

Short Communication

Volume and contents of residual water in recreational watercraft ballast systems

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Abstract

Transient boaters are a known vector of aquatic invasive species. This has led to the establishment of prevention guidance to reduce the risk of most boating activities. However, this guidance may not adequately reduce the risk of invasive species transport in wakeboard boats due to the presence of ballast systems, which may be difficult or impossible for a boater to drain. We documented that these watercraft transport relatively large volumes of residual water (mean water volume 31.7 L) even after drain pumps run dry and that live organisms can be found in residual water for at least a week after use. The amount of residual water found in ballast tanks was variable (range of 1.0 L to 86.8 L), indicating that there may be factors that would allow for more complete drainage of ballast tanks. Analyses of the invertebrate communities from the residual water found that native zooplankton were common in the samples, with two of the watercraft transporting small numbers of dreissenid veligers. Future efforts should identify factors that can reduce the amount of residual water and identify what other invasive species may potentially be transported through this new pathway. Additionally, more effort should be made to better understand the boating behaviors of wakeboard boat users.

Key words: aquatic invasive species, prevention, invasion pathways, boating, risk assessment

Introduction

Transient boaters can inadvertently transport vegetation, water and debris between waterbodies and are known vectors of aquatic invasive species (AIS; Johnson et al. 2001). Vegetation fragments can be invasive, and residual water on the boat can contain live organisms (e.g., viruses and invertebrates) and potential invasive species (Kelly et al. 2013). In the water-rich Great Lakes region, there are many waterbodies with multiple established invasive species where these pathways could introduce AIS into un-invaded areas.

Simple actions, such as removing attached aquatic vegetation and draining water, can greatly reduce the risk of watercraft transporting these species (Rothlisberger et al. 2010). These simple actions have become the standard preventative actions for the general boating public (e.g. Stop Aquatic

Hitchhikers!). Many boaters across the country are required to follow these steps to comply with regulations designed to prevent the spread of invasive species (e.g. Wisconsin, Minnesota, and Michigan). While these general recommendations are easy to perform on the majority of watercraft, there are some types of watercraft, such as wakeboard boats, where these recommendations may be more difficult to implement and may not acceptably reduce the risk of AIS transport.

Wakeboard boats are a relatively recent addition to recreational boating, with the sport becoming popular in the late 1980s, and the industry growing to sell around 10,000 new boats each year (NMMA 2011). Wakeboard boats often have a ballast system that is used to increase displacement to create a large wake that is used as a launching point for a towed rider to perform tricks behind the watercraft. These watercraft can take on hundreds of liters of ballast and

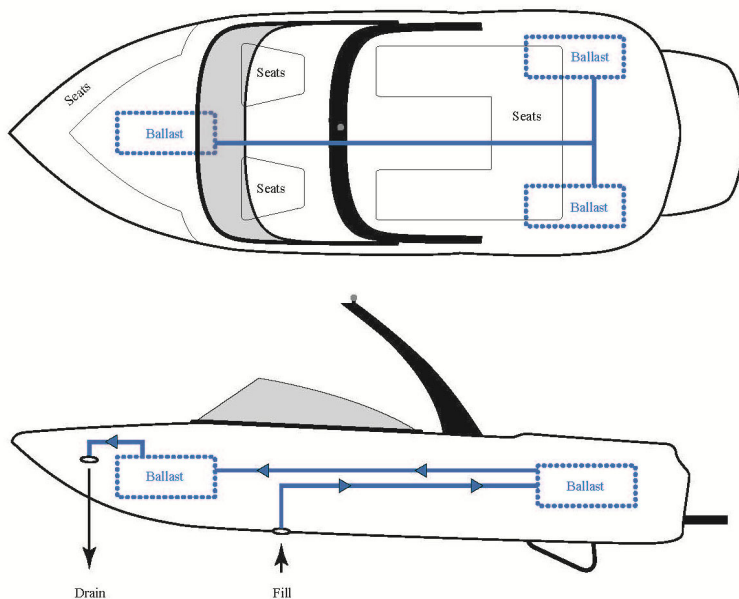


Figure 1. While wakeboard boat ballast systems are often custom and can differ from boat to boat, a common configuration is to have two ballast bags in the back storage and one in the center storage locker. Water is typically drawn into the system on the bottom through the hull and it exits the system out of a through-hull fitting on the bow.

have the potential to transport large volumes of residual ballast water. The ballast systems are often located in storage compartments and can be difficult, if not impossible, for a boater to drain completely (Figure 1). Anecdotal reports have indicated that these boats have transported large amounts of water, but until now it has never been verified.

