FishPass Research Plan

1. Introduction

This research plan is intended to describe the conceptual framework of selective fish passage to be implemented at FishPass and outline the phases of research to achieve the project mission and objectives (summarized in the Project Overview document). This plan reflects the high-level vision for research at FishPass and does not prescribe specific research strategies and tactics to be deployed. All specific research activities and achievable intermediate and long term targets will be formulated and reviewed by the Science Team and approved by the FishPass Advisory Board. As the Science Team further develops (2018-2021) and the Advisory Board implements this plan (2021), specific research questions and themes will arise; therefore, this plan is considered a living document and will be periodically annually by the Science Team and maintained on the FishPass website.

The primary mission of FishPass is aimed at sorting and selectively passing a mixed fish assemblage by predetermined categories of desirable and undesirable species by exploiting or overcoming differences in phenological, behavioral, physiological, social, and morphological attributes/traits of each fish at the individual and species-level. Safe, effective, cost-efficient, and timely functional passage for multi-species fish assemblages remains elusive, in part, because fish assemblages and their life histories and behaviors vary by site and species and little information on these attributes is available outside of commercially relevant species. Moreover, the attributes and behaviors of fishes comprising this assemblage are rarely accounted for in engineering designs for fish passage facilities. Consequently, integrated technologies for fish passage rarely exploit variation in fish attributes. The issue is exacerbated when passage of many fishes with disparate locomotor abilities, movement patterns, and behaviors is required and/or when non-desirable (e.g., invasive) species are present. Historical efforts to combine fish passage and invasive species control have focused on designs that target a single factor (e.g., leaping) to pass desirable and block non-desirable fishes; these efforts have had mixed, but limited, efficacy. FishPass will provide an adaptable platform for research to combine multiple technologies and techniques from fish passage and invasive fish control. This project will be the first time that such a flexible research platform is available.

1.1. Eco-engineering Approach

The problem of selective fish passage is fundamentally a question of how to sort a complex mixture of things. Sorting process can be distilled into three parts: (1) collect a fully comingled mixture of items (i.e., fish) which can vary over time; (2) organize items based on pre-determined attributes (i.e., size, shape, color, behavioral responses); and (3) selectively operate on attributes accordingly (i.e., pass or remove) to achieve the desired outcomes. The task of sorting an incoming stream of objects with variable attributes is not unique to fish passage, but has been effectively addressed in the materials-recovery industry. Recovery of consumer waste products (i.e., recycling) is wide spread and experienced success through the development of single-stream recycling (SSR). In SSR, an incoming stream of waste products are collected by trucks and brought to a material recovery facility (MRF) that employs a process train (i.e., network of sub-systems optimized for individual sorting tasks) to sort materials by their attributes, often recursively, into outgoing streams of material for industrial re-use (if the required purity is met) or sent to a waste disposal site. Utilizing unit processes, a single or group of operations that achieve simple sorting tasks and are amenable to technological improvements and optimization (e.g., velocity barrier, pheromone pumps), helps reduce the overall complexity of the sorting process. Originally accomplished through manual curb-side sorting, SSR emerged through advancements in automation and integration of multiple technologies. We recognize that a similar path driven by multi-factor (e.g., physical, biological, and behavioral attributes) evaluations with rapidly evolving technologies could yield similar results for selective fish passage. Fish passage, however, differs from recycling operations because fish are capable of making choices, exhibit consistent responses to their environment, and have patterned behavior (e.g., diurnal activity). While the decision making abilities of fish introduces more complexity to sorting operations, it also provides greater opportunity to exploit behavioral tendencies that could lead to self-sorting. We now use the processes and innovations developed in materials-recovery to (1) inspire an eco-engineering approach to develop and integrate new and existing techniques and technologies to achieve selective fish passage and (2) help set the expectations for selective passage.

2. Conceptual Framework

Fish passage is a continuous process in which the internal state of fish and environmental stimuli vary with time, each affecting the probability of a fish approaching, entering, and/or passing through a fishway. As a result, passage evaluations must consider the probability of a fish to successfully pass an obstacle and the time required to complete the process. The process of fish passing a fishway in either direction can be grouped into four sequential components: approach, entry, passage, and fate (See Table 2-1 for stage descriptions and Fig. 2-1 for applications at FishPass). For now, we primarily focus on selective upstream fish passage as the most pressing issue surrounding FishPass is the containment and removal of invasive sea lamprey. It is the intent of the Science Team to develop research goals examining downstream passage (i.e., fish passed upstream must be able to return and/or larvae to drift) at a later time.

