# Proposal for Research and Experimental Design of Tributary Diversion screens for Juvenile lampreys in the Columbia River Basin

## PROJECT SUMMARY

### Research Goal

The goal of this work is to ensure the safe and effective protection of lamprey ammocoetes and macropthalmia subjected to various types of tributary diversion screens throughout the Columbia River Basin (CRB).

### Study Objectives

1. Document the general passage characteristics of juvenile lampreys over selected screen types in the laboratory.

2. Estimate the rate of entrainment of juvenile lampreys at various screen sites in the field.

3. Document the general passage characteristics of juvenile lampreys experimentally released over screens in the field.

4. Develop velocity and operational criteria for the safe and effective passage of juvenile lampreys at different types of diversion screens in the CRB

### Relevance

The Columbia Basin Lamprey Technical Workgroup (a subgroup of the CBFWA Anadromous Fish Committee), the Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin (CRITFC 2008), and the USFWS Pacific Lamprey Draft Assessment and Template for Conservation Measures (USFWS 2010) identified the need to improve lamprey passage and survival at obstacles such as dams, culverts, and tributary and irrigation screens as one of the highest priorities for lamprey recovery. Although passage of Pacific lampreys (*Entosphenus tridentatus)* at large hydropower dams has been studied, little is known about the effects of smaller screened and unscreened irrigation diversions on lamprey populations. The screening of water diversions to protect juvenile anadromous salmonids remains a high priority task for fish recovery and habitat restoration throughout the CRB (NPPC 2010; NOAA 2008). However, screening criteria have been developed primarily for juvenile salmonids, not for lamprey. As such, current fish screen criteria and designs have been documented to adversely affect lampreys. Despite several species of lampreys being petitioned for protection under the Endangered Species Act in 2003 and continued population declines of Pacific lampreys, little is known about the effects of fish screens on juvenile lampreys. Developing hydraulic and design criteria specific for juvenile lampreys and understanding the effects of current screen types on lamprey populations would be an important step towards their recovery and seems prerequisite to the continued screening of diversions in the CRB.

This project, with CRITFC Accord funding, will continue to specifically address the issue of how well various types of screens work for the safe and effective passage or exclusion of juvenile lampreys. After a proven design is derived, modification of screens basin wide to protect juvenile lamprey will be sought.

This project was initiated in 2009 under funds from other sources. A draft summary report of the work completed to date is included in this proposal as Attachment 1.

## PROJECT DESCRIPTION

### Background

There are thousands of screened and unscreened tributary (including irrigation) diversions in the CRB. Water diversions are sources of entrainment and mortality of fish, a contributing factor to the decline of fish populations in the Pacific Northwest (USFS 1995), and are often considered stressors on aquatic systems (Dadswell and Rulifson 1994; Kingsford 2000a and Kingsford 2000b). In a statement to the Congressional Committee on Energy and Natural Resources for the reauthorization of the Fisheries Restoration and Irrigation Mitigation Act (FRIMA), the U. S. Fish and Wildlife Service wrote:

"*For decades, state, tribal, and federal fishery agencies in the Pacific Northwest have identified the screening of irrigation and other water diversions, and the resultant improvements to fish passage as an effective and important means to protect, recover, and restore native anadromous and resident fish populations. Irrigation districts in the Pacific Northwest also recognize that poorly designed or unscreened water diversions result in fish mortality. Nearly 80 percent of water diversions in the Pacific Northwest are unscreened, and many have passage obstructions that pose a major risk to juvenile and adult threatened and endangered fish, including salmon, steelhead, bull trout, cutthroat trout, and Klamath basin suckers.*"

To protect and restore declining salmon and steelhead runs in the CRB, legislation such as FRIMA and the Northwest Power and Conservation Council's (NPCC) Columbia River Fish and Wildlife Program call for effective screening of irrigation diversions (NPCC 2010). The screening of diversions in the CRB is largely meant to protect ESA-listed populations of fish and has not considered the needs of or impacts to other species of concern, including various species of lampreys. This is unfortunate because the juvenile life stages of lampreys may be particularly vulnerable to screening impacts due to their small size, unique morphology, and poor swimming performance (Dauble et al. 2006). Given the large number of water diversions in the CRB, the potential for these obstacles to negatively impact lamprey populations seems high. In the Columbia River, high rates of impingement have been observed for juvenile lampreys on extended length submersible bar screens (Moursund et al. 2003). However, little is known about the effects of smaller irrigation diversions on juvenile lampreys, including entrainment and impingement rates and the extent of injury or mortality of fish that do pass over screens. Many screens installed today operate under design and velocity criteria established by NOAA-Fisheries and meant to protect juvenile salmonids. Information on the performance of juvenile lampreys encountering such devices would document how well current teleost-based criteria work for lamprey passage.

