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Quagga and zebra mussel risk via veliger transfer by overland hauled boats

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Abstract

Invasive quagga and zebra mussels (*Dreissena rostriformis bugensis* and *Dreissena polymorpha*, respectively) pose a great threat to US waters. Recreational boats constitute a significant risk for spreading the organisms. Recreational boats circulate large amounts of raw water when in use, and if not drained and dried correctly can transport many mussel larvae, called veligers. Veligers experience very high mortality rates; however, the number of potentially transported veligers can be a serious risk to non-infested bodies of water, especially if multiple boats are involved. The risk of veliger transport was calculated for Lake Mead and Lake Michigan using boat capacities for water circulation and specific veliger density data. Results illustrate the importance of draining, drying, and/or decontaminating recreational boats after use.

Key words: veliger; *Dreissena rostriformis bugensis; Dreissena polymorpha*; transport; decontamination

Introduction

The risk for transporting microscopic larvae (called veligers) from the quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1897) or the zebra mussel *Dreissena polymorpha* (Pallas, 1771) between water bodies via retained raw water in a boat being hauled overland threatens spreading the invasive species to uninfected waters. It is unknown whether historical inoculations have involved breeding-sized mussels, larvae, or both. To determine the level of threat from veligers, the following example assesses the risk of overland mussel transportation based on veliger density data from Lake Mead on the Colorado River and Lake Michigan in the Midwestern United States. These lakes were selected for this assessment due to their large dreissenid mussel populations and because that boats from either lake have been intercepted throughout the Western United States, frequently with retained lake water and sometimes encrusted with live or dead dreissenid mussels.

The potential rate of reproduction and survival for this aquatic invasive species is alarming. Quagga and zebra mussels are known to be prolific breeders: a single adult female can produce 40,000 eggs or more per breeding cycle (Kachanova 1961; Karpevich 1955) and can breed multiple times per year when water temperatures are favorable (Borcherding 1991). Although the mussels have a high reproduction rate, they also have a high mortality rate. More than 90% of veligers spawned in laboratory conditions perish before reaching maturation and breeding (Nichols 1993). Furthermore, mussels must settle close enough to each other to achieve successful breeding, since reproduction is achieved via open water broadcast spawning between a male and female. Some contend that individuals existing just feet apart cannot successfully breed (McMahon, personal communication, 5 October 2011).

Breeding-sized quagga or zebra mussels and their veligers are known to survive an extended amount of time during transit on or within a boat. Adult mussels are known to live as long as 30 days out of water when humidity and temperature conditions are ideal; that is, temperatures are low but not freezing and humidity is high, near 100% (McMahon et al. 1993). Veligers can live in a static bath simulating contained water in a hauled boat for less than a day at 35 °C and as long as 24 days at 10 °C (Craft, Myrick 2011). Field tests demonstrate that veligers can survive 5 days in summer and about 27 days in autumn in contained water in the southwest United States (Choi et al. 2013). The goal of this paper is to assess the risk posed by these prolific and hardy veligers via overland hauled boats and how to minimize the risk.

Methods and results

Determination of the risk of mussel transport requires consideration of the density of veligers present in the water body and the total volume a boat can hold. Veligers are photophobic (Kobak 2001) and have a slight ability for locomotion (Sprung 1993).While they are consequently not as likely naturally found near the water surface in the daylight, they can be stirred upward by wave action from weather or surrounding boat use. It is thought that overland transport of small-craft boats is responsible for the spread of veligers (Rothlisberger et al. 2010; Schneider et al. 1998; Stokstad 2007). The threat is real: live veligers have been recovered from the engine cooling system of a boat traveling from Lake Mead to Lake Powell in March, 2011, where 19 confirmed veligers were found in the 0.47 L of water recovered (Lake Powell Invasive Mussel Prevention Coordinators Meeting Notes April 7, 2011, personal communication, 5 March 2013). It would therefore not be surprising for normal boat operations to inadvertently move some veligers via raw water circulation into boat motors, wells (bait, transom, and live), ballasts, or even sinks and showers (Colorado Division of Wildlife [CDOW] 2011). Splashed water or drippings from swimmers flowing into the bilge is another potential source for veligers to enter a boat. Given that larvae have been found evenly distributed throughout the water column in sites with disturbed waters (Lewandowski and Ejsmont-Karabin 1983), the number of veligers moved into a boat could be proportional to the estimated veliger density existing in the water column as determined by a vertical plankton tow sample.

