Technical Peer Review:

Report to Congress: An Analysis of the Effectiveness of Ballast Water Exchange (BWE) in Controlling Aquatic Non-indigenous Species (NAS) Introductions to the Great Lakes Basin and Chesapeake Bay

By:
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1] Is the charge clearly described in the report? Are all aspects of the charge fully addressed? Do the authors go beyond their charge or their expertise?

The charge is clearly described in this report. The report addresses the background surrounding biological invasions in the Great Lakes and Chesapeake Bay, and documents in detail the current situation. All statements and opinions are clearly referenced, and essentially all of the important ecological studies performed in these two water systems have been discussed.

2] Are the conclusions and recommendations adequately supported by evidence, analysis, and argument? Are uncertainties or incompleteness in the evidence explicitly recognized?

The conclusions and recommendations made in this report are adequately supported by evidence and analysis. Unfortunately, the main conclusion of this report is that "..... it is really much too soon to accurately assess the effects of ballast water management on the rate of invasions in any ecosystem." And further it is noted that "estimates of invasion rates are thus much too coarse to be used with great confidence for evaluating ballast management efforts that have only been implemented very recently." In other words, the authors imply that there can in fact be no analysis of the effectiveness of ballast water exchange in controlling non-indigenous species in the Great Lakes or Chesapeake Bay at this time. It seems this conclusion could have been developed before this study was undertaken.

The authors do not address major uncertainties in many of the studies that are reported in this survey. Specifically, investigations of shipboard ballast exchange experiments are described, and analyzed by the authors. They report that variable treatment efficiencies were achieved during these experiments but do not discuss these variable results in the context of the theory behind the ballast exchange process. They do not emphasize for example, that all of the reported experiments were run on different ballast tanks having different geometries, and different flow rates. This in fact means that none of the experiments are comparable to one another, and in fact are totally unique to the ballast tanks being tested. Because of the uncertainties associated with mixing within the ballast

tanks, the author's statements relating actual treatment effectiveness of ballast exchange are misleading.

3] If any recommendations are based on value judgments or the collective opinions of the authors, is this acknowledged and are scientifically defensible reasons given for reaching those judgments?

The recommendations put forward by the authors are by and large, not based on value judgments. Their recommendations are rather simplistic and in fact, are in line with the ongoing practice of ballast water management in both the Great Lakes and the Chesapeake Bay areas. The recommendation that "a quantitative and empirical assessment of the actual release of propagules from NOBOB vessels in the Great Lakes is needed to better guide management and policy in this area" is a value judgment by the authors, with no scientific reasons given for it, or any discussion on how this information will aid in generating solutions beyond what is already known.

4] Are the data and analyses handled competently? Are statistical methods applied appropriately?

The authors present data from various projects undertaken in the Great Lakes and Chesapeake Bay in this survey, therefore they are not responsible for how the original data were handled. They do discuss, in significant detail, the accuracy of the statistical methods that were utilized in some of the experiments. However, as indicated above, the authors did not relate ballast exchange results to fundamental physical theories, making correlation to standards of performance confusing. Specifically, the authors do not evaluate the results of the studies referenced in this report in line with a coherent theory of dilution and mixing. Because of this approach, statements are made through out the report that are confusing, and often in conflict with fundamental laws of mass transfer. The fundamental theme that must be followed in evaluating ballast exchange efficacy is that the process is simply one of dilution of water, impacted by mixing. It should be recognized that all existing, and proposed ballast exchange standards, such as those promulgated by the US Coast Guard, are based on the fundamental laws of dilution and mixing. For example, it should be inherently obvious that; if a tank containing water is emptied, and refilled with different water, then 100% of the original water has been removed. This simple concept is the basis for the empty-refill ballast exchange process. This process is assumed to be equivalent to 100% treatment of the ballast water. If a particular tank cannot be completely emptied because of plumbing limitations or other operational constraints, then, in this case, ballast exchange via "empty-refill" should not be employed, as it does not meet the "intent" of the regulations. More importantly, if the actual water (and suspended material) removal efficiency in a tank which is not completely emptied, and then re-filled, is measured, it is simply an observation of the uniqueness of that particular tank and associated plumbing system. Determining a "percentage" of removal in such a system has no meaning whatsoever except with regard

to that particular tank. It should also be obvious that every tank measured will yield different results.

