QUAGGA AND ZEBRA MUSSEL ERADICATION AND CONTROL TACTICS

2. MANUAL & MECHANICAL REMOVAL

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This series of information sheets is provided for educational purposes only. It is intended to provide a general overview of what is required for implementing tactics to eradicate and control aquatic invasive species (AIS). Although prevention is the best approach, it also is important to be prepared to respond quickly to new infestations and to reduce risks posed by existing infestations. No work should be conducted without first consulting the California Department of Fish and Wildlife (formerly California Department of Fish and Game) and the Regional Water Quality Control Board or, if in another state, the lead local resource management and water quality agencies for the AIS you are interested in managing. Consult the California Department of Pesticide Regulation or corresponding agency in another state before applying chemical tactics.

TACTIC

Mechanical tactics include manual removal of a pest, with or without the aid of mechanical equipment. These tactics are low on the Integrated Pest Management (IPM) pyramid and are often included in IPM strategies because they are fairly benign, typically having limited environmental impacts. For quagga and zebra mussels, they target the attached juvenile and adult life stages (Fig. 2-1). Juvenile and adult mussels are removed by hand-held tools or machine (mechanical suction, hydroblasting) to reduce the number of mussels currently, or soon to be, producing larvae. Proper disposal of removed mussels is important.

WHEN TO USE TACTIC

Figure 2-1. Quagga mussel attached to hard substrate by byssal threads. *Photo Credit:* Carolynn Culver

Removal, either by hand or another mechanical method, can potentially eradicate dreissenid mussels when 1) the structure from which mussels are being removed lends itself to this technique, and 2) when mussels are concentrated within specific areas of a water body or on particular infrastructure within it. Mussel populations *can* successfully be eradicated using this strategy only if 1) no additional larval or juvenile/adult mussels are entering the water body from infested waters (aqueduct or reservoir) and/or boat traffic, and 2) if enough mussels are removed to reach the point where the population can no longer sustain itself. Achieving the latter can be difficult, due to the mussels' ability to inhabit hard-to-reach places, limiting removal efforts and increasing chances that individuals will remain at the site. Where there are many hard-to-reach areas, a combination of tactics will likely be most effective.

Even when eradication is not possible, this strategy offers an effective method for *controlling* the population when applied appropriately, and when used in combination with other control tactics. For

example, the effectiveness of this management strategy can be enhanced by taking an IPM approach, in which this tactic that targets adults and juveniles is combined with one that targets the larval stage. Likewise, if the infested area is large (>20,000 square feet),[1] a combination of oxygen deprivation using tarps (see Oxygen Deprivation information sheet) and manual/mechanical removal may be useful. Manual removal by hand is being used to control a zebra mussel population in New York and was also used to eradicate an ocean pest from an intertidal area in California (see "Success Stories").

STEPS TO BE TAKEN

Prior to Discovering a New Mussel Infestation and/or Implementing Tactic

The following steps can be taken to reduce the time required to implement this tactic.

1. **Organize Divers.** Identify and get appropriate clearance for using dive staff or local dive groups to implement manual and mechanical removal of mussels. Many groups may be able to assist you with removing mussels either by hand or with mechanical equipment (see below). Take time **now** to determine group(s) that may be able to help you and work with your administrators to lay the foundation for necessary clearance for their access and activities. This is particularly important for those managing water bodies that do not have divers on staff and that do not allow swimming or SCUBA diving under normal circumstances. Take time to consider the trade-off between having fewer ***hired*** divers versus having higher numbers of ***volunteer*** divers. Hired divers will likely be more efficient due to their professional skills and experience, but they may increase the overall cost of the project. Volunteer divers may lower the costs, but increase concerns about liability and the number of people entering the lake/reservoir.

Potential Dive Groups

Divers from these groups at a minimum hold a SCUBA certification from an accredited SCUBA organization (PADI, SSI, NAUI). At least one team of divers should hold a technical dive certification and have experience *working* underwater, as do many divers with dive tech school certifications and university and agency research diver certifications (American Academy of Underwater Sciences [AAUS]), or commercial diver associations with professional accreditation. If using mechanical equipment such as a suction pump for removal, have the divers demonstrate skill in using the apparatus (some research and commercial divers may be familiar with these techniques).

