Fisheries and Oceans Canada Pêches et Océans Canada
Science Sciences
Canadian Science Advisory Secretariat
Central and Arctic Region Science Response 2014/031

LAKE WINNIPEG ZEBRA MUSSEL TREATMENT

Context

The Zebra Mussel (*Dreissena polymorpha*), a native of the Black and Caspian seas region in Southeastern Europe, has a long history of invasion in freshwaters of both Europe and eastern North America. This species was introduced to the Laurentian Great Lakes in the mid-1980s as a result of ballast water discharge from ships. The mussel has rapidly dispersed throughout the Great Lakes region, into river systems, and smaller lakes and reservoirs. The species has had a large economic and ecological impact where it has become established, resulting in severe negative impacts on food webs and nutrient processing. Zebra Mussel was first discovered in the Red River basin in the United States in about 2009. In October 2013, the species was first reported in Lake Winnipeg, Manitoba.

The Province of Manitoba has implemented a Rapid Response Protocol based on Locke and Hanson (2009) in an attempt to eradicate known populations and suppress the spread of the species. To that end, they have requested the closure of four Small Craft Harbours in Lake Winnipeg for a period following ice-out in spring 2014 to apply a liquid potash treatment to kill Zebra Mussel found there.

Fisheries and Oceans Canada's (DFO) Small Craft Harbours has requested Science information and advice on this request. Advice is required by April 22, 2014 to allow the Department time to evaluate the province's request and make a decision about closing the harbours.

Specifically, DFO Science has been asked the following questions:

1. Does DFO Science support the Manitoba Zebra Mussel Science Advisory Committee's recommendation to eradicate/suppress Zebra Mussel at four Small Craft Harbour sites on Lake Winnipeg by isolating the harbours and applying a liquid potash treatment?
2. If yes, does DFO Science support the recommended timing window for the eradication/suppression treatment to be carried out (i.e., immediately following ice-out but before water temperatures reach 10°C)?
3. Has DFO Science identified and reviewed alternative treatment options?

This Science Response Report results from the Science Response Process of April 2014 on the review of the proposed treatment for Zebra Mussel in Lake Winnipeg.

Background

In 2012, DFO Science conducted a risk assessment for Zebra Mussel in Canada (DFO 2012, Therriault et al. 2013). Zebra Mussel was found to pose a high risk to most regions of western Canada. The probability of survival (habitat suitability) was determined primarily based on calcium concentrations which indicated that most watersheds in the prairies were highly suitable for survival and establishment of Zebra Mussel. Zebra Mussel establishment has been shown to have significant, irreversible ecological impacts to freshwater ecosystems.

Human-mediated dispersal, specifically recreational boating activities including overland transport of boat trailers and water-based equipment, are important vectors contributing to the spread of Zebra Mussel in Canadian freshwaters. Natural dispersal downstream in major river systems can occur rapidly over large distances.

Species Biology

Zebra Mussel ingests small planktonic algae and zooplankton. Adults compete with larger zooplankton for food which impacts ecosystem structure and function.

The threshold temperature for Zebra Mussel reproduction is approximately 10–12°C (Therriault et al. 2013). Fertilized eggs develop into veligers within 3-5 days and are free-swimming for up to a month (Therriault et al. 2013). Dreissenid mussels have a short maturation time (1–2 years), high fecundity (up to 1 million eggs per female for each spawning event) and a high capacity for dispersal. Their dispersal is aided by a planktonic veliger stage as well as the ability for juveniles and adults to attach to hard surfaces (e.g., boats, trailers, hard-shelled animals) which are often transported between different ecosystems. Shell growth is temperature dependent. Zebra Mussel can survive up to 6–9 years (generally 3–4 years) with shorter lifespan associated with warmer lake temperatures. When conditions are favourable mussel densities can be very high (exceeding 1,000,000 individuals m^{-2}) in localized areas.

Zebra Mussel are typically found in lakes, rivers, canals and estuaries attached to a wide variety of substrates such as rocks, shellfish, aquatic plants and human produced composite (e.g., HDPE and PVC) substrates. Zebra Mussel typically settle at moderate depths (4–7 m) and tend to be rare in the profundal zone (>50 m) due to the finer sediments and cold (~4°C) temperatures. Zebra Mussels are known to be negatively phototaxic[1].

