

Michigan Freshwater Mussel Survey Protocols and Relocation Procedures for Rivers and Streams



**U.S. Fish and Wildlife Service and Michigan Department
of Natural Resources**

Executive Summary – Michigan Freshwater Mussel Survey & Relocation Protocols (Version 4.0, April 2026)

Purpose of the Protocol

This protocol was first developed in 2016 with the purpose of standardizing mussel survey and relocation work across Michigan. The original authors were Scott Hanshew (Michigan Department of Natural Resources, MDNR), Joseph Rathbun (MDEQ), Peter Badra (MNFI), James Bettaso (U.S. Fish and Wildlife Service, USFWS), Barabara Hosler (USFWS), Jessica Pruden (USFWS), and Jeff Grabarkiewicz (MDOT). Additional contributions and editing have been provided Cleyo Harris (MDNR), John Buszkiewicz (MDNR) and Michael Hillary (MDNR). The authors would also like to recognize and thank the numerous professional biologists who have offered feedback and improvements over the years. This document provides standardized guidance for surveying, handling, and relocating freshwater mussels in Michigan's rivers and streams. The goal is to protect state and federally listed mussel species, ensure consistent field practices, and minimize project-related impacts to aquatic ecosystems.

The protocols ensure that mussel surveys are scientifically robust, protective of imperiled species, and coordinated efficiently between Michigan DNR, USFWS, and project proponents. They standardize expectations for survey methods, relocation requirements, reporting, and compliance.

Substantive Changes in Version 4.0 (April 2026)

- Consolidated former Groups 3a & 3b into a single Group 3
- Added Michigan Freshwater Mussel Identification Test information
- Extended survey/relocation season by two weeks to May 15–October 15
- Clarified expectations for species richness curves
- Removed outdated criteria for “Diverse Mussel Community” guidance

Critical Deadlines, Timing Requirements, and Permitting Clarifications

Survey & Relocation Season:

- MDNR Scientific Collectors permits are always required for mussel surveys
- USFWS permit required for Group 3
- May 15 – October 15, when water $\geq 10^{\circ}\text{C}$ and air temp $10\text{--}32^{\circ}\text{C}$

Agency Notifications:

- Permittees must notify MDNR/USFWS ≥ 15 days before survey work begins
- MDNR Fisheries needs 30 days to review final survey before construction

Reporting:

- Preliminary findings to MDNR Fisheries: within 30 days
- Final report: within 90 days after survey/relocation completion
- USFWS reporting must follow federal permit requirements
- DNR Wildlife permit reporting must follow their program requirements

Data Validity

- Survey data are typically valid for five years, unless major habitat alteration has occurred

Stream Group Categories (Overview of Approach)

Michigan rivers/streams are placed into three management groups based on mussel species presence, conservation status, and habitat modeling. These groupings determine survey effort and required methods.

Group 1 – Special Concern Streams

- Streams likely to support state special concern species, but with limited site-specific mussel data
- Reconnaissance recommended

- Timed searches are optional unless mussels are encountered
- State-listed species trigger relocation planning
- Federally listed species: stop work + USFWS/MDNR coordination

Group 2 – State T&E Species Streams

- Streams expected to contain state threatened or endangered mussels
- Semi-quantitative timed survey methods required
- Species richness curves recommended if relocation isn't proposed
- State-listed mussels: relocation required
- Federally listed species: stop work + USFWS/MDNR coordination

Group 3 – Federal Listed Species Streams

- Streams where federally listed mussels are expected
- Prior USFWS consultation required
- Semi-quantitative surveys to determine presence of federally listed species
- If detected → quantitative density surveys + full coordination with MDNR Fisheries/USFWS
- Preliminary findings to agencies within 5 days

Survey Approach Summary

Reconnaissance Survey

- Confirms presence/absence of mussels
- Includes surface searches of all substrates
- 60–90 person-min minimum (stream-size dependent)

Semi-Quantitative Surveys (Timed Search)

- Required in Groups 2 and 3
- Visual + tactile searches across all microhabitats
- Effort varies by substrate complexity
- Species richness curves used to confirm sampling completeness

Quantitative Surveys (Quadrat-Based)

- Required in Group 3 when federally listed species are confirmed
- Measures density, distribution, and uncertainty

Mussel Processing Requirements

- Identification, measurement, photos
- Immediate return to substrate or relocation site
- Strict handling procedures to minimize stress

Relocation Overview

Relocation is required when listed mussels are detected and avoidance is not possible.

Key points:

- Must have authorization from MDNR Fisheries (and USFWS for federal species)
- Recipient sites must be upstream where possible, with equal/better habitat
- Multiple passes required during salvage until detection rates drop to threshold
- All listed species tagged; non-listed species marked or subsampled
- Post-relocation monitoring required within 12 months

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1. Introduction and Purpose

In North America, 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 Species Protection, of the Michigan Natural Resources and Environmental Protection Act (1994 PA 451) (MDNR 2023). Seven 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.) (ESA), though only five species remain extant in Michigan¹. An additional 13 species are in decline and are identified as species of special concern. The primary reasons for decline of unionid mussels include habitat loss as a result of dam and road construction, stream channelization, water quality degradation, siltation, alterations to natural streamflow, and the introduction of non-indigenous species such as zebra mussels (Williams et al. 1993; Watters 2000; Strayer 2008). Many of these reasons for declines occur concurrently and more evidence is required to determine causation (Downing et al. 2010).