- Regional lakes with trained divers on staff
- AAUS (typically university divers)
- Scientific Diving International (SCIDI) (trains divers for scientific research)
- Agency research divers (e.g., Department of Fish and Wildlife, National Park Service)
- Association of Diving Contractors International (ADCI) members
- California Professional Divers Association (CPDA)
- Professional divers, Chamber of Commerce (certified divers listed by region)
- Community dive clubs[2] (e.g., Reef Check California Divers)

2. **Train Divers.** Have divers complete training in mussel detection, monitoring and removal techniques to ensure that effective, efficient and consistent removal practices, including collection and disposal protocols, are used. Hands-on, in-water training sessions held at locations where small (<12 mm or <1/2 inch) mussels already occur will be most beneficial.

   Even if mussels have not been detected at a water body, managers will benefit from holding annual diver training sessions to prepare divers for potential rapid response activities. Lake managers within a region may find it effective to collaborate and coordinate such trainings.

Figure 2-2. Early detection and monitoring training using touch to find small mussels. Lake Murray, San Diego County, CA. *Photo Credit:* Jodi Cassell

Early Detection & Monitoring Training

Mussel detection techniques include visual and tactile surveys (Fig. 2-2).[3,4] Trainings in early detection and monitoring of quagga and zebra mussels have been conducted in California by the U.S. Fish and Wildlife Service in collaboration with the California Sea Grant Extension Program and the California Department of Fish and Wildlife (CDFW).

Implementing Tactic

1. **Determine Distribution of Mussels.** Have trained divers complete a presence/absence survey of high-risk areas including marinas, boat launches, retaining walls, docks and other submerged structures to determine the extent of the infestation and locate "hot spots" (heavily infested areas). In areas where mussels are found, have divers conduct more detailed surveys to determine how far out the infestation radiates from the spot. For more information and assistance with conducting diver surveys contact the CDFW.

2. **Conduct Pre-Implementation Survey.** Consult with agency or university biologists to develop pre- and post-surveys as part of a monitoring program. These surveys are necessary for a before-and-after comparison of the effects of the tactic on mussels and selected indicator species. Have trained divers and staff conduct both visual and tactile underwater dive or remotely operated vehicle (ROV) surveys and deploy artificial monitoring substrates.

3. **Prepare Target Site.** Have divers mark off the treatment area with nylon lines. Transects or gridlines can be installed and are useful guides to ensure mussels are removed from the entire target area, and for delineating the pre-implementation survey area.

4. **Manually Remove Mussels using Hand-Held Tools.** Divers can detach mussels individually using tools such as paint scrapers, screwdrivers, chisels and dull knives (Fig. 2-3). Tools with straps (leashes) that attach to a diver's wrist to prevent tools from being dropped or lost are best. Brightly colored tools are useful in murky conditions as they are easier to see. In some cases it may be easier to remove objects (e.g., small rocks, plants) that are infested with mussels,

instead of removing the mussels from the object. However, this may not be permitted depending on the object and the water body; determine regulations regarding removal of plants or other materials when making a plan. Be sure to have divers remove mussels from cracks and crevices, not just easy-to-reach flat surfaces.

5. **Collect Removed Mussels.** It is essential to have divers collect removed mussels and not allow them to fall to the bottom of the lake, particularly in well-oxygenated waters. Dreissenid mussels can detach from their byssal-thread attachment and relocate, particularly when young. Any mussels dislodged by mechanical action or collection by hand can easily survive and re-attach if environmental conditions are suitable. Removing mussels also eliminates the chance that survivors will release larvae into the water body. Furthermore, removing the shells reduces the surface area available for new mussels to infest, as well as minimizing the danger that sharp shells pose to swimmers and fishing gear.

