Supplemental Documents

Submitted to: Burnett County Natural Resource Committee

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Date: 12/3/2025

Introduction

Engine cooling systems and ballast tanks retain residual water that enables zebra mussel survival and transport. Thermal decontamination eliminates these organisms when appropriate internal temperatures are reached. The included documents summarize the biological risk, confirmation that 120°F water effectively and safely decontaminates engine cooling pathways, and a feasible 109°F protocol for ballast tanks that meets public time-limit constraints.

Document Order

1. Zebra Mussel Attachment in Boat Motor Cooling System Pathways
2. Empirical, Institutional, and Safety Validation of 120°F Decontamination
3. Evaluation of 120°F Water Use for Engine Cooling-System Decontamination
4. 109°F Internal Ballast-Tank Lethality Feasibility Under Publicly-Acceptable Time Limits

Zebra Mussel Attachment in Boat Motor Cooling System Pathways

Zebra mussels are documented to enter, attach to, and proliferate within the internal cooling pathways of boat motors. These organisms can be drawn into engines via water intake systems. Once inside, veligers settle and mature on internal surfaces of metallic and polymeric components. The byssal thread attachment mechanism allows adults to form dense aggregates inside hoses, strainers, intake manifolds and heat exchangers, which reduces flow, causes overheating, and may lead to engine failure[1].

Multiple government and inter-agency assessments consistently identify motor cooling systems as a primary vector for mussel translocation across water bodies. One survey of residual-water in recreational boat motors empirically verified the presence of veligers within sterndrive and outboard cooling passages, confirming that larvae can persist in engine cooling systems under typical post-use conditions.[5] These pathways are recognized as high-risk compartments, requiring targeted decontamination and inspection protocols[2,3]. The persistent presence of mature mussels in such compartments also complicates physical removal and increases maintenance costs.

Technical guidelines for watercraft decontamination explicitly list engine cooling systems among the compartments requiring flushing, drying, or chemical treatment before trailering to new waters[4]. The cumulative evidence supports the conclusion that zebra mussels not only survive transit through coolant pathways, but can establish viable populations inside these confined engine systems, thereby serving as a vector for aquatic invasive spread.

Citations

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Empirical, Institutional, and Safety Validation of 120°F Decontamination

Empirical Evidence Demonstrating 120°F Lethality to Zebra Mussels

A peer-reviewed Wisconsin study, Acute Upper Thermal Limits of Three Aquatic Invasive Invertebrates: Hot Water Treatment to Prevent Upstream Transport of Invasive Species (Environmental Management, 2011), provides the most regionally relevant dataset for assessing thermal decontamination efficacy[1]. The research, cited 34 times in subsequent literature, tested specimens collected from Wisconsin waters under controlled immersion treatments from 32°C (89.6°F) to 54°C (129.2°F).

Adult zebra mussels (Dreissena polymorpha) reached 100% mortality after 5 minutes at 43°C (109°F), while exposure to 49°C (120°F) achieved complete mortality within 1 minute[1]. The spiny water flea (Bythotrephes longimanus) showed a similar threshold—total mortality at 49°C within 1 minute. Considering that these findings were obtained under controlled laboratory conditions, a 2-minute field application at 120°F offers an added margin to account for natural variation in water temperature, system geometry, and flow dynamics. This duration reasonably ensures that thermal exposure throughout the engine pathway remains within the lethal range demonstrated in the study, making 120°F for 2 minutes a practical and evidence-supported approach for reliable decontamination.

This dataset forms a direct scientific foundation for adopting 120°F as the operational decontamination temperature: empirically lethal, rapidly effective, and regionally validated.

Authoritative Protocols Already Use 120°F for Engine-Path Decontamination

Multiple government agencies and state programs have formalized 120°F hot-water decontamination procedures, confirming both efficacy and safety across operational contexts.

The Minnesota DNR Watercraft Decontamination Handbook specifies engine flushing at 120°F for 2 minutes, capped at 140°F[2]. The Minnesota Pollution Control Agency's SOP for water-quality monitoring requires a hot-water source capable of 120–140°F, prescribing 2 minutes at 120°F or 10 seconds at 140°F for decontaminating field equipment[3].

At the federal level, the Aquatic Nuisance Species Task Force's Voluntary Guidelines to Prevent the Introduction and Spread of Aquatic Invasive Species: Recreational Activities directs boaters to flush motors with hot water (120°F) for 2 minutes[4]. The U.S. Forest Service's Guide to Preventing Aquatic Invasive Species Transport by Wildland Fire Operations (PMS 444) further codifies hot-water immersion ≥120°F (50°C) for 1 minute to kill both adult and larval quagga/zebra mussels[5].

These existing standards demonstrate unified agreement among state and federal agencies that 120°F water is a proven, lethal, and operationally safe decontamination temperature.

