FINAL RESEARCH PROPOSAL (COE) (FY10)

TITLE: Evaluation of juvenile salmonid gatewell egress using updated orifice lighting treatments at McNary Dam

PROJECT LEADER: Gordon A. Axel
Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112
(509) 542-4033

ADMIN. OFFICER: Doug Dey
Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112
(206) 860-3237

STUDY CODE:

PROJECT DURATION: FY2010-11

SUBMISSION DATE: January 2010

PROJECT SUMMARY

This study will compare gatewell egress rates for juvenile run-of-the-river yearling and subyearling Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, coho salmon *O. kisutch*, and steelhead *O. mykiss* under different orifice lighting treatments. The gatewell will be equipped with standard vertical barrier screens (VBS) and extended length bar screens (ESBS). Fish will be collected and PIT tagged at the Juvenile Fish Collection Facility at McNary Dam. Gatewell egress will be measured with an in-line PIT detection system utilizing the existing orifice trap in Gatewell 6B and compared to each light treatment. During testing, turbine unit 6 will be

operated at 62 MW (standard loading). Results of this study may provide direction pertaining to modifications in current orifice lighting strategies in place at USACE projects on the Snake and Columbia Rivers.

RELEVANCE

This study addresses Reasonable and Prudent Alternatives (RPA) 21 and 53 in the 2008 FCRPS Biological Opinion (NMFS 2008), and element BPS-P-10-1 of the U. S. Army Corps of Engineers (COE) Anadromous Fish Evaluation Program. This study also addresses Question 3 of the Ten Key Questions for Salmon Recovery in the NMFS Salmon Research Plan (NWFSC 2002).

Artificial lighting in gatewell orifices is currently being utilized, to varying degrees, at all Columbia and Snake River USACE projects. While previous studies have shown a variable response to light for each salmonid species (Rainey 1985, Fields 1966, Hoar 1957, Puckett and Anderson 1988), the literature suggest that improvements can be made with respect to orifice passage efficiency (OPE) if light intensity and wavelength can be optimized in order to allow juvenile salmonids to find the orifice more easily. Laboratory and field studies conducted by Mueller and Simmons (2008) suggested that different lighting could be tested to determine if white light or light that is emitted within the peak action spectra of salmonids (blue-green region) is best for attracting fish to the orifice. The proposed study evaluates both lighting alternatives to identify which may have a more positive effect on OPE, as well as a light off treatment to see if light treatments might negatively effect OPE.

STUDY OBJECTIVES

Specific study objectives may change based on recommendations from the Studies Review Workgroup (SRWG).

Objective 1

Develop orifice lighting alternatives in conjunction with the USACE.

We propose to test two different types of light to determine if white light or light emitted within the peak action spectra for salmonids is best for attracting run-of-the-river yearling and subyearling Chinook salmon, sockeye salmon, coho salmon, and steelhead to pass through the orifice. The exact type of lighting used will be determined in conjunction with the USACE and SRWG. A third test with lights off will also be used to determine if lighting causes an avoidance effect for a particular species.

Objective 2

Measure light intensity and water turbidity prior to each test release.

We will measure light intensity and water turbidity within the gatewell prior to and after each test in order to determine variations in orifice illumination that may cause changes to egress.

Objective 3

Compare gatewell egress rates for each release group with implemented lighting scheme.

We will compare gatewell egress of run-of-the-river smolts including yearling and subyearling Chinook, coho, and sockeye salmon, and steelhead at McNary Dam. An existing orifice trap will be utilized in the B gatewell (south orifices) in turbine unit 6 during the spring and summer

outmigrations (April – July). Gatewell egress will be measured using in-line PIT detection systems on the orifice trap. Fish will be released either through a release hose placed behind the trash rack or using canisters placed into the gatewell (to be determined later). Fish will be diverted through the PIT detection system and then released directly back into the collection channel with no holding required. Therefore, the orifice trap will not require constant supervision during testing. Releases will be made in the morning and evening to compare diel differences in OPE.

Evaluations will begin as soon as sufficient numbers of test fish are available (early to mid-April) and will continue until water temperature limits the general handling and examination of juveniles (early to mid-July).

METHODOLOGY AND SAMPLE SIZE ESTIMATION

The juvenile salmonid outmigration at McNary Dam is generally separated into a spring (early April – mid June) and summer (June – July) run. The spring outmigration is made up of yearling Chinook salmon, coho salmon, sockeye salmon, and steelhead. The predominant species will be yearling chinook, but substantial numbers of steelhead and sockeye will also pass McNary Dam during the month of May. Subyearling Chinook salmon are the predominant species during the summer outmigration and will make up in excess of 95% of the fish that are passing during this period.

