TECHNICAL PEER REVIEWS AND RESPONSES

Note: Each Peer Review Comment is presented in bold text, followed by a labeled italicized response. Page and section references in our responses refer to the final version, released as NOAA Technical Memorandum GLERL-142.

REVIEWER 1

Question 2

"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."

Response: It appears that this reviewer misunderstands the primary purpose of this report, which was to present the current state of knowledge about the effectiveness of BWE. Although this was stated clearly in the Forward, we have added additional clarification by (a) changing the title, (b) adding comments to the Forward, (c) adding a synopsis with a statement about the purpose, and (c) attempting to further clarify throughout the chapters.

The Reviewer suggests that "this conclusion could have been developed before this study was undertaken," implying that the study should not have been conducted. While this is perhaps true for scientists in the field, it certainly is not the case for those without technical expertise. At the present time, a synthesis (achieved in this report) does not exist, and the primary purpose of this report was to provide such a synthesis. Moreover, there are conflicting messages in the literature on the effectiveness of BWE, resulting in part from a lack of synthesis and a lack of consistency in approaches. This report attempts to remedy this.

We stand by our original statement, which is that invasion history cannot be used to accurately assess the rate of invasion in any ecosystem, and that estimates of invasion rates are not currently useful for interpreting the effectiveness of BWE. We can and do analyze available data to evaluate likely changes in propagule supply attributable to changes in shipping practices and to BWE, in order to assess the likely effects BWE has had as a prevention strategy applied to these two ecosystems.

"…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."

Response: We disagree with the Reviewer's conclusion that because the on-board BWE experiments were run in different ballast tanks under different circumstances, that our conclusions on the effectiveness of the exchange process are misleading. The data presented are a synthesis of empirical measures on BWE aboard actual ships, this provides a broad-based estimate of actual performance (effects) across several major ship types. Although we do not understand the specific sources of variation (across ships), these data provide the most comprehensive and robust measures available to date. The approach used here is statistically valid, using controlled experiments to test (measure) the effect of BWE across many different ships. While there remains unexplained variation, this in no way invalidates the approach.

More broadly, the reviewer misses several key points, in comments here and elsewhere on estimating effects of BWE. First, a primary goal here was to synthesize and interpret available information about the performance of BWE to remove organisms --- and this is what is provided. Second, while theoretical calculations are possible to estimate effect of BWE exchange on removal, this is largely undeveloped at the present time to adequately portray the hydrodynamics and removal of water (and especially organisms, which may behave differently from water) in real-world ballast tanks. Critically, the few existing theoretical estimates represent hypotheses that have not been tested. Third, for this reason (#2), the synthesized information focused on empirical measures. Fourth, while it is possible and clearly useful to compare theoretical and empirical estimates of BWE for different ballast tanks (and conditions), and this is an excellent goal for future work, the purpose of our report was synthesis of existing data.

See Question 4, below for further discussion.

We have also tried, in our discussions, to be clear and identify where we have data and where we are speculating or using estimates. For example, in Section 3.3 we state "Unfortunately only pieces of the necessary information are available, and direct data on ballast water characteristics are incomplete, inconsistent, and subject to large uncertainties. Even so, we can examine the characteristics of the shipping trade and how factors associated with ballast water may have changed between the two periods of interest, and speculate about how those changes may have affected propagule pressure to the Great Lakes."

Question 3

"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."

Response: We added the following clarification to Section 3.5.4 (page 67) "Current knowledge about discharge of residual sediments, especially resting eggs and spores contained therein, and the effectiveness of BWE on sediments is insufficient to assess the risk NOBOB residuals and other sediments pose to the Great Lakes with a reasonable level of confidence. The volume of residual sediments is difficult to quantify and can vary quite widely among vessels. The discharge of sediment or organisms during deballasting has not been studied due to the inherent difficulties associated with access to ballast discharges during outflow. Ballast flow rates can vary considerably depending on the rate of intake or discharge needed for ship operations, and this will affect the amount of sediment resuspension and sediment and organism discharge." The statement in the Recommendations section is simply a summary statement that is a logical outcome of these facts.

Question 4

"…as indicated above, the authors did not relate ballast exchange results to fundamental physical theories, making correlation to standards of performance confusing. 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."

