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2006 Annual Report

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A Research Project to Enhance Iteroparity in Columbia Basin Steelhead *(Oncorhynchus mykiss)*

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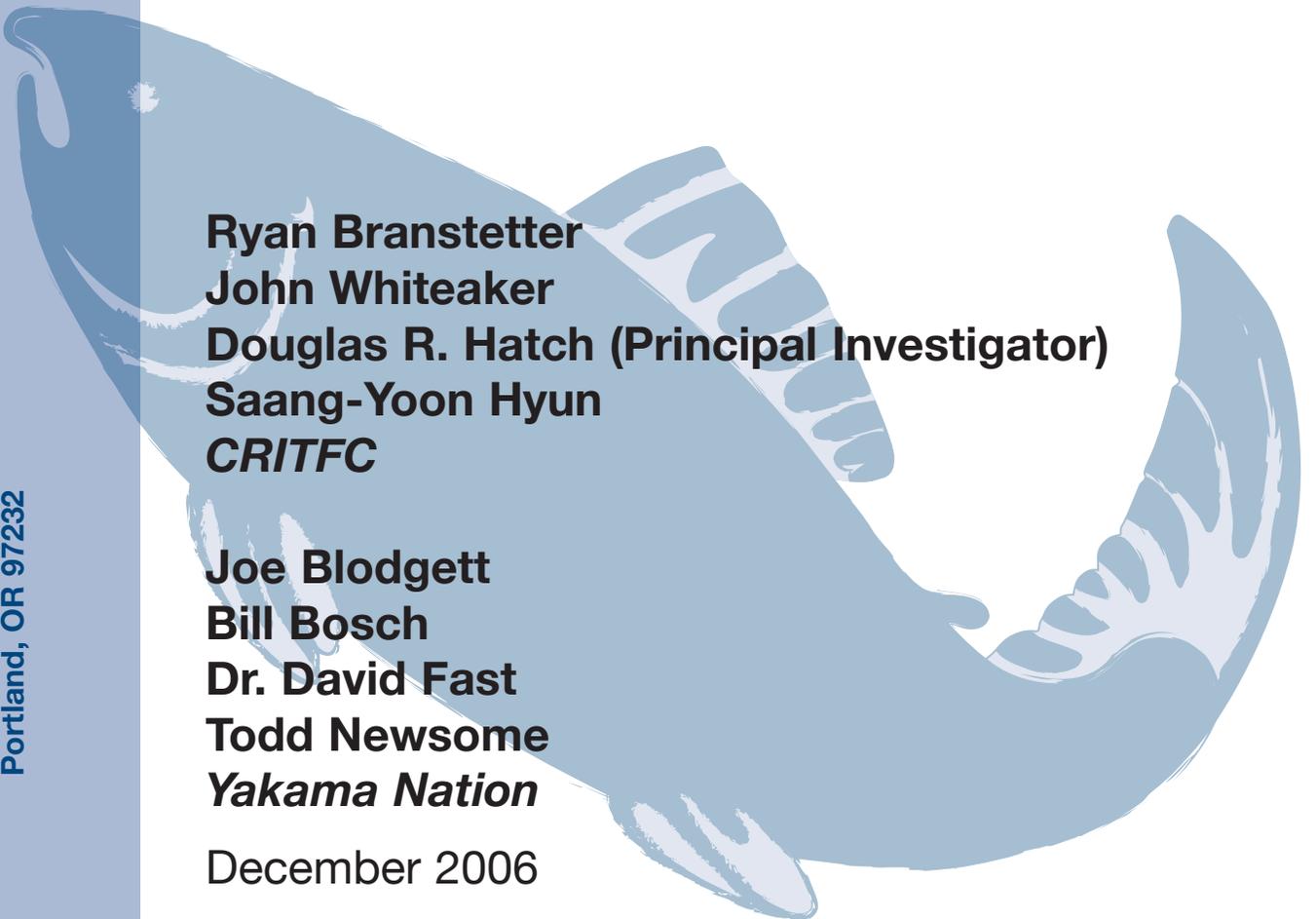
2006 Annual Report

**Kelt Reconditioning: A Research Project to Enhance Iteroparity in
Columbia Basin Steelhead *(Oncorhynchus mykiss)***

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ABSTRACT

Iteroparity, the ability to repeat spawn, is a natural life history strategy that is expressed by some species from the family Salmonidae. Estimated rates of repeat spawning for post-development Columbia River steelhead *Oncorhynchus mykiss* populations range from 1.6 to 17%. It is expected that currently observed iteroparity rates for wild steelhead in the Basin are severely depressed due to development and operation of the hydropower system and various additional anthropogenic factors. Increasing the current expression of repeat spawning rates using fish culturing methods could be a viable technique to assist the recovery of depressed steelhead populations, and could help reestablish this naturally occurring life history trait. Reconditioning is the process of culturing post-spawned fish (kelts) in a captive environment until they are able to reinitiate feeding, growth, and redevelop mature gonads. Reconditioning techniques were initially developed for Atlantic salmon *Salmo salar* and sea-trout *S. trutta*. The recent Endangered Species Act listing of many Columbia River Basin steelhead populations has prompted interest in developing reconditioning methods for wild steelhead populations within the Basin. To test kelt steelhead reconditioning as a potential recovery tool, wild emigrating steelhead kelts were placed into one of four study groups (in river release, direct capture and transport, short-term reconditioning, or long-term reconditioning).

Steelhead kelts from the Yakima River were collected at the Chandler Juvenile Monitoring Facility (CJMF, located on the Yakima River at river kilometer 75.6) from 7 March to 8 June 2006. In total, 348 kelts were collected for reconditioning at Prosser Hatchery. Captive specimens represented 17.0% (348 of 2,002) of the entire 2005-2006 Yakima River wild steelhead population, based on fish ladder counts at Prosser Dam. Steelhead kelts were reconditioned in 20-foot circular tanks, and fed freeze-dried krill initially (first 2 months of long-term reconditioning) or for the duration of the experiment. Long-term steelhead kelts also received Moore-Clark pellets to provide essential minerals and nutrients necessary for gonadal redevelopment. Oxytetracycline was administered to all reconditioned fish to boost immune system response following the stress of initial capture. To control parasitic infestations two methods were used: an intubation of Ivermectin^{TM} was administered to control internal parasites (e.g., *Salmincola spp.* and, a Formalin drip system was administered via drip system for the duration of reconditioning to prevent fungal outbreaks.

From the steelhead kelts collected at the CJMF, four experimental groups were established; in-river release, direct transport and release, short-term reconditioning and long-term reconditioning. Short-term kelts were reconditioned for 3 to 5 weeks. Surviving specimens were released on May 15, 2006 and June 27, 2006. Long-term steelhead kelts were held for a 6-9 month period with a release in October 18, 2006.

No-term release kelts and short-term reconditioned kelts received PIT-tags with a portion of each group receiving hydro-acoustic tags to assess return survival, travel

time, and migratory behavior below Bonneville Dam. In total, 49 No-term release kelts and 50 short-term reconditioned kelts were PIT-tagged, with all surviving No–term and short-term reconditioned kelts successfully receiving a surgically implanted hydro-acoustic tag as well. With the conclusion of this third year we have completed a number of multi year analyses to better understand how kelts are fairing in the lower river as well as laying the groundwork for a cost analysis.

ACKNOWLEDGEMENTS

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INTRODUCTION

History

Populations of wild steelhead *Oncorhynchus mykiss* have declined dramatically from historical levels in the Columbia and Snake rivers (Nehlsen et al. 1991; NRC 1996; *US v. Oregon* 1997; ISRP 1999). Since 1997[1] steelhead in the upper Columbia River have been listed as endangered under the Endangered Species Act (ESA). Those in the Snake River have been listed as threatened, since 1997[1]. Stocks originating in the mid-Columbia were listed as threatened in 1999[2]. Causes of the declines are numerous and well known which include hydropower operations and habitat loss (TRP 1995; NPPC 1986; NRC 1996; ISRP 1999). Regional conservation plans recognize the need to protect and enhance weak upriver steelhead populations while maintaining the genetic integrity of those stocks (NPPC 1995).

Iteroparity, the ability to repeat spawn, is a natural life history strategy that is expressed by *0. mykiss,* with rates estimated to be as high as 79% for populations in the Utkholok River of Kamchatka, Russia 1994-96 (Savvaitova et al. 1996). Historical rates for the Columbia River have not been accurately documented but emigrating steelhead averaged 58% of the total upstream runs in the Clackamas River from 1956 to 1964 (Gunsolus and Eicher 1970). Current iteroparity rates for Columbia River Basin steelhead are considerably lower, due largely to high mortality of downstream migrating kelts (post-spawn steelhead) at hydropower dams (Evans and Beaty 2001), and potentially inherent differences in iteroparity rate based on latitudinal and inland distance effects (Withler 1966; Bell 1980; Fleming 1998). The highest recent estimates of repeat spawners from the Columbia River Basin were in the Kalama River (tributary of the unimpounded lower Columbia River) having exceeded 17% (NMFS 1996). Farther upstream, 4.6% of the summer run in the Hood River (above only one mainstem dam) are repeat spawners (J. Newton, ODFW, pers. comm.). Iteroparity rates for Klickitat River steelhead were reported at 3.3% from 1979 to 1981 (Howell et al. 1984). Summer steelhead in the South Fork Walla Walla River have expressed 2% to 9%

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[1] Final Rule 8/18/97: 62 FR 43937-43954.

iteroparity rates (J. Gourmand, ODFW, pers. comm.), whereas repeat spawners composed only 1.6% of the Yakima River wild run (from data in Hockersmith et al. 1995) and 1.5% of the Columbia River run upstream from Priest Rapids Dam (L. Brown, WDFW, unpubl. data).

Rationale

Post spawn steelhead represent the portion of the population that successfully survived through an entire life cycle and spawned. These fish have experienced and survived stochastic events, selective forces and have demonstrated their ability to reproduce successfully. The hydrosystem exerts a strong selection force against iteroparity, therefore, efforts to mitigate for this effect may help preserve the evolutionary legacy of the species. Kelt reconditioning promotes re-initiation of feeding, thereby enabling kelts to survive and rebuild energy reserves required for gonadal development and repeat spawning. Techniques used in kelt reconditioning were initially developed for Atlantic salmon *Salmo salar* and sea-trout *S. trutta.* A review of these studies and those applicable to steelhead kelts are summarized in Evans *et al*. (2001). Additional reviews of this subject (Hatch et al. 2002 and 2003) provide strong support of the benefits of kelt reconditioning to address population demographic and genetic issues in steelhead recovery. This year's project continues to identify and systematically tests short- and long-term kelt reconditioning approaches as well as direct transport and release.

Yakima In-River Release

For the second year, we systematically collected a portion of the kelts that would have been suitable for reconditioning, PIT-tagged them, and then released them immediately back to the Yakima River to monitor the rate of natural respawning. These baseline data will provide an opportunity to compare Hockersmith et. al. (1995) reported respawner rates inferred from steelhead scale pattern analysis from the Yakima River.

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[2] Final Rule 3/25/99: 64 FR 14517-14528.

No-term Study

This year we continued to directly transport steelhead kelts around the hydro system to evaluate the effect on iteroparity rates. Given the high mortality rates of emigrating kelts observed during radio telemetry experiments in the Snake River (Evans et al. 2001; Evans 2002; Hatch et al, in prep), iteroparity may simply be augmented by transporting kelts around the hydro system, thereby increasing the number of kelts that successfully have access to the marine environment.

The purpose for this objective is to evaluate the lowest cost alternative aimed at increasing steelhead iteroparity. Prior to an implementation of a large-scale kelt steelhead transportation program, it is important to evaluate whether these fish migrate through the estuary and recondition in the ocean or if they maintain residence in the estuary, which could impact salmonid smolts. It is also important to assess whether transportation impacts the homing ability of these fish. To address this unknown, all steelhead kelts were PIT-tagged with a portion of them receiving hydro-acoustic tags. This technology will provide us with the necessary information regarding fish survival, movement, distribution, travel time, velocity, residence time in the estuary, and return rates.

Short-Term Reconditioning Study

Successful expression of iteroparity in steelhead may be limited by post-spawning starvation and downstream passage through the mainstem corridor. Thus, short-term reconditioning may augment iteroparity rates by initiating the feeding response and then allowing kelts to naturally undergo gonadal recrudescence in the estuary and marine environments. Short-term reconditioning is defined as the period of time needed (approx. 3-5 weeks or up to 3 months) for kelts to initiate post-spawn feeding, followed by the transportation of kelts around mainstem hydroelectric facilities for release, natural reconditioning, and rematuration in the Pacific Ocean. Since short-term reconditioned fish were also transported and released below Bonneville Dam, PIT-tag and hydro-

acoustic tags were used to assess fish survival, movement, distribution, travel time, velocity, as well as residence time in the estuary.

Comparison of No-term Release and Short-term Reconditioning Using Biotelemetry and Blood Indicators

Biotelemetry

The success of kelt reconditioning should be assessed based on the number of individuals that successfully spawn in the wild following reconditioning and release. Although it is difficult to witness individual fish spawning in the wild, and even more difficult to assess the viability and quality of gametes, we have designed future experiments to determine if reconditioned kelts contribute to subsequent generations.

Data collected by Foster and Schom (1989) provided evidence that the ability to home in Atlantic salmon kelts is imprinted during the fish's juvenile life stage and that reconditioning does not alter homing instincts. Based on the data collected by Foster and Schom (1989) we believe that reconditioning should have no deleterious effects on outward migration as well. Because the kelts collected at Prosser Dam are wild fish that could have originated in any of several upstream areas, we cannot know locations of specific spawning grounds for specific individuals. However, use of acoustic telemetry technology and Passive Integrated Transponder (PIT) tags can help address such critical uncertainties.

Comparisons of the No-term release and short-term reconditioning experiments will be made using acoustic telemetry data as a means to quantify any differences that may be present from the two experimental groups.