Freshwater mussels are an important component of the biodiversity of Michigan's aquatic ecosystems. They have a unique ecological role in both rivers and lakes and are valuable indicators of ecosystem integrity and function (Adkinson et al. 2013). Mussels are of significant value to the health of aquatic ecosystems (Vaughn 2017). They are a food source for some fish and terrestrial animals and often comprise a significant amount of the total biomass of all benthic invertebrates (Strayer et al. 1994, Strayer 2008). The spent shells also serve as physical habitat and are often colonized by a variety of aquatic insects and other macroinvertebrates. Since they are filter feeders, they play an important role in nutrient uptake and increasing water clarity (Strayer 2017). Freshwater mussels are sensitive to declines in physical habitat and water quality; this is especially true during early life stages. Newton *et al.* (2008) suggest that during early life periods, mussels may be the most sensitive to ecological disturbance compared to other aquatic organisms. Because mussels are generally long-lived, relatively immobile, and reliant on host fish for reproduction and dispersal, their community status can provide an integrative view of physical, chemical, and biological changes in a watershed.

The protocols herein are applicable to projects whose potential impacts are limited spatially (e.g. streambed disturbance, or temporarily increased sedimentation), not for projects or events impacting multiple kilometers of river (e.g. chemical or oil spills, mussel kills, or large dredging projects). Such large-scale surveys will require alternative survey designs. Recommended references include Strayer and Smith (2003), Metcalfe-Smith *et al.* (2000), and Smith *et al.* (2001).

These protocols are designed to document the potential presence or absence of state or federally listed mussel species as well as provide guidance for survey and relocation activities to minimize impacts to native mussels in Michigan. The following mussel survey and relocation protocols are applicable to most Michigan streams and rivers; however, inland lakes, impoundments, the Great Lakes, Lake St. Clair, or Great Lakes connecting waters are not covered by these protocols. Projects that may adversely affect mussels in these waters should consult the [Michigan Mussel Rescue and Relocation Protocols for Reservoir Drawdowns](#), [Michigan Freshwater Mussel Survey & Relocation Protocols for Projects in Lakes & Reservoirs](#), and develop site specific plans in coordination with the Michigan Department of Natural Resources (MDNR) Fisheries and/or the U.S. Fish and Wildlife Service (USFWS).

The survey and relocation protocols described in this document were adapted for Michigan from the West Virginia Mussel Survey Protocols (Clayton et al. 2015) and the Ohio Mussel Survey Protocols (ODNR 2020). The Michigan protocols provide project proponents with guidance to minimize impacts to mussel species that are currently identified as threatened or endangered by the State of Michigan or Federal ESA (Table 1). This protocol document is intended to be updated.

¹ Endangered White Catfish (*Epiplatys perobliqua*), and Scaleshell (*Leptodea leptodon*) are considered extirpated from Michigan by the USFWS.

Table 1. List of freshwater native unionid mussels in Michigan listed alphabetically by scientific name, also including common name, and current conservation status ([Michigan Mussels DNR List](#)). Status listing abbreviations are as follows: E=Endangered, T=Threatened, SC=Special Concern.

Scientific Name	Common Name	Michigan State Listing Status	Federal Listing Status
<i>Alasmodonta marginata</i>	Elktoe	SC	
<i>Amblema plicata</i>	Threeridge		
<i>Anodontoides ferussacianus</i>	Cylindrical Papershell		
<i>Cambarunio iris</i>	Rainbow	SC	
<i>Cyclonaias tuberculata</i>	Purple Wartyback	T	
<i>Elliptio complanata</i>	Eastern Elliptio		
<i>Epioblasma perobliqua</i>	White Catspaw	Extirpated	Extirpated
<i>Epioblasma rangiana</i>	Northern Riffleshell	E	E
<i>Epioblasma triquetra</i>	Snuffbox	E	E
<i>Euryntia dilatata</i>	Spike		
<i>Fusconaia flava</i>	Wabash Pigtoe		
<i>Lampsilis cardium</i>	Plain Pocketbook		
<i>Lampsilis fasciola</i>	Wavyrayed Lampmussel	T	
<i>Lampsilis siliquoidea</i>	Fatmucket		
<i>Lasmigona costata</i>	Flutedshell		
<i>Leptodea leptodon</i>	Scaleshell	Extirpated	Extirpated
<i>Ligumia recta</i>	Black Sandshell	T	
<i>Obliquaria reflexa</i>	Threehorn Wartyback	E	
<i>Obovaria olivaria</i>	Hickorynut	E	
<i>Obovaria subrotunda</i>	Round Hickorynut	E	T
<i>Ortmanniana ligamentina</i>	Mucket		
<i>Paetulunio fabalis</i>	Rayed Bean	E	E
<i>Platynaias compressa</i>	Creek Heelsplitter		
<i>Pleurobema clava</i>	Clubshell	E	E
<i>Pleurobema sintoxia</i>	Round Pigtoe	SC	
<i>Potamilus alatus</i>	Pink Heelsplitter		
<i>Potamilus fragilis</i>	Fragile Papershell		
<i>Pressodonta viridis</i>	Slippershell Mussel	T	
<i>Pterosyna complanata</i>	White Heelsplitter		
<i>Ptychobranchus fasciolaris</i>	Kidneyshell	SC	

Table 1. List of freshwater native unionid mussels in Michigan listed alphabetically by scientific name, also including common name, and current conservation status ([Michigan Mussels DNR List](#)). Status listing abbreviations are as follows: E=Endangered, T=Threatened, SC=Special Concern.