Response: We disagree with the reviewer's conclusion that none of the experiments are comparable to one another or that the results are misleading. The approach used and the source of data is clearly described. In fact, the data presented represent empirical measures across several different ship types and conditions. While it is true that the sources of variation are not understood or characterized, the approach used is certainly valid and describe the effect of BWE on these vessels.

All ballast tanks have common elements of architecture and the guidelines for empty-refill, or for flow-through exchange, are the same regardless of the ship and the tank design. Flow rate may make a difference and yes, it would be nice to have experiments on all types of tanks for all flow rates. However, that is not feasible from both a cost and a personnel standpoint. What we do have is a suite of common, well planned on-board experiments that included experimental controls for comparisons. They were run on different ships with different ballast tanks and exchanged under different conditions, but followed a common set of guidelines. We examine the results for commonalities and found that the results (stated as average efficacy in removing coastal organisms) all fall into a relatively small range (80-99%; if containerships are not included, results fall into an even smaller range) and we thus believe that these results typify, and can be used to characterize, ballast water exchange that has been conducted according to guidelines.

". . . 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."

Response: We disagree and suggest that the reviewer is greatly oversimplifying the issues related to BWE. True, BWE is driven by simple mixing and dilution and this is the basis for the 3-volume/95% rule. However, BWE is not just about water replacement, it is about organism replacement and/or mortality. Simple physics do not and cannot address the biological component of BWE, yet it is this component, NOT the water, that is most critical and the reason for BWE in the first place. An assessment based purely on the physics of mixing would not be accurate with respect to the effectiveness against AIS.

Moreover, even the theoretical aspect of estimating "mass balance" for water replacement specifically for ballast tanks is not developed. We have cited the available literature on this topic, and it appears to be an early stage of development. We certainly agree that a theoretical approach is important and useful, and we look forward to its advancement. Development of such theory is beyond the scope of the current report, which focuses on synthesis and not initiating new research. It is further noteworthy that the few existing projects that have explored this approach have been multi-year endeavors for even a single ballast tank design.

As discussed above (see Question 2), even if and when such theory is available, it will require validation with empirical measures. In the absence of available theoretical assessments, we have provided the existing empirical measures of BWE efficacy that are now available.

". . . 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."

Response: The Reviewer misunderstands the basis for this assessment, which is not to simply assess whether or not the physics of mixing works. The BWE standards promulgated by the Coast Guard are, indeed based on simple mixing and dilution models, but the actual target and reason for implementing BWE regulations is clearly not just to assure water replacement. The assumption behind BWE is that biological organisms act and behave like a water particle. However, numerous studies have shown that this is not the case, and to base an assessment of BWE on physics alone would be misleading and naive.

The reviewer also mischaracterizes the end-point of the empty-refill BWE process and does not acknowledge the limitations of real ballast systems on real ships. For example, ballast systems on a majority, if not all, ships in service today use a vertical pipe extending nearly to the bottom of each ballast tank, from which water is added and removed to/from the tank. The bottom edge of that pipe must terminate a minimum distance off the bottom plate of the tank in order to provide the flow that matches the capacity and pumping rate of the ballast pumps, which can be several thousand gallons per minute. Therefore, when pumping water out during empty-refill, it is usually impossible for all of the water in a ballast tank to be removed. This is also dependent on the trim of the ship, which can pool the water, making pump-out more, or less, efficient.

Thus the Reviewer's concept that empty-refill equates to 100% removal of water is not correct. There are several studies that indicate residuals exist and removal is incomplete. A skillful crew and very good operating conditions can likely achieve at least 99% water removal. The regulations assume that BWE, whether by an empty-refill or a flow-through process, will achieve at least a 95% replacement of water and organisms, and that this results in a reduction in risk of AIS introduction.

Question 5

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.

Response: What we said is that we cannot use nonindigenous species discovery rates in an ecosystem to analyze the effectiveness of BW. We have, in fact, assessed BWE for both efficacy and effectiveness as a prevention tool. We have also revised the title and added additional text to clarify the goal/purpose of this report (see Question 2 above).

Question 6

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.