Analysis and Response

The Province of Manitoba was alerted to the potential presence of Zebra Mussel in Lake Winnipeg on October 11, 2013 by a member of the public. Individual mussels were found on a private dock in the harbour at Boundary Creek Marina/Winnipeg Beach and on several fishing vessels in Gimli Harbour on October 12 and 13, 2013. Their identification as Zebra Mussel was confirmed by several experts. Subsequently evidence was provided that about five mussels found in 2011 on a piece of PVC pipe in amongst some shoreline debris in Traverse Bay, Lake Winnipeg were Zebra Mussel. The individual who found the cluster of zebra mussels indicated the mussels appeared to be dead at the time of capture.

DFO and Manitoba have an Aquatic Invasive Species task group as part of the Canada Manitoba Fishery Advisory Committee. Manitoba's Zebra Mussel Science Advisory Committee (MB-ZM-SAC) was established following the detection of Zebra Mussel in the province. The Committee met and provided direction to Manitoba on data needed to inform an 'Early Detection Rapid Response Plan'.

Sampling to inform demarcation

The Province of Manitoba has an annual Zebra Mussel monitoring program, which includes the inspection of the navigational buoys removed from the Red River and Lake Winnipeg in the fall as well as monthly veliger sampling in the Red River at Emerson (Figure 1). No Zebra Mussel veligers or adults have been detected in the Red River portion of their assessment. Manitoba contacted utilities (i.e., those with significant infrastructure within the Red River that could be colonized by the mussels) and to date, there has been no indication that Zebra Mussel has colonized the Red River. Manitoba has also operated inspection stations at the international border crossing in Emerson for several years during the open water season but has found no Zebra Mussel on incoming boats or trailers.

[1] Negatively phototaxic–movement of an organism away from a source of light.