This proposal seeks to add CRITFC Accord Lamprey Project (i.e. *Implement Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin*) funding to existing collaborative funding from several sources including the USFWS, US Bureau of Reclamation and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). As part of the 2010 ISRP review of the CTUIR Accord lamprey project (1994-026-00), this proposal has already been reviewed and commented on by the ISRP and supporting answers to ISRP critique from that review is provided as Attachment 2 to this proposal. Therefore it is anticipated that most if not all of the technical scientific questions regarding this proposal have already been addressed.

**Objectives**

This project will address three working objectives and use laboratory and field-based approaches to understand the impacts of irrigation diversions on juvenile lampreys.

1) A suite of laboratory experiments will be designed to provide detailed information on the passage characteristics of juvenile lampreys over various types of devices(mechanical and passive), screen orientations (horizontal, vertical, and drum), and screen material (perforated plate and profile bar). Because of the small size of juvenile lampreys—particularly ammocoetes—and the variety of screen types and hydraulic conditions to be tested, we suggest that a laboratory approach would facilitate a more detailed analysis under controlled conditions and would allow for development of effective methods for use in the field. We also want to learn more about the migratory and swimming behavior of juvenile lampreys to help design relevant field experiments.

2) Methods will be developed to estimate the rate of entrainment of lampreys at various screen sites in the field. Included would be the use of PIT-tag technology and possibly the development and use of artificial juvenile lampreys. If juvenile lampreys—again, particularly ammocoetes—drift passively in water currents, the development and use of artificial lampreys for testing would allow large sample sizes and minimize the impact on natural populations. With this objective, we hope to identify screen sites that have high rates of entrainment and the hydraulic or mechanical conditions that may cause it. Such sites could be areas of high priority for remedial measures.

3) The ability of various types of screens in the field to safely and effectively pass juvenile lampreys will be tested. This work will involve determination of sites and experimental releases of fish over the screens to assess injury and direct or delayed mortality. Eventually, we hope to develop operational and design criteria for screens that facilitate the safe and effective passage of juvenile lampreys of all sizes. For all of this work, we propose to use juvenile Pacific lampreys, but suggest that our results would be applicable to all species.

**Objectives, tasks, and methods**

*Objective 1. Document the general passage characteristics of juvenile lampreys over selected screen types in the laboratory.*

Task 1.1. Obtain prototype test screens and materials and establish laboratory facilities.

We will obtain scaled-down versions of screens or screen materials commonly used in the field for use in laboratory experiments. For example, we can obtain a 10-ft.-long module of the Farmer's Screen (a horizontal flat plate screen) for testing. We will design a modular test apparatus to accommodate various types of screens. This will likely be a circular or oval tank or a flume equipped with flow-inducing pumps to achieve a variety of hydraulic conditions.

Task 1.2. Experimentally release juvenile lampreys over laboratory screens

We will release groups of ammocoetes and macropthalmia over the laboratory screens and assess passage characteristics under a variety of hydraulic conditions. We would first test the performance of lampreys subjected to current NOAA-Fisheries operational criteria for juvenile salmonids, including approach velocity (AV), sweeping velocity (SV), and water depth over the screen, if applicable. Initially, we will use only NOAA-Fisheries approved fish screens materials for testing. If these tests suggest that a smaller sized mesh is needed to prevent entrainment of ammocoetes, we will embark on tests with smaller mesh sizes. We will use underwater video cameras to document the behavior and entrainment of juvenile lampreys exposed to the various screen types and hydraulic conditions. Details of the experimental design will be developed pending discussions with colleagues and review of the literature.

Task 1.3. Document the migratory behavior of lamprey ammocoetes and macropthalmia.

We propose to use a large artificial stream to document the behavior of juvenile lampreys during downstream movements. The artificial stream could be the same device used in Task 1.2 or may be developed separately. Groups of lampreys would be stocked in the artificial stream, filmed, and observed during times of downstream movement. Our intent with these experiments is to determine whether the downstream migration of lampreys consists of mostly passive drifting or active swimming.

Task 1.4. Develop artificial juvenile lampreys that could be used in field experiments evaluating rates of entrainment at screen sites.

If juvenile lampreys do primarily drift downstream, especially ammocoetes, then the development of an artificial model would be useful for field evaluations. We envision the model as having the same shape and size characteristics, buoyancy, and flexibility of live animals. We believe the notion of an artificial juvenile lamprey is more feasible for ammocoetes than for macropthalmia. As we discuss in Objective 2 below, releases of large numbers of realistic artificial lampreys could be effective for evaluating entrainment at screen sites in the field.

*Objective 2. Estimate the rate of entrainment of juvenile lampreys at various screen sites in the field.*

Task 2.1. Locate several fish screen sites in the field for performance evaluations.

We will select screen sites for evaluation based in part on the following criteria: (1) the installations represent modern technology; (2) juvenile lampreys are located in the area; and (3) the sites have good access and offer potential for some experimental manipulation. Based on previous work by us (Rose and Mesa 2008), there should be no shortage of screen types available for evaluation. Final selections will be made after discussions with personnel from key agencies and field visits.