Response: The comment is correct; we are unable to rigorously evaluate the effect of ballast exchange on invasion outcome. However, there is no indication that the Reviewer felt our "tone" was not impartial. Again, the charge from Congress for this report was to focus on the Great Lakes and Chesapeake Bay, which should be evident in the front materials.

Question 7

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.

Response: We strongly disagree with the reviewer, as outlined under Questions 2 and 4, above. Also, the Executive Summary has been revised (but not in the manner suggested by the Reviewer) to remove any misunderstanding about the purpose of this report. We have also clarified what we mean by efficacy vs. effects/effectiveness, and both are discussed in this report.

Question 9

"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."

Response: The reviewer has somehow misunderstood the purpose of this report, which was intended as a synthesis of information and understanding about the effectiveness of BWE (see Questions 2 and 4 above).

We disagree that there is no utility to this report. As shown in the Synopsis (which was added after the reviews), we considered and discussed several approaches for evaluating the effects of BWE on invasion risk and chose one that provides further confidence that total propagule supply and thereby invasion risk has declined for each ecosystem as a result of BWE. We estimate the contributions of BWE, especially in the Great Lakes chapter, where we also show the likely effects of changes caused by economic factors and ship management practices. We also added statements pointing out that the exemptions for coastwise trade and NOBOBs represent gaps that have weakened the protection framework for which BWE is the centerpiece.

"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 onboard? Based on their findings, do they think ballast exchange has any effect on invasion rates?"

Response: This would be well beyond both the charge from Congress and the scope of this report. It would require a different mix of expertise. We were not charged with evaluating ship designs or ballast water treatment technologies. We don't address invasion rates, for reasons outlined in the report, but we do address the effect of BWE on propagule supply.

REVIEWER 2

INTRODUCTION, 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."

Response: This statement is no longer in the document in that form, except in the Foreword, where we say "In particular, there are several questions under debate within both the scientific and regulatory communities about the magnitude of reduction for coastal plankton that results from BWE, and its effect on risk of invasion."

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."

Response: Since this was part of the Executive Summary, the content was designed to summarize key points and findings, not restate the detailed explanations and calculations supporting those findings, which are provided in the full chapter. However, the Great Lakes chapter was substantially rewritten and presents the data and analyses in a different, and we believe, more defensible manner. In reference to this particular comment, there is information in Chapter 3 about changes in economic climate and ship management practices that explain the "why" and these factors are noted in summary form in the third paragraph on page 7.

Page ES-8. "Comment that "… treatment is not applied to coastwise traffic between domestic ports" West Coast data and 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."

Response: This was a statement in both the Executive Summary and the Conclusions chapters. We modified it (see Pages 13 and 123) to read "BWE does have several limitations. First, some coastal organisms remain even after BWE is completed according to guidelines. Second, to conduct BWE, a ship must have sufficient time in transit (i.e., between ports), acceptable sea state, and be a sufficient distance from shore. As a result, this treatment is often not applied to coast-wise traffic between domestic ports, and this represents a sizeable loophole for the transfer and spread of nonindigenous species in U.S. waters."

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 preceded by previous ship source invasions. – They just got very much worse."

Response: We added the following to the Great Lakes chapter describing vessel entry history (Section 3.2.2.1, page 48): "Prior to opening the Seaway, saltwater vessel traffic into the Great Lakes was considerably less, but was not zero, because a system of canals allowed limited passage up the St. Lawrence River to Lake Ontario, and the Welland Canal connected Lake Ontario to the rest of the Great Lakes (P. Jenkins, pers. comm.)."

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

Response: Revised recommendation (Pages 15 and 126) as follows: "A quantitative, empirical assessment of the actual release of propagules from NOBOB vessels in the Great Lakes is needed for a better risk assessment to guide management and policy in this area."

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."

Response: (This paragraph is now Section 1.5 on page 22). We didn't change this statement. The point being presented is that hull-fouling is another potentially important ship-related vector for aquatic invasions ("both modes of ship transfer can be important sources of invasions, and some uncertainty exists about the relative importance of hull fouling versus ballast water for coastal marine systems"), but hull-fouling is not perceived as being as important for freshwater habitats, especially the Great Lakes. It may be that zebra mussels could have survived the transit, as could some other fresh-water tolerant hull-fouling organisms, but ballast water discharge is identified as the dominant vector for the Great Lakes, far surpassing hull fouling as a probable source for Great Lakes invaders. Our original statement ("<u>many</u> organisms attached to hulls are not thought to withstand the transition between marine and freshwater.") is correct, and the possibility raised by the Reviewer is inherently included.

