MONITORING AND EVALUATION
YAKIMA/KLICKITAT FISHERIES PROJECT

Final Report 2000

DOE/BP-00000650-1

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“MONITORING AND EVALUATION”

PROJECT NUMBER 95—063-25

THE CONFEDERATED TRIBES AND BANDS OF
THE YAKAMA NATION

“YAKIMA/KLICKITAT FISHERIES PROJECT”

FINAL REPORT 2000

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YAKIMA/KLICKITAT FISHERIES PROJECT

MONITORING AND EVALUATION PROJECT REPORT

Preface

The monitoring and evaluation objectives and tasks have been developed through a joint process between the co-managers, Yakama Nation (YN, Lead Agency) and Washington Department of Fish and Wildlife (WDFW). The Science/Technical Advisory Committee (STAC), which consists of core members from the co-managers, employs the services of a work committee of scientists, the Monitoring Implementation Planning Team (MIPT) to develop the Monitoring and Evaluation (M&E) Plan.

The process employed by STAC to verify these designated activities and the timing of their implementation involved the utilization of the following principles:

1. YKFP monitoring should evaluate the success (or lack of it) of project supplementation efforts and its impacts, including juvenile post release survival, natural production and reproductive success, ecological interactions, and genetics;
2. YKFP monitoring should be comprehensive: and,
3. YKFP monitoring should be done in such a way that results are of use to salmon production efforts throughout and Columbia basin and the region.

Utilizing these principles, STAC and MIPT developed this M&E action plan in three phases. The first phase was primarily conceptual. STAC and MIPT defined critical issues and problems and identified associated response variables. The second phase was quantitative, which determined the scale and size of an effective monitoring effort. A critical element of the quantitative phase was an assessment of the precision with which response variables can be measured, the probability of detecting real impacts and the sample sizes required for a given level of statistical precision and power. The third phase is logistical. The feasibility of monitoring measures was evaluated as to practicality and cost. The Policy Group has determined that the M&E activities covered by this agreement are necessary, effective and cost-efficient.

Background

Previously, the M&E program consisted of a number of biologically related sub-tasks that were funded under different projects and associated contracts. This year, the plan grouped related M&E tasks into general categories under an overall umbrella proposal. It is structured under this format:

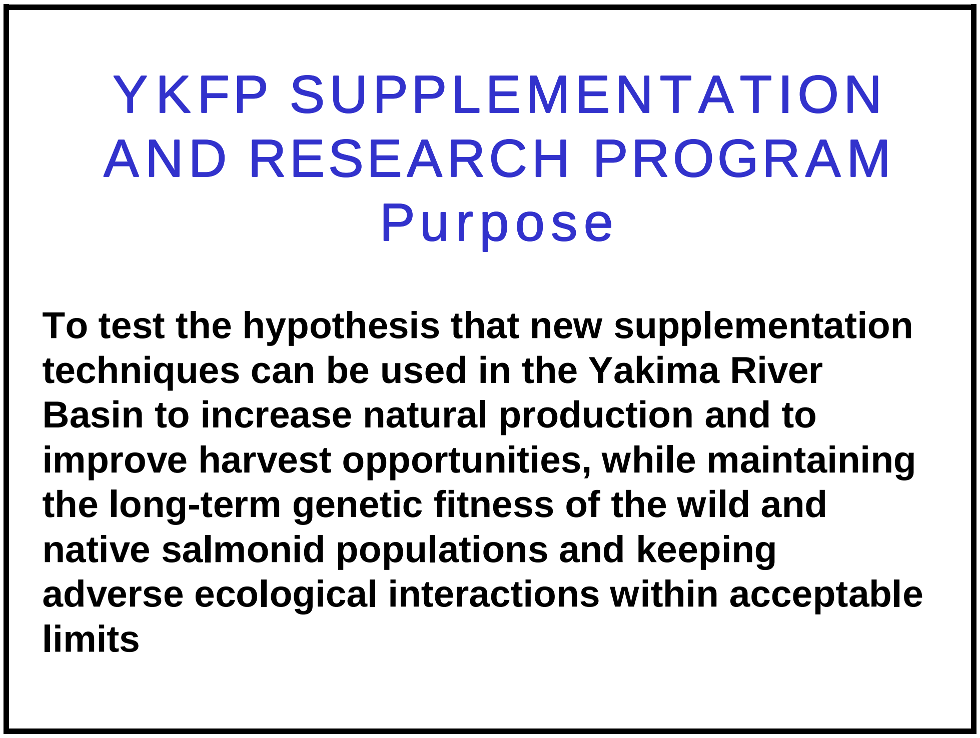
1. Monitoring and evaluation: to include marking, adult and juvenile enumeration, data management, biometrical support and other related tasks.

