PREVENTING SPREAD OF AQUATIC INVASIVE ORGANISMS COMMON TO THE INTERMOUNTAIN REGION

GUIDANCE FOR *2008* FIRE OPERATIONS

The following guidelines were developed for fire personnel to help them avoid the spread of aquatic invasive species, and are a revision of the 2007 guidelines. Though no substantive changes have been made to the guidelines since last year, some clarifications and additional information have been added. Changes include: new quaternary ammonium compound shelf life and disposal recommendations; how to test the concentration of disinfectant solutions; and using quat compounds for didymo.

All documents are available on the Region 4 Aquatic Invasive Species website (http://www.fs.fed.us/r4/resources/aquatic/guidelines/index.shtml).

The aquatic invasive species considered here were selected based on their current significance in the intermountain area and do not include fish. Because of the large expanses which fire crews travel, the potential to serve as vectors for invasive species is significant. These guidelines are intended for use during the 2008 fire season and will continue to be refined and revised over time.

The table (*Aquatic Invasive Species of Concern in the Intermountain Region and Methods of Control*) outlines specific disinfection treatments for each species and the sources of information. The table serves as a reference. Included are specific recommendations for fire operations broken down by organism. For additional information, the Appendix provides background and technical information for the recommended chemicals, including supply sources for chemicals and use of swimming pool products. The spreadsheet *Technical Chemical Information for Disinfecting Aquatic Invasive Species* gives details and calculates dilutions and relative costs of various products. See the Material Safety Data Sheets at http://www.fs.fed.us/r4/resources/aquatic/guidelines/index.shtml for chemical safety precautions.

The amount of detail and technical information presented in these guidelines is necessary to document the science behind the protocols, and to keep a record of sources of information. However, in their entirety the guidelines are too complicated for practical field use. It is suggested that Forests tailor the guidelines for their own uses by extracting portions relevant to their situations and simplifying. For a good example, see "Cleaning/Sanitation of Equipment for Fire Operations—*Sawtooth National Forest*".

Below are seven guidelines that distill the information in the table and generalize the recommendations to all species:

OPERATIONS GUIDELINES

(1) Obtain maps of where aquatic invasive organisms occur in watersheds where the operation will take place. GIS coverages of individual species for most areas are accessible to biologists,

resource advisors, and fire personnel. These GIS coverages are contained in a personal geodatabase ("Invasives Database"—7.2 mb) available for download at http://www.fs.fed.us/r4/resources/aquatic/spatial_data/index.shtml. You can never be certain that invasives are NOT present, but at least you will know ahead of time where they ARE present.

(2) Avoid entering waterbodies or contacting mud and aquatic plants. Avoid transferring water between drainages or between unconnected waters within the same drainage.

(3) Avoid sucking organic and bottom material into water intakes when drafting from streams or ponds.

(4) External equipment surfaces:

(a) Prior to leaving the project site (or, if equipment has been obtained from a source where sanitizing history is unknown), power wash all accessible surfaces with clean water (and ideally, soap, as in a car wash), and completely remove all mud and organics. Weed washers are effective, and can be used to do double duty. Power washing will greatly reduce the likelihood that any target aquatic invasives are present, and chemical treatment of external surfaces is not recommended. However, New Zealand mudsnails may insert themselves in small crevices and resist flushing. Unless vehicles are driving through streams or helicopter buckets scrape up bottom sediments, snails are unlikely to get on external surfaces.

(b) Thoroughly drying equipment is an easy and effective sanitizing method for all the organisms. However, required drying times vary considerably with the species (see Table) and may not be practical for a quick turnaround. Drying may be practical, however, after the incident.

(5) Water tenders, engines, and other equipment with internal tanks:

Intake hoses, pumps, and tanks can be contaminated with infected water or through sucking the organisms (in particular, NZ mudsnails) up from the stream/pond bottom.

Disinfect tanks after the incident, and also disinfect tanks before use if equipment has an unknown sanitizing history. First, flush tanks and hoses with clean water and drain to an upland location. Flushing will reduce the concentration of organisms and lower the risk of infection. A rinse with 5% solution of *Quat128*® (6.4 oz per gal) or its equivalent (see Table and Appendix) will destroy most if not all target invasive organisms. The solution must be in contact with the surface being sanitized for at least 10 minutes.

Some forests fill a pumpkin with disinfectant and use it to fill helicopter buckets and draft into tankers. The tankers decontaminate their tanks by driving around for 15 min, and then pump the disinfectant back to the pumpkin.