Scientific Name	Common Name	Michigan State Listing Status	Federal Listing Status
<i>Pustulosa pustulosa</i>	Pimpleback		
<i>Pyganodon grandis</i>	Giant Floater		
<i>Pyganodon lacustris</i>	Lake Floater	SC	
<i>Quadrula quadrula</i>	Mapleleaf		
<i>Sagittunio nasutus</i>	Eastern Pondmussel	E	
<i>Simpsonaias ambigua</i>	Salamander Mussel	E	
<i>Strophitus undulatus</i>	Creeper		
<i>Toxolasma lividum</i>	Purple Lilliput	E	
<i>Toxolasma parvum</i>	Lilliput	E	
<i>Truncilla donaciformis</i>	Fawnsfoot	T	
<i>Truncilla truncata</i>	Deertoe	SC	
<i>Utterbackia imbecillis</i>	Paper Pondshell	SC	
<i>Venustaconcha ellipsiformis</i>	Ellipse	SC	

2. Identifying Stream Group

Michigan river and stream reaches have been grouped according to information regarding mussel distribution and individual species conservation status (refer to [Michigan Natural Features Inventory \(MNFI\) Mussel Map Viewer](#)) for modeled river and stream reaches. It is important to note that the Mussel Map Viewer is not reflective of real time data given the process for updating the model post field season with new occurrence data. As such the Mussel Map Viewer is a helpful planning tool, however, it is not a decision tool. Please contact the [MDNR Fisheries](#) for confirmation of site-specific information and project planning purposes.

For Group 3 rivers please request a species list through [IPAC](#) and if the project qualifies for use, run the project through our All Species Michigan Federal Endangered Species Determination Key ([Michigan Dkey](#)). If technical assistance is needed for work within a Group 3 stream, please contact [USFWS](#).

Although these stream group designations are based on occurrence and habitat data, specific project sites that don't fall within the grouped areas may still need to be surveyed based on proximity to the grouped section, and may be up to the discretion of the MDNR regional fisheries biologist and/or USFWS.

These stream groups determine the amount of survey effort and the specific survey protocol(s) to follow when conducting a mussel survey at a project site. For Group 1 and 2 streams and rivers refer to the [MNFI Mussel Map Viewer](#) for modeled reaches. For Group 3 rivers and streams please use [IPAC](#) to determine Group 3 modeled reaches.

Group 1: Streams and rivers likely to support mussels considered to be special concern by the state of Michigan, but lacking mussel occurrence data at the project site.

Group 2: Streams and rivers likely to support populations of State threatened and endangered mussels.

Group 3: Streams and rivers likely to support populations of federally listed mussels.

2.1 Permit Requirements

All mussels in the state of Michigan are protected either by State laws or by the federal ESA. Individuals planning to conduct surveys 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. The MDNR and USFWS encourage all project proponents to consider ways to avoid and minimize adverse effects to listed mussels to the maximum extent practicable prior to conducting surveys.

2.1.1 State of Michigan Permits

The DNR's Fisheries Division will only issue [Scientific Collectors Permits](#) to contractors who are certified in Michigan freshwater mussel identification. To be "certified" means the person has successfully passed the Michigan Freshwater Mussel Identification Test. "Contractors" are defined as an individual or company hired to conduct freshwater mussel surveys within the State of Michigan. If the contractor holds an Ohio Freshwater Mussel Certification, that can be submitted with the Scientific Collectors Permit application in lieu of the Michigan certification. Contractors (or subcontractors) will need at least one person in their field unit that is certified in freshwater mussel identification. If the permit applicant is not a "Contractor" including students, academics, naturalists, etc. a certification is not required to obtain a Scientific Collectors Permit for mollusks, but it is recommended. Before conducting any mussel surveys or relocations, please consult the [MDNR website](#) to ensure you are in compliance with all regulatory requirements. In addition, if it is anticipated that state threatened or endangered mussels will be encountered at the project site, a [Threatened and Endangered Species Permit](#) may be required. Before conducting any survey work, email DNR-StateTEPermit@michigan.gov to determine permit needs or to obtain a DNR Threatened and Endangered Species Permit.

Disinfection procedures should adhere to applicable sampling permit requirements. For additional information and guidance regarding various types of disinfection procedures please visit: [Invasive Species Decontamination for Field Operations in Michigan](#); and [Preventing the Spread of Invasive Species](#).

2.1.2 Federal Permits

The potential presence of federally listed species will also require coordination with the [USFWS Michigan Ecological Services Field Office](#). For more information contact the Threatened and Endangered Species Coordinator at the USFWS Michigan Field Office in East Lansing, (517) 580-0395. A federal permit pursuant to [section 10\(a\)\(1\)\(A\)](#) of the ESA is required to survey for federally listed species. Surveyors must receive site-specific authorization from the USFWS, Michigan Ecological Services Field Office, prior to conducting surveys on any Group 3 streams.

Please use [IPaC](#), obtain an official species list, and if the project qualifies for use, run the project through the USFWS All Species Michigan Federal Endangered Species Determination Key ([Michigan Dkey](#), [Standing Analysis](#)). Dkeys are tools to help Federal agencies and other non-federal project proponents determine if their proposed action has the potential to adversely affect threatened and endangered species and critical habitat ([instructions](#), [video overview](#)). If listed mussels have been reported previously from the project location, coordination with USFWS and/or MDNR, will be required.