We will evaluate entrainment at several types of screens. Rotary drum and vertical fixed plate fish screens are the most common types of fish screens in the CRB and may pose the greatest risk to juvenile lampreys. Because macropthalmia commonly adhere or become impinged on screen surfaces (Moursund et al. 2001; Ostrand 2007), automated cleaning devices (e.g., traveling brushes) common on vertical screens may injure fish during operation. Other types of screens, including various types of horizontal flat plate screens, end of pipe screens, pump screens, and bubbler screens, are also common throughout the CRB and have yet to be evaluated for lamprey passage.

Task 2.2. Configure the entrance of each screen site with a monitoring or detection apparatus.

At each site, we will place a device at the entrance to facilitate quantifying the rate of entrainment of juvenile lampreys. We define an entrained animal as one that was drawn in and transported to the screen by the flow of water. Because the entrance of each screen site will probably differ, the device to be used will also vary. Potential devices could include PIT-tag interrogation systems, modified fyke or other type of trap nets, or large metal detectors (to detect coded-wire tags). The choice of device will be determined after site visits.

Task 2.3. Release large groups of fish upstream of the screen site and evaluate the rate of entrainment.

We will release large groups of ammocoetes and macropthalmia upstream of the screen site and quantify the number and percentage of fish that become entrained. The release area will be the nearest upstream habitat suitable for ammocoete rearing. The animals to be released will both be captured from the stream and held, or they will be the artificial models developed in Task 1.4. We will release groups of animals under a variety of flow conditions to derive relations between hydraulic conditions and rate of entrainment.

*Objective 3. Document the general passage characteristics of juvenile lampreys experimentally released over screens in the field.*

Task 3.1. Assess the hydraulic characteristics of each selected screen under a variety of stream flow and diversion levels.

We will measure selected hydraulic variables, including: (1) approach and sweeping velocities; (2) water depth over the screen [if applicable]; (3) river discharge; (4) bypass flow; and (5) diversion discharge. Water velocity information will be collected using an electronic meter. Approach velocities at all screens will be estimated by dividing the effective screen area by the diversion rate (Rose and Mesa 2008). Sweeping velocities will be taken over every 30-$cm^2$ section of screen surface area and 7.6 cm above the screen surface or at 0.6(depth) in shallower water. Stream discharge will be measured from the first suitable location upstream of the screen following the protocol of Gallagher and Stevenson (1999). Diversion rates will be estimated from screen outflow pipes using the same protocol. Water depth profiles over the screen will be measured using a depth gauge. The hydraulic performance data collected during this phase of the study will serve as baseline information for the selected screens, will be compared to established NMFS and ODFW screening criteria, and will establish the context for the fish injury studies.

Task 3.2. Examine the effects of screen passage on the behavior and well being of juvenile lamprey at several fish screen sites in the field.

These experiments are designed to answer questions about the fate of fish after they become entrained and encounter the screen. We will experimentally release fish across each screen type and evaluate their behavior, rates and severity of injury, and mortality that occurs during or after passage. Releases of fish will be conducted at most, if not all, of the screens evaluated in Objective 2. We will attempt to test fish under a variety of conditions, including high, base, and low stream flows, various AV's and SV's, and with and without mechanical cleaning devices in operation.

*Collection of fish*.—Lamprey ammocoetes will be collected by means of a backpack electrofisher from stream sections adjacent to the fish screen. If necessary, fish may be collected from nearby tributaries or from juvenile fish bypass systems on Columbia River dams and transported to the study site area for testing. For macropthalmia, we will collect fish from dams and transport them to the test site. Fish will be placed in live-cages near the screen prior to processing.

*Pre-passage fish examinations.*—Groups of 10 fish will be anesthetized in a solution of clove oil and given a brief examination for injuries. Our intent is to create groups of relatively healthy, uninjured fish for our tests. We will modify criteria outlined by Rose and Mesa (2008) and quickly assess the skin for abrasions, hemorrhages, or cuts, whether any fins were frayed, broken, or missing, and any injuries to the eyes. Fish without serious injuries will be divided into two groups, treatment and control ($N$ = 70 per group). Groups of 10 fish will be held in each of fourteen buckets and allowed to recover overnight prior to testing.

*Experimental setup.*—A device to quickly and safely capture fish after passage will be installed on the downstream exit of the fish screen. This device will allow fish to occupy an area away from turbulence and facilitate gentle handling and transfer for post-passage assessment. If possible, one or more underwater video cameras may be used to document travel times, screen contacts, impingements, fish orientation, and depths of fish in water column. Video cameras may be mounted above the water if shallow water or turbulence precludes underwater filming.