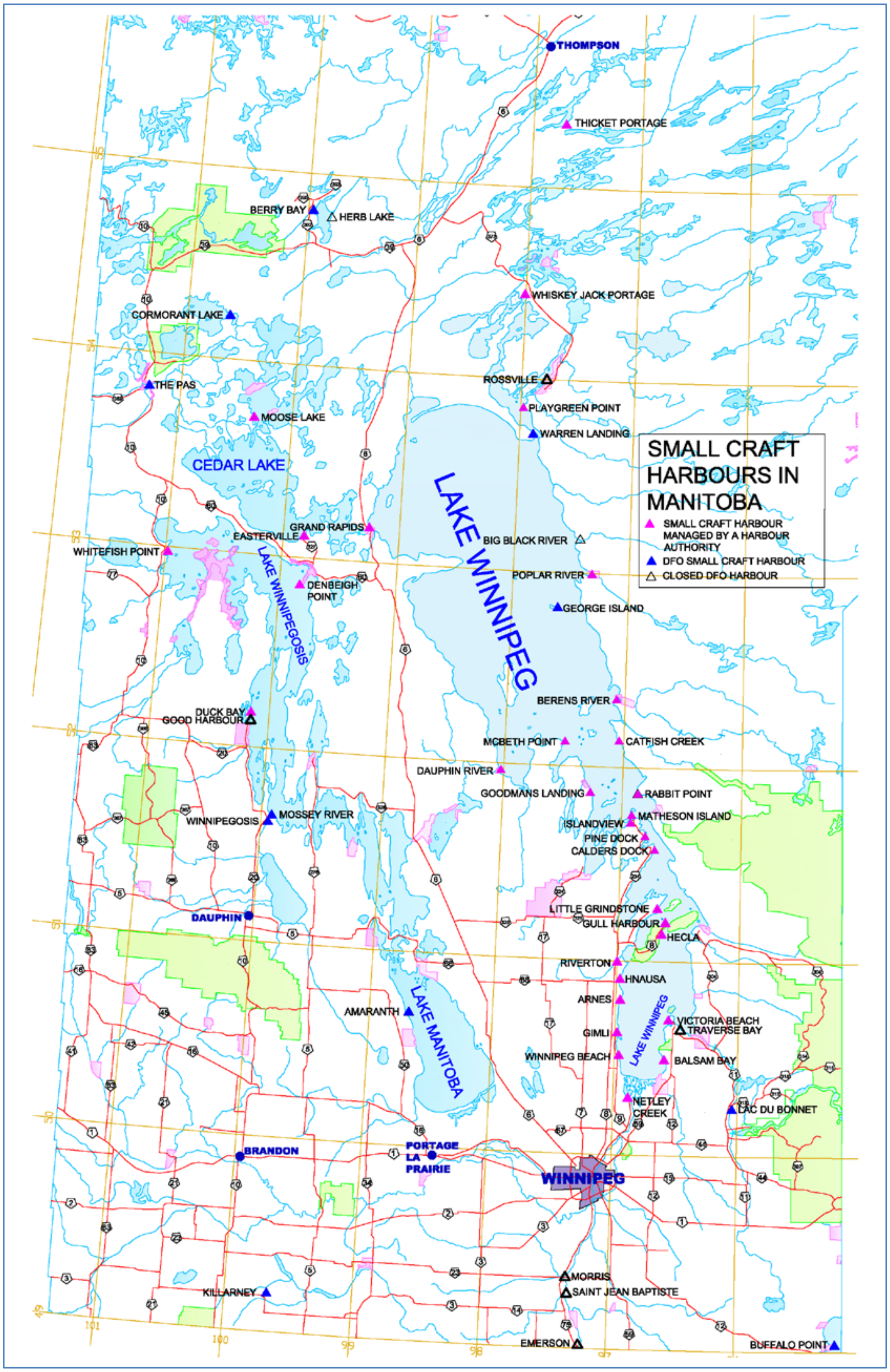

Figure 1. Manitoba Small Craft Harbours.

In October 2013, a survey was conducted to determine the spatial extent and density of the Zebra Mussel infestation. Hard structures (docks, dry docked vessels and shoreline) were checked from Gull Harbour on the west side of the south basin of Lake Winnipeg to Seymourville (almost directly across the lake from Gull Harbour) on the east side of the south basin of the lake. Main boat launch locations, not just harbours were searched as well as shorelines in the areas adjacent to the harbours. Other private docks along Willow Point (1-2 km south of Gimli, Manitoba) and in the subdivisions of Siglavik and Huskavik (south of Gimli) were also checked. Manitoba Hydro staff were asked to check the Jenpeg Generating Station. All the navigational buoys removed from Lake Winnipeg and the Nelson River were examined. Zebra Mussel populations were found at four DFO Small Craft Harbours (Arnes, Gimli, Winnipeg Beach, Balsam Bay) and a small private docking area at Willow Point. A total of 425 adults were recovered from the five locations. Zebra Mussel were not found at any other locations during the survey. However, public works staff reported removing a single zebra mussel from the bottom of each of two swimming piers located at Whytewold after the piers were removed. During the survey, not all surfaces were checked as the main purpose of the survey was to determine presence or absence, estimate density and obtain size distribution to estimate life stage. Population density of mussels on hard structures was relatively low and was similar between Gimli, Winnipeg Beach, and Balsam Bay (~3 ind/m2 of available surface area). As the size of the harbours and available substrate is much higher in Gimli and Winnipeg Beach, the total populations in those locations were highest (estimated at >1000 individuals). Approximately five mussels were removed from a sailboat dry docked at Silver Harbour Resort/Arnes Harbour. Willow Point is just south of Gimli harbour and Zebra Mussel were found on a private dock within a narrow channel of a marsh. It is likely that the channel would freeze to the bottom in this location and there is a lower risk of mussels surviving through the winter. Monitoring plates and veliger tows in the area will be used to evaluate continued infestation in 2014.

Data from the 2013 fall survey indicated that Zebra Mussel populations at these locations were at an early stage of colonization. The size structure of the population suggested colonization of these harbours occurred during the 2013 open water season.

Lake Winnipeg is large and many locations were not sampled. However, samples collected for Spiny Waterflea in many locations around the lake during the spring, summer, and fall of 2013 were analysed for Zebra Mussel veligers and none were detected in locations away from the infested harbours.

Eradication recommendation

The MB-ZM-SAC recommended that the Province of Manitoba attempt to eradicate, or suppress, Zebra Mussel from the five known locations in the southern basin of Lake Winnipeg (four of which are DFO Small Craft Harbours). The window of opportunity for successful eradication is very short. As Zebra Mussel has a very high reproductive output and spawning can occur as water temperatures reach 10°C , the Committee recommended that eradication and suppression attempts be made either in winter (under ice) or in early spring (after ice-out but before water temperatures reach 10°C). After reproduction occurs, dreissenid mussel veligers may drift from the harbours and/or be carried to new locations on the hulls of vessels (overland, or within Lake Winnipeg).

Eradication methods

The MB-ZM-SAC discussed several eradication options.

