A New Challenge for Resource Advisors: Preventing the Spread of Aquatic Invasive Species During Fire Operations

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Introduction

With the discovery of quagga mussels (*Dreissena rostriformis bugensis*) in the Lower Colorado River, United States, in January 2007, containment of spread of this notorious invasive species became a high priority for many state and federal agencies. Most of the focus was on boats, which are a widely recognized vector for spread between hydrologically disconnected water bodies. Many effective containment and control strategies have already been developed in the Great Lakes region and eastern waterways. However, the distribution of this highly invasive and destructive organism into western waters highlights a vector rarely considered by the aquatic invasive species community: wildland firefighting operations and equipment.

In the ten-year period between 2000 and 2009, 28,050,090 ha (69,313,271 acres) burned in 785,490 wildland fire incidents in the United States of America (NIFC 2010a), most of which were unplanned ignitions occurring in public lands in the western states. With potential impacts resulting from climate change, such as longer fire seasons and lower fuel moisture conditions, coupled with fuel accumulations due to a century or more of fire suppression in fire adapted ecosystems, the prognosis is for more and larger fires in many western states in the future (NWCGEB 2009). An increase in fire frequency means an increase in the number of fire incidents, leading to a greater possibility of fire operations and equipment serving as vectors. Similarly, larger fires mean more Type I (national) and Type II (national or regional) fire management organizations mobilizing over large geographic areas. Overall, an increase in fire means an increase in the opportunities for fire incident operations and equipment to spread aquatic invasive species.

Water is a key fire suppression tool. Most use of water during a fire incident is delivered aerially and by engines, hoses, etc., to either extinguish flames or to wet the fuels ahead of the flame front and curtail fire growth. There are no statistics on the amount of water used annually on wildland fires. If chemical retardants are any indication, however, the amount is substantial. For example, in 2008, nearly 21 million gallons of chemical retardant were delivered in more than 13,000 drops from helicopters and fixed-wing aircraft (USDA 2009).

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Mechanisms of invasion during fire operations

In the terminology of invasive species biology, the *reservoir* for aquatic invasive organisms is the raw water source used in firefighting operations, meaning a natural water source (e.g., river or lake), or a human-made water source (e.g., reservoir or stock tank) that has not been treated for municipal use or human consumption. It should be noted that municipal water supplies distributed via hydrants may also be used in firefighting operations, and are not considered as reservoirs of invasive species. Raw water sources serve as reservoirs that may harbor a variety of aquatic invasive species from several different taxa, including quagga mussels (*D. r. bugensis*), zebra mussels (*D. polymorpha*), New Zealand mud snails (*Potamopyrgus antipodarum*), whirling disease (*Myxobolus cerebralis*), didymo*Didymosphenia geminata*), hydrilla (*Hydrilla verticillata*), Eurasian watermilfoil (*Myriophyllum spicatum*), giant salvinia (*Salvinia molesta*), as well as many vertebrate species. In some cases, the occurrence of aquatic invasive species is well known but for many western waters such information is incomplete or nonexistent. There could also be incipient invasions that are not yet detectable by the survey or monitoring methods in use.

The *vectors* are the actual pieces of firefighting equipment that contact and/or transport raw water, such as portable pumps (including floatable pumps), portable tanks, helicopter buckets, and internal tanks of fire engines, water tenders, helicopters, and fixed wing aircraft. Typically, the components of the equipment that cannot be drained and dried completely are most likely to harbor invasive organisms, and thus serve as vectors.

The *pathways* of invasion operate on multiple scales. Within an incident, raw water is routinely moved between tertiary and sub-tertiary watersheds, and sometimes even secondary or primary watersheds (e.g., when a fire straddles the Continental Divide or the Pacific Crest). Typically, major water bodies, such as lower elevation reservoirs, serve as a primary water source to fill various types of firefighting equipment. The equipment then transports and disperses that water across the landscape directly on, or in front of, the fire. Rarely, water loads may be dropped well away from the fire when an aircraft aborts its mission and must jettison its load prior to landing. A very common tactic in many fire incidents is the use of helicopters equipped with snorkels and internal tanks or buckets to dip or draft water from raw water sources, then transport it to higher elevation areas affected by fire. In this way, infested downstream water is transported to upstream sites and dispersed across the landscape where it may enter isolated headwaters and springs, and introduce aquatic invasive organisms. While most of the water lands on the fire, vegetation, or soil, some may enter natural water sources.

The sharing of firefighting equipment between incidents provides pathways for invasion in even larger geographic areas, and particularly between primary watersheds. Most firefighting equipment is highly mobile during fire season, often being re-assigned from incident to incident, sometimes hundreds or even thousands of miles apart. The well-established interagency coordination of firefighting on federal, tribal, and sometimes state lands provides a highly efficient and effective framework to quickly move equipment and personnel where needed. A piece of equipment contaminated by AIS in the Lower Colorado River can be working on a different fire incident in the Columbia River drainage within a matter of days, or even hours. Similarly, equipment such as fire engines can be released from an incident and returned to their home unit in a different state, thus potentially bringing invasive organisms into a landscape that isn't on fire, or otherwise at risk to invasion by aquatic invasive species in firefighting equipment. Similarly, some firefighting equipment is moved around between geographic areas outside of fire incidents to provide coverage for equipment that is down for service (e.g., cover engine), or to provide extra response capability during periods of high fire danger (e.g., severity detail).