*Fish releases.*—Soon after the hydraulic variables have been measured at the screen, we will experimentally release fish across it. A group of 10 fish, or perhaps two groups, already in buckets from the day before, will be gently poured into water at the upstream end of the screen and allowed to pass. After one hour, if necessary, we will gently prod any remaining fish and force them to move downstream. After all of the treatment fish have been released, we will cover the entire screen area with Plexiglas or shut off withdrawal discharge at the screen and release groups of control fish in a similar manner. Fish that passed over the screen will be subject to a post-passage examination (described below) prior to the release of new fish. Several underwater and above water video cameras will be used to document the behavior of fish during passage. All video tapes will be reviewed at our laboratory and we will record the time required for each fish to pass over the screen, its general orientation towards current, how often fish contacted the screen or became impinged, and their general depths and location of travel. We will also note any interactions between the fish and mechanical cleaning structures of the screens when applicable.

*Post-passage fish examinations.*—After passage, fish will be gently transferred in 5-gallon buckets from the capture device to a work-up area. Groups of fish will be anesthetized in a solution of MS-222, followed by a clean water bath and then placed in a bath of Fluorescein dye (200 mg/L) for six minutes. Fish will then be removed from the solution and immediately rinsed in a series of three clean water baths, each lasting for 1 minute. Fish will then measured (fork length to the nearest mm), weighed (nearest g), and examined for injuries based on the criteria described above. For each fish, we will record whether it was injured (yes or no) after passage over the screen and what type of injuries it sustained. We will use a fluorescein dye test described by Noga and Udomkusonsri (2002) to determine the extent of ulceration on the skin, eyes, and fins of each fish. Briefly, areas of a fish that have been injured incorporate this dye and fluoresce a bright green color when viewed under ultraviolet (UV) light. For this, a group of fish will be placed on wet paper towels in complete darkness, illuminated with UV light, and photographed on each side against a dark background with a digital camera. Photos will be downloaded to a computer and analyzed at our laboratory. Because the dye fluoresces at 520 - 530 nm, the green band of images will be extracted and converted to bitmap files with computer software. The percentage of surface area of the fish that fluoresces green—which corresponds to the percentage of ulceration—will be quantified.

*Post-passage fish survival.*—In addition to the fish injury studies described above, we may also assess the extent of delayed mortality of groups of treatment and control fish. Briefly, groups of fish will be treated and released over the screen as described above. After passage, groups of treatment and control fish ($N = 70 – 150$ per treatment) will be held in circular tanks with flowing water. We will hold fish for 24 h and tally the number of mortalities in each group. After 24 h, fish will be returned to their original capture location.

*Statistical analyses.*—We will examine the relations between rate of injury, number of times fish contacted the screen, impingement, AV, SV, water depth, and diversion rate using simple and multiple regression analysis. The mean surface area with fluorescent dye for treatment and control fish will be compared using *t*-tests. We will compare the proportion of fish that were injured or killed between treatment and control groups using Fisher's Exact Test (Zar 1984). For all tests, the level of statistical significance will be $\alpha = 0.05$.

*Exceptions and potential modifications*.—Because conduct of this work is dependent on the local conditions around the screen itself, fish availability, and funding levels, our methods may require modification. We will work with personnel from the relevant fish and wildlife agencies, hydraulic engineers, and other interested parties to adaptively modify this work as needed.

*Objective 4. Develop velocity and operational criteria for the safe and effective passage of juvenile lampreys at different types of diversion screens in the CRB*

Based on the results of the work described above, we will develop—if necessary—velocity, design, and operational criteria for the safe and effective passage of juvenile lampreys at a variety of different screen types. We say "if necessary" because part of this project involves testing how well current NOAA-Fisheries criteria for teleosts work for juvenile lampreys. If the current NOAA-Fisheries criteria offer safe and effective passage for juvenile lampreys, then there would be no need to change them. If, however, other criteria result in more effective passage of juvenile lampreys, we will develop and present them to fisheries agencies for consideration. It is possible that different criteria may be needed for different screen types.

**Facilities and equipment**

We anticipate that all of the laboratory work for this project will be based out of the USGS's Columbia River Research Laboratory (CRRL). The CRRL, which has a long history of conducting fisheries research throughout the basin, has fully equipped wet laboratories for the conduct of experiments. The CRRL is also well equipped with most of the state of the art equipment necessary to conduct a wide array of field work. We are fully capable of working in a variety of field situations, from large reservoirs to small streams. Our offices are well supplied with the modern equipment and analysis software necessary to complete this research. In short, our laboratories already have much of the equipment and technology necessary to complete this research.

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**Attachment 1**

## Executive Summary

### *Effectiveness of common fish screen materials to prevent entrainment of Pacific lamprey ammocoetes*

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Pacific lampreys *Entosphenus tridentatus* are an important cultural and ecological resource in the Pacific Northwest and their populations have declined in recent years. The Columbia Basin Lamprey Technical Workgroup (a subgroup of the Columbia Basin Fish and Wildlife Authority Anadromous Fish Committee) has identified the need to improve lamprey passage and survival at obstacles such as dams, culverts, and irrigation screens as one of the highest priorities for lamprey recovery. Although passage of Pacific lampreys at large hydropower dams has been studied, little is known about the effects of smaller screened diversions on lamprey. For this reason, we evaluated the effectiveness of common fish screen materials to prevent entrainment of lamprey ammocoetes at a simulated water diversion. The results of this work should be useful in the development of design and operational criteria for screened water diversion structures to protect larval lampreys.

