

Watercraft Pressure Wash: How High is High?

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Invasive Species

Invasive species and anthropogenically induced climate change are now considered as the top two threats to our planet's biodiversity

(Vitousek et al. 1997 Science 277: 494-499;

Halpern et al. 2008 Science 319: 948-952)

Invasive Species Introduction

- Most invasive species introductions are **accidental** consequences of the global distribution networks that facilitate international commerce. New species invade new territory attached to the hulls of ships; as stowaways in wooden crates or packing materials; hidden inside unprocessed logs, fruits, or seeds; by aircrafts; **most common of all, swimming in the ballast water discharged by ships entering ports**

AIS Spread to Inland Waters

- The spread of AIS to the inland water bodies of North America is most likely be attributed to the **unintentional overland transport of trailered boats** contaminated with the invasive organisms into an uninfested body of water (Bossenbroek et al. 2001; Johnson et al. 2001; Leung et al. 2006).



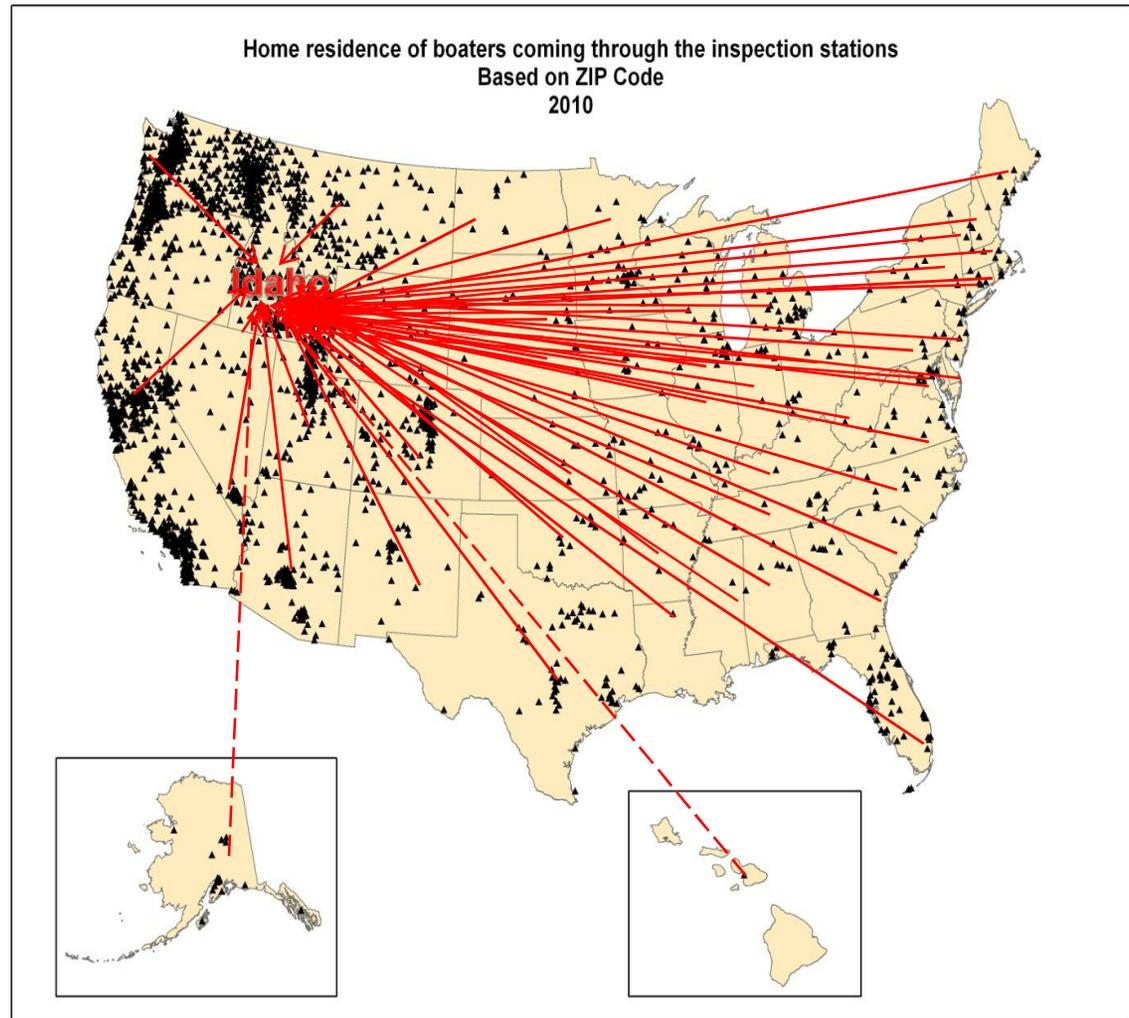
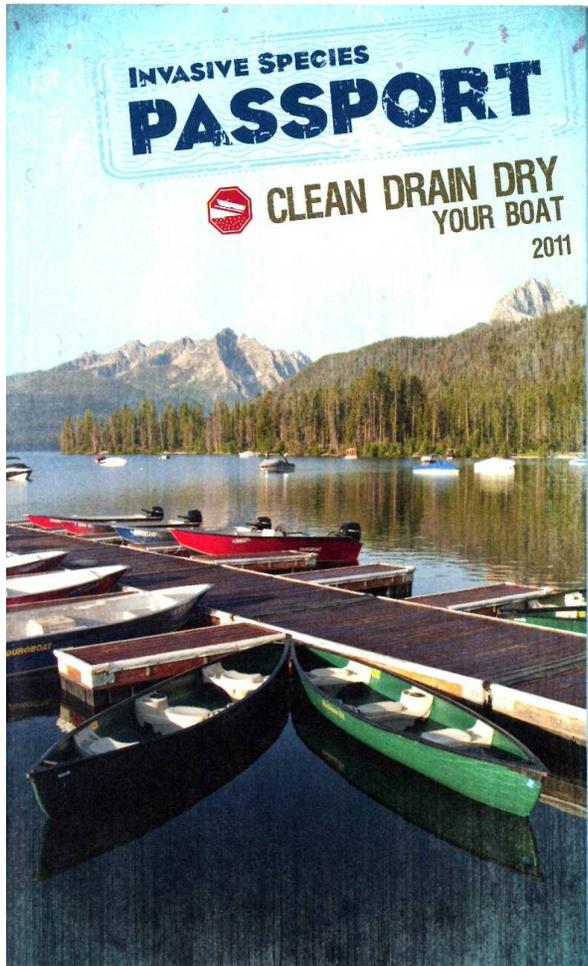
Photos by David Wong and MNDNR

AIS Spread to Inland Waters

Table 3. Aquatic and terrestrial taxa collected in filters during the field survey. Taxa are identified variously to order, family, or genus.

Category	Order	Suborder	Family	Genus	Instar	Common Name	Total number collected from 85 boats washed (estimated from sub-samples)	
Aquatic (Miscellaneous)	Amphipoda				Adult	Amphipod	209	
	Isopoda				Adult	Isopod	3	
	Oligochaeta				Adult	Freshwater segmented worm	3	
	Ostracoda				Adult	Ostracod	3	
	Prostigmata				Adult	Water mite	206	
Aquatic insect larvae	Diptera		Tipulidae		Larval	Cranefly	56	
	Diptera		Chironomidae		Larval	Midge	740	
	Diptera		Cuculidae		Larval	Mosquito	1	
	Ephemeroptera		Baetidae		Larval	Baetid mayfly	18	
	Ephemeroptera				Larval	Other mayfly	65	
	Odonata	Zygoptera			Larval	Damselfly	18	
	Odonata	Anisoptera			Larval	Dragonfly	89	
	Trichoptera		Hydropsychidae		Larval	Caseless caddisfly	24	
	Trichoptera		Leptoceridae		Larval	Leptocerid caddisfly	18	
	Trichoptera				Larval	Other caddisfly	50	
Aquatic mollusks	Mesogastropoda		Viviparidae	Campelema	Adult	Campeleomid snail	191	
	Pulmonata		Planorbidae		Adult	Planorbid snail	18	
	Pulmonata		Physidae	Physa	Adult	Physid snail	228	
	Sorbeoconcha		Hydrobiidae	Amnicola	Adult	Amnicola snail	314	
Zooplankton	Calanoida				Adult	Calanoid copepod	6	
	Cladocera		Bosminidae	Bosmina	Adult	Waterflea	27	
	Cladocera		Daphniidae	Daphnia	Adult	Waterflea	12	
	Cladocera		Sididae	Diaphanasoma	Adult	Waterflea	27	
	Cladocera				Adult	Waterflea	1	
	Cyclopoida				Adult	Cyclopoid copepod	6	
	Phylum: Rotifera				Adult	Rotifer	6	
	Subclass: Copepoda				Larval	Copepod nauplius	3	
	Subclass: Copepoda				Adult	Copepod	6	
	Terrestrial (Miscellaneous)	Araneae				Adult	Spider	205
Coleoptera					Adult	Beetle	53	
Coleoptera					Larval	Beetle	62	
Collembola					Adult	Springtail	51	
Diptera					Adult	Other dipteran	153	
Diptera			Drosophilidae	Drosophila	Adult	Fruit fly	6	
Diptera			Ceratopogonidae		Adult	Gnat	285	
Diptera			Muscidae		Adult	Housefly	123	
Diptera			Chironomidae		Adult	Midge	695	
Diptera			Cuculidae		Adult	Mosquito	458	
Diptera			Ichneumonidae		Adult	Ichneumonid wasp	200	
Ephemeroptera					Adult	Mayfly	3	
Homoptera			Aphididae		Adult	Aphid	6	
Homoptera			Cicadellidae		Adult	Leafhopper	17	
Homoptera					Adult	True Bug	14	
Hymenoptera			Formicidae		Adult	Flying ant	117	
Hymenoptera			Formicidae		Adult	Ant	342	
Hymenoptera			Halictidae		Adult	Sweat bee	6	
Isodida					Adult	Tick	294	
Lepidoptera					Larval	Caterpillar	3	
Trichoptera					Adult	Caddisfly	9	
Terrestrial seeds		Fagales		Betuleaceae	Betula	Seed	Birch tree seed	2,931
		Rosales		Ulmaceae	Ulmus	Seed	Elm tree seed	3,596

