PRELIMINARY PROPOSAL FOR FY 2007 FUNDING

Title:	Evaluate depth of migration and depth of neutral buoyancy for run-of-the-river juvenile salmonids
Study Code:	TSP-06-01
Principal Investigators/ Project Leaders:	Noah S. Adams, John W. Beeman, and Kenneth M. Cash

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PROJECT SUMMARY

Research Goals

The goal of this project is to determine the in-situ depth of neutral buoyancy of run-of-the-river juvenile salmonids. The depth of neutral buoyancy can be directly related to the potential for injury when fish pass through a turbine intake. When fish pass through the powerhouse, they experience increased pressure as they travel down in the water column followed by a sudden decrease in pressure inside the turbine. This sudden decrease in pressure causes the air in the swim bladder to expand. The extent of expansion, and the potential for injury, depends on how much air is in the swim bladder before entering the turbine environment. Fish that are neutrally buoyant at the surface would have relatively little air in their swim bladder while fish that are neutrally buoyant at depth would have more air in their swim bladder.

Regardless of the depth of neutral buoyancy of run-of-the-river fish, implanting active transmitters in juvenile salmonids does effect their buoyancy and fish can and do compensate for the added weight of the transmitter by gulping air into their swim bladder (Perry et al. 2001). Because fish compensate for the transmitter based solely on the weight of the transmitter in water, buoyancy compensation occurs irrespective of the type of technology used in the tag (i.e. radio or acoustic). At any given depth a tagged fish is likely to have more air in the swim bladder than an untagged fish. If untagged fish are neutrally buoyant at depth and tagged fish have incrementally more air in their swim bladder than untagged fish, they could be injured at a higher rate when passing through a turbine. This could mean that estimates of turbine survival using biotelemetry may be negatively biased.

Injuries to juvenile salmonids after exposure to a pressure time series thought to be similar to that experienced by fish passing through a turbine have been reported (Bettelle PNNL, 2005). Injuries were more common in fish acclimated to greater depths and tagged fish appeared to be effect more than untagged fish. The pressure history used in these tests included a short period near vapor pressure. It is uncertain if the pressure time series used in this test represents what fish really experience when passing through a turbine. Sensor fish released in 2006 into turbines at Bonneville, John Day and Ice Harbor dams under a wide range of operating conditions determined that nadir pressures less than about 10 PSIA rarely occur at these dams (Martin Ahmann, personal communication). Although there is some uncertainty of the actual pressure fish experience inside a turbine, it is clear that a reduction in pressure occurs and could differently affect tagged and untagged fish that are neutrally buoyant at different depths.

Objectives

Objective 1. Determine the depth of neutral buoyancy of run-of-the-river juvenile salmonids.

The objective of our research is to determine the feasibility of evaluating the depth of neutral buoyancy of run-of-the-river juvenile salmonids. By doing so, we should be able to shed some light on the relative importance of examining fish injury relative to pressure change as well as to validate turbine survival estimates that are obtained using biotelemetry.

Methodology

We propose to capture fish at various depths in the reservoir and test the feasibility of several techniques to quantify the amount of air in the swim bladder. While determining the state of the swim bladder of outmigrating juvenile salmonids seems to be a relatively simple biological question, it is difficult to address. Capturing fish at various depths is relatively simple. The difficulty comes in assessing the swim bladder without changing ambient pressure. When fish are captured at depth and brought to the surface, the air in the swim bladder expands and could be expelled or "burped" by the fish. To accurately assess the amount of air in the swim bladder it is necessary to maintain the ambient pressure. We propose to test several methods that would allow us to assess the swim bladder without altering the ambient pressure at which fish were capture. Tests would be conducted using fish that have been acclimated at known depth before attempting this on fish that have been captured in the river at selected depths.

Relevance to the Biological Opinion

Hydrosystem Substrategy 1.1; Key Alternatives Under Development─Turbine Survival Improvements for John Day Dam; Powerhouse Improvements for Ice Harbor Dam; Project Configuration RM&E─-Turbine Studies; Hydrosystem Studies on Turbine Survival.

PROJECT DESCRIPTION

Background and Justification

Many studies of the effects of dam operations on the mortality of juvenile salmonids have led to specific guidelines and management actions for operation of the Federal Columbia River Power System (NMFS 2001). For example, studies have been conducted throughout the basin to examine potential operational and structural changes that could increase the survival of juvenile salmon passing through turbines. The majority of these studies have used biotelemetry. Inherent in this methodology is making inferences about the entire population under the assumption that the survival of the test fish is unaffected by the transmitter. To make this assumption requires knowledge of whether the transmitter affects fish physiology and behavior.

