Quagga and Zebra Mussel Eradication and Control Tactics

Authors:
Carolynn Culver, California Sea Grant Aquatic Resources Specialist, University of California
Heather Lahr, California Sea Grant Research Assistant, University of California
Leigh Johnson, Coastal Resources Advisor, University of California ANR, Cooperative Extension
Jodi Cassell, Natural Resources Advisor, University of California ANR, Cooperative Extension

California Sea Grant Report No. T-076
UCCE-SD Technical Report No. 2013-1

Cover Photos & Design by Gillian Clague, Heather Lahr and Carolynn Culver: Mussels infesting rocks and aquatic vegetation with some surfaces exposed after a water draw-down. Inset: Close-up of mussels attached to a branch of vegetation. El Capitan Reservoir, San Diego County, CA.

Technical Report compiled by Gillian Clague, California Sea Grant Extension and Michelle Lande, University of California Agriculture and Natural Resources, Cooperative Extension.

Acknowledgements
We gratefully acknowledge the following people and organizations for providing information and/or review of this educational material.

- Lars Anderson, USDA Agricultural Research Service, University of California, Davis
- Steve Chavoya, Cachuma Lake, County of Santa Barbara, Community Services Department
- Dan Daft, City of San Diego, Public Utilities Department
- Susan Ellis, California Department of Fish & Wildlife
- Ray Fernald, Virginia Department of Game and Inland Fisheries
- Joann Furse, California Sea Grant
- Liz Gaspar, Cachuma Lake, County of Santa Barbara, Community Services Department
- Marsha Gear, California Sea Grant
- Mark Hatcher, Sweetwater Authority
- Cathy Karp, United States Bureau of Reclamation
- Kevin Kidd-Tackaberry, City of San Diego, Public Utilities Department
- Jennifer LaBay, California Department of Fish & Wildlife
- Carrie Link, Marrone Bio Innovations
- Louanne McMartin, U.S. Fish and Wildlife Service
- Sandra Nierzwicki-Bauer, Darrin Fresh Water Institute, Rensselaer Polytechnic Institute
- Dominique Norton, California Department of Fish & Wildlife
- Dave Roberts, Marrone Bio Innovations
- Ron Smith, U.S. Fish and Wildlife Service
- Patrick Stone, Tahoe Regional Planning Agency
- Daniel Sussman, Lahontan Regional Water Quality Control Board
- Ted Thayer, Tahoe Regional Planning Agency
- Jonathan Thompson, U.S. Fish and Wildlife Service
- Martha Volkoff, California Department of Fish & Wildlife
- Brian Watson, Virginia Department of Game and Inland Fisheries

Sponsors This educational material was supported in part by the National Sea Grant, Aquatic Invasive Species Initiative, Project No. NA2233-C; California Sea Grant, NOAA Grant No. NA100AR4170060; University of California Agriculture and Natural Resources; University of California Cooperative Extension; County of San Diego; and the Marine Science Institute, University of California, Santa Barbara. The statements in this technical report are those of the authors and not necessarily those of the sponsors or reviewers. The mention of consultants or commercial products, their source, or their use in connection with material reported herein, is not to be construed as actual or implied endorsement.

Carolynn Culver, California Sea Grant Aquatic Resources Specialist, University of California
Heather Lahr, California Sea Grant Research Assistant, University of California
Leigh Johnson, Coastal Resources Advisor, University of California ANR, Cooperative Extension
Jodi Cassell, Natural Resources Advisor, University of California ANR, Cooperative Extension

California Sea Grant College Program Report No. T-076/UCCE-SD Technical Report No. 2013-1

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

1. INTRODUCTION

This technical report 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.

OVERVIEW

This technical report is a compilation of six information sheets that have been developed to help managers of water bodies prepare for and implement eradication and control tactics for quagga and zebra mussels in lakes, reservoirs and irrigation canals. Others have developed information for controlling mussel infestations in water and power facilities, including intake lines, trash racks and other infrastructure. Here, we complement facilities-based information by addressing eradication and control of *source populations* of mussels residing in water bodies (Fig. 1-1). In this information sheet we discuss 1) the concept of eradicating a pest population versus controlling it, 2) the importance of being proactive against aquatic pests, and 3) how using an integrated pest management strategy can greatly increase the success of eradication and control efforts. Also included are some tips on getting started, along with website links to additional resources. (Note: websites are hyperlinked within the text as well as cited in full at the end of each information sheet).

The other five information sheets compiled in this technical report address:

- Manual & Mechanical Removal (pp. 6-13)
- Oxygen Deprivation (pp. 14-19)
- Chemical Application (pp. 20-25)
- Emerging Technologies (pp. 26-28)
- Permitting & Regulatory Processes (pp. 29-34)

While this technical report is focused on eradication and control of quagga and zebra mussels specifically, the information is broadly applicable to all types of aquatic pests. Invasive freshwater mussels serve as a model to illustrate general concepts and specific steps required for taking action against AIS.

Figure 1-1. Mussel infestation exposed on rocks after a water draw-down. El Capitan Reservoir, San Diego County, CA.
Photo Credit: Carolynn Culver

ERADICATION VS CONTROL: WHAT IS THE GOAL?

Once an established pest population has been detected, management actions are needed to reduce impacts on the system and to minimize the chance that it will spread to other systems. Defining the ***goal*** of the eradication or control action is an important first step. Depending on the situation, you may

only be able to achieve control rather than complete eradication. This should be considered when developing a management strategy.

Eradication

Eradication is the complete elimination of a pest population. Although eradication of aquatic pest populations has proven difficult, success stories exist for various species. In general, eradication has been achieved when a pest population has been contained within a fairly small area, allowing for targeted eradication efforts.

Such efforts require that the population be reduced to a point where it can no longer sustain itself. Because it is extremely difficult to know exactly how many individuals from a pest population will need to be removed before the population collapses, it is recommended that as many individuals as possible be eliminated. Often this requires applying eradication tactics not only to those areas where you can readily see the individual pests, but also to areas where the pests may occur that are difficult to access or see (e.g., in rocky crevices among riprap). Given the difficulty of completely eliminating a pest population, continuing surveys over many years is an essential component of an eradication effort. This is required to ensure that no pests remain and no new larvae are being produced.

In Southern California, quagga mussel larvae are continually entering many water bodies via the Colorado River Aqueduct. As a result, at this point in time eradication of quagga mussels is not possible at such locations unless incoming water can be effectively treated to eliminate larvae. Despite this, proactive control measures are still necessary and important. Effort will not be wasted if a control strategy takes into account the inflow of larvae. While directly reducing the source of larvae may be difficult, timing the implementation of control tactics, based on when larvae are entering and settling in the system, will greatly improve chances of control.

Control

When eradication is not feasible, control measures can be implemented. Control means reducing the pest population and containing it at as low a level as possible. By implementing control tactics the economic and environmental impacts can be significantly reduced. As with eradication efforts, careful consideration of the pest's life cycle and other species in the system is required when developing a control strategy.

Developing a Management Strategy

Proactive Approach

A proactive approach can greatly enhance the ability to manage an aquatic invasion. Preventative measures are an important first step and are in use at many locations. However, aquatic pests have continued to spread, despite sound prevention programs. Proactive measures that address newly detected and established pest populations are critical components of a successful management strategy. Many steps can be taken prior to detecting an aquatic pest to improve the chances of successfully eradicating or controlling it. The first step is to develop a carefully thought-out management strategy that fits the situation.