In order to gain a better understanding of these watercraft and to ultimately prescribe better prevention actions, we undertook a study to determine if wakeboard boats were transporting water, and if so, how much water. We also quantified the types of invertebrates that were being transported. This study will provide the AIS and boating community with additional understanding of this issue, which can then be used to develop best practices to reduce the risk of AIS transport.

Methods

Twenty-three wakeboard boats were sampled in September and October of 2013 at Ft. Fremont Marine in Fremont, Wisconsin. Wakeboard boats were first identified from the pool of watercraft on site and checked for ballast systems. If ballast systems were present, then system type was identified. Only boats with ballast bags (as opposed to hard ballast tanks) were chosen for sampling given the difficulty of sampling hard tanks, which are not easily removable (Figure 2). Before the ballast bags were removed for sampling, they were drained using the

existing pumps to ensure only water that could not be drained was being measured. The ballast bags were then removed and any residual water emptied into buckets which were then weighed (kg) and converted to a volume (L, 1.0 kg = 1.0 L). The residual ballast water was then filtered through a 90 micron plankton net and the contents preserved in 70% ethanol.

For the invertebrate analysis, the preserved samples were filtered through 80 micron mesh in the lab and diluted with distilled water. The entire volume of each sample was analyzed by using subsamples of 20–25 mL that were then transferred to a gridded plate where veligers were then counted using cross polarized light microscopy and normal light was used to determine relative abundances of all other invertebrates (Montz and Hirsch *unpubl. data*). Sample processing was completed by Minnesota Department of Natural Resources staff.

Results

Out of the 23 wakeboard boats examined, five watercraft had no ballast tanks while another five had hard tanks that were inaccessible. The remaining thirteen watercraft had bag ballast systems that could be effectively removed and sampled. The mean residual ballast water in the thirteen watercraft examined was 31.7 L (\pm 28.7 L) with a range of 1.0 L to 86.8 L (Figure 3).

Nine of the thirteen watercraft with removable ballast bags had viable organisms present in the residual



Figure 2. A ballast bag is pliable and collapsible, and often has two connected hoses in order to fill and drain the ballast (left). It was observed that the hoses could lift the drain connection above the lowest part of the ballast bag, resulting in a significant amount of residual water in the ballast bag (right). A hard ballast tank (bottom) fills an entire compartment, even when not full, and is generally inaccessible without tools. Photo credit: Tim Campbell.



ballast water, with thirteen different families of zooplankton and macroinvertebrate observed (Table 1). The *Chironomidae*, *Cladocera*, and *Copepoda* were the most commonly detected zooplankton families. Dreissenid veligers were detected in two samples, with 9 and 47 veligers (2.4 and 0.6 veligers/liter, respectively) present in those samples.

Discussion

These results document the existence of residual water and invertebrates, including dreissenid veligers, in wakeboard boat ballast systems even after onboard pumps indicate that the ballast water systems are empty. This transport of water in ballast systems creates risk of these watercraft transporting AIS and makes watercraft with these types of ballast water systems in violation of regulations prohibiting the transport of lake and river water designed to prevent the spread of AIS (e.g. Wisconsin Administrative Code chapter NR 40, Minnesota state statute Conservation Chapter 84D.09). The variability in the

volume of ballast water in a given watercraft suggests that there may be certain situations or equipment that are more effective at draining water than others. Given the small number of watercraft we were able to sample, no patterns emerged indicating what systems or watercraft drained the most amount of water. However, ballast systems are often aftermarket additions to watercraft and can be added to many places on a boat by any marine service center which increases the variability in ballast system design. This provides the opportunity to develop best practices that minimize residual ballast water for both ballast system design and installation, and for boater behaviors. The less residual ballast water remaining will make manual draining or other treatment options easier and more efficient.