Several types of boats frequent at-risk and infected waters and take up some amount of water, including wake boats, fishing boats, and multi-use boats. Boat capacities for water uptake vary greatly, and in our effort to assess risk, we will describe our assumptions on boat capacities as we see most likely to represent the type of boats in question. Wake boats are used for recreational purposes (wake boarding, water skiing, tubing, etc.), and wake boaters regularly circulate raw lake water into their ballasts (a tank used to provide stability and adjust the boat's center of gravity), achieving extra weight to create an ample wake for these recreational purposes. The most aggressive wake-boaters desire between 450 and 1360 kilograms of extra weight, which equates to approximately 470 to 1420 liters of ballast water. For the scenario to follow, we will assume a ballast of 950 L. Fishing boats take up water in a different way: they have live wells and bait wells to keep their catches and bait alive and active. The capacities of these wells varies greatly according to boat and fishing needs, but the combined volume of these wells range from 38 to upwards of 200 liters (CDOW 2011; Petersen Marine Draper UT, personal communication, 11 April 2013). For the risk scenarios presented below, we will assume the capacity of a fishing boat that has 130 liters of on-board life or bait wells. Multi-use boats are those that take on significant ballast and also have live or bait wells onboard. It is also common for the bilge of many of these boats to collect up to 75 liters of water before the bilge pump kicks in to remove it. This water can be collected from leaks, water splash from wave action, or drippings from swimmers. Therefore, boaters failing to drain the ballast, wells, and bilge between various locations could transport significant volumes of water, which could, in turn, contain veligers. Boaters, inadvertently, would then pump the retained raw water and veligers into the next water body upon resumption of routine boat operations.

Two risk scenarios follow which incorporate veligers into these water estimates. The density of dreissenid veligers in lakes is also important to consider in these scenarios. Lake Mead at times has high veliger densities, particularly during the fall season. Researchers have counted Lake Mead veligers via vertical plankton tow samples in all months of the year, with a peak in September 2008 showing 28 veligers per liter. The numbers during other months of the year

Table 1. Risk Scenario – Initial count of veligers aboard a vessel obtained from raw water.

	Lake Mead#		Lake Michigan^	
	Low estimate	High estimate	Low estimate	High estimate
Wake-boat[a]	5,700	26,600	11,400	29,450
Fishing boat[b]	780	3,640	1,560	4,030
Multi-use boat[c]	6,930	32,340	13,860	35,805

Table 2. Risk Scenario – Count of veligers aboard a vessel after veliger mortality, with 10% survival.

	Lake Mead#		Lake Michigan^	
	Low estimate	High estimate	Low estimate	High estimate
Wake-boat[a]	570	2,660	1,140	2,945
Fishing boat[b]	78	364	156	403
Multi-use boat[c]	693	3,234	1,386	3,580*

Water volume estimates: *[a]950 L in ballast, [b] 130 L in live/bait wells, [c]1155 L sum of ballast, live/bait wells, and 75 L bilge*
Veliger populations*: #Lake Mead low-month average: 6 veligers/L; high (Sep 2008) value: 28 veligers/L; ^Lake Michigan low month average: 12 veligers/L; high (Oct 2008) value: 31 veligers/L*
*Value rounded down to the nearest whole number

vary, but average at about 6 veligers per liter (Gerstenberger et al. 2010; Holdren et al. 2010). Likewise, Lake Michigan also has high veliger densities in the fall. The highest veliger density for 2008 was in October, with approximately 31 veligers per liter, and the average of the low months in Lake Michigan was 12 per liter (Nalepa et al. 2010). These numbers constitute our high and low estimates for veliger density.