2. Tech Pool: funds the participation of the YKFP tribal technicians for the operation and labor associated with numerous monitoring and evaluation tasks.
3. Modeling: includes the Ecosystem Diagnosis and Treatment model development, calibration and operation to evaluate the watersheds for future salmonid enhancement project prioritization and to guide habitat restoration.
4. Video monitoring: to enumerate the adult returns to the watershed.
5. Klickitat: to fund all of the tasks associated with the Klickitat portion of the YKFP.
6. Fall Chinook: to fund the fall chinook programs that have become a part of the YKFP.
7. Coho: tasks designed to evaluate the feasibility of reintroduction of coho salmon into the Yakima basin.

This report will only reference the respective tasks that WDFW are contracting for, since they are responsible for reporting on them. It is anticipated that this revised method will facilitate better coordination and administration of the M&E aspect of the YKFP. This report will follow the format of the contract utilizing Attachments when necessary and a reference catalogue.

Special acknowledgement and recognition is owed to all of the dedicated YKFP personnel who are working on various tasks. The referenced accomplishments and achievements are a direct result of their dedication and desire to seek positive results for the betterment of the resource. The readers of this report are requested to pay special attention to the Personnel Acknowledgements. Also, these achievements are attainable because of the efficient and essential administrative support received from all of the office and administrative support personnel for the YKFP. This team approach is proving to be beneficial in achieving the goals and objectives of the YKFP, as referenced in this report.

The NPPC's provincial "rolling review" process for the Yakima Subbasin was initiated during this reporting period. The YKFP Research Manager, Dr. David Fast, was selected as the "Team Leader" to assemble the Yakima Subbasin Summary (YSS). The majority of the lead biologist's time was spent organizing, compiling and synthesizing information from various agencies and disciplines to develop the Subbasin Summary.



YKFP SUPPLEMENTATION AND RESEARCH PROGRAM
Purpose

To test the hypothesis that new supplementation techniques can be used in the Yakima River Basin to increase natural production and to improve harvest opportunities, while maintaining the long-term genetic fitness of the wild and native salmonid populations and keeping adverse ecological interactions within acceptable limits

Figure 1. The stated YKFP purpose and overall project goal.