2.2 Prior Notification and Data Longevity

Even though standardized protocols are established, survey plans must be provided to MDNR Fisheries (all rivers/streams) and/or USFWS (Group 3) for review in advance. The survey plan shall include a map of the survey and/or relocation area(s) along with the proposed project activities and a copy of the valid collecting permit(s). Project planners are encouraged to coordinate with the MDNR Fisheries and USFWS early when developing their survey plan to ensure agencies can provide the appropriate technical assistance in a timely manner. This will ensure that the appropriate protocol is being applied for a given stream type and construction activity and to allow time for agency staff to review existing data and work with the applicant to design the appropriate survey. Please coordinate with the local [MDNR Management Unit](#) biologist. MDNR and/or USFWS staff shall be notified at least 15 days prior to the time of survey implementation. In addition, MDNR Fisheries shall be given at least 30 days to review final survey results prior to the anticipated start of construction. In general, activities conducted in Group 2 and Group 3 rivers and streams must have received written concurrence from the MDNR and/or USFWS prior to conducting any project activities including, surveys, relocations, and/or construction.

Mussel survey data collected at a specific site will generally be considered valid for five years from the date the survey was conducted. If significant habitat alteration has occurred within the five-year period, additional mussel surveys may be required. Facilities/areas that have been dredged within the past five years do not need to be re-surveyed, unless the dredged area is to be expanded or moved.

3. Survey Guidelines

3.1 Survey and Relocation Season and Data Collection

Unionid mussels burrow during the colder months, therefore, all surveys and relocation must be conducted between **May 15 and October 15**. Mussel surveys and relocations in Michigan may be conducted only when the water temperature is greater than 10 °C and the air temperature is between 10 to 32 °C (https://molluskconservation.org/Mussel_Protocols.html). Survey work conducted outside of this time frame will be conducted only under extenuating circumstances and with prior approval from

MDNR Fisheries and/or USFWS.

Surveys must be conducted during periods of stable flow and adequate visibility. Qualitative surface surveys must have a minimum visibility of 0.5 meter (m). If the area cannot be effectively surveyed due to high flow or poor visibility, then the survey must be rescheduled. In streams with high background turbidity, modified survey methods and/or excavation surveys may be required.

Refer to Appendix A for a checklist of data that must be included in the final survey and/or relocation report. Habitat data to be collected at each transect, cell, or quadrat includes: water depth, visual estimates of percent areal coverage of macrophytes, percent areal coverage of woody material, and substrate particle composition (clay, silt, sand, gravel, pebble, cobble, boulder) (Wentworth 1922). In addition, percentage estimates of unsuitable mussel habitat (e.g., areas of scour, bedrock, etc.) in the project area must be reported. The final report shall include a map of the survey and/or relocation area(s) along with the proposed project activities and a copy of the valid collecting permit(s). Preliminary findings must be submitted to MDNR Fisheries within 30 days of completion of survey and relocation activities. Final survey reports must be submitted within 90 days of survey and relocation completion. Survey and relocation reports must be submitted to the USFWS in accordance with their section 10a1A permit requirements, section 10a1B incidental take permit requirements, or terms and conditions of a Biological Opinion. Survey data is generally good for five years. Data (i.e., search area, methodology, results) must also be reported in accordance with the requirements of any other state and/or federal permits.

3.2 Survey Area

Survey coverage shall include the area of direct impact (ADI) and all applicable buffers: upstream (USB), downstream (DSB), and lateral (LB) (Figure 1). If the project will affect the natural hydrology of the stream upstream and/or downstream of the ADI (e.g., installation or removal of instream structures, stormwater outfalls, etc.), the affected area must be included in the ADI. In these instances, hydraulic modeling may be necessary to delineate the bounds of the ADI. Likewise, the mixing zone of stormwater and other outfalls shall be included within the ADI. The size of the buffer areas will be determined on project specific basis and must include consideration of substrate particle size, indirect impacts (e.g., changes in flow regime, reduced water quality, etc.) and construction methods. Project proponents should consult with MDNR and USFWS to delineate the ADI and appropriate buffers early in the project planning process.



ADI – area of direct impact
DSB – downstream buffer

USB – upstream buffer
LB – lateral buffer

Figure 1. Survey extent shall include the area of direct impact (ADI) and all applicable buffers.

4. Survey Methodology and Mussel Processing

4.1 Reconnaissance Survey

A reconnaissance survey can be utilized to confirm the presence or absence of unionid mussels within a project area. Advanced coordination with MDNR and/or USFWS is recommended in Group 2 and 3 streams. Surveys may be conducted in accordance with the following conditions:

- Water levels at the site are at normal or low flows (unless using divers in deeper areas)
- Water clarity is high
- From May 15 and October 15 when the water temperature is greater than 10 °C and the air temperature is between 10-32 °C
- Substrate may be examined using mussel viewing tubes, glass-bottom buckets, SCUBA/SSA

Stream substrates (not just suitable habitats), stream banks, and gravel bars should be visually searched for evidence of shells, shell fragments, or live mussels within the ADI and all applicable buffers. Special attention should be paid to heterogeneous substrates where living mussels may be difficult to see (e.g. sand and gravel interspersed with cobbles). Live mussels should not be removed from the substrate for identification unless the surveyor has valid state and federal permits. The site should be searched for at least 60 person-minutes for small and medium streams (26-259 square kilometers [km²]), or 90 minutes for large streams (>259 km²), unless evidence of a mussel population is found. Once the presence of live mussels or fresh dead shells is confirmed, the survey does not have to continue. If only weathered dead shells or shell fragments are observed, the entire survey time (either 60 or 90 minutes based on stream size) should be used to determine if mussels are still present within the survey area. No species list will be generated from these surveys, unless the biologist possesses the certification to accurately identify mussels to species. Representative photos of the survey area, shell material observed, and live mussels should be taken. If no mussels are found (shell or live individuals) and habitat is determined to be unsuitable, no other surveys are recommended. The reconnaissance survey should be documented using the Michigan Mussel Habitat Assessment Form (Appendix B). The presence of fresh dead mussel shells and live mussels will trigger a mussel survey by a certified surveyor.