We conducted a series of laboratory tests to determine the rates of entrainment of juvenile lampreys exposed to common fish screen materials relative to fish size. Lamprey ammocoetes—ranging in length from 28 – 153 mm (Table 1)—were exposed to screen panels in an oval-shaped tank equipped with a flow-inducing propeller that produced a water velocity of about 12 cm/s through the fish screen (i.e., the approach velocity). The five sections of screen material, which were placed perpendicular to the flow, used for testing included: (1) perforated plate with 2.4-mm round openings (PP); (2) horizontally oriented bar screen with a slot width of 1.75 mm in its narrowest direction (VB); (3) 12-gauge wire cloth (12WC); (4) 14-gauge wire cloth (14WC); and (5) horizontally oriented interlock bar screen with a maximum slot width of 1.75 mm in its narrowest direction (IL). These screen types represent those used most often in the Columbia River Basin for screening fish at diversion sites. Groups of fish within a certain size class (N = 10 per group) were released into the oval tank upstream of the screen panels and we monitored the number of fish that became entrained, partially entrained, or remained upstream during a 1 h observation period.

For all tests, fish exposed to the test chamber and the screen material were not severely injured or killed. This occurred even though most fish contacted the screen during testing. Overall, the PP screen prevented the entrainment of 85% of the fish, protected all fish larger than 46 mm in length, and offered the best protection of all the screen types tested (Figure 1). The IL and PB screen panels protected 74% and 67% of the fish and prevented all fish larger than 58 mm and 55 mm from becoming entrained. The WC12 and WC14 screen panels prevented the entrainment of 34% and 38% of fish, prevented all fish larger than 90 mm and 78 mm from becoming entrained, and offered the lowest overall protection of all the screen types tested. For all screen types, most entrainment events occurred within the first ten minutes of the test (Figure 2).

Our results are the first of their kind and present basic information on entrainment rates of young lampreys relative to screen type and approach velocity only. Thus, our tests may represent the worst case scenario for fish that encounter a screened diversion site—that is, fish interacting with a vertical screen without a bypass route or a sweeping velocity component (i.e., water traveling parallel to the screen face). Current fish screening criteria require that diversion screens must have an effective bypass route and sweeping velocities that are greater than the approach velocities. As such, our results may underestimate the amount of protection that these screening panels provide for juvenile lampreys in the field. Future studies will evaluate the effectiveness of various sweeping velocities and screen angle configurations at preventing entrainment of juvenile lampreys.

Table 1. Mean total length (±SD) and number of fish released for each size class and screen type.

| | Extra-small | | Small | | Medium | | Large | | Extra-large | |
|---|---|---|---|---|---|---|---|---|---|---|
| Screen Type | FL (mm) | *N* | FL (mm± SD) | *N* | FL (mm± SD) | *N* | FL (mm±S D) | *N* | FL (mm±S D) | *N* |
| Interlok | 43±5 | 19 | 52±4 | 19 | 65±10 | 24 | 104±16 | 20 | 132±7 | 15 |
| Perforated Plate | 40±5 | 18 | 50±3 | 21 | 60±9 | 26 | 94±11 | 20 | 134±6 | 13 |
| Profile Bar | 42±4 | 17 | 50±4 | 21 | 66±11 | 19 | 97±15 | 20 | 139±6 | 14 |
| 12-Ga. Wire Cloth | 45±3 | 20 | 53±3 | 19 | 64±8 | 25 | 98±16 | 20 | 139±10 | 18 |
| 14-Ga. Wire Cloth | 42±4 | 22 | 52±2 | 20 | 65±10 | 25 | 99±11 | 20 | 136±5 | 15 |
| Control | 44±3 | 20 | 48±3 | 19 | 62±9 | 24 | 107±14 | 17 | 133±10 | 15 |

