Allison Zach
Nebraska Invasive Species Program Coordinator
506 Hardin Hall, 3310 Holdrege St., Lincoln, NE 68583-0995
Phone: (402) 472-3133 Email: Azach3@unl.edu

The attached document is guidance on how to perform a watercraft decontamination. This protocol was prepared using research and written by the Western Regional Panel on Aquatic Nuisance Species. The entire document this protocol comes from can be accessed here: **https://docs.wixstatic.com/ugd/0e48c2_16afde152b894bf4bff2c72d008e7bdd.pdf**. It is suggested that chemicals not be used to decontaminate watercrafts as they can have adverse effects to the watercraft and engine components. Here is a document that specifically discusses chemicals and watercraft decontaminations: **https://docs.wixstatic.com/ugd/0e48c2_9d1772846e684a4dab9e3af36b882ec8.pdf.**

I am providing this guidance to ensure your watercraft decontaminations successfully remove and kill zebra mussels and other aquatic invasive species. Here is a link to an overview of how to conduct a watercraft inspection for aquatic invasive species: **https://neinvasives.com/Watercraft%20Decon%20Guidance%202019.pdf**.

Please contact me with any questions.

Sincerely,

Allison Zach

Allison Zach
Nebraska Invasive Species Program Coordinator
Email: azach3@unl.edu
Phone: (402) 472-3133
Website: https://neinvasives.com/

Table 2. Quagga mussel mortality (%) under different treatments at day 10.* Treatments of four control groups and eight exposure duration groups for each of the seven temperatures were tested. Adapted from Comeau et al., 2011.[1]

Temp (°F)	1 s (%)	2 s (%)	5 s (%)	10 s (%)	20 s (%)	40 s (%)	80 s (%)	160 s (%)
68	4	4	6	0	0	2	2	0
104	2	2	8	12	94	**100**	**100**	**100**
122	10	22	36	82	**100**	**100**	**100**	**100**
129	54	72	98	**100**	**100**	**100**	**100**	**100**
140	72	92	**100**	**100**	**100**	**100**	**100**	**100**
158	88	98	**100**	**100**	**100**	**100**	**100**	**100**
176	86	98	**100**	**100**	**100**	**100**	**100**	**100**

[1] Susceptibility of quagga mussels (*Dreissena rostriformis bugensis*) to hot-water sprays as a means of watercraft decontamination. Comeau et al., 2011. Biofouling. Reprinted by permission of Taylor & Francis Ltd, www.tandfonline.com

*Note the above table reflects research on the mortality of quagga mussels. This scientific information has informed the current protocols and standards found within this document and are a reflection of a maxiumum time and temperature that will achieve mortality of quagga and zebra mussels. Zebra mussels have thicker shells and consequently require more exposure time.

Decontamination: Following inspection, if a watercraft is confirmed or suspected to have mussels on board, three options are available: 1) decontamination, 2) quarantine to allow sufficient drying or 3) exclusion. Hot water decontamination using a pressure washing unit is currently the only scientifically validated method that kills and removes mussels. Coupling hot water spray with a recommended period of drying (using the 100th Meridian Initiative Drying Time Calculator) is the most effective means to assure that all mussels are killed, and to the extent practical, all visible mussels are removed. The objective of decontamination is to KILL all mussels and to the extent practical REMOVE all visible mussels. Killing prevents establishment of new populations resulting from watercraft/equipment transfer, but removing dead mussels is also important. It may be possible that dead mussels could influence monitoring results by affecting environmental DNA (eDNA) or polymerase chain reaction (PCR) samples from waterbody monitoring efforts (i.e. resulting in a false positive). Furthermore, determining the viability of attached mussels in the field within the context of a watercraft inspection or decontamination can be problematic. Therefore, mussels on watercraft or equipment that appear dead do not necessarily indicate that those mussels are in fact dead.

The best current technology available for watercraft and equipment decontamination is hot water pressure washing (Table 2). The exclusive use of hot water (140°F or 120°F *at the point of contact*) and pressure washing or flushing equipment with various attachments to kill and remove any possible mussels and kill all veligers from every area of the watercraft, engine, trailer and equipment is recommended.

