Michigan Mussel Rescue and Relocation Protocols for Reservoir Drawdowns

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Michigan Mussel Committee

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Introduction and Purpose

In North America, native freshwater mussels (Order: Unionoida) have been identified as the most imperiled of any major group of animals (Williams *et al.* 1993; Master *et al.* 2000; Strayer 2008). Of the 44 mussel species found in Michigan, 19 (43%) are listed as either endangered or threatened pursuant to Part 365, Endangered and Threatened Species, of the Michigan Natural Resources and Environmental Protection Act (1994 PA 451) (NREPA 1994). Four of these species are also federally listed and receive additional protection pursuant to the Endangered Species Act (87 Stat. 884, as amended 16 U.S.C.§ 1531 *et seq.*). An additional 12 species are in decline and are identified as species of special concern ("River Protocol", Hanshue *et al.* 2021).

The Michigan Mussel Rescue and Relocation Protocol for Reservoir Drawdowns ("Drawdown Protocol") is intended to supplement the Michigan Freshwater Mussel Survey Protocol and Relocation Procedures ("River Protocol", Hanshue *et al.* 2021) and the Michigan Freshwater Mussel Survey & Relocation Protocols for Projects in Lakes & Reservoirs ("Lakes & Reservoirs Protocol", Johnson *et al.* 2022). The River Protocol and Lakes & Reservoirs Protocol are designed to document the potential presence or absence of state or federally listed mussel species that may be affected by construction projects or other human disturbances in discrete locations so that conservation efforts, including mussel relocation can be conducted. The two protocols provide guidance for survey and relocation activities to minimize impacts to native mussels in Michigan including guidance to minimize impacts to mussel species that are currently identified as threatened or endangered by the State of Michigan or U.S. Government. The Drawdown Protocol is intended for mussel rescue and relocation methods specific to reservoir drawdowns.

Dams are a ubiquitous component of most developed watersheds. There are approximately 2,500 dams in Michigan including about 1,000 dams regulated by the state and 100 dams regulated by the federal government. The reservoirs (or impoundments) behind these dams are drawn down for a variety of reasons including dam repairs and maintenance, protection against ice scour and shoreline erosion, private infrastructure repair, sediment removal, aquatic plant control, and dam removals. Drawdowns can result in large areas of exposed bottomland or aquatic habitat and stranded aquatic organisms. Since reservoirs are likely to contain freshwater mussels – thousands to more than a million in very large reservoirs (Englund and Heino 1994, Wisconsin DNR 2006; Figure 1) – **most reservoir drawdowns will require mussel rescue and relocation operations.** Possible exceptions for required mussel rescue and relocation efforts might include short-term drawdowns where the elapsed time between starting the drawdown and completely refilling the reservoir does not exceed 3 days.

Every effort should be made to ensure the drawdown purpose is justified given the myriad negative environmental effects. Even a well-managed drawdown will have significant impacts on the mussel population. Prior to developing plans for mussel rescue and relocation, seek to limit the frequency, duration, depth, and rate of the drawdown as much as possible, and ensure the drawdown occurs during time periods expected to reduce stress and mortality to aquatic

organisms. **The Michigan Department of Natural Resources (MDNR) and United States Fish and Wildlife Service (USFWS) encourage all dam owners to employ alternatives to avoid or minimize adverse impacts to mussels to the maximum extent practicable prior to planning any drawdowns.**

The purpose of this Drawdown Protocol is to provide guidance for individuals developing mussel rescue survey plans for reservoir drawdown projects to minimize impacts to native freshwater mussels, highlight regulatory responsibilities and requirements, outline methods for documenting species diversity and density of mussels in a drawn down reservoir, describe relocation procedures, and share information from recent reservoir mussel rescue and relocation efforts.

Figure 1 Mussels rescued and relocated during a drawdown.

Be Prepared for Challenges

Freshwater mussels have several sensitivities that tend to increase the likelihood that they will be stressed or killed during drawdowns. While each species and situation varies, mussels can be easily shocked by rapid changes in air and water temperatures, can desiccate if their habitat is dewatered, cannot survive in water with unsuitable dissolved oxygen and water chemistry, can be easily smothered, crushed, or buried, and can be subject to increased predation and sublethal effects from stress.

Several characteristics of mussel ecology, reservoirs, and the drawdown process can make mussel rescue a challenge. In addition to the sensitivity of mussels due to their basic ecology, some life history traits interact with common drawdown scenarios to require additional consideration to minimize stress and mortality. In this section, common challenges are described and strategies to address those challenges are offered.

Biology, Behavior, and Life History of Mussels

- Challenge: Some mussels may spend significant portions of their lives buried in sediment.
  - Strategy: In some instances, shallow excavation using garden rakes with stiff tines to remove mussels may be possible, particularly in the substrate below areas with high density of mussels on the surface (Figure 2).
  - Note: The unavoidable impacts and feasibility issues associated with large scale excavations are a good reason to limit the frequency and extent of drawdowns.

Figure 2 Using garden rakes to search exposed sediment in a drawn down reservoir.

- Challenge: Many mussels also burrow into sediment when water temperatures drop in the autumn.
  - Strategy: Adhere to timing recommendations for planned drawdowns (June 1 – October 15).
  - Strategy: When emergency conditions necessitate rescue and relocation during late autumn, winter, or early spring, emphasize documentation and triage as efforts will almost certainly miss most mussels and even those relocated will have a diminished probability of survival.
- Challenge: Mussels often react to falling water levels by burying or moving in random directions (Figure 3), and buried mussels are extremely difficult to rescue efficiently.
  - Strategy: Plan survey to include wetted portion of reservoir as drawdown is occurring.
  - Note: Recognize that some amount of stress and mortality will occur as a result of disturbing the aquatic environment, which is why justification, impact mitigation, and regulatory approval of any drawdown is required.

Figure 3 A fingernail clam (Family Sphaeriidae) reacting to a reservoir drawdown.

- Challenge: For mussels that do move towards deeper water, even gradual multi-day drawdowns may expose expanses of sediment too large for mussels to traverse before the next drawdown increment, before the sediments dry out or, in cold weather, freeze. Exposed mussels will begin to die in hours to days, depending on time of year.
  - Strategy: At a minimum, require daily surveys with increased search frequency when environmental conditions pose increased risk of stress and mortality.
  - Strategy: Deploy greater numbers of workers or concentrate effort in flat areas and obtain site bathymetry in advance to identify where these areas are likely to occur.

- Strategy: Begin surveys in the wet, particularly where sediments are unconsolidated and difficult to traverse once exposed. Deploy small vessels or individuals with flotation devices before the elevation drops too low to support working in the wet. Wet surveys are most effective when water depth is about 1.5-2' and there are few navigational hazards.
- Strategy: For areas where unconsolidated sediments are exposed and further rescue efforts are needed, consider using snowshoes.

Site and Drawdown Conditions

- Challenge: Drawdowns of large reservoirs can expose hundreds or even thousands of acres of lakebed (Figure 4), which may pose logistical challenges (e.g., labor, access, reducing stress to organisms).
  - Strategy: Evaluate the necessity of the drawdown. Consider alternatives for addressing the problem which would not require a full drawdown (e.g., divers, coffer dams).
  - Strategy: If not already available, conduct mussel surveys and bathymetry mapping to help concentrate efforts towards where mussels and gradual slopes of preferred substrates may be present - refer to Planning Process Section, Table 1.
- Challenge: Sediment composition can drastically limit mussel collection; sand is often quickly stable enough to walk on, but thick deposits of water-saturated silt can remain too soft to walk on for days, weeks, or longer (Figure 4).
  - Strategy: Begin surveys in the wet, particularly for areas of unconsolidated sediment which may be difficult to traverse once exposed. Deploy small vessels or individuals with flotation devices before the elevation drops too low to support them working in the wet. Wet surveys are most effective when water depth is about 1.5-2' and there are few navigational hazards.
  - Strategy: Snowshoes have been used to traverse soft silty sediment (Todd Crail, University of Toledo, personal communication). In these conditions, it is critical to perform rescue operations with other personnel, make your location and timeframe known to others, and wear personal protective equipment.
  - Strategy: Inflatable mattresses and basket-style fruit pickers have been used for general surveys in the wet and could be deployed for surveying backwaters.

Figure 4 Extensive post-drawdown "mud flats".