Blood Indicators

Observations of unusual kelt steelhead migration behavior in the lower Columbia River provided the motivation for this task. In 2005, some kelt steelhead with acoustic transmitters were detected in the lower Columbia River near the upper extent of the estuary migrating in an oscillating pattern. That is the fish would be detected moving downstream and then hours to a few days later the same fish would be heard moving

upstream. These patterns contrasted with other observations where individuals were heard moving downstream in a linear fashion directly from detection array to detection array. We speculated that gill Na^+, K^+-ATPase activity level and / or plasma thyroxin concentration (T4) could be useful predictors of lower river migration patterns and ultimately of kelt steelhead survival. Farther we speculated that if migration behavior correlated with gill Na^+, K^+-ATPase activity level and / or T4 concentration, in the future individuals could be selected for treatments that may maximize returns based on endocrine measures.

Long-term Reconditioning Study

We have defined long-term reconditioning as holding and feeding post-spawn steelhead until approximately the end of the calendar year and then release them at Prosser Hatchery, thus allowing them to mingle with the upstream run.   By this time most surviving fish have rematured.   Based on the past four years' results, steelhead long-term reconditioning appears very promising. During 2006, we continued with the most efficient and successful of the long-term steelhead reconditioning regimes by repeating the most successful diet and treatment identified during the 2001 and 2002 studies (krill and Moore-Clark pellets) (Hatch et al. 2001 and Hatch et al. 2002).   Long-term reconditioned steelhead kelt were released on October 17, 2006. Results from the 2005 long-term release are included in this years report.

Management Recommendations

Major goals of this research project are to: 1) evaluate the ability of various tested scenarios to enhance wild steelhead iteroparity (e.g. short- and long-term reconditioning, kelt transportation around the hydrosystem); 2) to perform cost analysis on resulting project data; and 3) provide preliminary management recommendations concerning implementation of tested treatments.

Gamete and Progeny Success

Long-term reconditioning and subsequent captive spawning will provide valuable new quantitative data on endocrine function and gonadal processes of steelhead rematuration.   Data resulting from this research will greatly contribute to the evaluation of reconditioning. This experiment involves a replicated, controlled experimental design to assess and compare egg and progeny viability of reconditioned vs. first time spawners.   In 2006, we studied Skamania stock steelhead collected from the Hood River.

Tasks and Objectives

Area and Facilities

Kelt reconditioning research was conducted at the Prosser Fish Hatchery in Prosser, Washington. Prosser Hatchery is located on the Yakima River at river kilometer (Rkm) 75.6, downstream from Prosser Dam, and adjacent to the Chandler Juvenile Monitoring Facility (CJMF) (Figure 1). The Yakima River is approximately 344 km in length and enters the Columbia River at Rkm 539. Summer steelhead populations primarily spawn upstream from Prosser Dam in Satus Creek, Toppenish Creek, Naches River, and other tributaries of the Yakima River (TRP 1995). The Yakama Nation (YN) operates Prosser Hatchery, with a primary function of rearing, acclimation, and release of fall chinook salmon *O. tshawytscha*. The facility is also used for coho salmon *O. kisutch* rearing prior to acclimation and release in the upper Yakima River Basin.
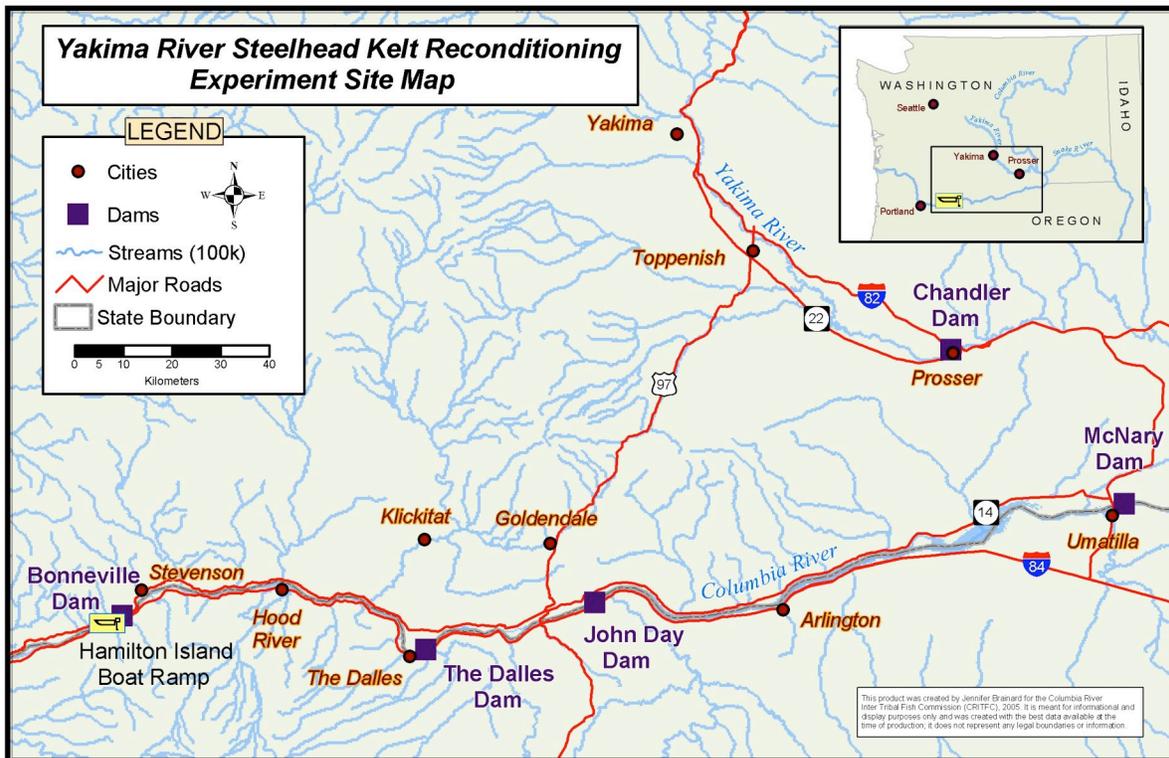
Figure 1: Reconditioning Site (Prosser, WA) and Release Site (Hamilton Is. Boat Ramp) for No-term and Short-term reconditioning experiments.

Kelt Collection and In-Processing

After spawning naturally in tributaries of the Yakima River, a portion of the steelhead kelts that encounter the Prosser Dam facility during emigration are diverted into an irrigation channel that directly connects to the Chandler Juvenile Monitoring Facility (CJMF). The CJMF diverts migratory fishes away from the irrigation canal to reduce mortality associated with agriculture. Once diverted into the CJMF, emigrating kelts can be manually collected from a fish separation device (a device which allows smaller juvenile salmonids to "fall through" for processing in the juvenile facility while larger fish can be dipnetted off the separator for processing or released back to the river). Yakama Nation (YN) staff monitored the Chandler bypass separator 24 hours a day from March 7 to June 8, 2006. All adult steelhead arriving at the CJMF separator, regardless of maturation status (kelt or pre-spawn[3]), were dipnetted off the separator and placed into a water-lubricated PVC pipe slide that was directly connected to a

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[3] The term pre-spawner refers to a sexually mature fish that has yet to spawn.

temporary holding tank 20' (l) x 6' (w) x 4'(h) containing oxygenated well water (57^{0}F or 13.8^{0}C).

Out-migrating steelhead kelt specimens were identified (Evans and Beaty 2001) then transferred with a dipnet from the temporary holding tank to a nearby 190-L sampling tank containing fresh river water, and anesthetized in a buffered solution of tricaine methanesulfonate (MS-222) at 60 ppm.

All specimens visually determined to be prespawn individuals were immediately returned to the Yakima River. Following kelt identification, we collected data on weight (collected in pounds but converted to kg for this report), condition (good- lack of any wounds or descaling, fair- lack of any major wounds and/or descaling, poor- major wounds and/or descaling), coloration (bright, medium, dark), and presence or absence of physical anomalies (e.g., head burn, eye damage). Passive Integrated Transponder (PIT) tags (if not already present) were then implanted in the fish's abdominal cavity for later identification. Every fifth steelhead kelt was released back in river to establish a natural repeat spawner rate. The remaining steelhead kelts deemed to be in "good" condition were retained for reconditioning while steelhead kelts found to be in "poor" condition and dark in color were released back to the river.

Reconditioning Tanks

Upon admission of kelts to the reconditioning program at Prosser Hatchery, all kelts were retained in one of four 20'(d) x 4'(h) circular tanks. Individual tank carrying capacity was set at a maximum of 200 fish based on the aquaculture experience of YN hatchery staff, and the project goal of maximizing kelt survival in captivity. Formalin was administered five times weekly at 1:6,000 for 1 hour in all reconditioning tanks to prevent fungal outbreaks.

In kelt reconditioning tanks, severe infestation of parasites can be lethal to cultured fishes; steelhead may be especially susceptible to *Salmincola* in such environments. *Salmincola* is a genus of parasitic copepod that can inhibit oxygen uptake and gas

exchange at the gill lamellae/water surface interface by attachment to the lamellae. Recent research by Johnson and Heindel (2000), suggested that Ivermectin[TM] – a treatment often used to control parasites in swine and cattle – increases the survivorship of cultured fish by killing the adult morph of the parasite. Due to its successful use in treating *Salminicola* in this project's kelt reconditioning experiments during 2000 (Evans and Beaty 2000), Ivermectin[TM] was diluted with saline (1:30) and injected into the posterior end of the fish's esophagus using a small (1cc) plastic syringe. Steelhead kelts deemed to be quality candidates for reconditioning received a one-time subcutaneous injection of Oxytetracycline. Success was assessed based on increased survival and increases in weight gain.

Kelt Mortality

The following data were collected on all kelts that died during the reconditioning process at Prosser Hatchery. On discovery of a mortality, fish were first subjected to an external examination by hatchery personnel to record the suspected time of death, general condition (good, fair, poor), fish color (bright, intermediate, dark), color of the gill arches (red, pink, white), size of the abdomen (fat, thin), presence of any scars or obvious lesions, and any other anomalies. Once the external exam was completed, an internal examination was conducted to record color of muscle tissue (red, pink, white), type of gonads (ovaries, testes), size of gametes (small, large), and presence of any internal anomalies. PIT tags, acoustic tags and radio tags were also removed from mortalities and identification numbers were entered into a computer database along with the growth measurement data. We attempted to reuse viable tags whenever possible.

Maturation Assessment and Release for Spawning

Steelhead kelts from the No-term release and short-term experiments were weighed at initial capture and prior to release respectively on April 24 and May 15 for No-term release with May 15 and June 27, 2006 for short-term reconditioning, to ascertain if they were feeding. Based on weight change during captivity, we classified surviving specimens as either feeders or non-feeders. Fish in the long-term experiment will be released mid October 2006 to coincide with natural spawn timing. Upon release all

surviving steelhead in the long-term experiment were examined with ultrasound equipment (Evans *et al*. 2001) to assess maturation status. Growth measurement data and rematuration status were also recorded on all released individuals. Overall success of the reconditioning process was based on the proportion of fish that survived the reconditioning process and specifically for the long-term experiment the number of fish that successfully rematured (based on ultrasound examinations).

Objectives

In order to evaluate the feasibility of kelt reconditioning as a potential recovery and restoration strategy for wild steelhead in the Columbia River basin, this project was designed to satisfy the following research objectives:

Objective 1: Evaluate hydrosystem effects or status quo on iteroparity using in-river release.

Objective 2: Evaluate effects of directly transporting steelhead kelts around the hydro system on enhancement of iteroparity.

Objective 3: Evaluate effects of short-term kelt reconditioning and subsequent transportation of kelts around the hydro system on enhancement of iteroparity.

Objective 4: Evaluate effects of long-term kelt reconditioning and subsequent release for natural spawning on enhancement of iteroparity.

Objective 5: Evaluate effects of long-term kelt reconditioning and captive spawning on: a) gamete and progeny viability; and b) enhancement of iteroparity.

Objective 6. Comprehensive project evaluation and management recommendations.

Yakima In-River Release

Objective 1: Evaluate hydrosystem effects or status quo on iteroparity using in-river release.

Capture, Mark, and Release

Yakima in-river release were kelts captured at the CJMF, PIT-tagged, and then immediately released back into the Yakima River. In-river release specimens were selected to correspond with the run timing by systematically sampling every fifth fish that was collected at the CJMF from 3/29- 5/2/2006.

No-Term Release

Objective 2: Evaluate effects of directly transporting steelhead kelts around the hydro system on enhancement of iteroparity.

Treatment

No-term release steelhead kelts were held for 1 week or less. All No-term kelts received oxytetracycline to boost immune system response after the initial stress of capture and captivity. The following design employed two separate releases:

Release 1 = Steelhead kelts were collected on the April 21, 2006 and released on April 24, 2006.

Release 2= Steelhead kelts were collected on the May 12-13, 2006 and released on May 13, 2006.

Truck Transport

All No-term kelts were transported then released at the Hamilton Island Boat Ramp, below Bonneville Dam. We expect fish to return from this study in 2006 and also 2007.

Biotelemetry

Acoustic Telemetry

Some No-term kelts had acoustic tags surgically implanted in their abdomen. A licensed veterinarian performed surgeries so that adverse effects associated with handling and surgery would be minimized and that steelhead kelts would have a high tag retention rate. Each acoustic tag has a unique acoustic bandwidth pulse that provides individual identification codes. After release, the migration to the Pacific Ocean was tracked using acoustic telemetry arrays that spanned sections of the Columbia River and estuary below Bonneville Dam (Appendix A). The complete array was up and running from mid- April and anticipated to be deployed to December of 2006. This year's array placement remained fixed and was based on the success of last year's detection system nonetheless; we continued to suffer receiver loss due either to incremental weather, boater collision, or the likely cause vandalism.