The overall success or failure of a passage attempt depends on how fish traverse each phase; failure to pass any of the stages results in a failed passage attempt. Success or failure at each consecutive component is not independent, but a result of a fish's experience (i.e., past success and failures) and internal state. Such high risk for passage failure has made improved fish passage a challenging goal to attain, but one that lends itself to a conservative management approach for limiting the passage of undesirable fishes. In this light, we can also define the four passage components in reference to blocking or trapping of undesirable fishes (Table 2-1). Each stage of the passage process presents an opportunity to introduce a suite of technologies and techniques that exploits and/or overcome attributes and behaviors of fishes to effectively guide, sort, and pass/block a mixed fish assemblage. For example, the internal passage component could replicate a SSR process train by encompassing a network of small-scale passage scenarios (i.e., unit processes) each with independent approach, entry, and passage stages that can be designed to target individual or guilds of similar species and/or similar attributes (e.g., all freshwater suckers in the family Catostomidae).

Table 2-1. Description of fish passage components from the perspective of desirable fish passage and undesirable fish control in the upstream direction.

Passage component	Desirable fish	Undesirable fish
Approach	Fish detect and are guided toward a fishway entrance from long distance	Fish detect and guided toward a trap or deterred from entering the fishway
Entry	Fish detect and are guided to the fishway and choose to enter	Fish detect and are guided to a trap or reject entering the fishway
Internal Passage	Fish move through the fishway and exit at the opposite end	Fish do not move through the fishway, but are either removed from the system or deterred away from the fishway
Fate	Fish exit in good condition and complete life history stage	Fish do not pass or have low survival effectively suppressing or preventing undesirable consequences of passage

The FishPass facility was designed to maximize flexibility and accommodate concurrent testing based on the fish passage conceptual framework described in Table 1. FishPass contains multiple approach and entry locations for fish moving both up- and down-stream and the fish-sorting channel is designed to permit the integration of a network of technologies and techniques to provide selective bi-directional passage (Fig. 2-1). Similar approaches could be implemented in the nature-like bypass if needed, but with less control over hydraulic conditions and the complication of conflicting uses, such as recreation.