In the same manner, the authors do not relate treatment efficiency measurements in flow-through ballast water exchange systems to the fundamental theories of mass transport. Once again, the result is that data collected from such projects can not be related to, or correlated with regulatory standards for ballast water treatment. As is the case with the "empty-refill" concept of ballast water exchange, the "flow-through" concept is again based on fundamental laws of dilution, impacted by mixing constraints. In this system, a tank filled with water is continuously diluted by adding different water to the tank, allowing overflow. The dilution of original water in the tank is a predictable process, and follows a simple exponential decay. As with any simple process following an exponential decay, the amount of dilution of the original water can be predicted at any time in the process, or if the volumetric transfer rate is known, then the dilution can be calculated based on equivalent tank volumes of added water. If this process is normalized (% dilution), then it is simple to calculate any "% dilution" of original water as a function of volume of new water added to the tank. For example, to achieve a 95% dilution of the original water, three equivalent tank volumes of new water must be added. This is the basis of the standards for ballast exchange utilizing a flow-through process. However, the fundamental assumption behind this standard, is that the tank itself is completely mixed during the dilution process, otherwise regions in the tank remain stagnant, or short-circuiting between the inflow and outflow of the tank occurs. In these cases, there is not a predictable exponential decay of the original water, and the overall behavior of the tank does not follow the model that is assumed, which is the basis for "flow-through" standards. In fact, because most of the ships currently in the world's fleet have ballast tanks that were not designed to be completely mixed during an exchange process, the dilution process in those tanks cannot be related to the theoretical dilution process assumed to be occurring by the regulatory agencies. Once again, if ballast exchange experiments are undertaken to determine treatment efficiency in a "flow-through" process, only measurements of mixing within the tank are required, and if the tank is completely mixed then dilution estimates can be easily made. If the tanks are not completely mixed, then any measurements of treatment efficiency are essentially meaningless, except for that individual tank.

Because the authors did not evaluate ballast exchange projects in the theoretical context described above, many erroneous statements are made through out this report. For example, in *Chapter 2 - efficacy of ballast water exchange,* it is noted that ballast water exchange can be highly effective, removing between 80 and 99% of suspended planktonic organisms, when compared to control tanks. Considering the variability in tanks described above, it seems that no true control tanks could have been identified. In addition, the authors attempt to correlate ballast exchange efficiency data amongst "ship types". Once again, the differences in dilution behavior will occur between individual tanks only, and unless different classes of ships have absolutely identical ballast tanks and pumping systems, then there can be no correlation assumed at this level.

It is suggested that the authors reevaluate data from previous and ongoing ballast water exchange experiments in line with fundamental theories of mass transport. This will generate more logical results which can be utilized by regulatory agencies to establish and evaluate ballast water exchange standards. In addition, it will also point out the deficiencies of the experimental designs associated with many of the ballast exchange efficacy studies. In fact, this reviewer believes it will demonstrate that the very little reliable or useful information has been collected related to ballast water exchange, only tank specific dilution data.

Many of the conclusions of this study are not consistent with material presented in the document, e.g. (*C. Chesapeake Bay*) "considerable confidence that there is a real upsurge in invasions in the Chesapeake" over the past 50 years. Yet, on pg. 5-10 it is noted that the new discoveries may only be due to increased sampling.

The Conclusions (pg. 2-10) should be re-written in line with the discussion above to remove obvious inconsistencies, e.g. "our data show that 100% empty-refill BWE removed greater than 97% of the original water mass for three vessel types .....", and "reporting that 300% removed approximately 95% of the water ..... ". As noted above these statements are confusing, and as written, have little meaning.

5] Are the report's exposition and organization effective? Is the title appropriate?

The exposition and organization of this report are adequate for the charge. Considering that the main discovery of this report is that; analyzing the effectiveness of ballast water exchange for controlling aquatic non-indigenous species in the Great Lakes and Chesapeake Bay is not possible, perhaps the title should be changed to reflect this possibility.

6] Is the report fair? Is its tone impartial and devoid of special pleading?

The report is fair and very little "special pleading" occurs. The report is heavily slanted towards the ecology of the two water systems tested. In this respect it is not impartial, as the authors were not able to rigorously evaluate the ballast exchange component of the charge.

7] Does the executive summary concisely and accurately describe the key findings and recommendations? Is it consistent with other sections of this report?

As noted above, the interpretation of ballast water exchange efficacy is misinterpreted by the authors through out this report. The executive summary currently reflects these misinterpretations.

8] Are signed papers or appendices, if any, relevant to the charge? If the report relies on signed papers to support consensus findings or recommendations, do the papers meet criterion three above?

Signed papers or appendices are not relevant to the charge of this report.

9] What other significant improvements, if any, might be made in the report?