PIT Tags

Kelt movement, timing, and survival can be assessed with Passive Integrated Transponder tags (PIT-tags), as the fish move through the hydropower system in the Yakima and Columbia rivers. When caught in the CJMF, all fish used in the No-term study receive a PIT tag in the abdominal cavity. Each tag is unique and identifies an individual fish. Automatic adult PIT detectors are present in all ladders at Bonneville, McNary, and Prosser Dam. These data can be helpful in telling us how many fish survive as they move from one life stage to the next or from one location to the next.

Short-Term Reconditioning

Objective 3: Evaluate effects of short-term kelt reconditioning and subsequent transportation of kelts around the hydro system on enhancement of iteroparity.

Feeding and Treatment

Short-term reconditioned kelts were fed a diet of krill for the duration (3-5 weeks) of their captivity. All short-term kelts were medically treated with oxytetracycline and formalin to improve fish health during captivity. The following design, employing two separate releases was used:

Release 1 = Steelhead kelts were collected on April 11, 2006 and released on May 15, 2006.

Release 2= Steelhead kelts were collected on May 11 and May 16, 2006 and released June 27, 2006.

Truck Transport

All short-term reconditioned kelts were transported then released at the Hamilton Island Boat Ramp, below Bonneville Dam. We expect fish to return from this study in 2006 and also 2007.

Biotelemetry

Acoustic Telemetry

A portion of the short-term reconditioned kelts had acoustic tags surgically implanted in their abdomen. A licensed veterinarian performed surgeries so that adverse effects associated with handling and surgery would be minimized and that steelhead kelts would have a high tag retention rate. Each acoustic tag has a unique acoustic bandwidth pulse that provides individual identification codes. After release, the migration to the Pacific Ocean was tracked using acoustic telemetry arrays that spanned sections of the Columbia River and estuary below Bonneville Dam (Appendix A).

PIT Tags

Kelt movement, timing, and survival can be assessed with Passive Integrated Transponder tags (PIT-tags), as the fish move through the hydropower system in the Yakima and Columbia rivers. When caught in the CJMF, all fish used in the various treatments receive a PIT tag in the abdominal cavity. Each tag is unique and identifies individual fish. Automatic adult PIT detectors are present in all ladders at Bonneville, McNary Dams, and have been recently installed on all fish ladders at the Prosser Dam on the Yakima River. These data can be helpful in telling us how many fish survive as they move from one life stage to the next or from one location to the next.

Comparison of No-term and Short-term Reconditioning Using Biotelemetry and Blood Indicators

Acoustic Telemetry

Using acoustic telemetry data we compared No-term and short-term reconditioning experiments to determine if there are any effects on migrational patterns due to reconditioning. All steelhead kelts from the No-term and Short-term reconditioning experiments were surgically implanted with a coded Vemco© V16-4H transmitter (length 65 mm, weight in water 10g which constitutes on average less than 1% of the fishes total body weight). We correlated run timing to tidal oscillations to determine if there were any differences between the release groups and to also determine the type of behavior that these fish were exhibiting as they traveled downstream. Secondly, we directly compared run times and survival probability (Appendix B) between the two experimental groups to determine any migrational differences between the two release groups.

Blood Indicators

In 2006 we began to collect baseline data to determine if we could devise a quantitative measure for determining readiness to kelt. We used two typically used indicators in smolts ATPase and Thyroxine (T4):

ATPase

Samples were collected for the control group (no-term 2; sampled May 15, 2006) and the experimental group (short-term reconditioning group 1; sampled May 15, 2006 & 2; June 28, 2006) shortly after out-processing (biological data and acoustic tagging). Collection of .2- .5 grams of gill tissue was taken from the front gill arch. Samples were placed in a homogenizing medium SEI buffer (Zaugg 1982) and then stored at -80°C until analysis. The ATPase analysis method is a whole homogenate assay described in Johnson et al 1977.

Thyroxine (T4)

Samples were collected shortly after the collection of ATPase samples and were collected for all release groups; control release 1 and 2; sampled April 15, 2006 and May 15, 2006 and the experimental release 1 and 2; sampled May 15, 2006 & 2; June 28, 2006. Using 1.5 ml vacutainer © (EDTA) blood serum sampling kit we collected roughly 1 ml of blood from an artery at the base of the caudal peduncle. After the collection of samples they were stored on ice for centrifuge at the lab. Samples were centrifuged at 10,000 g for 5 minutes and then were stored at –80°C until analysis.

At the lab the thyroxine analysis method was a modification of the Jaklitsch et al. 1976, method. The major modification was the replacement of peroxidase with alkaline phosphatase and the use of nitrophenylphosphate as a substrate.

Long-Term Reconditioning

Objective 4: Evaluate effects of long-term kelt reconditioning and subsequent release for natural spawning on enhancement of iteroparity.

Feeding and Treatment

2005

The long-term reconditioned fish were initially fed freeze-dried krill for 2.5 months then were fed Moore-Clarke pellets until they were released.

Release 1 = Fish were collected from March 15 to May 25, 2005 and were reconditioned to release on December 12, 2005.

2006

The long-term reconditioned fish were initially fed freeze-dried krill for 2.5 months and are currently being fed unaltered Moore-Clarke pellets.

Release 1 = Fish were collected from March 7 to June 8, 2006 and are slated to be reconditioned for release on October 18, 2006. We changed the long-term reconditioning release date based on our preliminary data from our Reproductive Success Study (BPA project # 200306200) and review of scientific literature suggests that food availability and environmental cues experienced in the fall/winter could be important factors in contributing to spawning readiness and success. Long-term kelts were released nearly 2 months later in an attempt to sync the long-term reconditioned fish with returning first time spawners in the Yakima River.

Truck Transport

All long-term reconditioned kelts will be transported then released at the Mabton Boat Ramp (Yakima Rkm 96.3). We expect fish to migrate to the spawning grounds during the 2006-2007 spawning migration.

Biotelemetry

Radio Telemetry 2005

In order to continue to investigate in-season homing, migration patterns, and spawning ground selection of long-term reconditioning experiment 10 steelhead kelts were radio tagged using the gastric insertion technique. Any data that we collect will be used to compare against previous years' monitoring efforts. Tags for in-season homing were programmed to last a minimum of 30 days and will be placed using the gastric insertion technique. This group was released along with the other long-term reconditioned kelts at the Mabton boat launch near Prosser Hatchery in December 2005. These fish were tracked using fixed and mobile tracking systems in conjunction with telemetry work currently being conducted on coho salmon.

Fixed receiver sites are located at Prosser Dam (Rkm 75.6), Slagg Ranch (Rkm 106.2), Sunnyside Dam (Rkm 167.0), Roza Dam (Rkm 205.8), Naches River (Cowiche Dam Rkm 5.8), Toppenish Creek (Rkm 71.1), and Simcoe Creek (Rkm 13.0). Mobile tracking will be done by road and by raft. Mobile tracking allows for actual pinpoint

locations and observations of steelhead kelt redd construction and spawning. The mobile and fixed radio-tracking receivers made by Lotek Inc. and National Marine Fisheries Service (NMFS) were last used in 2005-06. We will primarily rely upon upstream movement and visual observations as indicators of live fish. Tags will be recovered from dead fish whenever possible

PIT Tags

Kelt movement, timing, and survival can be assessed with Passive Integrated Transponder tags (PIT-tags), as the fish move through the hydropower system in the Yakima and Columbia rivers. When caught in the CJMF, all fish used in the various treatments receive a PIT tag in the abdominal cavity. Each tag is unique and identifies individual fish. Automatic adult PIT detectors are present in all ladders at Bonneville, McNary Dams, and have been recently installed on all fish ladders at the Prosser Dam on the Yakima River. These data can be helpful in telling us how many fish survive as they move from one life stage to the next or from one location to the next.

Gamete and Progeny Success

Objective 5: Evaluate effects of long-term kelt reconditioning and captive spawning on: a) gamete and progeny viability; and b) enhancement of iteroparity.

Gamete Viability

Due to unforeseen difficulties capturing first-time spawners at Satus Creek the decision was made to find an alternate location. Our first choice was to collect fish from a subbasin of the Snake River, but due to logistical difficulties an alternate location was needed. Ultimately, we decided on the Parkdale Fish Hatchery on the Hood River, due to the short distance between the trap and the rearing facility and the deft abilities of the staff at both sites. Fish captured for this experiment were trapped from February 22, 2004 to March 11, 2004. Fish were then truck transported to the Parkdale Fish Facility to be held until they ripened for air spawning. Male gametes were collected manually first then frozen and stored cryogenically; afterwards female gametes were collected using the air-spawning technique (Leitritz and Lewis 1980) and mixed with cryogenically

thawed milt. Eggs were then held until certification was made that eyed eggs were disease free and could be shipped across state lines. Eyed eggs were then transported to the University of Idaho Aquaculture Research Institute for gamete and progeny analysis.

Specifically, the following parameters and variables were measured to assess and compare egg viability.

1) Proportion of eggs within lots that reach 2-cell/4-cell stages (percent fertilization)
2) Proportion of eggs within lots that successfully complete early development
3) Proportion of eggs within lots that hatch
4) Egg diameter may also be measured and compared between virgin (first time) spawners.

Progeny Viability

The following parameters and variables will be measured to assess and compare juvenile fish viability from the same experimental spawnings from the above gamete viability study:

1) Percent survival of various early life stages
2) Growth, length, weight, and condition factor measurements

Management Recommendations

With this report marks the completion of the third year of this study. This project has been recommended for funding by the NPCC for the next three years. This additional time will allow for the return of reconditioned fish to the spawning grounds, which is the ultimate measure of success. In this report, we present a framework for analysis of kelt management strategies. These analyses will include biological metrics as well as a cost analysis.

Objective 6. Comprehensive project evaluation and management recommendations.

This aspect of the study is designed to evaluate project data with appropriate parametric and/or non-parametric tests, depending on the nature of resulting empirical data distributions. This project essentially imposes treatment structure on an otherwise observational study, to provide rigorous comparisons between and among In-river release, No-term, short, and long-term kelt reconditioning.

RESULTS/DISCUSSION

General Population Characteristics

A total of 520 kelts were captured with 348 kelts retained for reconditioning, 53 were used in the Yakima in-river release, 51 for the No-term release, 31 culled due to poor condition, 37 found to be dead on arrival, at Prosser Hatchery from March 7 to June 8, 2006. Collection generally followed migrational waves with the peak collection day occurring around April 21 (Figure 2). The total number of kelts used for reconditioning represented 17.3% (348 of 2,002) of the entire Yakima River ESA-listed population, based on fish ladder counts obtained from Prosser Dam for the period July 1, 2005 to June 30, 2006. It was likely that many of the out-migrating kelts from the Yakima River were never diverted into the irrigation channel and passing over the spillway, due to especially high flows during collection time which shut down the facility a few times due to debris jams.

The overwhelming majority of kelts captured were female (Table 1) which is a consistent finding in previous steelhead kelt reconditioning work. This may be indicative of the evolutionary advantage of female iteroparity. Based on visual observations, 479 (92.1%) of the kelts were classified as female, whereas only 41 (7.9 %) as male in 2006.
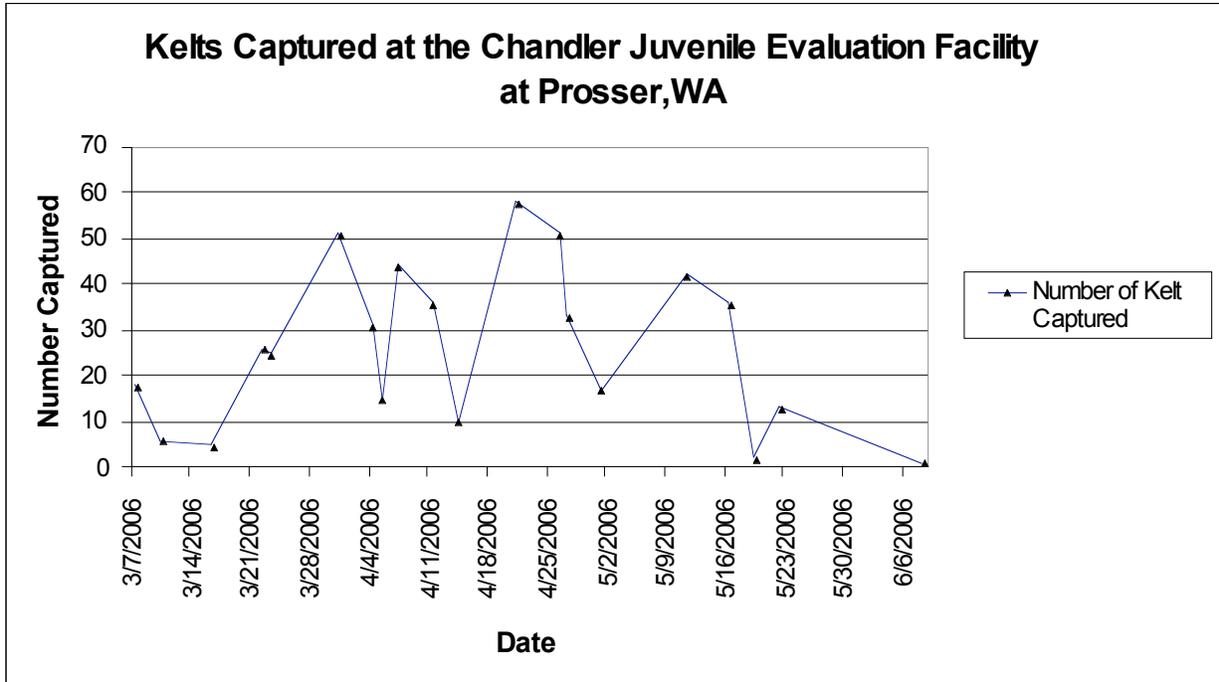
Figure 2. Kelt collection dates and numbers of fish removed from Chandler bypass facility involved in reconditioning procedures at Prosser Hatchery during 2006.