Two types of chemicals are shown in the Table. Both can be effective. Liquid bleach (such as Clorox) is readily available in supermarkets but evaporates quickly and damages gaskets and canvas gear. Quaternary ammonium compounds (brand names *Quat 128*® [or 'Waxie'] and *Sparquat 256*®) need to be ordered from a supplier (see Appendix) but solutions are safe for gear and remain effective for **at least** a day if not overly diluted or muddied (see Storage and Shelf-life; and How to Test the Concentrations of Quat 128® or Sparquat 256® Solutions, in the Appendix). In addition, both bleach and quaternary ammonium compounds are available in bulk as swimming pool chemicals at reduced cost. See Appendix for details.

(6) Cleaning and sanitizing equipment as described above will be necessary before use as well as after use if equipment has been obtained from a source where sanitizing history is unknown. While operational quality control is beyond the scope of this guidance, some sort of equipment check-in system where sanitizing could be documented and guaranteed with certification or tagging would be extremely valuable.

(7) Do not dump treated water into any stream or lake, or on areas where it can migrate into any water body. Do not dispose of diluted quat chemicals in municipal sewer systems. While wastewater treatment plants can process small volumes of used quat solutions, large volumes (hundreds of gallons) of quat solutions could overwhelm a treatment facility, especially ones in small towns (Ron Cook, Spartan Chemical Co., pers. comm.).

All of these chemicals can cause permanent eye damage and skin burns. Check the MSDS's for precautions.

AQUATIC INVASIVE SPECIES OF CONCERN IN INTERMOUNTAIN REGION AND METHODS OF CONTROL						
	Whirling Disease	**New Zealand Mudsnails**	**Chytrid Fungus**	**Zebra/Quagga Mussels**	**Didymo**	**Eurasian Watermilfoil**
Sources	C.Wilson; E. Wagner UDWR Hedrick UCDavis Wagner 2002	M. Vinson, USU G. Schisler, CDOW Hosea&Findlayson 2005 Richards et al 2004	K. Hatch, BYU (Johnson et al 03)	J. Herod, FWS; Cope et al. 2003	Spaulding and Elwell, 2007 Kilroy et al. 2006 Matthews 2007	Smith&Barko 1990 Madsen&Smith 1997
Wash and remove organics (e.g. mud)	Yes	Yes	Yes	Yes, pressure wash flushes veligers	Yes	Yes
Temperature	90 °C (195 ° F);10 min	46°C (120°F); 5 min -3°C (27 °F); 1 hr	60°C (140°F);5 min	≥140°F water	60°C (140°F); 1 min	NA
Drying	Be dry for 24 h, in sunlight best	Be dry for 48 hr, in sunlight best	Be dry for 3 hr, in sunlight best	3-5 days, in sunlight best	Be dry for 48 h, in sunlight best	NA
Bleach (e.g. Clorox®) 6% sodium hypochlorite (NaClO)	For 10 min: 1% bleach solution (500 ppm NaClO) ▪Liquid oz Clorox per gallon water = 1.1 ▪Tbsp liquid Clorox per gallon water =2.2 ▪Gallons Clorox per 100 gallons water = 0.9	Not effective	For 30 sec: 20% bleach solution (>1% NaClO) ▪Liquid oz Clorox per gallon water = 22 ▪Gallons Clorox per 100 gallons water =17 OR For 10 min: 7% bleach solution (0.4% NaClO) ▪Liquid oz Clorox per gallon water = 9 ▪Gallons Clorox per 100 gallons water = 7	Gear rinsed with 0.5% bleach solution (250 ppm NaClO) ▪Liquid oz Clorox per gallon water = 0.6 ▪Tbsp liquid Clorox per gallon water =1.1 ▪Gallons Clorox per 100 gallons water =0.5	For 1 min: 2% bleach solution (800 ppm NaClO) ▪Liquid oz Clorox per gallon water =1.8 ▪Tbsp liquid Clorox per gallon water =3.6 ▪Gallons Clorox per 100 gallons water = 1.4	NA