Boat Inspection and Decontamination



Idaho' boat inspection and decontamination program (Ferriter and Anderson 2015)



Boat Decontamination Methods

- **Chemical Decontamination**
- **Physical Removal**
- **Desiccation**
- **Freezing**
- **Heat (regarded by most authorities as the most effective and easy to use of the control methods)**

Hot Water Spray: Temperature & Time



Hot Water Spray: Temperature & Time

Temperature	Quagga Mussel	Zebra Mussel
68oF	No Mortality	No Mortality
104oF	40 S	40 S
122oF	20 S	40 S
130oF	10 S	10 S
140oF	5 S	10 S
158oF	5 S	5 S
176oF	5 S	5 S

Boat Decontamination Methods

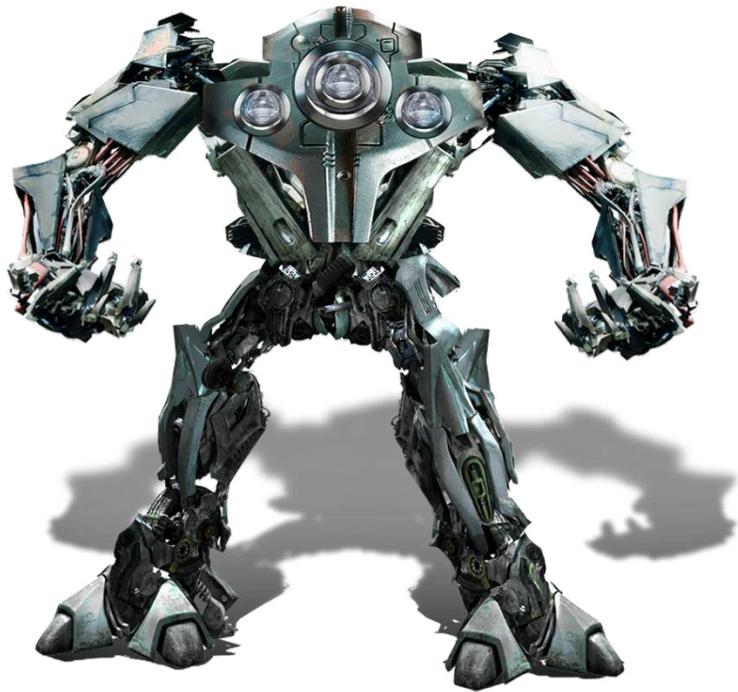
- Dry Ice (Solid CO₂)



Boat Decontamination Methods



I Robot







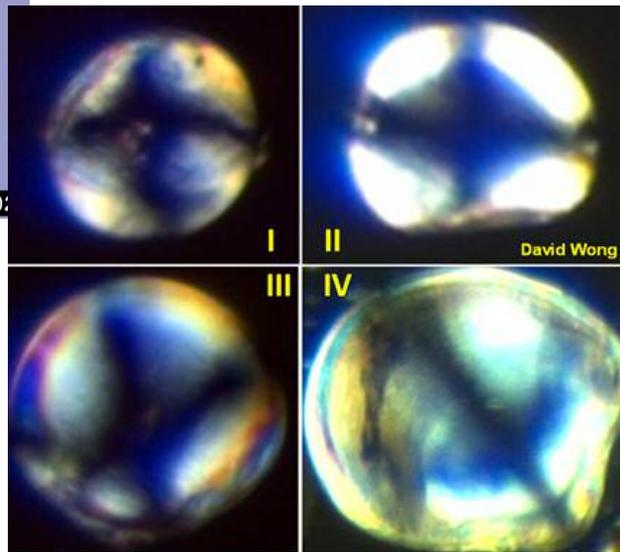
Why CLEAN?

- Make sure no spread to an AIS-free waterbody
- Alive/Dead Organisms or Residuals
- Early Detection: EDNA can still recognize even it is dead or just piece of the organism; It will provide confusing results

Clean: Physical Removal



Aquatic Plant Seeds and Microorganisms



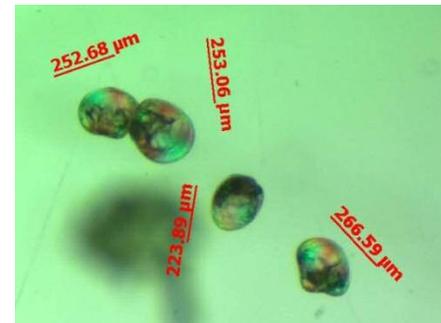
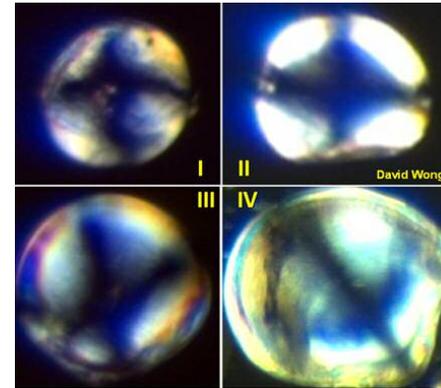
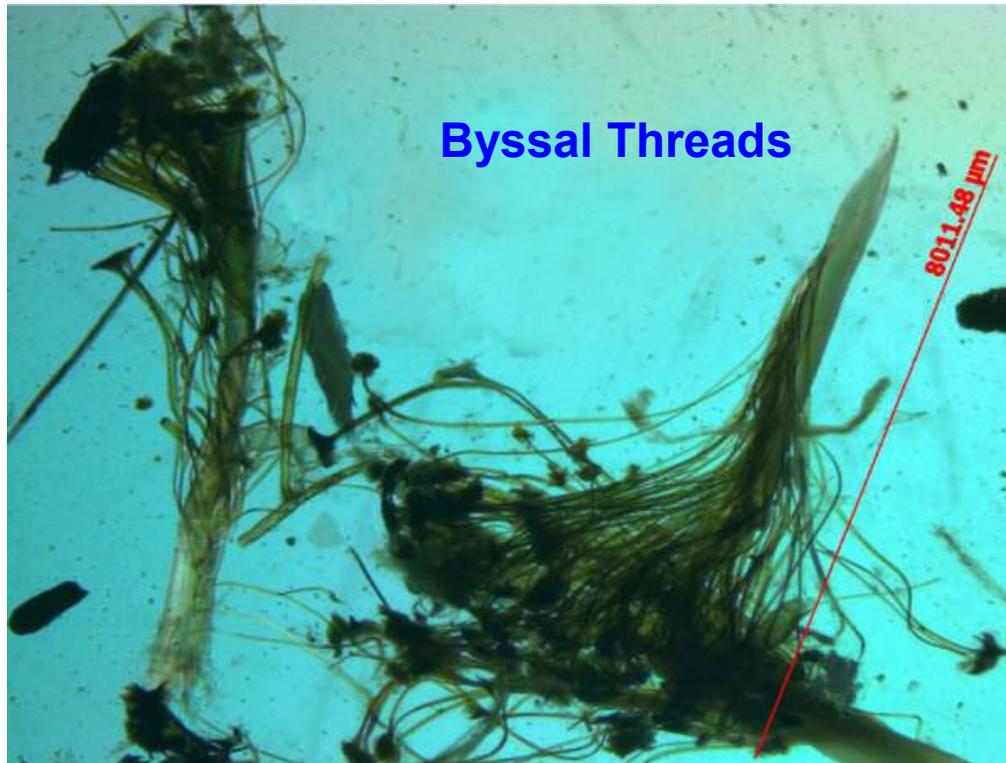
Clean: Pressure Wash



Clean: Pressure Wash



Dreissenid Life Cycle







Objectives

1. How high pressure is needed in order to effectively remove 100% of dreissenids from a watercraft using high pressure spray in winter and summer?
2. What is the minimum amount of time required to remove 100% of dreissenids using pressurized water spray from an encrusted watercraft in winter and summer seasons?
3. If a watercraft has been stored out of the water for a while, will it be easier to remove attached dreissenid mussels compared to being fresh out of the water?