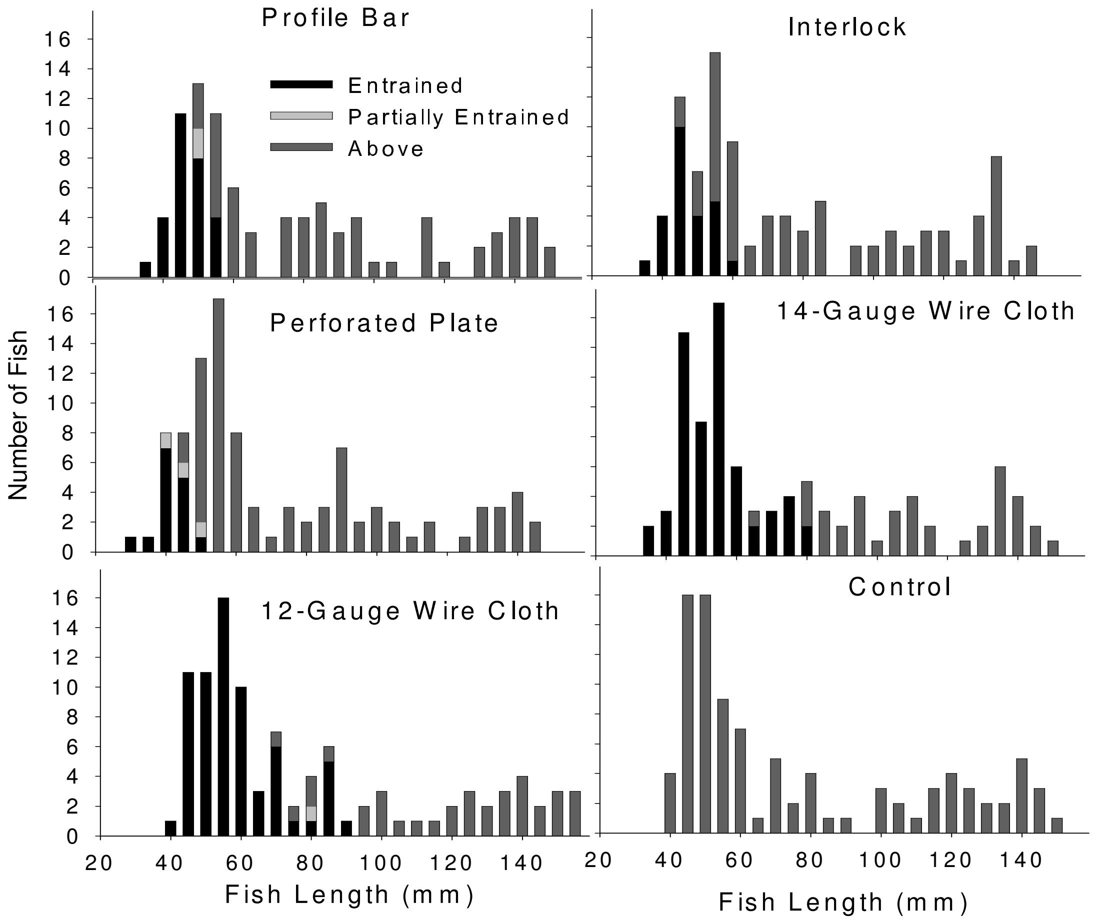


**Figure 1**. Frequency distributions of the lengths of fish that either passed through the screen (entrained), traveled at least half way through the screen but were not entrained (partially entrained), or were above or impinged on the screen at the end of the one hour test period.

