FISH PASS

GIIGOOK MAH-JOWAG

FishPass: Assessment Plan

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** This is a living document and subject to change according to the FishPass Advisory Board**

1. Introduction

This assessment plan describes the monitoring and assessment techniques to address FishPass objectives and achieve biological goals (summarized in FishPass Project Overview). The purpose of this document is to provide fishery managers the information needed to evaluate the effectiveness of selective fish passage at FishPass and to help adaptively determine which species to pass and in what numbers to meet fish community objectives for the Boardman River. While the plan establishes basic monitoring needs and standardized monitoring techniques, future appendices to this plan will be developed to outline the technical details and specific methods, data storage protocols, quality-assurance/quality control procedures, and analytical approaches. All assessment activities described herein are reviewed by the Science Team and approved by the FishPass Advisory Board. As the Science Team further develops and the Advisory Board implements an annual plan of research, as outlined in the FishPass Research Plan and Model, new monitoring and assessment needs will arise; therefore, this plan is a living document that will be periodically updated and maintained on the FishPass website (http://www.glfc.org/fishpass.php).

The assessment plan addresses broad monitoring efforts associated with FishPass objectives and biological goals—it does not explicitly address monitoring requirements for individual research projects within FishPass. Individualized monitoring plans will need to be developed for each research project (both internal and externally led) and integrated via the FishPass Advisory Board into this assessment plan. Assessment methods for all research at FishPass should be consistent with the standards described herein. This document represents minimum standards that must be met for any study supporting FishPass unless there is a specific justification that indicates why they are not possible or appropriate. All collection permits and fish handling protocols are to be acquired and addressed by the Principle Investigator (PI) for each project and subject to the conditions and requirements of the PI's institution.

FishPass has three overarching objectives (FishPass Project Overview):

1) develop and implement selective bi-directional fish guidance, sorting, and passage techniques and technologies;
2) determine protocols for implementing selective passage solutions within the Boardman (Ottaway) River and throughout the Great Lakes Basin; and
3) set solutions in a global context so the approach can be exported.

Objective 1 is the primary focus of FishPass and critical to project implementation, whereas objectives 2 and 3 pertain to the effects of selective fish passage on the Boardman River ecosystem and beyond (i.e., consequences of passage) and are critical to determining project success and exporting knowledge gained to other ecosystems. Note, objectives 2 and 3 were established to document the changes caused by selective fish passage, not to demonstrate the achievement of specific fish community objectives, which will be established by the Michigan Department of Natural Resources (MIDNR) in consultation with the Tribes and public. Assessment data will provide a basis for future evaluation of fish community objectives.

An overview of the current fish community present in the Boardman River is available in Appendix 2 (Tables App-2-App-5). Additional considerations are being made for rare, historic, and potential invasive species. While various species may be prioritized in the context of individual research plans and sorting techniques and technologies, the assessment plan is structured to encompass the entire fish community with flexibility to focus on priority species as needed. The current fish community was identified through a combination of historic and current fish community data (Appendix 2) and the con-current development of a sortable guild analysis project (Appendix 1).

Monitoring activities for developing and implementing selective fish passage (FishPass objective 1) are first described (section 2.1 – assessment priority 1) followed by monitoring activities to determine the consequences of fish passage (FishPass objectives 2 & 3; section 2.2 – assessment priority 2). This organization (Figure 1-1) is intuitive and places the emphasis on the primary FishPass objective, particularly during the initial phases of the project. Within each of the two major assessment priority areas, assessment activities are delineated by timeframes according to the three phases of the FishPass Research Plan: (1) basic (2018-2033+); (2) applied (2023-2033+); and (3) extension (2033+) [*to be added at a later date*]. At this time, the assessment plan focuses on **upstream passage only;** monitoring activities for downstream passage will be addressed in the future.

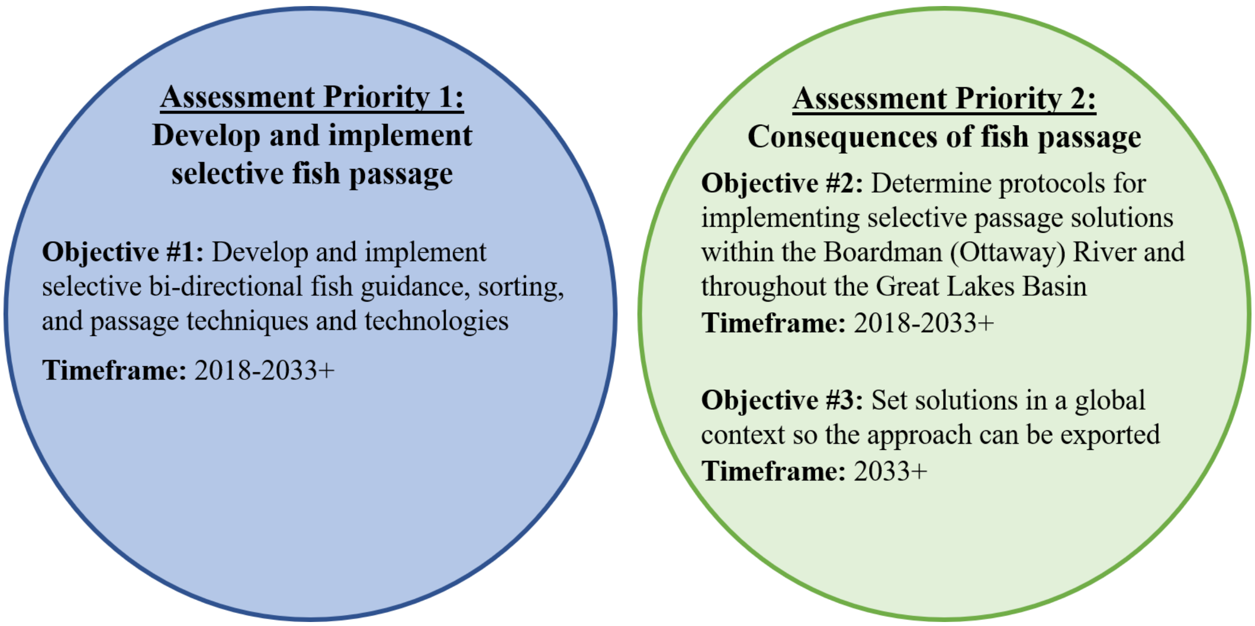

Figure 1-1. Alignment of assessment priorities described herein with FishPass objectives and timeframes. Note, activities within each assessment priority will be assigned to a research phase with distinct timeframes: basic (2018-2033+); applied (2023-2033+); and extension (2033+).

2. Monitoring Program

FishPass assessment activities associated with each assessment priority are outlined in the following sections. The research phases: **basic, applied, and extension** (FishPass Research Plan) are used to demark time periods in which the activities will occur. Basic research will be emphasized during the design and construction of the FishPass facility (2018-2033+) and focus on compiling and synthesizing available data, developing a baseline data set under existing conditions, and identifying critical gaps in our understanding of fish attributes and passage, guidance, and barrier technologies. Once FishPass is operational (2023-2033+), the applied research phase and primary focus of FishPass will begin. The extension phase seeks to examine the broad impacts of selective passage on a watershed. This extension phase requires continuous monitoring efforts that occur throughout the life of the project comparing data obtained in the basic research phase to conditions present once FishPass is functioning as a selective fish passageway (2033+). This assessment design will allow managers to make annual adjustments to adapt FishPass operations in terms of the number of individuals and species passed to effectively enhance fishery production in the Boardman River or meet fish community objectives.

2.1. Assessment Priority 1: Develop and implement selective fish passage

FishPass seeks to reconnect the waterscape for only desired species (i.e. selective passage) by integrating a multitude of existing and novel passage techniques and technologies. The probability of a fish passing through a sorting system is dependent on environmental conditions and a fish’s motivation ─ its internal state in relation to environmental stimuli. While fish decision making abilities introduce complexity to the sorting operations, they also provide an opportunity to exploit behavioral tendencies and abilities to achieve selective sorting. The monitoring program aims to quantify fish movement and sorting capabilities associated with both individual mechanisms and integrated sorting systems. The results of the monitoring program will be used to inform future adjustments to the selection of techniques and technologies and their configuration to optimize passage of desirable species while blocking and/or removing undesirable species.

2.1.1. Fish movement

The process of fish moving through a fishway is defined by four sequential stages: (1) *approach*; (2) *entry*; (3) *passage/blockage*; and (4) *fate*. The proportion of individuals and their time spent within each stage are the parameters we are most interested in measuring. The proportion of individuals is calculated as the number of individuals transitioning to a consecutive stage (in either direction) of those available in the previous stage. We consider multiple scales in the context of the entire system (e.g. Boardman River, FishPass – project site), partial system (e.g. within the fish sorting channels, nature-like bypass channel), and even individual sorting mechanisms.