Figure 2-3. Examples of hand-held tools, some brightly colored and with leashes, useful for removing mussels from hard-to-reach places. Dive collection mesh bag useful for holding tools and for collecting removed animals. *Photo Credit:* Carolynn Culver

Manual Collection

Mussels can be manually collected as they are being removed by placing them into fine-mesh collection bags (e.g., paint strainer bags or dive collection bags) or plastic bags with easy closing mechanisms (e.g., zipper sealable plastic bags). It is best to use collection bags that can contain the smallest of mussels. To keep plastic bags from floating away, small rocks can be placed inside to weigh them down. This is not necessary for mesh bags as they will sink when wet. Mesh dive collection bags are also useful for holding tools.

Mechanical Collection through Suction

To reduce the effort required to collect mussels by hand, divers can use a simple suction pump made from PVC and connected to a SCUBA tank to continuously vacuum the detached mussels into collection bags (Fig. 2-4). One diver detaches the mussels using scrapers and other hand-held tools, while the other diver uses the suction pump to collect the detached mussels. For heavier mussel infestations, divers can use a surface-supplied air source for the pump and larger collection bags. Venturi dredges are another mechanical device to consider, especially for removal of mussels in very shallow water. These devices are powered by a portable gasoline engine that is placed on a boat or dock and connected to the suction equipment. Collection bags need to be added to the device to contain the suctioned material (mussels). Consider working together with other lake managers in your region to identify, set up, use and share mechanical suction equipment.

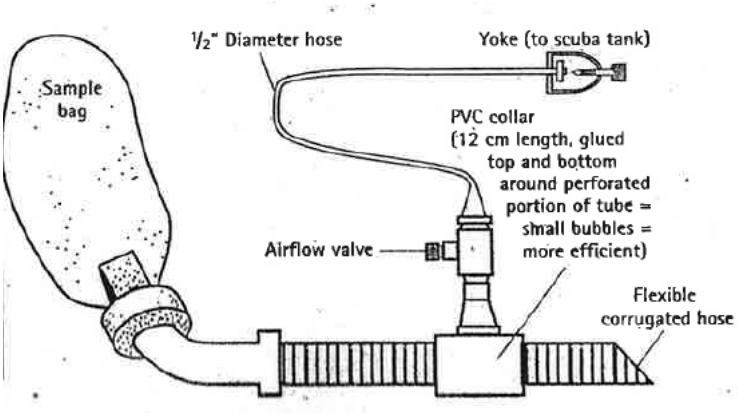

Figure 2-4. Suction pump diagram from *The Underwater Catalog: A Guide to Methods in Underwater Research* by Coyer, J., D.L. Steller and J. Witman. Third Edition, 2012. Shoals Marine Laboratory, Ithaca, NY.

Hydroblasting

Using high-pressure water guns to detach mussels from infrastructure is an option only when the detached mussels will sink into deeper water with extremely low oxygen (dissolved oxygen ≤2 milligrams per liter [mg/L]). As such, you will need to know the dissolved oxygen content of the water column in the water body if considering this method. Mussels should be detached when the low oxygen condition persists for at least one month (the amount of time a mussel can stay alive with little to no oxygen). Note: if this method is used repeatedly, the large amount of decomposing mussels may impact water quality.

6. **Dispose of Removed Mussels.** *Prior to disposing of any mussels, contact the CDFW to determine whether a disposal permit is required.* After mussels have been removed, have personnel kill the mussels as quickly as possible and then dispose of them in accordance with CDFW requirements. Disposing of mussels before they are dead may lead to the spread of this invasive species. Removed mussels taken out of water can close their shells and remain alive for up to a month, depending on environmental conditions. Thus, it is best to put removed mussels in bags and freeze them for at least 24 hours before disposing of them. Hot water also can be used to kill the mussels by exposing them to temperatures over 40°C/104°F. For large amounts of mussels that do not readily fit into a freezer and where hot water is not available, desiccation is an option. However, to eliminate spread of mussels by other animals (e.g., raccoons, rats), be sure to desiccate the mussels in a *closed or protected* location. Hot, dry conditions will speed desiccation. Follow CDFW requirements when disposing of frozen or desiccated mussels.