- Challenge: If many mussels are recovered, there may be logistical challenges associated with timely transport to the relocation site.
  - Strategy: Begin survey and relocation efforts well ahead of drawdown commencement.
  - Strategy: Plan and map out as many suitable relocation sites as possible and have multiple “back-up” sites to reduce likelihood of catastrophic stochastic events at any given relocation area.
- Challenge: Dense macrophyte growths, even when dead and laying on the sediment, and deposits of dead leaves can interfere with finding mussels (Figure 5).
  - Strategy: Garden rakes are useful for clearing away dead plant material.

Figure 5 Dead aquatic macrophytes (left) and dead leaves on sediment (right) exposed by a reservoir drawdown.

A complete list of recommended equipment specific to rescue and relocation efforts during drawdowns can be found in Appendix A.

Rescue and Relocation Guidelines

All native freshwater mussels, including non-listed species, are protected in Michigan. In addition, there are 4 species of freshwater mussels that are extant in Michigan that are federally listed as endangered pursuant to the Endangered Species Act (ESA) (87 Stat. 884; 16 U.S.C. 1531 *et seq.*). **In general, all mussels found during a rescue operation must be relocated.** Project proponents planning drawdowns are advised to contact the MDNR and USFWS early in the drawdown planning process to plan any necessary mussel rescue and relocation. If federally listed mussels have been reported previously from the project location, coordination with USFWS will be required.

Depending on air temperature and humidity, sediment moisture content, proximity to groundwater, and level of predation, exposed mussels may survive for a few days to up to several weeks. It is imperative that mussel rescue and relocation activities begin as soon as possible. For planned drawdowns, mussel rescue operations should start before the drawdown. For emergency drawdowns, mussel rescue operations should begin as soon as possible after the need for a drawdown is identified or a drawdown is occurring or has occurred.

Impact Minimization Steps

Seek to limit the frequency, duration, depth, footprint, and rate of the drawdown to the maximum extent practicable and ensure the drawdown occurs during time periods expected to reduce stress and mortality to aquatic organisms. In some cases, steps to minimize impact may eliminate or reduce the need for further efforts. Mussel surveys and relocations in Michigan may be conducted only when the water temperature is greater than 50°F and the air temperature is between 50-90° or between June 1 to September 30. Reservoir drawdowns outside of this window should be avoided whenever possible, for the following reasons:

- Many mussels naturally burrow into the sediments in the autumn and are then very difficult to locate and rescue.
- The colder the air and water temperature during and after an extended drawdown, the higher the mortality of mussels that are buried in the exposed sediments. Mussels may survive in damp sediments for some days but will die very quickly when the sediments freeze (Figure 6).
- Relocating mussels when water is cold may result in high mortality, even when the mussels are partly or wholly buried in the sediment at the relocation site.

All entities responsible for maintaining or operating dams should develop site-specific plans for resource protection and acquire necessary materials and information to assist in response efforts in the event of a planned or emergency drawdown condition.

Figure 6 Winter drawdown.

Prior Notification

Survey plans must be provided to MDNR and Department of Environment, Great Lakes, and Energy (EGLE; all waters) and USFWS (Group 3 waters only) for advanced review. To coordinate with the appropriate MDNR Fisheries management unit, refer to the following website. To coordinate with the appropriate EGLE staff, refer to the following website. This will allow agency staff to review existing data to help inform survey efforts and review relocation sites. **MDNR and EGLE staff shall be notified at least 90 days prior to the time the actual survey will occur,** and as soon as possible after potential for an emergency condition is identified. USFWS staff shall be notified at least 15 days prior to the time the actual survey will occur. Surveys conducted in Group 3 reservoirs must have received written concurrence from the USFWS prior to conducting any surveys. Relocation of federally listed mussels will require authorization through Section 7 consultation (for federally funded or permitted projects) or issuance of a Section 10 permit. Consultation with the USFWS is necessary to determine which authorization process is appropriate depending on the nature of the project. Impacts to federally listed species and their habitats must be avoided or minimized to the maximum extent practicable. Conservation measures in addition to relocation efforts may be required if the proposed project may adversely affect federally listed species. All applicable state and federal permits must be obtained prior to starting any survey and relocation work.

State and Federal Permit Requirements

All mussels in the state of Michigan are protected either by State laws or by the federal Endangered Species Act (ESA). Those individuals undertaking rescue and relocation efforts as a result of drawdowns are required to obtain permits in advance of any work. The type of permits required will depend on whether state and/or federally listed species are present. Michigan rivers and streams have been categorized into three groups, depending on whether special concern, state-threatened and endangered, or federally listed mussels may exist in those locations. Stream groups depicting expectations of the presence of federally listed species can be found in Appendix A of the Rivers Protocol (Hanshue *et al.* 2019). If uncertain, contact USFWS.

State of Michigan Permits are required before conducting any mussel surveys or relocations. Contact MDNR Fisheries Division at (517) 599-5734 or visit the website to obtain the Cultural and Scientific Collector's Permit. Additionally, if state-threatened or endangered mussels are anticipated at the site (i.e., in Group 2 waters), a Threatened and Endangered Species Permit is required. Contact the MDNR Endangered Species Program Staff at (517) 284-6210 or visit the website prior to the start of work. Applicants should apply for these permits at least 30 days prior to the anticipated start date of a project to allow time for proper review.

If federally listed species are anticipated at the site (i.e., in Group 3 waters), a USFWS permit will be required before conducting any mussel surveys. Contact the USFWS Michigan Field Office in East Lansing (517) 351-2555 or visit the website. Information on the presence of federally listed mussel species can be found at the following website and in the Rivers Protocol. If federally listed species are unexpectedly encountered in non-Group 3 watersheds, immediately stop the field work and contact USFWS for further instructions. Please note, the ESA's implementing regulations provide a limited exception that allows for any employee or agent of the USFWS, any other Federal land management agency, or a State conservation agency, who is "designated by his agency for such purposes, may, when acting in the course of his official duties" to take endangered wildlife without a permit if such action is necessary to aid a sick, injured, or orphaned specimen (50 CFR 17.21(c)(3)(i)). Use of this provision may be applicable in some emergency draw-down situations and has additional limitations and reporting requirements (see 50 CFR 17(c)(4) and (5)).

Surveyor Qualifications

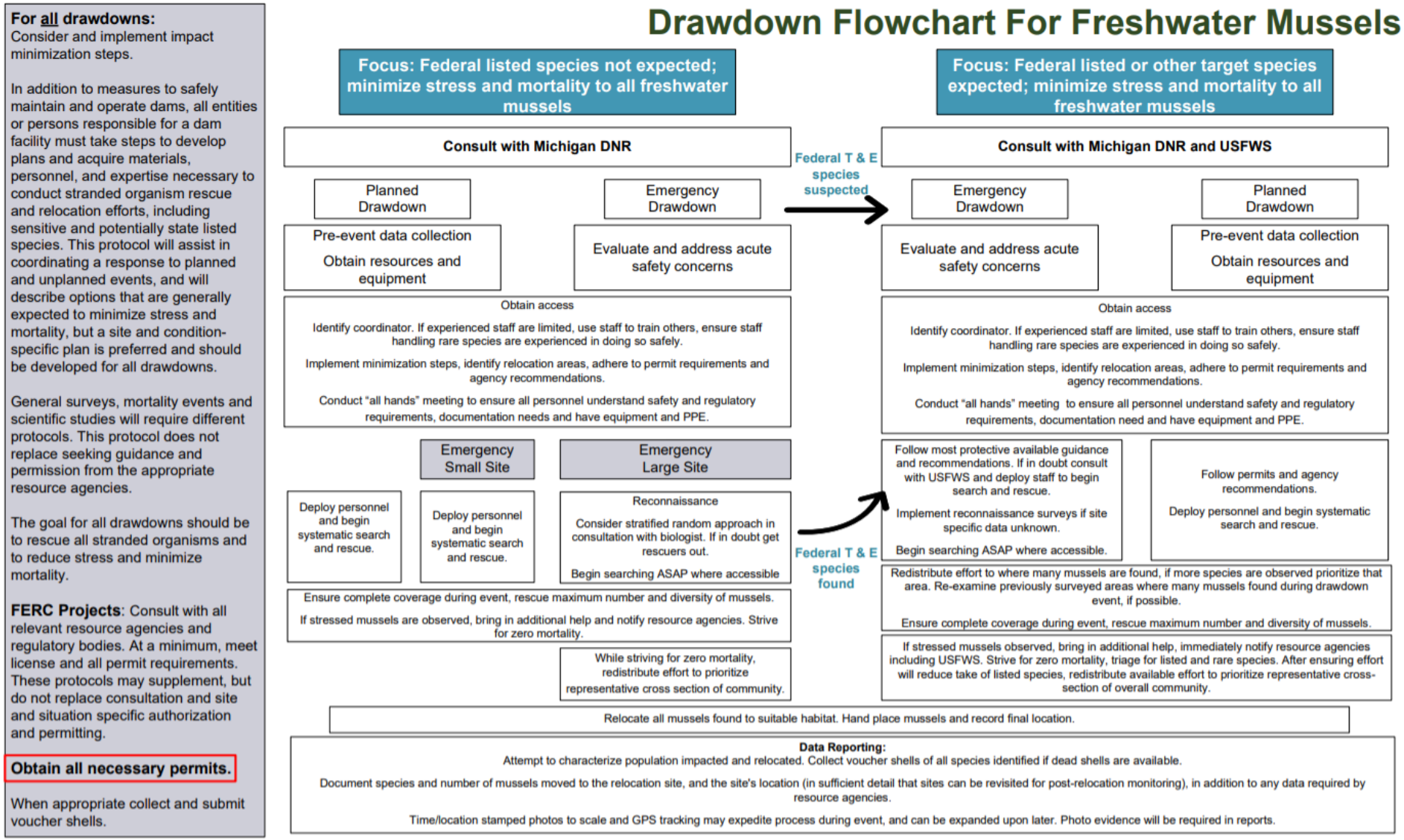
Mussel surveyors must have sufficient experience, including documented fieldwork, to execute these survey protocols and to locate and identify state and federally protected mussel species. The survey leader(s) must possess a Bachelor of Science degree in biology, natural resources, or a related field or possess sufficient experience as evidenced by documented fieldwork and have demonstrated knowledge of the biology and ecology of freshwater mussels. Surveyors must hold a valid permit to handle native mussels as outlined above. Additionally, in Group 3 reservoirs surveyors must also hold an ESA Section 10(a)(1)(A) permit from the USFWS. Pursuant to their ESA permit, surveyors must receive site-specific authorization from the USFWS Michigan Ecological Services Field Office prior to conducting surveys in any Group 3 reservoirs.