Integrated Pest Management

We recommend using the Integrated Pest Management (IPM) approach when developing a management strategy for AIS. IPM has long been used to manage pests in agriculture and buildings and it is the framework used for this series of information sheets. In general, IPM calls for management ***strategies*** that use a combination of ***tactics***, such as physical, mechanical, biological, chemical and cultural, to target one or more life stages of the pest. As illustrated in the IPM pyramid (Fig. 1-2), the approach requires using more benign tactics whenever possible (bottom of pyramid). The most toxic tactics (chemical, top of pyramid) are used sparingly to reduce impacts on the environment and human health. Good record-keeping, ongoing evaluation of the success of implemented tactics, and replacing, supplementing or modifying them as needed are also critical components of an IPM strategy.

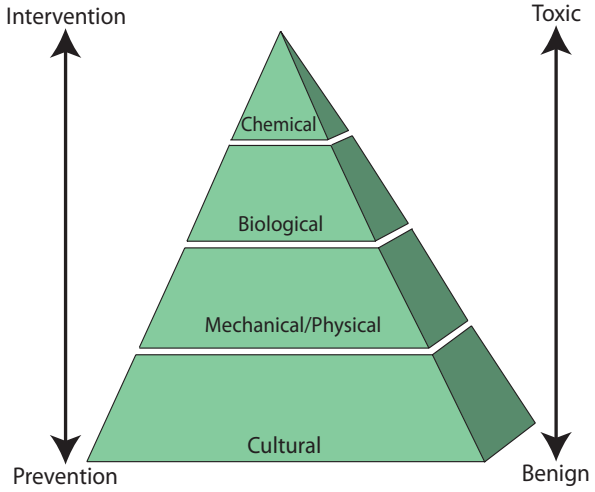

Figure 1-2. Pyramid of Integrated Pest Management (IPM) Tactics. Pennsylvania State University. 2012. IPM-Pyramid of Tactics

We highly recommend developing a carefully thought-out IPM strategy[1] regardless of whether an aquatic pest that requires management actions has been detected in the water body. By evaluating potential tactics and how they can be combined, managers will be able to identify next steps and ways to prepare for implementing eradication and control tactics. Begin by considering 1) the pest's life cycle, 2) location and status of the infestation, 3) presence of other species, and 4) feasibility of eradication/ control tactics given the situation. For pests of concern that are not yet present, consider the most likely point of entry and establishment. If the pest is already established, consider areas where it is highly abundant and develop a plan that includes details of how to implement eradication/control strategies. Consider employing more than one tactic to target more than one life stage of the pest. The other information sheets can help with identifying and evaluating potential tactics.

Management Plan Tips

1. Timing is important. Haphazard pest removal efforts can be detrimental, leading to further spread and increased densities of the pest. That is, doing "*something*" can be worse than doing nothing. For example, efforts to remove Asian kelp, *Undaria pinnatifida*, are believed to have spread the invasive seaweed because it was removed when it was actively reproducing (releasing spores). This example illustrates how the timing of eradication and control efforts is extremely important, requiring knowledge of the pest's biological characteristics.

2. Act when the population is small. Instead of waiting to see what "might" happen, consider taking action while the population is small. For example, in some cases newly detected pest populations may appear to be contained and not increasing in number. Waiting to see whether they will increase may prove to be very costly in the long run. Such costs can be avoided if simple actions are taken while the population is small. In other cases, a pest population may be cyclic, increasing quickly to high numbers

("boom") followed by a rapid decline ("bust") in the population. The population is vulnerable during the "bust" phase. Thus, consider implementing simple eradication/control measures during this phase when the pest population is small by targeting areas with high concentrations of the pest. Doing so can vastly reduce chances that the pest will be able to increase and reach high densities ("boom") again.

RAPID RESPONSE PLANS

Once mussels have been detected in a California water body, managers are required by the California Department of Fish and Wildlife (formerly California Department of Fish and Game) to submit a rapid response plan (sometimes called "Response Plans"). These are comprehensive documents that discuss which and how eradication/control tactics will be launched, communication systems, and other administrative details associated with managing the incident. Various agencies have developed rapid response plans that can be used as templates to assist managers with their own plans including:

- Quagga/Zebra Mussel Infestation Prevention and Response Planning Guide
- Bay Delta Rapid Response Plan For Dreissenid Mussels
- The Columbia River Basin Interagency Invasive Species Response Plan

This series of information sheets can be useful in preparing and implementing a rapid response plan. They are step-by-step resource guides for considering which eradication and control tactics are best suited for a situation. They also contain tips for organizing resources needed for implementing various actions.

GETTING STARTED

Developing an IPM strategy and implementing eradication/control tactics can be daunting. The additional sheets in this series include steps that can be taken **now**, whether or not the water body you oversee has become infested. Listed below are some activities that may be helpful before and during the implementation process (in no particular order). This list was partially created by participants in the *Quagga and Zebra Mussel Eradication and Control Workshop*, held in San Diego, CA in February 2012. It reflects on-the-ground advice from people who have dealt with, or are currently preparing to deal with, quagga and zebra mussels and other invasive species.

- Develop a matrix of eradication and control options and what can/cannot work in specific areas.
  - Develop an "expert" network of people with experience in eradication and control of AIS and specific tactics of interest.
  - Look at existing cases where the tactics have been implemented.
  - Identify potential detrimental effects—ecological impacts to nontarget species, impacts on humans and recreation.
- Identify a timeline for implementing specific tactics.
  - Consider the need for partial or total lake closure during eradication/control efforts.
- Do a pilot study or dry run prior to implementing the strategy.
- Assess the situation. Determine the pest source (if possible), density and distribution of the pest, affected habitats, and water fluctuation patterns (seasonal and draw-down schedules).
- Develop a budget, including costs for continued monitoring (see general costs outlined in specific tactic information sheets).

- Identify and coordinate with appropriate agencies.
- Develop an action team and associated member tasks.
  - Form a working group to handle permit issues.
  - Designate a spokesperson.
- Get buy-in from local government, stakeholders and public.
  - Identify persons who may be able to help with permitting and funding.
  - Reach out to key representatives of fishing clubs.
    - Will help get the word out to other members.
    - May help with lobbying for funding.

POTENTIAL FUNDING SOURCES

Managing AIS is costly, and funding or in-kind support will undoubtedly help with securing necessary equipment or staff. When searching for funding it is important to consider industries and federal agencies, as well as state, regional, and local governments likely to be adversely impacted by the presence of invasive mussels or other aquatic species. By determining who will be most economically impacted you may identify partners who could provide financial or in-kind support for eradication and control efforts. Ongoing legislative efforts, such as the California bill AB2443 passed in 2012, which increases vessel registration fees to help fund preventative measures, may provide additional funding support. The following sources also may be useful.

- Grants
  - State/federal education and research grants
  - Local Fish and Wildlife Fines Committee grants
  - Corporate sponsorship/grants (e.g., Patagonia™ , Bass Pro Shops™)
  - Local nonprofit organizations and foundations that have an interest in fresh water resources, community development, watershed protection
- Donations from stakeholders
- Fees and/or fines
  - Raising usage rates, boat launching fees, and water rates, and adding the increased revenue to the maintenance budget for use in AIS control
  - Citation and violation fines (if mussels are found)
- In-kind resources (e.g., staff or equipment from other organizations, volunteers)

CITED WEB LINKS

Bay Delta Rapid Response Plan For Dreissenid Mussels - http://www.dfg.ca.gov/invasives/quaggamussel/
California Department of Fish and Wildlife (Guidance Documents) - http://www.dfg.ca.gov/invasives/quaggamussel/
Columbia River Basin Interagency Invasive Species Response Plan - http://100thmeridian.org/ActionTeams/Columbia/CRB%20Dreissenid%20Rapid%20Response%20Plan%20OCTOBER%201%202008.pdf
IPM (Pyramid of Tactics) - http://extension.psu.edu/ipm/schools/educators/elementary/pyramid/homepyramid/
Quagga and Zebra Mussel Eradication and Control Workshop – http://ca-sgep.ucsd.edu/quaggazebra_mussel_control/new_workshop
Quagga/Zebra Mussel Infestation Prevention and Response Planning Guide - http://nature.nps.gov/biology/Quagga/index.cfm

[1] De Leon, Ricardo, William Taylor and Paul A. Rochelle. 2012. Management of invasive quagga mussels in a large water supply system. Quagga and Zebra Mussel Eradication and Control Workshop. Presenter Abstracts.