Methods

- 3000 PSI
- 1500 PSI
- 1100 PSI



LANDA
Pressure Washer

Methods



Bayliner /sunken boat lift/ Canoe pieces encrusted with mussels

Methods—Experimental Design

- **Mussels were divided into 24 treatment groups (N=2040)**
 - **2 pressures (1500 and 3000 psi) x 2 densities (high and low) x 6 replicates**
 - High density: ~23,220-46,440 mussels/m² (~75-150 individuals)
 - Low density: ~7,772-10,363 mussels/m² (~15-20 individuals)

Mussel Density	1500 psi	3000 psi
High	6 replicates	6 replicates
Low	6 replicates	6 replicates

Results

Species	Season	Pressure	Week out of Water	Density	Second	N
Zebra	summer	1100	0	27,020	197	30
Zebra	summer	1500	0	3,665	256	12
Zebra	summer	3000	0	4,668	42	12
Quagga	summer	1500	0	6,578	233	12
Quagga	summer	3000	0	7,686	45	12
Quagga	winter	1500	0	8,956	319	12
Quagga	winter	3000	0	8,341	274	12

Results

Species	Season	Pressure	Week out of Water	Density	Second	N
Zebra	summer	1500	1	4,976	14	12
Zebra	summer	3000	1	4,466	5	12
Quagga	summer	1500	1	6,998	12	12
Quagga	summer	3000	1	8,811	6	12
Quagga	winter	1500	2	10,785	21	12
Quagga	winter	3000	2	10,485	4	12
Quagga	winter	1500	4	6,982	10	12
Quagga	winter	3000	4	7,039	1	12

Findings of the Study I: Pressure

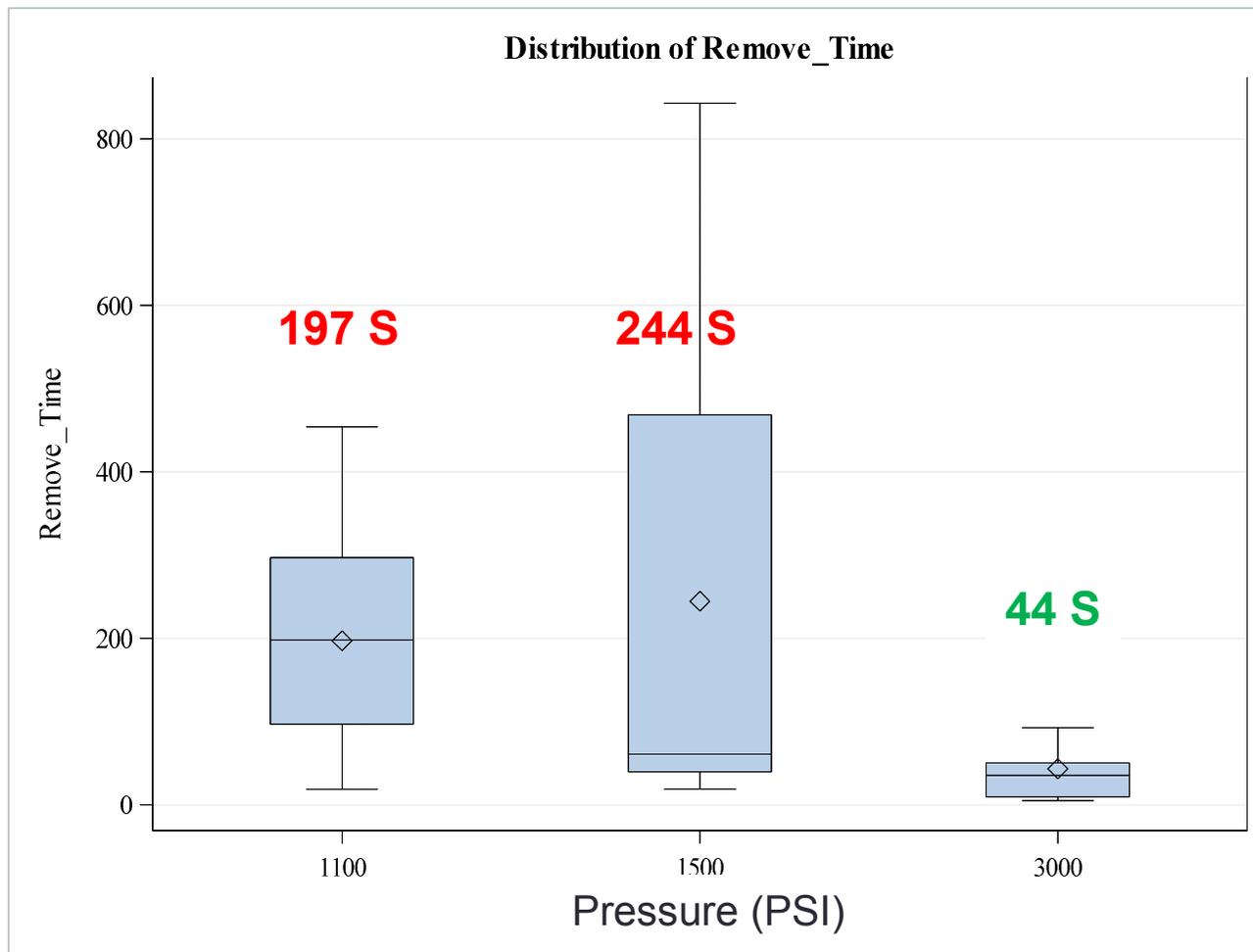
- Analysis of Covariance (Summer Tests):

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	717535.367	239178.456	8.50	<.0001
Error	74	2081731.855	28131.512		
Corrected Total	77	2799267.222			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Species	1	21842.5778	21842.5778	0.78	0.3811
Density	1	440114.7923	440114.7923	15.64	0.0002
Pressure	1	255577.9964	255577.9964	9.09	0.0035