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

Response: (reviewer comment refers to the last paragraph in Section 1.3, see pages 20-21). The reviewer is correct, but it was a policy decision by the Coast Guard, the reasoning for which is not central to this report.

Page 1-4. Second Paragraph. "I would suggest adding the word' perceived' 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."

Response: Done see page 20, 1st paragraph)

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."

Response: The Brazilian Dilution method is a variant of flow-through exchange wherein the incoming exchange water is pumped in at the top of the tank as the existing water is pumped out from the bottom via the standard ballast plumbing. It is not widely used and is not assessed in this report. The following paragraph was added to Chapter 2, Section 2.1 (page 27): "A third method approved by the International Maritime Organization (IMO), called the Brazilian Dilution Method, is a variant of the flow-through exchange. During BWE by this method, the incoming water enters from the top of the tank as water is discharged from the bottom, through the standard ballast system. A total of three times the tank volume is still required to flow through the ballast tank during this procedure. However, this method is not widely practiced and is not considered further in this report."

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."

Response: We don't have any data relevant to this question.

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 breakers of today. This is editorially discussed in 3.2.1 but a picture is worth something. Photos might also be appropriate to help understanding."

Response: In the revised Great Lakes chapter we note changes in size as represented by changes in gross tonnage in Section 3.3.2 (Page 52). However, tonnage is not directly related to risk <u>except</u> via correlation with ballast quantity. Since the new text includes a direct estimation of ballast quantity based on tonnage (see Figure 3-6, page 62), we feel more focus on tonnage in the text in this context would be a digression and distract from the main point.

We lack data from the pre-regulation decade with which to examine specific vessel size classes (e.g., break bulk vessels vs. Seaway Max breakers, etc.) – available classification data in the records we had aren't that refined.

We disagree as to the value of photos - the ships don't look that different without a scale of reference.

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

Response: Added, Section 3.2.3, page 50.

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

Response: In the revised chapter, Section 3.3.1 (page 51) there are two paragraphs covering the effects of changes in the economic climate and improvements in the quality of ship management practices that took effect by the early 1990s.

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 (i.e. 5700 /500) i.e. 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). "

Response: The entire discussion of sediment content and discharge has been revised, and a whole new section (3.3.4, page 54-56) was added that discusses sediment discharge and the assumptions we make about the amount of sediment that is discharged.

Page 3-14. "A concomitant increase in domestic vessel traffic" - 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."

Response: Discussion of "The role of transoceanic shipping"was entirely revised (now Sect 3.7.2.1, page 70-73) and in doing so the specific statement cited by the Reviewer was deleted.

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

Response: (This is now Figure 4-4, page 94). The values of "n" (the number of samples in the data set) are correct. Figure 4-4 shows the percentage (y-axis) of each type of vessel from each source (foreign, domestic) that arrived "in ballast" during a three-month period in 2004. The figure shows that (n=) 63 domestic bulkers arrived, ~80% of which reported carrying ballast water; whereas (n=) 88 foreign bulkers arrived, about 70% of which reported carrying ballast water, etc.

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.""

Response: Entire section (now Sect 4.4, page 97-98) was revised and no longer makes that statement.

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."

Response: (Now Page 123 and elsewhere) This comment apparently refers to the phrase "when conducted according to regulations", and gets to the question of whether and how ships' crews know the regulations vs. knowing the procedures specified in their Ballast Management Plans. However, our statement is not addressing whether ship crews know the actual regulations, rather, we are qualifying our conclusion that BWE can be highly effective by specifying that it must have been conducted according to procedures that achieve the requirements of those regulations (e.g., a three-tank volume overflow for BWE; or a single empty-refill, with a final salinity >30 ppt). Ballast Management Plans have to incorporate procedures allowed and/or specified in the regulations and each ship's Plan is subject to U.S. Coast Guard review. Thus, while we don't argue against the Reviewer's opinion, that issue does not change our conclusion.