Some studies have examined the effects of transmitters on physiological indicators such as growth and swimming performance (McCleave and Stred 1975; Mellas and Haynes 1985; Greenstreet and Morgan 1989; Moser et al. 1990; Adams et al. 1998a, 1998b). Additional research has investigated a transmitter's effect on buoyancy compensation (Gallepp and Magnuson 1972; Fried et al. 1976, Perry et al. 2001). It is clear from these studies that fish can and do increase swim bladder volume to compensate for the mass of the transmitter. Because fish compensate for the transmitters based solely on the weight of the transmitter in water, buoyancy compensation occurs irrespective of the type of technology used in the tag (i.e. radio or acoustic). Recently, preliminary laboratory studies (Rich Brown, Battelle presentation at 2005 AFEP Annual Research Review) have indicated that tagged fish that have added air to their swim bladder to compensate for the transmitter may be injured at a higher rate than untagged fish when exposed to pressure changes that might occur during the fish's passage through the turbine environment. If this is indeed the case, then estimates of turbine survival using biotelemetry may be negatively biased.

Differences between injury rates of tagged and untagged fish were most apparent in laboratory studies after fish where exposed to pressures at or near vapor pressure (zero absolute pressure including atmospheric pressure, or PSIA). Field data collected during 2006 at Bonneville, John Day and Ice Harbor dams indicate that exposure to this type of environment rarely occurs (Martin Ahmann, personal communication). Pressure sensors were released directly into the turbines at the three dams during a range of operating conditions. Releases of the pressure sensors were conducted at various locations to ensure that representative data was collected at possible locations were fish may pass. While the results indicated that there was significant variability in the data, the vast majority of the pressure readings were above 10 PSIA. Injury of tagged fish exposed to 10 PSIA is expected to be much less than injury to fish exposed to near vapor pressure.

To assess the extent of injury that could occur to fish passing through a turbine, it is vital to know the amount of air in the swim bladder before entering the turbine. If tagged fish are neutrally buoyant at depth prior to entering a turbine intake, they could have considerably more air in their swim bladder and be more susceptible to injury than untagged fish. Conversely, if fish are neutrally buoyant at depths near the surface before entering a turbine intake, it is unlikely that the relatively small amount of air needed to compensate for the mass of the transmitter at near-surface depth would make tagged fish more susceptible to injury than untagged fish when passing through a turbine. Laboratory test conducted by PNNL used fish that were allowed to acclimate, or achieve neutral buoyancy, at depth. For example, fish were allowed to acclimate at a pressure equal to 30 feet before they were exposed to a pressure change that included near vapor pressure. Fish that are acclimated at the surface and then exposed to increased pressure at 30 feet of depth will become negatively buoyant. If allowed access to air, they may gulp air into their swim bladder to become neutrally buoyant. Juvenile salmonids, physostomous species, can only effect substantial changes in air bladder volume by gulping air at the water's surface (Tait 1959; Harvey et al. 1968; Fried 1976). By allowing them to do this, the fish have more air in their swim bladder at 30 feet then they did when they were acclimated at the surface. When placed in an environment where the pressure is suddenly reduced to near vapor pressure, the air expands in accordance to Boyle's law (Jones 1951; Alexander 1966) and the size of, or pressure within, the swim bladder increases substantially. Each time the nadir pressure is reduced by 50%, the volume (or pressure) of the swim bladder increases by the same amount. As a result, a change of nadir pressure of only a few PSIA could significantly change the pressure exerted by the swim bladder. This can injure the fish by crushing internal organs or rupturing the swim bladder.

Clearly, it is important to know the state of the swim bladder of fish before they are exposed to dramatic changes in pressure that might occur inside a turbine intake. If they are neutrally buoyant at near-surface depths, it is less likely that they will be injured when passing through the turbine. The goal of our proposal is to examining the feasibility of determining the state of the swim bladder of run-of-the-river juvenile salmonids. If this can be determined, we should be able to shed some light on the relative importance of examining fish injury relative to pressure changes inside a turbine as well as to validate turbine survival estimates that are obtained using biotelemetry.

Current Status

We propose to start studies in 2007 which address questions about the potential bias in survival estimates that may result from the buoyancy compensation response of tagged fish. Some studies have examined the effects of transmitters on physiological indicators such as growth and swimming performance (McCleave and Stred 1975; Mellas and Haynes 1985; Greenstreet and Morgan 1989; Moser et al. 1990; Adams et al. 1998a, 1998b). Additional research has investigated a transmitter's effect on buoyancy compensation (Gallepp and Magnuson 1972; Fried et al. 1976, Perry et al. 2001). Preliminary laboratory studies have evaluated the effect of pressure changes during simulated pressure regimes similar to those experienced in the turbine environment on swim bladder condition (Rich Brown, Battelle presentation at 2005 AFEP Annual Research Review). However, little has been done to evaluate the state of the swim bladder of run-of-the-river fish. Determining the depth at which fish are acclimated before entering the turbine is a critical part of understanding the relative importance of the investigations into pressure related injuries of fish passing through turbines as well as validating turbine survival estimates obtained using biotelemetry.