The risks posed by aquatic invasive species to utility infrastructure, ecological systems, and recreational opportunities are well documented (Nalepa, Fanslow, and Lang 2009; Schloesser et al. 2006; Vinson and Baker 2008). What is less well recognized is the risk posed to firefighting equipment. While it varies by organism and life stage, as well as by equipment design, some hard-bodied organisms, such as dreissenid mussels and New Zealand mudsnails, may foul tanks, pumps, and virtually any hard surface that doesn't drain and dry completely. If the equipment uses raw water that contains veligers, and then is not used for a few days or weeks, those veligers may mature into adults, attach to hard surfaces, and clog the plumbing even after they die, rendering the equipment inoperable when it is next used. Considering that the primary use of firefighting equipment is during emergency situations, the potential risk of inoperable equipment caused by fouling by aquatic invasive species is a concern to the firefighting community.

Preventing the spread of aquatic invasive species during fire operations

The U.S. Forest Service (USFS) Region 4 recognized this risk and first took action in early 2007 with the creation of an internal guidance document, entitled "Preventing Spread of Aquatic Invasive Organisms Common to the Intermountain Region, Technical Guidelines for Fire Operations" under the direction of Cynthia Tait. After the discovery of quagga mussels in the Lower Colorado River system, an interagency working group was formed to develop similar guidelines for use in the southwestern United States, under the direction of Brenda Smith from the U.S. Fish and Wildlife Service (USFWS). The southwestern guidelines included some of the same species as those included in the Forest Service's Intermountain Region, as well as a few additional species that are more problematic in warm and alkali southwestern waters. The southwestern guidelines also included a short "Operational Guidelines," meant to aid fire incident managers in effectively establishing protocols and decontamination processes to prevent the spread of aquatic invasive species. In 2010, the issue gained national attention with the inclusion of prevention practices in the Interagency Standards for Fire and Aviation Operations 2010 (NIFC 2010b), which serves as the primary policy implementation guidance for almost all of the federal firefighting agencies in the United States. In addition, the National Wildfire Coordinating Group was established as sub-committee to evaluate and prescribe prevention practices and engineering solutions to be used nationally (Ryan Becker, subcommittee chair, pers. comm.).

The guidelines currently in place recommend the application of sanitation solutions using quaternary ammonium compounds, commonly referred to as "quats." Quats are well known and readily available disinfectants commonly used in industrial cleaning applications, such as hospitals and schools, to kill bacteria, fungi, and viruses. Quats are marketed under several trade names, but are essentially compounds with various ratios of carbon to nitrogen and chlorine, including alkyl dimethyl benzylammonium chlorides (ADBAC) and diecyl dimethyl ammonium chloride (DDAC). When used according to the label, quats are relatively nontoxic and do not damage fabric, most metals, or gaskets (USFS 2010), which are advantages over the use of bleach solutions for disinfecting applications. A few quat products have been systematically tested on some aquatic invasive species (Hedrick et al. 2008; Johnson et al. 2003). Most notably, the effectiveness of quats had not been tested on dreissenid mussels as of 2008, when the sanitation guidelines began seeing widespread application.

In 2009, the NPS and USFWS partnered with The University of Texas at Arlington to conduct laboratory trials to evaluate the efficacy of the recommended Sparquat 256 [a molluscicide] sanitation solution in killing various life stages of quagga mussels under various concentrations and contact times (Britton and Dingman 2011). Results suggest that exposure time affects quagga mussel veliger survival, which appears to be negatively correlated. Five minutes of exposure to a 3% solution of a quaternary ammonium solution was not sufficient to kill all veligers by the end of that treatment. However, after removal from the treatment solution, 60 minutes later most, but not all, veligers had perished.

These results suggest that exposure to a 3% solution of Sparquat 256 for 5 minutes is insufficient for a complete kill, but that 10 minute exposure to 3% Sparquat 256 is sufficient to kill quagga veligers, at least on a small scale under laboratory conditions (e.g., ambient temperature near 22 °C). However, time is required post treatment for the quaternary ammonium solution to work, and 10 minutes may approach the minimum time necessary for a complete kill. Although this research supports the idea that existing decontamination procedures using quaternary ammonium solutions should be effective, this laboratory analysis suggests that the prescribed dosage and/or treatment duration may not be leave much room for error.

More research is needed to incorporate a rigorous survival analysis. Such a study should include zebra mussel veligers as well as quagga mussels veligers, as there may be subtle difference in tolerance to quaternary ammonium solutions. Additionally, quaternary ammonium solutions other than Sparquat 256 should be tested to ensure that others are equally effective. Experiments should also be conducted under a range of temperatures conditions that might be encountered in a wildland fire setting to account for any differences caused by thermal tolerance of the veligers, or temperature effects in quaternary ammonium solutions.

In the interim, fire incident resource advisors should be aware of the potential for spread of aquatic invasive organisms during fire operations and, where possible, incorporate measures to either avoid the potential for spread, or sanitize equipment exposed to raw water prior to demobilization. Additional information and "how to" guidelines are available at www.fs.fed.us/r4/resources/aquatic.

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