(1) *Approach*—The approach stage of fish passage initiates at some distance away from a feature of interest (e.g. river mouth, fishway, sorting mechanisms) and involves the fish encountering physical signals (e.g. water velocity, turbulence, chemical cue) that identify the location and conditions generated by the feature of interest. The scale of the approach stage depends on the propagation of the physical signal and the range at which fish can detect the signal.

(2) *Entry*—Upon locating a feature of interest, fish detect and respond at a finer scale to the stimuli associated with the feature and decide whether to enter or not. The scale of the entry stage is smaller than the approach stage.

(3) *Passage/blockage*—The passage/blockage stage begins once a fish enters a feature of interest (e.g. fish sorting channel or individual sorting mechanism), attempts to advance through it, and encounters a mechanism or stimuli that aims to facilitate or block passage. The scale of the passage/blockage stage is proportional to the size of the feature of interest (i.e., fish-sorting channel, individual sorting mechanism). Passage/blockage considers the fish species being targeted and it's relation to FishPass objectives and biological goals (summarized in FishPass Project Overview) management goals for the Boardman River. A failure to pass a desired species would be classified as an unintended blockage, while the failure to block an undesirable species would be classified as an unintended passage.

(4) *Fate*—Fate is the final stage of passage that relates to the condition and outcome of fish that successfully pass or are intentionally blocked. In the case of consecutive features of interest, fate considers whether fish continue progressing through consecutive features or reverse direction (i.e., return downstream) after a successful passage. The scale of the fate stage depends on the time frame considered and fish life history traits that possibly include the entire watershed upstream of the feature of interest to other river systems.

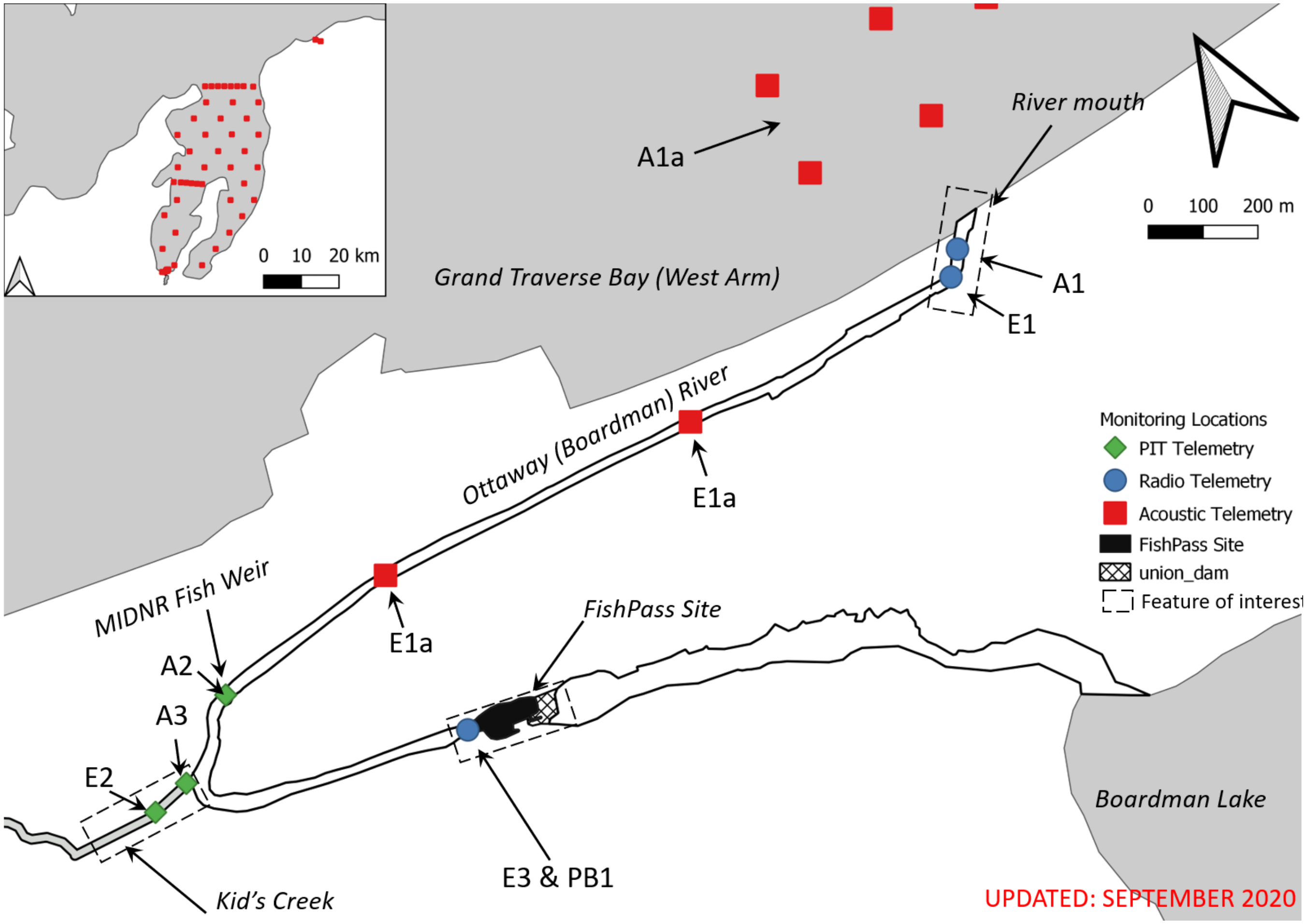

Figure 2-1. Diagram of fish movement detection array with respect to how *approach* (A), *entry* (E), and *passage/blockage* (PB) metrics are monitored in respect to features of interest (Boardman River, Kid's Creek, and the FishPass Site) during the basic research phase (2018-2021). For simplicity, the fate of fish is not represented here but can be inferred through the final detection in an individual's monitoring history dependent upon the spatiotemporal period of interest. The numbers associated with each metric differentiate the metrics by feature of interest and "a" differentiates acoustic monitoring technology while all others indicate PIT telemetry or radio telemetry. Note: all fish tagged with acoustic or radio transmitters are double tagged with a PIT tag.

Basic research phase

Approach (basic research phase).

During the basic research phase, fish *approach* is considered at three features of interest: (1) the Boardman River; (2) Kid's Creek; and (3) the future FishPass (Figure 2-1). Monitoring infrastructure (Figure 2-1) consists of six static array sites: 2 radio; 2 PIT; and, 2 acoustic telemetry sites. Note that some telemetry sites have spatially distinct antenna systems (Figure 2-1). All fish that are implanted with a radio or acoustic tag are double tagged with a PIT tag. Approach to the Boardman River is monitored at the entrance of the river using a radio telemetry receiver and an approach event is observed once a fish is detected on the downstream directional Yagi antenna at this site (Figure 2-1; A1). Approach to Kid's Creek confluence is monitored by a PIT system (Figure 2-1; A3) and an approach event is defined as a detection on the downstream antenna. Approach to the future FishPass site is monitored using a PIT system at the weir (Figure 2-1; A2) and quantified as the proportion of fish detected at the river mouth that are subsequently detected on the weir PIT system. Some ambiguity exists in this calculation as approach to the FishPass site can occur prior to approach of Kid's Creek due to the downstream location of the weir PIT system and thus is likely biased by the influence of fish choosing to move into the creek. At this time there is no monitoring system installed upstream of the Kid's creek confluence and downstream of the FishPass site. This ambiguity can be resolved through removal of individuals that enter Kid's Creek or the use of multi-state models. An acoustic telemetry array in Grand Traverse Bay, including a Vemco Positioning System (VPS) near the river mouth (Figure 2-1, A1a) will allow for quantification of the approach behaviors at the river mouth after September 2020.

Entry (basic research phase)

Entry at a feature of interest is monitored in a similar manor as approach with the distinction that an individual physically enters the feature. Entry into the Boardman River is monitored by both a radio telemetry system at the mouth of the river (Figure 2-1; E1) and two acoustic receivers placed approximately 1-1.5 km upstream from the river mouth (Figure 2-1; E1a). An entry event of radio tagged fish is documented once a fish is detected on the upstream directional Yagi antenna (Figure 2-1; E1). Similarly, an entry event of an acoustically tagged fish is documented once a fish is detected by either acoustic receiver within the river (Figure 2-1; E1a). Two receivers were deployed to maximize the detection probability of an entrance event. Entrance into Kid's Creek is monitored by a PIT system (Figure 2-1; E2). Entry to Kid's creek is documented when a PIT tagged fish is detected on the upstream PIT antenna (Figure 2.1; E2). Entrance to the future FishPass site is monitored with a radio telemetry system installed under the Union St Bridge (Figure 2-1; E3). Entrance events can be quantified as the proportion of tag fished that are detected on a monitoring system immediately downstream and subsequently detected at this site.