No Action

A ‘No action’ approach was also considered. No closure of harbours or regulatory approvals would be required. Data from 2013 surveys indicated that Zebra Mussel had very high growth rates within the harbour locations once established, indicating the harbours offer suitable habitat for the survival and growth of Zebra Mussel. There is a high risk of Zebra Mussel dispersing from the harbours via veligers or on the hulls of watercraft and being transferred to locations around the lake. There is an increased risk of mussels escaping overland via a boat trailer or boat hull, live well, or through ballast water. The ecological impacts of Zebra Mussel are well understood (Higgins and Vander Zanden 2010, Therriault et al. 2013) and potentially very high in Lake Winnipeg. Risks to the fouling of infrastructure (water intakes, hydroelectric dams, navigational buoys, etc.) are also very common and very costly. Other jurisdictions (e.g., United States) have been aggressive in prevention and 'slow the spread' efforts (much more so than Canada) and so, while outside of the science assessment, a 'no action' approach may cause inter-jurisdictional disagreements (e.g., between Canada and U.S. and between other western provinces and Manitoba).

Physical Treatment

Hand Harvesting

Hand harvesting of adult mussels was discussed as a possible means of eradication/suppression. It is being attempted in Lake Powell (USA), and Lake George (USA). There is no need for the addition of chemical or biological treatment; regulatory permits/requirements are minimal. The main disadvantage of this approach was the ability to eradicate was suspect. The low potential for removing 100% of adults, combined with high reproductive output (up to 1 million gametes per individual per spawning event) means that only a few surviving individuals are required to establish a viable population. Visibility in the harbours (near zero) would further limit the effectiveness of this approach.

Re-suspending sediments

Zebra Mussel have reduced growth and survival in locations with very high suspended sediment concentrations (i.e., poor food quality). The Committee discussed the potential to artificially elevate and maintain suspended sediment concentrations in the harbours in order to reduce growth rates and reproduction potential. As this would be a physical rather than chemical or biological treatment, there would be some reduction in regulatory approvals required (though not all, e.g., Section 35 *Fisheries Act*) and harbours would not need to be closed. This approach has not been used elsewhere and its effectiveness is unknown as are impacts to non-target organisms. More research is needed before this approach can be considered reliable. This approach could potentially be attempted in future if harbours are re-invaded.

De-watering the harbours

This would kill 100% of the mussels via asphyxiation. However logistically it would be very difficult, have a high cost, require regulatory approvals, and have high impacts on any non-target organisms within the harbours. The closure of harbours would likely be longer than other approaches.

Biological treatment

Zequanox

This is a biological treatment (biopesticide) that is currently allowed for use in enclosed industrial systems in the U.S. and Canada. It is a registered product for Zebra Mussel control under Health Canada's Pest Management Regulatory Agency (PMRA) for industrial use "in enclosed, semi-enclosed, and confined flowing water in infrastructure within dams and associated hydroelectric power plants." The United States Geological Survey is testing the efficacy of this treatment in an open lake scenario during 2014 in Minnesota. This pesticide, unlike many pesticides, appears effective at targeting Zebra Mussel with minimal impacts to other biota. Kill rates for this pesticide do not appear to be 100% effective (~90%), and there is high uncertainty with use in open lake environments. Although treatment would not impact non-target species, use of the biopesticide would require regulatory approval and closure of harbours, is more expensive than the proposed use of KCl and has not been demonstrated to be 100% effective in this set of environmental conditions.

Chemical treatment

Reducing pH

Zebra Mussel inhabit waters with pH between 6.6 and 8.5 (Benson and Raikow 2011), however adult Zebra Mussel may adapt and survive to pH levels below 5.2 (Heath 1993 as cited in Nalepa and Schloesser 2014). This method has not been tested elsewhere and there is high uncertainty that it would be effective. Treatment would impact non-target species and the ability to maintain low pH levels would be technically challenging, require regulatory approval and closure of harbours.

Copper sulphate

Copper sulphate has been proven to be successful for eradicating mussels in the family Dreissenidae in two ‘non-confined water’ locations: zebra mussels at a US Air Force Base in Nebraska, and black-striped mussels (*Mytilopsis sallei*) in Darwin Harbour, Australia (Fernald and Watson 2014). Copper is toxic to aquatic organisms at all trophic levels including non-target organisms: algae, invertebrates and fish (USEPA 2008) and a large fish kill occurred during the treatment at the US Air Force Base (Fernald and Watson 2014). For Lake Winnipeg the closure of harbours would be required. This product is not registered with the PMRA for Zebra Mussel control. Treatment would impact non-target species, require regulatory approval and closure of harbours, and may not be 100% effective in this set of environmental conditions.