As noted earlier, the recommendations of this report are basically to continue what is already being done to limit introductions of invasive species introductions to the Great Lakes and Chesapeake Bay. These recommendations coupled with the assertion that it is not possible to correlate introductions of non-indigenous species with ballast water exchange practices, for various reasons, means that there is not much utility to this report. The usefulness of this report would be significantly enhanced if the authors would step forward and estimate possible contributions from the ballast exchange process. It would also be useful if they made suggestions based on their scientific expertise, concerning ways and methods of making ballast exchange a reliable and effective ballast water treatment scheme.

In line with improvements noted above, a major addition would be the addition of a discussion relative to new-builds. Considering that the world's fleet contains approximately 40,000 ballast carrying ships, with an average operational life of 25 years, it is apparent that a large number of new ships are constantly being produced. What do these authors recommend for ballast water management systems on these new ships? Do they recommend ballast exchange capability? Do they recommend that the new ships should have other, more positive types of ballast water treatment systems installed on-board ? Based on their findings, do they think ballast exchange has any effect on invasion rates ?

Comments on – " Report to Congress: An Analysis of the Effectiveness of Ballast Water Exchgange in Controlling Aquatiuc NonIndigenous Species Introductions to the Great Lakes and Chesapeake Bay.

Editorial Comments

I 4th paragraph "… the risk associated with these ships is also debated" Where and why – it is discussed scientifically later in the document but is a statement that leaves one hanging as to why is it debated

Page ES-3 Last Paragraph. Figures are not unreasonable but need a discussion of the Great Lakes trade the explain 'why' . The previous paragraph indicates a general decrease but doesn't give enough information to the reader to accept what is not intuitively obvious.

Page ES-8 Comment that "… treatment is not applied to coastwise traffic between domestic ports" West Coast data nad California / Washington States require coastwise exchange. Canadian proposed regulations and existing Guidelines suggest it and ongoing risk assessment suggests a certain portion of the trade on the east coast is currently conducting BWE on coastal East Coast voyages.

Page ES-9 Great Lakes Paragraphs suggest by default that opening of the Seaway and the larger vessels are the start of the problem. Ships have been entering the Great Lakes system via the early locks since 1857 (Madeira Pet to Chicago from Liverpool) Think it would be useful to stress the exponential increase since the opening of the Seaway was proceeded by previous ship source invasions. – They just got very much worse.

Page ES-10 Would like to see stronger wording on recommendation 3 – informative for management and policy

Page 1-2 End of second paragraph - Personal communication between Stephan Gollasch and myself some time ago but I believe he had documented survival of zebra mussels from Thunder Bay to Hamburg as a hull fouling vector

Page 1-3 Federal Register never really explains 'Why ' the NOBOB policy of the USCG is voluntary

Page 1-4 Second Paragraph. I would suggest adding the word' percieved' in front of 'logistical and safety.." So far no evidence has come forth from any in the shipping community that BWE – done in the context of clearly defined, ship specific Ballast Water Management Plan approved by a Classification Society or Flag State – is unsafe.

Page 2-1 There are THREE accepted types of BWE – IMO has accepted the Brazilian dilution method and ships (interestingly enough some warships) do use it on occasion.

Page 2-3 I would be interested to know if there was a correlation of weather with empty – refill. Many ships in the Canadian trade will switch to flow through if empty refill not advisable because of weather.

Page 3-2 Graph. I would suggest a similar graph indicating tonnage would be appropriate as what a graph of transits don't show is the change in ship size and type from small general cargo – break bulk vessels when the Seaway to the mid 70's to the preponderance of Seaway Max bulkers of today. This is editorially discussed in 3.2.1 but a picture is worth something. Photos might also be appropriate to help understanding

Page 3-4 3.2.2 A minimum of two tanks and not less than 10% are inspected.

Page 3-5 3.2.3 Figures re incoming ballast are reasonable but as per previous comments think above – there is a trade and world politic reason for these fugures that might better help the 'story'cv

Page 3.5 second paragraph. …5700 tonnes of sediment… This would suggest that on average approx 500 transits are responsible for depositing that amount of sediment each voyage (ie 5700 /500) ie each ship deposits approx 11 tonnes of sediment per voyage. That is not intuitively logical for me. (and it is of great import to policy and discussion of threat of entrained organisms in the sediment on page 3-9)

Page 3-14 " A concomitant increase in domestic vessel trafiic' - Need to be supported. Lake Carrier / Canadian Ship Owners Association data would suggest the opposite. Tonnage is up in the late seventies with the introduction of the 1000 footers into the fleet but actual transits and trade is down significantly in the period. A large portion of the domestic fleet – both Canadian and US actually went to scrap in that period.

I agree with the statement in the last sentence but before the LCA and partners jump all over it – need to support the statement.