120°F Provides Equivalent Effectiveness with Substantially Higher Personnel Safety

Thermal injury data establish a clear non-linear rise in burn severity between 120°F and 140°F, even though both temperatures kill zebra mussels. Selecting 120°F for operational use preserves biological lethality while significantly reducing risk to operators and inspectors who handle hoses and control outlets during decontamination.

According to the U.S. Consumer Product Safety Commission, exposure to 120°F water causes third-degree burns after approximately 5 minutes, while 140°F water causes the same injury in about 5 seconds[6]. The American Burn Association cites similar findings, emphasizing that 120°F water can be tolerated long enough for reaction and withdrawal, but 140°F contact produces immediate deep tissue damage[7]. Shields et al. (2013) confirmed these data, reporting that 140°F water caused severe scald burns within 3 seconds[8].

Because this procedure involves engine decontamination with motor muffs or a fake-a-lake, incidental contact with running or splashing water is unavoidable. Operators often work in confined positions beneath the transom—frequently on their backs—while aligning and securing the fake-a-lake. Under these conditions, exposure to discharge or spray at 140°F presents an immediate burn hazard. These factors make 140°F unsuitable for open handling during field decontamination, where direct splash and hose contact cannot be fully controlled. Using 120°F provides a substantially safer margin for staff performing low-clearance or ground-level tasks while still maintaining complete mussel lethality within the demonstrated 2-minute exposure period, reducing both injury risk and liability

Conclusion

Empirical laboratory evidence, government practice, and occupational safety data converge:

- **Lethality**: 120°F achieves immediate 100% mortality in zebra mussels and spiny water fleas.
- **Precedent**: 120°F is already the decontamination standard for multiple state and federal programs.
- **Safety**: 120°F minimizes burn and scald risk while maintaining the same biological effectiveness achieved by 140°F treatments.

Adopting a 120°F, 2-minute engine-flush protocol aligns Burnett County practice with both scientific data and established inter-agency standards, while ensuring worker safety and equipment longevity.

Citations

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Evaluation of 120°F Water Use for Engine Cooling-System Decontamination

Material Tolerance and Institutional Validation of 120°F Engine Decontamination

Marine engine raw-water cooling systems are built from materials and components rated for continuous operation well above 120°F. This temperature has also been validated through years of use in government-sanctioned aquatic-invasive-species decontamination programs. Together, the engineering and institutional evidence demonstrate that flushing engines with 120°F water is both materially safe and operationally proven.

Material Tolerance and Manufacturer Specifications

Marine cooling systems rely on elastomeric impellers, gaskets, and seals engineered to withstand high thermal stress. Johnson Pump lists neoprene, EPDM, and nitrile impeller ranges of +3°C to +65°C (≈ 37°F to 149°F), with only reduced life at extremes[1]. Jabsco specifies neoprene 45°F to 160°F and nitrile to 180°F[2]. Xylem defines continuous service between 45°F and 180°F[3]. Run-Dry® comparison data show standard neoprene fails sooner than the upgraded compound at elevated temperatures[4].

Rubber & Seal identify temperature range as the core selection factor for impeller elastomers[5]. Parker lists EPDM stable to 150°C (302°F) and up to 180°C (356°F) in water and steam, with neoprene rated to ≈ 100–120°C (212–248°F)[6]. Marco Rubber confirms EPDM (–65°F to 300°F), NBR (–35°F to 250°F), and neoprene (–35°F to 250°F)[7]. Timco Rubber documents EPDM ≤ 350°F, neoprene ≤ 250°F, nitrile ≤ 250°F, and natural rubber ≤ 175°F[8]. DuPont's Viton™ data extend FKM elasticity to ≈ 399°F, intermittent 601°F[9]. All exceed 120°F by large safety margins.

These specifications confirm that common impeller and gasket materials used in marine engines operate safely at or above 120°F, establishing clear design tolerance for the decontamination temperature.

Government Decontamination Protocols Validate 120°F Engine Flushing

Public-sector decontamination programs across multiple jurisdictions use hot-water engine flushing as a primary method to eliminate zebra and quagga mussels.

The Minnesota DNR prescribes running engines until discharge water reaches 120°F for two minutes, capped at 140°F[10]. The Western Regional Panel requires discharge water at 140°F for ten seconds[11]. Connecticut DEEP instructs running the engine 1–2 minutes with hot water flow through the cooling system—no temperature limit specific to engines[12]. The Invasive Mussel Collaborative lists "motor flushing ≥ 140°F for 10 seconds" as a standard method[13]. Massachusetts DEP directs operators to run engines until exit water reaches 140°F, not exceeding that inlet temperature[14]. New York DEC recommends flushing motors with ≥ 140°F water while verifying manufacturer specifications[15]. The U.S. Army Corps of Engineers notes that water > 110°F kills larvae and > 140°F kills adults when flushing engine cooling systems[16].