Page 6.1, Third paragraph "… BWE does not address potential risks with NOBOBs…" - this needs to be clarified because wording is not consistent with the wording of the US NOBOB policy which suggest BWE or flushing is effective.

Response: We reorganized this entire Chapter. The statement is now incorporated into the last bullet under Section 6.1.1 (page 123). However, as a conclusion, it was and remains correct - <u>BWE regulations</u> DID NOT address the NOBOB risk. The new

voluntary guidelines added by the U.S. Coast Guard are still not part of U.S. BWE regulations; they were added as separate (but related) non-regulatory policy. This may change in the future. We also added a bullet under Section 6.1.2 (see page 124) that says "An important step forward in protecting the Great Lakes was the implementation in 2006 of Canadian requirements that all ballast water, including NOBOB residual water, be 30 ppt or greater salinity. If these requirements prove equally effective as BWE, we would expect significant additional reductions in the propagule supply due to this vector."

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."

Response: As a general conclusion what we said was correct (see page 123) and not misleading if one reads the report. We applied no time frame to our statement, other than the actual opening date of the Seaway. The timing of when larger ships began arriving is not important to the end-result, that the Seaway permitted the influx of more ships, and larger ships, with a concomitant increase in propagules of nonindigenous organisms.

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."

Response: We modified the text to remove the "interim" reference. We now state (page 125) "The use of high-salinity water to flush NOBOB ballast tanks should be considered a useful and beneficial management practice to reduce species transfers and invasion risks associated with NOBOB ships entering the Great Lakes. In the absence of proven alternatives, this practice provides some level of protection against some adult and larval life stages, but probably not against resting eggs and spores of zooplankton and phytoplankton."

REVIEWER 3

General Comments: "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." See below with specifics…"

Response: This was an error and was corrected in the present version. See below.

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)."

Response: This refers to the Great Lakes chapter summary in the Executive Summary. The Great Lakes chapter was entirely reorganized and revised and is reflected in the Executive Summary. The statement in question (see page 9) only summarizes the findings reported in the NOBOB Assessment Final Report. Those estimates were not for the ballast material that is actually discharged by NOBOBs, but only what was found in NOBOBs that had entered the Great Lakes. We state that "the extent to which the species composition in residuals varies over time and with season, and the extent to which viable organisms are actually discharged (released) to surrounding waters, and their fate of discharged organisms, is not well known or understood." The number of NOBOBs that actually discharge ballast in the Great Lakes is not well known and can't be estimated with any confidence, although we do discuss (in the full chapter) that it likely increased over time. Because of gross uncertainties and variances in the ballast water composition in both BOBs and NOBOBs (water amount, sediment amount, viable and nonindigenous species composition of water, viable and nonindigenous species composition of sediment, amount of sediment and related viable nonindigenous species discharged during deballasting, variations by season and source ecosystem) our Great Lakes analysis is based only on estimated total quantities of ballast (water plus sediment) likely carried into the Lakes each year, and we make the assumption that ballast quantity is a useful, although very coarse proxy for actual propagule pressure. We do not attempt to identify the indigenous from the nonindigenous species components (insufficient data). We believe that the discussions in the revised chapter (and Executive Summary section) preceding this statement make our approach and the highly speculative nature of many of our assumptions clear.

Section 3.2.3. "Volume of exchanged ballast is estimated at 760,000 tonnes per year during the period 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."

Response: This discussion of ballast loads is now part of Section 3.3.3, beginning on page 52 and is summarized in Section 3.3.5, page 58; the numbers changed slightly, but not significantly relative to this comment.

We used SLSDC data for consistency between the pre and post regulation decades (CG data is not available pre-1992). In 1995, the SLSDC reported only 49 upbound transits in ballast and an average cargo tonnage (presumed equivalent to ballast capacity) of 14,217 tonnes – giving just 697,000 tonnes of ballast that year. To reach the Aquatic Sciences Inc value of 5,000,000 tonnes suggested by the reviewer, each of these 49 ships would have needed to carry in excess of 100,000 tonnes of ballast – not likely or even possible.