7. **Decontaminate Persons and Gear.** Be sure divers and boat operators decontaminate themselves and their gear in order to minimize the possibility of transferring live mussel larvae, juveniles or adults to other water bodies. Consider following the CDFW decontamination protocol before leaving the water body. Or, review the Hazard Analysis and Critical Control Point (HACCP) planning guidelines by the U.S. Fish and Wildlife Service, which aim to reduce or eliminate the spread of undesirable species through proper planning.[5]

8. **Evaluate Tactic Success.** Have staff conduct follow-up surveys (e.g., diver, remotely operated vehicle [ROV], substrate sampling) to evaluate the effectiveness of the removal efforts. During the first year of the project, these surveys should be conducted frequently (quarterly at a minimum) to measure the initial effectiveness of the effort. **If eradication was the goal,**

frequent assessments are critical and will allow rapid follow-up measures to be implemented as needed. If the eradication effort appears to be successful after one year, surveys can then be conducted less frequently but at least once a year. Annual surveys are essential for determining the long-term success of the effort, as it is difficult to detect low infestations of a pest. Be sure to budget for and conduct surveys for 5 to 10 years. **If control was the goal,** continual monitoring will help determine how long the tactic remains effective and thus how often it will need to be reapplied. Consider using a third-party agency or university biologist when designing and conducting surveys to validate the scientific design and findings.

SAFETY

Proper safety precautions are essential when conducting any eradication or control tactic. We support these and other recommendations covered in the National Park Service Quagga/Zebra Mussel Infestation Prevention and Response Planning Guide:

1) No work should be started unless appropriate safety controls are in place;
2) Have a safety professional review your implementation plan; and
3) Make sure employees are properly trained, well-rested and alerted to hazards before starting.

Dive Safety Plan

Anyone involved in the project (divers, volunteers, dive support staff, biologists, etc.) must know all natural and man-made hazards or potential hazards in the area where they will be working (e.g., intake structures, nearby energized equipment, boat traffic). They must also be trained in and follow all applicable Occupational Safety and Health Administration (OSHA) and industry safety requirements and guidelines that can be found on the ADCI website. If volunteer divers are involved, the project manager and lead diver must brief them on potential risks and safety issues. Liability waivers may also be required in some situations.

COSTS TO CONSIDER

Many costs are associated with implementing this mechanical eradication and control tactic. The following list highlights some of the primary equipment and staffing needs, along with some additional expenses that may be incurred when using this tactic.

Equipment

- SCUBA gear, including gloves and flashlight or headlamp
- Steel rebar and nylon lines (for marking the treatment area)
- Dive bags (for holding tools and collecting removed mussels)
- Mussel collection bags (sealable plastic bags, fine-mesh bags)
- Tools (e.g., paint scraper, screwdriver, chisel, dull knife)
- Straps/clips to attach tools and bags to diver
- Extra SCUBA tank and associated gear, if using underwater suction pump
- Venturi dredge and associated engine and gasoline, if using this system

Staffing (Technical/Volunteer)

- At least 3 trained SCUBA divers (volunteers or paid staff), and additional volunteers trained in mussel removal
- Boat operator (depending on location of mussels)
- Volunteers for above-water support to handle removed mussels, record specific locations of mussel populations, assist with other field tasks
- Third party agency or university biologist to assist with survey design and to validate results

Additional Costs to Consider

- Follow-up surveys (water sample collection and analyses; substrate sampling and monitoring)
- Permits (see Permitting and Regulatory Processes information sheet)
- Public outreach materials
- Signage (closure signs, information signs)
- Lost revenue due to closures (if implemented)

SUCCESS STORIES

Lake George, NY

In the spring of 2000 at Lake George in New York, divers removed more than 19,000 juvenile and adult zebra mussels by hand. This effort significantly reduced the population of mussels and prevented an irrevocable invasion, despite the initial establishment. While less than 20 remnant mussels per year have been found and removed from 2008 to 2011, no new small (<27 mm) mussels have been detected in that time period, indicating the population is no longer self-sustaining.[6,7] Surveying and monitoring continue. Environmental conditions likely helped restrict the distribution of mussels in the lake, facilitating control efforts. Over time, this effort may prove to be a successful eradication effort if the population is no longer self-sustaining and dies off completely.