Protocols:

1. **Find a location to conduct the decontamination that is away from the waterbodies and where the run-off and solids from the decontamination process can be contained and will not re-enter any waterbody. Compliance with all state and federal discharge regulations is advised. If possible, wastewater and solids as a result of the decontamination process should be totally contained and directed to an appropriate waste treatment or dis-**

posal facility.

2. Consider requesting a liability waiver signature from the watercraft operator as a condition of the decontamination. Most operators typically agree to sign a liability waiver when the option is quarantine or exclusion. Agencies should consult with their legal staff on liability issues.

Note: Temperature and Duration
Scientific studies have determined lethal temperature and exposure time for a variety of AIS. There may be temperatures and times capable of effectively killing that are lower than those recommended here for some AIS. However, the temperatures and times recommended here were determined to increase the success of killing AIS during the decontamination process for the most resilient species or when species are unknown. For any decrease in lethal temperature, protocols must be amended with an increased exposure time.

3. Once decontamination process and alternatives have been explained and before beginning a decontamination procedure, permission from the vessel operator should be granted.

Standards:

1. Use a plastic scraper, brushes and gloves to remove attached mussels before applying hot water spray to significantly reduce the time required to complete the watercraft decontamination.

Note: Decontamination Safety Advisory
Extreme caution should always be used when working in and around watercraft and equipment, specifically when working with high pressure equipment, hot water and vehicles.

2. Monitor water temperature at the nozzle and at the point of contact to be sure that equipment is operating as required before initiating decontamination. Water loses approximately 10-15°F degrees per foot of distance when sprayed from a power nozzle, so initial temperature should be increased to account for this heat loss to the point of contact. Always use a thermometer or temperature logger to verify and maintain proper water temperatures at the point of contact.

3. Use 140°F water at the point of contact to kill mussels and veligers on the exterior (hull, engine and trailer) and 120°F on the interior (compartments) (Table 3).

4. When using a hot water pressure washer or flushing attachment to kill and remove attached mussels from the surface of watercraft/equipment, allow 10 seconds

Table 3. A summary of scientific research indicating the lethal water temperature at point of contact and duration for decontamination. Information is grouped by the location of the boat that is targeted and the life form of dreissenid mussel targeted (e.g. adult mussel or veliger). Please refer to the *Student Training Curriculum for Watercraft Inspectors and Decontaminators to Prevent and Contain the Spread of Aquatic Invasive Species* for complete step by step procedures.

	Boat Part/Location	Water Temperature	Duration*	Type of application	Target Life Stage
Exterior	Hull	140°F	10 seconds	High pressure spray[1]	Adult
	Trailer	140°F	70 seconds	Low pressure spray[2]	Adult
	PFDs, anchor, paddle	140°F	10 seconds	Low pressure spray	Adult or Veliger
Propulsion System	Gimbal	140°F	132 seconds	Low pressure spray	Adult
	Engine	140°F[4]	See Note	Flush	Veliger
Interior	Ballast tanks	120°F[4]	130 seconds	Low risk – Flush[3]	Veliger
				High risk– Fill and flush	
	Live well/Bait well	120°F	130 seconds	Low pressure spray or flush	Veliger
	Bilge	120°F	130 seconds	Flush or low pressure spray	Veliger

*the times listed are the minimum times necessary to achieve mortality
[1] High pressure = 3000 psi
[2] Low pressure = Using the pressure from the decontamination unit with no nozzle, essentially a garden hose flow
[3] Flush = Adding water to a compartment of a boat and forcing the water out
[4]These temperatures denote the exit temperature (i.e. temperature of water exiting the boat not exiting wand or flush attachment).
Note: Engine flushing relies on the exit temperature as a guideline for decontamination duration, see page 26.

to elapse from the leading edge of the spray to the tailing edge when moving the wand across the surface to maintain sufficient "lethal" contact time. If larger mussels are present, it may require more time to remove them from the surface than to kill them.