4.2 Semi-Quantitative Methods

Semi-quantitative surveys utilizing timed search methods are used to determine if mussels are present. Timed search surveys (transects or cells) consist of a visual and tactile search of all microhabitat types throughout the defined project area including the ADI, USB, DSB, and LB for a given amount of time. The visual search includes moving cobble and woody debris, hand sweeping away silt, sand and/or small detritus, and disturbing/probing the upper 5 cm of substrate to increase the likelihood of mussel detection. Hand grubbing and view buckets should be used in waters less than 0.5 m in depth. In project areas where the water exceeds this depth, mask and snorkel combined with hand grubbing should be used. In large, deep rivers, surveying may require the use of surface supplied air (SSA) or SCUBA.

Habitat complexity will determine search effort. A minimum of 0.5 minute/m² of visual and tactile searching shall be expended in homogenous substrates or shifting bedloads and 1 minute/m² in areas of with heterogeneous stable substrates. Deviation from this level of effort will be handled on a case-by-case basis in coordination with MDNR and USFWS. If consultation with a DNR or USFWS biologist is necessary and staff cannot be reached, documentation of why the level of effort has been changed is important. In waters known to support small-bodied mussels (i.e. ≥4 cm, Slippershell, Salamander mussel, Purple Lilliput, Lilliput, Rayed Bean) level of survey effort should be increased to 2 minutes/m² to enhance detection. In areas with documented unsuitable substrate (e.g. bedrock), timed searches can be reduced from 2 minutes/m². Data should be reported separately for ADI and applicable buffers.

4.2.1 Cell Surveys

Cell surveys divide the entire impact area into cells, which are surveyed using visual-tactile methods. Cells are more appropriate for small-medium streams or larger rivers with small impact areas (e.g., bridge replacements, scour protection around bridge piers, shoreline protection, outfalls, etc.). Maximum acceptable cell size is 100 m² with the dimensions determined by the surveyor based on stream channel morphology.

4.2.2 Transect Surveys

Transect surveys consist of visual and tactile searches along transects. Transects shall be established throughout the proposed site and placed perpendicular to river flows. Transect spacing in small and medium rivers (drainage area <777 km²) should not exceed 10 m and in large rivers transects will be spaced 25 m apart. Each transect will be sub-divided into 5 m segments. Along each transect, surveyors shall visually and tactilely search an area 1 m wide for mussels. Data shall be recorded by 5 m segments along the transect. If mussels (live or shells) are not observed in two adjacent transects, with at least one of the transects containing suitable mussel habitat, then a timed visual-tactile search will occur between the two transects in the area of suitable habitat. If any live or recent dead mussels are found between the two transects during the search, then an additional transect will be placed there and searched as described above.

4.2.3 Species Richness Curve (i.e., species accumulation curves)

Species richness curves should be developed during semi-quantitative surveys for Group 2 and 3 streams when salvage and relocation is not being proposed. Species richness curves are needed to confirm that no threatened or endangered species are present, and sampling effort adequately represents mussel richness present at the project site. Timed visual-tactile searches should be conducted until a plateau is reached on a plot of cumulative number of individuals (x-axis) versus cumulative number of species (y-axis) with 90% confidence intervals (Figure 2). Sampling in the project area shall be conducted until at least five timed searches (for small sites) are completed without the addition of new species. Consult with DNR or USFWS biologists for guidance on additional sampling effort for larger sites.

A figure depicting the curve and associated logarithmic regression line should be provided. The number of individuals required to be collected for recovery of an additional species should be calculated. In the example below, a total of 352 individuals were collected, representing 19 species. Using the regression formula, it would require the collection of 611 individuals to find one additional species.

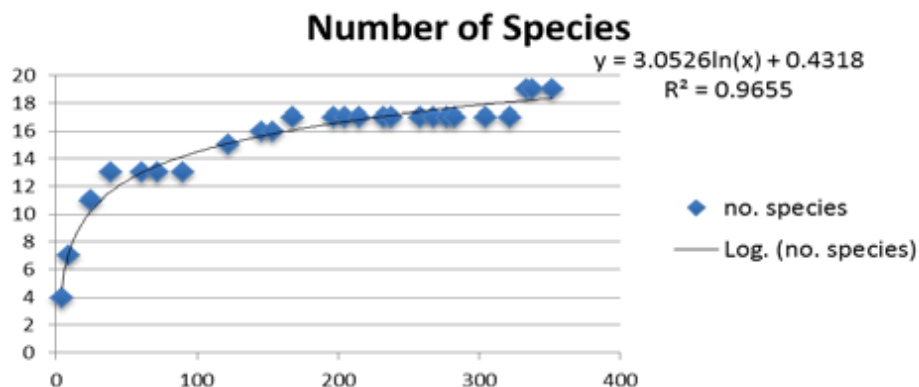


Figure 2. Example of a species richness curve (Y-axis: number of species represented in collection, X-axis: number of individuals collected)

4.3 Quantitative Methods

Quantitative Surveys provide more detailed information about sites (e.g., density) and are used to calculate uncertainty. Quantitative sampling will be conducted using 1 m² or 0.25 m² quadrats and a systematic sampling design with three random starts in 3 x 5 m blocks oriented perpendicular to stream flow in accordance with the methodology as described by Strayer and Smith (2003). Regardless of quadrat size used, survey results should adequately represent the total survey area. Blocks will be arranged in a continuous manner to provide bank-to-bank coverage. The approach to quantitative sampling will be determined in consultation with USFWS and MDNR to ensure quantitative sampling adequately represents the impact area. Quadrat surfaces will be visually inspected for mussels prior to excavation to 15 cm followed by post-excavation visual searches. Data shall be reported separately for each quadrat sampled in the ADI and applicable buffers. In locations with high-density mussel communities (>2.5 m²), quadrat size may be reduced to 0.25 m² with excavation depth remaining 15 cm (6 in). Overall survey coverage must remain equivalent.