AQUATIC INVASIVE SPECIES OF CONCERN IN INTERMOUNTAIN REGION AND METHODS OF CONTROL							
	Whirling Disease		**New Zealand Mudsnails**	**Chytrid Fungus**	**Zebra/Quagga Mussels**	**Didymo**	**Eurasian Watermilfoil**
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diecyl dimethyl ammonium chloride [DDAC])	For 10-15 minutes: (1500ppm quat compounds) *Quat128*® solution (7.7% quat compounds)		For 10 min: 4.6% *Quat128*® solution ▪Liquid oz Quat128 per gallon water = 6.4 ▪Gallons Quat 128 per 100 gallons water = 5 OR 3.1 % *Sparquat256* ® solution ▪Liquid oz Sparquat256 per gallon water = 4.3 ▪Gallons Sparquat256 per 100 gallons water = 3.4	For 30 sec: .015% *Quat128*® solution ▪Liquid oz Quat128 per gallon water =0.02 ▪ml Quat128 per gallon water= 0.6 ▪tsp Quat128 per gallon water= 1/8 ▪Cups Quat 128 per 100 gallons water = ⅓ ▪Tbsp Quat128 per 100 gallons water = 4	No data, but likely effective	For 1 min: 2% *Quat128*® solution ▪Liquid oz Quat128 per gallon water= 2.4 ▪Gallons Quat 128 per 100 gallons water = 1.9 OR 1.2% *Sparquat256* solution ▪Liquid oz Sparquat256 per gallon water =1.7oz/gal ▪Gallons Sparquat256 per 100 gallons water = 1.3 (See Matthews 2007 for support documentation)	NA
	Low Risk 4.4% *Quat128* ▪Liquid oz Quat128 per gallon water = 6.1 ▪Gallons Quat 128 per 100 gallons water = 4.8	Unknown Level of Risk 2%*Quat128* ▪Liquid oz Quat128 per gallon water = 2.4 ▪Gallons Quat 128 per 100 gallons water = 1.9					
	OR *Sparquat 256*® solution (12.5% quat compounds)						
	Low Risk 3% *Sparquat* ▪Liquid oz Sparquat256 per gallon water =4.1oz/gal ▪Gallons Sparquat256 per 100 gallons water = 3.2	Unknown Level of Risk 1.2% *Sparquat* ▪Liquid oz Sparquat256 per gallon water =1.7oz/gal ▪Gallons Sparquat256 per 100 gallons water = 1.3					

RECOMMENDATIONS					
Whirling disease	**NZ Mudsnails**	**Chytrid Fungus**	**Zebra/Quagga Mussels**	**Didymo**	**Eurasian Watermilfoil**
The principle vector for spread of whirling disease is contaminated fish parts and not typically through fire activities. Avoiding and removal of organics (the spores reside in mud), power washing, and flushing will greatly reduce or eliminate spores on external gear surfaces. However, wet internal tanks and hoses should be decontaminated with a quaternary ammonium compound, such as *Quat128*. 'Low risk' concentrations of quat compounds are backed by research. 'Unknown level of risk' dilutions are **likely** effective, but not yet proven. While 6.1 oz per gal (low risk) is required for whirling disease, a slightly higher concentration (6.4oz/gal) would also knock out NZ mudsnails.	NZ mudsnails are resistant to treatment, and may insert themselves in small crevices and resist flushing. However, unless vehicles are driving through streams, or buckets scrape bottom sediments, they are unlikely to get snails on external surfaces. Avoiding organics, power washing, flushing, and drying gear in the sun for 48 hours (if possible) will reduce risk. Wet internal tanks and hoses should be decontaminated with a quaternary ammonium compound, such as *Quat128* at a concentration of 6.4oz/gal. This concentration will also kill whirling disease spores and chytrid fungus.	Avoiding organics, power washing, flushing, and letting equipment dry in the sun for 3 hours (if possible) will reduce risk of transfer on external surfaces. However, wet internal tanks and hoses should be decontaminated with a quaternary ammonium compound, such as *Quat128*. While only 1/8 tsp per gal is required for chytrid, a higher concentration (6.4oz/gal) would also knock out whirling disease and /or NZ mudsnails.	Fire activities are unlikely to come into contact with adult mussels. However, it is possible that water used for activities or surfaces of gear may be contaminated with the microscopic veliger stage. Pressure washing and strong flushing of tanks and hoses should be sufficient to injure and remove these organisms.	Didymo is a native diatom that erupts into high densities in special habitats, such as tailwaters below dams. Avoiding contaminated water sources and organics, power washing, and flushing would likely reduce risk of transfer on fire equipment to acceptable levels. For waders, routine protocols for chytrid or whirling disease may apply for this species. Though little research is available for effectiveness of quat compounds, it is probable that the concentrations provided for *Quat128* and *Sparquat* will work. See Matthews 2007 for supportive documentation.	Watermilfoil propagates from broken stems. Avoiding organics, power washing, and flushing to ensure the removal of all plant parts will prevent transport on external and internal gear.