2. MANUAL & MECHANICAL REMOVAL

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 machines (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. 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 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.

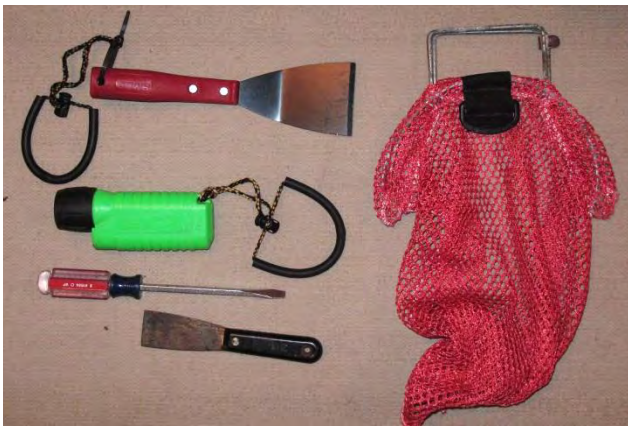

Figure 2-3. Examples of hand-held tools, some brightly colored and with leashes, useful for removing mussels from hard-to-reach places. Dive collection mesh bag useful for holding tools and for collecting removed animals. *Photo Credit:* Carolynn Culver

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.

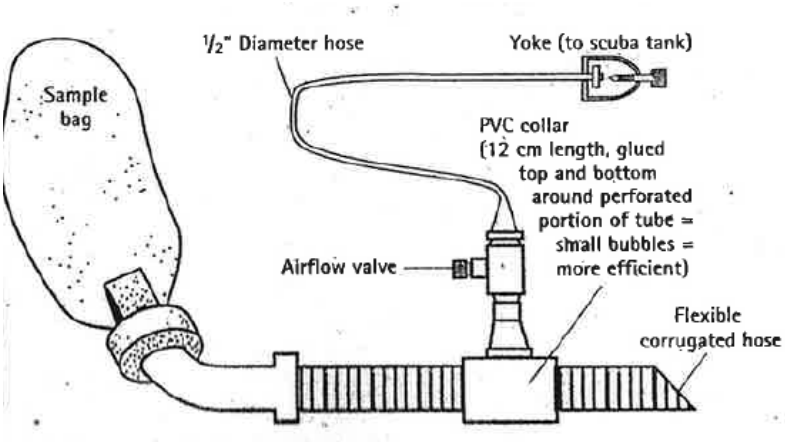

Figure 2-4. Suction pump diagram from *The Underwater Catalog: A Guide to Methods in Underwater Research* by Coyer J., D.L. Steller and J. Witman. Third Edition, 2012. Shoals Marine Laboratory, Ithaca, NY.

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 - http://www.dfg.ca.gov/invasives/quaggamussel/
California Professional Divers Association – http://www.prodivers.org
Community dive clubs - www.gooddive.com
Decontamination protocol - http://www.dfg.ca.gov/invasives/quaggamussel/
Diver surveys - 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/

---

[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.

3. OXYGEN DEPRIVATION

TACTIC

Depriving mussels of oxygen through the application of "tarps," also known as bottom/benthic mats or barriers, is a fairly benign physical control tactic. Thus, it is placed low on the Integrated Pest Management (IPM) pyramid. "Tarping" involves installing tarps over pest populations, typically on lake bottoms, and weighing or anchoring the tarps down with sandbags or rebar respectively. Tarps also can be installed around large rocks, pylons, docks, etc. Oxygen depletion under the tarps kills the pest. In the case of invasive mussels, tarps are used to target the attached juvenile and adult mussel stages. Chemicals or biocides, such as chlorine or potassium chloride, may be applied under tarps to accelerate the extermination process. However, using such chemicals requires additional permits and considerations (see Chemical Application and Permitting and Regulatory Processes information sheets).

WHEN TO USE TACTIC

This tactic is best used for low to moderate mussel infestations as a site-specific eradication and control method. When there are too many mussels to remove by hand, or they are situated in hard-to-reach locations (crevices), tarping offers an efficient way to cover and thereby eventually exterminate mussels in selected areas. Shells of the deceased mussels will remain in the water body, reducing the cost of disposal but potentially providing substrate for new mussel infestations and leaving sharp surfaces that can harm swimmers and fishing gear. Consider enhancing the effectiveness of this management strategy by taking an IPM approach, which combines this tactic that targets adults and juveniles with another tactic that targets the larval stage. Tarping has been used to control the Asian clam, *Corbicula fluminea*, in Lake Tahoe, CA (see "Success Story").

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 and Boat Operators.** Identify and train current dive staff or other local dive groups to assist with underwater application of tarps (see Manual & Mechanical Removal information sheet for list of divers and suggested training). Identify potential boat operators with current boat captain licenses. Collaborating with staff of other lakes in the region may reduce overall costs and help with the development of a team trained to implement this tactic.

2. **Locate Needed Supplies.** Work with managers of nearby lakes to develop a supply list and locations to purchase needed materials for implementing this tactic. A basic list of suggested supplies is provided at the end of this information sheet. If funds are available, develop a ready-to-use tarping tool kit that includes the necessary materials.

3. **Review the Need for Area Closures.** Consider the need to close various areas of the water body where tarps are installed. Closures may be required in high-traffic and shallow areas where other activities may interfere with the tarps, potentially making them ineffective if they are not continually secured. If you believe closures may be required, explore the potential for adding chemicals under the tarps to shorten the process (see Step 5 in the "Implementing Tactic" section).

Implementing Tactic

1. **Determine the Distribution of Mussels.** Have divers conduct surveys to determine the extent of the quagga or zebra mussel infestation. Identify specific areas with high densities of mussels ("hot spots") and areas that can easily be covered with tarps. For areas where mussels are found, have divers conduct additional surveys to determine how far out the infestation radiates from the spot. Based on the surveys, determine the size of the desired treatment area. For more information and assistance with conducting diver surveys contact California Department of Fish and Wildlife (CDFW).

2. **Conduct Pre-Implementation Survey.** Consult with agency or university biologists to develop pre- and post-surveys as part of your 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 and monitor artificial substrates.

3. **Conduct a Pilot Study.** Start with a small pilot study or test area to perfect tarping techniques and confirm that the materials are deployed and secured effectively.

4. **Install Tarps.** Install tarps over infested areas of the lake bottom, over large rocks, or wrapped about docks/pylons. Frames can be built with PVC pipe to support the tarps if large rocks or other objects are present (Fig. 3-1).

Figure 3-1. Tarping demonstration by Dr. Lars Anderson and Dan Daft at El Capitan Reservoir in San Diego County, CA. This series of pictures shows building a frame from PVC pipe to provide structure for tarps (used to cover large rocks or objects), rolling the tarp over the frame and then securing the tarp to the lake bottom with sand bags. *Photo Credit:* Jodi Cassell and Marsha Gear

Depending on the location of the mussels and the depth of the water, the assistance of divers may be required. For ease of installation, large rolls of tarps can be lowered to the infested area from a boat. Divers, with the assistance of floatation devices, can unroll the tarps over the infested surface and

secure them with large sand bags or rebar anchors (Fig. 3-2 and Fig. 3-3), as was done for Asian clams in Lake Tahoe, CA (see video).