4.4 Mussel Processing

For survey methods other than reconnaissance, any mussels or valves observed will be placed in a mesh bag and brought to the surface for further processing and positive identification. Mussels observed along a transect or within a cell will be recorded as occurring in a particular segment or cell. 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 flowing water to maximize dissolved oxygen concentrations and minimize water temperature around the mussels. To minimize handling stress, collected mussels should be submerged in water at all times, except for the brief period needed for processing. Mussels should not be stacked on shore while being processed. All live mussels will be identified to species and sexed when possible (see Appendix C for recommended field guides). To document the size distribution, mussel shell lengths shall be measured to the nearest millimeter using vernier calipers. Photographic vouchers (live and shell) of all native species must be provided to MDNR and/or USFWS. To confirm identifications, photographs of individuals representative of species found should include a close-up view of the umbo and one of the valves. Any questionable species should include photographs of the left valve, right valve, and dorsal view as well to provide adequate reference for verification. All mussels will be returned to the river alive, either at the sample location or to the pre-approved relocation site (see **Mussel Relocation Procedures** below). Shell material from unique species or outside of their known range shall be forwarded to the [University of Michigan Zoological Museum](#) collections for cataloging.

5. Survey Methodology Guidance by Stream Group

5.1 All Stream Groups

Reconnaissance surveys are recommended for all stream groups where conditions are wadeable and where the substrate is visible to confirm presence or absence of unionid mussels within the project area. This includes Group 1 waters lacking mussel occurrence data and Groups 2 and 3 waters where presence of listed mussels is expected but site-specific information indicates the species/ mussel community may be absent (e.g., impact that resulted in local extirpation etc.). Collection of recently dead individuals of any listed species should be interpreted as species presence and additional survey work will be required.

5.2 Group 1 Waters

Group 1 waters are river or stream segments known to support species of special concern and have suitable habitat but lack mussel occurrence data at the project site. Timed search surveys are recommended, but not required, for Group 1 river and stream segments when the presence of mussels has been confirmed by reconnaissance or existing data. If state listed mussels are encountered during the

survey, contact MDNR to develop a relocation strategy. If federally listed mussel species are encountered, surveyors must stop the survey, return the individuals to the substrate, and contact USFWS and MDNR for further consultation. **Note: the collection of recently dead individuals (e.g., complete periostracum, lustrous nacre) of any listed species should be interpreted as species presence and additional survey work will be required.** Relocation of non-listed mussels from the project area in Group 1 streams to pre-approved sites can occur at the time of the initial survey (see **Mussel Salvage and Relocation** below).

5.3 Group 2 Waters

Group 2 waters are stream and river segments where state threatened or endangered species are expected to be present. Mussel surveys within Group 2 river segments include semi-quantitative methods. A species richness curve could be planned for and developed at this time to assess the completeness of semi-quantitative surveys. If state listed species are detected, mussel relocation efforts are required and surveyors must contact MDNR Fisheries for further guidance (**Section 6, Mussel Salvage and Relocation**). All mussels will be returned to the river alive, either at the sample location or to the pre-approved relocation site. If federally listed mussels are encountered, surveyors must stop the survey, return the individuals to the substrate, and contact USFWS and MDNR Fisheries for further coordination. Prior to conducting the mussel survey, acceptable justification for not avoiding the area must be provided to the MDNR Fisheries and should be included in the survey proposal. Notification of preliminary survey results (e.g., species detected) must be provided to the permitting agencies within five business days of completion of the survey.

5.4 Group 3 Waters

Group 3 Waters are stream and river segments where federally listed mussel species are expected. Surveys in these river segments require prior consultation with USFWS and MDNR Fisheries. In most cases, these efforts will require completion of semi-quantitative surveys of the project area. Please consult with USFWS during survey plan development to determine if a species richness curve sampling approach is relevant. The objective of a semi-quantitative survey is to determine if a federally listed mussel species is present in the project area. Presence of a federally listed species will trigger quantitative survey effort and coordination with MDNR and USFWS. The objective of a quantitative survey for Group 3 streams is to collect sufficient data to quantify the densities of live mussels in the project area. Notification of preliminary survey results (e.g., species detected) must be provided to the MDNR within five days of completion of the survey.

6. Mussel Salvage and Relocation

6.1 Relocation Authorization

Mussel relocation will typically be required when state or federally listed mussel species are found at the project site and impact avoidance options have been exhausted. Relocation is also recommended for non-listed mussel species that may be negatively affected by the proposed construction activities. No mussels are to be moved without prior authorization from MDNR and/or USFWS for federally listed mussels. If mussels are assumed to be present in Group 1 and 2 streams, a relocation plan can be submitted with the survey plan for review and approval from MDNR Fisheries. Coordination with the USFWS and MDNR must occur prior to any relocation efforts in Group 3 streams. Relocation of federally listed mussels will require authorization pursuant to section 7 of the ESA (federally funded, authorized, or permitted projects) or apply for an incidental take permit pursuant to section 10(a)(1)(B) for non-federal actions. 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 may be required if the proposed project may adversely affect federally listed species.