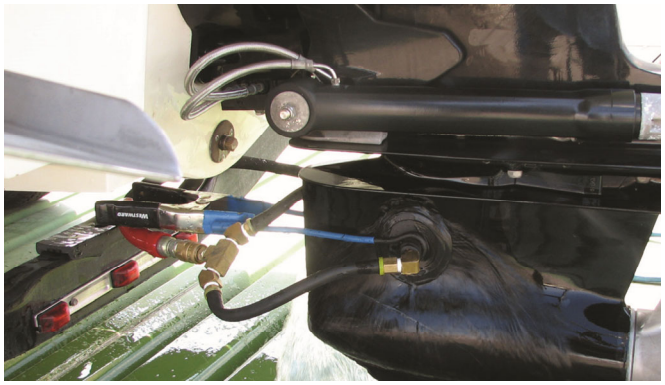
5. Use a power wash unit with 40 degree spray nozzle attachment to remove attached visible mussels from all exposed surfaces of the watercraft, piece of equipment, trailer and engine.

6. Use a flushing attachment to rinse all hard to reach areas and those areas where pressure may damage the watercraft or equipment (such as the rubber-boot in the gimbal area). A brush may also be used in conjunction with flushing to remove more mussels from hard to access areas.

Note: Power Wash Specifications
A power wash unit that can spray 5 gallons/minute with 3000 psi nozzle pressure are the recommended specifications. The 5 gallon/minute provides an adequate rate for cooling most watercraft engines. 3000 psi strikes a balance in effectively removing encrusted mussels and minimizing human hazards. Larger engines may require more gallons/minute to ensure a safe and effective flush. Specifications can be found in Appendix B.

7. When flushing hard to reach and sensitive areas, maintain a contact time of 130 seconds to assure that mussels receiving only indirect contact are killed since it may not be possible to remove them from these areas.

8. First drain and then use a flushing attachment and 120°F water to maintain contact time of 130 seconds to flush the live well, bait well, wet storage compartments, bilge areas, to kill any mussels and veligers that might be present. [Note: alternatively live/bait well, bilge areas can be filled with 120°F water and held for 130 seconds, and then drained. If the fill method is used, care must be taken in the bilge area to not flood the engine or reach the float valve which will expel water from the discharge port.]



9. To kill mussels in the engine cooling system, use appropriate attachment (e.g. fake-a-lake) connected to the pressure wash unit or other hot water source. Start the engine and make sure adequate water flow is provided to engine cooling system. Run ambient temperature water to allow the engine to warm up, and watch temperature gauge to ensure proper cooling is taking place. Engine manufacturers have preliminary recommendations that inlet water temperature is to be no greater than 140°F. Run the engine until exit temperature reaches 140°F to avoid possible damage to watercraft internal systems. Please refer to Special Considerations below for further information on engine cooling systems.

10. Some ballast system manufactures have indicated that their pumps or other electrical system components are designed for temperatures of no more than 120°F. For that reason, it is recommended to use a 3-4 foot hose extension from the end of the flushing attachment to the attachment to the system or component of the watercraft. The extension allows the water temperature to cool by an additional 15 to 20°F. To achieve 100% mortality, it is important to pump water into the area until the exiting water reaches a temperature of 120°F and for a minimum of 130 seconds. The water temperatures both entering and exiting the vessel need to have continual monitoring, not to exceed 120°F. [Note: ballast tank decontamination can be time consuming; it is recommended that this be undertaken at the beginning of the decontamination process].

11. Use a garden hose or diffuser attachment to treat personal flotation devices, anchor and lines, paddles, oars, water toys, boat fenders and other equipment that has been in the water by using low pressure 140°F water (or spraying if it will not damage the equipment) to kill any veligers or mussel present . Remember that equipment fouled with settled mussels will require more time to decontaminate.

12. All accessible surfaces of a trailer should be sprayed with 140°F water. Since trailers are normally out of the water, juvenile and adult mussel are not normally attached to any surfaces. However, mussels can be scraped off of watercraft and equipment during loading and become lodged on the trailer and should be removed with hot water spray. Be sure to drain and flush all hollow frame members. When carpeted bunks are present, do not use high pressure and flush for at least 70 seconds with 140°F water using a slow flush along the bunk that will allow the capillary action to pull enough hot water through the carpet to kill any veligers present. Any dislodged adult or juvenile mussels landing on the bunks will be killed by crushing action, so the boat does not need to be removed to access this area.

Note: Nozzle Head Configuration
Be sure to use a nozzle head that directs the water in a fan-like rather than a pinpoint spray. The shape of the spray as determined by the nozzle head used should be 2-3 inches wide and 8 inches out from the head to avoid any paint damage and allow a wider spray area of greater lethal contact time. Use a 40 degree flat fan spray nozzle and a 12-inch standoff to get the maximum coverage and to prevent damage to the vessel.