To adequately reduce the oxygen available to the mussels, tarps should be left intact for a minimum of one month.[1] Depending on the situation, it may be necessary to prevent lake users from entering the area and interfering with the tarps. For example, fast moving boats, water skiing, or "wake boarding" can dislodge the tarps.

Figure 3-2. Divers rolling out mats made from aspen shavings (see "Success Story"). *Photo Credit:* Jim Brockett, Tahoe Resource Conservation District

Figure 3-3. Diver securing tarps to the bottom of the lake with rebar. *Photo Credit:* Jim Brockett, Tahoe Resource Conservation District

5. **Add Chemicals/Biocides (if needed).** In high traffic areas, where prolonged closures would negatively impact the lake/reservoir operations, chemicals or biocides may be used to accelerate the extermination process and decrease the amount of time the tarps need to stay in place. In this case, chemicals or biocides are pumped under the tarp after the initial installation process. If using chemicals/biocides, additional permits and considerations will apply, potentially slowing implementation of this control tactic (see Chemical Application and Permitting & Regulatory Processes information sheets).

6. **Monitor During Installation.** Have divers continue visual and tactile monitoring around tarps to ensure the mussel population has been completely enclosed. If a dissolved oxygen probe is available, take weekly readings under the tarp to ensure the area beneath it remains anoxic (without oxygen).

7. **Remove Tarp.** Have divers remove a section of tarp and test for survivorship of the mussels. If the mussels are alive, replace the tarp and leave it for a longer period of time. If the mussels are dead, remove the tarp.

8. **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.[2]

9. **Evaluate Tactic Success.** Conduct follow-up surveys (e.g., diver, remotely operated vehicle [ROV], substrate sampling) to evaluate the effectiveness of the removal efforts. Within the first year of the project, conduct follow-up surveys 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 once a year. Annual surveys are critical for determining the long-term success of the effort. It is important to budget for and conduct surveys for 5 to 10 years because it is often difficult to detect low infestations. **If control was the goal,** continual monitoring will help determine how long the tactic was effective, thereby identifying 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.

Chemicals

When chemicals are used, managers should consult with chemical suppliers about the risks associated with each chemical and about the proper procedures regarding potential exposure to humans.

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 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

- Sheets or rolls of PVC/plastic tarps (non gas-permeable) or black pond liners (at least 20 mil thick) to cover infested areas
- Sandbags, bags of gravel or rebar to weigh or anchor the tarps to the bottom
- Boats for deploying tarps (this may require a larger, barge-type boat, as well as smaller dive-tender boats)
- Dissolved oxygen loggers to measure levels under tarp (optional)

Staffing (Technical/Volunteer)

- Professional and/or scientific divers (for installation of tarps)
  - See list of qualified divers in Manual & Mechanical Removal information sheet
- Boat operator(s)
- 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 & Regulatory Processes information sheet)
- Public outreach materials
- Signage (closure signs, information signs)
- Lost revenue due to closures (if implemented)

SUCCESS STORY

Lake Tahoe, CA

In 2010, a team of divers supported by two boats and a barge deployed large rolls of aspen shavings covered by non gas-permeable tarps on the lake bottom to control Asian clams in specific areas (Fig. 3-2). The aspen shavings absorb oxygen, thereby decreasing the amount of time the tarps need to stay in place. Nearly half an acre (~2,000 square meters) of the lake bottom was covered with the tarps, which were left in place for 120 days (July-November). Upon removal, the Asian clam population was reduced by 98% and remained significantly reduced (>90%) one year later.[3]

CITED WEB LINKS

ADCI - http://www.adc-int.org/
Decontamination protocol - http://www.dfg.ca.gov/invasives/quaggamussel/
Diver surveys - http://pubs.usgs.gov/of/2010/1308/
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
Video - http://digitaljournal.com/article/294522

---

[1] The one-month time period is based on an experiment in Lake George, NY. Personal communication, Dr. Sandra Nierzwicki-Bauer, Darrin Fresh Water Institute, February 2, 2012.

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

[3] Wittmann, M.E., S. Candra, J.E. Reuter, G.S. Schladow, B.C. Allen and J. Webb. 2012. The control of an invasive bivalve, *Corbicula fluminea*, using gas impermeable benthic barriers in a large natural lake. *Environmental Management* 49 (6): 1163-1173.

4. CHEMICAL APPLICATION

TACTIC

As with many household and garden pests, chemicals can be used to eradicate and control aquatic invasive species. Chemical control tactics are considered toxic, so they are placed high on the Integrated Pest Management (IPM) pyramid and used sparingly. For quagga and zebra mussels, infusing a water body with a pre-determined concentration of a chemical targets all life stages of the mussel: larvae, juveniles and adults. However, not all chemicals are equally effective at various concentrations and on the different life stages. Chemicals, including chlorine (Dichlor Max, active ingredient sodium hypochlorite), have been used successfully in *facilities* to control quagga and zebra mussels, yet potassium chloride (KCl) is the only chemical successfully used to eradicate mussels and not harm other species in a water body.[1,2] For this reason, only KCl will be discussed in this information sheet. It is unknown exactly how KCl kills the mussels, but evidence suggests that potassium interferes with the organism's ability to transfer oxygen across gill tissue, resulting in asphyxia, and eventually death. Although KCl is not currently approved for use as a pesticide in California, options for use can be reviewed with the Department of Pesticide Regulation.[3]

WHEN TO USE TACTIC

A system-wide application of KCl is typically only considered when the mussel infestation is dense and widespread and other more benign tactics, such as manual and mechanical removal and oxygen deprivation, are no longer options. Due to the costs and potential environmental impacts of the widespread application of chemicals, including KCl, such application is best used for eradication and not a long-term control measure.[4]

Broad application of KCl works best when lakes/reservoirs have no, or very little, flow-through that would increase dissipation of the chemical.[5] A target concentration of KCl must remain present in the water for a certain amount of time depending on water temperature and the life stage of the mussels in the system. The addition of KCl to a water body requires an in-depth, location-specific, permitting, and regulatory process that will impact the timeline for implementing the tactic and should be accounted for in the planning stages. KCl infusion has been used in Millbrook Quarry, VA to successfully eradicate zebra mussels (see "Success Stories").

In some cases chemical tactics may be used for site-specific control of aquatic pests, often integrated with other control tactics as part of an IPM approach. For example, chemicals can be used in conjunction with tarps or in small, contained areas to effectively control pest populations (see "Success Stories").

STEPS TO BE TAKEN

1. **Obtain Required Permits.** Seek guidance in obtaining the required permits for chemical applications in a lake/reservoir. Contact the Department of Pesticide Regulation for specific regulations regarding the use, transport and procurement of chemicals. See the Permitting and Regulatory Processes information sheet for agencies to contact and environmental consultants who may be able to provide assistance.

2. **Conduct Pre-Implementation Survey.** Consult with agency and/or university biologists to develop a pre- and post-application monitoring program that allows for a before-and-after comparison of the effects of the KCl on mussels and selected indicator species. Use trained divers and staff to carry out the monitoring program. For a list of potential divers, see Manual & Mechanical Removal information sheet. Note: This work also may occur prior to or concurrent with Step #1, depending on the situation and the permits required.

3. **Determine Quantity of Chemical.** Calculate the amount of KCl that will be needed to maintain an effective concentration of potassium for 2 to 4 weeks. The amount of chemical needed will vary based on the water temperature and volume of the lake/reservoir.[6] Consider lowering the water level (as occurs with a water draw-down) to reduce the volume of the water body and the amount of chemical needed. Additional storage infrastructure may be needed to store the chemical on land. The price of KCl has been known to fluctuate and in some cases may prove to be cost prohibitive.