Chlorine

Chlorine is an oxidizing agent and kills Zebra Mussel through asphyxiation. Chlorine is the most used treatment of Zebra Mussel in confined industrial applications in North America and Europe (Fernald and Watson 2014 and references therein), and its effectiveness has been demonstrated. Chlorine is a component of two products that are registered for industrial applications by the PMRA. It is toxic to non-target organisms and there are human health concerns (i.e., the production of carcinogenic trihalomethanes) (Waller et al. 1993). Closure of harbours is required. Treatment times in these harbours are uncertain and may requires long periods of closure since Zebra Mussel can close up and reduce metabolic activity in the presence of toxicants such as chlorine.

Potash

Liquid potash was successfully used, with 100% effectiveness, to eradicate Zebra Mussel from the Millbrook Quarry in Virginia, USA (Fernald and Watson 2014). Liquid potash is comprised of potassium chloride (KCl), and potentially other salts (e.g., carbonate, sulfate, nitrate). It is important to note that the ‘killing agent’ in potash is the potassium(K^+), which appears to interfere with the ability of the mussel to transfer oxygen across the gill membrane (Fernald and Watson 2014). At concentrations required to kill Zebra Mussel (< 100 ppm K^+) it is considered that there are no risks to human health or risks to non-target species except native freshwater mussels (ASI 1997, Waller et al. 1993, Fernald and Watson 2014). As potash is not registered by PMRA, the application would be authorized by PMRA under a Research Permit to test the efficacy of potash in killing Zebra Mussel in the harbours. Its application requires closure of harbours.

Among the eradication methods considered, the MB-ZM-SAC recommended that the addition of liquid potash (a mixture of potassium salts) be attempted, due to its successful use to eradicate Zebra Mussel in Millbrook Quarry in Virginia, U.S.A (Fernald and Watson 2014), and its relative high toxicity to Zebra Mussel and low toxicity to most other aquatic biota (except native mussels) at the concentrations proposed (<100 ppm). Application of liquid potash would require that specific Small Craft Harbours be closed for 10-60 days. The treatment would be undertaken by ASI Group Ltd (Aquatic Sciences Inc.).

Prior to beginning chemical treatment the consultant will seal off each harbour from Lake Winnipeg through the use of non-permeable geo textile membranes (Type 2 curtain) which will be installed by their marine division. This will in effect create a contained open water body. A shore based staging area will be situated in close proximity of each harbour and will be used throughout the duration of the project. Equipment will include High Density Polyethylene storage tanks with spill containment to protect against spills and also to ensure a constant supply of stock solution. A stock solution of approximately 12% potassium will be mixed by a chemical supplier and delivered to the site on an as required basis where it will be transferred to the storage tanks and kept in solution by an electric tank mixer. It is estimated that 336 metric tonnes of 20% KCl will be required to treat the approximately 356,000 – 427,000 m^3 of water contained within the harbours.

Water based operations will use a 22 ft. Sealander work boat outfitted with a specially designed diffuser assembly. Stock solution from the shore based storage tanks will continuously feed the diffuser through a floating 3.8 cm (1.5 in.) diameter supply line and shore based centrifugal pump transfer system. Proper diffusion of potassium; opposed to batch dumping, is a critical element of the treatment method.

Treatment will proceed on a systematic basis by separating the harbours into segments or treatment zones being characterized by water depth. The work platform based retractable 3 m x 1.2 m (10 ft. x 4 ft.) diffuser assembly will consist of ten perforated vertical flexible hoses having capped and weighted ends and being attached to the 3 m (10 ft.) horizontal section. This will allow for an enlarged mixing zone to be achieved while the flexible hose will reduce damage due to submerged obstacles. An echo sounder will be used to monitor water depth along with the depth of the submerged diffuser assembly in order to maintain an optimum height above the harbour bottom. This system will also reduce the risk of entangling the diffuser assembly on bottom features.

To ensure the potassium diffusion system is operating efficiently and is attaining target potassium concentrations throughout the treatment zone, potassium spot monitoring will be completed during each charge operation. This will provide ASI personnel with information on how quickly and how well the potassium is dispersing through the treatment zone. This information can be used to modify the treatment protocol, either by increasing or decreasing the dosing rate to achieve target concentrations.