Passage/Blockage (basic research phase)

Passage and *blockage* events are only monitored at the mouth of the Boardman River using the acoustic and radio telemetry systems. As this portion of the river system has no impediments to fish passage the monitoring systems essentially documents passage events as fish move into the Boardman River. Passage through the river mouth is considered when a fish is detected on the either the radio or acoustic receivers representing entry into the river mouth and subsequently detected on any upstream monitoring array. Currently, passage into Kid's Creek is not monitored. Union St. Dam currently blocks passage of all fish, and as a result, there are no passage events to monitor at the FishPass site and all fish are considered blocked.

Fate (basic research phase)

Fate corresponds to the outcome of a fish that completes the initial three phases of movement. Measures of fate are dependent on the spatiotemporal scale considered. The possible fates of fish in the Boardman River include: residency (i.e., retention; i.e., remaining in the river but not moving significantly up- or down-stream), returning downstream, return downstream and leave the system, or moving forward to the next feature of interest. Possible fates monitored in regard to Kid's Creek include only entry and return downstream to the Boardman River. Residency within Kid's Creek can be inferred from and entry event without an associated return event. Similarly, the fate of fish that enter the FishPass site is to remain or return downstream. Additional ecological fates (Section 2.3) of mortality and harvest may also be considered in associated with the features of interest in the basic research phase.

Applied research phase

Construction of FishPass will require an expansion of features of interest in the monitoring program to encompass the various components of FishPass and a greatly expanded receiver array to monitor the four main processes of fish movement. During the applied research phase, *approach*, *entry*, *passage*/*blockage*, and *fate* will be monitored at the FishPass site at a finer spatial resolution in comparison to the basic research phase. While the monitoring system to assess stages of fish movement within the fish sorting channel will be tailored to each experimental setup, details of the generic system that will serve as the basis for monitoring fish passage at FishPass are provided below. The generic monitoring system is described at a macro- (e.g., fish-sorting channel vs. nature-like channel) and micro-scale (e.g., individual sorting mechanism) in Figure 2-2 and 2-3 respectively. The monitoring system outlined in the basic research phase will remain during the applied research phase to further fish movement but the metrics of passage/blockage and fate will be further refined to encompasses the additional features of interest associated with the installation of the fishway.

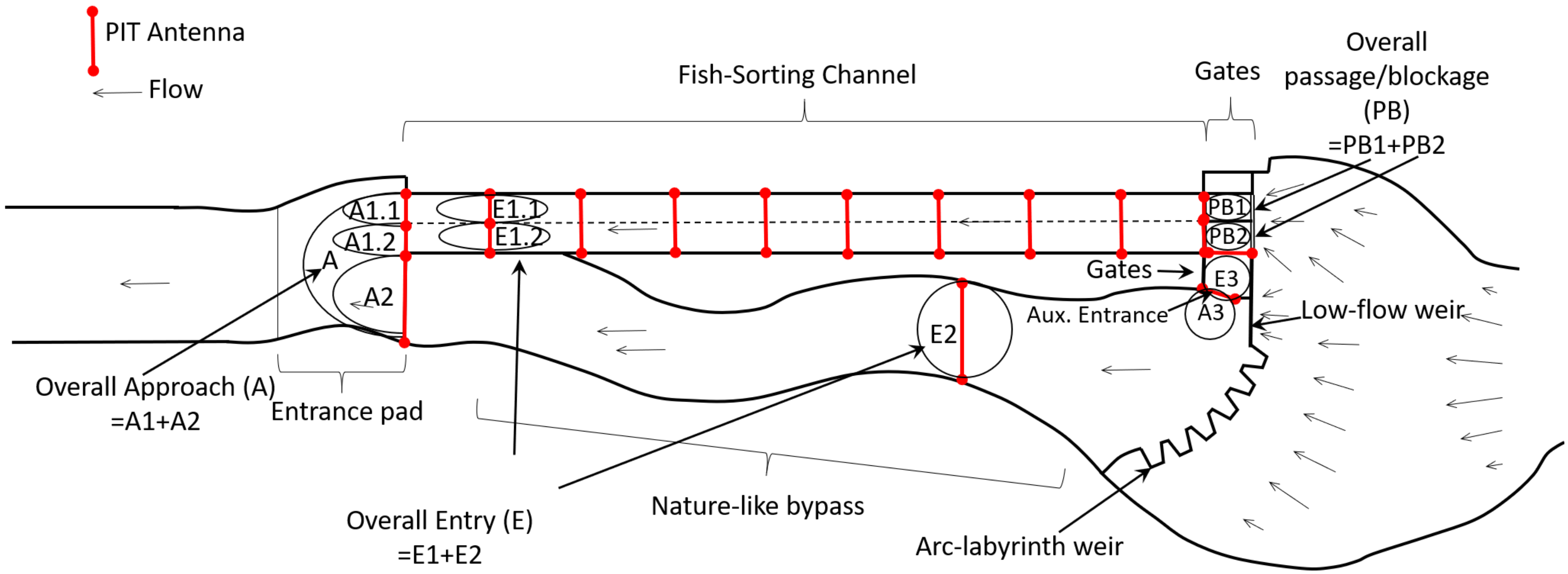

FIGURE 2-2. Idealized FishPass diagram with respect to how *approach* (A), *entry* (E), and *passage/blockage* (PB) will be measured during the applied research phase. The first numbers differentiate the metrics by feature of interest and the second number, when present, differentiates monitoring metric base on the sides of the sorting channel or cross-sectional distribution of movement events. For simplicity, the fate of fish is not represented here but can be inferred through the final detection in an individual's monitoring history within or outside the FishPass site dependent upon the spatiotemporal period of interest. Overall *blockage* is monitored as a failure to reach the monitoring stations of complete *passage*. *Blockage* at individual sorting mechanisms is omitted from this figure for simplicity (See Figure 2-3).

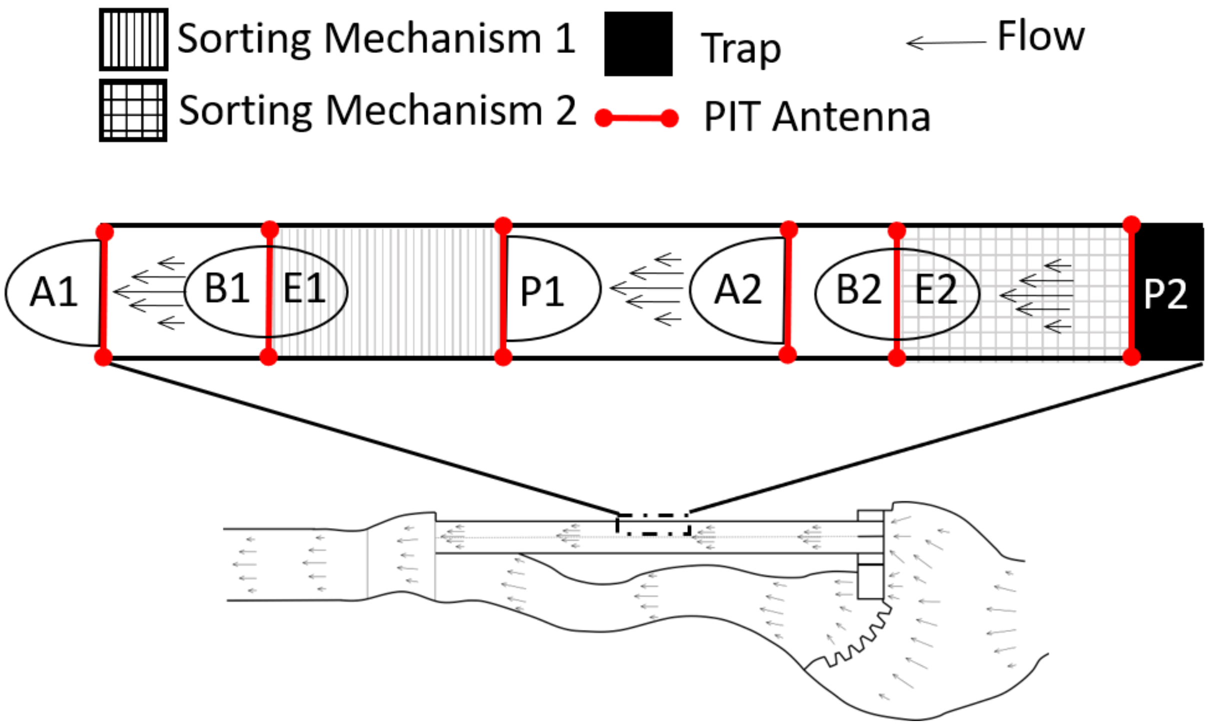

FIGURE 2-3. Example of the adaptive monitoring capability to understand *approach* (A), *entry* (E), *blockage* (B), and *passage* (P) at fine scale within the fish-sorting channels. In this example, passage and blockage are shown separately due to the scale. This hypothetical scenario includes the implementation of two sorting mechanisms. The numbers indicate a sequential monitoring of a fish attempting to move upstream longitudinally through the sorting channels.

