Aquatic Invasive Species Guide to Preventing Transport by Wildland Fire Operations

Appendix B:

AQUATIC INVASIVE SPECIES of Concern to Firefighters NATIONWIDE and Methods of Control —the species fire operations are most likely to encounter, their distributions, all disinfection methods, and references.

Zebra & Quagga Mussels

Dreissena polymorpha &
Dreissena rostriformis bugensis

Photo credit: The Nature Conservancy

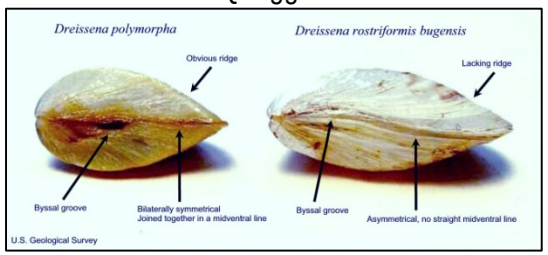

Photo credit: U.S. Geological Survey

General Information:

- **Quagga Mussel Distribution:** CA, NV, UT, AZ, CO, NM, OK, TX, midwest, Great Lakes region and NE US. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/
- **Zebra Mussel Distribution:** CA, UT, CO, OK, KS, NE, SD, ND, LA, AR, MO, IA, MN, MS, TN, AL, KY, IN, other midwest and Great Lakes regions and NE US. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/
- **Habitat:** Both mussels attach to hard surfaces in temperate lakes and slow rivers. Microscopic mussel larvae are released into open water where they swim about for several days before settling.
- **Fire Activities Posing Risk:** Most concern is with microscopic larvae present in water column. Larvae can survive for 5 days in internal tanks with residual water (summer months). Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water
- **Environmental Impacts:** Zebra and quagga mussels colonize water supply pipes and biofoul hydroelectric and nuclear power plants, public water plants, and industrial facilities. These species remove nutrients in aquatic ecosystems and litter beaches with sharp-edged shells.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER SPRAY To kill Quagga or Zebra mussel adults ≥ 140°F (60°C) for 5 to 10 seconds To kill Quagga/Zebra mussel free-swimming larvae ≥ 140°F (60°C) likely to be 'instantly lethal' HOT WATER IMMERSION: To kill Quagga/Zebra mussel adults and free-swimming larvae ≥ 120°F (50°C) for 1 minute	Comeau et al. 2011 (quagga adults); Morse 2009 (zebra adults) R. McMahon, pers. comm. (2014) Beyer et al. 2011	

Methods of Control for Firefighters	Details of Method	References	Notes
	FREEZING ≤ 32°F (0°C) for 48 hours or more for adults	McMahon 1996	
Drying	In summer, 5 days survival time for larvae in internal tanks with residual water; in cooler months; 28 days	Choi et al. 2013	
Mechanical	Scraping, brushing, hot water pressure washing to flush larvae	Comeau et al. 2011 and multiple sources	
CHEMICALS			
Quaternary ammonium Compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	To kill Quagga mussel larvae: *3.1% Sparquat256®* solution Mixing instructions: 4.3 oz per 1 gallon water 3.4 gallons per 100 gallons water Contact time = 10 minutes **OR** *1.8% Green Solutions High Dilution 256® solution* Mixing instructions: 2.5 oz per 1 gallon water 1.9 gallons per 100 gallons water Contact time = 10 minutes	Britton and Dingman 2011 Britton and Dingman 2011	Quat compounds methods are specifically for larvae likely found in the water column. Quat Compounds can corrode aluminum; not for use on aircraft equipment
Bleach (e.g. Clorox®) 6% sodium hypochlorite	*0.5% bleach solution* (250 ppm sodium hypochlorite) Mixing instruction: 0.6 oz bleach per 1 gallon water 1.1 Tablespoons of bleach per gallon water ½ gallon bleach per 100 gallons water Contact time = rinse only, no time specified.	Modovski 2011 (Based on Cope et al, 2003 which cited Gatenby 2000.	Bleach is corrosive to gear and metals

Methods of Control for Firefighters	Details of Method	References	Notes
Other Disinfectants	<u>To kill Quagga mussel adults & larvae</u>: 2% *Virkon Aquatic*® solution Mixing instructions: 20 g/liter 76g per 1 gallon of water 760g per 100 gallons water Contact time = 10 minutes <u>To kill Quagga mussel larvae only</u>: 0.5% *Virkon Aquatic*® solution Mixing instructions: 5 g/liter 19g per 1 gallon of water 190g per 100 gallons water Contact time = 10 minutes	Stockton 2011	Virkon is corrosive to soft metals. Although not specifically tested, may not be applicable for use on aircraft equipment

Asian Clam

Corbicula fluminea

Photo credit: Noel M. Burkhead-USGS

Photo credit: Flyforums.co

General Information:

- **Distribution:** Almost all US states except MT, ND and ME. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov//queries/FactSheet.aspx?speciesID=92
- **Habitat:** Lakes and streams, buried in sediments or larvae and juveniles drifting in currents
- **Fire Activities Posing Risk:** Most concern is with larvae and juvenile clams in swept into water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impacts**: Asian clams can biofoul power plant and industrial water systems. Juveniles secrete a mucousy dragline and can be easily transported in currents. The clams also clog irrigation canals and drinking water pipes.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<u>To kill Asian clam larvae and small juveniles</u>: HOT WATER It is probable that a hot water spray ≥ 140°F (60°C) for a few seconds would be lethal. No scientific study reports effectiveness. Flushing equipment with hot water would remove larvae and juveniles, which are easily entrained in flowing water. <u>To kill Asian clam adults</u>: ≥ 109° F (43°C) for 30 minutes	R. McMahon, pers. comm. (2014) McMahon and Williams 1986 Mattice and Dye 1975	

Methods of Control for Firefighters	Details of Method	References	Notes
Drying	Dry gear in air for 14–27 days in cool weather; much shorter dry times in full sun	McMahon and Williams 1984	
Mechanical	Scraping, brushing, remove all plant material	Multiple sources	
CHEMICALS	Though chemicals are used in hydroelectric facilities, Asian clams are resistant to chemicals: decontamination times are lengthy and kill rates < 100%.	For example, Barbour et al. 2013	

New Zealand Mudsnail

Potamopyrgus antipodarum

General Information:

- **Distribution:** WA, OR, CA, ID, MT, WY, UT, NV, AZ, CO, MN, IL, OH, PA, NY, and Canada. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/taxgroup/mollusks/newzealandmudsnaildistribution.aspx
- **Habitat:** Streams and lakes, occurring on rocky substrates as well as aquatic plants.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental impacts:** Mudsnails reproduce very quickly. It only takes a SINGLE snail can result in a colony of more than 40 million snails in just one year. New Zealand mudsnails can smother a streambed, crowding out the native aquatic species that provide food for fish.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: ≥ 122°F (50°C) for 15 seconds FREEZING: ≤ 27°F (-3°C) for 1 to 2 hours	Dwyer et al. 2003 Richards et al. 2004	
Drying	Dry gear in full sunlight for ≥ 50 hours Dry gear at 86°F (30°C) for 24hours Dry gear at ≥ 104°F (40°C) for at least 2 hours	Alonso and Castro-Diez 2012 Richards et al 2004	

Methods of Control for Firefighters	**Details of Method**	**References**	**Notes**
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	0.8% *Green Solutions High Dilution* 256® solution Mixing instructions: - ½ liquid oz. per 1 gallon water - 1 Tbsp. per 1 gallon water Contact time = 10 minutes 0.33% *Super HDQ*® Mixing instructions: - ½ liquid oz. per 1 gallon water - 1 Tbsp. per 1 gallon water Contact time = 10 minutes	Stout et al. 2016	Quat Compounds can corrode aluminum; not for use on aircraft equipment
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Hosea and Finlayson 2005	

Methods of Control for Firefighters	Details of Method	References	Notes
Other Agents	2% *Virkon Aquatic*® solution Mixing instructions: 77g per 1 gallon of water 770 g per 100 gallons water Contact time = 15-20 minutes	Stockton and Moffitt 2013	Virkon is corrosive to soft metals. Although not specifically tested, may not be applicable for use on aircraft equipment

Malaysian Trumpet Snail

Melanoides tuberculata

Also called: Red Rimmed Melania, Red Lipped Melania

Photo credit: Alex Kawazaki


Photo credit: Flickriver.com

General Information:

- **Distribution:** AZ, CA, CO, FL, HI, LA, MT, NC, NV, OR, UT, TX (possible in SD, VA and WY). For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1037
- **Habitat:** Slow moving rivers and lakes, on mud and plants
- **Fire Activities Posing Risk:** Risks include: helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** This trumpet snail can out-compete native snails and alter ecosystem functions

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: To kill snails of all sizes 122 °F (50°C) for 4-5 minutes FREEZING: Freezing in Ice water for 12-24 hours Freezing in salty ice water for 2 hours	Mitchell and Brandt 2005 Mitchell and Brandt 2009	
Drying	Very resistant to drying, >20 days	Mitchell and Brandt 2005	
Mechanical	Scraping, brushing, hot water pressure washing	Multiple sources	

Methods of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Mitchell et al. 2007	

Oriental Mystery Snail

Cipangopaludina spp.

