespie, 1995) and the European green crab (*Carcinus maenas*) (http://www.pac.dfompo.gc.ca/ops/fm/shellfish/crab/updates.html) into Pacific region waters in 1991 and 1999 respectively confirmed that B.C. waters continue to be vulnerable to invasion by potentially hazardous NIS. Although ballast water has not been confirmed as the vector for bringing green crab into Pacific region, it has been mentioned as a possibility.

In this paper, I discuss the current status of the short term methods for ballast water management being used in Pacific region. The short-term solution adopted by most jurisdictions around the world is mid-ocean exchange (MOE). In the long term, ballast water treatment to "sterilize" the water, either when ballast is taken aboard or discharged, may be the preferred method (see NRC, 1996; Anon, 1999; and Sutherland et al., 2000).

In 1997, VPA developed a progressive policy, the mandatory ballast water program, to reduce the risk of NIS arrival into waters under their jurisdiction. As explained below, the program includes an interview procedure which enables VPA to obtain specific data on ballast procedures during the ship's voyage to Vancouver. This policy is incorporated in the proposed Canadian national guidelines for ballast water management (Anon, 2000). Briefly, if a ship has not performed mid ocean ballast water exchange, the ship can be sent back out to sea to deballast, subject to safety concerns, and a number of exemptions.

B. Present methodology for Mid-Ocean Exchange

For MOE to be successful as a method to minimize risk of introductions of NIS, the organisms taken into ballast tanks must be open ocean organisms, intolerant of extant oceanographic conditions when they are released into B.C. coastal waters. Proposed Canadian national guidelines for MOE suggest water depth should be 2000 m when MOE occurs. The proposed Canadian national guidelines for MOE require that the ballast water be exchanged three times if a flow through exchange process is used and with sequential exchange 95% of the original volume of water in the ballast tank should be replaced with mid ocean water (Anon, 2000). The effectiveness of MOE is subject to a variety of factors such as pumps on a particular ship, weather, and cargo. Safety is a paramount concern. Effectiveness of MOE has ranged from 67-86 % tested with zooplankton (Locke et al. 1993) to 95 % tested with dye (NRC, 1996). However, this procedure is currently the only practical method available to ship operators to minimize risk of transporting NIS around the world. Planktonic organisms taken in during ballasting at sea are presumed to be adapted to high salinity mid-ocean conditions and are presumed to die when released in B.C. waters. When a bulk carrier leaves an overseas port, the vessel typically is light and needs to take ballast aboard soon after leaving the coast. However, it is likely that some ballast water is taken on while the ship is transiting the coast. For example, if a coal ship leaves a port in Korea some ballast water may be taken on in coastal waters before reaching the open sea. Since a full load of ballast water is required to enable a safe ocean crossing, water from the northwest Pacific or another mid-ocean location is taken into ballast tanks. Upon reaching port in B.C., the water is pumped out in preparation for taking cargo aboard.

C. Consideration of regional protocols to confirm MOE

In 1997, VPA issued their Standing Orders (VPA, 1997) for mandatory ballast water exchange which is considered to be one of the most progressive policies in the world for ballast water-NIS risk management. The Standing Orders were subsequently incorporated into the draft Canadian national guidelines for ballast water management (Anon, 2000) and the protocols were also adopted by the ports of Nanaimo and Fraser Port and were incorporated into draft national guidelines that are being discussed by agencies such as Transport Canada, Department of Fisheries and Oceans (DFO), and shipping organizations at the present time. The general mandatory ballast water exchange program has also been adopted in other jurisdictions (e.g. Port of Oakland, CA), with some variations in specific procedures. Policy and procedures concerning mandatory ballast water exchange is a complex and rapidly evolving issue. For example, the State of California's legislation on this topic has only recently (January 2000) been implemented. (See web site http://www.leginfo.ca.gov/pub/bill/asm/ab_07010750/ab_703_bill_19991010_chaptered.pdf).

The VPA Standing Orders require Masters of vessels planning on disposing of ballast water within the jurisdiction of the VPA to inform authorities if they have performed MOE or not. The Master completes a form, which is filed with VPA and provides details on where MOE occurred, origin and weight of ballast, location and amount of ballast to be released in particular areas of the harbour, etc. If the Master declares the ship has not performed MOE, the vessel is not allowed to deballast within VPA waters. The vessel can be required to return to sea and dispose of ballast on the west coast of Vancouver Island, subject to ship safety, at an alternate or "backup" location. This procedure has not been necessary since the Standing Orders were issued (personal communication with Chris Badger, VPA Harbour Master, on December 10 1999).