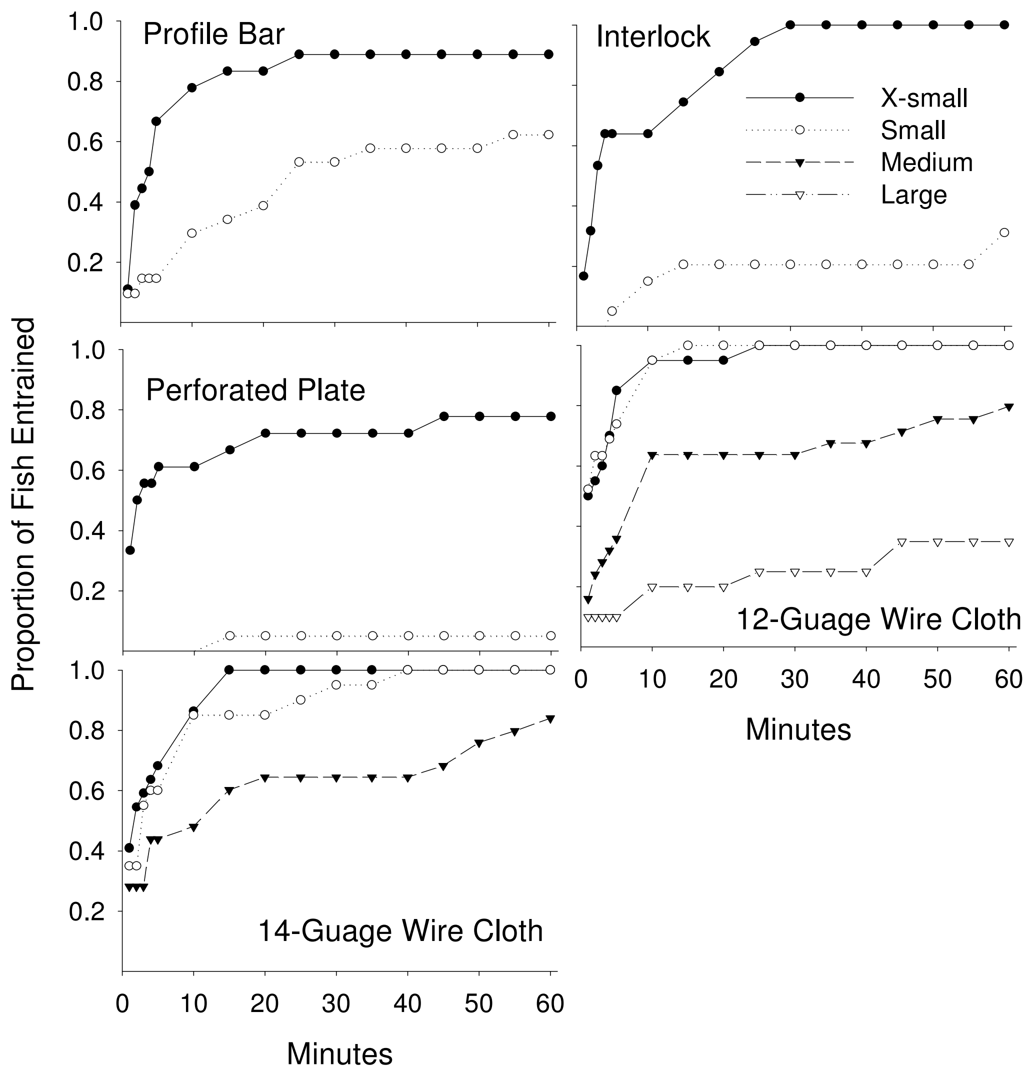


**Figure 2.** Proportion of fish entrained relative to time after release for five different types of screening panels. Observations were conducted at each minute for the first five minutes of the test and every five minutes thereafter. No extra-large fish were entrained and values of zero were omitted.

**Attachment 2**

November 9, 2010

Response to comments from the ISRP on Objective 7 of the CTUIR lamprey project dealing with the impacts of irrigation diversions on juvenile lampreys.

**The ISRP comment:**

*Objective 7 pertains to laboratory and field studies on impacts of irrigation diversion screens on larval lamprey and is not scientifically justified at this time. Before undertaking an extensive laboratory and field study, the proponents should conduct a preliminary study in the field to assess the relative magnitude of entrainment, injury, and mortality of juvenile lampreys and determine how serious a problem diversion screens present. This information could be used to justify a laboratory and more extensive field study. Objectives, research design, and methods for the USGS laboratory and field studies presented in the current proposal are insufficiently detailed to meet scientific criteria*

**Project Sponsor Response:**

We strongly disagree with the comments of the ISRP reviewer. Our research was purposely designed to *start* in the laboratory and to eventually move into field-based evaluations—just the opposite of what the ISRP is recommending. Most individuals concerned with lamprey conservation and restoration—including members of the Lamprey Technical Work Group and the Fish Screen Oversight Committee, researchers, tribal entities, and fish managers—readily acknowledge that irrigation diversions probably pose a serious threat to lamprey populations. There is ample justification and evidence for this concern, including the poor swimming performance of young lampreys, the ubiquity of irrigation diversions in the Pacific Northwest (PNW), and actual documentation of young lampreys becoming entrained at a variety of irrigation diversions in the PNW, including sites on the Umatilla River, the Methow River, Icicle Creek (Leavenworth Hatchery), and Herman Creek (Oxbow Hatchery). We have attached correspondence from numerous individuals below that document some issues and concerns relevant to lampreys and fish screens. Thus, for us, the first priority was *not* to assess the relative magnitude of entrainment, injury, and mortality in the field, but to first understand whether current regulatory screening criteria for juvenile salmonids provides adequate protection for young lampreys. We felt it was necessary to *first* understand how young lampreys fared under current approach and sweeping velocity criteria and the relative efficacy of different screen types (e.g., rotary drum, vertical, and flat plate screens) and screen panels (e.g., woven wire, perforated plate) to safely move fish away from diversions. Then, armed with this information, we would be in a much better position to target specific installations for assessment in the field and identify sites for remedial measures. In our opinion, ample evidence of a problem in the field already exists and the collective wisdom and scientific judgment of lamprey and fish screen experts confirms this notion.

In summary, we submit that a complete understanding of the impacts of irrigation diversions on young lampreys must *start* with laboratory experimentation and then move into field assessments. We must understand the basics first—the behavior and performance of fish as they approach different screen panels, the relative ability of different screen panels to prevent entrainment, the influence of fish size on entrainment, the ability of young lampreys to get themselves off of screens if they become impinged, and the efficacy of current salmonid-based velocity criteria. This type of approach—laboratory experiments or information followed by or at least coupled with field assessments—worked for the development of screening devices and criteria for passage of juvenile salmonids. We see no reason to change this approach for juvenile lampreys—it makes logistical, financial, and scientific sense.