Reporting Requirements

A final report will be provided to the MDNR, EGLE, or USFWS point of contact within 45 days following the rescue and relocation operation. Survey, relocation, and post-relocation monitoring reports must be provided to USFWS in accordance with federal permit requirements or terms and conditions of a Biological Opinion. Refer to Appendix C for a checklist of data that must be included these reports. Data must be reported in accordance with the requirements of any other state and/or federal permits.

A copy of the final report and raw data must be retained by dam owners to inform future work.

Figure 7 Schematic outlining rescue and relocation procedures by focus.



Planning Process

Identify Coordinator

One person needs to be responsible for organizing efforts, securing necessary equipment and personal protective equipment (PPE), delegating tasks, and adjusting the approach as needed. While the coordinator does not need to be a mussel expert, they do need strong communication, leadership, and organization skills. The coordinator or designee should collect all necessary equipment and provide ample personal protective equipment (see Appendix A for recommendations). Although some personnel will have personal PPE, backups should be provided.

In a best-case scenario, the coordinator would be familiar with ecological sampling or emergency response in a natural resource context. The coordinator is ultimately responsible for the safety of all persons on-site, compliance with permits and relevant regulations and laws, and the ultimate success of the rescue and relocation effort.

Coordinate with Dam Owner/Operator(s)

If possible, gain cooperation of the dam owner and operator(s) prior to the drawdown to reduce environmental impacts. While water level ramping rates (i.e., allowed changes in water elevation over time) and other parameters should be prescribed by permits, having the dam owner and operators involved in efforts to minimize mussel stress and mortality can be invaluable.

Planned Drawdowns: At a minimum, the coordinator should be aware of the anticipated schedule of operations (e.g., start date, daily rates, and elevations), and prepare a contingency plan should the drawdown not go as planned. The operators will likely have dam safety provisions that could change the rate of drawdown (e.g, adjustments for precipitation events). The coordinator may also need to work with the dam operators if rescue and relocation efforts are not keeping up, or if environmental conditions may significantly impact survival during relocation. Communication procedures should be established, and clear decision points laid out so expectations are managed and met.

Emergency Drawdowns*:* The ability of the coordinator to apply these protocols will depend on the nature of the emergency and the ability and willingness of the operator to cooperate by regulating the drawdown rate. There may be additional constraints due to dam safety concerns. At a minimum, the coordinator should maintain communication with the operator or their designee and be aware of whether the site can be safely accessed for mussel rescue and relocation activities.

Pre-event Data Collection

Reconnaissance "Recon" surveys for mussels prior to drawdown can inform the level of response efforts needed. Significant time and expense may be spared by conducting a Recon survey in consultation with MDNR and, if needed, USFWS. Recon surveys may yield sufficient evidence to indicate further planning for rescue and relocation may not be necessary. If many mussels are found during Recon, effort can be scaled up accordingly to avoid mussel stress and mortality.

Pre-event data collection is critical to the efficiency and effectiveness of all rescue and relocation operations, and should be conducted for all planned drawdowns and, to the maximum extent practicable, emergency drawdowns. Many waterbodies have available satellite imagery, maps, bathymetry, and other geographic information. These materials should be collected in advance, along with any biological or other data that may be relevant to planning the rescue effort. Bathymetry data will substantially increase efficiency of the survey and rescue process. For planned drawdowns, bathymetry data can provide an idea of where and when mussels will be exposed as the drawdown progresses.

Previous studies across multiple water bodies and circumstances suggest indicators that might be useful for targeting mussel diversity hotspots (Table 1). These indicators should be used to triage efforts during emergency events or in very large reservoirs. If previous pre-drawdown sampling in the reservoir was limited (e.g., associated with a construction project), site characteristics and species found can still help inform a broader sampling strategy. In emergency conditions, existing representative data from the reservoir can be used to facilitate skipping the systematic random sampling and focusing efforts on diversity or density hot spots. It is also worth asking dam owners and operators for insight, as they may be familiar with site conditions which would be conducive to locating mussels as well as hazards to navigation/search efforts.

Table 1 Indicators to help predict possible mussel population locations.

Indicators of high mussel density	Indicators of minimal mussel density
Gravel, sand or silt substrate	Bedrock or clay substrate, even with a thin veneer of soft substrate
Soft sediment < 30 cm deep	Soft sediment > 30 cm deep
Water depth prior to drawdown < 3 m	Water depth > thermocline depth, where the hypolimnion is anoxic (i.e., below the oxycline)
Water depth > wave-mixed layer	Water depth < wave-mixed layer
On the upwind end of a reservoir with a long fetch	On the downwind end of a reservoir with a long fetch

Large woody material on the reservoir bed	Very dense macrophyte beds, especially over deep silty substrates
	Substrate exposed by previous recent drawdowns
	Dense deposits of small woody material (twigs), at least 3 cm (1 inch) thick

It is also worth noting that mussel diversity and density are often higher at the upstream end of large reservoirs.

Designate Site Access and Centralized Meeting Location

The coordinator or their designee should identify all potential access sites and gain appropriate permissions for various means of accessibility (e.g., flat-bottomed motorboat, kayak/canoe, diving, wading, snorkeling, walk-in). It is beneficial, and in some cases necessary, to provide supporting facilities (e.g., restrooms, wash areas) in addition to parking and equipment staging areas. Ideally sites used for pre-event data collection can be used by personnel during the drawdown. It may be useful to establish a central meeting and mussel processing location when working on large reservoirs or when very high numbers of mussels are expected. Safety briefings and team/search area assignments can take place at the central location and experienced malacologist(s) responsible for final identification can process and prepare rescued mussels for transport to relocation sites. Additionally, pre-identified public access sites such as boat ramps or shoreline parks may serve as useful markers for emergency personnel if needed.

Identify Relocation Site(s)

Appropriate primary and alternative relocation sites must be identified in advanced to maximize survival and fitness of relocated mussels. See the Relocation Procedures, Site Selection section below for further details on relocation site selection.

Rescue Procedures

The following section is structured by whether USFWS consultation is known to be required in advance: 1) Community rescue procedures when federally listed mussel species are not expected; and 2) Rescue procedures when federally listed mussel species are expected or encountered. State listed mussel species may require additional approvals and attention; however, typically state agency representatives can be point of contact for state listed species as well as common species.