Across all agencies, no documentation warns of engine damage from these temperatures; most limit water temperature only to prevent exceeding 140°F. Since 140°F operation is standard practice without reported adverse effects, 120°F flushing is demonstrably within safe limits and maintains biological effectiveness.

Conclusion

Elastomeric materials in marine cooling pathways tolerate sustained exposure far beyond 120°F. Government agencies have successfully implemented decontamination programs at 120–140°F for years with no record of equipment failure in their operational procedure manuals. Combining these two independent bodies of evidence establishes that 120°F engine flushing for decontamination is scientifically and operationally validated as safe.

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109°F Internal Ballast-Tank Lethality Feasibility Under Publicly-Acceptable Time Limits

Ballast-tank decontamination imposes specific thermal and operational constraints. Tanks hold large volumes, retain substantial residual water, and cannot be manually purged by inspectors. Any temperature-based protocol must therefore achieve the required internal lethality threshold while operating within time limits that the public will comply with and that volunteer based decontamination stations can realistically execute.

It must also be acknowledged that achieving an in-tank temperature of 120°F is mechanically impossible unless either (1) no residual water remains, or (2) the entire ballast tank is completely filled and displaced with 120°F water. Any protocol that injects 120°F water into a tank containing cold residual volume will necessarily equilibrate to a lower mixed temperature, which is why the internal lethality target must be based on the achievable post-mix equilibrium rather than the injection temperature itself.

A temperature target of 109°F meets that requirement because it represents the lowest experimentally confirmed lethal breakpoint for zebra mussels under short-duration exposures, with Beyer et al.[1] demonstrating mortality thresholds in the 5–15 minute range that align with the operational time limits imposed on real-world decontamination stations.

Documented Agency Temperature Ceilings

State and interagency decontamination standards set explicit upper temperature boundaries for ballast-system components. The Minnesota Department of Natural Resources specifies that ballast-tank decontamination must not exceed 120°F due to the thermal limits of pumps and internal electrical assemblies[3]. The Uniform Minimum Protocols and Standards (UMPS-III) likewise report that ballast-system manufacturers identify 120°F as the maximum safe operating temperature for pumps and electrical components, requiring continuous monitoring to ensure temperatures do not exceed this threshold[4].

Residual Water Volume Constraint

Wake-boat ballast tanks retain non-trivial volumes after draining. Campbell et al. measured residual quantities across multiple vessels, identifying a maximum retained volume of ≈22.9 gal (86.8 L) even after operator-drain procedures[2]. This establishes the upper bound of ambient temperature water that any decontamination protocol must thermally overcome.

Thermal-Mixing Feasibility at 120°F Injection Temperature

A 15-minute fill at 5.5 gpm delivers 82.5 gal of 120°F water. Applying the thermal-equilibrium equation:

$$T_f = \frac{V_1T_1 + V_2T_2}{V_1 + V_2}$$

82.5 gal × 120°F mixed with 22.9 gal × 70°F yields ≈109°F. This meets the empirically observed lethal threshold from Beyer et al.[1] Even under worst-case residual conditions, the tank interior reaches the required thermal endpoint. Residual water temperature of 70°F is a seasonally realistic value for retained ballast water in Wisconsin. The 10-minute static hold allows internal conduction to equalize temperature throughout internal structures.

Ballast-Tank Volume and Fill-Rate Analysis

Typical ballast tanks hold 100–150 gal, with certain wake-surf models exceeding 250 gal per tank. Full-volume thermal displacement scales directly with flow rate. Counties must plan for both high-capacity and low-capacity systems.

High-Capacity System (5.5 gpm at 120°F)

- 82.5 gal: 15 min per tank. 45 min total
- 100 gal: 18.2 min per tank. 55 min total
- 150 gal: 27.3 min per tank. 82 min total
- 250 gal: 45.5 min per tank: 136 min total

Low-Capacity System (2.75 gpm at 120°F)

- 82.5 gal: 30 min per tank. 90 min total
- 100 gal: 36.4 min per tank. 109 min total
- 150 gal: 54.5 min per tank. 164 min total
- 250 gal: 90.9 min per tank. 273 min total

Time-Limit Constraint for Public Compliance

Decontamination ordinances must be enforceable. Multi-hour procedures will not be followed by the public and cannot be carried out by intermittent volunteer staffing.

Decontamination equipment must also remain available to service additional watercraft. Multi-hour thermal-fill requirements immobilize the station and prevent any throughput. Any ordinance that forces equipment to remain occupied for extended single-boat treatments eliminates the station's functional role and makes county-level implementation unworkable.

Operational Conclusion

The following ballast-tank decontamination method satisfies biological lethality, thermal feasibility, and public adherence.

• Inject 82.5 gallons of 120°F water
• Hold 10 minutes
• Target internal temperature: ≥109°F

This protocol heats the maximum documented residual volume to the empirically verified lethal threshold, fits within mandatory operational time limits, and avoids multi-hour fill times.

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