Naturally occurring female iteroparity essentially is analogous as cryopreservation of males is in other ESA listed salmon populations within the Columbia River Basin. In addition, since females are naturally able to reproduce in different years, this should increase the probability of gene flow between and among cohorts or year classes. This has a direct theoretical benefit in the form of increasing the number of breeders (N_b), and the effective population size (N_e) during each spawning season, thus contributing to increased population viability and persistence, crucial to threatened and endangered fish restoration. Rather than a genetic hazard, experimental reconditioning should be viewed as a potential demographic and population genetic enhancement measure, aimed at restoring a recently jeopardized, but naturally occurring evolutionarily stable life history strategy.

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Table 1. Sex of Adult Steelhead Kelts Captured and	
Processed at Chandler Juvenile Evaluation Facility 2006.	
Sex	No Captured (% of total Capture)
Male	41 (7.9%)
Female	479 (92.1%)
Total	520

The majority of kelts collected for reconditioning during 2006 were considered in good or fair overall condition. In terms of gross morphological and physiological condition at the time of capture, 156 (30.0%) kelts were classified as good, 312 (60.0%) as fair and 54 (10.3%) as poor. Regarding fish coloration, we classified 152 (29.2%) as bright, 335 (64.4%) as intermediate, and 35 (6.7%) as dark.   This data will be updated in the 2007 report to reflect the state of long-term reconditioned fish released in October of 2006.

Yakima In-River Release

Objective 1: Evaluate hydrosystem effects or status quo on iteroparity using in-river release.

Kelt Capture and Survival to Release

Yakima in-river release kelts were captured from March 29, 2006 to May 2, 2006 (Table 2). We assumed that we had high survivorship in this group due to little handling and immediate release to the hydrosystem. We observed no direct mortalities from this particular aspect of the study.

Table 2: Population statistics for kelts from the Yakima in-river release	
No. Collected	53
Mean Capture and Release-Weight (kg.)	1.9

Treatment Summary

The main objective for the Yakima in-river release group was to monitor and determine natural iteroparity rates for the Yakima River and compare those with iteroparity rates from our other experiments. A total of 53 steelhead kelts were captured, assessed, PIT-tagged and then released back to the Yakima River to attempt their seaward migration.

Biotelemetry

2005 PIT-Tag
There was one individual that was detected outmigrating in May of 2005 at McNary Dam with no subsequent downstream detection. There were a total of 3 distinct individuals detected at Bonneville in this group that attempted to return in late 2005 (August- October) of these individuals, two were detected making it past the Prosser Dam (October-December).

2006 PIT-Tag
As of October of 2006 there was one outmigrating kelt detected in mid April at McNary Dam. We anticipated seeing similar returns as the previous year in 2006, but have yet to see any PIT-tagged individuals attempting to return this year.

No-term Release

Objective 2: Implement and evaluate No-term release downstream from Bonneville Dam.

This objective was to determine if No-term is an effective method for increasing iteroparity in steelhead kelts. The other goal of this treatment was to keep it cost effective. Since fish were held for such a short time period it was determined that feed was not necessary. After initial capture steelhead kelts were given an initial shot of oxytetracycline to boost immune system response associated with capture and handling stress.

Kelt Capture and Survival to Release

The No-term control experiment continued with two treatment groups to assess temporal effects in 2006. One group was collected on April 18 and released on April 24, while the second group was collected on May 12-13 and released on May 15 (Table 3).

Table 3: Population statistics for kelts in the No-term control experiment.		
Release Date	Released 4/24/06	Released 5/15/06
No. Released	28	21
No. Implanted with acoustic tags	28	21
Mean Release Weight (kg.)	2.0	2.0

Mortality Statistics

All known mortalities for the No-term experiment occurred shortly after capture, fish processing, and subsequent surgery. Specific sources would be difficult to discern since all sampling and tagging procedures occurred on the same day. We had 2 mortalities from the first release (2 mortalities /30 total fish tagged = 6%). The second release had 3 mortalities (1 mortalities/ 21 total fish tagged = 4 % mortality). These individuals likely expired due to elevated stress levels. Overall, mortalities for this group were slightly higher than last year, it should still be noted though that a high survival rate of the No-term steelhead kelts may be misleading due to potential mortality after release.

Biotelemetry

Acoustic Telemetry

<u>Detection</u>
Acoustic tagged steelhead kelts from the No-term control experiment were released on April 24 and May 15, 2006 below Bonneville Dam (Rkm 233). Telemetry arrays were deployed at essentially three locations in the lower Columbia River, the Mouth of the Columbia (Rkm 5), around the Upper Estuary area (Rkm 43), and St. Helens (Rkm 138) (See Appendix A). The first release had a total of 28 and the second release had 21 steelhead kelts tagged, of these releases, 18 (64%) of release 1 and 13 (62%) of

release 2 were detected entering the upper estuary at either the Welch Island or Pillar Rock telemetry array (Table 4). The first release travel time averaged nearly 5 days (Table 4) whereas the second group averaged less than 4 days to the estuary (Table 5). Estuary residence for both release groups averaged less than 5 hours based on first and last detections. We detected 18 kelts (64% of total tagged) of the first release and 13 kelts (62 %) from the second release detected at the Mouth of the Columbia River arrays. On average it took kelts less than 5 days to migrate completely to the ocean (Table 5).

Table 4: Detection statistics of no-term group 1							
St Helens Detection		Time to St. Helens	Time to Estuary From Release	Time to Ocean From Release	Avg. km/hr from Hamilton Is. To St. Helens	Avg. km/hr from Hamilton Is. to Estuary	Avg. km/hr from Hamilton Is. to Ocean
23	River Only Detected Avg (hr: min: sec)	84:49:17	NA	NA	1.64	NA	NA
Estuary Detection 18	Estuary Only Detected Avg (hr: min: sec)	73:07:15	130:21:51	NA	1.89	1.06	NA
Ocean Detection 18	Ocean Detected Avg (hr: min: sec)	73:29:29	117:52:42	147:41:50	1.30	1.62	1.55

Table 5: Detection statistics of no-term group 2							
St Helens Detection		Time to St. Helens	Time to Estuary From Release	Time to Ocean From Release	Avg. km/hr from Hamilton Is. To St. Helens	Avg. km/hr from Bonneville to Estuary	Avg. km/hr from Hamilton Is. to Ocean
18	River Only Detected Avg (hr: min: sec)	76:52:00	NA	NA	1.25	NA	NA
Estuary Detection 13	Estuary Only Detected Avg (hr: min: sec)	73:27:15	107:50:00	NA	1.30	1.77	NA
Ocean Detection 13	Ocean Detected Avg (hr: min: sec)	61:26:54	93:14:37	108:46:42	1.55	2.04	2.11

Survival Probability

Utilizing a maximum likelihood indicator to determine survival at each array system, for the no-term individuals in 2006 suggested that steelhead kelts performed exceedingly well navigating the lower Columbia River to the Ocean with little mortality incurred during the outmigration (Table 6 and 7). The calculations were based on presence/absence of detection at S1 is equal to the St. Helens array (Rkm), S2 is equal to the upper estuary array (Rkm 43), and lambda which is a combination of the survival percentage and the probability which represents the Columbia River Mouth. It is

possible that some of our fish may not have been detected migrating to the ocean either due to tag loss (encapsulation then expulsion), excessive ambient sonar noise, or may have passed during times when there were holes in the detection system due to lost receivers. Considering all of these sampling pit falls, survival probability theory gives us a sound mathematical tool at determining what the survival probability and the standard deviation. After the lower most array system it was assumed that these individuals proceeded to migrate into the ocean beyond the array's detection range.

Table 6. Survival Probability of No-term Release 1, April 24, 2006

The	logarithm	of the	determinant	of the	hessian =	26.7723		
index	name	value	std dev	1	2	3	4	5
1	S1	0.8605	0.0665	1				
2	S2	0.9486	0.0670	-0.0344	1			
3	p1	0.9545	0.0444	-0.0523	0.0572	1		
4	p2	0.7875	0.0943	0	-0.3023	0	1	
5	lamda	0.8235	0.0924	0	-0.3375	0	0.199	1

Table 7. Survival Probability of No-term Release 2, May 15, 2006

The	logarithm	of the	determinant	of the	hessian =	38.2423		
index	name	value	std dev	1	2	3	4	5
1	S1	0.8571	0.0763	1				
2	S2	0.9388	0.0887	0	1			
3	p1	1	0.0000	-0.0001	0.0001	1		
4	p2	0.7692	0.1168	0	-0.3707	0	1	
5	lamda	0.7692	0.1168	0	-0.3707	0	0.2308	1

PIT-Tag

2004 Release
In 2004 63 no-term fish were PIT-tagged and released on May 3, 2004. We detected 3 of these steelhead kelts at the Bonneville Dam ladder during the later part of 2004. There were 2 additional returns detected in late 2005 at Bonneville of which, one of these was detected successfully migrating back to Prosser Dam. These detections

currently represent 7.9 % of the total released for this experiment, which demonstrated an attempt to return to spawn.

<u>2005 Release</u>
All no-term steelhead kelts were PIT-tagged (n = 96). Currently we have not detected any kelts attempting to return to spawn. We anticipate that we should see some returns in 2007. The lack of returns may be due to fish skipping a year before returning. We will report any findings in the 2007 annual report.

<u>2006 Release</u>
No detections of fish from this release group have been made so far. Any results will be presented in the 2007 annual report.

Short-Term Reconditioning

Objective 1: Implement and evaluate short-term kelt reconditioning, transportation and release downstream from Bonneville Dam.

Kelt Capture and Survival to Release

The short-term reconditioning experiment contained two separate treatment groups to assess temporal effects. These two groups were captured on April 11, 2006 (group 1) and May 11 and May 16, 2006 (group 2) and processed/released on May 15 and June 30, 2006 (Table 8).

Table 8: Population statistics for kelts in the short-term reconditioning experiment.		
Tank	Released 5/15/06	Released 6/30/06
No. Released (% of total captured)	20 (90%)	30 (88%)
No. with acoustic tags	20	30
Mean In-Weight (kg.)	2.01	1.88
Mean Out-Weight (kg.)	2.44	2.00

Mortality Statistics

We had two surgery related mortalities for the first release (2/22) of acoustic-tagged steelhead.   The second acoustic release group had 4 steelhead kelt mortalities associated with surgical implantation (4 mortalities/ 34 total fish tagged). An additional 6

experimental steelhead kelts from group 2 perished in captivity during the short-term reconditioning process, likely from compounded stress. Overall, the mortalities for both release groups was still relatively low, however it should be noted that the high survival rates of short-term reconditioned kelts may be misleading due to the possibility of more mortalities after initial release.

Feeding and Treatment Summary

The main objective for the short-term experiment was to elicit a feeding response from steelhead kelts. It is hypothesized that regaining the feeding response for steelhead kelts will benefit the fish once they are released and have an availability of natural prey. Short-term reconditioned steelhead kelts continued to receive a solitary diet of krill. Many of the short-term kelts lost weight for the duration of this experiment. The first release group had 1 individuals losing weight, 2 with no weight change and the rest gaining weight (Figure 3). Release group 2 gained weight overall (Figure 3).   Studies of ocean going steelhead have revealed that their ocean diet is diverse with such prey as squid, euphausiids, amphipods and various fishes (LeBrasseur 1966) and (Manzer 1968). This aspect of the experiment should help us to determine if a shortened feeding time will boost the survival of kelts to the ocean so that they can effectively obtain nutritiously rich ocean prey.
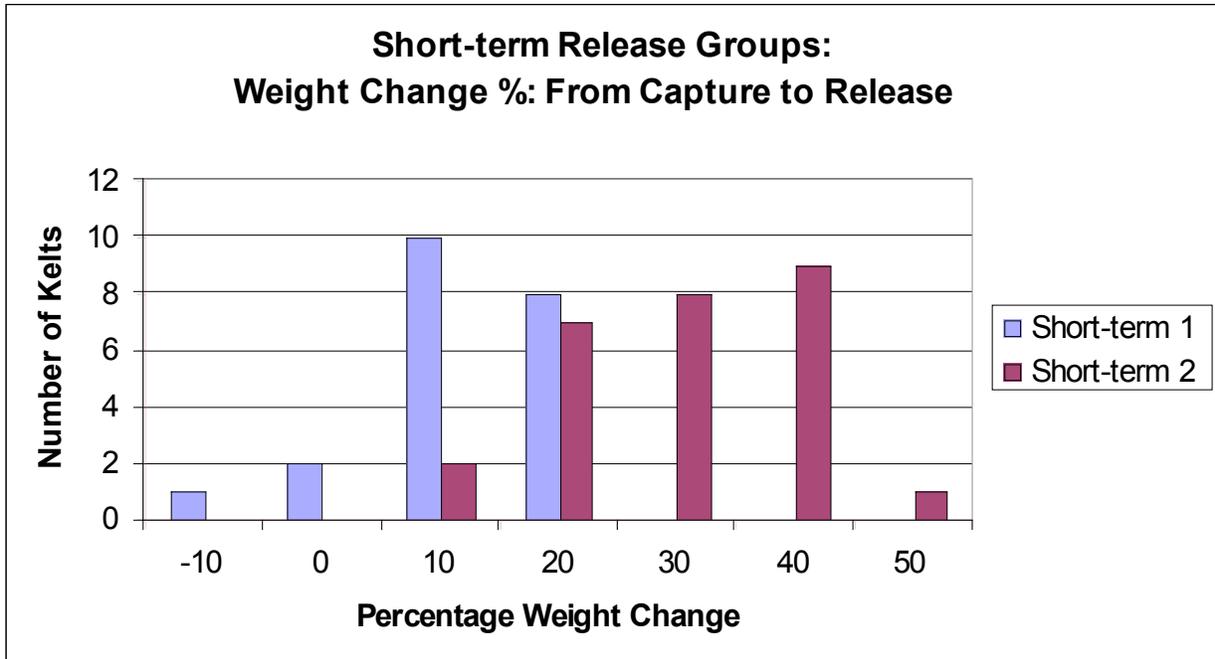
Figure 3: Weight gain distribution (weight gain as a percentage of collection weight) for short-term reconditioned kelts for release group1 and 2 at Prosser Hatchery during 2006.