4. **Apply Chemical.** Infuse the water body with the pre-determined amount of KCl to reach an effective potassium concentration. A small watercraft equipped with a diffuser system (Fig. 4-1) can be utilized to apply the required concentration of KCl to the water body. The watercraft should follow predetermined transects to ensure even distribution of the chemical throughout the water body. The goal is to infuse the lake with enough KCl to achieve the desired potassium concentration throughout the entire lake system. In Millbrook Quarry, KCl was dispensed at the surface and at a depth of 10 feet (3 meters) to achieve the target chemical concentration throughout the entire water body.[7] In water bodies with less efficient mixing, it may be necessary to add chemicals at additional depths to ensure the target concentration is achieved throughout the water body.

Figure 4-1. Watercraft equipped with diffuser system in Millbrook Quarry. *Photo Credit:* Virginia Department of Game and Inland Fisheries

5. **Monitor Chemical Concentration.** Have trained staff or volunteers monitor the chemical levels throughout the infusion process by sampling water at various locations and depths to ensure target concentration levels are met and maintained. Re-apply KCl as needed to maintain target potassium concentration, monitoring the status after each application.

6. **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 California Department of Fish and Wildlife (CDFW) decontamination protocol upon 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.[8]

7. **Evaluate Tactic Success.** Conduct post-application surveys (e.g., diver, remotely operated vehicle [ROV], substrate sampling) to evaluate the effectiveness of the KCl infusion (Fig. 4-2). 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. **When eradication is 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 critical for determining the long-term success of the effort, as it is typically difficult to detect low infestations of a pest. Be sure to budget for and conduct surveys for 5 to 10 years. Consider including a third-party agency or university biologist when designing and conducting surveys to validate the scientific design and findings. Due to the costs and potential environmental impacts, this tactic has not been applied system-wide over multiple years as a control tactic, but rather as an eradication measure.

Figure 4-2. Dead zebra mussels photographed by Aquatic Sciences L.P. using a robotic camera during extensive video surveys following chemical application in Millbrook Quarry. *Photo Credit:* Virginia Department of Game and Inland Fisheries

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.

Chemicals

Managers should consult with chemical suppliers about the risks associated with each chemical being used, and about the proper procedures regarding potential exposure to humans.

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 also may be required in some situations.

COSTS TO CONSIDER

Many costs are associated with implementation of this 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

- Land-based storage tanks and pump system
- Work boat outfitted with liquid diffuser system
- Floating pipeline
- Dive equipment (for pre- and post-monitoring)
- Water quality sampling kit

Staffing (Technical/Volunteer)

- Boat operator and assistant (for applying chemicals and assisting with monitoring)
- Professional and/or scientific divers (for pre- and post-monitoring surveys)
  - See list of qualified divers in Manual & Mechanical Removal information sheet
- Water quality monitoring personnel to evaluate chemical application (utilize local water quality lab or possibly students at a local university)
- Third party agency or university biologist to assist with survey design and to validate results

Additional Costs to Consider

- Pre- and post-application survey (e.g., water sample collection and analyses; substrate sampling and monitoring)
- Permits (see Permitting and Regulatory Processes information sheet)
- Price of desired chemical (this can fluctuate widely from year to year for KCl)
- Public outreach materials
- Signage (closure signs, information signs)
- Lost revenue due to closures (if implemented)

SUCCESS STORIES

System-Wide Application — **Millbrook Quarry, VA**

In January 2006, the Virginia Department of Game and Inland Fisheries eradicated the zebra mussel from Millbrook Quarry. In this system-wide application they infused the entire quarry with 174,000 gallons of potassium chloride (KCl) solution over a 3-week period. The target chemical concentration was 100 mg of potassium per liter of water, which was high enough to successfully eradicate the zebra mussel population but far below the level that would invoke environmental or human health concerns. (You would need to drink about 19 gallons (72 liters) of KCl-treated Millbrook Quarry water to consume your daily recommended dose of potassium.) [9,10] Post-application surveys indicate the eradication was successful with little impact to other aquatic species.

Enclosed Area Application — **Darwin Bay, Australia**

Chemicals also have been used successfully by closing off and treating certain sections of an infested water body. In late March 1999, black striped mussels were discovered in three marinas in Darwin Bay, Australia. A high-level management committee led by the Department of Primary Industry and Fisheries was created, and the marinas were immediately quarantined by closing a lock system and restricting access. In total 42,250 gallons (160,000 liters) of liquid sodium hypochlorite and around 6,600 tons (6,000 metric tonnes) of copper sulfate were added to the three marinas over two weeks, along with several tons of powdered calcium hypochlorite to create sterile "plugs" near the locks.[11] All the vessels that were either currently or recently in the marinas were also hauled out and chemically treated. By late April, after multiple dive surveys to confirm the eradication efforts were successful, the marinas were re-opened. It should be noted that other species in the locks experienced adverse effects due to the chemicals.

Site-Specific Application — **Carlsbad, CA**

Chemicals also can be applied to specific locations in a water body using tarps or similar barriers. In Carlsbad, CA, PVC tarps were used in conjunction with liquid sodium hypochlorite and chlorine tablets to contain, treat, and successfully eradicate the invasive alga *Caulerpa taxifolia* from a lagoon. Approximately 10,890 square feet (1,000 square meters) of lagoon floor was covered with overlapping large tarps anchored with sand bags.[12] It was estimated that 11,270 square feet (1,047 square meters) of *C. taxifolia* was present in the lagoon at the start of the eradication effort in summer 2000. This amount declined steadily throughout the eradication effort, with only 4.3 square feet (0.4 square meters) found in the lagoon in summer 2002. No *C. taxifolia* has been detected since that date.[13] This is considered a successful eradication effort.[14]

CITED WEB LINKS

ADCI - http://www.adc-int.org/
Decontamination protocol – http://www.dfg.ca.gov/invasives/quaggamussel/
Department of Pesticide Regulation - http://www.cdpr.ca.gov/
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
Quagga and Mussel Eradication and Control Workshop – http://ca-sgep.ucsd.edu/quaggazebra_mussel_control/new_workshop

[1] Note that other freshwater mussels and gill-breathing snails would be harmed by potassium. In the case of Millbrook Quarry, the only such species in the quarry was the Asian clam (*Corbicula fluminea*), another invasive exotic species (which also was killed as anticipated). Personal communication, Raymond Fernald, VDGIF, September 12, 2012.

[2] Various chemicals have been used in attempts to eradicate invasive mussels, but only potassium chloride (KCl) has been successful, albeit not in every case (see endnote 4). Unsuccessful eradication of zebra mussels was attempted with copper sulfate in Lake Ossawinnamakee in Minnesota and in Offutt Air Force Base lake in Nebraska. In both cases, the chemical application resulted in the killing of a large number of fish and harmful effects to other aquatic species.

[3] In Virginia, an emergency exemption to use KCl was granted to the VDGIF for the Millbrook Quarry eradication project. Details of the permitting process required for that eradication project are provided in the presenter abstracts (R. Fernald) from the Quagga and Zebra Mussel Eradication and Control Workshop.

[4] Note that potassium is potentially long-lived in the environment, in nonflowing waters. This persistence was a primary factor in the selection of KCl for use at Millbrook Quarry (i.e. as prophylaxis against reintroduction of zebra mussels or quagga mussels to the quarry, and as a "safety measure" in case isolated pockets of mussels somehow survived the initial treatment). Personal communication, Raymond Fernald, VDGIF, September 12, 2012.