In addition to interviewing the Master of the vessel and reviewing the ballast form, VPA authorities take "spot"samples of the ballast in particular tanks for salinity and biota, to confirm that MOE has taken place. If the confirmation samples show that MOE has not been performed, the ship may be sent to a backup location to exchange ballast water. Generally, the sampling procedures to obtain water samples to confirm MOE in the VPA testing (VPA, 1999) are similar to those used by others (e.g. Hay et al. 1997). A submersible pump is used to take a sample of ballast water to measure salinity and to obtain biological material. Two hundred litres of water are pumped and sieved through a 200 µ plankton net and organisms retained for microscopic examination. Salinities greater than 25 psu (measured by specific gravity and a refractometer) indicate confirmation of MOE in this protocol. The predominance of calanoid copepods compared to harpacticoid copepods in the biological sample is also viewed as confirmation of MOE. Drawings of these two major groups of copepods are provided to VPA staff to help identify them (VPA, 1999).

A brief comparison of these methods with those used by other agencies, primarily those on the west coast of North America, is given below. It should be noted that because of the complex mix of influential international organizations (e.g. International Maritime Organization) and national agencies such as Transport Canada and the U.S. Coast Guard (USCG), as well as individual port authorities, some comparisons given below may no longer be valid. Information below is as presented at the time of preparation of this document.

Number of ships and tanks on a particular ship: Statistical procedures to decide on how many ships or ballast water tanks to sample in order to ensure representativeness of MOE have not been worked out. Ballast tanks on a particular ship may have exchanged coastal water with mid-ocean water to varying degrees, depending on ship safety and other variables. VPA, Nanaimo, and Fraser Port authorities inspect all incoming ships but numerous B.C. harbours are not monitored. Off the U.S. west coast, each Coast Guard Marine Safety Office is required to conduct random ballast water boardings at the rate of 2-3 boardings per week. At least 10%, but no less than two of the vessel's ballast water tanks, are to be tested in order to confirm compliance with MOE (Anon, 1999).

Salinity: The USCG protocols state that ballast water salinity > 29.0 psu is confirmation of MOE (Anon 1999), four psu higher than the VPA level. Salinity may be a valuable index for ensuring ballast water exchange for vessels arriving into lakes and rivers after an ocean voyage. However, for ships travelling between ocean ports this measurement may not be reliable (Hay and Tanis, 1997).

Biological sampling methods and the harpacticoid copepod index: The VPA protocol for sampling ballast water organisms with a submersible pump and plankton net is used by many jurisdictions around the world (e.g. NRC, 1996; Hay and Tanis, 1998). However, the size of the submersible pump used may limit sampling of double bottom tanks through standpipes on some ships and hence double bottom tanks may be undersampled and wing tanks and holds oversampled. The water depth in the holds when water samples are obtained is variable depending on the loading status of the ship . It is not clear if sampling with this general protocol obtains representative samples of biota actually carried in the ballast water.

The concept of using the presence of harpacticoid copepods in ballast water as an index of MOE appears to be unique to VPA. Harpacticoids are typically found in coastal benthic or shallow water habitats and calanoids are typically found in the previous habitats as well as mid ocean regions. The procedure assumes that a ship taking on ballast water in a coastal region will have brought harpacticoids, and not calanoids, into ballast tanks, which are filled with water via pumps on the bottom of the vessel. It also assumes that the water was shallow enough to enable the ballast water pump to pull water and biota from near the sea floor where many harpacticoids live or that the harpacticoids were swimming at a depth where the pump could pull them into the ballast tank. After MOE, it is assumed the harpacticoid copepods are replaced with calanoid copepods which are the dominant copepod of mid ocean habitats. The only data found in a literature search supporting this concept are given from New Zealand in Hay et al. (1997), where 45 % of ballast tanks sampled containing non-exchanged water yielded harpacticoids compared to 5% for tanks that had exchanged water. The method has not been thoroughly investigated and hence reliability is unknown. Because a ship's ballast pump at a port may in fact have pulled in more calanoids than harpacticoids, there is some uncertainty about this method. Although advocated by Hay and Tanis (1997) for use by New Zealand authorities, the procedure does not seem to have been adopted by agencies other than VPA

D. Consideration of backup or alternate ballast water exchange locations in Pacific Region and adjacent U.S.waters

Alternate or backup ballast water exchange zones are areas closer to or on the continental shelf and are much closer to land than the recommended areas for MOE. Due to their oceanographic characteristics, they are thought to provide a lower risk of species introduction than inshore waters even though they may not meet the depth criteria, for example, for MOE.