Page 4-6 Graph One assumes the values of n are reversed for the Bulker category??

Page 4-11 Editorially the statement in the first sentence "… Although we have not.." It would seem a perfect invitation for some Senator from a mid west state with no water to say – ' Well why not – why haven't you.

I would suggest changes in the wording to prevent that.

Page 6.1 6.1.1 first paragraph While I am aware of the audience of this paper – I can assure you relatively few Mates or Master's doing a ballast water exchange think of the

regulations (or have actually read them) – other than they know they need to do a BWE prior to entry to US waters. They follow the Ballast Water Management plan

Third paragraph "… BWE does not address potential risks with NOBOB's… - This needs to be clarifies because wording iis not consistent with the wording of the US NOBOB policy which suggest BWE or flushing is effective.

6.1.2 First paragraph. While the statement is true – it is misleading as there were no large Bulkers available to bring more propagules in by 1959. Existing ships in 1959 were small, break bulk – but there were a lot of them and they often came from 'exotic" locations. It took until the mid seventies and later for the larger ships to predominate – but there were much less of them.

6.2 6.2 What is the politics here – why only interim measure while studying?? Precautionary principle would suggest make mandatory – subject to safety – then study the rest

Comments on BWE Report

General Comments:

The report is very informative, thorough and well-written. The content is up-to-date and the recommendations are sound. There is one error, however, in the calculation of the average number of NOBOB vessels discharging ballast to the Great Lakes system annually. As a result, the relative significance of the different ship types in misconstrued. In addition, residual sediments of NOBOB ships have been presented as a significant source of invader propagules – potentially encouraging interested parties to focus on management of residual sediments. As the introduction potential of invasive species from ballast sediments is expected to be low (and as sediments are likely also present in BOB ships), this may be unwarranted.

Specific comments:

ES-4: clarification is needed re: estimates of zooplankton densities in residual water and sediments – it needs to be clearly stated that the estimates provided are for the number of nonindigenous species in NOBOB vessels that *discharge* while operating on the Great Lakes (i.e., the number of propagules with *opportunity for discharge*, not for the total number of NOBOB vessels *entering* the Great Lakes annually).

Section 3.2.3

Volume of exchanged ballast is estimated at 760,000 tonnes per year during the period of 1994-2004. This appears very low, considering Aquatic Sciences Inc. reported 5,000,000 tonnes for 1995. This fact needs double-checked, especially since it will significantly impact the relative importance of the different shipping vectors.

Number of NOBOBs exiting the system without discharging ballast is underestimated at 21 (22) %. According to Colautti et al. (2003) nearly 49% of NOBOB vessels left the system without discharging ballast for the years 1994-2000. This error affects figure 3-4, estimates of ballast tonnage discharged into the lakes, as well as propagule pressure (figure 3-7) in later sections of the document.

For example, the statement that NOBOBs were more likely to exit the system without discharging ballast prior to the regulation period (given at the bottom of page 3-5) is no longer true.

Section 3.3

Clarification needed re: origins of ballast water – 58% came from last port of call, 17% were from ocean, what is the remaining 25%?

Figure 3-6 is misleading. Panel a) depicts source of ballast discharge based on most recent location of ballast uptake, based on tonnage, whereas panel b) depicts source

based on five most recent ballast loadings, based on number of ship transits. This is not an equal comparison. Is it fair to give equal weighting to all five previous sites of ballast uptake, when the most recent site likely has the greatest influence on the composition of the residual water? (though this may not be true for sediment)

Section 3.4

Statement that propagule pressure from NOBOB vessels increased 32% post-BWE needs to be verified after correction of the earlier error. It is likely not the absolute value of propagule pressure which has increased, rather it is the relative importance of NOBOBs?

Figure 3-7. Do the authors really want to present propagule pressure as being greatest for NOBOB sediments, when science has suggested that many of the propagules carried in sediments are not available for discharge from ships? This figure could very easily be taken out of context by policymakers – with the result that all future management efforts are focused on NOBOB sediments. It appears, however, that (limited) management efforts may be most effective for management of the water fraction. It may be prudent to present the relative risk of the different ballast fractions in terms of risk of introduction, rather than total propagules carried. In addition, there is no indication of the risk posed by sediments on BOB vessels, which is likely very similar to that of NOBOB vessels.

Section 5.4.3

It is stated earlier that domestic shipping comprises about 70% of the vessel traffic to Chesapeake Bay. Is it likely that domestic shipping may be responsible for many of the introductions to Chesapeake Bay through secondary transfer of species from previously invaded domestic ports? This may be an alternate explanation for the apparent inefficacy of management efforts and a discussion of this possibility might be added to this section of the report.