Also called: Chinese Mystery Snail

Photo credit: Cornell University

Photo credit: Oregon Dept of Fish and Wildlife

General Information:

- **Distribution:** WA, OR, CA, ID, UT, AZ, CO TX, NE, MO, GA, FL, NC, Great Lakes region, and northeastern US. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1044
- **Habitat:** Slow moving rivers and lakes, on mud and plants. Readily transported by equipment infested with snails hitchhiking on aquatic plants.
- **Fire Activities Posing Risk:** Helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** These snails form dense populations and outcompete native species for food and habitat. They are intermediate hosts for parasitic worms and can transmit diseases that kill waterfowl. Some mystery snails prey on fish embryos. Snail shells often litter shorelines and clog screens of water intakes.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122 °F (50°C) for 4-5 minutes	J. Havel, pers. comm. (2014)	
Drying	14 to ≥28 days, depending on snail size. Larger snails very resistant to drying.	Havel 2011	
Mechanical	Scraping, brushing, clean off all plant material	Multiple sources	

Method of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	No known studies, but as with other snails with sealing flaps (e.g. New Zealand mudsnails, trumpet snails), likely not effective		

Faucet Snail

Bithynia tentaculata

Photo credit: Amy Benson-USGS

General Information:

- **Distribution:** Great Lakes Region, WI, PA, NY, VT, VA, MD, and MT. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=987
- **Habitat:** Slow moving rivers and lakes, on mud and plants. Readily transported by equipment infested with snails hitchhiking on aquatic plants.
- **Fire Activities Posing Risk:** Helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** These snails outcompete native species for food and habitat in lakes and streams. They are intermediate hosts for parasitic worms and transmit diseases that kill waterfowl. Where abundant they infest municipal water supplies.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122 °F (50°C) for ≥1 minute	Mitchell and Cole 2008	
Drying	Dry gear for 14 to 21 days	Mitchell and Cole 2008	
Mechanical	Scraping, brushing, clean off all plant material	Multiple sources	
CHEMICALS			
Quaternary ammonium Compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Mitchell and Cole 2008	

Method of Control for Firefighters	Details of Method	References	Notes
Other agents	*Virkon*® Not effective	Mitchell and Cole 2008	

Spiny Waterflea

Bythotrephes longimanus

Photo credit: Minnesota Department of Natural Resources

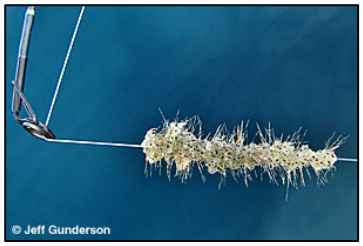

Photo credit: Jeff Gunderson

General Information:

- **Distribution:** Primarily in the Great Lakes Region of the US. For most up-to-date information on distribution, please see: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=162
- **Habitat:** Waterflea plankton (adults and juveniles) are free-swimming in water column of ponds and lakes; dormant (resting) eggs are in mud or silt.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** The rapidly reproducing spiny waterflea competes with small fish and fouls fishing gear. Larger fish that feed on waterfleas may die due to punctures from spines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER To kill adults, juveniles, and resting eggs: ≥ 122°F (50°C) for 5 minutes 140°F (60°C) for 1 minute	Branstrator et al. 2013 (resting eggs) Beyer et al. 2011 (plankton)	
Drying	Dry gear for ≥6 hours (planktonic adults and juveniles, and resting eggs)	Branstrator et al. 2013 (resting eggs) Branstrator, D.K., pers. comm. 2014; (plankton)	
Mechanical	Scraping, brushing, removal of organic and plant materials.	Multiple sources	

Methods of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Branstrator et al. 2013	

Didymo

Didymosphenia geminata

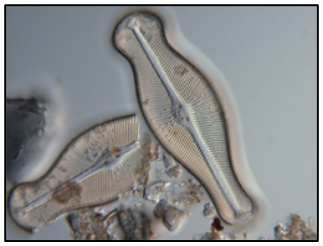

Photo credit: USGS

Photo credit: Biosecurity New Zealand

General Information:

- **Distribution:** WA, OR, CA, ID, MT, WY, CO SC, ND, AR, NC, VA WV PA, NY, NH, CT, AK, and Canada. For most up-to-date information on distribution, please see: http://www.invasivespeciesinfo.gov/aquatics/didymo.shtml
- **Habitat:** Didymo is a single cell alga that attaches to submerged rocks in cold streams and rivers.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water. Didymo can survive in residual tank water for <2 days in summer but up to 45 days in autumn (Kilroy et al. 2007).
- **Environmental Risk:** Didymo forms dense mats that trail downstream and can completely cover the substrate, smothering native plants, insects, and mollusks..