The general goals of mussel relocation efforts are to:

- Collect and relocate a high percentage of the unionids in the salvage area
- Maximize survival and fitness (both individual and population level)
- Minimize risks to the resident mussel fauna at the recipient site
- Document relocation outcomes to inform future relocation efforts

6.2 Site Selection

Selecting an appropriate recipient site is one of the most important decisions in any mussel relocation project. Careful consideration must be given to the location of the recipient site in the landscape. A hierarchy of preferred destinations is outlined below:

1. Within the same waterway and reach
2. Within the same waterway, but in a different reach
3. Within the same watershed, but in a different waterway

Depending on project circumstances and conservation goals, some other alternatives may be acceptable, such as:

4. Relocating to a hatchery or other holding facility
5. Temporarily “holding” mussels in flow through bags for quick projects and then replace in areas that were disturbed
6. Relocating to a different watershed to supplement an existing population or reintroduce an extirpated species

More specific recommended attributes of potential mussel recipient sites are listed below:

- Recipient sites should be upstream (preferred) and of equal or better habitat. Alternate locations will be reviewed on a case-by-case basis
- The presence of a mussel community whose species composition resembles the salvage area
- Evidence of recruitment as indicated by the presence of juvenile mussels
- Habitat conditions should be as similar as possible to the project site, including sediment composition and stability, water quality, water depth, flow regime, distribution of habitat features (pools, riffles, etc.), overall area (multiple recipient sites may have to be identified if the source site is particularly large), and upstream drainage area
- It should be secure for the foreseeable future from localized or reach-scale disturbances (e.g., trees falling, dredging, etc)
- If zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*) are absent from the project site, they must not be present either at the recipient site or upstream of the relocation site

6.2.1 Delineation and Survey Methods for Recipient Site Assessment

Visual-tactile and/or quantitative surveys may be considered to assess the composition of the mussel community at the recipient site (see Section III for details). This survey may be conducted no more than five years prior to the relocation. The recipient site survey may need to be repeated if an event or impact (e.g., a chemical spill) 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. Recipient sites lacking the listed species that need to be relocated should be avoided unless no other suitable sites are found, and approval is obtained from the MDNR for Group 2 streams and USFWS and MDNR for Group 3 streams.

If the ADI and/or buffers areas are large, it may be necessary to select more than one recipient site. In

this case, the combined total area of the recipient sites should be equal to or greater than the area of the salvage zone. The location of the recipient site(s) must be documented as indicated in the report checklist (Appendix A).

Prior to the salvage and relocation surveys, a report on the recipient 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-specific recommended attributes listed above.

6.3 Salvage and Relocation Methodology

Mussels shall be relocated from the salvage zone using a site appropriate method, such as wading with bathyscopes, snorkeling, or SCUBA/SSA in deeper water. The search process requires successive passes through the salvage unit (generally cell or transect) until two or fewer mussels, or less than five percent of mussels collected on the first pass, are recovered on the last pass. To facilitate mussel detection, gravel, cobble, and woody material should be moved; silt, sand and detritus should be swept away. Excavation of the substrate to a depth of 15 cm is necessary to detect mussels at most sites; some sites may require deeper excavation. Clam rakes or similar implements may be effective in some environments although their use must be approved by MDNR and/or USFWS.

Passes shall be completed at an approximate rate of 1 minute/m², with up to 2 or more minutes/m² spent in complex substrate types occupied by small-bodied mussels. In areas of poor habitat, 0.5 minutes/m² may be expended but at least one thorough first pass shall be completed. Pass data will be recorded to document the salvage unit (e.g., Cell A), person-minutes per pass, and number of mussels collected during each pass. If federally listed species are not expected at the site but found during salvage activities, stop work and contact the USFWS for guidance.

6.3.1 Moving Transect: When using a moving transect, a lead core (or other weighted) line is placed to delineate the focus area and salvage activities are completed along the transect – typically within one meter of each side. Transect lines may be positioned perpendicular or parallel to flow as long as the salvage zone is fully covered. Relocation activities must follow the methods outlined above in the **Salvage and Relocation Methodology**, with successive passes completed along each transect in accordance with effort and excavation guidance. Once an area is cleared, the transect is moved upstream, and new areas are cleared sequentially. The process is repeated until the entire salvage area is cleared of mussels.

6.3.2 Cell Searches: Cells are typically delineated in blocks measuring 100 m² or smaller, with the exact dimensions flexible to fit the stream environment. Corners and/or edges may be marked with buoys, weighted lines, stakes, or other means to clearly delineate cell limits. Like transects, successive passes are completed in accordance with the **Salvage and Relocation Methodology**. Passes are typically initiated at the downstream end of a cell, with collection advancing upstream although in environments with negligible flow this may not be necessary. Quadrats may be used within cells to help maintain position and ensure thorough mussel collection.

6.4 Tagging/Marking and Transport

Relocated mussels must be marked or tagged to facilitate post relocation monitoring. Specifically, the shells of:

- All relocated state and federally listed species must be tagged unless, due to size or shell thickness, tagging is not practical or could be potentially harmful
- All relocated non-listed species (or a subsample if high densities are encountered during relocation) must be marked

Both valves will be marked or tagged. Listed mussels shall be tagged with shellfish and/or passive integrated transponder (PIT) tags as described by Woolnough and Barnett (2013) and Kurth *et al.* (2007).

A file or small rotary tool can be used to etch a number or mark (e.g., an “X”) on both shells of non-listed species. Care must be taken while etching shells to not damage the mussel, as adults of some species and juveniles of all species have thin shells. The final report should detail methods used to mark relocated mussels.

Mussels shall be transported in containers that minimize jostling and must be kept cool and moist (e.g., use of water, or cover with wet towels/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 (i.e., less than 5 minutes). Maximum processing time from initial salvage to relocation should not exceed 24 hours (see Section III Mussel Processing). If a longer processing time is unavoidable, consultation with the permitting agency is required prior to 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 source 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.