Approach (Applied research phase).

Overall *approach* to the downstream end of the fish-sorting channels and nature-like bypass channel will be monitored through the use of PIT antennas affixed to the upstream end of the entrance pad (Figure 2-2; A1 and A2). Approach to the auxiliary entrance of the fish sorting channel via the nature-like bypass channel (Figure 2-2; A3) will also be monitored with PIT antennas. Approach to each side of the fish-sorting channel will be further refined through the use of individual antennas fit to the north and south sorting channels (Figure 2-2; A1.1, A1.2). Approach attempts and time spent will be calculated from the proportion of fish detected on a downstream monitoring station and subsequently detected at the feature of interest. Approach of fish to individual sorting mechanisms within the fish-sorting channel can be monitored using the planned 20+ PIT antenna system (Figure 2-2 & 2-3). Fine scale monitoring is vital to quantifying the behavioral responses to individual mechanisms. In the scenario shown in Figure 2-3, fish approaching sorting mechanism 1 and 2 can be monitored with two independent PIT antennas respectively (Figure 2-3, A1, A2).

Entry (applied research phase)

Entry into the fish-sorting channels as a whole can be monitored through the cumulative detections on PIT antennas on the downstream end of the sorting channel and the auxiliary entrance to the sorting channels (Figure 2-2, E1, E3). Entry into the nature-like bypass channel can be monitored through the use of pass over PIT antennas affixed river bottom between the entrance pad and arc-labyrinth weir (Figure 2-2; E2). Entry into each side of the fish-sorting channel will be further refined by PIT antennas fit to each channel side. (Figure 2-2; E1.1, E1.2). Entrance attempts and time spent in the entrance will be quantified from the proportion of fish that approached the feature. Entry at individual sorting mechanisms can be further refined within the sorting channel (Figure 2-3; E1-2).

Passage/Blockage (applied research phase)

Under normal operating conditions, overall *passage* is constrained to the fish-sorting channel as the low-flow and arc-labyrinth weir were designed specifically to block all fish passage. Testing of sorting techniques and technologies will occur below a barrier as the gates at the upstream end of the fish-sorting channel will remain impassable. Fish passage through or around a sorting mechanism can be monitored both with PIT antennas and traps at the upstream end the individual sorting mechanisms (Figure 2-3 P1-2). Failure to reach these monitoring mechanisms can be viewed as *blockage*. Blockage of individual sorting mechanisms can be further monitored through subsequent detections of fish returning downstream.

Overall upstream *passage* and *blockage* at FishPass must consider movement through three main routes: (1) fish-sorting channels, (2) arc-labyrinth weir and (3) the low-flow weir (Figure 2-2). The arc-labyrinth and low-flow weirs are designed to block all fish up to at least a 25-year storm event and block sea lamprey up to the 100-yr storm event; therefore, upstream passage is expected to be zero through the nature-like bypass channel. Similarly, the gates at the upstream end of the fish-sorting channel will be operated to maintain the same level of protection against unintended passage as the arc-labyrinth and low-flow weirs. Although the likelihood of passage over the arc-labyrinth and low-flow weir is marginal, unintended passage of fish may be possible. Unintended passage via all routes will be monitored following the monitoring actions described in Section 2.2.

Fate (applied research phase)

During the applied research phase, ascension of the fish-sorting channel terminates when fish reach the upstream end, which is blocked by gates. In this case, fish in the fish-sorting channel have the potential *fates* of remaining in the fish-sorting channel, returning downstream, extraction (e.g., traps), and mortality (e.g., over expenditure of energy, injury associated with a sorting apparatus). It is likely that traps will be deployed in the most upstream end of the fish-sorting channel to capture both desired and undesired fish to monitor sorting efficiency (Section 2.1.2). Fish are unable to move volitionally into the upstream pool, so fallback cannot be quantified as traditionally defined (i.e. fish that pass back downstream after the successful ascension of a fishway). Similarly, fish that enter the nature-like bypass channel that do not enter the auxiliary entrance are blocked by the low-flow and arc-labyrinth weir and can only remain or return downstream. Fish in the nature-like bypass channel have the potential fates of remaining in the bypass channel, returning downstream, and entering the fish-sorting channel.

At the scale of an individual sorting mechanism, fish that complete the initial three phases of movement have the potential *fates* of remaining between mechanisms, return downstream, continuing upstream to the next mechanism, mortality related to a given mechanism, and extraction if the mechanism is associated with a trap. The arrangement (distance between mechanisms and scale of stimuli) will dictate the spatiotemporal scale at which the fate of fish between sorting mechanisms is analyzed. At the FishPass system scale additional ecological fates (see section 2.3) of residency and harvest become relevant to the applied research phase due to the influence of the nature-like bypass channel. This feature of FishPass could potentially result in an island of high-quality habitat that fish may prefer. Furthermore, the nature-like channel is also an open fishery providing the potential for recreational harvest by anglers.

2.1.2. Sorting efficiency

The sorting process has "targets"; that is, the species or individual that is targeted by a particular sorting technique or technology. Recovery and grade are the two main metrics that quantify effectiveness of a sorting technique or technology with respect to a particular target. Recovery is defined as the percent of available targeted fish that reach the endpoint of an individual sorting mechanism or integrated system of sorting mechanisms. A recovery rate of 100% means all available targeted individuals reached the endpoint. Grade is synonymous with purity, and is defined as the ratio of targeted fish from all fish (sum of targeted and untargeted) that reach the endpoint of an individual or integrated system. A grade of 100% indicates no untargeted fish reach the endpoint. While these values could be calculated for fish movement events outside of the FishPass site (e.g., river mouth, Kid's Creek), the metrics are most useful to evaluate sorting and will only be calculated for fish passage events within FishPass. Calculation of recovery and grade will use data from all available telemetry systems and trap catches.

2.1.3. Abiotic variables of fish passage

Additional assessment of environmental conditions will be done in association with the monitoring of fish behavior. The monitoring program aims to develop a further understanding of the relationship between environmental variables, fish movement, and sorting capabilities associated with both individual mechanisms and integrated sorting systems.

Hydraulic and Hydrologic monitoring

Hydraulic conditions (e.g., velocity, turbulence) in the Boardman River and around FishPass will be characterized using a combination of field measurement and computer modelling. The minimum spatiotemporal resolution of hydraulic conditions is dependent on the scale of the fish passage stage being evaluated. Individual research projects will need to develop a specific plan for hydraulic measurements. The following techniques are provided as the minimum level of characterization.

Hydraulic characterization and requisite measurement techniques are broadly categorized by the range of spatial resolution (Table 1-1). At the largest spatial scale (>10 m), cross-sectional averaged velocities should be quantified at a minimum for a range of seasonal discharge conditions (e.g., high, median, low). Cross-sectional averaged velocities can be measured in the field using either an Acoustic Doppler Current Profiler (ADCP) or by averaging multiple velocity point-measurements using a velocity probe. The watershed scale Hydraulic Engineering Center's River Analysis System (HEC-RAS) model can also be used to estimate cross-sectional average velocities for differing discharge events. At the intermediate spatial scale (1 - 10 m), velocity profiles should be quantified for a range of seasonal discharge conditions and at locations relevant to the passage stage. Velocity profiles can only be practically measured in the field using ADCP, but an Acoustic Doppler Velocimeter (ADV) could be used over smaller areas. At the smallest scale (< 1 m), instantaneous velocity components should be collected using a Particle Image Velocimeter (PIV) or ADV. ADV measurements will be acquired within the fish-sorting channels using an automated data carriage that can traverse the entire channel at pre-programmed locations. Depending on the measurement technique and spatial resolution of measurement, instantaneous velocity timeseries data can be used to quantify turbulent statistics (e.g., turbulent kinetic energy, turbulent intensity, turbulent length scale) and define flow structure (e.g., eddies). A computational fluid dynamics (CFD) model of FishPass (between the Union St. and Cass St. Bridges) was developed during the engineering design using Flow-3D (Flow Science) software. The CFD model has the capability to further characterize three-dimensional velocities, turbulent statistics, and flow structure at a resolution of less than 15 cm.