Regarding the comment from the ISRP reviewer that the USGS study plan had insufficient detail, we request that the reviewer expand on this a bit. In other words, we would like more specific detail from the reviewer about what is lacking in the proposal. Currently, the study plan clearly states the goal, four objectives, relevance, background and justification, tasks and methods, analysis details, and facilities and equipment. The only piece missing from the study plan was the references, which can be added. In our opinion, there is sufficient detail in this study plan to understand the purpose and direction of the work, the methods, and anticipated results or outcomes. Again, if more detail is needed, please provide some guidance and the authors will revise as needed.

**Unedited correspondence from individuals on the impacts of irrigation diversions on juvenile lampreys, as requested by USGS researchers in response to ISRP comments:**

From John Crandall, Methow Monitoring Coordinator:

*There may be two factors involved with this. In the Methow, and elsewhere I am certain, the diversion canals upstream of the screens provide suitable habitat for larvae (these are not screened). These lead-ins are commonly dewatered when ditches are shut down at the end of the irrigation season. I have little data from behind screens (i.e. entrainment), but know of several locations that see use and mortality each year in the upstream canals. I hope to do a more extensive survey behind screens next summer (not funding this year, or set for next, but hopefully we can find some!). I do know cyprinids continue to be entrained and I would expect all small larvae would be as well.*

From Patrick Schille, Washington Department of Fish and Wildlife:

*During our fall fish salvage we also are seeing Lamprey in the areas between the river intake and screen. Our salvage efforts are typically concentrate in this area so we do not spend much time looking behind the screens. Also we are not doing salvage on all of our site, only the ones where stranding is known to occur. I have attached a memo that Eric created that may be the one you referenced. In a technical workshop held in Toppenish this year there was a gentleman who did a presentation on a re-introduction project in the Umatilla R. above the 3-Mile diversion site. He indicated they found significant amount of Lamprey behind these screens. This is a Oregon/BOR facility that I am fairly sure has the old 1/8" woven wire mesh. Spawning close by and 1/8" mesh size could be the primary causes of the entrainment. We have made the offer for field verification of entrainment as part of our screen inspection program a couple of* *time but so far no requests. A verification of presence or absence could be done on all of our sites, (175 +-) during fall shut downs at a minimal cost.*

From Jody Brostrom, USFWS, a summary of information collected during the regional process for Pacific Lamprey Assessment:

*I have attached some newer information that we have accumulated through the Pacific Lamprey regional review (see below), which may be helpful in your response. Of particular concern to larval and juvenile Pacific Lamprey are the direct and indirect impacts of water diversions, barrier screens, and fish passageways that are ubiquitous throughout much of their present range (Sutphin and Hueth 2010; US Fish and Wildlife Service 2010). These structures are not typically designed considering the species swimming ability (Dauble et al. 2006). The issues of impacts from irrigation diversions and screening of municipal, industrial, and residential water diversions has been identified as a fairly significant threat to Pacific lamprey throughout their range in the U.S. We have repeatedly heard these concerns from biologists who participated in our regional meetings in Washington, Oregon, Idaho, and California to provide information on Pacific lamprey demographic information and threats. In the NatureServe assessment contained in the U.S. Fish and Wildlife Service draft Pacific Lamprey (Lampetra tridentata) Assessment and Template for Conservation Measures; these threats have been ranked fairly high in scope and severity in a number of watersheds in the upper Salmon, Yakima, Walla Walla, Umatilla, John Day, Hood, lower Columbia River, southern Oregon, Sacramento, San Joaquin, and drainages south of Point Conception California (USFWS 2010). It may also be helpful to point out that the USFWS, USGS, and USBOR contributed funding towards this research because of the anecdotal reports of problems and the information on swimming speeds that point toward a fundamental problem with screen designs.*

*Other related information on swimming speeds and impingement also points toward these studies being extremely important. The screening, bypass, and transportation facilities at Columbia River mainstem dams were designed to improve passage conditions at dams for juvenile salmonids during their seaward migration; and were not designed to facilitate the passage of lampreys (Mesa and Copeland 2009). However, it has been identified that juvenile lamprey move downstream primarily at night, but they are profoundly affected by flow (Moser and Mesa 2009, Dauble et al. 2006). With the development of suctorial discs during metamorphosis, juvenile lampreys demonstrate protracted periods of attachment to the substrate (Dauble et al. 2006). Macropthalmia may need attachment structure to rest between burst of swimming, similar to adult lamprey (Moser and Mesa 2009). Swimming endurance for macropthalmia decreased rapidly as water velocities exceeded 46cm/s and swimming endurance of ammocoetes is likely lower, due to greater dependence on anaerobic metabolism (Dauble 2006). In addition, Dauble et al (2006) found that the ability to avoid barrier screens by juveniles is greatly reduced when perpendicular velocities exceed 0.4m/s (Dauble et al. 2006). Other research revealed that macropthalmia cannot swim faster than velocities found at the screen face of Columbia River mainstem dams (Morsund et al. 2002 & 2003).*

*Given the declining population levels for Pacific lamprey and the wide spread scope and severity of the potential impact from screened diversions, the continuation of this research is extremely important to Pacific Lamprey conservation efforts.*

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