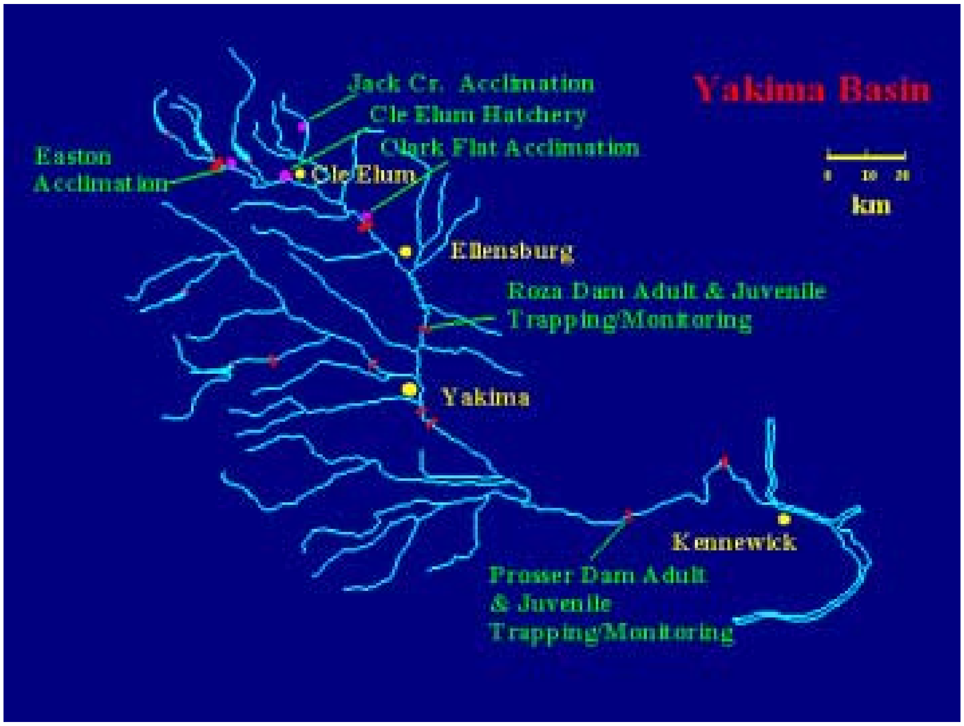
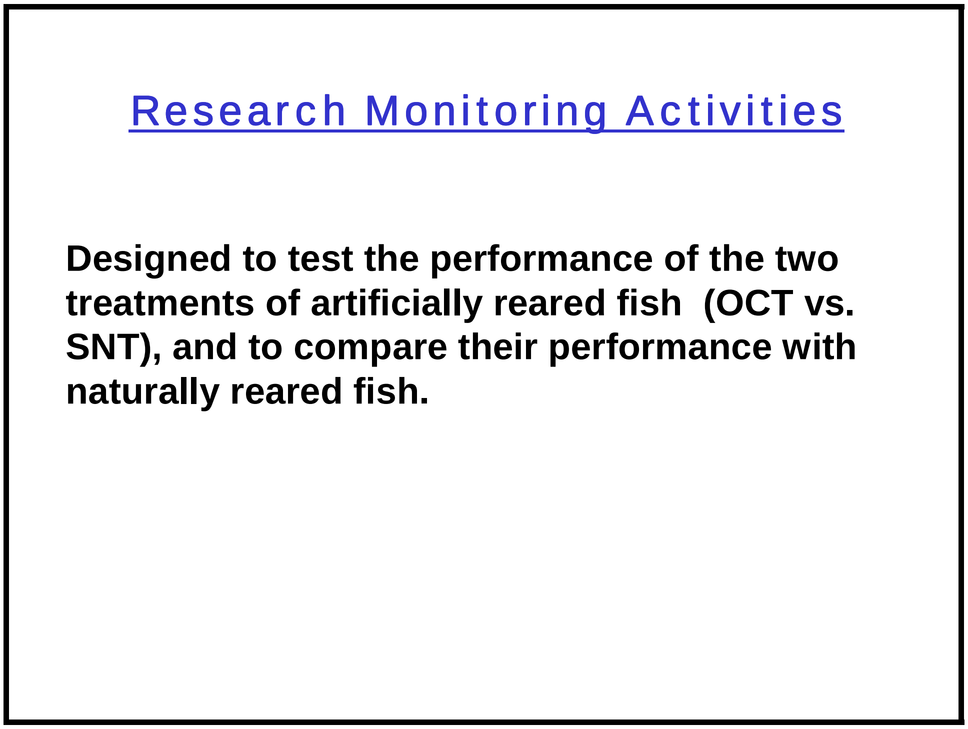


Figure 2. A map of the Yakima Basin showing the YKFP monitoring and fish culture facilities.

Figure 3. Aerial view of the Cle Elum Supplementation and Research Facility located near the city of Cle Elum.