The following tables represent the risk scenarios for Lake Mead and Lake Michigan, based on the veliger density data and the potential raw water circulation from boats discussed above. Table 1 reflects a scenario based on the number of individual veligers that could be taken aboard a water vessel at each use. Table 2 shows the resulting scenario, assuming the 90% mortality rate found by Nichols (1993). It presents the number of veligers taken aboard each vessel that, theoretically, could likely survive to reproductive maturity, and could survive transport between bodies of water by recreational boaters.

As a worst case scenario, a single multi-use boat containing 1155 L of raw water, when not drained, could haul between 6,930–32,340 veligers from Lake Mead to another water body, re-depositing the veligers upon resumption of normal boat operations. From Lake Michigan, such a boat could haul between 13,860–35,805 veligers. Based on the assumption that 90% of the veligers would fail to survive to maturity, the single inoculation is reduced to between 693–3,234 veligers from Lake Mead and from 1,386-3,580 veligers from Lake Michigan. Risk increases if veliger transfer occurs at a point in time when the veligers have matured to the pre-settler pediveliger stage (e.g., November to January for Lake Mead) because much of the natural mortality has already occurred (Gerstenberger et al. 2010).

On the other hand, if the worst-case scenario multi-use boat were to be drained, but not dried, approximately 4 liters of water are estimated to be retained (likely a few liters always remain in an un-dried boat, no matter the efficiency of draining) (CDOW 2011; Petersen Marine Draper UT, personal communication, 11 April 2013). Regarding Lake Mead or Lake Michigan, respectively, this equates to 2–11 and 4–12 surviving veligers that could be transported, after accounting for a 10% survival rate. Thus, the risk for dreissenid veliger transfer is reduced when a boat is drained. However, if the boat were air dried over a period of time following its draining, as defined by the 100th Meridian Initiative (2011), the risk would be minimized, since all retained veligers would likely perish.

Discussion

The above Lake Mead and Lake Michigan examples only assess inoculation risk from veligers in retained water within a boat and do not assess risk from other life forms of dreissenid mussels when attached to boats.

Considering a 90% mortality rate from the initial (trochophore) larval stage of a veliger to a breeding-sized dreissenid, the risk of veliger transfer in retained water is between 693–3,234 veligers from Lake Mead and 1,386–3,580 from Lake Michigan if transferred by a single multi-use boat containing as much as 1,155 L of raw lake water. The risk of veliger transfer is even lower (2–11 veligers from Lake Mead and 4–12 from Lake Michigan) if that boat is drained. However, if the boat is drained and allowed to dry for a suitable period of time, the risk from veligers is likely negligible.

Transport in onboard raw water is a source for inadvertent movement of *Dreissena* mussels. The risk of successful inoculation increases with multiple boats transporting veligers. However, advanced life stages of a live dreissenid mussel (settlers, juveniles and breeding sized or larger adults) attached to a hauled boat or other wetted equipment as compared to veligers in retained water may present the greatest risk. Attached mussels may already be a breeding colony or will soon become one if the boat is not decontaminated prior to launch. Nonetheless, the above examples demonstrate the need for boats departing *Dreissena* mussel-affected waters to be drained and preferably fully decontaminated prior to entering another water source. This is a core recommendation of the national "Stop Aquatic Hitchhikers!" campaign (ANS Task Force 2013). Nearly all state wildlife agencies in the Western United States advise that boats departing any water body be decontaminated after each use, since the presence of aquatic invasive species, including dreissenid mussels, is never fully predictable (100th Meridian Initiative 2011; Zook and Philips 2012). Successful decontamination by boat owners may be an effective deterrent to introducing aquatic invasive species to new water bodies.

Various states and water body managers should develop and enforce sufficient laws coupled with useful outreach programs to encourage boaters and other water body users to participate in the appropriate management and minimized spread of aquatic invasive species (Zook and Phillips 2012). It is critically important that boat operators, no matter where they originate, be required to decontaminate their vessels prior to use on another water body. Success in controlling the spread of aquatic invasive species, including quagga and zebra mussels, can only be achieved if the public understands the problem and risks to water delivery infrastructure, outdoor recreation areas, and aquatic resources. Unless the public understands, we cannot expect that they will become willing participants in best management practices, that is, boat and wetted equipment inspection and decontamination.

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