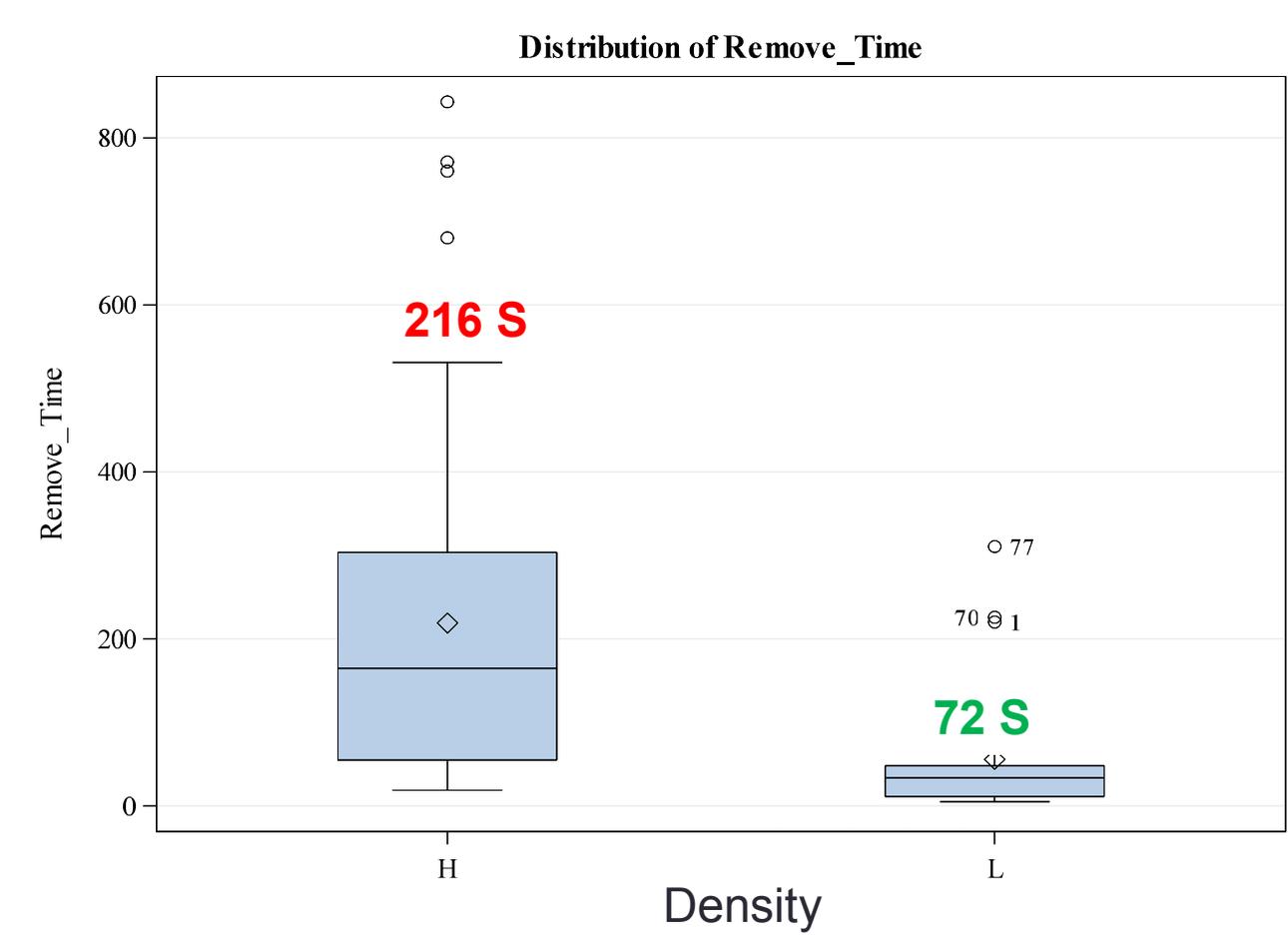
Findings of the Study I: Pressure

- Analysis of Variance (Summer Tests):



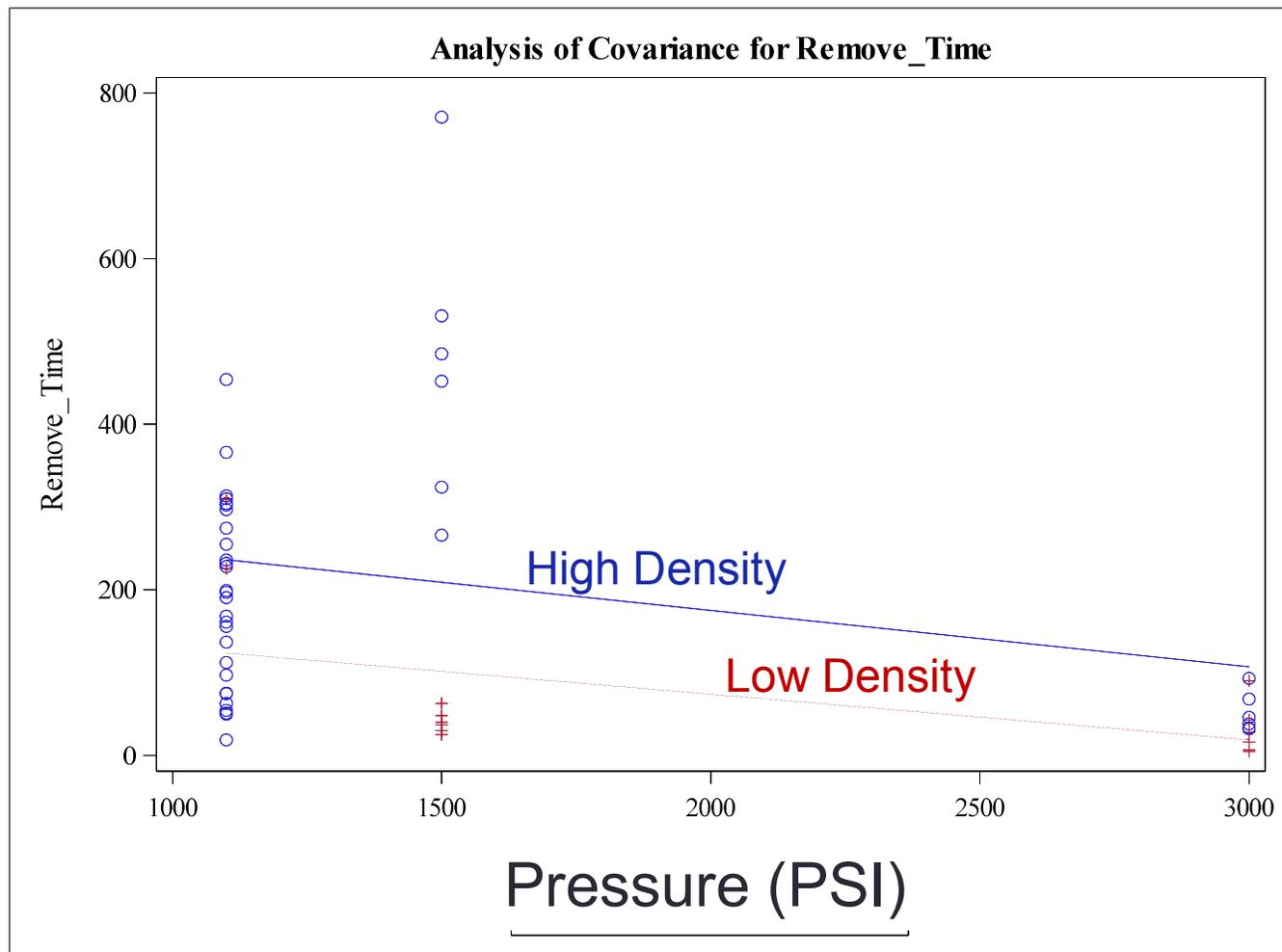
Findings of the Study I: Density

- Analysis of Variance (Summer Tests):



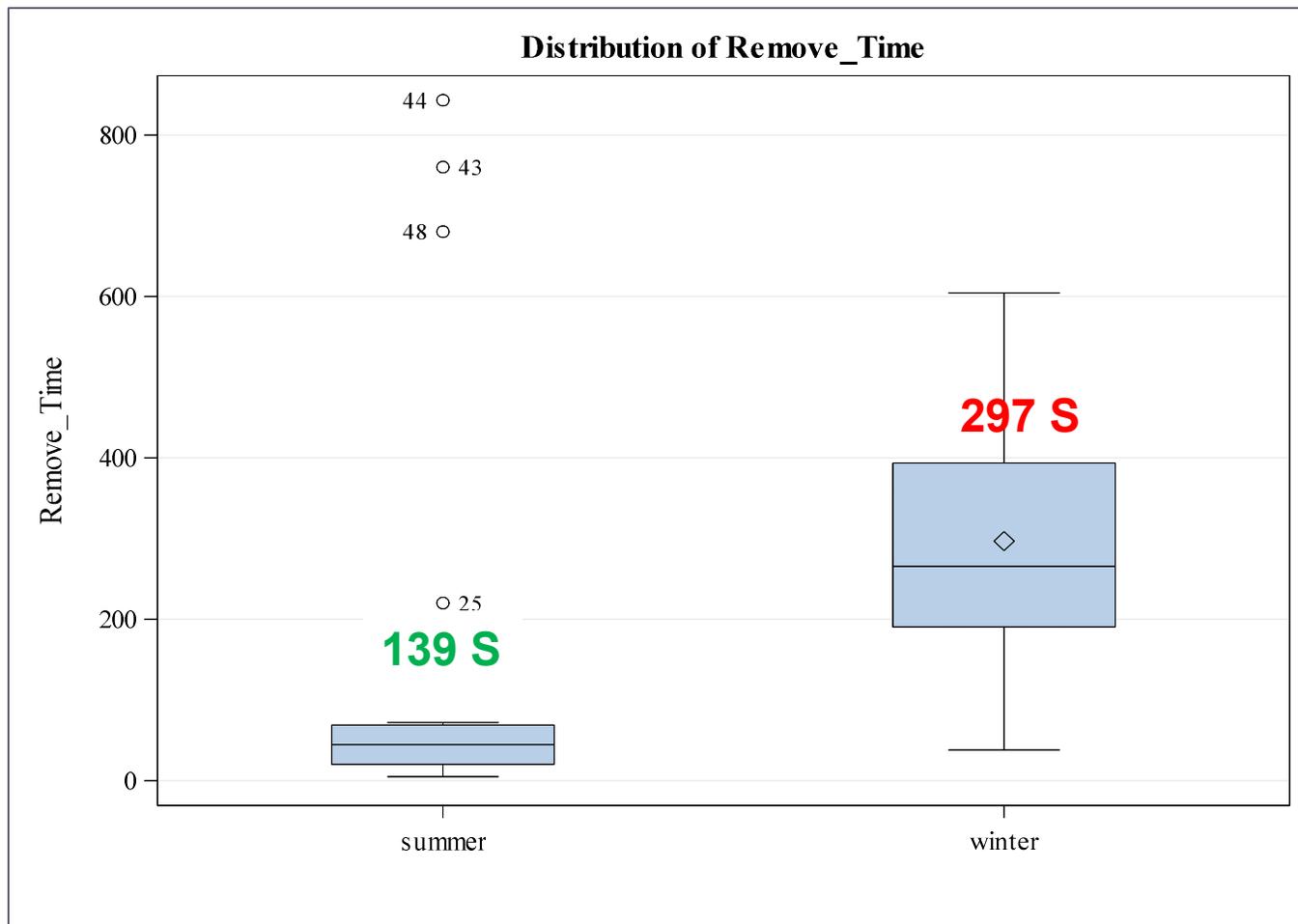
Findings of the Study I: Pressure & Density