Project Overview

Methods for determining the state of the swim bladder of run-of-the-river juvenile salmonids are not without uncertainties. If this was an easy task, it would have already been completed. Needless to say, it is an important question given the plethora of biotelemetry studies that are used to estimate turbine survival and the potential bias that might exist depending on the nadir pressure during turbine passage. We propose to develop methods to evaluate swim bladder condition in fish that are acclimated at known depths. After the procedures have been verified, we propose to capture fish in the reservoir and determine the state of the swim bladder. Field sampling will be conducted during a one week period during the peak outmigration time in the spring and again in the summer.

Methodology

We propose to capture fish at selected depths in the reservoir and test the feasibility of several techniques to quantify the amount of air in the swim bladder. Techniques will be tested using fish that are acclimated to known depths. Upon verification of the techniques, we propose to capture fish in the reservoir and determine the state of the swim bladder. Field sampling will be conducted during a one week period at the peak outmigration time in the spring and again in the summer. Samples will be taken at several depths (e.g., 1, 5, 10, and 15 m). A control group consisting of fish held at these depths will be tested concurrently for a total of four treatment and four control groups. Each group will consist of 15 fish for a total of 120 fish in the spring and 120 fish in the summer.

We propose to use an anchored system that allows us to adjust the depth of the fish trap. This is a relatively straight forward approach that has been tested and refined over the years. After trapping fish at depth, the difficulty becomes assessing the state of the swim bladder without changing ambient pressure. If fish captured at depth are brought to the surface, the air in the swim bladder will expand and could be expelled or burped by the fish. To accurately asses the amount of air in the swim bladder it is necessary to maintain the ambient pressure. This can be done in several ways. The assessment of the swim bladder could be done by SCUBA divers at the depth fish were captured. Alternatively, the fish could be captured inside a cylinder that would be sealed from the surface or by SCUBA divers. Sealing the cylinder would maintain the ambient pressure and allow the cylinder to be brought to the surface. Once at the surface, the capture cylinder could be placed inside a pressurized evaluation chamber. The evaluation chamber would essentially be a pressurized incubator. Once inside the evaluation chamber the fish could be anesthetized, removed from the capture cylinder and evaluated for swim bladder condition.

Measuring the volume of air in the swim bladder could be done using acoustic technology, ultrasound, X-ray, or salinity baths. Off-the-shelf technology would need to be modified to achieve this. To use salinity baths, the capture cylinder could be connected to a recirculation system that would allow incremental increases to the salinity of the water inside. Salinity would be increased until the fish's body achieved neutral buoyancy. Salinity gradients are a common way to quantify buoyancy (Perry et al. 2001) but other solutions are available. The pressure inside the cylinder together with the salinity of the water at which the fish achieves neutral buoyancy could be used to calculate swim bladder volume. The buoyancy of fish is not solely determined by the amount of air in the swim bladder. When using salinity gradients to measure buoyancy, density of the tissues and bones as well as lipid content can play a role in determining the buoyancy of the fish and introduce variability in the data.

Tasks and Objectives

Objective 1. Determine the depth of neutral buoyancy of run-of-the-river juvenile salmonids.

Rationale

For this objective, we propose to test several methods to evaluate the state of the swim bladder of fish that are captured at selected depths in the reservoir. These data are needed to help interpret results from laboratory tests of exposure to pressure regimes thought to exist during turbine passage and to validate turbine survival estimates obtained using biotelemetry. If tagged fish are neutrally buoyant at depth prior to entering a turbine intake, they could have considerably more air in their swim bladder and be more susceptible to injury than untagged fish. This could mean that turbine survival tests using active tags are negatively biased. Conversely, if fish are neutrally buoyant at depths near the surface before entering a turbine intake, it is unlikely that the relatively small amount of air needed to compensate for the mass of the transmitter at near-surface depth would make tagged fish more susceptible to injury than untagged fish when passing through a turbine.

Schedule of Tasks

Task 1.1: Refine innovative methods for assessing the state of the swim bladder for fish acclimated at known depths.

Activity 1.1.1: Assess acoustic methods, ultrasound, and/or X-ray for measuring swim bladder volume. This would require working with potential vendors to adapt current off-the-shelf technology.
Schedule: Jan., 2007

Activity 1.1.2: Assess the feasibility of using a pressurized incubation chamber to function as a testing area to evaluate the state of the swim bladder using standard techniques such as salinity baths.
Schedule: Jan. – Feb., 2007

Activity 1.1.3: Assess the concept of connecting a sealed cylinder that is brought up from various depths to a pressurized recirculation system. The recirculation system would have an induction vent. The induction vent would be used to introduce anesthesia at lethal concentrations. The induction vent would then be used to adjust the salinity of the water. Salinity would gradually be increased up to the point at which the sacrificed fish would float, indicating neutral buoyancy.