Table 1-1. Summary of hydraulic measurement techniques and their applicable spatial scales.

Spatial scale	Measurement: Field technique	Measurement: Computer model	Variables	Fish passage stage
>10 m	• ADCP • Velocity probe	• HEC-RAS	• Average velocity	• Approach
1 - 10 m	• ADCP • ADV	• CFD	• Velocity profiles (3D)	• Approach • Entry
<1 m	• ADV • PIV	• CFD	• Instantaneous velocity (3D) • Turbulent statistics • Flow structure	• Entry • Passage / Blockage

Abbreviations: ADCP – Acoustic Doppler Current Profiler; ADV – Acoustic Doppler Velocimeter; PIV – Particle Image Velocimeter; HEC-RAS – Hydraulic Engineering Center's River Analysis System; CFD – Computational Fluid Dynamics.

Hydrologic conditions (e.g., river discharge, water level) in the Boardman River and around FishPass are remotely monitored by gauges at five locations. Discharge in the Boardman River is continuously monitored by USGS gauges at Beitner Road (04127200) and Brown Bridge Road (04126970), and can be adjusted for sampling location through direct drainage area ratio adjustment. River stage (feet relative to sea level) data are collected from three sensors installed on the US-31 Highway Bridge over the Boardman River mouth, Union Street Bridge (downstream of Union Street Dam), and Cass Street Bridge (upstream of Union Street Dam; Table 2-1). The upstream water level gauge will be offline once construction starts but will be reinstalled on the new structure once it is completed. Both water level sensors near the FishPass facility will be accompanied by water staff gauges to be used as a rapid indicator of water level and to calibrate the sensors.

Water quality

Continuous water quality data are collected using a YSI multiparameter water quality SONDEs installed at the MIDNR fish weir and Beitner Road (between Sabin Dam and Brown Bridge Road; Table 2-1). Water quality parameters measured include temperature, specific conductivity, conductivity, turbidity, dissolved oxygen, and dissolved oxygen saturation.

2.2. Assessment Priority 2: Consequences of fish passage

The second and third objectives of FishPass implicitly embrace the effects of selective fish passage on the Boardman River ecosystem (i.e., consequences of passage). The development and anticipated success of the FishPass project carries with it an obligation and opportunity to monitor the ecosystem effects of selective fish passage. Understanding the consequences of selective fish passage are key to communicate the success of the project in the context of its goals and objectives summarized in FishPass Project Overview. Vital to understanding these consequences is the development of monitoring activities that document the immediate and long-term effects of selective fish passage on the Boardman River ecosystem.

2.2.1. Immediate monitoring

The purpose of immediate monitoring is to document the habitat extent used by fish that pass above FishPass and the ecological fate of those individuals. Both habitat extent and ecological fate of passed fish can be used to further develop the framework outlined in the monitoring of fish movement (Section 2.1.1) during the extension phase of FishPass. Monitoring ecological fate can also transition to a more detailed analysis of selective passage during the extension phase to represent the final fate, in the context of the ecosystem, after passage is achieved.

Habitat Extent

In the future, an acoustic telemetry array will be installed in Boardman Lake and a combination of multiple types of telemetry systems (e.g., acoustic, PIT, and radio telemetry) in the Boardman River above Boardman Lake. We will begin deployment of these systems during the construction portion of the basic research phase and applied research phase prior to the initiation of selective passage to further expand the baseline movement data set and also to facilitate ongoing research on energy and nutrient dynamics. After the onset of selective passage, we will use this telemetry data to look at geographic extent of the river basin in which tagged individuals utilize.

Ecological Fate

Telemetry data can be used to begin to evaluate the ecological fate (i.e. residency, migratory return, spawn, eat, be eaten, and harvest) of fish that ascend FishPass through an analysis of their detection histories. We can analyze telemetry data to understand periods of residency in a given habitat and also the return patterns of migratory fish. This analysis can be constrained to periods of spawning for a given fish species to infer the habitat in which these fish likely complete spawning. Long-term monitoring efforts (Section 2.2.2) will need to be further developed to include methodology to identify genetic contributions (i.e., parentage assessment) of fish pass and/or identify egg and larval abundances in spawning habitats to corroborate that the fish are actually spawning in these habitats. Determination of mortality and predation events constitutes a much more complicated analysis. Future developments in this area could potentially employ the use of some type of predation and/or mortality capturing telemetry tags. Evaluations of predation dynamics could also initiate some level of dietary analysis to explore food webs in greater detail. Investigations of mortality within the current monitoring framework can be inferred through detection histories (e.g., tagged fish that never move). Angler reported captures are used to understand the fate tagged fish being harvested. This process relies on public engagement to participate in reporting tagged fish capture. Further, MIDNR conducts periodic creel census on the Boardman River which can be used comparatively to further elucidate harvest patterns. Currently, a project investigating the energy and nutrient dynamics is being developed and will be used to inform these fates to a limited extent as upstream fluxes in nutrients can be attributed to gamete deposition, carcass deposition, and to a more limited extent predation.

2.2.2. Long-term monitoring

The purpose of long-term monitoring (LTM) is to document changes in fish community and habitat use over time at stationary sites located throughout the Boardman River. Six monitoring sites have been established, two downstream of Union Street Dam and three upstream (Figure 2-4). Routine measurements of fish community, habitat, stream morphology, and water quality (Table 2-1) will be collected at each site over a period of at least 10 years. The upstream sites were selected based on existing MIDNR monitoring plans and monitoring efforts associated with previous dam removals in the Boardman River. Specifically, the Brown Bridge Road site is a MIDNR index site and fisheries surveys have been conducted regularly since 1985. The downstream sites are new monitoring locations as of 2017. Monitoring techniques planned for each LTM site are provided in Table 2-1. The MIDNR samples the Ranch Rudolf site as part of an existing status and trends protocol (Schneider, 2000) on a three year on three year off return interval. These data are also available to document changes in fish community and habitat overtime. A detailed summary of monitoring efforts organized by agency responsibility, data collected, and recording units is provided in the Appendix 4 Table App-6.