Biotelemetry

Acoustic Telemetry

A total of 20 short-term reconditioned kelts from the first release and 30 from the second release group received acoustic tags to assess their emigration behavior and timing after release from below Bonneville Dam to the estuary.

Acoustic tagged steelhead kelts from the short-term reconditioning were released on May 15 and June 27, 2006 below Bonneville Dam (Rkm 233) at Hamilton Island. Telemetry arrays were deployed at various locations in the lower Columbia River, from the North and South Jetties (Rkm 0) to St. Helens (Rkm 138) (Appendix A). Release group 1 had good detection rates at St. Helens (17 individuals detected 85%) and they traveled faster (averaged 60 hours) (Table 9) than the no-term group (70 hours) but not as quickly as last year (30 hours). Estuary detection continued to be good for the first release at 16 (80%) at either the Welch Island or Pillar Rock telemetry arrays (Table 9). The first release averaged just less than 5 days (Table 9) to the estuary. Estuary residence for release group 1 averaged less than 11 hours based on first and last

detections. We detected 9 kelts (45% of total tagged) from the first release at the Mouth of the Columbia River arrays.

The second short-term release group faired the best out of all of the kelt releases in 2006 with the best survival and fastest outmigration times recorded (Table 10). There were a total of 27 (80%) steelhead kelts from the second release detected at the St. Helens array and 23 (76%) detected moving out towards the ocean (Table 10). This is a complete reversal from fish that were released around the same time last year. This is likely due to the increased flow and lower temperatures that were present in 2006.

On average it took both short-term released kelt groups less than five days to migrate completely to the ocean (Table 9 & 10).

Table 9: Detection statistics of short-term reconditioned kelts release group 1							
St Helens Detection		Time to St. Helens	Time to Estuary	Time to Ocean From Release	Avg. km/hr from Hamilton Is. To St. Helens	Avg. mi/hr from Bonneville to Estuary	Avg. mi/hr from Bonneville to Ocean
17	River Only Detected Fish Avg (hr: min: sec)	62:04:37	*	*	1.53	*	*
Estuary Detection 16	Estuary Only Detected Fish Avg. (hr: min: sec)	34:22:13	69:42:17	*	2.79	2.75	*
Ocean Detection 9	Ocean Detected Fish Avg. (hr: min: sec)	43:29:00	75:35:10	118:10:55	2.20	2.53	1.93

Table 10: Detection statistics of short-term reconditioned kelts release group 2							
St Helens Detection		Time to St. Helens	Time to Estuary	Time to Ocean From Release	Avg. km/hr from Hamilton Is. To St. Helens	Avg. mi/hr from Bonneville to Estuary	Avg. mi/hr from Bonneville to Ocean
27	River Only Detected Fish Avg (hr: min: sec)	*	*	*	*	*	*
Estuary Detection 24	Estuary Only Detected (hr: min: sec)	36:45:12	62:20:32	*	2.63	3.06	*
Ocean Detection 23	Ocean Detected (hr: min: sec)	32:54:05	60:24:30	83:40:32	2.96	3.16	2.74

Survival Probability

Utilizing a maximum likelihood indicator to determine survival at each array system for short-term individuals in 2006, suggests that both short-term release groups of

steelhead kelts successfully navigated the lower Columbia River to the Ocean with little mortality incurred during the outmigration (Table 11 and 12). The calculations were based on presence/absence of detection at S1 (St. Helens array Rkm 138), S2 (upper estuary array Rkm 43), and lambda which is a combination of the survival percentage and probability (Columbia River Mouth Rkm 5). The first release did well, although S2 did not perform as well as the other releases it still was good survival rate (Table 11 and 12). It is possible that some of our fish may not have been detected migrating to the ocean either due to tag loss (encapsulation then expulsion), excessive ambient sonar noise, or may have passed during times when there were holes in the detection system due to lost receivers. Considering all of these sampling pit falls, survival probability theory gives us a sound mathematical tool at determining what the survival probability and the standard deviation. After the lower most array system it was assumed that these individuals proceeded to migrate into the ocean beyond the array's detection range.

Table 11. Survival Probability of Short-term Release 1, May 15, 2006								
The	logarithm	of the	determinant	of the	hessian =	22.3624		
index	name	value	std dev	1	2	3	4	5
1	S1	0.9350	0.0794	1				
2	S2	0.6188	0.1294	-0.2107	1			
3	p1	0.9091	0.0867	-0.4621	0.1877	1		
4	p2	0.7778	0.1386	0	-0.1893	0	1	
5	lamda	0.7778	0.1386	0	-0.1893	0	0.2222	1

Table 12. Survival Probability of Short-term Release 2, June 27, 2006								
The	logarithm	of the	determinant	of the	hessian =	57.5634		
index	name	value	std dev	1	2	3	4	5
1	S1	0.9000	0.0548	1				
2	S2	1.0000	0.0000	0	1			
3	p1	1.0000	0.0000	0	0	1		
4	p2	0.8889	0.0605	0	0	0	1	
5	lamda	0.8519	0.0684	0	0	0	0	1

PIT-tag

<u>2004 Release</u>
All short-term steelhead kelts were PIT-tagged for a total of 83 short-term reconditioned individuals receiving tags. There were 3 kelts in 2004, and an additional 2 in 2005, which were detected by the PIT-tag detectors at Bonneville Dam. There were no detections of short-term steelhead kelts from this release year detected in 2006. These individuals represent 6.0 % of the total released. This group has done well making it back to Prosser with 4 individuals returning. It is unlikely that there will be any additional returns from this group but if there are any additional returns they will be reported in next years report.

<u>2005 Release</u>
A total of 96 steelhead kelts were PIT-tagged. Presently we have not detected any returns for this group. The lack of returns may be the result of a skip migration year and if so should see returns in 2007. Additional results will be published in the 2007 annual report.

<u>2006 Release</u>
There have been no returns this year for the 50 kelts that were PIT-tagged. Any detection will be presented in the 2007 annual report.

Comparison of No-term and Short-term Reconditioning Using Biotelemetry And Blood Indicators

Biotelemetry
Based on our analysis the two experimental groups differed little in percentage of fish detected although there was a small difference in run timing (Table 13). We will continue to monitor for all of these individuals at our telemetry arrays and with PITTAGIS.

Table 13. Comparison of Steelhead kelts detected (%) and migrational timing from No-term and short-term reconditioning			
No-term/Release	Migrational Times	Short-term Reconditioned	Migrational Times
St Helens Detection 83%	Time to St. Helens (hr: min: sec) 62:17:34	St Helens Detection 88%	Time to St. Helens (hr: min: sec) 35:47:18
Estuary Detection 63%	Time to Estuary (hr: min: sec) 86:51:59	Estuary Detection 66%	Time to Estuary (hr: min: sec) 62:10:31
Ocean Detection 63%	Time to Ocean From Release (hr: min: sec) 106:28:32	Ocean Detection 64%	Time to Ocean From Release (hr: min: sec) 138:25:39

Combined Survival Probability

Survival for the two release groups migrating through the lower river was extremely high this year (Table 14 and 15), which was likely due to the lower water temperatures and high flows that were present in the Spring of 2006 (Appendix B Figure 1 and 2). With such good values we should expect that in conjunction with good ocean conditions for steelhead we can anticipate a good return in 2007-2008.

Table 14. Survival Probability of Combined No-term Release 2006.								
The	logarithm	of the	determinant	of the	hessian =	57.5634		
index	name	value	std dev	1	2	3	4	5
1	S1	0.8594	0.0502	1				
2	S2	0.9440	0.0540	-0.0208	1			
3	p1	0.9737	0.0260	-0.0446	0.0455	1		
4	p2	0.7799	0.0735	0	-0.3319	0	1	
5	lamda	0.8000	0.0730	0	-0.3516	0	0.2131	1

Table 15. Survival Probability of Combined Short-term Release 2006.								
The	logarithm	of the	determinant	of the	hessian =	57.5634		
index	name	value	std dev	1	2	3	4	5
1	S1	0.9038	0.0428	1				
2	S2	0.8655	0.0587	-0.0352	1			
3	p1	0.9737	0.0260	-0.0896	0.0625	1		
4	p2	0.8438	0.0642	0	-0.2038	0	1	
5	lamda	0.8182	0.0671	0	-0.189	0	0.1686	1

Blood Indicators

A total of 99 fish were assayed for T4 and 74 of those same fish were assayed for gill Na$^+$, K$^+$-ATPase activity. Samples of T4 were collected from all fish in the no-term and short-term release experiments and ATPase was collected from the second no-term treatment and both of the short-term treatments.

The assay for T4 has a detection threshold of 0.4 ng/ml, therefore any measurements less than 0.4 were set to 0. From the 94 samples analyzed, T4 levels averaged 0.463 with a standard deviation of 0.412.   Gill Na$^+$, K$^+$-ATPase activity from the 74 samples averaged 2.273 μmoles P$_i$ h^{-1} mg protein^{-1} with a standard deviation of 0.867. Table 16. contains descriptive statistics for Gill Na$^+$, K$^+$-ATPase activity and T4 levels by treatment group.

We compared treatment (no-term and short-term) and fate (last detection in-river, in-estuary, or in-ocean) effects using 2-way analysis of variance (ANOVA) (Sokal and Rohlf 2000). Gill Na$^+$, K$^+$-ATPase activity was significantly higher in the no-term verse the short-term treatment (F=6.938; P=0.011). The effect of fate was nonsignificant (F=1.342; P=0.264) as was the interaction between treatment and fate (F=2.486; P=0.052). T4 concentrations were significantly higher in short-term verse the no-term treatment (F=7.138; P=0.009). The effect of fate was nonsignificant (F=1.704; P=0.156) as was the interaction between treatment of and fate (F=0.960; P=0.434). Concentrations of T4 decreased significantly with time between releases for both treatment groups (no-term and short-term).   For the short-term treatment, T4 concentration decreased significantly (P<0.001) from the first release on May 15, 2006 to the second release on June 27, 2006 with mean measurements of 0.870 and 0.357 ng/ml. For the no-term treatment, T4 concentration decreased significantly (P=0.006) from the first release on April 24, 2006 and the second release on May 15, 2006 with mean measurements of 0.218 and 0.448 ng/ml.

Chinook salmon (*O. tshawytscha*) gill Na$^+$, K$^+$-ATPase activity has been shown to increase as the juvenile fish migrate seaward (Ewing et al. 2001). Gill Na$^+$, K$^+$-ATPase activity in kelt steelhead in this study was significantly higher in the group of fish that were collected and nearly immediately transported and released below Bonneville Dam (no-term) verse the short-term group that were being held and fed for approximately 4 weeks prior to transport and release below Bonneville Dam. Retaining these fish for reconditioning may influence gill Na$^+$, K$^+$-ATPase activity, however, this reduction had no effect on the final fate of individual fish.

The ANOVA results indicated that concentrations of T4 were significantly higher (F=7.138; P=0.009) in the short-term than the no-term treatment groups, however, the effect of fate was nonsignificant (F=1.704; P=0.156). The concentration of T4 measured in kelt steelhead is over 2 orders of magnitude lower than measurements at the smolt stage (Dickhoff et al. 1978; Birks et al. 1985), therefore, we are reluctant to speculate about the importance of T4 in kelt outmigration. Instead we recommend that samples be collected to determine baseline values of T4 in kelt stage steelhead. Such work could lead to establishing the presence of a T4 surge in kelts similar to the classic surge described in smolts (Dickhoff et al. 1978) and ultimately to predictions of saltwater readiness and migration survival.

To better understand the relationship of T4 and gill Na$^+$, K$^+$-ATPase activity in kelt steelhead, we need to collect additional samples to establish a baseline and isolate variables that effect concentrations. In future years we recommend collecting samples from approximately 100 individuals distributed over the kelt migration. This collection would provide input to develop baseline levels of T4 and gill Na$^+$, K$^+$-ATPase activity in post-spawn steelhead. Additionally, we suggest that samples be collected from each treatment and test group in the future to characterize the influence of different variables on these endocrine system measures.

Table 16. Blood chemistry measures from kelt steelhead collected and Prosser Hatchery, Yakima River, in 2006.				
	Short-term Treatment Group		No-term Treatment Group	
	Gill Na$^+$, K$^+$-ATPase activity	T4	Gill Na$^+$, K$^+$-ATPase activity	T4
n	52	49	22	50
minimum	0.680	0.000	0.210	0.000
maximum	3.720	1.610	3.700	0.940
mean	2.117	0.577	2.640	0.351
Standard dev.	0.797	0.479	0.933	0.299

Long-Term Reconditioning

Objective 2: Continue to refine and improve efficiency and success of long-term steelhead reconditioning at the Prosser Hatchery.

Kelt Survival and Rematuration

2005 Long-term Reconditioning
Long-term kelts were held for 6-to-9 months in two different tanks.

Table 17. Population Statistics for Long-term Reconditioned Kelts Release in 2005.		
Tank	C1	C3
No. Released	20	45
No. Mature	17	34
Mean In-Weight (kg.)	1.49	2.15
Mean Out-Weight (kg.)	2.04	2.28
Mortalities	168	129
Survival (%)	10.7%	25.8%

2006 Long-term Reconditioning
Long-term kelts were held for 6-to-9 months in two different tanks. Experiment results for the 2006 release will be presented in the 2007 annual report.

Mortality Statistics

2005
Mortalities in both of the tanks were exceptionally high in 2005 (Table 17). This is the second straight year that survival rates have continued to decline which may be due to the use of early arriving kelts (higher quality when compared with mid to later running kelts) in the direct and no-term experiments.

2006
Mortality statistics for 2006 long-term reconditioned kelts will be reported in the 2006 annual report

Feeding and Treatment Summary

For all long-term experiments, steelhead kelts were fed krill as a starter diet for approximately 2.5 months and then were given Moore-Clarke pellets based on the exceptional weight gain of the diet established in the 2001 and 2002 feed trial experiments.