Given the results of this study, the simple actions that drain water on other types of watercraft (e.g. fishing boats, cruisers), such as pulling the drain plug and emptying the bilge, will not achieve the same risk reduction in wakeboard boats with ballast water systems. Owners of wakeboard boats can manually

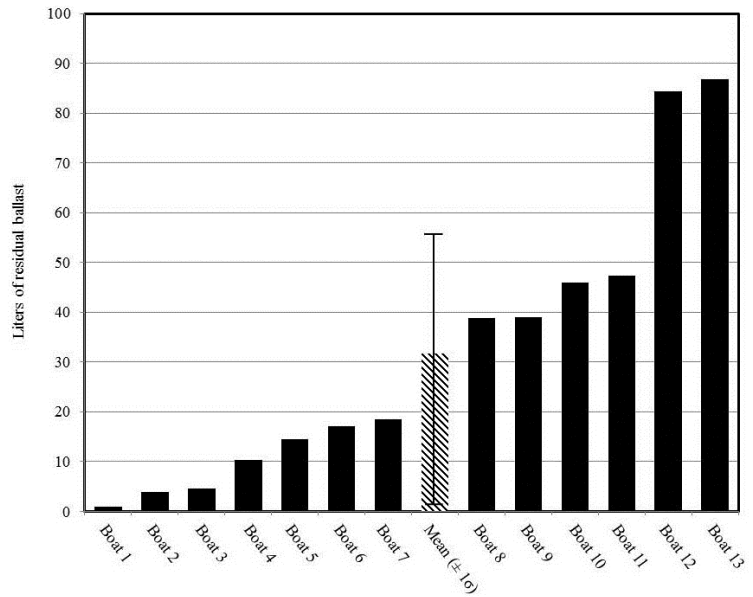


Figure 3. Liters of residual ballast water documented in each watercraft that was sampled. The striped bar is the mean ($\pm 1\sigma$) of all 13 watercraft.

Table 1. Invertebrate abundances for residual wakeboard ballast water. Native zooplankton were relatively common across the samples. Dreissenid veligers were found in only two samples (2 and 12). Samples 1 and 7 were not analyzed due to sample collection errors. Relative abundances per subsample are as follows: Rare (1–4), Present (5–9), Common (10–14), Abundant (15+).

Sample	Total ballast volume (L)	Veligers	Veliger/liter	Bythotrephes	Amnicola	Amphipoda	Ceratopogonidae	Chironomidae	Cladocera	Collembola	Copepoda	Diptera	Hydrachnida	Odanata	Oligochaera	Ostracoda
2	3.8	9	2.4	-	-	-	-	-	-	-	-	-	-	-	-	R
3	4.6	0	-	-	-	-	-	-	P	-	-	-	-	-	-	P
4	10.3	0	-	-	-	-	-	-	R	-	R	R	-	-	-	-
5	14.4	0	-	-	-	-	-	-	P	-	-	-	-	-	-	P
6	18.6	0	-	-	-	-	R	R	A	-	R	-	-	-	A	P
8	38.8	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	39	0	-	-	-	-	-	-	-	R	-	-	-	-	-	P
10	45.9	0	-	-	-	R	-	R	A	-	C	-	R	-	A	P
11	47.2	0	-	-	R	-	-	C	A	-	P	-	-	R	-	A
12	84.3	47	0.6	-	-	-	-	-	C	-	-	-	-	-	-	P
13	86.8	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

remove and drain some of the onboard ballast systems, but this process took around five minutes per ballast bag the course of this study, with most watercraft having three ballast bags. The time and effort required to take prevention actions are two reasons anglers cite for not taking prevention actions on their watercraft (Moy et al. 2014), so it is questionable as to whether boaters with more complex watercraft would be willing to manually remove and drain ballast bags, even with regulations that may

require it. More education and enforcement efforts may be needed to get boaters to take these prevention actions. Additionally, watercraft design is becoming more complex and some ballast systems are placed where they are inaccessible, making them difficult to drain. One possible solution would be to attempt to use the pumps to drain the ballast systems while on an incline or a boat ramp so that more water reaches the drain pump which often isn't placed at the lowest point of the watercraft. Alternatively, design features

that reduce AIS transportation risk without added effort from the owner could be used something that could be marketed to customers.