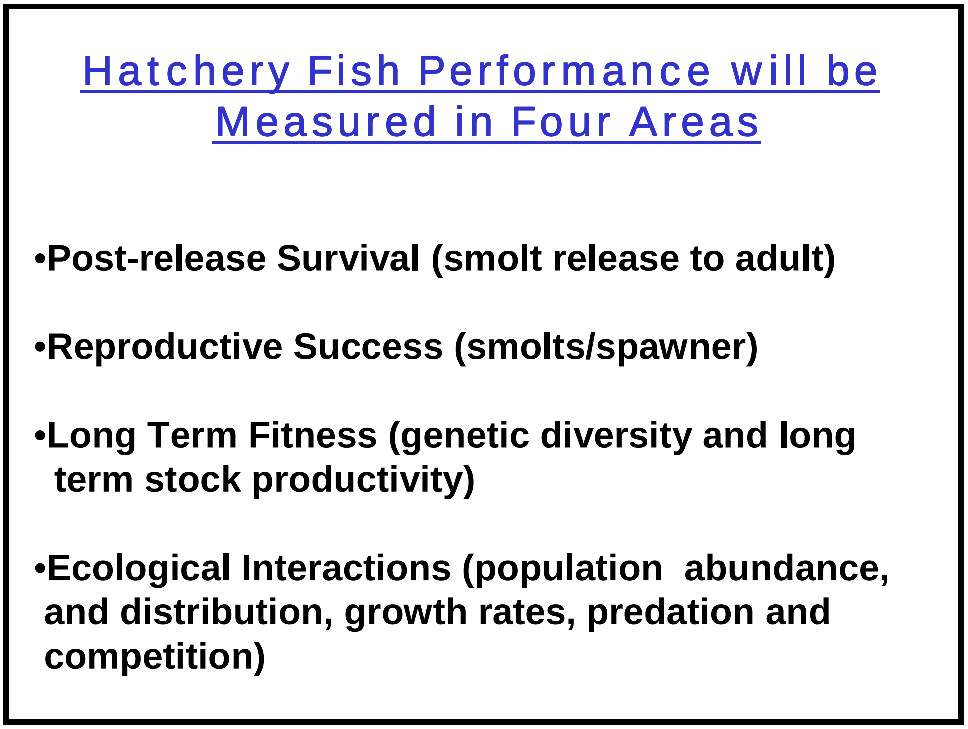
Research Monitoring Activities

Designed to test the performance of the two treatments of artificially reared fish (OCT vs. SNT), and to compare their performance with naturally reared fish.

Figure 4. The current YKFP supplementation research objective for upper Yakima spring chinook.

Figure 5. A OCT (optimal conventional treatment) spring chinook raceway at Cle Elum Supplementation and Research Facility.

Figure 6. A SNT (semi natural treatment) spring chinook raceway at Cle Elum Supplementation and Research Facility.



Hatchery Fish Performance will be Measured in Four Areas

- Post-release Survival (smolt release to adult)
- Reproductive Success (smolts/spawner)
- Long Term Fitness (genetic diversity and long term stock productivity)
- Ecological Interactions (population abundance, and distribution, growth rates, predation and competition)

Figure 7. The four areas of fish performance measured as part of the YKFP monitoring and evaluation program.

1. NATURAL PRODUCTION

Overall Objective: Develop methods of detecting indices of increasing natural production, as well as methods of detecting a realized increase in natural production, with specified statistical power.

Task 1.a Modeling

Rationale: To design complementary supplementation/habitat enhancement programs for targeted stocks with computer models incorporating empirical estimates of life-stage-specific survival and habitat quality & quantity.

Methods: To diagnose the fundamental environmental factors limiting natural production, and to estimate the relative improvements in production that would result from a combination of habitat enhancement and supplementation using the “Ecosystem Diagnosis and Treatment” (EDT) model.

Progress:

Yakima

YN staff and Mobrand Biometrics, Inc. (MBI) collaborated in developing EDT models for Yakima and Klickitat spring chinook, fall chinook, coho and steelhead. An initial diagnosis of the factors constraining natural production of spring chinook and steelhead in the Yakima Basin has been made and a final diagnosis of limiting factors for all Yakima and Klickitat species is in progress. A list of the most important reaches in the Yakima Basin from the standpoint of restoration potential and preservation value has been developed and circulated among Yakima fish and water managers. This list has proved to be valuable to the YN as well as other agencies in prioritizing habitat projects intended to enhance fish production.

Three "structural changes" to the current EDT models must be made before definitive enhancement plans can be developed for Yakima and Klickitat salmon and steelhead stocks. These changes are as follows.

Re-coding input data. A major immediate objective for the project is to translate "Level 3 data" to "Level 2 variables". The existing models for the Yakima and Klickitat Basins contain habitat data in the form of expected survival rates for various life stages – in terms of "Level 3 data". For example, the Level 3 input data in the current models for "sediment" as it impacts spring chinook fry is the expected survival rate for fry given the existing degree of fine sediment loading. In the period between the development of the existing Yakima and Klickitat EDT models and the initial diagnoses based on them, the EDT model itself has evolved. The model now describes fish habitat in terms of 45 strictly environmental "Level 2" variables (e.g., temperature, percent fine sediment, normative character of maximum and minimum flows, etc.), rather than a biologist's judgment of how such variables affect survival. The new EDT model also incorporates equations that estimate survival by life stage consistently, and strictly as a function of these 45 "Level 2" variables, thereby eliminating much of the subjectivity at the core of the old model, as well as increasing comparability and standardization between modelers. Therefore, in order to be able to make rapid progress on estimating the benefits of alternative enhancement scenarios, which are most easily expressed as changes in Level 2 variables, it is necessary to translate the current Level 3 input data in the models into Level 2 variables. The YN modeling staff and Mobrand Biometrics are in the process of doing this at the present time.