Mussel Community Rescue Procedures

The objective of a mussel community rescue effort is to maximize the number and diversity of mussels collected to capture a representative cross-section of the mussel community in the reservoir. **This strategy is not intended for use where federally listed mussels are known to occur (refer to Federal or State Listed Species Present: Modifications to Community Procedures section).** The following procedures only apply to drawdowns where a more protective, project-specific plan has not and cannot be developed in advance. Plans can and should be created with site-specific strategies for emergency conditions as well as non-emergency events. This procedure only applies to projects where the drawdown is necessary and its negative effects have already been minimized to the extent possible via appropriate timing, minimizing extent and duration of drawdown, and providing for protective drawdown rates as well as meeting all permit requirements. While this procedure would be superseded by project-specific plans or permit requirements if available, this document describes options for distributing effort across a site, methods, and detailed examples.

Deploying Personnel – Naming Site Locations

One strategy to aid in organizing response efforts is to create and maintain a stable geographic position grid with location names (e.g., "cells") for personnel to reference when deploying to locations and recording site data. Depending on the orientation of the system and its complexity, it may make sense to use a grid oriented relative to gradient or flow of water (Figure 8 Flow layout. Direction of cells oriented relative to flow where site is relatively simple and majority of search area is consistently off standard N/S/W/E directions.). In more complex systems, cardinal directions may be more effective (Figure 9).

Cell size should be scaled to the site size, complexity, and expected presence of difficult-to-locate mussels (e.g., smaller-bodied mussels). Each cell in the waterbody should have a unique identifier that is referenced in written records of work activity. For the purpose of documentation, cells should not exceed 10-m x 10-m or 0.1-0.5% of the reservoir drawdown area. Each workday, personnel should be assigned a series of cells which are close to each other and to designated entry/exit routes.

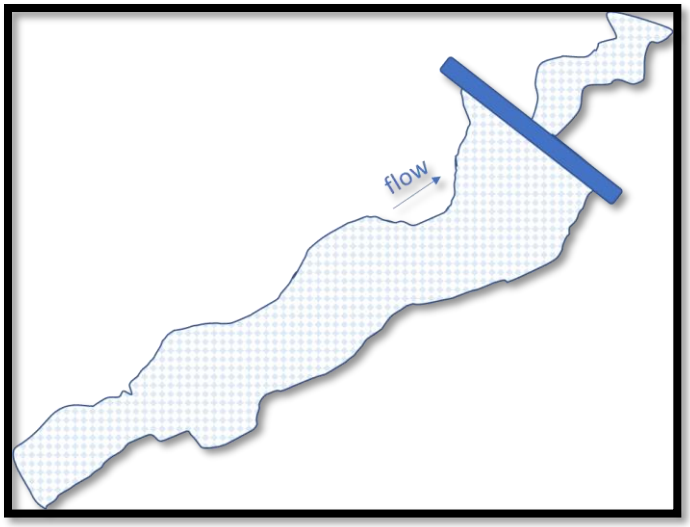


Figure 8 Flow layout. Direction of cells oriented relative to flow where site is relatively simple and majority of search area is consistently off standard N/S/W/E directions.

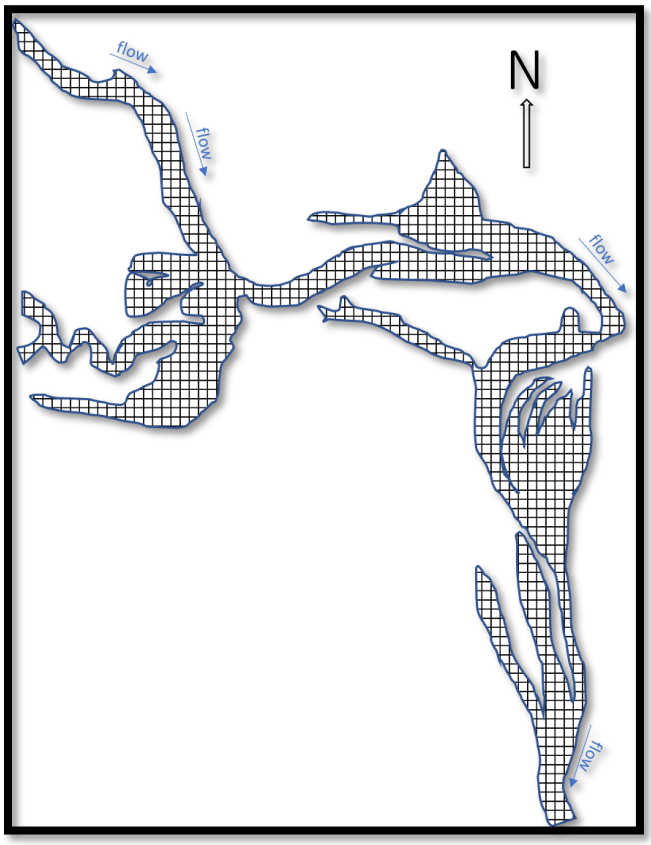


Figure 9 Cardinal Layout. Direction of cells oriented relative to cardinal directions, as GPS and/or compasses will likely be necessary to maintain locations. Creating temporary markers would be especially important in a site as complex as this.

Bathymetry data will substantially increase efficiency of this process. For planned drawdowns, bathymetry data can provide a rough idea of where and when mussels will be exposed as the drawdown progresses. For areas where bathymetry is unknown, a simple grid will at least enable survey personnel to reference known and commonly understood points.

Marking and Flagging Cells and Other Site Locations

Using a system of cells to designate areas for personnel to cover, as well as to later record locations of mussels, is more efficient than marking GPS coordinates for each individual organism observation. The coordinates of each cell centroid should be recorded using GPS and all mussels found in that cell assigned to it. Depending on the size of the drawdown area for any given day, cells of different proportions may be appropriate. For example, if narrow bands of steep-sloped sediments are exposed, long, narrow linear cells may be appropriate (e.g., at the targeted depth contour, such as 1-1.5 feet as the water is gradually lowered). In these cases, individuals can make judgement calls on search method depending on the resolution of data sought. Irrespective of cell shape, each cell in the waterbody must have a unique identifier to reference in written records of work activity. The naming system should be consistent with the search method if possible.

Primary relocation sites and alternative sites should be clearly marked and familiarized by all personnel. This will ensure timely relocation of rescued mussels, prevent trampling, risk to divers if used, etc.

Personnel Management

Although more personnel often mean an overall better response, organization is key. For safety reasons, personnel should not enter the survey area without being properly accounted for. Sites can be unsafe and foot, vehicle, and vessel traffic pose a risk to mussels and other organisms being rescued. Staff should receive a daily safety orientation specific to the site and conditions. In addition, regardless of the familiarity of personnel with freshwater mussel and ecological sampling, specific guidance about performance objectives must be provided. To assist with mussel identification by field crews, it can be useful to prepare site-specific laminated mussel identification cards, with illustrations of the expected species – see Appendix D for an example. Personnel should be familiar with checklists, PPE, and equipment. The coordinator should constantly evaluate efficiency during operations, as the ability of personnel to cover area in a given time varies widely among persons, site and weather conditions, substrates, topography, mussel species and densities, etc. The coordinator should plan to adjust work plans accordingly for following days or segments.

Search Techniques

Depending on site bathymetry, macrophyte cover, navigational hazards, and area exposed between search events, a combination of wading, diving, snorkeling, use of floating mats, snowshoes, small boats, and other equipment may be necessary.

Every effort should be made to maximize the comfort and safety of personnel conducting rescues. Searches often require extensive crouching, stooping, and other atypical movements, so to the extent ergonomics can be considered, the more successful a rescue effort will likely be. Detecting and relocating mussels in the wet (e.g., snorkeling, using floatation devices, using buckets with small vessels or waders in shallow water) has the advantage of allowing personnel to avoid traversing unconsolidated sediments and search from a prone position which may be more comfortable. If divers will be used during relocation efforts, they may be useful for searching in deep/unconsolidated areas or where macrophytes obscure the substrate.

Large Sites

Planned Drawdowns: Mussel community rescue is focused on collecting as many mussels representing the species richness and age distribution of the overall waterbody as feasible. At smaller sites, it is expected that all mussels will be rescued and relocated. At larger sites lacking pre-data, a stratified random survey design will need to be employed. With planned drawdowns, this stratified random approach should be applied during the pre-survey to validate indicators including habitat types (e.g., substrates, depth, fetch – see Table 1). These pre-survey findings can be used to prioritize areas during the drawdown to maximize the likelihood of rescuing a representative sample of the community. If any of these indicators of mussel presence are found to be incorrect once the rescue begins, simply shift effort accordingly as soon as possible.