Note: Live Baitfish
If the use of live baitfish is permitted in your jurisdiction and they are found during inspection, remove the bait, place in a holding bucket, drain and flush the live bait container with 120°F water and then return the bait to the clean container. While this process does not assure that mussel veligers or even small settlers are not present on or in the fish, it is the best minimum standard for dealing with this situation. If the live or bait well uses a pump, make sure to check the owner's manual for maximum temperature to avoid damaging equipment.

WARNING: WATERCRAFT/ENGINE DAMAGE CAN OCCUR IF DECONTAMINATION PROTOCOLS ARE NOT CAREFULLY FOLLOWED. The most likely place where the decontamination process may cause damage to a watercraft or marine engine are during the cooling system flush where it is critical that engines are run at idle for a maximum of 130 seconds and that the engine flushing mount ("ear muffs") or "fake-a-lake" attachments are properly and securely sealed. **It is recommended to treat water in the pump areas with lower temperatures and longer exposure.** In the ballast tank flush it is critical that water temperature be reduced to avoid damage to the pumps. Please refer to the *Student Training Curriculum for Watercraft Inspectors and Decontaminators to Prevent and Contain the Spread of Aquatic Invasive Species* (Brown, 2015) for step by step procedures.

Quarantine or Drying Time: The use of quarantine or drying time can be used for a variety of situations. In its simplest form, drying is a technique for desiccating dreissenids or other invasive species to decrease their viability. Quarantine/drying is likely the most effective way to assure that live mussels are not transported between waterbodies on trailered watercraft or equipment (Morse 2009). The two primary situations where drying is utilized are 1) following watercraft decontamination of an infested conveyance, and 2) when decontamination is not possible.

The 100th Meridian Initiative's Drying Time Calculator is the recommended tool for determining the appropriate quarantine time. The Drying Time Calculator determines the length of quarantine or drying time needed to assure that a watercraft or piece of equipment is safe to launch (except when ballast tanks or other inaccessible raw water storage systems are involved). The amount of time required to achieve complete desiccation varies depending on temperature, relative humidity and size of the mussels, and can range from 1-30 days (McMahon, University of Texas at Arlington, personal communication). Further, the drying time may be less effective in some geographic locations with widely varying temperature or humidity compared to more uniform weather locations. Therefore, current conditions should be considered when utilizing the calculator.

In the case of a decontamination process, the manual application of hot water decontamination is not always 100% effective in removing all mussels from hidden areas found on some types of watercraft and/or equipment. Further, the survivability of attached mussels in some areas of watercraft is difficult to determine visually. Therefore, it is **recommended all watercraft and equipment with attached mussels are subject to a drying period sufficient to achieve complete desiccation after inspection, mechanical removal and hot water decontamination.** Further, drying time will not apply in the same way to watercraft with ballast tanks or other water storage areas that are not easily accessed for inspection or cannot be completely drained. If these areas maintain water, then the actual time required to achieve 100% mortality either through desiccation or anoxia will most likely exceed the drying time standards recommended (Choi et al., 2013).

If watercraft and/or equipment suspected of carrying quagga or zebra mussels cannot be decontaminated for any reason, then the watercraft must be held out of water for an appropriate period of time necessary to desiccate and kill all mussels and veligers on-board. This is often referred to as quarantine. Quarantine can be voluntary or mandatory in that a boater may have to leave their watercraft in dry storage on site, or may be required to keep it out of the water at home. The legal act of seizing the watercraft is considered impound and must be performed by law enforcement personnel. Both quarantine and impound have significant implications for liability and logistics. Program managers should fully explore legal and logistic options before conducting quarantine or impound operations.

The major concern with quarantine/drying alone is that it does not remove attached mussels.

If mussels remain on the vessel, they will eventually drop off. If that occurs at a boat ramp or beach, the presence of mussel shells can raise concern of a new infestation (either by someone finding a shell or via eDNA monitoring of the waterbody), triggering alarm and resulting in expensive and unnecessary action. In many states the possession of dead AIS is prohibited in addition to live AIS. For those reasons, it is recommended that all visible mussels be removed from quarantined/dried watercraft before they are allowed to launch.