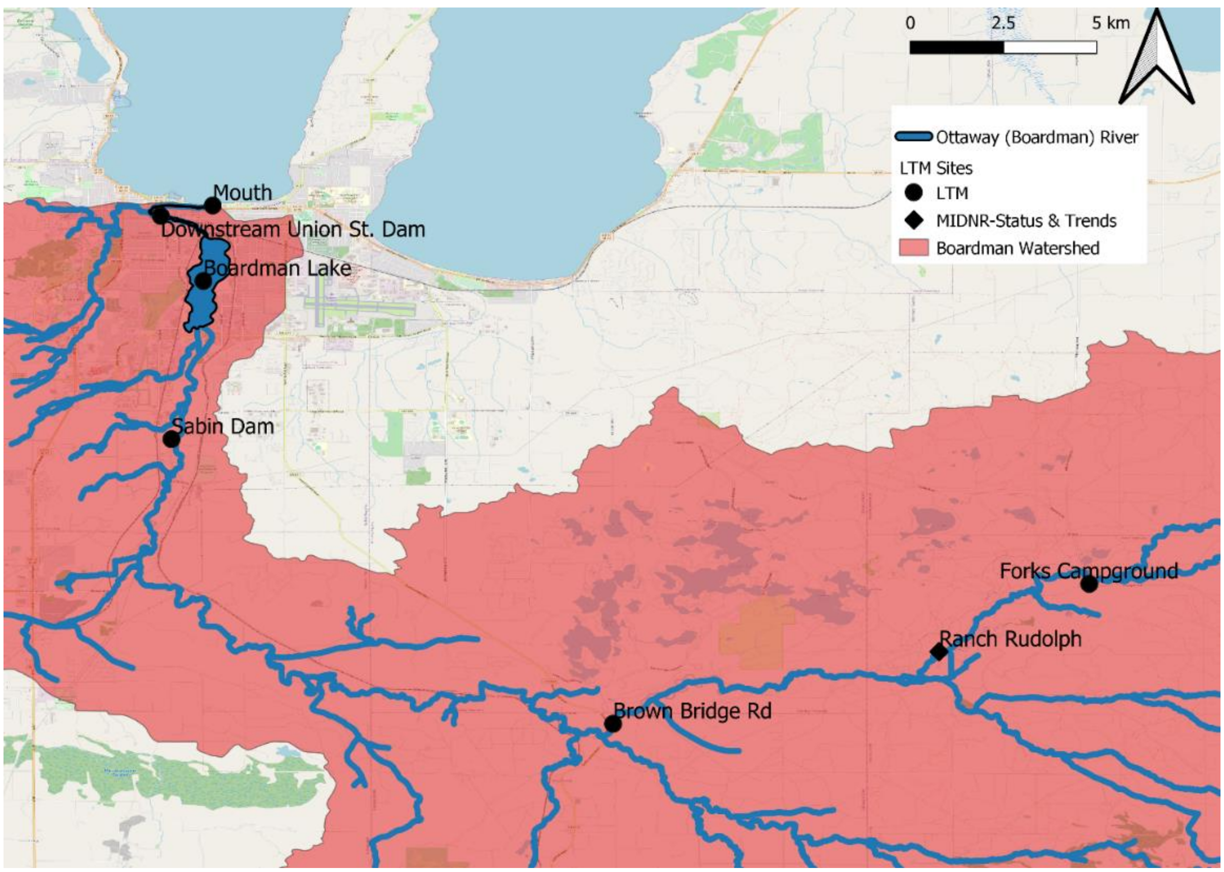

Figure 2-4. Locations of six long-term monitoring sites and one Michigan Department of Natural Resources (MIDNR) status and trends site in the Boardman River.

Fish community

Electrofishing surveys are conducted by the Grand Traverse Band of Chippewa and Ottawa Indians (GTB) and MIDNR and will follow the MIDNR electrofishing sampling protocols (Wills et al., 2011). The frequency and associated effort of each survey is outlined in in Table 2-1. Note that this table represent annual goals, but the completion of all surveys will be subject to weather and stream conditions. All fish identified, except semelparous salmonids, will be PIT-tagged prior to release until the desired sample sizes of the basic research phase are achieved (Table App-2). Electrofishing surveys provide data to identify or estimate species composition, abundance (when two passes are utilized) or relative abundance (number of fishes per unit of sampling effort), biomass (pounds/acre), density (fish/acre), size structure (mean length in inches at age), and percent survival (%).

Habitat/Stream Morphology

Habitat surveys conducted in the upper portion of the Boardman River follow MIDNR habitat sampling protocols (Wills et al., 2011). Generally, habitat surveys will document: (1) riparian zone conditions (dominant vegetation within 30 feet of water's edge); (2) width (feet), depth (feet), and substrate type (classify as pool, riffle, or run); (3) large woody material (count of material >6 inches in diameter and > 6 feet long); and (4) discharge (ft^3/s).

The lower Boardman River (downstream of FishPass) is a highly urbanized section of river with mostly hardened shoreline. The lower section does not have pool, riffle, and run habitat as typically defined in a natural stream. As a result, habitat in this reach will be assessed in terms of submerged habitat using hydro-acoustic data. Protocols for hydro-acoustic habitat acquisition will model those presented in Kaeser and Litts (2010). Transects will be surveyed once prior to the installation of FishPass, once after, and at least one bankfull event. Within the nature-like bypass channel, a photographic log of in-stream structure (channel banks, engineered log jam, riffle habitat, and erosion protection) and topographic survey of the longitudinal profile of the channel will be updated annually.

Table 2-1. Monitoring techniques used at each LTM site. Agencies responsible for data collection are listed in parentheses.

LTM Site	Monitoring techniques
Mouth	• 4+ electrofishing transects per year and habitat survey (MIDNR, GTB, GLFC) • Water level gauge (GLFC)
Downstream of Union Street Dam	• Quarterly electrofishing transects and habitat survey (MIDNR, GTB) • Water level gauges up- and down-stream of dam (GLFC) • Water quality sensor at Trap-and-Transfer Facility (GLFC)
Boardman Lake	• MIDNR status and Trends Survey in 2021 (MIDNR) • Fall meeting 2021 evaluate results and determine return interval and effort over the next 10 years
Sabin Dam	• 2 Pass electrofishing survey (MIDNR, GTB)
Beitner Rd.	• Water quality sensor at Beitner Rd. (GLFC) • Stream gauge (USGS)
Brown Bridge Road	• 2 Pass electrofishing survey and habitat survey (MIDNR) • Stream gauge (USGS)
Ranch Rudolf	• 2 Pass electrofishing survey and habitat survey following MIDNR Status and Trends protocol (MIDNR)
Forks Campground	• 2 Pass electrofishing survey (MIDNR/GLFC)

Growth

As part of the LTM, size structure (mean length in inches at age) data are collected during a subset of field collections. These data can be used during the extension phase of FishPass to evaluate changes to growth rate over time.

Production

Electrofishing surveys provide data to identify or estimate species composition and abundance or relative abundance depending on the monitoring site. Estimates of abundance from mark-recapture and relative abundance data allow for fisheries production to be assessed in the context of adult population size. The collection of these metrics during the basic and applied research phase is vital to understand the population dynamics of the Boardman River in order to assess changes to these dynamics that result from various passage scenarios achieved at FishPass during the extension phase. Further, any future evaluation of abundance or relative abundance in Boardman Lake (Recommended for 2021; Table 2-1) lend themselves to a more complete understanding of the entire system. The anticipated success of selective passage provides additional complexity because it will intentionally result in open population dynamics within a formally mostly isolated fish community. As a result, it is likely that additional study of early life phases of index species be identified in order to provide a more complete understanding of the fishery production.

Ecosystem and food web changes

Interactions between upstream and migrant (i.e., passed) fish are expected to influence fish production and ecosystem dynamics, particularly through enhanced lower food-web productivity. To monitor these expected changes, in 2020, members of the Science Team began development of an "Energy and Nutrient Dynamics" project. This project aims to establish a baseline of energy and nutrient cycling in the Boardman River to enable future evaluation of ongoing restoration on dynamics and ultimately fisheries production. The specific objectives are to determine (1) if nutrients limit fish productivity in the upper Boardman River; (2) if enhanced connectivity between the Boardman River, Grand Traverse Bay, and Lake Michigan will reestablish energy and nutrient transfer enhancing energy and nutrient availability; and (3) if passage of fishes above FishPass will provide bio-available lake-derived energy and nutrient subsidies that will increase primary productivity along an upstream longitudinal gradient resulting in enhanced upstream fishery production (particularly for brown and brook trout) and downstream fishery production resulting from larval transport out of the system.

Sea lamprey assessment

Assessment of sea lamprey populations downstream of the Union Street Dam are conducted by the GTB in collaboration with the U.S. Fish and Wildlife Service (USFWS) and larval assessments are conducted upstream of the dam by the USFWS. Two sea lamprey traps are installed on the downstream side of Union Street Dam during April-June to capture, enumerate, and remove migrating adult sea lamprey. A portion of trapped sea lamprey are tagged and released back downstream to provide an estimate of abundance (Mullett et al., 2003; GLFC, 2018). The Science Team in collaboration with USFWS will need to evaluate how these methods will change once FishPass is constructed. During the construction period (2021-2023) GTB will continue to maintain traps for the assessment of sea lamprey populations downstream of the former Union Street Dam although trapping locations are likely to be dynamic during this time due to the influence of construction processes. Upstream of the Union Street Dam, larval assessments are done annually (July-August) by backpack electrofishing at two LTM sites (Hansen and Jones, 2008). Upstream production potential of sea lamprey is being examined using quantitative assessment (Slade et al, 2003) of native lamprey (*Lethenteron appendix* and *Ichthyomyzon* spp.), used as surrogates, at each LTM site prior to construction of FishPass.

Genetic Change

Collecting baseline genetic data from sites up- and down-stream of the Union Street Dam will allow the Science Team to determine the potential genetic consequences and benefits of fish passage on the genetic diversity of fish populations upstream of FishPass. Genetic samples (fin clips) were collected, in 2017-2019 at LTM sites, from common white sucker, smallmouth bass, walleye, yellow perch, and rock bass above and below the Union St. Dam. Genetic samples from brook trout were also collected from above the Union St. Dam. These samples were analyzed using restriction-site-associated DNA (RAD) sequencing to genotype thousands of genetic markers. Additional genetic samples will be collected and comparable analysis conducted during the extension phase of FishPass. The basic hypothesis being that decreases in genetic differentiation between fish populations separated by the Union Street Dam and increases in genetic diversity of populations upstream of the dam will be detectable 5-10 years after fish passage has been initiated.