Emergency Drawdowns: In an emergency drawdown, a stratified random sampling structure should be applied in the initial effort (e.g., first day), where the habitat features are noted along with observations of stranded organisms. The coordinator can then prioritize areas/cells to be searched based on results from that initial effort. If other indicators are found to be predictive of mussel occurrence, document and validate it and please share your findings with the authors of this document. Because of the time-sensitive nature of emergency drawdowns, survey efforts should be reevaluated constantly – delegate time and staff where high densities of mussels are found and divert staff from areas found to be lacking in mussels.

Generally, the greatest survey effort should be concentrated during the first week of the rescue operation, when mussel survival probability is highest. Field staff should focus on newly dewatered and partly dewatered areas where mussels are visible. Shallow-draft boats and kayaks can be used to access offshore locations (e.g., islands) and search partly dewatered locations.

Small Sites

For smaller sites, all dewatered areas should be searched daily regardless of whether it is a planned or emergency drawdown. If timed properly and the site conditions are suitable for doing so, the bulk of search effort can be dedicated within a contour between 1 and 1.5 feet of water, allowing personnel to work within easy reach from vessels or by crouching. Within each cell, a variety of search methods can be used, but generally a serpentine pattern is most efficient (Figure 10).

Figure 10 Note footprints traversing in a serpentine pattern for searching within cells.

Mussel Handling, Processing, and Documentation

Mussels collected during rescue operations should be kept cool, moist, and protected from prolonged exposure to air. Any mussels collected will be placed in a mesh bag and brought to the surface for further processing and positive identification. Mesh bags, perforated buckets, or comparable containers may be used to temporarily hold mussels prior to identification, measuring, photographing, and marking. Bags or buckets should be placed in shaded water if possible to maximize dissolved oxygen concentrations and minimize temperature fluctuations around the mussels. To minimize handling stress, collected mussels should always be kept in water except for the brief period needed for processing.

Daily reporting forms should be drafted and printed in advance (see Appendix B for an example). The minimum data collected should include collector names, date and time, drawdown extent/frame of reference, area covered, method and information on mussels found including location/cell, species, length/age, condition, fate (relocated or not relocated) and voucher information (photo taken of individual, bag, sample kept). Rescued mussels should be identified to species by a qualified biologist using the Michigan Mussel Field Guide (Mulcrone and Rathbun 2020) or other recommended guides (Appendix A). Daily reporting forms should be submitted to the appropriate MDNR point of contact no later than 24 hours after the survey completion date. If federally listed species are unexpectedly found, USFWS must be notified immediately to ensure proper compliance with the ESA. Similarly, if unforeseen field conditions arise, notify permitting agencies immediately. Additional information may be required by permitting agencies.

If shells of a species previously unknown to exist in the watershed is encountered, retain a voucher shell, note location found on the daily reporting form, and notify MDNR and EGLE at the completion of the survey. The shells should be retained for submittal to the University of Michigan Zoological Museum for cataloging (Note: The Museum will require proof that the shells were collected under the appropriate state and/or federal permit).

A balance must be struck between reducing mortality and gathering information. In cases where additional drawdowns are expected to occur in the future, locations of dense mussel populations should be noted to inform future rescue and relocation efforts and reduce long-term impacts.

Crisis Situations

While plans should be in place for likely contingencies (e.g., staff needs, backup relocation areas as necessary, weather), unexpected situations may arise. Notify permitting agencies immediately of any significant changes to approved mussel rescue plans and undertake interim measures which may reduce harm/stress to the mussels. Until additional guidance can be obtained, the procedures for emergency drawdowns may provide the best method for triage and rescue of a representative cross-section of the community.

Federal or State Listed Species Present: Modifications to Mussel Community Rescue Procedures

The objective of rescue efforts when federal and state listed threatened, endangered, special concern species are present is to prioritize reducing stress and mortality to these organisms, while minimizing stress and mortality to the broader community to the extent possible. Ideally, individuals of every species will be rescued regardless of listing. In small reservoirs, it is expected that all mussels will be rescued; however, for larger reservoirs, prioritization in targeted areas and potentially species focus will be required, in which case listed species must take precedent. Unless otherwise specified, provisions used for the small-site community rescue apply to listed mussels. **Consultation with USFWS is required when federally listed mussels are present or discovered in the reservoir.** Relocation of federally listed mussels will require authorization through Section 7 consultation (for federally funded or permitted projects) or issuance of a Section 10 permit. In emergency situations, the ESA's implementing regulations allow for the take of endangered species when necessary to protect human lives (50 CFR 17.21(c)(2). Consultation with the USFWS is necessary to determine which authorization process is appropriate depending on the nature of the project. Impacts to federally listed species and their habitats must be avoided or minimized to the maximum extent practicable. Conservation measures in addition to relocation efforts may be required if the proposed project may adversely affect federally listed species. Formal consultation with the USFWS or USFWS issuance of an incidental take permit pursuant to Section 10 of the ESA may result in different requirements than those outlined below.

If mussel surveys have been conducted in or near the reservoir, use those reports to help guide representative sampling and provide indicators of potential high diversity sites. In systems where listed mussels are expected, survey efforts should prioritize habitats in which they more likely to be found (e.g., snuffbox are more likely to be found in riffle habitats, paper pondshell are more likely to be found fine-grained substrate) followed by representative habitats as indicated in Table 1.

It is important to note that lack of known presence of listed species does not mean absence of listed species. The coordinator should be prepared to contact USFWS staff if federally listed mussels are encountered.

Personnel Management

In addition to concerns about organization and safety of personnel, mussels may subject to physical harm by inadequate site management (e.g., foot or all-terrain vehicle traffic, grounding of vessels).

Search Techniques

Large Sites: Prioritizing Listed Species

Rescue operations involving listed mussels are chiefly focused on individuals of these species. While it may be tempting to pick the bigger and easier to spot individuals, care should be taken to rescue individuals across age classes with particular focus on the most fecund ages if known (i.e., neither juveniles nor exclusively very old adults).

Emergency Drawdowns: Initial efforts (e.g., first day) should focus on habitats associated with the listed species, with targeted search areas modified in following days based on predictive success. If other indicators are found to be predictive of mussel occurrence, document and validate it and please share your findings with the authors of this document. Because of the time-sensitive nature of emergency drawdowns, survey efforts should be reevaluated constantly – delegate time and staff where high densities of mussels are found and divert staff from areas found to be lacking in mussels. If habitat indicators are not known or are proving ineffective, it is possible that shifting to a community approach may yield additional success in rescuing listed mussels.

Example scenario: Coordinator plus 4-person crew. Initially, each person might be assigned ¼ of the exposed area. However, within the first few hours of the survey, the coordinator notices that one person encountered a very high density and diversity area. The other three people have relatively low density and diversity of mussels in their area. One of the other three people should be diverted to the high density and diversity cell, and the cells originally assigned to that person should be divided among the staff remaining in the low-density areas. Even in a planned event, some amount of triage is warranted to reduce stress and mortality of stranded organisms. Among other duties, the coordinator is responsible for ensuring work is allocated in a manner that maximizes the survival of stranded mussels.

Initial distribution of effort: Ensuring coverage of all dewatered areas will generally require assigning areas to individual personnel or teams. After an initial reconnaissance of assigned areas, the coordinator should determine whether to reassign individuals or teams from less densely populated areas to more densely populated or harder to traverse areas.

Small Sites

At small sites, all mussels must be rescued regardless of status and should follow the method set forth for small site community rescues, above.

Mussel Handling, Processing, and Documentation

When federally listed species are expected or encountered, follow the methods described in Mussel Handling, Processing, and Documentation in the Community Rescue Procedures section and/or any requirements specified in a Biological Opinion or incidental take permit pursuant to Section 10 of the ESA.

Marking Relocated Mussels

Post-relocation monitoring is recommended and may be required for relocated mussels. The USFWS should be consulted on post relocation monitoring requirements for federally listed species. The Rivers Protocol currently requires post-relocation monitoring in Group 2 and 3 waters, and MDNR and/or USFWS may require post-relocation monitoring in these watersheds, as well as Group 1 or unspecified waters. If post-relocation monitoring is required, relocated mussels should be marked as follows:

- Federal Threatened and Endangered species shell lengths should be measured to the nearest millimeter and shells should be marked with a passive integrated transponder (PIT) tag as described by Woolnough and Barnett (2013) and Kurth *et al.* (2007).
- State Threatened and Endangered species shell lengths should be measured to the nearest millimeter and the shells marked. A small rotary tool can be used mark both shells. Great care must be taken while etching the shells to not damage the mussel, as adults of some species and juveniles of all species have thin shells. Do not use this method for very thin shelled species (e.g. P. lacustris and grandis, U. imbecillis).