6.5 Post Relocation Monitoring

Post-relocation monitoring is recommended in Group 1 streams. In Group 2 and Group 3 streams, at least one post-relocation monitoring survey may be required to assess survival of all mussels moved to the recipient site when state or federally listed species are found during salvage. Additional post-relocation monitoring efforts may be required for some projects. The post-relocation survey must occur within 12 months of relocating the mussels. Elevated post-relocation mortality (>40%) of all relocated mussels (not each species) may indicate that conditions at the recipient site are inappropriate for long-term survival. This would be documented by actual moribund animals as opposed to an inability to find animals. If this occurs, the permitting agency should be contacted to determine what follow-up action may be necessary.

The appropriate post-relocation monitoring survey methodology should be determined in consultation with the MDNR for Group 1 and 2 streams and the USFWS for Group 3 streams. An effort to locate all marked and/or tagged individuals should be made within the recipient site and should include searching a buffer area to account for mussel movement.

6.6 Reporting

A report will be provided to MDNR Fisheries for all surveys within 90 days of completion of the relocation and subsequent monitoring activities. Refer to Appendix A for a checklist of data that must be included in these reports. DNR T&E and Scientific Collectors permits have different reporting requirements. Refer to those programs for specific guidance. Survey, relocation, and post relocation monitoring reports must also be provided to USFWS in accordance with federal permit requirements or terms and conditions of a Biological Opinion.

7. References

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Appendix A

Report Checklist

Introduction

- ☐ Description of the stream and watershed including:
 - Name (if stream is named)
 - Receiving waters of surveyed stream
 - Location, including:
 - Coordinates – at center of ADI
 - River mile (if available)
 - Township Range Section
 - County
 - Drainage area at survey site
 - Summary of any water quality data or previous mussel surveys reports near the area of impact
 - Surrounding land use

Methods

- ☐ Personnel
- ☐ Date(s) of survey
- ☐ Area surveyed, including:
 - Description of survey/buffer areas (e.g., length, bank-to-bank)
 - Coordinates of survey/buffer areas (ADI, USB, DSB)
 - Map delineating survey/buffer areas (ADI, USB, DSB, LB). Map can be included within text or in Tables & Figures 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 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)

Results

- ☐ Habitat assessment within each transect, cell, or timed search area, including:
 - Substrate composition (include information about the stability of the substrates)
 - In-stream features (e.g., channel alterations, impoundments)
 - 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 stream and substrate
- ☐ An overview of the results, including:
 - Number of individuals found
 - Number of species found

- Any notable species found
- 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 (include this section when salvage and relocation was completed)

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

Post-Relocation

Relocation site monitoring

- Environmental conditions at the relocation site(s) including the same parameters documented prior to relocation
- The numbers, calculated percent of living, dead, and missing mussels for each marked relocated species
- Tag ID numbers for living, dead, and missing mussels
- Observations on the condition of the mussels and the relocation site(s)

Conclusion

- Summary of findings, and conclusions

References

- Include citations for any literature cited within the text of the report

Tables and Figures

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

Appendices

- Photos of stream and substrates
- Representative photos of each mussel species found
- Video of questionable species
- Raw datasheets
- Copy of State and/or Federal permits
- Site-specific authorization from USFWS for Group 3 stream surveys

Appendix B

Michigan Freshwater Mussel Habitat Assessment Worksheet

Project Information

Project Name _____

Waterbody _____ Stream Group _____

County _____ Township/Range/Section _____

Latitude (DD.DDDDD) _____ Longitude (DD.DDDDD) _____

Methods

Name of Surveyors _____

Qualification of Surveyor(s): USFWS Permit Number _____
MDNR Scientific Collectors Permit (Yes/No) _____

Date(s) of Survey _____ Distance Surveyed _____

Total Survey Effort (minutes x No. of Surveyors) _____

Describe in detail any deviations from the Michigan Mussel Habitat Assessment Methods:

Habitat Description of Survey Area

Drainage Area at Survey Location (if known) (kilometers²): _____ Water Temp. (°C): _____ Air Temp. (°C): _____

Substrate Types (include %):

☐ Gravel _____	☐ Detritus _____
☐ Sand _____	☐ Muck _____
☐ Cobble _____	☐ Boulder _____
☐ Bedrock _____	☐ Hardpan _____
☐ Artificial _____	☐ Silt _____

Water Level:	☐ High	☐ Up	☐ Normal	☐ Low	☐ Dry/Interstitial
Visibility:	☐ 0-15 cm	☐ 15-30 cm	☐ 30-50 cm	☐ >50 cm	☐ Visible to Bottom

Average Depth (cm):	Riffle _____	Run _____	Pool _____
Max Depth (cm):	Riffle _____	Run _____	Pool _____

Results

Evidence of Mussels: Presence of fresh dead mussel shells and living mussels will trigger a full mussel survey				
☐ None	☐ Mussel Shell Only - Subfossil	☐ Mussel Shell Only - Weathered Dead	☐ Mussel Shell Only - Fresh Dead	☐ Living Mussels
Site Sketch. Approximate numbers and locations of shells and live mussels. Include species list if possible.				
Required Attachments 1) Location Map and 2) Photo Log				

Appendix C

Recommended Guides for Identifying Michigan Mussels

Mulcrone, R. S. and J. E. Rathbun. 2018. Field Guide to the Freshwater Mussels of Michigan. Michigan Department Natural Resources.

Other useful references

Clarke, A. 1981. *The Freshwater Molluscs of Canada*. National Museums of Canada. National Museums of Science.

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