Protocols:

1. Requiring quarantine or drying time should be applied to all watercraft following full decontamination on watercraft with adult mussels attached. It is also recommended in lieu of, or in addition to, decontamination for watercraft that have operated on or in any suspect, positive or infested waterbody in the last 30 days.

2. Implementation can take several forms:

    - Physical quarantine of a watercraft or piece of equipment requires providing a safe and secure holding area where it can be parked for the amount of time required to desiccate all mussels. A few agencies/organizations have used this option to take or over-see possession of suspect watercraft (with or without the owner's permission, depending on individual jurisdiction authority) until they remain out of the water long enough to be considered safe. Establishing and maintaining a dedicated quarantine facility can be expensive and comes with some potential liability issues.
    - When a quarantine facility is not available, then quarantine/drying time can be achieved by sealing (secured connection between watercraft and trailer) the watercraft or piece of equipment to the trailer or other means of transport. The operator is advised or required not to launch until the date indicated on the seal and/or an accompanying receipt.
    - The final option is simply to require that all high-risk watercraft serve a predetermined drying/waiting period prior to launch, or after exiting an infested, positive or suspect water (duration determined by risk level and current temperature and humidity conditions). Under this scenario, all high-risk watercraft are prohibited from launching in a new water until the required drying time has passed, as determined by the inspection.

3. All visible mussels should be removed from watercraft or equipment following quarantine or drying period before being allowed to launch.

Note: "Hidden" Mussels

The standard is to remove all visible mussels; however, it may not be possible to remove all attached mussels from every area of the watercraft/equipment. A day or two following decontamination, it is not unusual for mussels to appear as byssal threads begin to decompose. If properly treated, these mussels are dead and in the process of decay. In addition there are some areas of a watercraft or piece of equipment that cannot be easily accessed to remove dead mussels. Brushes may be used in conjunction with flushing in some of these areas to increase the effectiveness of mussel removal.

Standards:

1. To determine the appropriate drying time refer to the Drying Time Calculator

2. Watercraft with ballast or other internal

water storage tanks that cannot be completely drained should be treated differently with regard to drying time. NOTE: Because of the difficulties of removing residual water of ballast tanks, it is recommended to utilize decontamination with hot water. If hot water decontamination is not possible an extended drying time will be required to kill veligers. Research suggests that veligers can survive 27 days in residual water of compartments (Choi et al., 2013). Variation in ballast tanks drainage capabilities will influence the length of time required to dry.

Watercraft/Equipment Exclusion: High-risk watercraft that is not decontaminated and/or quarantined should be excluded and not allowed to launch. Exclusion can be the result of vessel operator refusal to submit to an inspection, lack of available equipment or trained applicators, traffic or facilities.

Exclusion will vary based on state regulation or local authority. The use of exclusion should not be a long-term substitute for development of a more user-friendly and proactive inspection program that recognizes the value of recreational boating to the economy and the legitimate interests and enjoyment of the boating public.

The case for using exclusion as a prevention strategy has diminished as agencies and organizations have been able to develop public policy, establish regulations, budget for equipment and manpower, train staff and purchase equipment needed for more proactive and considerate approaches.

Protocols:

1. Watercraft and equipment that have not been or cannot be inspected, decontaminated or meet the quarantine/drying time standard are excluded from launching.

2. The information obtained from the screening interview used to determine risk level should be shared with the watercraft owner/operator and made available on a real-time basis at all access points to prevent excluded watercraft/equipment from attempting to launch from any other point of access on the same waterbody.

Standards:

1. Watercraft or equipment that were last used in infested, positive or suspect dreissenid mussel areas within the past 30 days and have not been decontaminated and/or been out of the water for the required time (determined by the Drying Time Calculator) should be:

   - decontaminated if appropriate facilities are available or
   - placed in quarantine for the required time frame or
   - excluded

2. Watercraft that are not clean (attached vegetation, debris or surface deposits that can mask the presence of small mussels), drained (having visible water in any live well, bait well, bilge area, engine compartment, floor or cooler) and dry (not been out of the water long enough for attached mussels to desiccate) should be decontaminated and/or quarantined or excluded.