Allowing a watercraft to dry for five or more days is also an often recommended prevention action (ANSTF 2013). This is effective for many vessels and potential AIS when all of the recommended practices are completed. However the large amounts of residual ballast water in wakeboard ballast systems documented in this study undermine the potential effectiveness of this guidance. The design of these ballast systems prevents them from completely draining, and the closed system would not allow any amount of water to evaporate in even the thirty days that some AIS prevention programs in the western United States use as a standard quarantine time. Live invertebrates were found in the residual ballast water of watercraft examined in this study at least seven days after the watercraft arrived at our sampling location. It is possible that the organisms may have survived longer than seven days since we only know the day the watercraft arrive at the our sampling location. The actual time organisms survived in these ballast tanks was seven days plus the number of unknown days it was unused before being delivered for winterization. Future work could determine how long organisms would be able to survive in recreational ballast tanks. Recent work shows that quagga mussel veligers can survive at least seven days in small amounts of water (Snider et al. 2014), and up to 27 days in less extreme conditions (Choi et al. 2013). Another AIS of concern, the spiny water flea (*Bythotrephes longimanus*), has a dormant resting egg that has been noted to be viable after years of dormancy, making it well suited to survive long periods of time in residual ballast water provided the ballast tanks do not desiccate or reach temperatures above 50°C (Branstrator et al. 2013).

The presence of viable veligers confirms that this is a potential invasion pathway for these highly invasive mussels. The abundances counted in these samples were low relative to a similar study of other recreational watercraft (Montz and Hirsch *unpubl. data*), but the watercraft in our study were sampled out of convenience and might not accurately reflect the risk of these watercraft transporting AIS. Since it is unknown where the boats in this study originated from, additional work should pair sampling of lake water and residual ballast water at sites with known populations of invasive species at times where their abundances are high. This will help quantify the highest densities of AIS that these systems can be expected to retain and transport. An increased sample size of wakeboard watercraft and craft details will also help managers obtain a clearer picture of what

watercraft pose more of a risk than others and what they might be transporting.

Little is known about the boating habits of wakeboard boat owners. While each watercraft with a ballast water system is likely transporting water, it is important to note that wakeboard and ski boats make up a small amount of the new boats sold each year in the US, with around 10,000 new units sold each year (NMMA 2011). Conversations with local industry representatives suggest that many wakeboard boats may pose a reduced risk of transporting potential AIS to new waters given that they stay on the same body of water and when they do travel, they often visit many of the same locations repeatedly. However, wakeboard boat owners may transport their watercraft long distances for a vacation or competition. Understanding these movement patterns and the current prevention behaviors exhibited by wakeboard boat owners will be important in assessing risk and developing specific AIS prevention recommendations for this portion of the boating market.

The wakeboard boat industry is aware of AIS issues. The American Boat and Yacht Council hosted an AIS Summit in Consideration of Watercraft Design for Invasive Species Prevention in January of 2015. Both AIS professionals and members of the boating industry attended and partnerships were formed to begin to address AIS issues, including design issues that would help all types of watercraft drain more fully (ABYC 2015). Filtration devices (e.g. the Wake Worx Mussel Mast'R) are a possible solution that could prevent the transport of organisms in wakeboard ballast. While they have proven to be effective at preventing organisms from entering ballast, they do not necessarily ensure that these watercraft comply with all existing local regulations. Collaboration between regulators and industry will be needed to make sure that any technological solutions (i.e. filtration, chemical treatment) are complementary in preserving access to water bodies whilst protecting against AIS translocation through compliance with local regulations. Collaboration will also be needed so that industry can continue to be aware of AIS issues and design solutions into future model years.

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