Some of the discrepancy may be due to different sources of data – the Coast Guard consistently reports 20% fewer total vessels but nearly double the BOB vessels relative to the Seaway (1992-2004). These differences are due to (a) difference in reporting location (CG misses vessels which operate in the St. Lawrence River downstream of Massena, NY) and more importantly (b) differences in accounting of partially ballasted vessels (CG considers a vessel to be ballasted if it is carrying any pumpable ballast, the SLSDC reports a vessels as 'in cargo' if it is carrying any cargo). That said, even using the Coast Guard figures of 106 compliant BOB vessels in 1995, each vessel would have been carrying an average of 47,000 tonnes of ballast in order to reach the 5,000,000 figure – which we find unlikely especially as half were carrying at least some cargo when they entered the Seaway. For consistency, we estimated total ballast quantities carried by ballasted, partially ballasted, and NOBOB vessels using the baseline transit data compiled by the SLSDC over the entire period of record. These were the most consistent data and thus the best available.

Section 3.2.3. "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."

Response: The Reviewer is correct. We were using the wrong table from the Colautti paper. We are indebted to this Reviewer for catching that error. However, in addressing this error, we revised our approach and no longer attempt to apply a correction for % of NOBOBs leaving the system, since there is simply no way to gauge the accuracy of a back-extrapolation (or forward extrapolation) from the very limited data that are available. The topic of NOBOBs leaving the system without deballasting is discussed in Section 3.3.1 (page 51) and also at the end of Section 3.3.3.3 on page 54.

Section 3.3. "Clarification needed re: origins of ballast water – 58% came from last post of call, 17% were from ocean, what is remaining 25%?" Either coastal areas <300 miles offshore (rare) or ports not equivalent to Last Port of Call (presumably prior ports, with ballast discharged as cargo was taken on at the last port of call). "

Response: Now Section 3.4, page 59. A third set of data were added and the discussion was expanded. We believe the discussion is now clear as to sources.

Section 3.3. "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 be true for sediment)."

Response: We don't agree that Figure (now 3.5, page 59) is misleading. The figure is clearly labeled, and the text clearly states, the sources of the data and that two of the pie charts represent ballasted (BOB) ships (and thus the characterization is related to ballast water), while the other is clearly labeled " NOBOB". Residual water in NOBOB ships would primarily represent only the last 1-2 ballast intakes, but if our estimate is reasonably representative that sediment from only 20-40% of a tank bottom (that nearest the bellmouth) is discharged during a single deballasting, then sediments in the tank likely reflect biota integrated over many previous ballast intakes, since sediment accumulates while water doesn't. However, the main message from these figures is the consistent importance of western Europe and the Mediterranean as a source for material in ballast tanks associated with the Great Lakes trade. In addition, the NOBOB figure reveals that the Great Lakes themselves may be significant when considering sediment biota.

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."

Response: We reorganized and revised the Great Lakes chapter. Based on our revised approach to estimating propagule pressure, this comment no longer applies. However, as noted above, we did correct the information we presented about NOBOBs that depart without deballasting, but that information is not used in our illustration of potential changes in propagule pressure.

Section 3.4. "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…"

Response: In our revised approach to estimating propagule pressure, we no longer attempt to separate sediment load from water load. Reconsideration of our previous

approach led us to the conclusion that the data needed to make that calculation meaningful is not available. Thus, Figure 3.7 is not reproduced in the latest version.

Section 3.4. There is no indication of the risk posed by sediments on BOB vessels, which is likely similar to that of NOBOB vessels.

Response: Sediment content is now discussed in Section 3.3.4.2 (page 57) and includes all three categories of ships (BOB, BOB-A, and NOBOB). The first sentence under this revised section brings up the issue of BOB 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.

Yes, it is likely that some of the invasions to Chesapeake Bay result from domestic, coastwise shipping, as the reviewer states. However, an interesting issue for the Chesapeake is that many invasions are not attributed specifically to ballast water but may result from hull fouling. We have attempted to clarify the potential "dual role" of shipping, which operates to deliver organisms both in ballast tanks and also on the underwater outer surfaces (hull, propeller, bow thruster, etc). While hull-mediated transport may also occur into the Great Lakes, it is likely to much less important, simply due to the transition from seawater to freshwater environments and its effect on survivorship of organisms.

NOAA REVIEWER MP

All editorial corrections were reviewed, and were used to revise and clarify the text.