The final report should detail methods used to mark relocated mussels.

Relocation Procedures

Mussel relocation efforts are required for all mussels encountered during the rescue operation described above (i.e., both listed and non-listed species). However, no mussels are to be moved without prior authorization from MDNR and USFWS if federally listed species are known or suspected to occur. If state-listed species are expected to be present at the project site, a relocation plan can be submitted with the survey plan for review and approval from MDNR. If federally listed species are expected, coordination with USFWS and MDNR must occur prior to any relocation efforts. Relocation of federally listed mussels will require authorization through Section 7 consultation (for federally funded or permitted projects) or issuance of a Section 10 permit (for all non-federal projects). Consultation with the USFWS is necessary to determine which authorization process is appropriate depending on the nature of the project. Impacts to federally listed species and their habitats must be avoided or minimized to the extent practicable. Conservation measures in addition to relocation may be required if the proposed project may adversely affect federally listed species.

The general goals of mussel relocation are to:

- Maximize survival and fitness of the relocated individuals, including genetic diversity.
- Minimize risk to the resident mussel fauna at the relocation site.
- Document relocation outcomes to inform future relocation efforts.

The procedures described below are intended to maximize attainment of these goals.

Site Selection

Selecting an appropriate relocation site is the most important decision in any mussel relocation project. Careful consideration must be given to the location and characteristics of the relocation, including proximity to the reservoir, habitat characteristics, and details of the existing mussel community (Table 2).

Table 2 Recommended mussel relocation site considerations for reservoir drawdown projects.

• Relocation sites shall be upstream (preferred) or downstream of the reservoir. Alternate locations, including within the reservoir footprint, will be reviewed on a case-by-case basis (Figure 11). • The presence of a similar mussel community comprised of all or most of the species to be relocated. • Evidence of recruitment as indicated by the presence of juvenile mussels. • Habitat at the relocation site should be as similar as possible to the rescue area in terms of sediment composition and stability, water quality, water depth, overall area, and upstream drainage area. Multiple relocation sites may be necessary if the rescue area is particularly large.

- Appropriate fish host species must be present. If juvenile mussels are present, or if the relocation site is within the drawdown reservoir, host fish presence is assumed.
- The relocation site should be secure for the foreseeable future from disturbances (e.g., dredging or exposure during future drawdowns).
- Mussels should not be relocated into tributaries that drain into the reservoir if the drawdown was the result of a rapid dam failure, as very rapid drawdowns can trigger headcuts that destabilize the tributary streambed for substantial distances upstream of the reservoir footprint.
- In the case of a full dam removal, care should be taken when choosing a relocation site upstream of the reservoir if the sill has been completely removed AND the streambed downstream of the dam has incised below its original elevation, because this downstream incision could migrate upstream of the reservoir footprint. This relatively rare situation will be revealed during pre-removal geomorphology surveys.
- If zebra mussels (*Dresissena polymorpha*) and quagga mussels (*D. rostiformis*) are absent from the rescue area, they must not be present either at the relocation site or upstream of the relocation site.

Visual-tactile and quantitative surveys will be required to assess the composition of the mussel community at the relocation site (see Rivers Protocol, Section V – Survey Techniques for details). An estimate of the size of the relocation site must be included in the survey. This survey may be performed up to 5 years prior to the relocation. The relocation site survey may have to be repeated if an event or impact (e.g., chemical spill, dredging) has occurred during the time between the original survey and the proposed relocation that could have impacted the resident mussel community or altered environmental conditions. State or federally listed species must be relocated to sites where those species already occur, unless no other suitable sites are identified, and permission is obtained from the MDNR for Group 2 streams and USFWS and MDNR for Group 3 streams.

If the reservoir area from which mussels will be relocated is large, it may be necessary to select more than one relocation site. In this case, the combined total area of the relocation sites should be equal to or greater than the area from which mussels are rescued.

For drawdowns that empty most of the reservoir for an extended period, mussels are usually best relocated to nearby stream reaches upstream or downstream of the reservoir. Mussels could be relocated to the thalweg of the developing channel within the drawn down reservoir if its final location is predictable. However, predicting the final location of the developing channel can be difficult and getting it wrong will necessitate relocating the same mussels two or more times. Figure 11 outlines assessing the suitability of the developing river channel as a mussel relocation site. The figure begins with a permanent reservoir drawdown caused by a dam removal, but the right side of the figure is appropriate for any type of drawdown. **Additionally, mussels should not be relocated into areas of deep reservoirs (e.g., approximately 20 to 30 feet deep after refill) that could lack oxygen if the reservoir stratifies during the summer.**

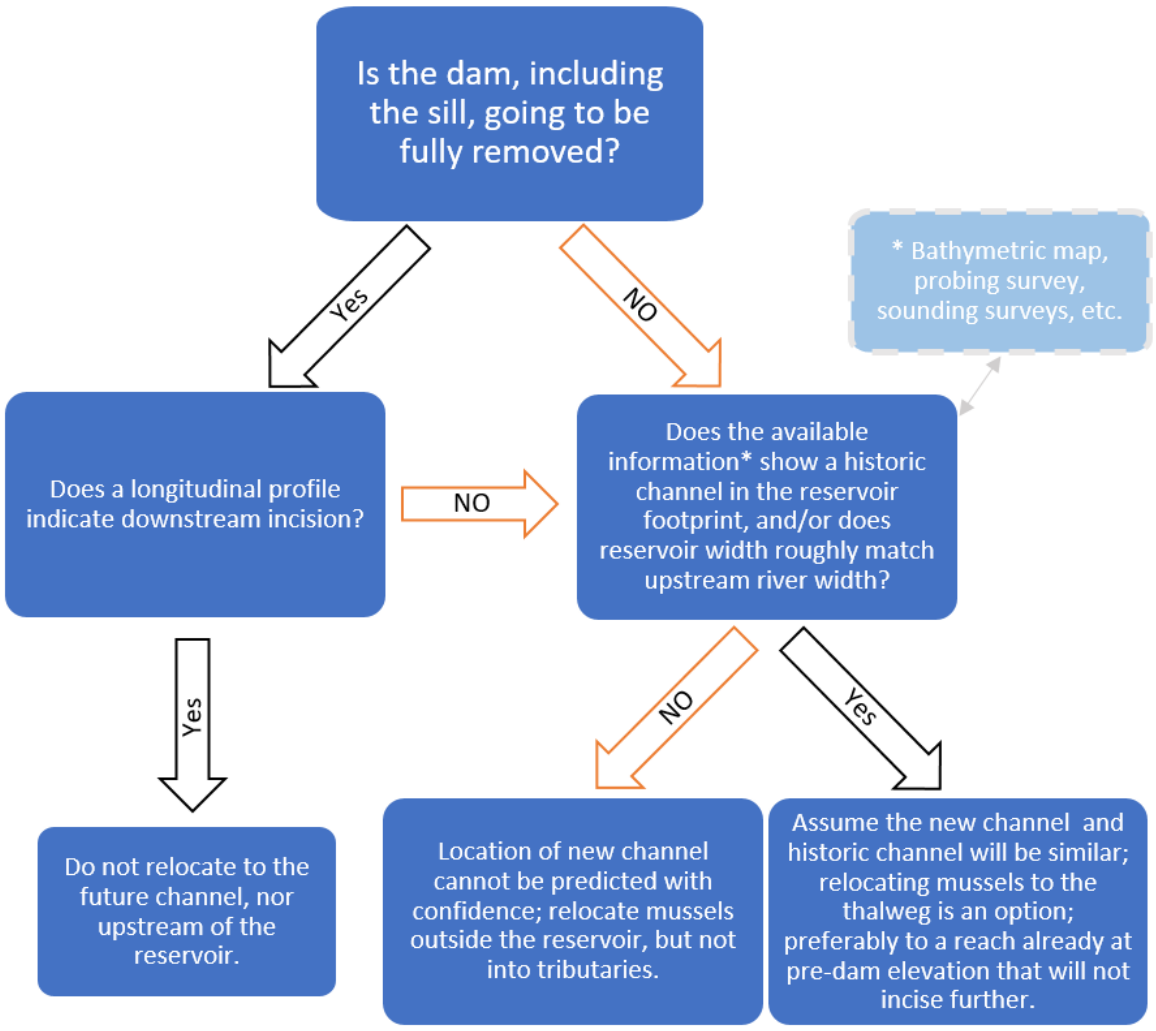


Figure 11 Flow chart for assessing the suitability of the developing river channel as a mussel relocation site.