- **Analysis of Covariance (Summer Tests on Zebra Mussels Only):**



Findings of the Study II: Season

- Analysis of covariance on Quagga Mussels (Summer vs. Winter)



Findings of the Study III: Time out of water

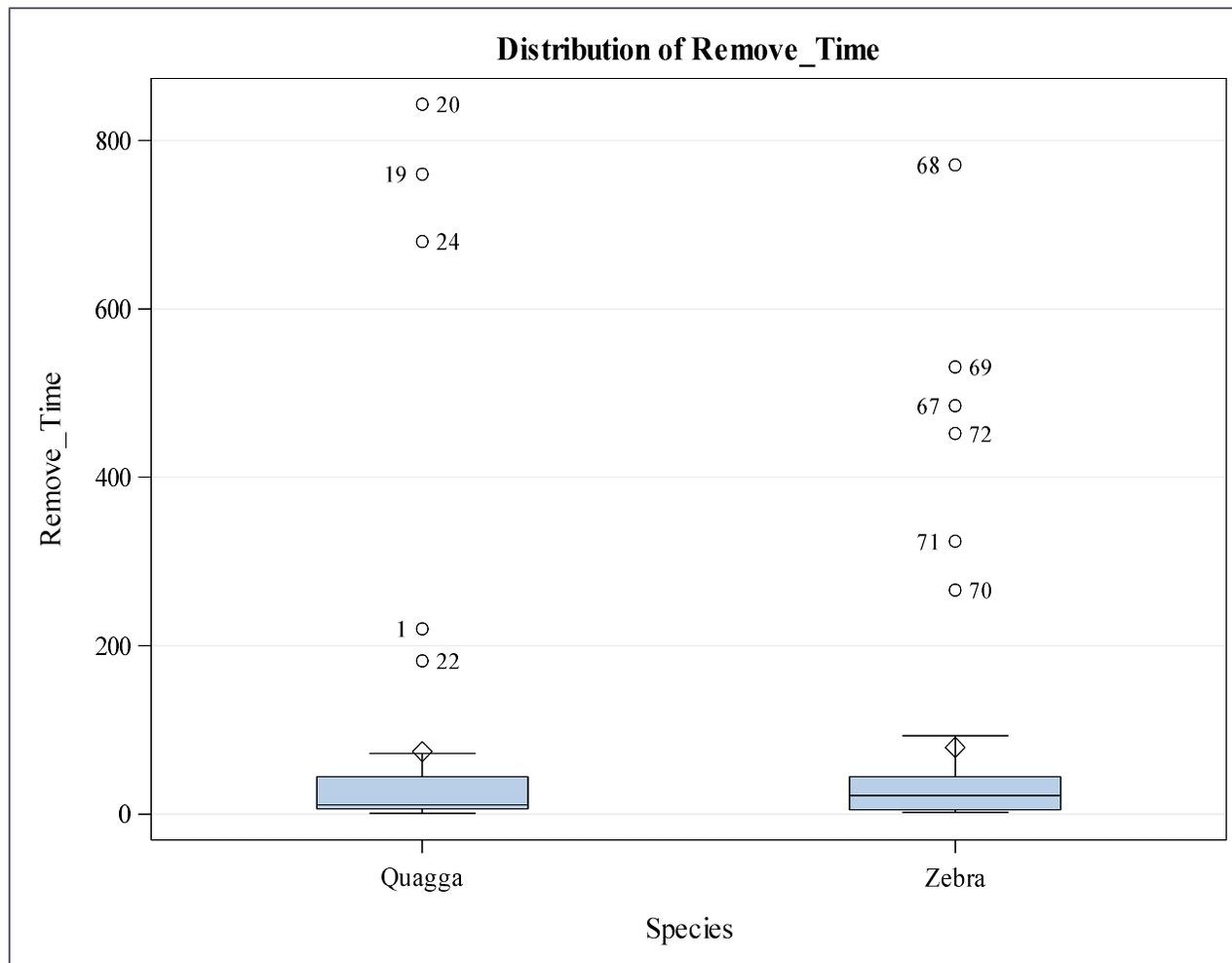
- Analysis of covariance (Summer: 0 and 1 week):

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	966549.125	241637.281	11.74	<.0001
Error	91	1872204.281	20573.673		
Corrected Total	95	2838753.406			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Species	1	615.0938	615.0938	0.03	0.8631
Density	1	269558.0104	269558.0104	13.10	0.0005
Time out of water	1	435646.7604	435646.7604	21.17	<.0001
Pressure	1	260729.2604	260729.2604	12.67	0.0006

Findings of the Study III: Time out of water

- Analysis of covariance (Summer: 0 and 1 week):



Findings of the Study III: Time out of water

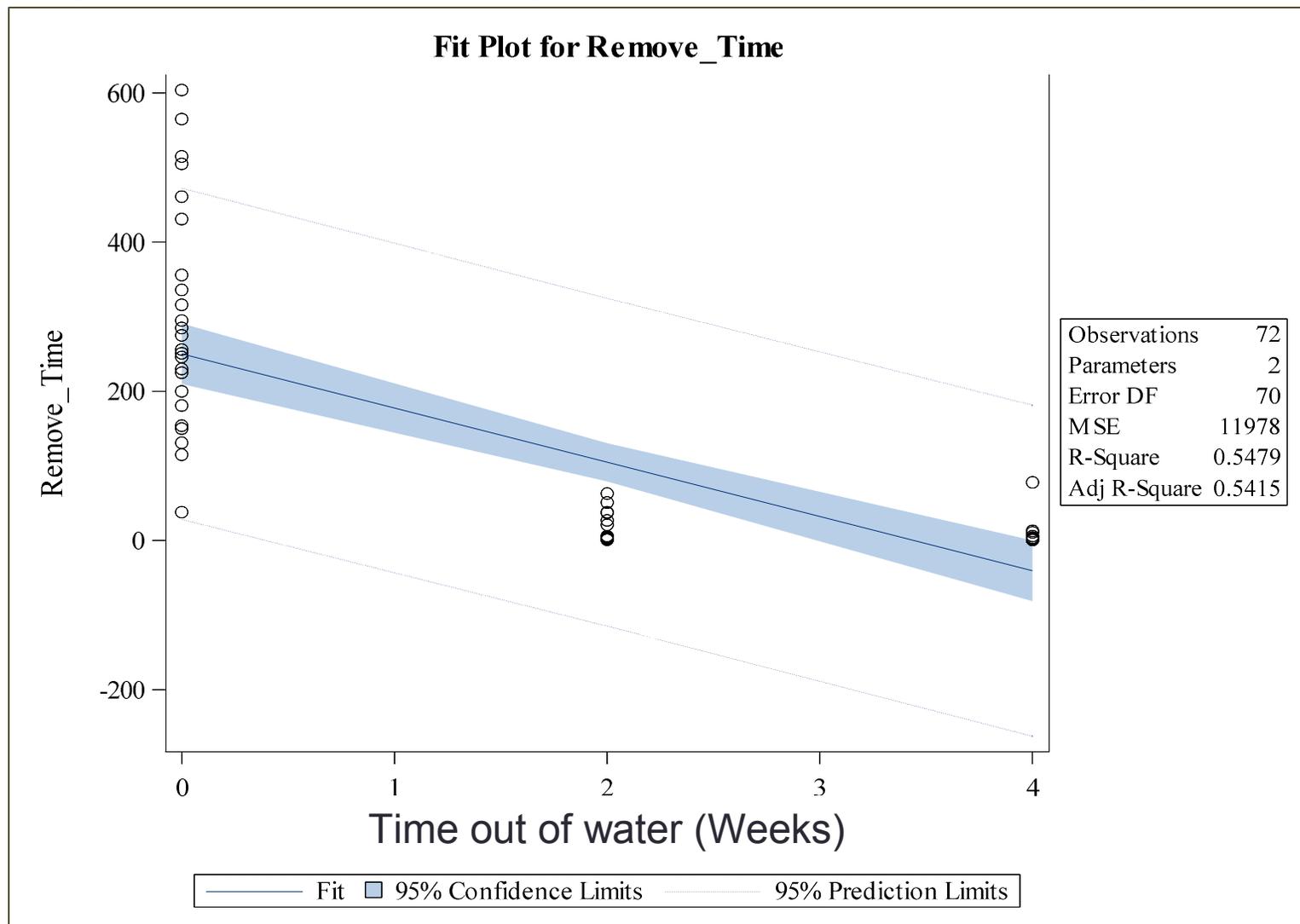
- Analysis of covariance (Winter: 0, 2 and 4 weeks):