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 113°F (45°C) for 20 minutes 140°F (60°C) for 1 minute FREEZING: 28°F (-2°C) for 4 hours ; 5°F (-15°C) for 2hours	Kilroy et al. 2007 Kilroy et al. 2007	
Drying	Dry external surfaces and internal tanks for 48 hours in summer	Kilroy et al. 2007	
Mechanical	Scraping, brushing, removal of organic and plant materials.		
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium	*2.0 % Sanicare Quat128*® solution Mixing instructions: 2.4 oz per 1 gallon water 1.9 gallons per 100 gallons water Contact time = 1 minute	Matthews 2007, derived from Kilroy et al. 2007	

Methods of Control for Firefighters	Details of Method	References	Notes
chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	**OR** *1.2% Sparquat256®* solution Mixing instructions: 1.7 oz per 1 gallon water 1.3 gallons per 100 gallons water Contact time = 1 minute **OR** *0.7% Green Solutions High Dilution 256®* solution Mixing instructions: 1.0 oz per 1 gallon water 0.8 gallons per 100 gallons water Contact time = 1 minute		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	*2.0% bleach solution* (800 ppm sodium hypochlorite) Mixing instructions: 1.8 oz bleach per 1 gallon water 3.6 Tablespoons bleach per gallon water 1.4 gallon bleach per 100 gallons water Contact time = 1 minute	Root and O'Reilly 2012	≥90% effective in killing didymo; corrosive to fabric and metals
Other Disinfectants	1% *Virkon Aquatic®* 10 g/liter Contact time = 10 minutes *Greenworks* dish detergent: 5% solution for 1 minute *Dawn* dish detergent: 5% solution for 1 minute	Root and O'Reilly 2012	~80% effective ≥95% effective ≥95% effective

Chytrid fungus
Batrachochytrium dendrobatidis


Photo credit: Microbiologybytes


Photo credit: DPIW.tas.gov.au

General Information:

- **Distribution:** Chytrid fungus occurs on most continents
- **Habitat:** Zoospores are free-swimming in water column and can survive in wet mud or silt.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** This aquatic fungus feeds on living vertebrates and primarily affects the skin of amphibians. Because amphibians breathe and take up water through their skin, the disease causes widespread amphibian declines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HEAT 140°F (60°C) for 5 minutes (tested in incubators)	Johnson et al. 2003	
Drying	Dry gear for ≥3 hours; in sunlight is best.	Johnson et al. 2003	
Mechanical	Scraping, brushing, removal of organic and plant materials.		
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	*0.15% Sanicare Quat128*® solution Mixing instructions: 0.02 oz per 1 gallon water ⅛ teaspoon per 1 gallon water Contact time = 30 seconds **OR** *0.04% Sparquat256*® solution Mixing instructions: 0.06 oz per 1 gallon water	Johnson et al. 2003.	

Methods of Control for Firefighters	Details of Method	References	Notes
	0.36 teaspoon per gallon of water Contact time = 30 seconds **OR** *0.02% Green Solutions High Dilution 256*® solution Mixing instructions: - 0.03 oz per 1 gallon water - 0.2 teaspoon per 1 gallon water Contact Time = 30 seconds		
"Regular Clorox® Bleach" 6% sodium hypochlorite	*22% bleach solution* (1.2% sodium hypochlorite) Mixing instructions: 1 part bleach:4 parts water 26 oz bleach per 1 gallon water 20 gallons bleach per 100 gallons water Contact time = 5 minutes	Ultra Clorox® Label (EPA Reg #5813-50)	These mixing instructions are approved by EPA specifically for chytrid fungus
"Clorox® Germicidal Bleach" 8.25% sodium hypochlorite	*22% bleach solution* (1.2% sodium hypochlorite) Mixing instructions: 1 part bleach:5.5 parts water 20 oz bleach per 1 gallon water 15.4 gallons bleach per 100 gallons water Contact time = 5 minutes	Germicidal Healthcare Clorox® label (EPA Reg. No. 5813-100)	These mixing instructions are approved by EPA specifically for chytrid fungus
Other Disinfectants	*0.1% Virkon*® 1 g/liter Contact time = ≥ 2 seconds	Johnson et al. 2003	

Whirling Disease

Myxobolus cerebralis

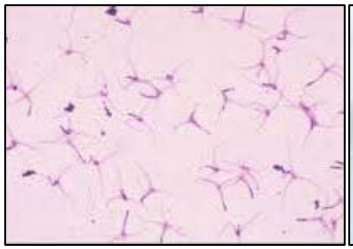

Photo credit: Colorado Parks and Wildlife

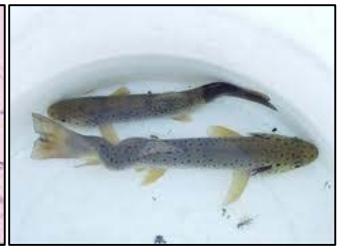

Photo credit: Colorado Parks and Wildlife

General Information:

- **Distribution:** WA, OR, CA, ID, NV,AZ, NM, UT, CO, NE, WY, ID, MT, MI, WI, OH, WV, VA, DE, MD, PA, NJ, CT, NY, MA, VT, NH, AK. For most up-to-date information on distribution, please see: http://www.invasivespeciesinfo.gov/microbes/whirling.shtml
- **Habitat:** Free-swimming microscopic larvae occur in water column, resistant spores in mud and bottom sediments. Spores can remain viable in mud for 12 years.
- **Fire Activities Posing Risk:** Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Whirling disease afflicts trout species, causing spinal distortions and population declines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: To kill spores 195°F (90°C) 10 minutes To kill free-swimming larvae ≥ 167°F (75°C) for 5 minutes	Hoffman and Markiw 1977 Wagner et al. 2003	
Drying	Dry gear for 24hours, drying in sunlight is best to kill spores and larvae	Hedrick et al. 2008	
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds	*4.6% Sanicare Quat128*® solution	Hedrick et al. 2008	

Methods of Control for Firefighters	Details of Method	References	Notes
(e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	Mixing instructions: 6.4 oz per 1 gallon water 5 gallons per 100 gallons water Contact time = 10 minutes. OR *3.1% Sparquat256®* solution Mixing instructions: - 4.3 oz per 1 gallon water - 3.4 gallons per 100 gallons water Contact time = 10 minutes OR *1.8% Green Solutions High Dilution 256®* solution Mixing instructions: 2.5 oz per 1 gallon water 1.9 gallons per 100 gallons water Contact time = 10 minutes		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	*1% bleach solution* (500 ppm sodium hypochlorite) Mixing instruction: 1.1 oz bleach per 1 gallon water 2.2 Tablespoons bleach per gallon water 0.9 gallon bleach per 100 gallons water Contact time = 15 minutes	Hedrick et al. 2008 (spores) Wagner et al. 2003 (larvae)	

Viral Hemorrhagic Septicemia

Novirhabdovirus sp.

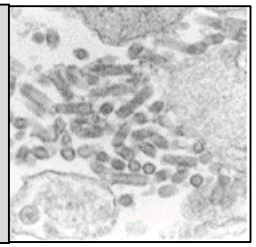

Photo credit: Seagrant.suny.edu

Photo credit: D. Kenyon Michigan DNR

General Information:

- **Distribution:** Great Lakes and St. Lawence River. For most up-to-date information on distribution, please see: http://www.invasivespeciesinfo.gov/microbes/vhs.shtml
- **Habitat:** VHS is carried in the water column and in aquatic invertebrates, such as snails and crustaceans, as well as fish parts.
- **Fire Activities Posing Risk:** Most concern is with virus free floating in the water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects**: Over 50 fish species are susceptible to this disease which causes significant fish die offs.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122°F (50°C) for 10 minutes 158°F (70°C) for 1 minute	Jørgensen 1974, cited in Bovo et al. 2005	
Drying	Dry gear for 4 days at 70°F (21°C)	Pietsch et al. 1977 (for IHNH virus). (Bovo et al. 2005)	IHNV and VHSV are closely related viruses. It is presumed that inactivation studies on one virus may pertain to the other.
Mechanical	Thoroughly wash and dry	Multiple sources	

Method of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	*0.4% Green Solutions High Dilution 256*® solution Mixing instructions: ½ oz per 1 gallon water 0.4 gallon per 100 gallons water Contact time = 10 minutes	EPA label Reg. No. 1839-167 (2010)	These mixing instructions are approved by EPA for closely related viruses in the same family, but not specifically for VHS
Bleach (e.g. Clorox®) 6% sodium hypochlorite	*0.2% bleach solution* (98 ppm sodium hypochlorite) Mixing instructions: 0.26 oz/1 gallon water ~ ½ tablespoon/1 gallon water 26 oz/100 gallons water 0.2 gal/100 gallons water Contact time: 2 minutes	Ahne 1982, cited in Bovo et al. 2005	
Other Agents	0.5% - 1% *Virkon Aquatic*® 5 g/liter to 10 g/liter Contact time = 10 minutes	Yanong and Erlacher-Reid 2012	

Spring Viremia of Carp

Rhabdovirus carpio

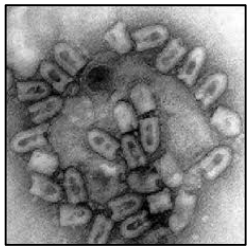

Photo credit: ytponet

Photo credit: USGS

General Information:

- **Distribution: NC, Il, WI OH,MN, MO, WA, Ontario.** For most up-to-date information on distribution, please see: http://www.glerl.noaa.gov/res/Programs/glansis/nas_database.html
- **Habitat:** SVC is carried in the water column and survives long periods in wet mud.
- **Fire Activities posing risk:** Most concern is with virus free floating in the water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** This virus is a major cause of disease and death in carp and 50 other fish species.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122°F (50°C) for 5 minutes	Ahne 1976, cited in Bovo et al. 2005	
Drying	>28 days at 70°F (21°C)	Ahne 1982	
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	*0.4% Green Solutions High Dilution 256*® solution Mixing instructions: ½ oz per 1 gallon water 0.4 gallon per 100 gallons water Contact time = 10 minutes	EPA label Reg. No. 1839-167 (2010)	These mixing instructions are approved by EPA for closely related viruses in the same family, but not specifically for SVC.