Coding the steelhead model for rainbow/steelhead interactions. Another very important immediate objective is the description of the factors that determine the proportion of a rainbow-steelhead population that will become anadromous or will remain resident. This is an issue of very great concern in the upper Yakima and Naches, as the available data suggests that there is no genetic difference between steelhead and rainbow trout there. Therefore, the proportion of the population of *O mykiss* in these areas that become anadromous must be due to an interaction between life history and habitat quality. More specifically, it implies that the proportion of steelhead in such populations must be some function of the ratio of expected egg production for steelhead to the expected egg production for rainbow:

$$N_{sthd} / N_{trout} = F\{(\prod_{sthd,i} s_i * f_i) / (\prod_{trout,i} s_i * f_i)\}$$

where N_{sthd} and N_{trout} are, respectively, the equilibrium numbers of steelhead and rainbow, "s" is the survival to year-class i, "f" is the fecundity of year-class I and "F" is the function for which the argument is the relative expected egg production ratio.

This concept basically proposes that the number of future progeny expected for resident and anadromous ecotypes is a trade-off between the greater probability of surviving to successive reproductively mature age-classes for trout and the much greater fecundity of steelhead. It also implies that any steelhead management plan is also inevitably a rainbow trout management plan, and that any habitat measure that increases steelhead smolt-to-adult survival will shift the expected egg proportion ratio to the advantage of steelhead, ultimately resulting in a lower mean abundance of rainbow. It is therefore obvious that this relationship must be coded into the final EDT models quite carefully. To reiterate, the YN modeling staff and MBI are in the final stages of completing this task.

Incorporating empirical habitat data collected in the Reaches project. The "Reaches" project, a collaboration between Central Washington University (CWU) and the Bureau of Reclamation (BOR), has amassed a very large quantity of current and historical habitat data for large portions of the Yakima Basin. Much of this data corresponds exactly to Level 2 parameters, or is directly related to them. Unfortunately, almost all of it resides in the form of aerial imagery and GIS databases, and would require considerable time and effort to translate into a form directly useable by the EDT model. Therefore another immediate goal of the YN modeling team is to make provisions to work collaboratively with CWU and the BOR to have this data and information processed and incorporated into current EDT models. For the reaches covered, incorporating this habitat information would increase the accuracy of EDT habitat descriptions dramatically.

Once these three structural modifications are made to the current Yakima and Klickitat EDT models, a final diagnosis will be made for all stocks and intensive simulations of alternative fisheries enhancement programs will begin. These alternatives will include strictly diagnosis-based actions as well as actions that are likely to occur independently of YN planning, which might be termed "political reality". Among such actions are the "Waldo Action Plan", a series of measures intended to improve fish production, water quality and irrigation system reliability put together in the wake of a stalled state salmon recovery initiative; and the proposal by the BOR to examine the effects of breaching Keechelus Dam such that normative flows would be restored to the Easton to Keechelus reach. A report describing initial enhancement plan alternatives for spring chinook and steelhead in the Yakima and Klickitat Basins will be completed by the end of the fiscal year (March 31, 2002).

Klickitat

Spring Chinook

Modelers ran the recently complete Phase I of the Klickitat spring chinook model and produced output describing stream reach restoration potential. In addition, modelers ran various supplementation scenarios describing results in production of both natural and hatchery origin fish. Based on model runs using exiting habits rankings the EDT model predicted a natural spawning escapement of 485, while 12 years of redd counts data estimates a spawning escapement of approximately 500 spawners (2.5 spawners per redd), indicating an accurate portrayal of current habitat conditions effecting natural production.

Steelhead

The Steelhead EDT model was populated with the final habitat ranks for the mainstem and selected tributaries. Modelers conducted the Phase I run analysis and presented output in the form of stream reach preservation and restoration potential. This output enable biologists to present critical reaches for preservation and restoration in the various planning arenas. Model runs were conducted using various supplementation scenarios with output describing increases in natural production, harvestable surplus and hatchery returns. The model will be run using several YKFP supplementation scenarios habitats in the future.