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1084021.028	361340.343	31.89	<.0001
Error	68	770616.847	11332.601		
Corrected Total	71	1854637.875			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Density	1	57743.347	57743.347	5.10	0.0272
Time out of water	1	1016172.000	1016172.000	89.67	<.0001
Pressure	1	10105.681	10105.681	0.89	0.3484

Findings of the Study III: Time out of water

- Analysis of covariance (Winter: 0, 2 and 4 weeks):



Findings of the Study: Summary

- Time (0, 1, 2, or 4 weeks) the watercraft out of the water is the most significant factor affecting removal time
- Water pressure is significant on time to remove mussels from a watercraft
- No significant difference between quagga and zebra mussels was found in the summer season (No data for removal times of zebra mussels in the winter season)

Study Limitations

- Using pressurized water spray to remove zebra mussels from watercraft in winter has never been completed
- 1100 PSI on quagga mussels are not done whether in summer or winter time
- The current study is only for hull/surface area

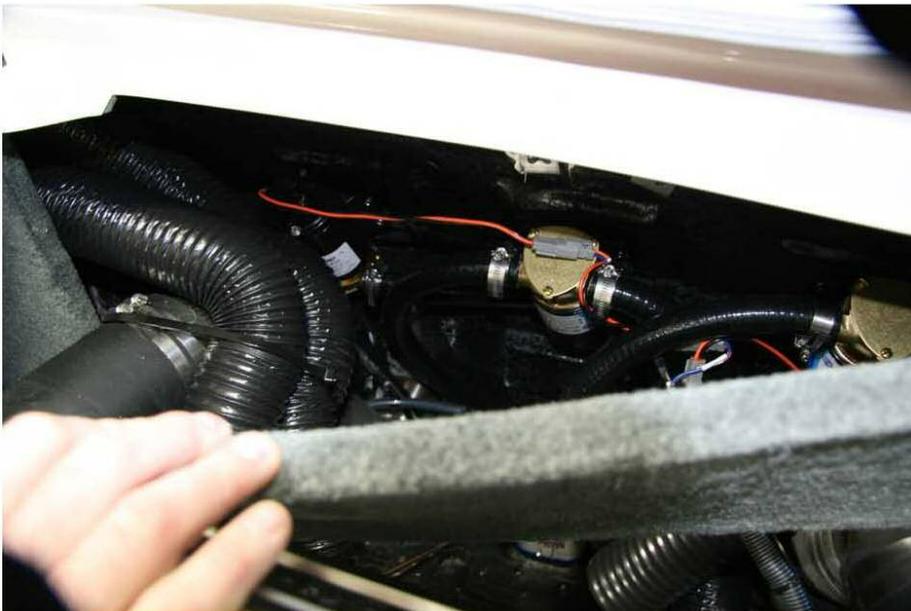




Hull: Easy to access



Gimbal area: Hard to access



Ballast system:
Cannot be Accessed

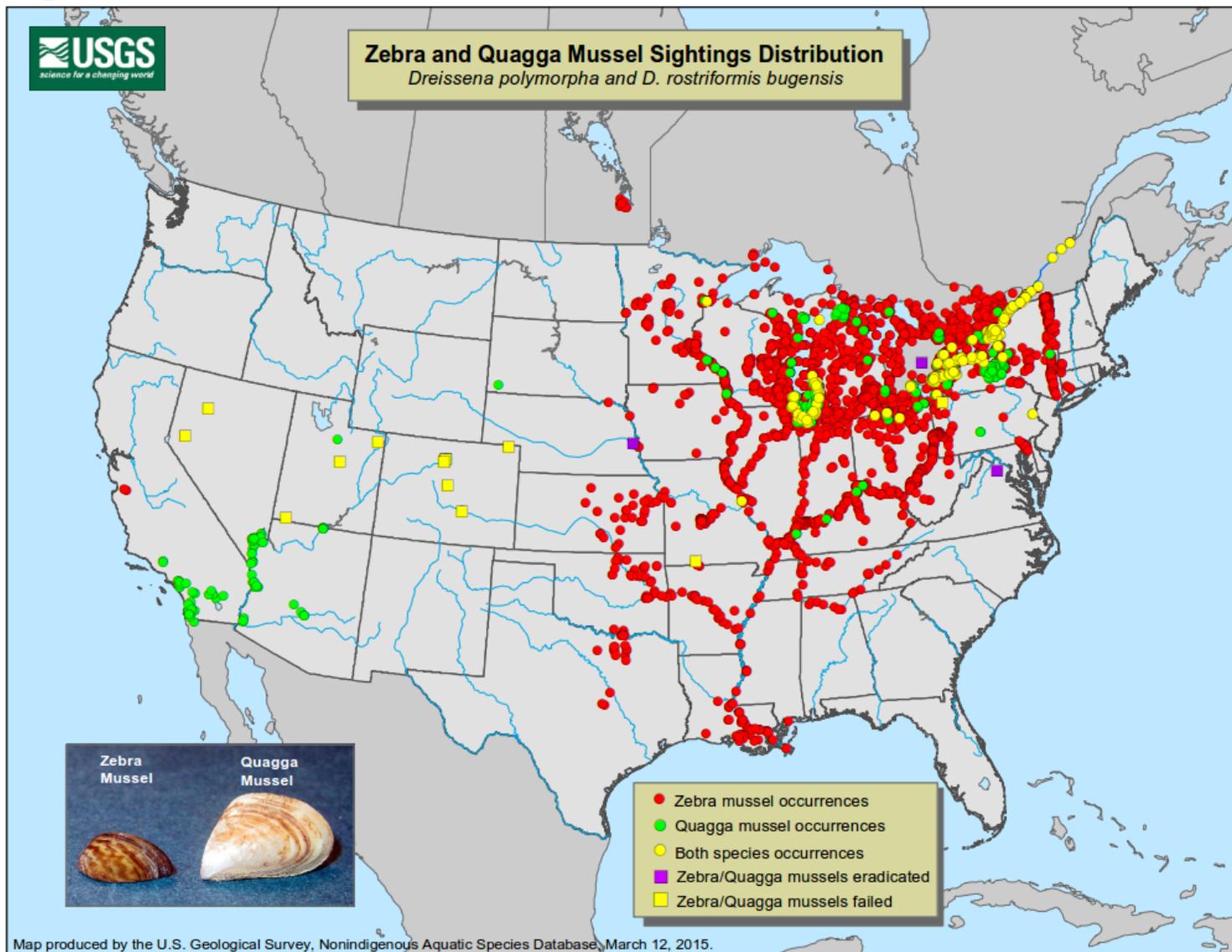
What we learned

- When water pressure is high (3000 psi of water), the boat has been out of the water for some time, and mussel density is low, and mussels are removed at a faster rate