Method of Control for Firefighters	Details of Method	References	Notes
Bleach (e.g. Clorox®) 6% sodium hypochlorite	*0.1% bleach solution* (55 ppm sodium hypochlorite) Mixing instructions: ¼ teaspoon per 1 gallon water 11.5 oz per 100 gallons water Contact time: 2 minutes	Ahne 1982, cited in Bovo et al. 2005	
Other Agents	*0.5% to 1%Virkon Aquatic*® 5 g/liter to 10 g/liter for 10 minutes 0.1% *Virkon Aquatic*® 1 g/liter for 30 minutes	Bowker et al 2012	

Port Orford Cedar Root Disease (*Phytophthora lateralis*)

&

Sudden Oak Death (*Phytophthora ramorum*)

Photo credit: USDA Forest Service

Photo credit: phytophthoradb.org

General Information:

- **Port Orford Cedar Root Disease Distribution: WA, OR, CA**. For most up-to-date information on distribution, please see: http://www.issg.org/database/welcome/.
- **Sudden Oak Death Distribution: CA, OR**. For most up-to-date information on distribution, please see: http://www.issg.org/database/welcome/
- **Habitat:** Spores swim in standing water and can be carried large distances in flowing water; they also occur in soil.
- **Fire Activities Posing Risk:** Most concern is with spores carried in untreated water. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Port Orford cedars of all sizes may be killed by the root disease. Sudden oak death affects other trees as well as oaks, leading to widespread forest destruction.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
"Regular Clorox® Bleach" 6% sodium hypochlorite	Add **1 gallon** bleach to 1000 gallons of drafted water (~50 ppm sodium hypochlorite). Prepare the mixture at least 5 minutes prior to application for dust abatement, fire suppression, and cleaning vehicles and logging, road building, and maintenance equipment.	Ultra Clorox® Label (EPA Reg. No. 5813-50) AND Southwest Oregon Interagency Fire Management Plan (USDA Forest Service 2013)	[1]See note below for application.

Method of Control for Firefighters	Details of Method	References	Notes
"Clorox® Germicidal Bleach" 8.25% sodium hypochlorite	Add ¾ **gallon** bleach to 1000 gallons of drafted water (~50 ppm sodium hypochlorite). Prepare the mixture at least 5 minutes prior to application for dust abatement, fire suppression, and cleaning vehicles and logging, road building, and maintenance equipment.	Germicidal Healthcare Clorox® label (EPA Reg. No. 5813-100)	

[1] Locate vehicle washing stations (with chlorinated water) where water will not run into streams. When refilling tenders/engines, fill with water first, pull 150' away from the stream (or where overland flow will not run back into the stream), and then add the chlorine. Avoid dropping buckets of or directly releasing chlorine-treated water into streams or wetlands. Don't treat water from streams that are uninfected with the root rot disease, unless it is for use at washing stations (to avoid unnecessary use of chlorine). (Southwest Oregon Interagency Fire Management Plan 2013

Aquatic Invasive Plants

Purple Loosestrife Photo credit:universityofconn.com

Parrot feather. Photo credit: Aquariussystems.com

Hydrilla. Photo credit: nwdistrict.ufl.edu

General Information:

- **Distribution:** Varies based on species. For most up-to-date information on distribution, please see: http://www.invasivespeciesinfo.gov/aquatics/main.shtml
- **Habitat:** Aquatic plants are usually confined to shorelines and relatively shallow portions of waterbodies, though plant pieces can float throughout.
- **Fire Activities Posing Risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects**: Non-native aquatic plants clog waterways and threaten the diversity and survival of native species.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER PRESSURE WASH: ≥140°F (60°C) for 2 minutes; inspect and re-treat as needed.	Blumer et al. 2009	This study is specific to Eurasian watermilfoil, but lethal temperatures likely comparable for other submerged species.
Mechanical	Scraping, brushing, high pressure washing and mud removal. Some seeds may remain viable after washing, so disposal or filtration of treated water is recommended.	Multiple sources	

REFERENCES

Ahne, W. 1976. Untersuchungen über die Stabilität des karpfenpathogenen Virusstammes. Fisch Umwelt 2: 121-127.

Ahne, W. 1982. Vergleichende Untersuchung ünte die Stabilitbi von vier fischpathogenen Viren (VHSV, PFR, SVCV, IPNV). Zentralblatt fen Veterinarmedizin, 29: 457-476.

Alonso, A., and P. Castro-Diez. 2012. Tolerance to air exposure of the New Zealand mudsnail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca) as a prerequisite to survival in overland translocations. NeoBiota 14:67-74.

Barbour, J., McMenamin, S., Dick, J., Alexander, M., and J. Caffrey. 2013. Biosecurity measures to reduce secondary spread of the invasive freshwater Asian clam, *Corbicula fluminea* (Müller, 1774). Management of Biological Invasions 4(3):219-230.