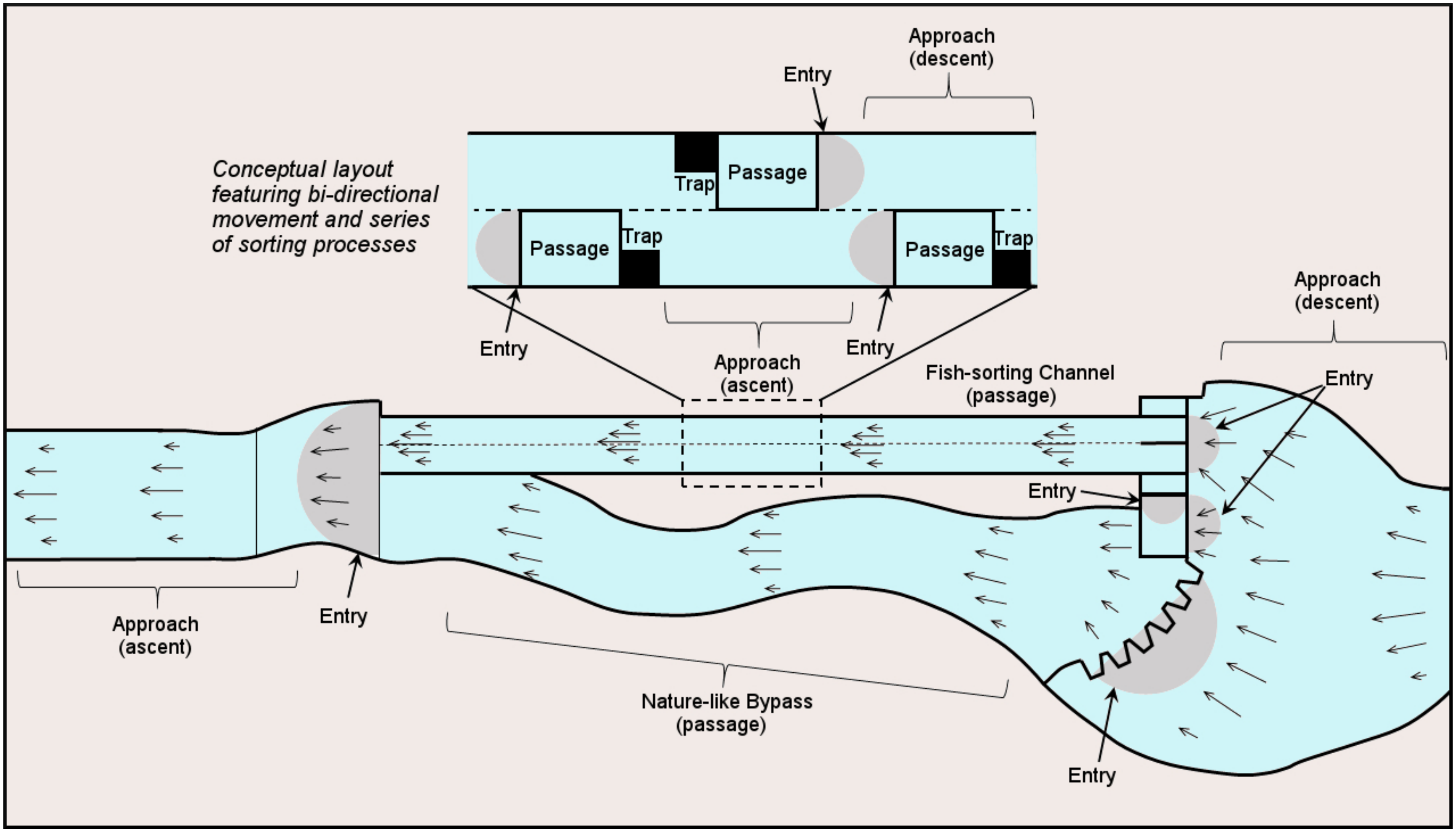

Figure 2-1. Components of fish passage applied to the FishPass facility with bi-directional fish-sorting channel, nature-like bypass channel, and multiple entry locations. Inset image of fish-sorting channel depicts a conceptual layout of a network of small-scale fish passage scenarios with linked approach and entry phases. Arrows indicate direction of flow.

3. Research Phases

The FishPass research plan relies strongly on insights gained from past successes and failures from both traditional fish passage science (e.g., fishways) and invasive species management techniques (e.g., barriers and traps). The priority of FishPass research activities are linked to the development timeline (i.e., pre- or post- construction) of the FishPass facility, which is comprised of **basic research, applied research, and extension phases** (Fig. 3-1). Basic research will be emphasized during the design and construction of the FishPass facility (YR -3 to YR 0) and focus on reviewing available data and identifying critical gaps on fish attributes and passage, guidance, and barrier technologies. Information gathered during Phase 1 will allow the Science Team to recommend a program of coordinated applied science be conducted once the facility is operational. While basic research will need to continue post-construction, an iterative engineering process, needed to translate it into passage concepts quickly, will be prioritized. Once FishPass is operational, the applied research phase and primary focus of FishPass will begin (YR 0 to YR 9). This work will encompass multi-component sorting systems meant to accomplish project goals for passing desirable fishes while blocking and removing undesirable fishes. Phase 2 will be implemented using an adaptive management approach, where the Science Team will apply treatments within FishPass to optimize fish sorting and passage efficacy, assess fish passage and fish community responses, and modify the following year experimental approach based on previous year evaluations. As opposed to a research facility where multiple independent research projects will be implemented, FishPass Phase 2 research will comprise installation of a coordinated program of applied science aimed at solving the connectivity conundrum (i.e., passing the desirable and blocking the undesirable). Finally, the extension phase seeks to examine the broad impacts of selective passage on a watershed. This phase requires continuous monitoring efforts (detailed in the Assessment Plan document) that occur throughout the life of the project (YR -3 to YR 10+).