[5] In 2010, KCl was applied continuously for 32 hours, every 15 minutes to Sister Grove Creek in Texas in an attempt to stop the spread of zebra mussels. This was the first attempt at using the chemical in a “flowing” system. While initial results showed mussels died, further investigation showed pockets of zebra mussels remained alive. Eradication was not achieved because the target concentration of KCl could not be maintained due to flow in the water body. No tarps or other barriers were deployed to contain the chemicals in the upstream area. https://fishgame.com/article.php?ArticleID=5166

[6] Based on laboratory studies, minimum concentration of KCl needed to kill zebra mussels is 30 mg/L at a temperature of 17°C (63°F). http://www.sciencedirect.com/science/article/pii/S0380133093712575
The successful field application at Millbrook Quarry used a higher concentration of 100 mg/L (see “Success Story”).

[7] The target concentration was 100 mg of KCl per liter of water [mg/L, or parts per million (ppm)]. However, a lower concentration (50 ppm) of KCl was used as a minimum “acceptable” concentration. When a concentration of 50 ppm or higher was detected, surveys were then started to assess impacts on the mussels and other organisms. A lower concentration was used as a trigger for the surveys because it was unclear how much KCl was being taken up by vegetation or bound to sediments, thereby reducing the net concentration of KCl in the water column. Personal communication, Brian Watson, VDGIF, September 12, 2012.

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

[9] Final Environmental Assessment Millbrook Quarry Zebra Mussel and Quagga Mussel Eradication. Dec. 2005. Prepared by VDGIF, Wildlife Diversity Division.

[10] Fernald, R.T. and B.T. Watson. 2012. Eradication of zebra mussels from Millbrook Quarry, Virginia: Rapid response in the real world. Quagga and Zebra Mussel Eradication and Control Workshop. Presenter Abstracts.

[11] Ferguson, R. Dec. 2000. The effectiveness of Australia’s response to the black striped mussel incursion in Darwin, Australia. http://www.environment.gov.au/coasts/imps/publications/pubs/bsmfinalreport.pdf

[12] Anderson, L.W.J. 2005. California’s reaction to *Caulerpa taxifolia:* A model for invasive species rapid response. *Biological Invasions* 7: 1003-1016.

[13] Woodfield, R. and K. Merkel. 2006. Eradication and surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California. Fifth Year Status Report January to December 2005. Prepared for Steering Committee of the Southern California *Caulerpa* Action Team. 15 p.

[14] Anderson, Lars W.J. 2012. Rapid response and eradication of *Caulerpa taxifolia*: Lessons learned from a successful team effort. Quagga and Zebra Mussel Eradication and Control Workshop. Presenter Abstracts.

5. EMERGING TECHNOLOGIES

OVERVIEW

New eradication and control tactics are being evaluated for potential use in lake and reservoir systems. The emerging tactics presented below have not been implemented in these habitats, but theoretically and in some cases experimentally they show some promise.

ZEQUANOX®

Zequanox® is a biological, environmentally compatible product developed specifically to control invasive zebra and quagga mussels (*Dreissena* species).[1] Derived from the naturally occurring microbe, *Pseudomonas fluorescens*, Zequanox® is highly selective and has been proven to be lethal to zebra and quagga mussels without harming humans, infrastructure, nontarget species, or the environment. The product—comprised of dead cells of the microbe—is seen as a nonthreatening food source; the target mussels readily consume the product along with their normal phytoplankton diet from the water. Once ingested, the active ingredient in Zequanox® deteriorates the mussel's digestive lining, causing death. Toxicological studies have been completed on numerous species of fish, molluscs, plants, algae, crustaceans and insects, as well as mallard ducks, with no indication that Zequanox® has any harmful effects on other species.

Potential Uses

In March 2012, the Environmental Protection Agency (EPA) approved the commercial formulation of Zequanox® for use in enclosed/semi-enclosed systems with an inlet and an outlet (e.g., water facility pipes). Trials in these systems have achieved greater than 90% mortality in both adult and juvenile mussels. Zequanox® has been registered in several states for this type of application, but not in California (as of December 2012).

Marrone Bio Innovations—maker of Zequanox®— is currently collecting data to complete an EPA application for the use of this biocide in open-water settings, such as lakes and reservoirs. In July 2012, an open-water trial was completed in Deep Quarry Lake, DuPage County, IL, where the product achieved greater than 97% mortality of adult mussels. These data, along with post-application survey data, will be reviewed as part of the approval process for open-water application of Zequanox® to control mussel infestations in lakes/reservoirs. However, even if approved, such system-wide open-water application may be cost prohibitive, depending on the concentration required to treat the system and the volume of water to be treated. Zequanox® may be most appropriate for site-specific applications for population control, nuisance abatement, infrastructure maintenance, habitat protection or in applications where there is a strong environmental concern for nontarget species. Trial studies indicate this biopesticide will be particularly effective when used with in-lake barrier systems to help maintain product concentration during treatment periods. For more information visit Marrone Bio Innovations.

FISH BIOCONTROL

Research is underway to evaluate whether resident fish in a mussel-infested system could be used for *site-specific* control of quagga and zebra mussel infestations. System-wide application, where the overall density of fish is increased within a lake to increase predation on a target species, is not currently being considered. Several fish species feed on various life stages of quagga mussels.[2] Redear sunfish (*Lepomis microlophus*), common carp (*Cyprinus carpio*) (Fig. 5-1) and blue catfish (*Ictalurus furcatus*) are molluscivores that are known to feed on both juvenile and adult mussels, while threadfin shad (*Dorosoma petenense*) and small (<90 mm, <3.5 inch) bluegill (*Lepomis macrochirus*) are planktivores and consume the planktonic larval stage of the mussel. These species are not native to western waterways, but they were introduced long ago and are now common sportfish in many water bodies of the region. Unfortunately, no native fishes have been identified as promising biocontrol agents for quagga and zebra mussels. While the non-native species may prove useful where they already ***occur***, the researchers and others do not promote their introduction anywhere else.

Figure 5-1. Common carp, *Cyprinus carpio*, a predator of and potential biocontrol agent for quagga and zebra mussels. Lake Mead, NV. *Photo Credit:* Carolynn Culver

Potential Uses

If proven effective, cages may be used to apply higher fish densities at specific sites to control quagga and zebra mussels. For example, mussel infestations on docks, water towers, dams and irrigation canals may potentially be controlled by caging fish around these structures or in the canals. If shad or other planktivores consume sufficient mussel larvae, they could minimize the number of larvae that settle. If redear sunfish or other predatory fish consume sufficient juvenile and adult mussels, they could minimize populations of these stages. If fish biocontrol is proven effective, using a combination of planktivores and molluscivores may be more effective at reducing mussel populations than using just one or the other. Depending on the research results, applications of contained fish could be focused on periods of high mussel settlement. For more information visit United States Bureau of Reclamation and California Sea Grant/UCSB Western Region IPM Project.

ADDITIONAL ALTERNATIVES

The following tactics are still in the beginning stages of development for lakes/reservoirs and are most likely best suited for facilities and infrastructure. Visit the websites provided below to learn more about development and use of these tactics.

pH Manipulation

Mussels have a relatively narrow range of pH tolerance, with the optimum from 7.5 to 9.3. Research is underway to determine if manipulating the pH above or below this range will prove to be an effective control strategy or a preventative measure against initial mussel settlement.[3] For more information visit RNT Consulting.

Pulse Pressure Technology

Pulse pressure technology using seismic guns has recently been used to combat various invasive fish species. Investigators hypothesize that fine manipulation of seismic waves may effectively kill all life stages (larvae, juveniles and adults) of quagga and zebra mussels.[4] If this tactic is found to be effective for invasive mussels, it may provide a more cost-effective means for controlling these pests. For more information visit U.S. Geological Survey.