Beyer, J, Moy, P., and B. DeStasio. 2011. Acute upper thermal limits of three aquatic invasive invertebrates: hot water treatment to prevent upstream transport of invasive species. Environmental Management 47:67-76.

Blumer, D., Newman, R., and F. Gleason. 2009. Can hot water be used to kill Eurasian watermilfoil? J. Aquat. Plant Management 47: 122-127.

Bovo, G., Hill, B., Husby, A., Hästein, T., Michel, C., Olesen, N., Storset, A., and P. Midtlyng. 2005. Pathogen survival outside the host, and susceptibility to disinfection- Work Package 3, Report QLK2-Ct-2002-01546 Fish Egg Trade, VESO, Oslo, Norway.

Bowker, J.D., Trushenski, J.T., Gaikowski, M.P., and D.L. Straus, Editors. 2012. Guide to using drugs, biologics, and other chemicals in aquaculture. American Fisheries Society Fish Culture Section.

Branstrator, D., Shannon, L., Brown, M., and M. Kitson. 2013. Effects of chemical and physical conditions on hatching success of *Bythotrephes longimanus* resting eggs. Limnol. Oceanogr 58:2171-2184.

Britton, D.A., and S. Dingman. 2011. Use of quaternary ammonium to control the spread of aquatic invasive species by wildland fire equipment. Aquatic Invasions 6(2): 169-173.

Choi, W.J., Gertenberger, S., McMahon, R., and W. Wong. 2013. Estimating survival rates of quagga mussel (*Dreissena rostriformis bugensis*) veliger larvae under summer and autumn temperature regimes in residual water of trailered watercraft at Lake Mead, USA. Management of Biological Invasions 4(1) 61-69.

Cope, W. G., Newton, T. J., and C.M. Gatenby. 2003. Review of techniques to prevent introduction of zebra mussels (D*reissena polymorpha*) during native mussel (Unionoidea) conservation activities. Journal of Shellfish Research 22(1): 177–184.

Comeau, S., Rainville, S., Baldwin, W., Austin, E., Gerstenberger, S., Cross, C., and Wai Hing Wong. 2011. Susceptibility of quagga mussels (*Dreissena rostriformis bugensis*) to hot-water sprays as a means of watercraft decontamination, Biofouling, 27: 3, 267-274.

Dwyer, W., Kerans, B., and M. Gangloff. 2003. Effects of acute exposure to chlorine, copper sulfate, and heat on survival of New Zealand mudsnails. Intermountain J. Sciences 9:53-58.

EPA Service Bulletin, Germicidal Clorox (EPA Registration No 5813-100). 2013. http://www.clorox.com/pdf/5813-100_service-bulletins.pdf [accessed 3/2014]

Gatenby, C., Morrison, P., Neves, R., and B. Parker. 2000. A protocol for the salvage and quarantine of unionid mussels from zebra mussel-infested waters. Proceedings Conservation, Captive Care, and Propagation of Freshwater Mussels Symposium, 1998:9-18.

Havel, J.E. 2011. Survival of the exotic Chinese mystery snail (*Cipamgopaludina chinensis malleata*) measuring air exposure and implications for overland dispersal by boats. Hydrobiologia 668:195-202.

Hedrick, R., McDowell, T., and K. Mukkatira. 2008. Effects of freezing, drying, ultraviolet irradiation, chlorine, and quaternary ammonium treatments on the infectivity of myxospores of *Myxobolus cerebralis* for *Tubifex tubifex*. Journal of Aquatic Animal Health 20:116-125.

Hoffman, G.L., and M. E. Marliw. 1977. Control of whirling disease (*Myxosoma cerebralis*): use of methylene blue staining as a possible indicator of effect of heat on spores. J. Fish Biology 10:181-183.

Hosea, R.C., and B. Finlayson. 2005. Controlling the spread of New Zealand mudsnails on wading gear. California Dept of Fish and Game, Office of Spill Prevention and Response, Administrative Report 2005-02

Johnson, M.L., Berger, L., Philips, L., and R. Speare. 2003. Fungicidal effects of chemical disinfectants, UV light, desiccation and heat on the amphibian chytrid *Batrachochytrium dendrobatidis*. Diseases of Aquatic Organisms 57:255-260.

Jørgensen, P.1974. A study of viral diseases in Danish rainbow trout: their diagnosis and control. Thesis, Royal Veterinary and Agricultural University, Copenhagen. 101pp.

Kilroy, C., Lagerstedt, A., Davey, A., and K. Robinson. 2007. Studies on the survivability of the invasive diatom *Didymosphenia geminata* under a range of environmental and chemical conditions. Biosecurity New Zealand NIWA Client Report: CHC2006-116. National Institute of Water and Atmospheric Research LTD. Christchurch, New Zealand.