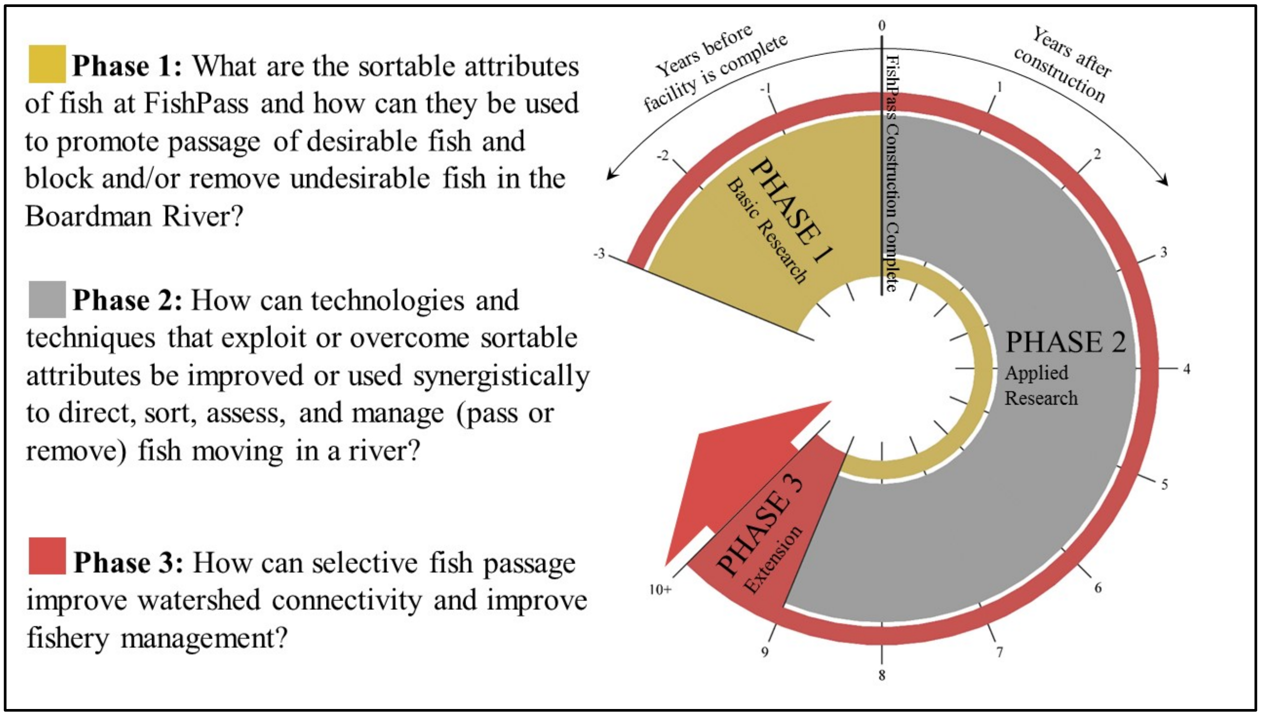

Figure 3-1. Timeline of FishPass research as defined by research phase. Project years are defined by reference to construction completion (YR 0). Width of research phase band correlates to the priority level. For example, in YR -3 to YR 0 basic research has the highest priority while applied research is emphasized in YR 0 to YR 9.

The research phases are intended to guide the Science Team to identify specific research questions and corresponding experiments on an annual basis. In addition, they will aid the Advisory Board to prioritize facility operation and usage. The research phases are described below in detail.

Phase 1: Basic Research

What are the sortable attributes of fish at FishPass and how can they be used to promote passage of desirable fish and block and/or remove undesirable fish in the Boardman River?

The first step in developing a fish sorting strategy is to define the status of all fishes present in the Boardman River and potentially moving through FishPass and identify their attributes. Attributes for the purposes of sorting, can be grouped into the following classifications: phenology, behavior, physiology, and morphology. Several sortable attributes of some key species, including invasive sea lamprey, lake sturgeon, and introduced salmonids, have been identified; however, a number of unknowns exist for many other species. The purpose of this research phase extends beyond characterization of attributes for individual species to identifying how commonalities and differences in attributes among species can be exploited to achieve selective fish passage. A crucial aspect of this phase is identifying which species are available, representative of the fish community, and should be targeted during the applied research phase.