The original standing orders of the VPA (VPA, 1997) state that a location "in the out going current of the north side of the Strait of Juan de Fuca, west of Race Rocks" could be used as a backup location for ships that had not achieved MOE. This backup location is of concern because of proximity to a pilot Marine Protected Area at Race Rocks. However, as of 1999 the location is given as Sheringham Point, at a water depth of at least 100 m, north of the ship Traffic Lane and West of the military ordinance location (John Jordan, VPA, email Sept 17 1999). R.E. Thomson (DFO, Institute of Ocean Sciences) suggested that the "central portion of Juan de Fuca Strait, just north of the separation line (between U.S. and Canada), not too close to the entrance" might be a suitable location (personal communication given in Gramling 2000). Oceanographic models are being developed to investigate larval drift from ballast water disposed at various locations in Juan de Fuca Strait (Foreman et al. 1999).

Beeton et al. (1998) suggested backup locations for ships off the Washington and Oregon coasts (continental shelf of the US), specifically no closer (to the shore) than in or along the California Current, and west of the Current where it passes close to shore. To reach this recommendation, these authors focused on oceanographic characteristics that were relative to the probability that "any biological material so entrained on the shelf could settle in nearshore environments, within at least two or more weeks after release (noting that many invertebrate larvae (meroplankton) are capable of surviving at least two weeks in the water column and often a good deal longer"). An analysis of oceanographic characteristics of these locations is needed to determine if organisms released at these locations could potentially colonize habitats in Canada. Beeton et al.'s recommendations were accompanied by a number of caveats stating that use of the particular region might not be totally effective in reducing the risk of introducing NIS to the U.S. coast.

Shipping agencies in the United States engaged in coastwise trade (e.g. between Pacific U.S. ports) are currently discussing alternative exchange locations, realizing their vessels may not be able to reach open ocean conditions as described for MOE. For example, members of the Puget Sound Steamship Operators asks members to conduct ballast water exchanges on coastal voyages if it is safe and if the vessel is at least 25 nautical miles offshore (Gramling, 2000). No information is available for ships that may be deballasting en route to southeast Alaska ports (e.g. Ketchikan).

E. Consideration of exemptions from the VPA standing orders

Ships that have taken on ballast north of Cape Mendocino (near Eureka, California) or involved in coastwise trade

As mentioned by Anon (1999), the short voyages and presence of highly-invaded estuaries on the west coast suggest that coastal shipping poses a serious risk for the spread of NIS. The VPA decision to exempt vessels that have taken on ballast water from the above region was based on an assumption that organisms from north of Cape Mendocino can be carried naturally to B.C. waters by north flowing currents off the coasts of northern California, Oregon, and Washington (VPA, 1998). Planktonic communities north of Cape Mendocino through to British Columbia are considered homogenous, and therefore organisms taken in with ballast water from this region are thought to be capable of eventually moving with water masses and coastal currents to Canadian waters.

This rationale does not take into account situations where ballast water and estuarine/freshwater organisms may have been taken on in river ports such as Portland, OR, and released into freshwater ports such as New Westminster, B.C. on the Fraser River (Levings et al., 1998). It also does not consider the possibility of NIS being taken aboard from possible "hot spots" north of Cape Mendocino [e.g. Coos Bay, OR; Grays Harbour, WA (Cordell and Morrison, 1996; Jamieson et al 1998; Cordell, personal communication)] and then being released into a comparable estuarine habitat in a B.C. port. Although data have not been obtained on this topic, it is likely that ballast water organisms would survive in ships travelling between ports on the west coast of North America because of the short voyage times. As examples, some NIS organisms such as amphipods do not have planktonic stages and certain copepods may be restricted to estuaries or rivers e.g., the Asian diaptomid copepod *Pseudodiaptomus inopinus* (Cordell and Morrison, 1996). A related species *Pseudodiaptomus marinus*, known as a NIS in southern California, has been found in ballast water from ships arriving in B.C. ports (Levings et al. 1998) but as far as known it has not colonized B.C. waters.