Mattice, J., and L. Dye. 1976. Thermal tolerance of adult Asiatic clam. In: G. Esch and R. McFarlane (eds.), Thermal Ecology II: 130-135. US Energy Research and Development Admin., CONF-750425, National Technical Information Service, US Dept Commerce, VA.

McMahon, R. 1996. The physiological ecology of the zebra mussel, *Dreissena polymorpha*, in North America and Europe. Amer. Zool. 36:339-363.

McMahon, R.E, and C. Williams. 1984. A unique respiratory adaptation to emersion in the introduced Asian freshwater clam *Corbicula fluminea*. Physio. Zool. 57(2):274-279.

McMahon, R.E, and C. Williams. 1986. Growth, life cycle, upper thermal limit and downstream colonization rates in a natural population of the freshwater bivalve mollusk, *Corbicula fluminea*, receiving thermal effluents. American Malacological Bulletin, Special Ed. 2:231-239.

Matthews, L.J. 2007. Report on the use of quaternary ammonium disinfectants for Didygem (Didymo) disinfection. Vermont Agency of Natural Resources, Department of Environmental Conservation, Water Quality Division, Waterbury, VT.

Mathews, M.A., and R.F. McMahon. Survival of Zebra Mussels (*Dreissena polymorpha*) and Asian Clams (*Corbicula fluminea*) under extreme hypoxia. U.S. Army Corps of Engineers, Waterways Experiment Station. Technical Report EL-95-3.

Mitchell, A. J. and T.M. Brandt. 2005. Temperature tolerance of red-rim melania *Melanoides tuberculatus*, an exotic aquatic snail established in the United States. Transactions of the American Fisheries Society 134:126-131.

Mitchell, A. J. and T.M. Brandt. 2009. Use of ice-water and salt treatments to eliminate an exotic snail, the red-rim melania, from small immersible fisheries equipment. North American Journal of Fisheries Management 29(3): 823-828.

Mitchell, A. J., and R. Cole. 2008. Survival of the faucet snail after chemical disinfection, pH extremes, and heated water bath treatments, North American Journal of Fisheries Management, 28:5, 1597-1600.

Mitchell, A.J., Hobbs, M., and T.M. Brandt. 2007. The effect of chemical treatments on red-rim melania, *Melanoides tuberculata*, an exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA. North American Journal of Fisheries Management 27(4): 1287-1293.

Modovski, C. 2011. [Personal communication]. Environmental Scientist, Labat Environmental, Broken Arrow, OK.

Morse, J. 2009. Assessing the effects of application time and temperature on the efficacy of hot-water sprays to mitigate fouling by *Dreissena polymorpha* (zebra mussel Pallas). Biofouling 25(7):605-610.

Pietsch, J., Amend, D., and C. Miller.1977. Survival of infectious hematopoietic necrosis virus held under various conditions. Journal of Fisheries Research Board of Canada 34: 1360-1364.

Richards, D.C., P. O'Connell, and D.C. Shinn. 2004. Simple control method to limit the spread of the New Zealand mudsnail, *Potamopyrgus antipodarum.* American Journal of Fisheries Management 24:114-117.

Root, S., and C.M. O'Reilly. 2012. Didymo control: increasing the effectiveness of decontamination strategies and reducing spread. Fisheries 37(10): 440-448.

Schisler, G.J., Vieira, N., and P.G. Walker. 2008. Application of household disinfectants to control New Zealand mudsnails. North American Journal of Fisheries Management 28(4):1172-1176.

Spaulding S.A. and L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom *Didymosphenia geminata*. U.S. Geological Survey Open-File Report 2007-1425. USGS, Reston, Virginia.

Stockton, K.A. 2011. Methods to assess control and manage risks for two invasive mollusks in fish hatcheries. M.S. Thesis, University of Idaho.

Stockton, K.A., and C.M. Moffitt. 2013. Disinfection of three wading boot surfaces infested with New Zealand mudsnails. North American Journal of Fisheries Management 33:529-538.

Stout, J. B., Avila, B., and E. Fetherman. 2016. Efficacy of commercially available quaternary ammonium compounds for controlling New Zealand Mudsnails *Potamopyrgus antipodarum.* North American Journal of Fisheries Management 36:277–284.

USDA Forest Service. 2013. Southwest Oregon Interagency Fire Management Plan. Rogue River-Siskiyou National Forest. http://www.fs.usda.gov/detail/rogue-siskiyou/home/?cid=stelprdb5314299 [accessed 3/201].

Yanong, R., and C. Erlacher-Reid. 2012. Biosecurity in Aquaculture, Part1: An Overview. Southern Regional Aquaculture Center, SRAC Publication 4707, February 2012.

Wagner, E., Smith, M., Arndt, R., and D. Roberts. 2003. Physical and chemical effects on viability of the *Myxobolus cerebralis* triactinomyxon. Diseases of Aquatic Organisms 53: 133–142.