To compare the biological effect of artificial light levels on juvenile salmon passage rates through orifices into the McNary Dam JBS, we will PIT-tag groups of fish, release them into the gatewell of Turbine Unit 6B, and record subsequent PIT-tag detection at the orifice trap in the

collection channel and at the full flow and facility detectors. We will release fish for one light treatment per day and monitor detections for a 24-hour period (later detections will be recorded but will be considered "right-censored" at 24 hours when forming the passage time distribution) (Hosmer et al., 2008). Therefore, if three treatments are conducted, a three-day "block" will be required. For each fish group released, we will calculate the median passage time from release until first detection in the orifice trap PIT-tag detector (we will also calculate passage times for the orifice trap to JBS to evaluate the relative passage time within the bypass system). The estimated medians are not expected to be affected by censoring of fish passing after 24-hours unless they are actually greater than during the first 24 h.

Differences between median passage rates for light treatments will be statistically compared using a Block ANOVA. While medians (and other percentiles) may not be normally-distributed, we expect the mean of medians across blocks to be approximately normally-distributed by the central limit theorem (Mood et al., 1974). We will examine graphical plots of the data versus model residuals to assess this assumption. Additionally, we will model the travel time distributions using time-to-event methods (e.g., Kaplan-Meier; Hosmer et al., 2008) to assess whether the treatments alter the shape of the distributions as well as their central location (i.e., medians).

The study objective is to test for a minimum difference, d, in median passage rates between fish experiencing different light levels at the orifices (calculations are for pair-wise comparison regardless of number of treatments). The number of x-day blocks, b, (x = number of treatments) that are required can be calculated from

$$b \approx \frac{\left(t_{\alpha/2} + t_{\beta}\right)^2 s^2}{d^2}$$

for α (0.05), β (0.20; i.e. power = 80%), desired detectable difference stated in hours, and where s^2/b is the estimated variance of d (Steel and Torie 1980). We estimated s^2 from similar PIT-tagged releases at McNary Dam in 2005 as twice the mean-squared error term (MSE) from an ANOVA on replicate medians of 0.08948 for yearling Chinook salmon (medians averaged roughly 1.0 hour) and 0.02302 for subyearling Chinook salmon (medians averaged roughly 0.25 hours). Note that the term with the t values depends on b, so the solution is found iteratively. The data used to estimate s^2 was based on group sample sizes of roughly 100-200 fish. We will tag and release similar group sizes for all species, if possible. Table 1 shows numbers of blocks needed for various detectable differences using the criteria above.

During the spring migration, sufficient numbers of smolts should be available for 6-8 replicates of each 3-d block for both yearling Chinook salmon and steelhead to achieve a detectable difference of 0.35-0.40 h. Therefore, we anticipate PIT tagging from 1,800-5,400 smolts of each species. Sockeye and coho salmon collection is less consistent so we will attempt to achieve similar replicates, but chances are that we will have fewer replicates for these species. During the summer migration, we anticipate tagging from 6-8 replicates for each 3-d block for a detectable difference of 0.15-0.17 h. Therefore, we anticipate PIT tagging from 3,600-5,400 subyearling Chinook salmon.

Table 1. Required numbers of three-day blocks to achieve a range of detectable differences of median passage rates (TT) based on daily treatment groups of 200 PIT-tagged salmon, with α=0.05 (two-sided test) and β=0.20 (i.e., power = 80%). These should be considered minimum numbers due to unpredicted experimental error and unplanned fluctuations in numbers sampled per test.

Yearling Chinook salmon		Subyearling Chinook salmon	
Required blocks	Detectable difference in median TT (hours)	Required blocks	Detectable difference in median TT (hours)
72	0.10	203	0.03
33	0.15	74	0.05
20	0.20	39	0.07
13	0.25	20	0.10
10	0.30	15	0.12
8	0.35	10	0.15
6	0.40	8	0.17
5	0.45	6	0.20
5	0.50	5	0.25

CRITICAL LIMITATIONS

The degree of success of this study will be contingent upon six primary factors: 1) adequate numbers of fish being collected and tagged during the required time frame; 2) the pre-determined replicates and sample sizes providing the necessary precision for measuring differences in gatewell egress between lighting treatments; 3) PIT-tag detectors and the bypass system at McNary Dam operating for the duration of the study; 4) uninterruptible power source to run the PIT detection system; 5) the acquisition and availability of detailed operations data in order to correlate OPE with project operations; and 6) access to McNary Dam outside normal business hours.