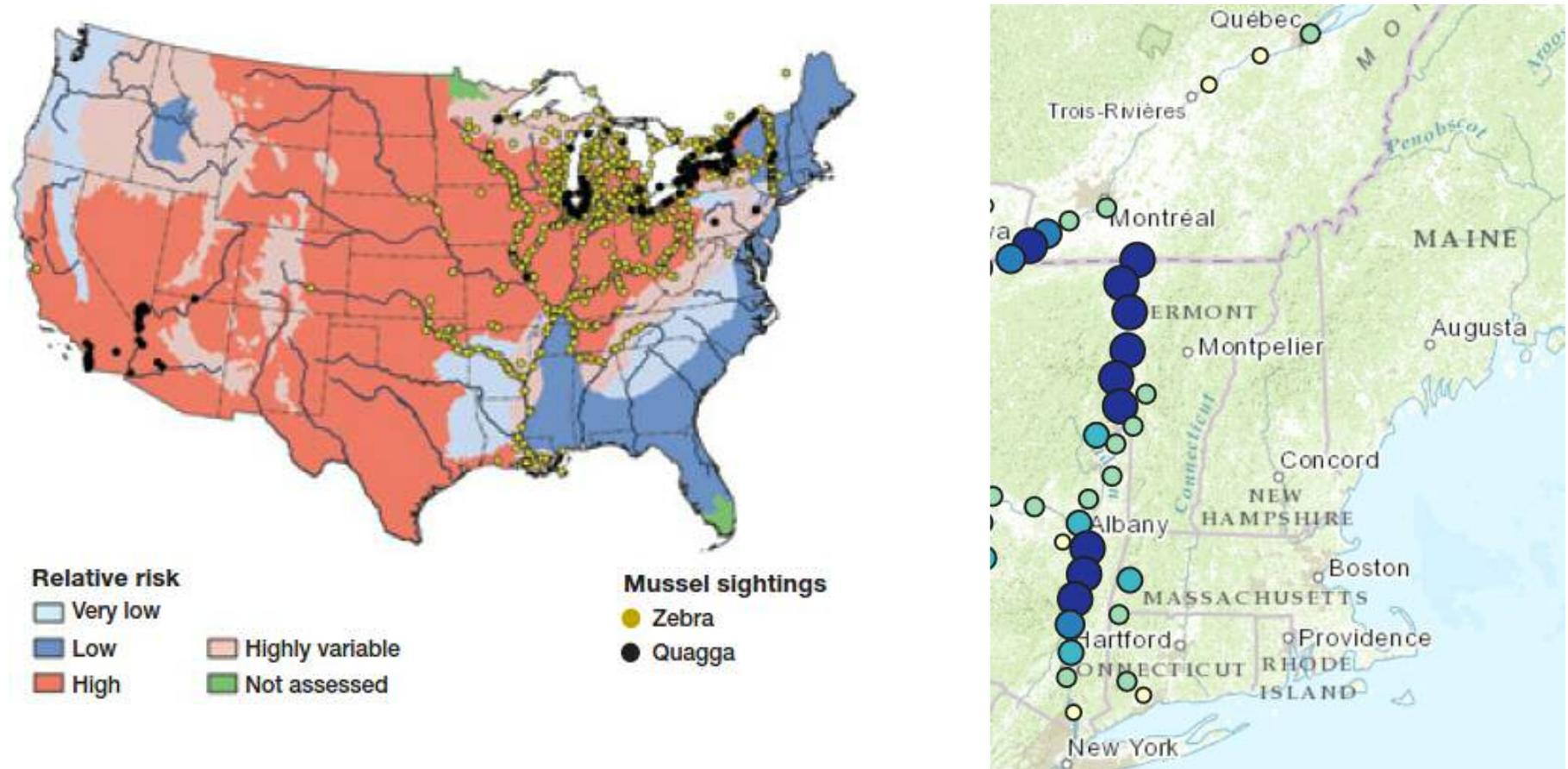
Proposed Protocol

- To decontaminate watercraft by removing dreissenid mussels:
 - Combine high pressure and hot-water applications
 - Use 3000 psi of water on the hull, centerboard box and keel (sailboats), lower unit, cavitation plate, and prop
 - For internal and other sensitive areas of watercraft, manual removal, using brushes and scrapers, of mussels may be necessary
 - Leave the boat out of water for a couple days if it is possible

Implementation for the Northeast



Implementation for the Northeast



Whittier et al. 2008

Implementation for the Northeast

Successful survival, growth, and reproductive potential of quagga mussels in low calcium lake water: is there uncertainty of establishment risk?

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² Department of Water Resource Management, University of Nevada, Las Vegas, NV, United States

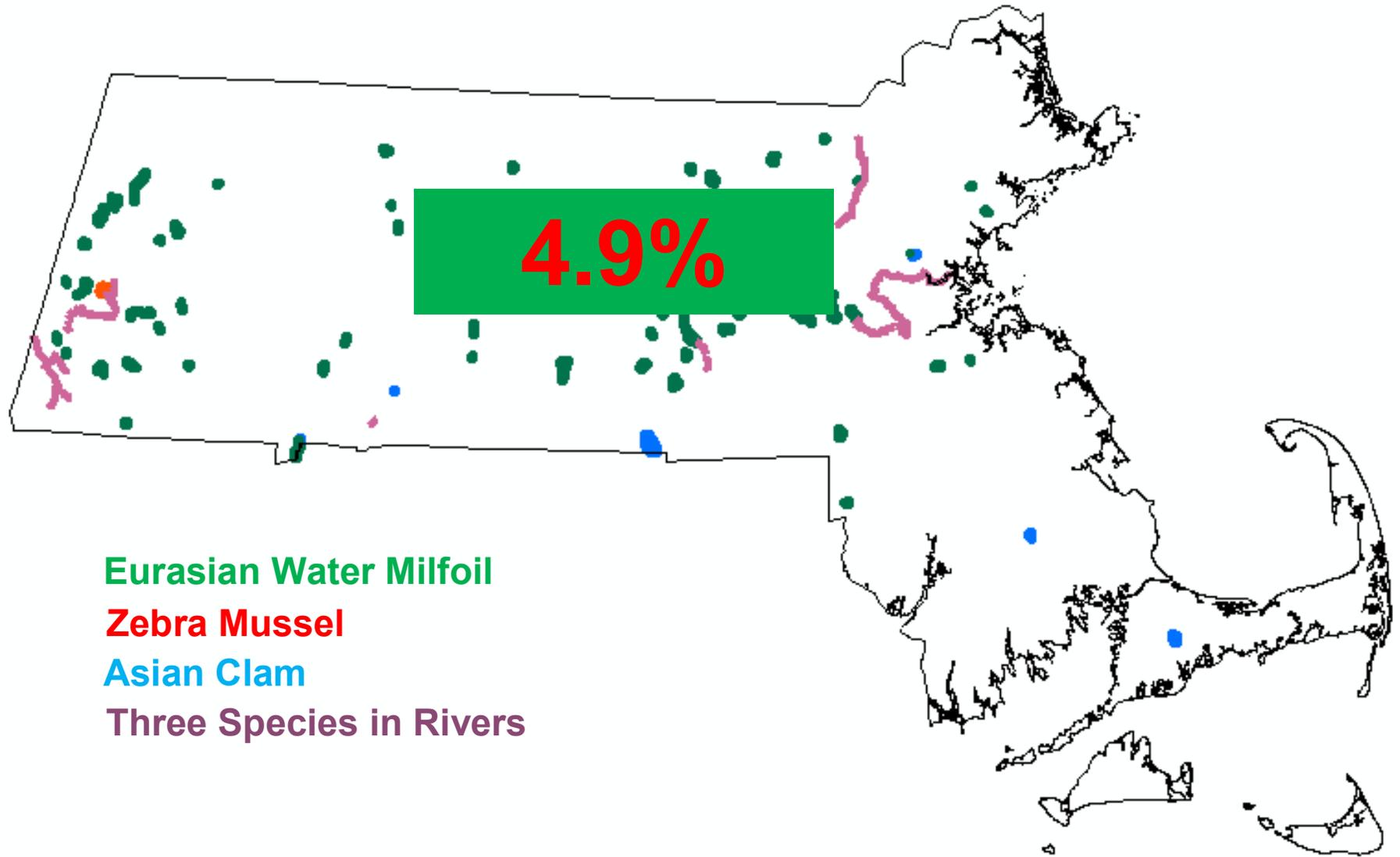
³ Division of Hydrologic Sciences, Desert Research Institute, Las Vegas, NV, United States