Biotelemetry

Radio Telemetry
2005
When long-term reconditioned fish were released in early December of 2005 ten individuals were had 10 radio tags implanted utilizing the gastric insertion technique. We had no subsequent detections shortly after release which may be due to the cold conditions that resulted in the river icing over.

PIT-Tag Data

2004 Long-term Reconditioning Release
In 2005, 25 of the 2004 long-term release were recaptured at the Chandler juvenile evaluation facility attempting to emigrate again. A majority of these recaptured individuals (12) were placed back into the long-term reconditioning study, 2 were placed

into the direct transport and release study, 3 into the short-term study, 2 into the Yakima in-river release, 1 cull, and 7 were mortalities. The mortalities broke down into 2 dead on arrivals, 3 long-term mortalities, and 2 that were recaptures from the Reproductive Success Project.

2005 Long-term Reconditioning Release
A single long-term reconditioned fish that was released in December of 2005 was captured in March 2006 and placed back into the long-term reconditioning program.

2006 Long-term Reconditioning Release
This section will be updated in the 2007 annual report.

Management Recommendations

Cost Analysis Framework

The Northwest Power Planning Council (NPCC) produced some important documents that outlined which methods are best used to analyze restoration projects (NPPC 1997) and determine the balance between cost and effectiveness. Initially this project proposed to produce a cost benefit analysis but after further consideration have instead opted for a basic cost analysis. In trying to assign value to an ESA listed species using standard cost benefit analysis the NPCC (1997) states "…the task of quantifying the value of preserving endangered species in dollar terms may be hopelessly difficult". Considering that our experiment is still underway and a number of important questions remain to be answered to determine the most effective technique for kelt reconditioning and restoration, we opted to lay the framework for a standard cost analysis instead of a cost-benefit analysis. The framework for this analysis can be used to determine initial start-up costs for a site appropriate method.

When laying the groundwork for a cost analysis there are a number of costs to consider. The first consideration is determining what management scenario would likely be used. Will long-term reconditioning, short-term reconditioning, salt water reconditioning, or will

simple transport around the hydrosystem be effective at producing viable spawning individuals? Continuing research will narrow down which options are the most effective (this subject is discussed under our Management Scenarios section). A large-scale long-term reconditioning would likely be the most intensive and therefore the most expensive while a large scale simple transport around the hydrosystem would be comparatively inexpensive to the first experiment while the other two would fall somewhere in between. The second consideration is site selection which can increase the cost of a facility in a number of ways: land purchases if existing facilities cannot be accommodated, necessary equipment purchases to insure water quantity and quality, determining the size and location of the needed facility (e.g. Lower Granite Dam a large number of fish (thousands) to capture versus in comparison much smaller number of fish (e.g. Omak Creek in the hundreds) (see list below for itemized list of possible costs).

Major Costs:
Capitol Costs: Land, Holding Tanks, Chillers, Recirculating systems, warning systems, backup systems, water (wells, generators and pumps), housing costs (trailer or manufactured home for crew)
Labor Costs: Depending on size, personal for maintenance of fish and facilities
Culturing Costs: Medications, Training, Feed

Minor Costs:
Minor equipment, transportation costs, electricity

The next step would be to compare these costs against other similar conservation tools such as a conservation hatchery and a captive broodstock program. Based on rough estimations it would seem that we would be comparable to the cost of a conservation hatchery and considerably cheaper than a captive broodstock program. There could be cost savings associated with the pairing up of a conservation hatchery with a kelt reconditioning program.
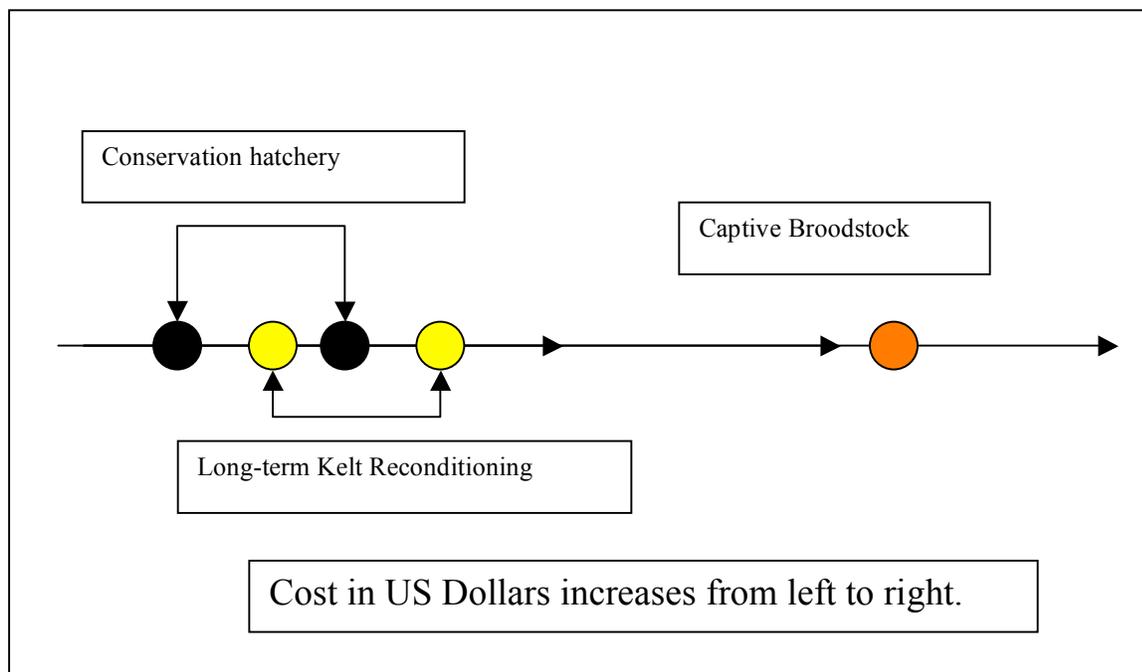
Figure 4. Cost Estimate. Cost in US Dollars represented by line increasing in total cost from left to right. Black dots are estimated costs for startup and operation of a Conservation Hatchery.,yellow dots represent costs for a Steelhead Kelt Reconditioning program, while the red dot represents a Captive Broodstock program.

An additional beneficial aspect of steelhead kelt reconditioning is that we are collecting fish that have already spawned naturally whereas the other two programs must collect first time spawners which pulls them from the spawning grounds. This has been criticized for limiting the genetic pool and contributing to a lack of natural selection. Steelhead used for steelhead kelt reconditioning are captured as wild adults and are released as wild adults that have already survived the rigors of the natural selection process. Another potential hidden benefit to consider is that a reconditioning type of facility may not be as contentious as a conservation hatchery, due to the on-going debate of whether such hatcheries may produce unfit individuals which could add litigation costs due to continued opposition from environmental groups.

Steelhead are an invaluable resource of the Columbia River basin, from the communities that depend on fishing for income (American Indian and Non-Indian alike), to terrestrial and aquatic ecosystems that rely on the nutrients that returning fish provide.

<u>Survival Probability Theory</u>

Using similar methods as listed in the previous survival probability theory sections we went with a slightly altered formula to determine our probabilities due to the repositioning of receivers in 2005. We began our analysis at the upper estuary (Rkm 43) and our final detection point at the mouth of the Columbia River (Rkm) this way we could compare the survival probabilities of the last three years releases (Appendix B). The remarkable thing is that it appears that both groups (No-term and Short-term) faired nearly equally well (Appendix C, All Tables), except for the short-term release in 2005 at it's first detection point which is likely due to the high temperatures which kept most of the last short-term reconditioned release from making it past the St. Helens array which in the combined groups showed a poor survival probability (Appendix C, table 6 and Figure 2).

Using a Pearson correlation test to determine what effect that temperature and flow are having on kelts ability to successfully navigate the lower Columbia River we see that there is a positive relationship between flow and suvival and that with greater flow we see greater survival. There was a negative relationship between temperature and suvival which translates into decreased survival with increasing water temperatures.

Table 18. Pearson Correlation Matrix (Temp, Flow, and Survival)			
	Temperature	**Flow**	**Survival**
Temperature	1		
Flow	0.134	1	
Survival	-0.213	0.312	1

Gamete and Progeny Success

2005

Our single Yakima River female that was air spawned in 2005 died in early 2006 leaving us without a kelt comparative analysis for 2006.

2006

We decided to move our gamete and progeny study from Prosser to another facility due to the difficulties of obtaining, transporting, and holding suitable first-time spawners from

Satus Creek. All of the other systems in the Yakima River basin had no suitable backups that would facilitate easy collection. Another concern that was raised was that we were mining from the natural ESA-listed population which we felt was not in the best interest of the resource when there are suitable non-ESA listed populations that we can work with. Initially, we attempted to conduct the experiment through Dworshak National Fish Hatchery but were unable due to logistical difficulties and disease concerns.

Further investigation of suitable facilities lead us to the Parkdale Hatchery just outside of Parkdale, Oregon. Currently Oregon Department of Fish and Wildlife (ODFW) releases Skamania stock steelhead smolts from the Oak Springs facility to provide for a sport fishery run. With the removal of the Powerdale Dam and the focus on restoring the native-run winter steelhead, the Skamania Stock program will be terminated in the near future. Currently the Skamania Stock steelhead are interrogated by ODFW at a trap near the Powerdale Dam and recycled below the dam for the sports fishery. In a collaborative effort with The Warm Springs Tribe and ODFW 20 breeding pairs would be captured and held at the Parkdale facility until ripe and then ship the eyed eggs to U of I.

In our first year at this site we did not collect many steelhead (3 males and 1 female in early 2006) due to the late start. We successfully air spawned the female and manually collected and cryopreserved 2 out of the 3 males milt. Gametes were transported to the University of Idaho for analysis. The female is currently still living and we hope to air spawn sometime in mid March of 2007.

2007

Currently we have collected 18 males and 17 females from the Powerdale Dam trap. These fish are currently being held at the Parkdale facility. These fish should be ready to spawn in mid March of 2007.

Currently we have also identified another site that will provide for us a backup along with geographic replication, and greater statistical power for the gamete and progeny

study. In a collaborative effort with the Confederated Tribes of the Colville Reservation Tribal Fish Program and Washington Department of Fish and Wildlife we intend to collect another 20 breeding pairs from Wells Hatchery to compare the gamete and progeny success of kelts that are reconditioned. Results from this portion of the study should be available in early 2009.

Gamete Viability

Semen samples from two steelhead males were collected at Parkdale and cryopreserved (male 1, 2 and a pooled group, C) at Bonneville on April 4, 2006. Approximately 1500 eggs from a single female were fertilized with cryopreserved milt (1, 2, C) on April 10, 2006. Fertilized eggs were maintained at Parkdale until disease free certification could be made. Embryos were then preserved in a formalin-based Stockard solution on April 28, 2006 for keel stage determination. (Preserved samples were analyzed on June 6, 2006.) Keel stage success:

Male	+ Keel	-Keel	%Keel
1	13	13	50
2	10	15	40
C	12	12	50
		Avg:	47%

Eyed eggs were shipped to UI on May 17, 2006. Eggs were placed into trays of a Heath incubation system at Aquaculture Research Institute (ARI) at the University of Idaho.
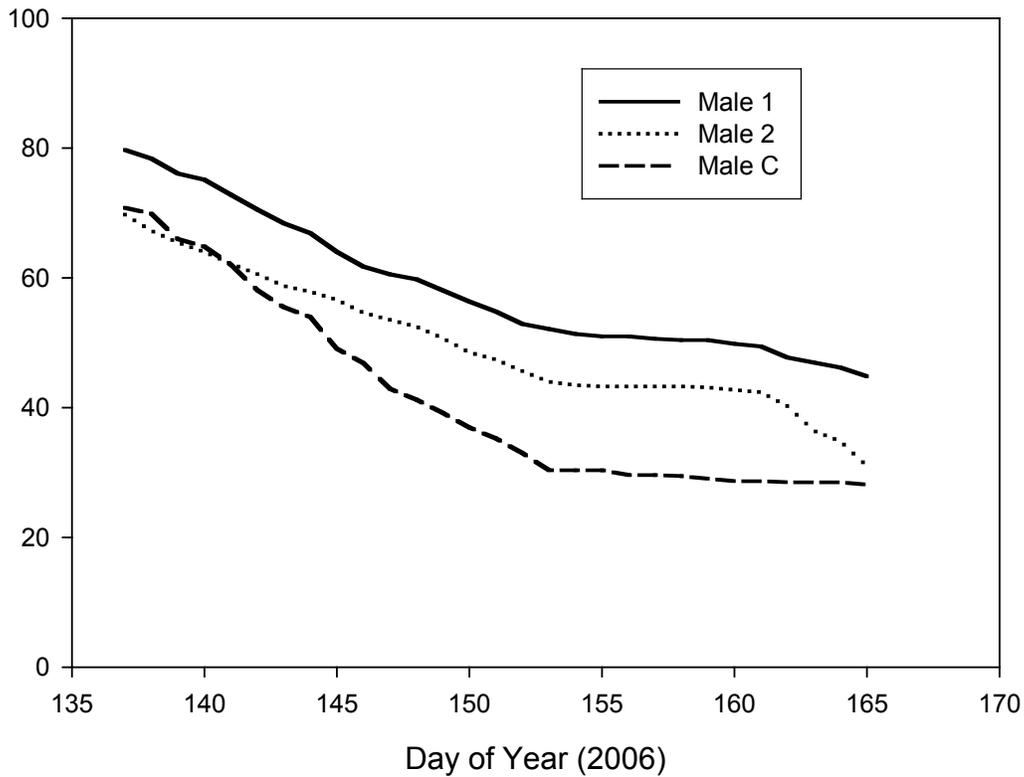
Figure 5. Daily mortality assessed

Hatching began on May 26, 2006. Fry were transferred to Heath growth system at the ARI and aquaria at 10C in Gibb Hall on 14 June. On that date, there were 234, 172 and 150 fry from fertilizations with males 1, 2, and C still alive. 100 fry (4 groups of 25) from each fertilization group were transferred to the Heath system at ARI (12 containers). 50 fry from each fertilization group were transferred to the aquaria in Gibb Hall. All other fry were euthanized.