CITED WEB LINKS

California Sea Grant/UCSB Western Region IPM Project - http://www.wripmc.org/CenterProjects/RIPM%20grants.html#2011
Marrone Bio Innovations - http://marronebioinnovations.com/products/zequanox/
Quagga Mussel Eradication and Control Workshop – http://ca-sgep.ucsd.edu/quaggazebra_mussel_control/new_workshop
RNT Consulting - http://www.rntconsulting.net/People/Principals/Claudi_Renata.aspx
United States Bureau of Reclamation - http://www.usbr.gov/mussels/research/current.html
U.S. Geological Survey (USGS) - http://www.nrmsc.usgs.gov/staff/jgross/research

[1] Link, Carolyn and Sarahann Rackl. 2012. Zequanox: Invasive mussel control for watershed management. Quagga Mussel Eradication and Control Workshop. Presenter Abstracts.

[2] Carp, Kathy. 2012. Summary of laboratory experiments to evaluate consumption of juvenile/adult quagga mussel by redear sunfish and bluegill. Quagga Mussel Eradication and Control Workshop. Presenter Abstracts.

[3] Claudi, Renata. 2012. Adjustment of background pH as a control strategy for dreissenid mussels in raw water conveyance systems. Quagga Mussel Eradication and Control Workshop. Presenter Abstracts.

[4] Gross, Jackson. 2012. UV light and seismic technology as potential control strategies for dreissenid mussel invasion. Quagga Mussel Eradication and Control Workshop. Presenter Abstracts.

6. PERMITTING & REGULATORY PROCESSES

OVERVIEW

The objective of this information sheet is to provide a brief overview of regulatory organizations and permitting processes that water agencies may need to address when planning an eradication or control program for invasive freshwater mussels and other aquatic pests. Required permits and approvals depend on a variety of factors including, but not limited to, location of water body, jurisdiction, lake uses, other animal species present, size of the proposed project, and type of eradication or control tactic to be implemented. The most benign tactic, manual and mechanical removal, generally requires fewer permits and approvals resulting in a shorter implementation timeline. Less benign tactics, such as changing the environment by using tarps or applying chemicals, requires additional permits and may require special exemptions. To assist with the planning process, we provide examples of permits that were required for the successful eradication and control programs discussed in each information sheet. They can serve as guidelines for what may be required for each tactic. Additional and/or different permits may be required by the State of California (or other states, municipalities, districts, etc.) depending on the situation.

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

The following steps can be taken to reduce the time required to implement eradication and control tactics.

1. **Communicate with Agencies that have Jurisdiction over the Water Body.** Create a list of all agencies that have jurisdiction over eradication and control actions to be conducted in the water body. Each organization will likely require a written approval for any eradication or control effort. Have staff contact each agency *now* to identify what type of approval or permit they will require to implement such activities.
2. **Assess Lake Characteristics and Uses.** Conduct a basic assessment of key characteristics and uses of the water body. These parameters include 1) identifying existing threatened and endangered species, 2) determining historic sites or landmarks, 3) identifying patterns of water level fluctuation due to draw-downs and seasonal rainfall patterns, and 4) listing all lake uses and associated seasons of use. This information is critical for determining which permitting processes may be required.
3. **Explore Development of Regional Permits.** Meet with other lake managers in the region to discuss applying for permits as a group. In California, check with the Association of California Water Agencies (ACWA) to see whether they are aware of any similar regional permits or ongoing associated efforts.

MANUAL AND MECHANICAL REMOVAL

Manual and mechanical removal requires the fewest permits, thereby serving as a primary rapid response tactic.

Entry Approval for Divers

Divers need to be cleared by the proper authorities to enter the water body. This may require private, city, county and/or state approval.

Scientific Collecting Permit

If mussels and/or rocks and plants with attached mussels are removed from the water body, a scientific collecting permit is required. Applications are on the California Department of Fish and Wildlife's website. Currently, there is a small processing fee (~$100 in 2012) and a processing time of six months to one year.

Permits Required
Lake George, NY: Zebra Mussel Eradication [1,2]

- **Collection permit** for zebra mussels from the New York State Department of Environmental Conservation
- **Volunteer release forms**

OXYGEN DEPRIVATION (TARPING)

The number and types of permits/approvals required for using tarps in a lake/reservoir ranges from simple access approval to completing a complex Environmental Impact Review (EIR) and initiating the California Environmental Quality Act (CEQA) process. Key factors that will affect the type of permits needed include, but are not limited to:

- Location of the tarps (if wrapping docks/pylons, fewer permits will be needed)
- Size of the area to be tarped (if the area is large and will require closures, more permits may be needed)
- Use of chemicals or biocides (if applied under tarps, more permits will be required, see Chemical Application section)

To assist with planning and timing a project, some of the permits and approvals that MAY be required when applying tarps follow in alphabetical order.

California Environmental Quality Act (CEQA)

The California Environmental Quality Act (CEQA) "requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible." CEQA applies to *projects* that require *discretionary approval* by a government agency. A "discretionary approval" entails the use of judgment on the part of the approver.[3] A "project" is a proposal (or any part of a proposal) that may result in physical changes to the environment or a reasonably foreseeable indirect change.[4] In summary, **if the proposed project requires government approval, and will have some impact on the environment, then CEQA documentation is required.** It is important to note that

high filing fees are associated with this process (~$1,000–$3,000 in 2012). The following websites provide more details about various aspects of CEQA.

- Information about CEQA fees
- CEQA facts
- CEQA process flow chart
- County-approved CEQA consultants:
  - San Diego County
  - Riverside County

The National Environmental Policy Act (NEPA) is often referred to in conjunction with CEQA. They are similar laws with the common purpose of "examining and weighing the potential environmental consequences of proposed government actions before such actions are undertaken."[5] NEPA is required if the action is being undertaken by a *federal* agency and CEQA is required if the action is being taken by *California* state or public agencies.

Lakebed Alteration Agreement with California Department of Fish & Wildlife (CDFW)

CDFW requires notification by any person, business, state or local government agency, or public utility that proposes an activity that will:

- substantially divert or obstruct the natural flow of any river, stream or lake;
- substantially change or use any material from the bed, channel, or bank of any river, stream, or lake; or
- deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake.

401 Water Quality Certification

This permit is required from the Regional Water Quality Control Board for projects involving discharges of dredged or fill material to waters of the United States, including wetlands and other water bodies. Such discharges may result from navigational dredging, flood control channelization, levee construction, channel clearing, filling wetlands for development, or other activities. These projects involve the removal or placement of soil, sediment, and other materials in or near water bodies. Fees associated with this certification start at $1,000 (in 2012).

Permits/Approvals Required
Lake Tahoe, CA: Asian Clam Benthic Mat (Tarping) Pilot Control Project[6]

- **CEQA** – Notice of Exemption from the Secretary of Resources at the California Natural Resources Agency.
- **California State Lands Commission** – Approval and formal acknowledgment that California Department of Parks and Recreation (the project lead agency) is operating under their existing lease with the state for use of the lake bottom.
- **Clean Water Act Section 404 General Permit** – Issued by U.S. Army Corps of Engineers (USACE) before beginning any nonexempt activity involving the placement of dredged or fill material in waters of the United States.

- **Clean Water Act Section 401 Water Quality Certification** – Issued by the California State Water Resources Control Board usually in conjunction with the USACE Clean Water Act Section 404 permit.

- **Lakebed Alteration Agreement** – Provided by California Department of Fish and Wildlife.