ABSTRACT

The risk of quagga mussel (*Dreissena rostriformis bugensis* Andrusov 1897) establishment into water-bodies of the western US has expanded the geographic concern regarding the ecological and economic impacts this species will have in aquatic ecosystems. Thresholds based on calcium concentrations, an element critical for mussel growth and physiology, have been used as a primary predictor of quagga mussel establishment success to aid management decisions. We evaluated the invasion potential of quagga mussels in low calcium waters using laboratory experiments to compare the survival, growth and reproductive potential of adult mussels held for 90 days at low (9 and 12 ppm), moderate (15 to 32 ppm) and high (72 ppm) calcium water concentrations. In conjunction with adult experiments, veliger stage survival, growth and settlement were evaluated under similar low, moderate, and high calcium water treatments. Adult mussels survived, grew and showed reproductive potential in low calcium water (12 ppm). Veligers were also able to survive, grow and settle in low calcium water. Higher levels of natural seston biomass appeared to improve adult mussel life history performance in low calcium water. Survival curve analysis predicted that 99% adult mortality could occur in <170 days at 9 ppm and 12 ppm, however water with >15 ppm could have adults surviving more than a year. The results from these bioassays provide further evidence that quagga mussels have higher risk of establishment in low calcium lakes if habitats exist that have slightly elevated calcium. These results should help emphasize the



Implementation for the Northeast: MassDEP monitoring waters



	Common Name	Scientific Name
Pathogens	Viral Hemorrhagic Septicemia	
	Salmonid whirling disease	Myxobolus cerebralis
	Furunculosis	Aeromonas salmonicola
Algae	Didymo	Didymosphenia germinate
Vascular plants	Flowering Rush	Butomus umbellatus
	Fanwort	Cabomba caroliniana
	Brazilian elodea	Egeria densa
	East India hygrophila	Hygrophila polysperma
	Japanese knotweed	Fallopia japonica
	Hydrilla	Hydrilla verticillata
	European frog bit	Hydrocharis morsus-ranae
	Yellow Flag Iris	Iris pseudacorus
	Purple Loosestrife	Lythrum salicaria
	Eurasian watermilfoil	Myriophyllum spicatum
	Parrot's Feather	Myriophyllum aquaticum
	Variable-leaved Watermilfoil	Myriophyllum heterophyllum
	Southern naiad	Najas guadalupensis
	Slender-leaved naiad	Najas minor
	Yellow Floating Heart	Nymphoides peltata
	Common Reed	Phragmites australis
	Curly leaf pondweed	Potamogeton crispus
	Great Water cress	Rorippa amphibia
	Giant salvinia	Salvinia molesta
Water Chestnut	Trapa natans	
Zooplankton	Spiny water flea	Bythotrephes cederstroemi
	Fish Hook Water Flea	Cercopagis pengoi
Invertebrate	Asiatic clam	Corbicula fluminea
	Zebra mussel	Dreissena polymorpha
	Quagga mussel	Dreissena rostriformis bugensis
	Green-lipped mussel	Perna viridis
	Faucet snail	Bithynia tentaculata
	Chinese mystery snail	Cipangopaludina chinensis
	New Zealand mud snail	Potamopyrgus antipodarum
	Rusty Crayfish	Orconectes rusticus
Chinese mitten crab	Eriocheir sinensis	
Fish	Eurasian ruffe	Gymnocephalus cernuus
	Round Goby	Neogobius melanostomus
	Tubenose Goby	Proterothinus marmoratus
	Tench	Tinca tinca
	Blueback herring	Alosa aestivalis
	Alewife	Alosa pseudoharengus
	Common Carp	Cyprinus carpio
	Grass Carp	Ctenopharyngodon idella
	Gizzard Shad	Dorosoma cepedianum
	White Perch	Morone americana
	European Rudd	Scardinius erythrophthalmus
Snake head	Channa argus	
Bird	Mute Swan	Cygnus olor



Implementation for the Northeast



**Department of
Environmental
Conservation**

For Immediate Release: 11/23/15

Contact: Jomo Miller | (518) 402-8000
Press Office | PressOffice@dec.ny.gov

DEC ANNOUNCES \$2 MILLION GRANT PROGRAM TO HELP PREVENT THE SPREAD OF AQUATIC INVASIVE SPECIES STATEWIDE

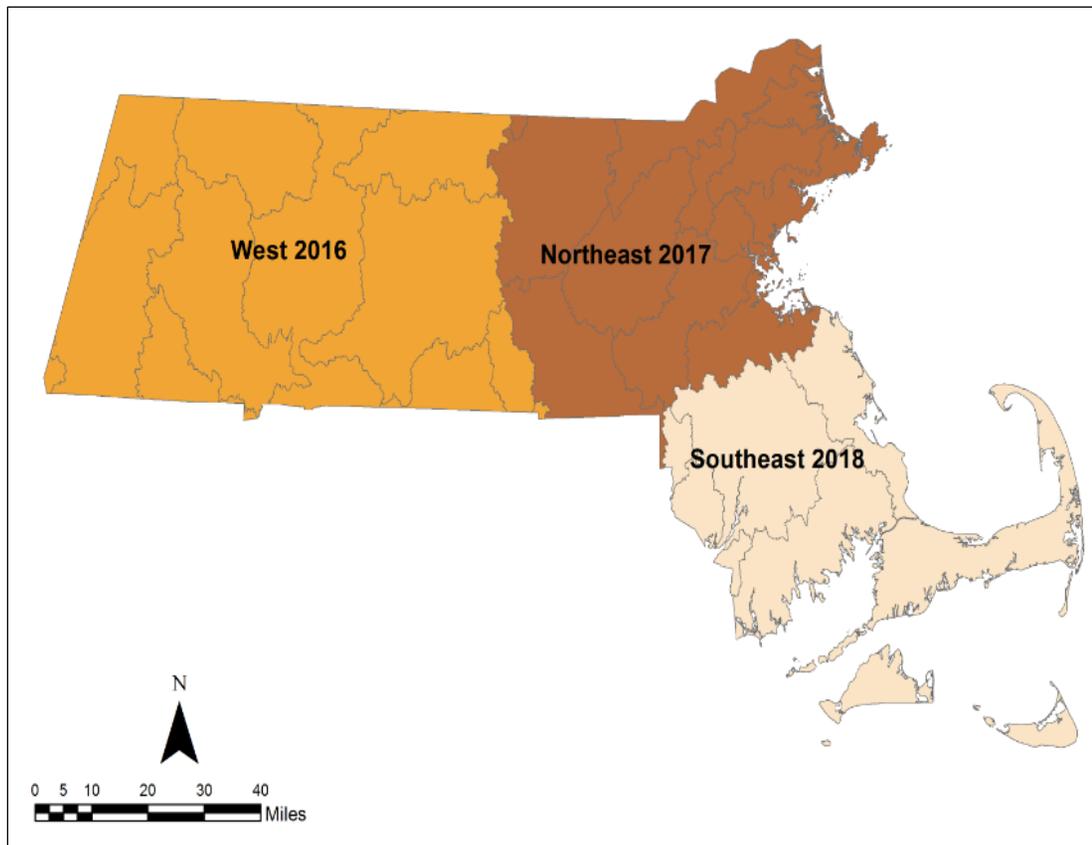
Grants Build Upon State's Actions to Slow the Spread of Aquatic Invasive Species

Applications Accepted Through January 29

Implementation for the Northeast: Pressure Wash to Clean Boats and Equipment



Implementation for the Northeast: MassDEP Pressure Wash to Clean Boats and Equipment



Name

Adams Car Wash
Bestway Car Wash
Dalton Car Wash
Tyler Street Car Wash Center
The New Scrub Board Laundromat & Car Wash, Inc.
Elm Street Car Wash
KCM Auto Wash
Canaan Car Wash
Lee Car Wash
Doleva Car Washes
Doyle's Car Wash
Queen Bee Car Wash
Bradley Auto Wash
Laser Auto Wash
Mr Sparkle Car Washes III Inc
Laser Auto Center
Soft Touch Auto Wash & Detail
Friendly Carwash
House of Wax Car Wash and Detailing
Toy Town Car Wash
Auto Shower Carwash
Auto Shower Carwash
Automated Laser Car Wash
Palmer Auto Wash
Big Bunny Car Wash
Express Auto Wash
Ernie's Touchless Car Wash
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Wilson Lake Marina