Following the “charge” activities, a final sampling exercise will be conducted throughout each harbour to characterize potassium concentrations at various depth profiles. Monitoring points at each harbour will be spaced 20-45 m (75 to 150 ft.) apart depending on the harbour width at each transect location. Approximately three to five sites will be monitored along each transect to ensure feasible and maximum monitoring coverage of the treated transect area. Duplicate samples will be collected and analyzed for every tenth sample for quality assurance and quality control (QA/QC) purposes.

To determine the potassium concentrations, water samples will be obtained by two different methods. Surface grabs will be conducted where water depths are less than 2 m and will be collected at least 0.15 m below the surface. A peristaltic pump or Kemmerer bottle will be used to collect samples from each thermocline present in the harbour and at depths greater than 2 m. Samples will be analyzed with an Orion 290A pH/ION concentration meter, in combination with a potassium probe.

Sample identification, location, depth, date, GPS coordinates for each monitoring point and other pertinent information will be recorded in the field logbook and on reporting log sheets. The field instruments will be calibrated prior to use every day with standards of known value. Monitoring will be conducted daily throughout a 12 hour shift.

Several bioassays will be employed to determine the effectiveness of each treatment. Bioassays involve placing 100 healthy adult Zebra Mussel into 75 micron screened tubes, and then exposing the mussels to the potassium-charged water in various locations. These locations will be determined based on potassium analysis results, and will target areas and depths where potassium concentrations fluctuate. It is estimated that up to five bioassays per harbour will be conducted at various locations and depths. Measures will be in place to keep bioassay tubes in place within the harbours and to ensure no release of veligers from the bioassay specimens.

Zebra Mussel used for the bioassays will be collected from Lake Simcoe where they occur without Quagga Mussel (another invasive dreissenid species). The mussels will be picked by hand and transported in UV treated water to prevent transmission of any other AIS, including disease, where they will be held in a contained setting for up to 7 days prior to transporting to Manitoba. Upon arrival in Manitoba, transport water will be disposed of away from any surface water, packaging will be disposed of in the garbage and any containers will be washed with hot water (140°C).

There will also be one control sample of zebra mussels (held most likely at Gimli Harbour) in a flow-through aquarium located in a trailer brought on site. Untreated water from the Lake Winnipeg side of the harbour will be pumped through the aquarium. The effluent will pass through a multitude of filters ending with a 40 micron screen before entering the “charged” harbour. The mesh size is smaller than any literature recorded size of Zebra Mussel eggs. The control environment will terminate immediately following 100% kill of all the Zebra Mussel in the bioassay cages and prior to the barrier being dismantled (at least 1-2 days).

The bioassay cages will be constructed from PVC tubing with 40 micron mesh at the ends. Only after the harbour is sealed, charged with potash and monitoring has occurred to ensure the potash is at the right concentration will the bioassay cages be placed throughout the harbour. The current plan for Gimli harbour is to place 10 lines throughout the harbour with two cages attached one near the top and one near the bottom on each line. Each line will be anchored by a cinder block and identified with a buoy. Bioassay cages will be checked and any mussels that appear dead will be removed and placed in an aquarium with untreated flow-through water to ensure that they are actually dead and not just paralysed by the potassium.

In addition to the bioassays seeded in the harbours, a control bioassay will be conducted by monitoring 100 adult mussels contained in fresh, untreated water in a climate-controlled site trailer to mimic harbour water conditions. The control mussels will monitor the health of the population during the bioassay to ensure the reliability of the mortality results.

To determine if there is any leakage occurring at each of the barriers water samples will be obtained at various depths along a transect adjacent to the outside of each barrier implementing the same methods as described above. If leakage is detected then water samples at various depths would be collected until the potassium levels are at a level not toxic to mussels (or is at background).

Upon removal of each barrier, water samples will be taken to determine the extent and duration of the potassium plume using the methods described above. To the extent possible there will be a follow up within the plume area to determine if any freshwater bivalves were affected within this area.