Ships with ballast < 1000 tonnes

This volume-specific exemption is based on a *de minimus* rationale such that the discharge of smaller volumes of ballast water would not provide a critical mass of NIS and thus pose a risk for introduction. However, phytoplankton can be grown from single mud-slurry samples collected from the bottom of a ballast tank (Kelly, 1993). Diatom resting spores and dinoflagellate cysts were identified in a mud slurry sample < one litre in volume from a ship in Vancouver harbour, preceding vegetative growth generated during an incubation experiment (Sutherland, 1999, unpublished). Thus, it is likely that even a small amount of ballast water could support the introduction of non-indigenous species. This problem is recognized in the recently implemented California ballast water regulations (op cit) where procedures such as washing the mud off anchors are recommended.

F. Conclusions and Recommendations

a. Regional protocols to confirm MOE

VPA's procedures to interview the Masters of all incoming ships to obtain data on where ballast originated, amounts and location of ballast water disposal, and where MOE has occurred are providing valuable data for interpretation of the risk of introducing NIS. While research agencies such as DFO Science Branch have a current interest in interpretation of these data, in the long term an ocean management agency should work with VPA to review these data on an annual basis. This procedure is now being used by the ports of Nanaimo and Fraser Port but there are numerous other harbours (e.g. Prince Rupert) in Pacific region which should be using the system. Risk assessment for NIS introductions on the north coast of B.C. cannot be performed as there are no data being obtained in the area.

The protocol used for confirming MOE needs to have a rigorous statistical basis. At present it is not clear if the samples obtained in the VPA verification procedure are representative of the biota carried by the ship or if the number of ships sampled is adequate to determine risk to Pacific region ecosystems. An analysis of existing data might help in the development of a statistically valid sampling guide.

There is uncertainty about the use of ballast water salinity and abundance of harpacticoid copepods as indices to confirm MOE. Further research is needed to accept these two indices as indicators of MOE. An analysis of existing data might help determine the scope of the needed research.

Backup or alternate deballasting locations in Pacific Region and adjacent U.S. waters

The recent declaration of Sheringham Point as a backup deballasting location for VPA instead of Race Rocks may not have significantly reduced the risk of introducing NIS to the latter pilot Marine Protected Area. Research is currently underway using oceanographic models to predict dispersion of NIS in ballast water from the locations in the mouth of Juan de Fuca Strait and should assist decision makers. There is a need to coordinate backup locations with U.S. authorities concerned with deballasting or MOE sites off the Washington coast near the Canada-US border. Data on deballasting procedures on the north coast of B.C. are not available and port authorities in that area are not systematically collecting information to assist in risk assessment. For example, no information is available on proposed backup deballasting sites in Dixon Entrance or off the Queen Charlotte Islands where ships in ballast arrive from overseas bound for both Canadian (Prince Rupert) and U.S. ports (e.g. Ketchikan). The exchange of ballast water near Bowie Seamount, another pilot Marine Protected Area within Canada's waters, may be a concern.

Exemptions from the VPA standing orders

There is growing recognition of the importance of coastal "leap frogging" of NIS species between ports and along the west coast of North America. Prevailing coastal currents and water masses shifts (e.g. El Nino) can move larvae of some marine organisms into the Pacific region from habitats to the south. However, estuarine organisms without pelagic larval stages, as well as freshwater organisms, can be moved quickly by ballast water because of the short distances and travel times. For this reason, the VPA decision to exempt ships that have taken on ballast water at ports north of Cape Mendocino should be re-examined. Specific research on the survivorship of NIS between Canadian and U.S. ports on the west coast is required.

NIS organisms can be moved by ships in very small amounts of water. The de minimus exemption of ships disposing of < 1000 tonnes of ballast water should therefore be re-examined. Small amounts of sediment in the bottom of ballast tanks and on anchors should also be considered as source material for bringing NIS into the Pacific region.

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