Progeny Viability

Fish were weighed as a group live and then returned to their aquaria. The wet weight of the fish on July 14 (DoY 195) and Aug 14, 2006 (DoY 226):
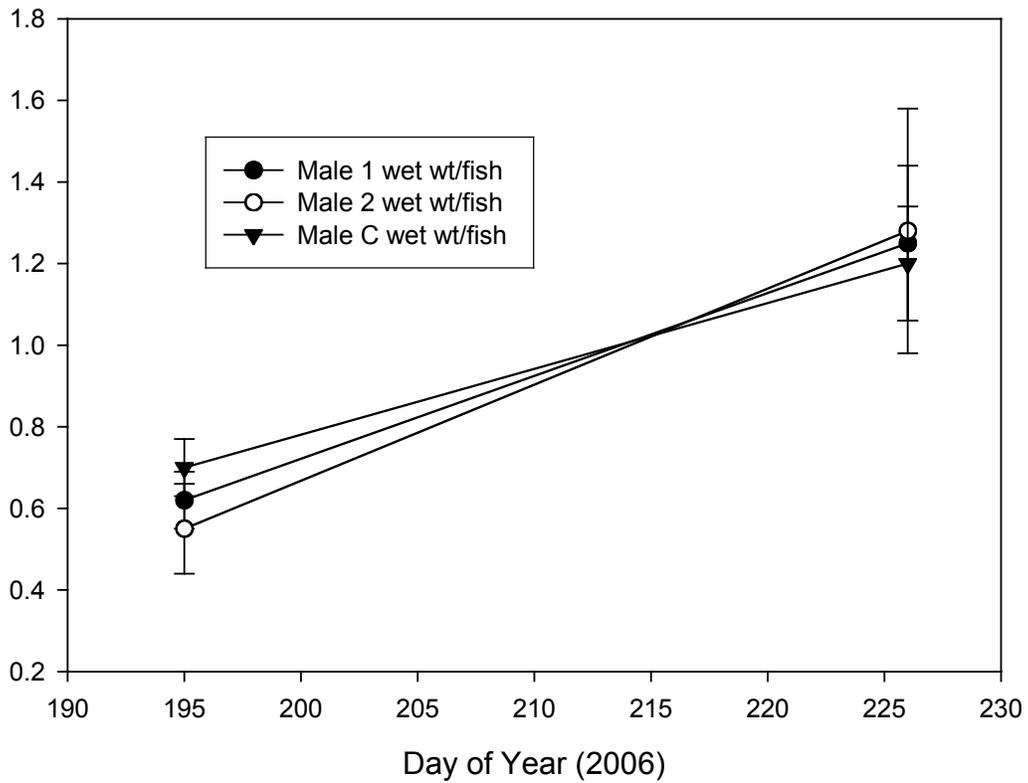
Figure 6. Wet weight.

Growth data were collected from fry transferred to Gibb Hall. Growth continues to be monitored.
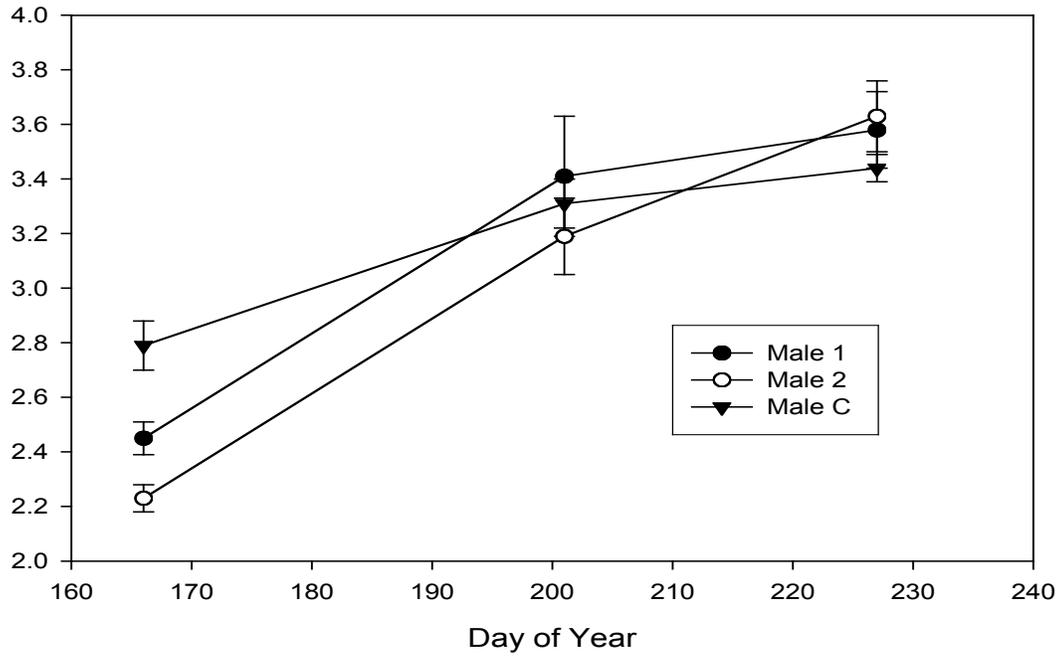
Figure 7. Length
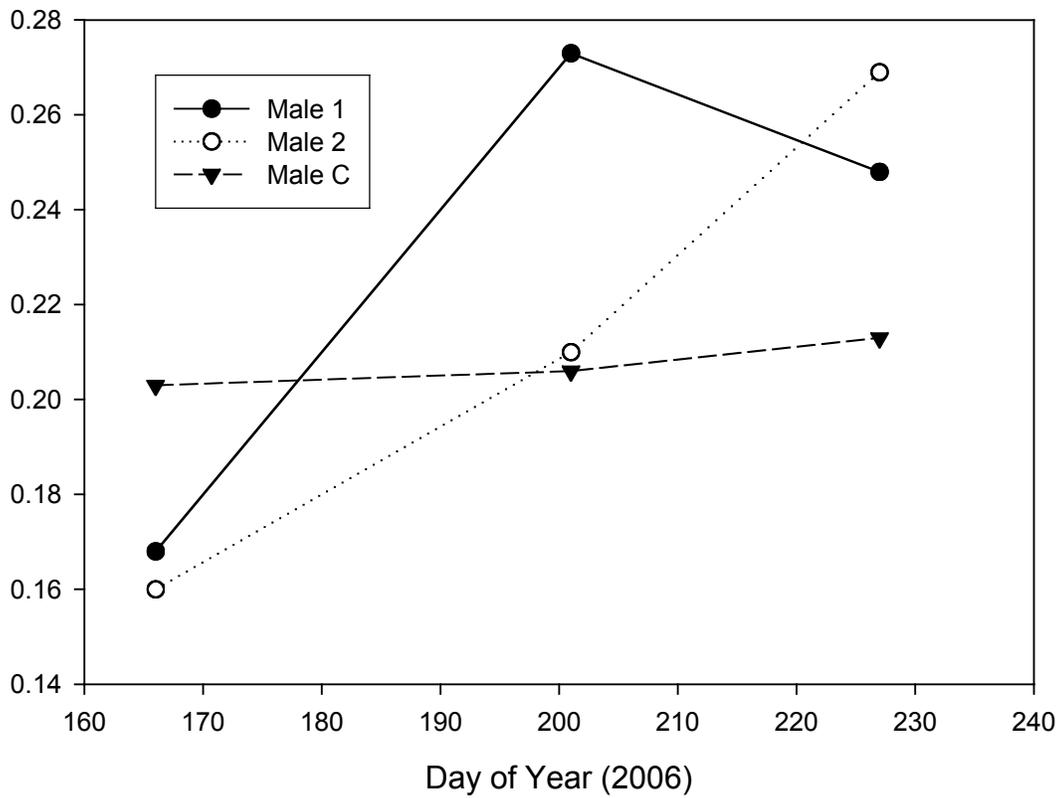
Figure 8. wet weight
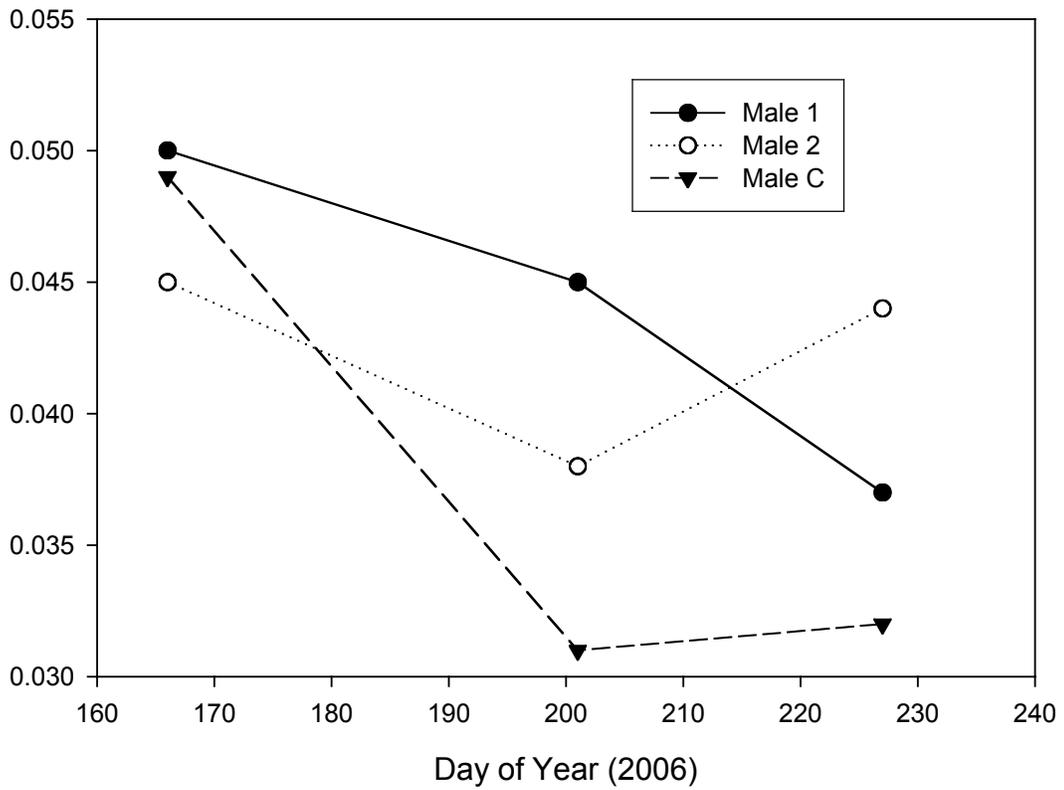
Figure 9. dry weight

Other Outcomes

Using the experimental system detailed in the above manuscript, data has been collected on motility characteristics of steelhead sperm and were compared with white sturgeon. The results of this experiment are currently being prepared by UI researchers for subsequent publication.

CONCLUSIONS

Kelt Research

- Steelhead kelt reconditioning shows great promise to assist the restoration of imperiled wild steelhead populations in the Columbia basin, based on empirical results of this project.

  During 2000, the Yakama Nation collected 512 wild kelts (38% of the subbasin's run that year) at the Chandler Juvenile Monitoring Facility (CJMF) for reconditioning at Prosser Hatchery, producing a first year recondition rate of 10% (51/512). Subsequently, kelt rematuration rates in captivity more than doubled from 10% (2000), 21% (2001), 50% (2002), and 85% (2003). As previously reported by Evans *et al*. (2001), Hatch *et al*. (2002), and other previous annual reports, kelts reconditioned by this project will substantially bolster the number of repeat spawners in the Yakima River.

  The number of kelts successfully emigrating to the ocean has been increased. We're seeing preliminary numbers that indicate that there is an increase in the number of multiple spawning kelts returning to the Yakima River.

- This project is successfully refining techniques, which appear very applicable to increasing project success and has the potential to help population enhancement efforts at larger geographic scales for wild Columbia Basin steelhead.

- Kelt reconditioning at this time should be viewed as experimental, though it is worth mentioning that it has been very successful, continues to rapidly improve, and appears very promising. Implementation of best methods should be targeted following several years of rigorous, replicated studies of each approach, including ecological and economic cost/benefit analysis.

Management Implications of Successful Kelt Reconditioning

Unlike other species of Pacific salmon *(Oncorhynchus spp.)* anadromous steelhead naturally exhibit varying degrees of iteroparity (repeat spawning). Wild steelhead populations have declined dramatically from historical levels in the Columbia and Snake Rivers, for many reasons. Successful steelhead iteroparity involves downstream migration of kelts (post-spawned steelhead) to estuary or ocean environments. Thousands of ESA listed kelts in the Snake R. and mid-Columbia River are incidentally collected each spring (March - June) in the juvenile collection systems throughout the Snake and Columbia rivers. Despite their efforts to migrate to the ocean, results from a telemetry study Evans et al. (2001) suggested that only a very small percentage (<5%) successfully navigated the Snake and Columbia River hydropower system, although this survey occurred during low and no-spill years. In-river survival rates of emigrating kelts may increase considerably during average and above water years since emigration paths through open spillways may be available. For this life history expression (iteroparity) to persist in future steelhead runs, successful methods must be developed to augment the current rate of iteroparity among Snake and Columbia River steelhead populations.