PROJECT IMPACTS

1. The existing orifice trap will need to be modified in order to inject light into the orifice.
2. Orifice trap modifications to incorporate the PIT detection system in the bypass channel at McNary Dam will occur during the period when the orifice flow into the channel is shut down (January – March, 2010).
3. Office and storage conexes will be required on the McNary Dam intake deck.
4. Turbine loading will have to remain constant at the selected loading during the evaluation.
5. Power supply to the PIT detectors will need to be uninterrupted in order to adequately measure OPE.
6. All fish for the study will be collected at McNary Dam. Changes in the daily smolt monitoring sampling schedule and sample rates may be required to meet daily target numbers for tagging. Collection operations at McNary Dam during April through July will be coordinated with the

Project Office and Smolt Monitoring Program personnel.

7. Activities related to fish handling may occur during all hours; therefore, unusual vehicle traffic and activity may occur outside normal COE duty hours during April through August. NOAA Fisheries personnel will require access to the juvenile fish collection channel at all hours of the day during study period.

PERMIT REQUIREMENTS

These studies will be carried out under an ESA Section 10 Permit issued to NOAA Fisheries and under any necessary state permits.

TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred to the fisheries community by presentations at meetings and workshops, by personal contact, by annual and final reports to the U.S. Army Corps of Engineers, and through scientific publications. A schedule of planned deliverables will include:

Preliminary Report (i.e. preliminary data results tables)	Sept. 1
Draft report	Sept. 30
Final report	Pursuant to regional reviews

KEY PERSONNEL AND DUTIES

Gordon A. Axel	Principal Investigator
Michael H. Gessel	Principal Investigator
Jesse Lamb	Biological Technician
Nathan Dumdei	Biological Technician
Matthew Nesbit	Biological Technician
Benjamin P. Sandford	Statistician
Jim Simonson	Maintenance Mechanic
Jeffrey Moser	Maintenance Mechanic
Thomas E. Ruehle	Field Coordinator
Dr. John G. Williams	Program Manager
Doug Dey	Administrative Officer
Dr. John W. Ferguson	Division Director

REFERENCES

Fields, P. E. 1966. Final Report on Migrant Salmon Light Guiding Studies at Columbia River Dams. Report to U.S. Army Corps of Engineers, Portland, OR.

Hoar, W. S., M. H. A. Keenleyside, and R. G. Goodall. 1957. Reactions of Juvenile Pacific Salmon to Light. Journal of Fisheries Research Board of Canada 14:815-830.

Hosmer, D. W., S. Lemeshow, and S. May. 2008. Applied Survival Analysis: Regression Modeling of Time-to-Event Data, 2nd Ed. Wiley & Sons. New Jersey.

Mood, A. M., F. A. Graybill, and D. C. Boes. 1974. Introduction to the Theory of Statistics, 3rd Ed. McGraw-Hill. 564 p.

Mueller R. P., and M. A. Simmons. 2008. Characterization of Gatewell Orifice Lighting at the Bonneville Dam Second Powerhouse and Compendium of Research on Light Guidance with Juvenile Salmonids . PNNL-17210, Pacific Northwest National Laboratory, Richland, WA.

NMFS (National Marine Fisheries Service). 2004. Endangered Species Act, Section 7(a)2 Consultation, Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(I)(A) Permit for Juvenile Fish Transportation Program. (Available from internet at http://www.salmonrecovery.gov/BiologicalOpinions/FCRPS/2008Biop.aspx.

NWFSC (Northwest Fisheries Science Center). 2002. National Marine Fisheries Service Salmon Research Plan Vol. I & II. Northwest Fisheries Science Center, Seattle, WA. Available online at research.nwfsc.noaa.gov/.

Pucket, K. J., and J. J. Anderson. 1988. Conditions Under Which Lights Attract Juvenile Salmon. In Proceedings: Fish Protection at Steam and Hydroelectric Power Plants, W. C. Micheletti (ed). Electric Power Research Institute, Palo Alto, CA.

Rainey, W. S. 1985. Considerations in the Design of Juvenile Bypass Systems. In Proceedings of the Symposium on Hydropower and Fisheries, FW Olson, RG White, and RH Hamre (eds). American Fisheries Society, Bethesda, Maryland.

Steel, R. G. D., and J. H. Torrie 1980. Principles and Procedures of Statistics, 2nd Ed. McGraw-Hill. 633p.