The location of the relocation site(s) must be documented as indicated in the report checklist (Appendix B). **Prior to the relocation activities, a report on the relocation site(s) will be prepared and submitted to MDNR for state listed species or MDNR and USFWS for federally listed species for approval.** This report shall include summaries of the site attributes as listed in Table 2. If the number of mussels to be moved is large and suitable habitat at the relocation site for state listed or federally listed species is limited, non-listed mussel species may be moved to appropriate watered habitat within the reservoir as long as it is not expected to be dewatered by the drawdown.

Transport and Placement (Mussel Handling)

On the day(s) of the relocation, minimum expected air temperatures should be greater than 50°F, and maximum expected air temperatures should be less than 90°F. Also, relocations should be

performed when stream discharge is stable and turbidity is low. Mussels shall be transported in containers that minimize jostling or impact. It is not necessary to transport the mussels in water, but they must be kept cool and moist, which is best accomplished by covering with wet towels or burlap bags. Do not place the mussels on ice, which may cause temperature shock. Exposure to air during measuring, marking, and transporting must be minimized and should be kept to less than 5 minutes. Maximum processing time from collection to relocation should not exceed 24 hours and moving mussels on the same day they are collected is preferred. If a longer processing time is unavoidable, consultation with the permitting agency is required prior to the relocation. Signs of physiological stress include shell gaping, foot extension, and mucus secretion. Stress can be reduced by holding mussels in flowing water prior to processing (measuring and marking), reducing the number of mussels held and processed at one time, processing mussels in the shade, and having a short distance between the rescue site and the relocation site.

Mussels shall be placed into the sediment at the relocation site by hand, posterior end up, and buried half in the sediment. If necessary, use a trowel to dig a small pit.

Reporting

A final report on all rescue and relocation efforts will be provided to MDNR within 45 days of completion of relocation. Survey, relocation, and post-relocation monitoring must be provided to USFWS in accordance with federal permit requirements or terms and conditions of a Biological Opinion. Refer to Appendix C for a checklist of data that must be included in these reports.

Post-reservoir refilling monitoring

If the drawdown triggers a long-term assessment of mussel community recovery, it is recommended that recruitment be assessed 5 or more years after the reservoir is refilled. In this case recruitment is broadly defined to include both juvenile mussels (≤ 3 years old) plus mussels that are “younger than” those relocated to the refilled reservoir (e.g., 5-year-old mussels are found in a reservoir that was refilled 7 years ago). Mussel density could also be an indicator of recovery, but only if pre-drawdown data exist for the drawn down reservoir; density data for other, nearby reservoirs are not necessarily comparable to the drawn down reservoir.

Conclusions

Due to the interactions between mussel ecology, reservoir, and drawdown characteristics, mussel mortality can be very high even when the drawdown lasts only a few days. Therefore, reservoirs drawdowns are arguably the largest acute anthropogenic cause of mussel mortality in the state of Michigan compared to other short-term impacts (e.g., dredging or bridge construction projects). Despite these challenges, rescuing and relocating mussels during a reservoir drawdown is still extremely important and worthwhile, as freshwater mussels are one of the most imperiled group of organisms in the United States and the ecosystem services they provide are well-recognized and documented. It is also important to consider that mussel populations are slow to rebound after significant population losses due to their complex life cycle and loss of critical population size for reproduction. Therefore, it is critical to protect all mussel communities and especially those where natural reproduction is occurring. While many current mussel populations are a fraction of what they once were, their protection may mean the difference between extirpation and persistence of the aquatic community over time. This is true even when a site has a history of repeated drawdowns.

As is often the case, resource protection has a high return on investment relative to restoration. Mussel propagation facilities and techniques are still in the early stages of development and testing, and the specific host and habitat requirements of many mussel species are not well understood. Although this document pertains to activities in highly altered systems, a tremendous amount of work has gone into integrating aquatic ecosystem health with infrastructure and development – one no longer precludes the other. Efforts to increase watershed connectivity and promote stream functions, even in systems where hydraulic control infrastructure remains in place, have the potential to allow mussel communities protected today to rebound over time.

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Appendix A: Recommended Equipment and Field Guides

Mussel collection

Digital camera, preferably able to operate underwater

Field forms, preferably on waterproof paper, and clipboard

GPS unit

Watch, to record survey duration

Measuring tapes or rangefinders, to measure survey area

Waders, snorkeling gear, SCUBA gear, as needed

Mesh bags or buckets, for carrying mussels

Viewing cones or glass bottom buckets

Survey flags

Canoe or flat bottom boat, or inflatable air mattresses, and personal floatation devices, if working in the water

Snowshoes, for walking on unconsolidated sediment (use with great caution)

Apple picker on a long pole

Garden rake

Two-way radios or cell phones

Binoculars

Thermometer for air and water temperature

Lake bathymetry map and/or lake maps

State T&E permit

Federal T&E permit (if needed)

Scientific Collector's Permit

Copies of survey methods/protocols/workplan/QAPP etc. for each survey team

Mussel processing

Blanket/tarp, for sorting mussels on

Small dry erase board and markers

Extra rite in the rain or other water-resistant paper

Magnifying hand lens

Small stainless-steel scrub brush, for cleaning shells to facilitate identification

Mussel identification guide

Perforated buckets or laundry baskets

Binder for datasheets

Pencils, sharpies

Qualitative search data sheets (rite in rain paper)

Quadrat data sheets (rite in rain paper)

Mussel relocation

Tubs, coolers or similar containers, to transport mussels

Towels, to cushion and cover mussels

Trowel, if needed to position mussels into the substrate

Recommended Field Guides

Mulcrone, R. S. and J. E. Rathbun. 2020. Pocket Field Guide to the Freshwater Mussels of Michigan. Michigan Department Natural Resources.

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Appendix B: Daily Reporting Form

Project Information

Project name:

Waterbody:

Dam/Reservoir name:

Stream Group:

County:

Rescue Operation Information

Surveyor names:

Survey date:

Area surveyed (acres):

Time searched (minutes x number of surveyors):

Water temperature (^{o}F):

Air temperature (^{o}F):

Visibility (cm):

Substrate composition(s):

Describe any deviations from Drawdown Protocol (if applicable):

Describe any access/safety issues:

Other relevant observations:

Results

Evidence of Mussels:

- ☐ None
- ☐ Mussel Shell Only – Subfossil (nacre chalky; periostracum largely missing; shell edges chipped or cracked)
- ☐ Mussel Shell Only – Weathered Dead (nacre not glossy; periostracum starting to flake off; algae and/or marl on inside of shell if shell is exposed to water)
- ☐ Mussel Shell Only – Fresh Dead (nacre intact and glossy; periostracum intact; perhaps soft tissue present; shell halves often joined by hinge ligament)
- ☐ Living Mussels

Shell Only Species and Numbers:

Living Species and Numbers:

Use separate page for site sketch and include search area, locations of shells and live mussels, and location and direction of photos.

Required Attachments

1. Location Map
2. Photo Log

Appendix C: Final Report Checklist

Introduction

- ☐ Description of reservoir and watershed including:
  - Dam owner(s)
  - Dam function (e.g., recreation)
  - Regulatory authority (e.g., State of Michigan)
  - Name (if stream and reservoir are named)
  - Reservoir description, including:
    - Size (acres)
    - Depth
    - Substrate
  - Location, including:
    - Coordinates – at center of reservoir
    - River mile (if available)
    - Township, range, and section
    - County
  - Drainage area at survey site
  - Summary of any water quality data or previous mussel survey reports near or in reservoir
  - Surrounding land use
- ☐ Description of drawdown
  - Purpose
  - Rate
  - Duration

Methods

- ☐ Personnel
- ☐ Date(s) of survey
- ☐ Area surveyed, including:
  - Description of survey (e.g., acres covered)
  - GPS coordinates of survey
  - Map delineating survey area. Map can be included within text or in Figures & Tables section.
- ☐ Survey method, including:
  - Type of mussel survey completed (e.g., visual-tactile, transects, cells)
  - Length and spacing of transects or size of the cells
  - Time searched
  - Method of detection (e.g., SCUBA, view bucket, quadrats)
  - Whether or not shoreline/banks were searched for shells
  - Trigger (for quantitative studies)

- Description of additional transects (for quantitative studies), including coordinates and delineated map
- Mussel handling and processing procedures
- Quality control procedures (includes taking representative photos of each species and video of any questionable specimens)
- Safety and access issues encountered