The list of potential tools to implement at FishPass is drawn from fisheries research on invasive fish management and fish passage engineering. Several studies have identified technologies and techniques capable of manipulating fish movement based on one or more of the attributes identified above. In the Great Lakes, over 50 years of research has generated numerous methods to influence sea lamprey movement for the purpose of control, including: semiochemicals, electric currents, light, sound, hydraulics, screens, and vertical barriers. Recent advances in fish passage engineering have started to address the generally poor passage efficiency for non-salmonid species through traditional fishways. Better understanding of fish locomotor limitations and behaviors near and in fishways has been the primary catalyst behind such advances. Identifying the technologies and techniques that correspond to sortable attributes of the key species at FishPass is the second step to developing a fish guidance, sorting, and passage strategy. This approach includes technologies and techniques that: (1) influence fish behavior to exploit and/or manipulate movement tendencies and (2) exploit non-varying attributes during passage attempts, such as size and shape, to sort fish in a way that are independent of behavior.

The basic research phase will identify differences between desirable and undesirable fishes to prioritize/identify research (e.g., techniques or technologies) that is best suited to sort fish at FishPass. As a result, the Science Team should be able to "self-exclude" certain lines of research if there is no way to utilize it for fish sorting. Research conducted under this phase is fundamental in nature and need not be addressed directly within the FishPass facility.

Phase 2: Applied Research

How can technologies and techniques that exploit or overcome sortable attributes be improved or used synergistically to direct, sort, assess, and manage (pass or remove) fish moving in a river?

Development of a system capable of sorting a complex assemblage of fishes requires the information gathered in Phase 1 regarding fish biology and accompanying technologies. The core aspect of Phase 2 is to identify the optimal components and configuration of techniques and technologies to selectively direct, sort, assess and manage fish moving in a river. The FishPass facility is designed to accommodate tests using multiple devices to sort fish and can be rapidly and easily modified to aid in the research and development process. The need for integrative automatic or semi-automatic solutions is drawn from the desire to improve upon the manual trap-and-sort approach, which is the current and only known method to selectively pass and block fish by species. Manual sorting of fish is time consuming, costly, and can be detrimental to fish health; therefore, the goal of FishPass is to arrange different sorting mechanisms in a configuration that automatically or semi-automatically passes desirable fishes and blocks undesirable fishes while minimizing the need for human intervention. Similar to material-recovery industries, optimizing the fish sorting process does not solely focus on technological improvements, but also identifying ways to change/enhance fish attributes (e.g., behaviors) that improve the abilities of existing technologies to sort fish. The exact composition of technologies and techniques will likely be site-dependent and differ on the basis of the fish assemblage present, geology, hydrology, site development, and human use needs; but the process followed to select which devices to include and where, should be applicable to most fish passage situations in the Great Lakes and beyond.

This research phase will attempt to determine how best to arrange and integrate different fish guidance, sorting, and passage technologies and techniques in FishPass, to determine the logical order of operations in terms of attributes fish are sorted on, and to understand sorting efficiencies, efficacies, and needed redundancies in operations to achieve acceptable levels of sorting. Phase 2 will be implemented using an adaptive management approach. The Science Team will consider technologies and techniques for guiding fish movement both inside the sorting channel and nature-like channel as well as outside of the FishPass footprint (i.e., river channel downstream of the Union Street Bridge or upstream of the Cass Street Bridge). This research phase also attempts to address ways to manage the few individuals of an undesired species that are not blocked or removed by the sorting technique or technology systems; i.e., is it necessary to achieve 100% efficacy in passage or blockage, if not, what is acceptable?).

Phase 3: Extension

How can selective fish passage improve watershed connectivity and improve fishery management?

Efforts to improve passage of desirable fishes and blockage of undesirable fishes must be tied to broader Great Lakes and individual watershed conservation goals such as increasing productivity, increasing the sustainability of fish species, preserving biodiversity, restoring genetic connectivity, or managing against invasive species. Although many long-term impacts of increased connectivity will take several years (or decades in the case of long –lived species like Lake Sturgeon) to be realized, it is critical to identify passage priorities and monitoring strategies at the onset of a project. For example, is it better to pass some native fishes and block all invasive species or to pass all natives and block some level of invasive species? What are the tradeoffs from an ecological and economical perspective of various passage scenarios?

This research phase will attempt to determine what metrics should be used to assess passage success, how might the efficacy of management actions be measured, how might long-term goals be managed during the research/optimization and long-term operational phase, what is the relationship between metrics of passage success and management outcomes, and how can resource user and local values be reflected in the management of FishPass. A detailed understanding of FishPass effects on the Boardman River fish community will help guide similar approaches to the global problem of enhancing connectivity while minimizing the risks from aquatic invasive species.