Cayucos, CA

In the 1990s, a similar effort occurred for a non-native ocean sabellid, polychaete worm that had infested snails and cultured abalone in South-central California. By removing 1.6 million host snails by hand and applying other tactics prior to and after the removal, the pest population was reduced and eventually eliminated. The program was deemed successful following 9 years (2001-2009) of post-removal surveys without detecting new or old pest infestations. [8,9] This program is an example of an IPM strategy that used multiple tactics and targeted all pest life stages.

CITED WEB LINKS

Association of Diving Contractors International (ADCI) - http://www.adc-int.org/
California Department of Fish and Wildlife d http://www.dfg.ca.gov/invasives/quaggamussel/
California Professional Divers Association - prodivers.org
Community dive clubs d www.gooddive.com
Decontamination protocol d http://www.dfg.ca.gov/invasives/quaggamussel/
Diver surveys d http://pubs.usgs.gov/of/2010/1308/

Early Detection Monitoring Manual for Quagga and Zebra Mussels - http://ca-sgep.ucsd.edu/focus-areas/healthy-coastal-marine-ecosystems/quaggazebra-mussel-monitoring
Hazard Analysis and Critical Control Point (HACCP) planning guidelines - http://training.fws.gov/EC/Resources/pdf/HACCP%20Manual.pdf
National Park Service Quagga/Zebra Mussel Infestation Prevention and Response Planning Guide - http://home.nps.gov/applications/digest/headline.cfm?type=Announcements&id=5488&urlarea=npsnews
OSHA - http://www.osha.gov/SLTC/commercialdiving/index.html
Professional divers, Chamber of Commerce (certified divers listed by region) - http://www.chamberofcommerce.com/california/professional-divers/
Quagga and Zebra Mussel Eradication and Control Workshop – http://ca-sgep.ucsd.edu/quaggazebra_mussel_control/new_workshop
Reef Check - http://www.reefcheck.org/
Scientific Diving International - http://www.scientificdivinginternational.com
U.S. Fish and Wildlife Service -http://www.fws.gov/stockton/ais/Species%20of%20Interest/Quagga_Zebra_mussels.html
100th Meridian - http://www.100thmeridian.org/

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[1] Area determined from an experiment conducted in Lake George, NY. Personal communication, Dr. Sandra Nierzwicki-Bauer, Darrin Fresh Water Institute, August 25, 2011.

[2] These groups will not have the same level of training as professional groups, but may be helpful in initial surveys.

[3] The Early Detection Monitoring Manual for Quagga and Zebra Mussels is available through the California Sea Grant Program. A 50% discount on the purchase price is available for multiple (5 or more) copies.

[4] Additional information also is available from the following websites: 100th Meridian, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife

[5] HACCP training is available from the U.S. Fish and Wildlife Service at the National Conservation Training Center.

[6] Wimbush, J., M. Frischer, J. Zarzynski and S. Nierzwicki-Bauer. 2009. Eradication of colonizing populations of zebra mussels *(Dreissena polymorpha)* by early detection and SCUBA removal: Lake George, NY. *Aquatic Conservation: Marine and Freshwater Ecosystems.* Vol. 19: 703-713.

[7] Nierzwicki-Bauer, S.A., J. Wimbush, M.E. Frischer, and J.W. Zarzynski. 2012. Eradication of colonizing populations of zebra mussels *(Dreissena polymorpha*) by early detection and SCUBA removal: Lake George, NY. Quagga and Zebra Mussel Eradication and Control Workshop. Presenter Abstracts.

[8] Culver, C.S. and A.M. Kuris. 2000. The apparent eradication of a locally established introduced marine pest. *Biological Invasions*. Vol. 2: 245-253.

[9] Personal communication, Dr. Jim Moore, California Department of Fish and Wildlife, November 20, 2012.

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http://ca-sgep.ucsd.edu/quaggazebra_mussel_control