Results

- Habitat assessment within each transect, cell, or timed search area, including:
  - Substrate composition (include information about stability of substrates)
  - In-stream features (e.g., channel alterations, reservoirs)
  - Average stream depth
  - Water velocity (cubic feet per second)
  - Visibility (say what the visibility was, not just that it met the minimum requirements)
  - Water temperature
  - Suitable habitats within the area of the survey
  - Photos of reservoir and substrate
- An overview of the results, including:
  - Number of individuals found
  - Number of species found
  - Any notable species found (e.g., listed species, species not known to exist in the watershed)
- A description of the results of the semi-quantitative and quantitative surveys separately
  - Tables of results, including (either within text or attached in Appendix):
    - Species data for each transect and/or cell
    - Relative abundance
    - Condition (living, fresh dead, weathered, subfossil)
    - Sex of individuals if determinable
    - Morphometric data (optional if not required by permit or site-specific authorization)

Mussel Relocation

- Relocation site(s), including:
  - Location (coordinates at center)
  - Map delineating area. Map can be included within text or in Figures & Tables section.
  - Results of required semi-quantitative and quantitative surveys
  - Method of rescuing mussels from search area
  - Environmental characteristics (water depth, velocity, sediment composition, etc.)
  - Number of each species relocated
  - Type of mark used (shellfish tag, PIT tag, etching)

Post Relocation

- Relocation site(s) monitoring, including:
  - Environmental conditions, including the same parameters documented at time of relocation
  - Numbers, lengths, and calculated percent of living, dead, and missing mussels for each marked relocated species
  - Observations on condition of mussels and relocation site

Conclusion

- Summary of findings and conclusions

References

- Citations for any literature cited within text of report

Figures & Tables

- If not provided in text, provide a separate section for Figures (maps and aerial photos showing extent of survey) and Tables (transect and quadrat data, morphometric data)

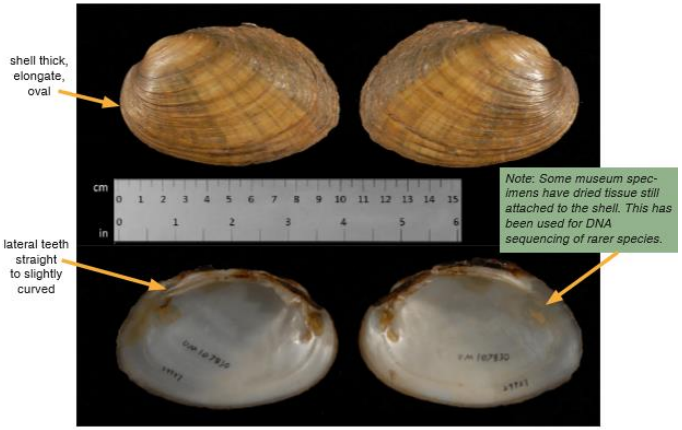
Appendix

- Photos of reservoir and substrates
- Representative photos of each mussel species found
- Video of questionable species
- Raw data sheets
- Copy of State and/or Federal permits
- Site-specific authorization from USFWS for Group 3 rescue and relocation work

Appendix D: Example Field ID Sheet

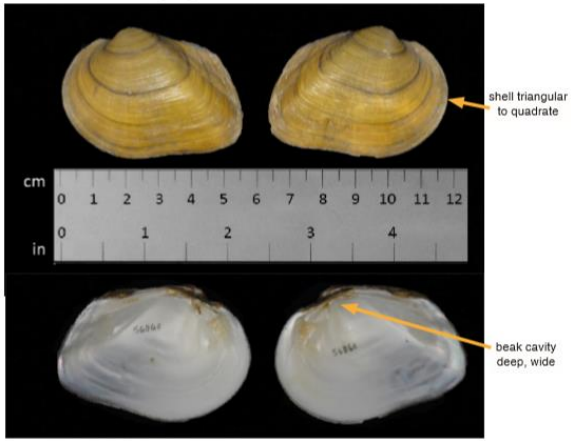
Quick Guide to the Known Mussels of Lake X

Mucket, *Actinonaias ligamentina*



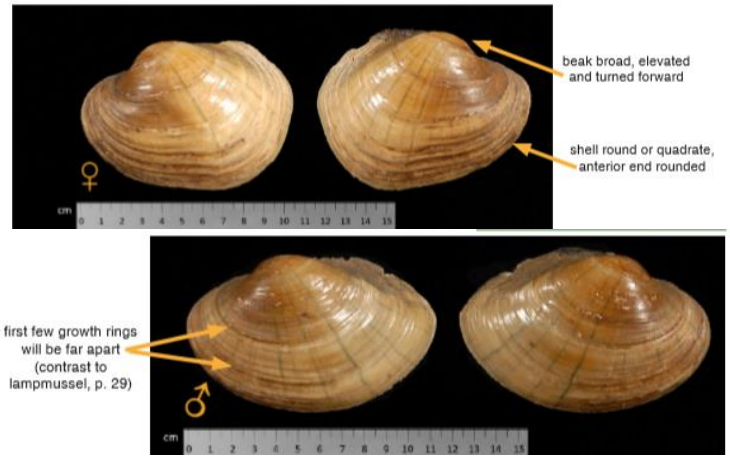
Not listed

Wabash pigtoe, *Fusconaia flava*



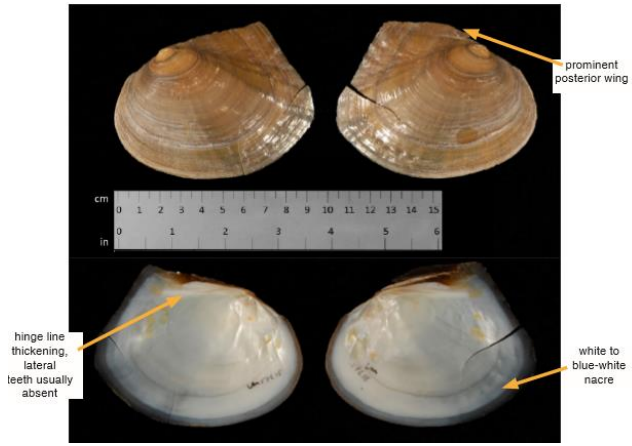
Not listed

Plain pocketbook, *Lampsilis cardium*

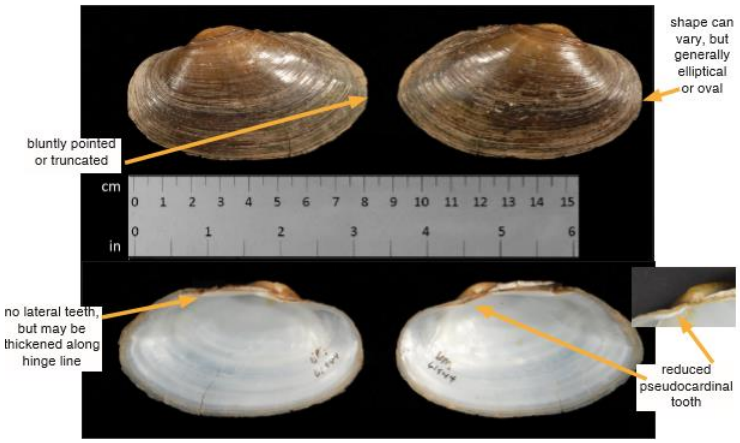
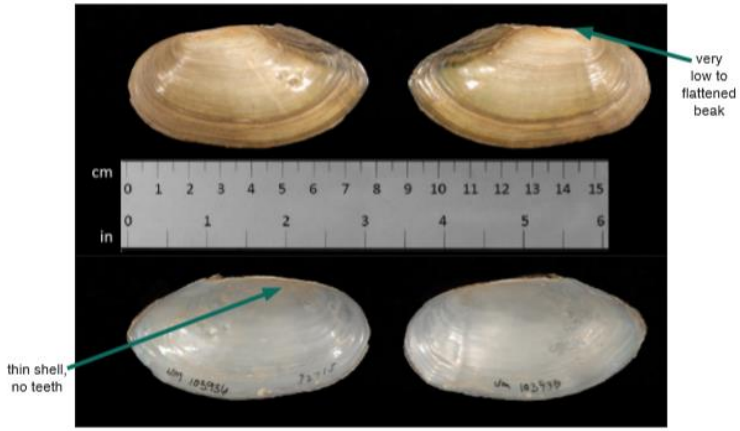


Not listed

White heelsplitter, *Lasmigona complanata*



Not listed

Creeper, *Strophitus undulatus*	**Paper pondshell, *Utterbackia imbecillis***
	
Not listed	Michigan Species of Special Concern