Impacts to Species at Risk

The only species listed under the *Species at Risk Act* that may be found in Lake Winnipeg is Mapleleaf. Although there have been historic references of Mapleleaf in Lake Winnipeg, neither the COSEWIC nor DFO Recovery Potential Assessment (RPA) processes have been able to confirm these unverified reports (DFO 2011). The current distribution of adult Mapleleaf in Canada indicates that this species tends to occur in medium to large rivers (DFO 2011). Water flow does not appear to be limiting factor for Mapleleaf as it has been found in both slow- and fast-flowing rivers. Recent surveys have indicated that Mapleleaf preferred substrate is dominated by firmly-packed coarse gravel or rubble, although it can also be found over mud, sand or fine gravel substrates. Water velocity values for successful Mapleleaf detection sites from the Assiniboine River ranged from 0.42 to 0.72 m s^{-1}. The greatest limiting factors to the stabilization and growth of freshwater mussel populations in Canada are largely attributed to the introduction and establishment of dreissenid mussels and decreases in the quality of available freshwater mussel habitat. Threat level for Mapleleaf in the Red River from exotic species was considered High (DFO 2011). The likelihood of Mapleleaf being present in the harbours is relatively low. However successful establishment of a Zebra Mussel population could have a high impact on Mapleleaf.

Sources of Uncertainty

The main uncertainty is whether or not a viable population of Zebra Mussel exists outside the known infestation sites. If such populations exist, there would be a reduced (but not eliminated) need for eradication/suppression of the mussels within the harbours. The benefits of suppression, even if there is an established population in the lake, is to reduce the risk of Zebra Mussel attaching on a recreational boat, boat trailer, or in bilge water/live well and escaping to another lake. This would breach the containment, and additional strategies (at elevated cost) would be required to contain Zebra Mussel in multiple lakes/provinces.

In terms of the treatment, the effectiveness of potash to kill Zebra Mussel has been demonstrated in previous studies (ASI 1997, Fernald and Watson 2014). The main uncertainty is the logistical feasibility of maintaining potash concentrations near target levels for the duration of the treatment (e.g., if large wind events cause changing water levels and flushing of the harbours). The contractor has indicated that they have mitigation measures (curtain at mouth of harbours to restrict flow, ability to ‘re-charge’ harbour with potash if needed) in place to deal with such an occurrence.

An additional uncertainty is what to do if, following the eradication effort, Zebra Mussel re-establish in the currently infested harbours or in new locations. It is uncertain if future eradication efforts would be attempted as it would likely depend on a number of factors/considerations.

If treatment activities are not initiated prior to the water temperature warming above 10°C, reproduction from surviving adults would start to occur. If the containment is not in place, it is possible that veligers would escape from the harbour locations. This was undoubtedly true during the summer of 2013, before the mussels in the harbours were detected. It is fortunate that most of the locations near the harbours have soft substrates that are considered sub-optimal habitat for this species. If the treatment were delayed until the fall, not only would veligers escape but Zebra Mussel attached to boat hulls could be transported around the lake to colonize in other harbours and open lake locations.

Conclusions

Establishment of Zebra Mussel in Lake Winnipeg poses a high risk to the lake ecosystems. Though the extent and magnitude of changes that may occur as a result of successful establishment in Lake Winnipeg are unknown, studies elsewhere provide insight into possible impacts. Data from studies across their invaded range indicate that Zebra Mussels cause dramatic restructuring of food webs and energy/nutrient fluxes within freshwater systems (Higgins and Vander Zanden 2010, Higgins 2014).

Locke et al. (2011) developed a Canadian Rapid Response Framework for Aquatic Invasive Species, the optimal outcome being the elimination of all further risks associated with the presence of the target species (i.e., eradication). A risk assessment of the Zebra Mussel in Canadian freshwater ecosystems has already been undertaken and establishes that the probability of invasion is very high and the risk to the environment is high for Lake Winnipeg (DFO 2013).

DFO Science agrees that, based on the available information, the MB-ZM-SAC has recommended the appropriate action (an application of liquid potash) in attempting to eradicate the Zebra Mussel from harbours of Lake Winnipeg harbours where they have been detected.

Several treatment options were considered. The Liquid potash treatment proposed appears to be the most effective option with the least impact on other species and has been used successfully elsewhere.

DFO Science agrees that the timing proposed for the treatment (i.e., in the early spring following ice-out) would be the most effective at achieving the goal of eradicating/suppressing Zebra Mussel in the harbours. Postponing treatment until later in the season would increase the risk of Zebra Mussel establishing elsewhere in the lake as well as breaching the containment, and being transported to other lakes in, and potentially outside, Manitoba.

The eradication/suppression of the mussels within the harbours should be followed with a strategy for decontamination to reduce the risk of transporting Zebra Mussel between waterbodies.

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