Contaminant transfer

The potential for migratory fishes to act as a vector for contaminant transfer in the Boardman River watershed is also being assessed. As part of this work researchers will: (1) assess the contaminant burden of Great Lakes spawners to inform future fish passage decisions; (2) evaluate the background contaminant burdens of resident fishes prior to dam removal; (3) measure background contaminant levels of water within the Boardman River watershed; and (4) couple empirically collected diet data to a lifetime bioenergetics-bioaccumulation model to determine the impact of various fish passage scenarios on resident fish growth and bioaccumulation.

Future research during the extension phase will be needed to evaluate the overlap in distribution between Great Lakes migrants and stream-resident fishes to further infer benefits of restored connectivity and risk of contaminant transfer. This work can inform which migrants pose the greatest risk for contaminant transfer and thus help inform managers on species and numbers of individuals of a given species to pass. Further, this work can also inform consumption guidelines relating to the potential effects on human consumption limits after re-establishing connectivity by understanding.

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Appendix 1

Table App-1. overviews the title, objectives, time period of study, principle investigator (PI), and associated contact information for the PI of all projects that support the assessment of the FishPass project.

Project Title	Project Objectives	Time Period	Principle Investigator — Contact Info
Space use of resident and migratory fishes in the lower Boardman River before installation of a selective fish passage facility	Pilot level study to (1) establish a baseline understanding of fish movement in the Boardman River, especially below Union Street Dam, and (2) identify changes in movement in response to selective passage. A baseline fish movement monitoring program will eventually help distinguish the relative effectiveness each selective fish passage treatment and identify ways to increase efficacy	2018-Present	Reid G. Swanson, Assessment Biologist, Great Lakes Fishery Commission, Office: 231-421-1834, Cell: 715-797-2225, rswanson@glfc.org
Genetic assessment of Boardman River fish populations prior to dam removal	(1) characterize baseline genetic structure for five fish species up- and down-stream of the Union Street Dam to determine if these populations are significantly differentiated and/or show differences in diversity; and (2) determine the utility of eDNA for investigating species diversity and distribution patterns.	2018-2020	Dr. Wes Larson, Genetics Program Manager, Alaska Fisheries Science Center, NOAA, 907-789-6079, wes.larson@noaa.gov

Project Title	Project Objectives	Time Period	Principle Investigator — Contact Info
Predicting contaminant transfer following re-establishment of controlled connectivity in the Boardman River	(1) assess the contaminant burden of Great Lakes spawners to inform future fish passage decisions; (2) evaluate the background contaminant burdens of resident fishes prior to dam removal; (3) measure background contaminant levels of water within the Boardman River watershed; and (4) couple empirically collected diet data to a lifetime bioenergetics-bioaccumulation model to determine the impact of various fish passage scenarios on resident fish growth and bioaccumulation.	2018-Present	Dr. Brandon Gerig, Assistant Professor, Northern Michigan University, 906-227-2302, bgerig@nmu.edu
Determining Connectivity Between the Boardman River, Grand Traverse Bay, and Lake Michigan Proper in Support of FishPass	Determine (1) the proportion of fish tagged and released in the Boardman that are subsequently detected elsewhere in Grand Traverse Bay and the outer-bay/Lake Michigan ecosystem; (2) the extent and timing of fish movement into and out of the Boardman River, and (3) the variables that cue the timing of river entry/exit	2020-Present	Reid G. Swanson, Assessment Biologist, Great Lakes Fishery Commission, Office: 231-421-1834, Cell: 715-797-2225, rswanson@glfc.org
Characterization of fish guilds by attributes that can be sorted in a selective fish passage system	(1) identify key phenological, morphological, behavioral, and physiological attributes that can be used to sort an assortment of fishes and (2) determine if species can be grouped into sortable guilds on the basis of their attributes.	2021-Present	Reid G. Swanson, Assessment Biologist, Great Lakes Fishery Commission, Office: 231-421-1834, Cell: 715-797-2225, rswanson@glfc.org

Project Title	Project Objectives	Time Period	Principle Investigator — Contact Info
Boardman River Energy and Nutrient Dynamics	determine (1) if nutrients limit fish productivity in the upper Boardman River; (2) if enhanced connectivity between the Boardman River, Grand Traverse Bay, and Lake Michigan will reestablish energy and nutrient transfer enhancing energy and nutrient availability; and (3) if passage of fishes (particularly longnose and white sucker) above FishPass will provide bio-available lake-derived energy and nutrient subsidies that will increase primary productivity along an upstream longitudinal gradient resulting in enhanced upstream fishery production (particularly for brown and brook trout) and downstream fishery production resulting from larval transport out of the system.	2021-Present	Dr. Greg Jacobs, Post-Doctoral Researcher, Cornell University, 231-342-0368, greg.jacobs25@uga.edu

Appendix 2

Fish community assemblage and known movements

Fifty-nine fish species are known to occur in the Boardman River for part of their life cycle (Kalish & Tonello, 2014). The current species composition within different habitats present in the Boardman River are being monitored as part of the long-term monitoring program (Section 2.2.2). This data is used to develop the finite list of target species for passage because not all species are relevant to fish passage studies in the lowermost reach of the river, have sufficient abundance to detect effects, or are easily obtained and/or tagged. Fish community assemblages are documented by location: below Union St. Dam (Table App-2), Boardman Lake (App-3), and upstream of Boardman Lake (Table App1-4).

Table App-2. Target species for study based on current occurrence down-stream of Union Street Dam as documented by all fisheries surveys from 2017-2020 (R. Swanson, personal communication).

Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Ale wife	*Alosa pseudoharengus*	Green sunfish	*Lepomis cyanellus*
Atlantic salmon	*Salmo salar*	Lake trout	*Salvelinus namaycush*
Black bullhead	*Ameiurus melas*	Longnose sucker	*Catostomus*
Bluegill sunfish	*Lepomis macrochirus*	Northern pike	*Esox lucius*
Brown trout	*Salmo trutta*	Pumpkinseed sunfish	*Lepomis gibbosus*
Chinook salmon	*Oncorhynchus tshawytscha*	Rainbow trout	*Oncorhynchus mykiss*
Cisco	*Coregonus artedi*	Rock bass	*Ambloplites rupestris*
Coho salmon	*Oncorhynchus kisutch*	Round goby	*Neogobius melanostomus*
Common carp	*Cyprinus carpio*	Sea lamprey	*Petromyzon marinus*
Common white sucker	*Catostomus commersonii*	Smallmouth bass	*Micropterus dolomieu*
Gizzard shad	*Dorosoma cepedianum*	Walleye	*Sander vitreus*
Golden redhorse	*Moxostoma erythrurum*	Yellow perch	*Perca flavescens*
Golden shiner	*Notemigonus crysoleucas*		

Table App-3. Target species for study based on occurrence up-stream of Boardman Lake as documented by MIDNR fisheries surveys (H. Hettinger, personal communication).

Common Name	Scientific Name	Common Name	Scientific Name
This table was intentionally left blank until the data becomes available to the Science Team			

Table App-4. Target species for study based on occurrence up-stream of Union Street Dam in Boardman Lake as documented by MIDNR status and trends survey in 2003 (H. Hettinger, personal communication) and sampling data collected by electrofishing, gill nets, and fyke nets in 2019 (B. Gehri, personal communication).

Common Name	Scientific Name	Common Name	Scientific Name
Bluegill sunfish	*Lepomis macrochirus*	Pumpkinseed sunfish	Lepomis gibbosus
Brown trout	*Salmo trutta*	Rainbow trout	*Oncorhynchus mykiss*
Common carp	*Cyprinus carpio*	Rock bass	*Ambloplites rupestris*
Common white sucker	*Catostomus commersonii*	Round goby	*Neogobius melanostomus*
Grass pickerel	*Esox americanus vermiculatus*	Sand shiner	*Notropis stramineus*
Johnny darter	*Etheostoma nigrum*	Smallmouth bass	*Micropterus dolomieu*
Largemouth bass	*Micropterus salmoides*	Walleye	*Sander vitreus*
Northern pike	*Esox lucius*	Yellow perch	*Perca flavescens*

Lake sturgeon are also a target species for passage, but abundance is currently very low in the Boardman River. Only a few individuals have been observed downstream of the Union Street Dam in the last decade. Lake sturgeon will be included in indirect measurement efforts (e.g., fish surveys), fin clip taken for genetic testing, scanned for any existing tags, tagged if not already tagged, and released. At present, the MIDNR has not made any decisions regarding stocking or local rearing efforts of rare species like lake sturgeon or Arctic grayling.