REFERENCES

See also "Useful Aquatic Invasive Species Literature"

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APPENDIX

ABOUT THE SOURCES OF INFORMATION USED IN THIS GUIDANCE

The methodologies and decontaminants recommended in this guidance derive from primary data sources, either peer-reviewed and published original studies, research studies that are in press or review, or in some cases, personal communication with researchers from established institutions who are currently working with a particular invasive species. Sources of information for each species are listed in the Methods of Control table (pg 3) and under References. Information was not borrowed or passed on from other protocols without first tracing it to its source of origin and assuring its validity.

USING CHLORINE BLEACH

Important note: Mixing any chlorine-containing compounds (including any form of household bleach or dry form of chlorine) with any ammonia-containing compounds (including fire retardant mixes or residues, and quaternary ammonium compounds) can lead to extreme health and safety hazards, including the release of chlorine gas.

Liquid bleaches, such as household bleach, are a 5—8% solution of sodium hypochlorite, a stabilized form of chlorine. Bleaches can be very corrosive to fabrics, plastics, rubber, and metal, and disinfectant properties will dissipate quickly when exposed to air.

Dry bleach products

Many dry forms of chlorine are available that would offer advantages for transport and storage. Products such as DryTec or CCH are granular 68% calcium hypochlorite (Arch Chemicals, Inc., manufacturer of both products, 800-478-5727). Granular calcium hypochlorite (68%) can also be ordered from GSA (NSN No. KE0472). The sanitizing active agent in liquid chlorine bleach is the chlorine (Cl^-) produced when dry bleach is added to water. The accompanying Technical Chemical Information spreadsheet shows how much dry calcium hypochlorite to mix per gallon of water to obtain the desired concentration. The spreadsheet will automatically calculate dilutions if the dry form of chlorine you purchase has a different percentage of hypochlorite (other than 68%). Just type in the percentage hypochlorite in the yellow cell.

Lithium hypochlorite is also available in dry form but provides less than half the available chlorine per volume compared to calcium hypochlorite, and is much more expensive.

Do NOT use any pools chemicals that contain something called “trichlor”, which is very commonly used as a swimming pool chlorinator. It is trichloro-s-triazinetrione, which includes cyanuric acid to extend its photostability. Following the recent retardant-sodium ferrocyanide decisions, a great deal of caution would be advised before recommending any compounds containing any form of cyanide-containing compound, regardless of its expected safety.

Similarly, do not use chemicals containing “dichlor”, or dichloro-s-triazinetrione, another member of the chlorinated iso-cyanurate family that is very commonly used in swimming pools. Caution is advised for the same reason as trichlor.

USING QUATERNARY AMMONIUM COMPOUNDS

Quaternary ammonium compounds, or 'quats', are common disinfectants with an array of uses, from killing algae in swimming pools to sanitizing workout equipment at the gym. They are relatively nontoxic and do not damage fabric, metals, or gaskets. Solutions of quat compounds retain their effectiveness over days and can be reused if not excessively diluted. These compounds exist as a family with various ratios of carbon to nitrogen and chlorine. There are hundreds, but much of research for their effectiveness against aquatic invasive species has focused so far on one of the alkyl dimethyl benzylammonium chlorides, abbreviated as ADBAC, the active ingredient in Formula 409®. Formula 409® was selected to test against whirling disease and New Zealand mudsnails because it was thought to be easy to obtain for anglers, but this household product is not practical for land management use. However, ADBAC, along with other quaternary ammonium compounds, also occurs in Quat 128®, Sparquat 256®, Bioguard Algicide®, and other commercial disinfectants.

Another quaternary ammonium compound, diecyl dimethyl ammonium chloride, or DDAC, was tested against chytrid fungus and found to be effective (see below). DDAC also occurs in Quat 128®, Sparquat 256®, and Bioguard Algicide®.

Whirling disease and quaternary ammonium compounds

The effectiveness of quaternary ammonium compounds against whirling disease spores is based on research (in review) by Ronald Hedrick of University of California—Davis. He tested the active ingredient in Formula 409® (ADBAC), and found it to efficiently kill spores in 10 minutes at a concentration of 1500 ppm. The commercial quaternary ammonium products recommended in this guidance contain ADBAC as well as other quaternary compounds which may be quite good at killing spores but that have not been tested. Hedrick (pers. comm.) assumes that the other compounds would function similarly with respect to damaging the spores and thus provide an additive effect in a mixed formulation such as Quat 128®, but because his testing was limited specifically to ADBAC, there is currently no proof that the other compounds would have the same effects as ADBAC. *Consequently, two concentrations of quaternary ammonium products are given in this guidance for whirling disease.* One ("low risk") is conservative and based only on the amount of ADBAC in the product. The other concentration ("unknown level of risk"), which is less than half the concentration of the first, assumes that all the quaternary ammonium compounds in Quat 128® or Sparquat 256® are equally effective; however, this assumption has not yet been tested.