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# Appendix A: Acoustic Receiver Locations on the Columbia River
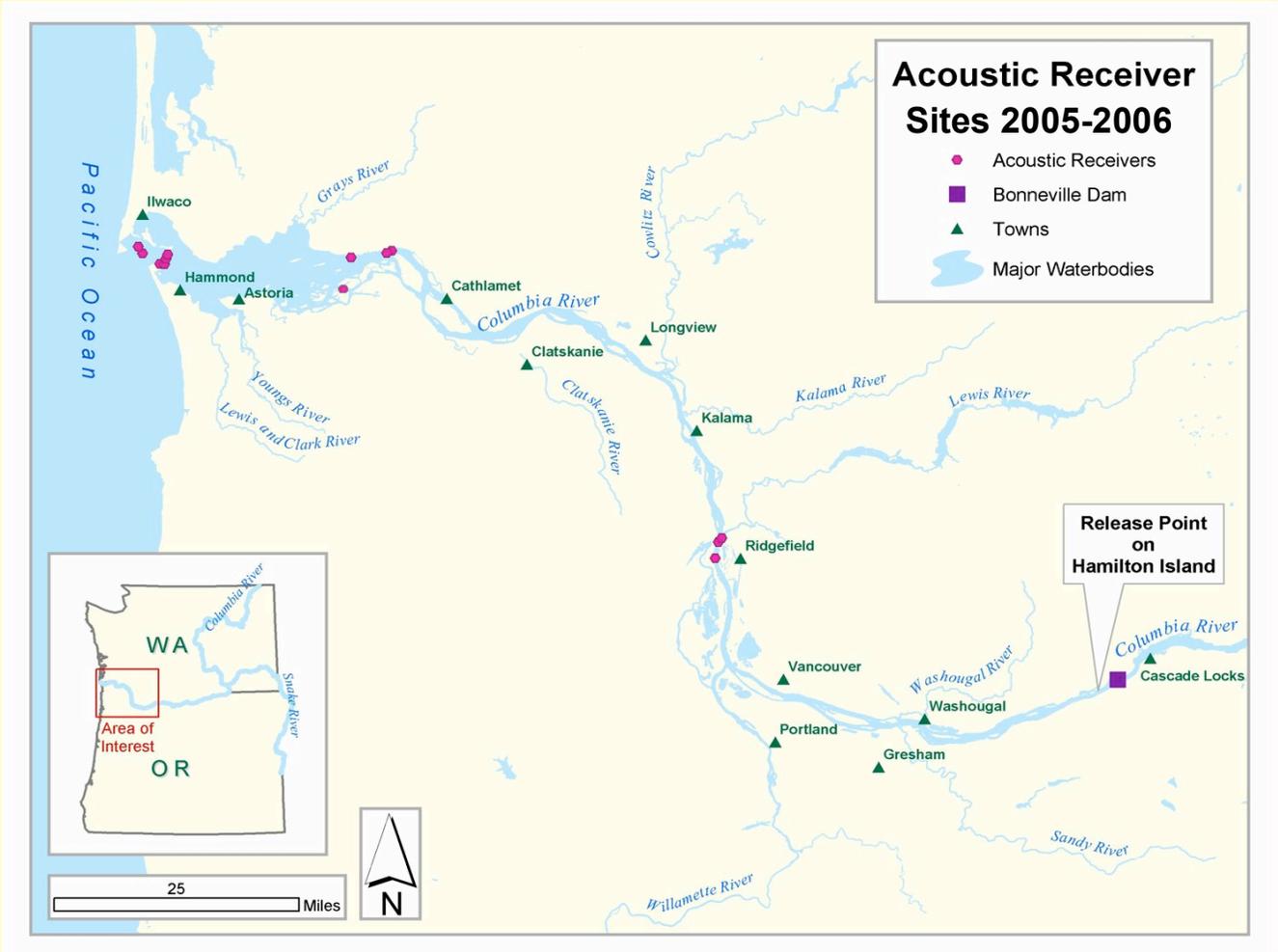
Figure 1. All acoustic receiver deployments 2006 and release site.

Figure 2. Lower River (upper) deployment 2006.

Figure 3. Lower Columbia River acoustic receiver deployment 2006.

Appendix B: Likelihood functions of parameters

For a tagged fish to be detected at receivers after release, the fish should not only survive to the receiver location but also be successfully detected by receivers. Thus, the number of fish detected in a location involves two parameters: fish survival and receivers' detection rate.

We describe estimation of parameters in a generalized setting where two detection locations are considered (Fig. 1). Even when there are more than two detection locations, the estimation principal remains the same. First, we arrange available data as in Table 1. In case of the experiment design in Fig. 1, numbers of fish released at stage 1 and then detected at stage 2 or 3 become multinomial random variables.

$$(n_{g2}, n_{g13}) \sim Multinomial(R_{g1}, \theta) \tag{1}$$

where parameter vector $\theta = (sp_{g1}, sp_{g1}(1-p_2))$. First element of vector θ (i.e., $\theta_{(1)} = sp_{g1}$) means the probability that a fish from stage 1 survives to next stage, and also is detected at the next stage. The second element $\theta_{(2)} (= sp_{g1}(1-p_2))$ indicates the probability that a fish from stage 1 survives to stage 2, is not detected at stage 2, survives from stage 2 to stage 3 and finally is detected at stage 3.

Also, when considering that the number of fish detected at stage 2 is the new release number, the number of fish detected at stage 2 being detected at stage 3 again becomes a binomial random variable.

$$n_{g23} \sim Binomial(n_{g2}, sp_{g22}) \tag{2}$$

where sp_{g2} means the probability that a fish from stage 2 survives to stage 3 and then is detected at stage 3. However, so-called success/failure probability in the binomial mass function in eq. 2 consists of two parameters of s_{g2} and p_2, and such two parameters cause an over-parameterization problem because a success/failure parameter in a binomial mass function is only one. That is, we cannot separately estimate s_{g2} and p_2 and thus express the product as one parameter, say λ_g (Table 1). The expression of λ_g is not problematic in this study, because our ultimate goals are to compare two fish groups (control vs. treatment) not to estimate receivers' detection rates. A difference in λ_g between two fish groups is due to only fish survival s_{g2} not receivers' detection rate p_2 (Table 1). So, comparing two fish groups based on estimates of λ_g is justifiable.

Further these multinomial and binomial events do not affect each other, so they are independent. That is, the probability of those two events is the product of the respective probabilities.

$$p(n_{g1}, n_{g2}, n_{g3}, d_1, d_2 | \theta) \quad \theta \quad ?$$

(3)

$$= Multinomial \cdot Binomial_{g1} \quad l$$

By definition, the likelihood function of parameters, $L(\theta | n)_{gggg \ 121323}$ is eq. 3. Ignoring constants with respect to parameters, the likelihood function of parameters is

$$L(\theta | n)_{gggg(1)(2)(1)(2)} \quad \theta \quad \theta \quad ---$$

(4)

Note that this likelihood function has three parameters as variables: s_{g1}, p_1, and λ_g. For convenience of the calculation of maximum likelihood estimates (MLEs) of those three parameters and the variances, we take the natural logarithm for the likelihood function of eq. 4. The conversion to the log likelihood form is straightforward so we don't show it here. Finally, implementing the log likelihood function to software, Automatic Differentiation Model Builder (ADMB) (Fournier 2000), we differentiate the log likelihood function with respect to parameters to obtain the MLEs, and further calculate the Hessian matrix for calculation of the variances. We can provide our ADMB codes and executable file for the calculation of the MLEs and variances on request.

Reference

Fournier, D.A. 2000. An introduction to AD Model Builder version 4: For use in nonlinear modeling and statistics. Otter Research Ltd., Sidney, B.C., Canada.

Table 1. Notations. Release and detection stages are illustrated in Fig. 1.

Index

g Fish group (control or treatment).

i, j Stage index.

Data

R_{gi} The number of fish from group g being released at stage i.

n_{gij} The number of group g-fish being released at stage i and then detected only at stage j. For

example, n_{g13} = the number of group g-fish being released at stage 1, and then detected

not at stage 2 but at stage 3.

Parameters

s_{gi} Probability of a fish from group g surviving from stage i to next stage (i +1).

p_i Probability of a fish released from stage i to be successfully detected at next stage (i +1).

Note that this parameter depends only on receivers' detection ability not on fish. So it does

not have subscript, g.

λ_g Product of s_{g2} and p_2 (i.e., $\lambda_g = s_{g2} \times p_2$).
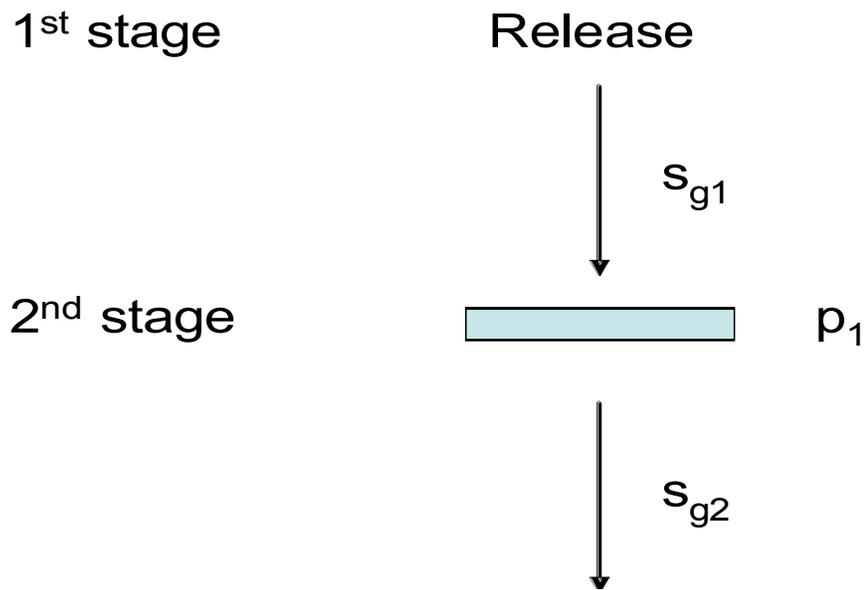

Figure 1. Parameters in the process of fish being released and detected in two different locations. A flat rectangle indicates a detection location. When there are two detection locations, four parameters of S_{g1}, p_1, S_{g2}, and p_2 are involved (Table 1).

Appendix C. Multi year Analysis Graphs

Table 1. Survival Probability of No-term Release May 3, 2004						
The	logarithm	of the	determinant	of the	hessian =	28.8201
index	name	value	std dev	1	2	3
1	S1	0.7143	0.0854	1		
2	p1	1.0000	0.0001	-0.0001	1	
3	lamda	0.7500	0.0968	0	0.0001	1

Table 2. Survival Probability of Short-term Release May 11, 2004						
The	logarithm	of the	determinant	of the	hessian =	27.851
index	name	value	std dev	1	2	3
1	S1	0.7308	0.0870	1		
2	p1	1.0000	0.0001	-0.0003	1	
3	lamda	0.5790	0.1133	0	0.0002	1

Table 3. Survival Probability of No-term Release 1, April 22, 2005						
The	logarithm	of the	determinant	of the	hessian =	11.9957
index	name	value	std dev	1	2	3
1	S1	0.4583	0.1223	1.0000		
2	p1	0.8000	0.1789	-0.5332	1.0000	
3	lamda	0.3636	0.1450	-0.2989	0.3568	1.0000

Table 4. Survival Probability of No-term Release 1, May 13, 2005						
The	logarithm	of the	determinant	of the	hessian =	28.0989
index	name	value	std dev	1	2	3
1	S1	0.7778	0.0800	1		
2	p1	1.0000	0.0001	-0.0004	1	
3	lamda	0.5238	0.1090	0	0.0002	1

Table 5. Survival Probability of Short-term Release 2, May 13, 2005						
The	logarithm	of the	determinant	of the	hessian =	26.4075
index	name	value	std dev	1	2	3
1	S1	0.5333	0.0911	1		
2	p1	1.0000	0.0002	-0.0006	1	
3	lamda	0.3750	0.1210	0	0.0003	1

Table 6. Survival Probability of No-term Release 1, July 1, 2005						
The	logarithm	of the	determinant	of the	hessian =	-3.88484
index	name	value	std dev	1	2	3
1	S1	0.0000	0.0001	1		
2	p1	0.5000	374.2500	-0.2866	1	

3	lamda	0.5000	374.2500	-0.2866	0.2349	1

Table 7. Survival Probability of No-term Release 1, April 24, 2006

The	logarithm	of the	determinant	of the	hessian =	14.3547
index	name	value	std dev	1	2	3
1	S1	0.8265	0.0868	1		
2	p1	0.7778	0.0980	-0.2667	1	
3	lamda	0.7778	0.0980	-0.2667	0.2222	1

Table 8. Survival Probability of No-term Release 2, May 15, 2006

The	logarithm	of the	determinant	of the	hessian =	13.2841
index	name	value	std dev	1	2	3
1	S1	0.8048	0.1046	1		
2	p1	0.7692	0.1169	-0.2698	1	
3	lamda	0.7692	0.1169	-0.2698	0.2308	1

Table 9. Survival Probability of Short-term Release 2, May 15, 2006

The	logarithm	of the	determinant	of the	hessian =	12.2467
index	name	value	std dev	1	2	3
1	S1	0.5786	0.1206	1		
2	p1	0.7778	0.1386	-0.1899	1	
3	lamda	0.7778	0.1386	-0.1899	0.2222	1

Table 10. Survival Probability of Short-term Release 2, June 27, 2006

The	logarithm	of the	determinant	of the	hessian =	26.3584
index	name	value	std dev	1	2	3
1	S1	1.0000	0.0003	1		
2	p1	0.8000	0.0730	-0.0028	1	
3	lamda	0.4333	0.0905	-0.0012	0	1

No-term Releases Correlated to Temp and Flow at Bonneville Dam
2004-2006

Legend:
- Outflow (kcfs)
- No-Term Release
- No-Term Release 1
- No-Term Release 2
- No-Term Release 1
- No-Term Release 2
- Temperature (WQM) (deg C)

Short-term Releases Correlated to Temp and Flow at Bonneville Dam
2004-2006

Legend:
- Outflow (kcfs)
- Short-term Release
- Short-term Release 1
- Short-term Release 2
- Short-term Release 1
- Short-term Release 2
- Temperature (WQM) (deg C)