Movement phenology of adults of many target species in the Boardman River is generally understood (Figure A1-1); however, site specific timing and movement cues are unknown. The Union Street Dam acts as a barrier to nearly all upstream fish movement. However, sea lamprey larvae have been observed upstream of the Union Street Dam and periodic lampricide treatments have occurred since 1963. The dam has a pool and weir type fishway, but velocity conditions and step heights preclude passage by most native fishes; only introduced Pacific salmonids and some brown trout have been observed passing. In 2018, the uppermost step of the fishway was blocked with a screen to prevent passage of any fish, including salmon, during- and post-removal of Sabin Dam.

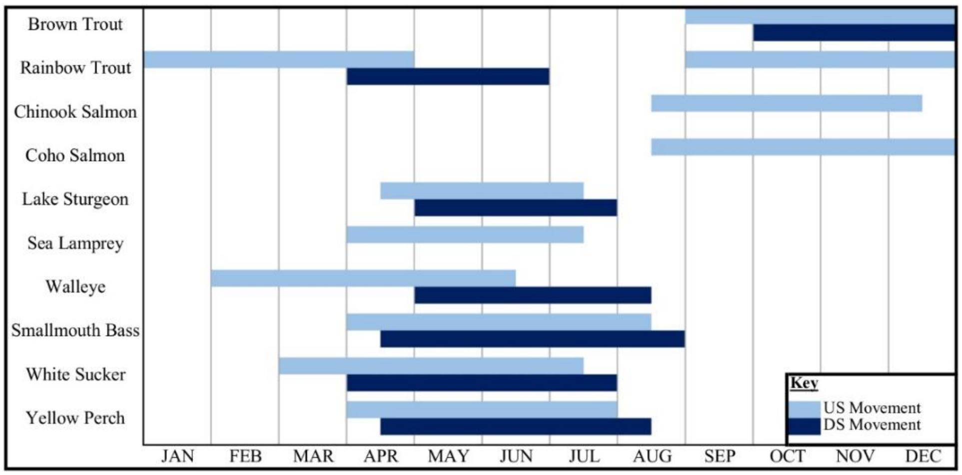

Figure App-1. Migration timing of adults of select target species in the Boardman River. Timing data adapted from Goodyear et al. (1982), Biette et al. (1981) and Velez-Espino et al. (2011).

Approximately 0.75 kilometers downstream of Union Street Dam is the James P. Price Trap-and-Transfer Facility (weir), which is owned by Traverse City and operated by MIDNR. The MIDNR installs removable grates in the fall to direct migrating salmon into a fish ladder where coho and Chinook salmon are harvested and rainbow and brown trout are returned to the river upstream of the weir. When the weir is not installed, fish moving upstream from Grand Traverse Bay have unimpeded access up to Union Street Dam. Fish may also enter Kid's (Hospital) Creek, the only tributary located between Union Street Dam and the Trap-and-Transfer Facility.

Appendix 3

Table App-5. Summary of fish sampling organized by location for FishPass monitoring efforts.

<table>
<tr><th>Site/Study</th><th>Long Term Monitoring</th><th>Sea Lamprey Assessment</th><th>Telemetry</th><th>Genetics</th><th>Contaminant</th></tr>
<tr><td>River Mouth</td><td>Quarterly sampling all species
(ID, length, weight, number)</td><td>None</td><td rowspan="2"><u>All samples DS of Union Street Dam</u>

Radio Tags (total of 10-15 individuals each, >30 g):
•Sea Lamprey •Steelhead •Common Carp
•White Sucker •Walleye •Smallmouth Bass

PIT tag (Max 50 per species, >30 g):
•All species except semelparous salmonids</td><td rowspan="2"><u>Samples DS of Union Street Dam (any site)</u>

Fin clips (50 individuals per species per year):
•White Sucker •Walleye
•Smallmouth Bass •Yellow Perch
•Rock Bass</td><td rowspan="2"><u>Samples DS of Union Street Dam (any site)</u>

Whole fish samples (5 males and 5 females of each species, approx. same size, >20 g):
•Lake Trout •Sea Lamprey •Steelhead
•Chinook Salmon •Coho Salmon •Brown Trout
•Walleye •Yellow Perch •White Sucker
•Longnose Sucker</td></tr>
<tr><td>Downstream of Union Street Dam</td><td>Quarterly sampling all species
(ID, length, weight, number)</td><td>Sea lamprey index trapping</td></tr>
<tr><td>Boardman Lake</td><td>MIDNR Status and Trends 2021 for evaluation of return interval</td><td>None</td><td>None</td><td rowspan="5"><u>Samples US of Union Street Dam (any site)</u>

Fin clips (50 individuals per species per year):
•White Sucker •Walleye
•Smallmouth Bass •Yellow Perch
•Rock Bass</td><td><u>Samples US of Union Street Dam (Boardman Lake/ S. Airport Rd.)</u>

Whole fish samples (5 males and 5 females of each species approx. same size >20 g):
•Brook Trout •Brown Trout •Walleye •Yellow Perch</td></tr>
<tr><td>Sabin Dam</td><td>2 Pass electrofishing survey all species
(ID, length, weight, number)</td><td>None</td><td>None</td><td><u>Samples US of Union Street Dam (Sabin Dam/Lone Pine)</u>

Whole fish samples (5 males and 5 females of each species approx. same size >20 g):
•Brook Trout •Brown Trout</td></tr>
<tr><td>Brown Bridge</td><td>2 Pass electrofishing survey all species
(ID, length, weight, number)</td><td>None</td><td>None</td><td><u>Samples US of Union Street Dam (Brown Bridge)</u>

Whole fish samples (5 males and 5 females of each species approx. same size >20 g):
•Brook Trout •Brown Trout</td></tr>
<tr><td>Ranch Rudolph</td><td>2 Pass electrofishing survey all species
(ID, length, weight, number)</td><td>None</td><td>None</td><td><u>Samples US of Union Street Dam (Ranch Rudolph)</u>

Whole fish samples (5 males and 5 females of each species approx. same size >20 g):
•Brook Trout •Brown Trout</td></tr>
<tr><td>Forks Campground</td><td>2 Pass electrofishing survey all species
(ID, length, weight, number)</td><td>None</td><td>None</td><td>None</td></tr>
</table>

Table App-6. Monitoring techniques used at each LTM site with agency responsibility, data collected, and units.

Site/Study	Monitoring Technique	Agency	Data	Units
River Mouth	Quarterly electrofishing transects	MIDNR, GTB	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
	Quarterly habitat survey	MIDNR, GTB	• Riparian zone condition • Width, depth, substrate type • Large woody debris • Discharge	• Dominant veg. with 30ft of water's edge • feet, feet, classify as pool, riffle, or run • count on material >6 in dia. & > 6 ft long • ft^3/s
	Water level gauge	GLFC	• River stage	• feet relative to sea level
Downstream of Union Street Dam	Quarterly electrofishing transects	MIDNR, GTB	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
	Quarterly habitat survey	MIDNR, GTB	• Riparian zone condition • Width, depth, substrate type • Large woody debris • Discharge	• Dominant veg. with 30ft of water's edge • feet, feet, classify as pool, riffle, or run • count on material >6 in dia. & > 6 ft long • ft^3/s
	Water level gauge (up- and down-stream of dam)	GLFC	• River stage	• feet relative to sea level
	Water quality sensor at Trap-and-Transfer Facility	GLFC	• Temperature • Conductivity • Turbidity • Dissolved oxygen	• °C • µS/cm • NTU • mg/L
Boardman	MIDNR Inland Lakes Status and Trends with discretionary additions	MIDNR, GLFC	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
Sabin Dam	2 Pass electrofishing survey	MIDNR, GTB	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
	Water quality sensor at Beitner Rd.	GLFC	• Temperature • Conductivity • Turbidity • Dissolved oxygen	• °C • µS/cm • NTU • mg/L
	Stream gauge (04127200)	USGS	• Discharge	• ft^3/s
Brown Bridge	2 Pass electrofishing survey	MIDNR	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
	Habitat survey	MIDNR	• Riparian zone condition • Width, depth, substrate type • Large woody debris • Discharge	• Dominant veg. with 30ft of water's edge • feet, feet, classify as pool, riffle, or run • count on material >6 in dia. & > 6 ft long • ft^3/s
Ranch Rudolf	2 Pass electrofishing survey	MIDNR	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA
	Habitat survey	MIDNR	• Riparian zone condition • Width, depth, substrate type • Large woody debris • Discharge	• Dominant veg. with 30ft of water's edge • feet, feet, classify as pool, riffle, or run • count on material >6 in dia. & > 6 ft long • ft^3/s
	Stream gauge (04126970)	USGS	• Discharge	• ft^3/s
Forks Campground	2 Pass electrofishing survey	MIDNR/ GLFC	• Fish ID • Total length • Weight • Abundance • 3 x 15ml water sample	• Species name • inches • pounds • count • eDNA