Chytrid fungus and quaternary ammonium compounds

The quaternary ammonium compound used as the active ingredient against chytrid fungus was a different one than was tested for whirling disease. For chytrid, Johnson et al. (2003) used DDAC. Both DDAC and the compound tested for whirling disease and New Zealand mudsnails, ADBAC, occur together in Quat 128® and Sparquat 256® (Sparquat has some other quat compounds as well). Consequently, the technical information and calculations for chytrid fungus are derived from DDAC and are shown separately on the spreadsheet.

Didymo and quaternary ammonium compounds
The only evidence we have about the effectiveness of quat products for didymo decontamination comes from New Zealand's *National Institute of Water and Atmospheric Research* (NIWA). Though NIWA did not study quat compounds directly, they reference a small study that suggested that a quat compound similar to one found in Quat 128® is very effective against didymo. However, neither Quat 128® nor Sparquat 256® was tested directly. A white paper from Vermont Agency of Natural Resources (see Matthews 2007) rationalizes the probable effectiveness of quaternary ammonium compounds for didymo and proposes addition research.

Using swimming pool algicides in place of Quat 128® or Sparquat 256®
Swimming pool chemicals used to kill algae and that have the proper quaternary ammonium compounds as their active ingredients may be substituted for Quat or Sparquat at almost HALF the cost. One example of a pool chemical is BioGuard Algicide28-40®, which is 40% ADBAC, the same active ingredient found in Quat and Sparquat but at a much higher concentration. Dilution formulas for BioGuard Algicide28-40® are calculated for you on the accompanying Excel spreadsheet. If you are looking at other brands of quaternary ammonium products and want to calculate concentrations, type in the % of the active ingredient in the yellow cell under Bioguard, and the spreadsheet will automatically recalculate the dilutions and costs. Bioguard products (BioLab Inc) are available from local pool vendors and are listed at http://www.bioguard.com/msds.cfm.

As the concentration of ADBAC increases, so do the occupational health and safety hazards (irreversible eye damage, skin burns, respiratory irritation) and importance of adhering to personal protective equipment requirements when handling the concentrated product. Check the MSDS's.

How to Test the Concentrations of Quat 128® or Sparquat 256® Solutions

When a large volume of quat solution (as in a pumpkin) has been used repeatedly and possibly diluted with excess water or mud, it is possible that the solution will lose its effectiveness. One way to determine if the solution is below the proper strength is to use "Quat Chek 1000" Test Papers.
Go to http://www.fs.fed.us/r4/resources/aquatic/guidelines/testing_quat_concentrations.pdf for more information.

Storage and Shelf-Life

Sparquat 256® and Quat 128® (Waxie) can be stored at least 2 years in an unopened container without losing their effectiveness. Both should be stored in a cool, dry place, out of direct sunlight. Temperatures can range from 32 to 110 F.

Once the quat solution is made up, it can be used repeatedly for up to a week unless heavily muddied or diluted. To monitor the solution's effectiveness, use Quat Chek 1000 Test Papers (see above). Solutions kept in sealed containers, free of contamination by foreign materials,

remain more stable and can be effectively used for longer timeframes (Ron Cook, Spartan Chemical Co., personal communication).

CHEMICAL SUPPLY SOURCES

Most of the recommended chemicals are available through GSA. See the General Services Administration website, and search with the product's NSN number:
https://www.gsaadvantage.gov

Liquid household bleach
Grocery stores, prices and strength vary

Calcium Hypochlorite, Technical—68%
Arch Chemical
GSA (NSN No. KE0472) =$112 per 100lbs

Quat 128® (Waxie)
Waxie's Enterprises Inc.
GSA (NSN No. 170304) =$36 per case (4 gal)

Sparquat 256®
Spartan Chemical Company
GSA (NSN No. 102504) Sparquat 256 = $52 per case (4 gal)

BioGuard Algicide28-40®
Bioguard products (BioLab Inc) are available from local pool vendors and are listed at
http://www.thepoolteammd.com/chemicalsandcleaners.html
Price quote from Dolphin Pools, Salt Lake City (801-277-8700, Paul) = $5-6 per quart