Schedule: Jan. – March, 2007

Task 1.2: Sample fish in the reservoir at selected depths during the spring to assess the depth of neutral buoyancy of run-of-the-river salmonids.

Activity 1.2.1: Obtain appropriate federal ESA permit and state collection and transport permits.

Schedule: Jan. – Feb., 2007

Activity 1.2.2: Deploy and test fish trap net in the reservoir.

Schedule: March- Apr., 2007

Activity 1.2.3: Utilize the methods refined under the pervious task to evaluate the state of the swim bladder of fish sampled at several depths ranging from near-surface to about 15 m. Samples would be collected during a one week period at the peak of the spring outmigration. A target sample size of 15 fish at each of the four depths would be evaluated.

Schedule: May, 2007

Task 1.3: Provide a control group for the field samples collected during the spring.

Activity 1.3.1: Fish would be held at several depths ranging from near-surface to about 15 m and evaluated for swim bladder condition. This would provide a control group to compare to the run-of-the-river fish.

Schedule: May, 2007

Task 1.4: Sample fish in the reservoir at selected depths during the summer to assess the depth of nutral buoyancy of run-of-the-river salmonids.

Activity 1.4.1. Utilize the methods refined under the pervious task to evaluate the state of the swim bladder of fish sampled at several depths ranging from near-surface to about 15 m. Samples will be collected during a one week period at the peak of the summer outmigration. A sample of 15 fish at each of the four depths will be evaluated.

Schedule: July, 2007

Task 1.5: Provide a control group for the field samples collected during the summer.

Activity 1.5.1: Fish will be held at several depths ranging from near-surface to about 15 m and evaluated for swim bladder condition. This would provide a control group to compare to the run-of-the-river fish.

Schedule: July, 2007

FACILITIES AND EQUIPMENT

The scope of this proposal is relatively small. As a result, there will be minimal special or expensive equipment for the proposed study. The most expensive equipment might be the trap net and potentially some specialized acoustic equipment for assessing swim bladder size.

The USGS operates the Columbia River Research Laboratory that includes research boats, vehicles, office space, and laboratory facilities to conduct this study. Boats will be operated at cost with no additional lease cost to the project. Only department of Interior certified boat operators trained in CPR and First Aid will operate boats. In order to meet U.S. Coast Guard standards, boats will be inspected by a third party. Furthermore, USGS will provide a quality control system consistent with the Good Laboratory Practices Act.

Other resources include:

-A selection of 27 boats up to 30 feet in length for work on the river.
-Two 2700 square foot storage facilities with a shop.
-A local computer network integrating state-of-the-art GIS capabilities.
-A technical staff of 60-100 fishery biologists, ecologists, and GIS specialists.
-An office and analytical laboratory in a 15,000 square foot facility.

IMPACTS

Impacts to other researchers

Because we will be trapping a relatively small number of run-of-the-river juvenile salmonids in the spring and summer, there is very small potential to impact other researchers. If we were to trap another researcher's fish, they would immediately be released and not be included in the evaluation.

Impacts to Projects

Because the field work for this proposal will occur well outside the boat restricted zone of any hydroelectric dam, there will be not impact to the projects.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

USGS currently has a service contract through IAP, Inc. Some of the personnel working on this project may be IAP employees.

List of Key Personnel and Project Duties

Personnel	Organization	Project Duties
Noah Adams	USGS	Co-Principal Investigator/Project Leader
John Beeman	USGS	Co-Principal Investigator/Project Leader
Kenneth Cash	USGS	Co-Principal Investigator/Project Leader
Dennis Rondorf	USGS	Section Leader

TECHNOLOGY TRANSFER

We plan to transfer information obtained from our analysis in the manners listed below. Once this information is transferred, it will be used to make decisions relative to operation of the Federal Columbia River Power System and Juvenile Transportation Program. In addition, the information will be used by other federal and state agencies, Indian Tribes, and the public to make management decisions to aid in the recovery of threatened and endangered populations of salmon in the Columbia Basin.

1. Presentation to the Anadromous Fish Evaluation Program (AFEP) in November 2007 as invited. Present preliminary findings to fisheries agencies, tribes, and the public upon invitation to the Studies Review Work Group in fall, 2007.

2. Expected draft report by December, 2007 and final report by March 10, 2008. This timeline provides up to 45 days for external peer review by parties determined by the U.S. Army Corps of Engineers and 60 days for USGS staff to revise and resubmit the manuscript in its final form.

3. Presentations at professional meetings (e.g., American Fisheries Society) and publication of information in peer reviewed journals.

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