CHEMICAL APPLICATION

The addition of chemicals, either by system-wide infusion or used with tarps, requires additional permits, possibly resulting in a longer and more expensive project. Their use generally triggers the CEQA regulatory process (see CEQA section). Emergency exemptions may be filed on a case-by-case basis and should not be relied upon. Answering the following questions will help to determine which permits and approvals might be needed to implement the application of chemicals. More detailed information about each permit/ approval is listed below.

Is the chemical pesticide you intend to use registered for use in California with the Department of Pesticide Regulation?

To determine if the product is registered visit Department of Pesticide Regulation

- **If yes,** a National Pollutant Discharge Elimination System (NPDES) permit for Residual Pesticide Discharges to the Waters of the United States is required.
  - If you are using Dixichlor and Dixichlor Max (active ingredient sodium hypochlorite) then you can apply for the Aquatic Animal Invasive Species General Permit, a statewide general NPDES permit for the use of this pesticide. These chemicals are typically only used in facilities or closed systems.
  - If using another registered chemical pesticide, then you need to get a NPDES permit from your Regional Water Quality Control Board (RWQCB). Some RWQCBs have a general permit for small discharges and it may be possible to utilize that permit for small chemical applications.
- **If no** (the chemical pesticide to be used is ***not*** registered, such as potassium chloride),
  - The product must first go through the DPR registration process.
  - A NPDES permit from Regional Water Quality Control Board also will be required.
  - **OR** obtain a emergency exemption.

Aquatic Animal Invasive Species General Permit

Agencies planning on applying the pesticide Dixichlor or Dixichlor Max (active ingredient sodium hypochlorite) to control aquatic animal invasive species may apply for coverage under the Statewide General NPDES Permit for Residual Pesticide Discharges to Waters of the United States from Aquatic Animal Invasive Species Control Applications, General Permit No. CAG 990006.

NPDES (National Pollutant Discharge Elimination System)

This permit program controls water pollution by regulating “point sources” that discharge pollutants into waters of the United States. If water that has been treated with chemicals is released into the surrounding environment, the water body could be considered a “point source” of pollution and NPDES will need to be considered. See CEQA section for links to county-approved CEQA consultants.

Emergency Regulations: Office of Administrative Law (OAL)

An emergency regulation is one that is necessary for the immediate preservation of public peace, health and safety. It may become effective before any public notice and hearing. Emergency regulations remain in effect for a 180-day period.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) – Section 18 Exemption

Under Section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), at the discretion of the administrator, a federal or state agency may be exempted from any provision of FIFRA if the administrator determines that emergency conditions exist which support the exemption. Such an exemption has been granted for programs involving invasive freshwater mussels and other species.

Permits/Approvals Required
Millbrook Quarry, VA: Zebra Mussel Eradication Project[7,8]

- **Entry Approval** – The Virginia General Assembly passed legislation listing zebra mussels as a Nonindigenous Aquatic Nuisance Species, authorizing the Virginia Department of Game and Inland Fisheries (VDGIF) to respond to such invasive species, and establishing civil penalties for violating the act or obstructing VDGIF from responding to such incidents.
- **Compliance with State and Federal Environmental Review Requirements** – The most significant environmental requirements included compliance with the federal National Environmental Policy Act (NEPA), Endangered Species Act, Coastal Zone Management Act, and Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and corresponding state laws.
- **FIFRA Emergency Exemption** – Potassium chloride was not registered for pesticide use, therefore the VDGIF had to secure an Emergency Quarantine Exemption under Section 18 of FIFRA.
- **Additional Considerations** – VDGIF had to ensure compliance with state and local regulations regarding pollutant discharge, submerged lands and wetlands protection, water quality, hazardous and solid waste management, sediment and erosion control, emergency preparedness, potable water quality protection, and undergo public review of all environmental documentation.

Permits/Approvals Required
Carlsbad, CA: *Caulerpa taxifolia* Eradication Project[9]

- **CEQA**, **Notice of Exemption** – Issued by the Secretary of Resources at the California Natural Resources Agency.
- **Consistency Determination** – Issued by the California Coastal Commission stating that the eradication activities were consistent with the coastal management plan. This was needed because the targeted lagoons are located within the coastal zone.
- **Research Authorization and Special Local Need Registration** – Issued by the California Department of Pesticide Regulation for the use of chlorine in the area.
- **Clean Water Act Section 404 General Permit** – Issued by U.S. Army Corps of Engineers (USACE) before beginning any nonexempt activity involving the placement of dredged or fill material in waters of the United States.

- **Nationwide Permit Number 25** – Under the authority of the Clean Water Act Section 404, a nationwide permit authorizes a category of activities throughout the nation and is valid only if the conditions applicable to the permit are met. They are valid for 5-year periods.[10]

- **Regional General Permit No. 64** – Similar to the Nationwide Permit, but this is assigned on a regional level.

CITED WEBLINKS

Aquatic Animal Invasive Species Permit - http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2011/wqo2011_0003.pdf
Association of California Water Agencies (ACWA) - http://www.acwa.com/
California Department of Fish and Wildlife - http://www.dfg.ca.gov/licensing/pdffiles/fg1379.pdf
CEQA Facts - http://www.ceres.ca.gov/ceqa/more/faq.html
Department of Pesticide Regulation - http://www.cdpr.ca.gov/
DPR Registration Process - http://www.cdpr.ca.gov/docs/registration/regprocess.htm
Emergency Regulations: Office of Administrative Law - http://www.oal.ca.gov/
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - Section 18 Exemption - Flow chart of the CEQA process - http://ceres.ca.gov/ceqa/guidelines/pdf/appen_a.pdf
Information about CEQA Fees - http://www.dfg.ca.gov/habcon/ceqa/ceqa_changes.html
Lakebed Alteration Agreement - http://www.dfg.ca.gov/habcon/1600/
National Environmental Policy Act (NEPA) - http://ceq.hss.doe.gov/
National Pollutant Discharge Elimination System (NPDES) - http://cfpub.epa.gov/npdes/
Riverside County - http://www.rctlma.org/epd/documents/BioConsultantsList.pdf
San Diego County - http://www.sdcounty.ca.gov/dplu/CEQA_Consultant_Resources.html
401 Water Quality Certification - http://www.waterboards.ca.gov/rwqcb3/water_issues/programs/401wqcert/index.shtml
http://cfpub.epa.gov/oppref/section18/search.cfm

---

[1] 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.

[2] 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.

[3] http://www.dera.saccounty.net/FAQs/tabid/88/Default.aspx#when_does_ceqa_apply

[4] http://ceres.ca.gov/ceqa/more/faq.html

[5] CEQA, NEPA and Base Closure - http://ceres.ca.gov/ceqa/more/tas/ceqa_nepa/section2.html

[6] Wittmann, M.E., S. Candra, J.E. Reuter, G.S. Schladow, B.C. Allen and J. Webb. 2012. The control of an invasive bivalve, *Corbicula fluminea*, using gas impermeable benthic barriers in a large natural lake. *Environmental Management* 49 (6): 1163-1173.

[7] Final Environmental Assessment Millbrook Quarry Zebra Mussel and Quagga Mussel Eradication. Dec. 2005. Prepared by VDGIF, Wildlife Diversity Division.

[8] Fernald, R.T. and B.T. Watson. 2012. Eradication of zebra mussels from Millbrook Quarry, Virginia: Rapid response in the real world. Quagga and Zebra Mussel Eradication and Control Workshop. Presenter Abstracts.

[9] http://www.globalrestorationnetwork.org/uploads/files/CaseStudyAttachments/71_c.-taxifolia-eradication.pdf

[10] The U.S. Army Corps of Engineers' Nationwide Permits Program: Issues and Regulatory Developments. http://www.fas.org/sgp/crs/natsec/97-223.pdf