EDT Steelhead Run Estimates:

1. Current conditions: 1,395 fish escapement with productivity of 2.44 (excluding harvest)
   Historic conditions: 11,712 fish escapement with productivity of 12.9

Future Klickitat EDT work - Phase 2:

- Review and refine habitat rating assembled in Phase I
- Completion of Habitat Rating Conversion
- Completion of Habitat rating and additional reaches and time periods.
- Generation of Habitat rating set for all species
- ID species life history and benchmark
- Completion of Life History Analysis of all species
- Diagnostic Summarization

Personnel Acknowledgements: Joel Hubble and Bruce Watson, YN biologists, are handling this Task for Yakima Basin stocks, while Bill Sharp, the YN Klickitat biologist, is handling the Klickitat stocks.

Task 1.b Yakima River Fall Chinook Fry Survival Study

Rationale: To determine the optimal locations within the lower Yakima basin where fall chinook production is feasible, and to guide location of future acclimation/release sites.

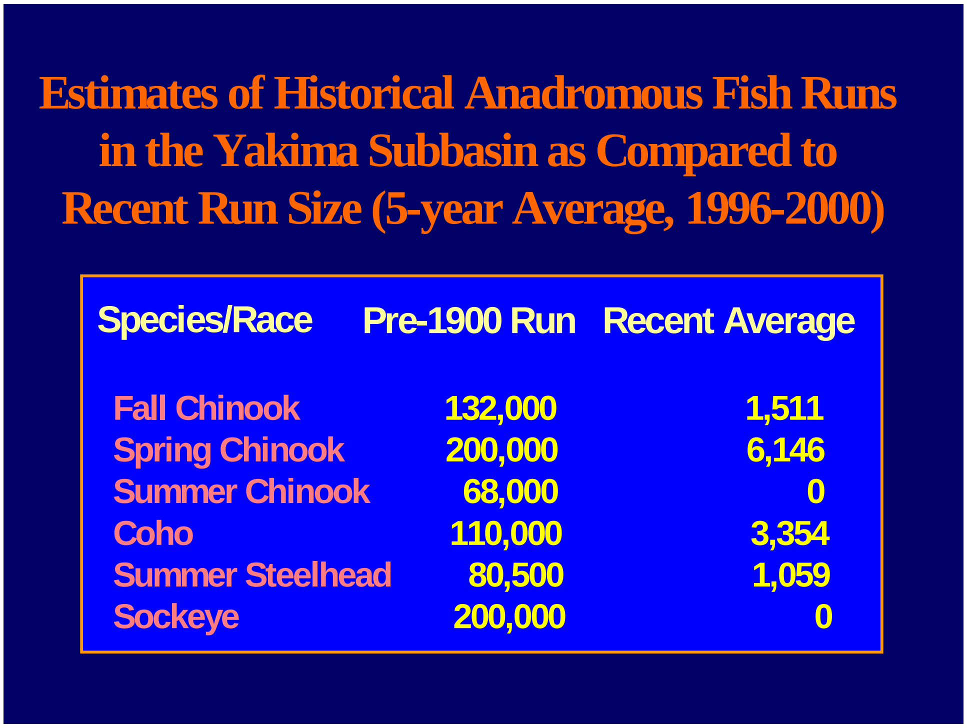
Progress: There were no funds or activities planned for this task in this fiscal year.

Personnel Acknowledgements: Jim Dunnigan is the lead biologist for this task.

Task 1.c Yakima River Coho Life History Study

Rationale: To gain knowledge about the freshwater life history and survival of juvenile coho.

Progress: There were no funds or activities planned for this task in this fiscal year.



Estimates of Historical Anadromous Fish Runs in the Yakima Subbasin as Compared to Recent Run Size (5-year Average, 1996-2000)

Species/Race	Pre-1900 Run	Recent Average
Fall Chinook	132,000	1,511
Spring Chinook	200,000	6,146
Summer Chinook	68,000	0
Coho	110,000	3,354
Summer Steelhead	80,500	1,059
Sockeye	200,000	0

Figure 8. Estimates of historical and current (recent-most 5 year average) salmonid populations in the Yakima Basin.

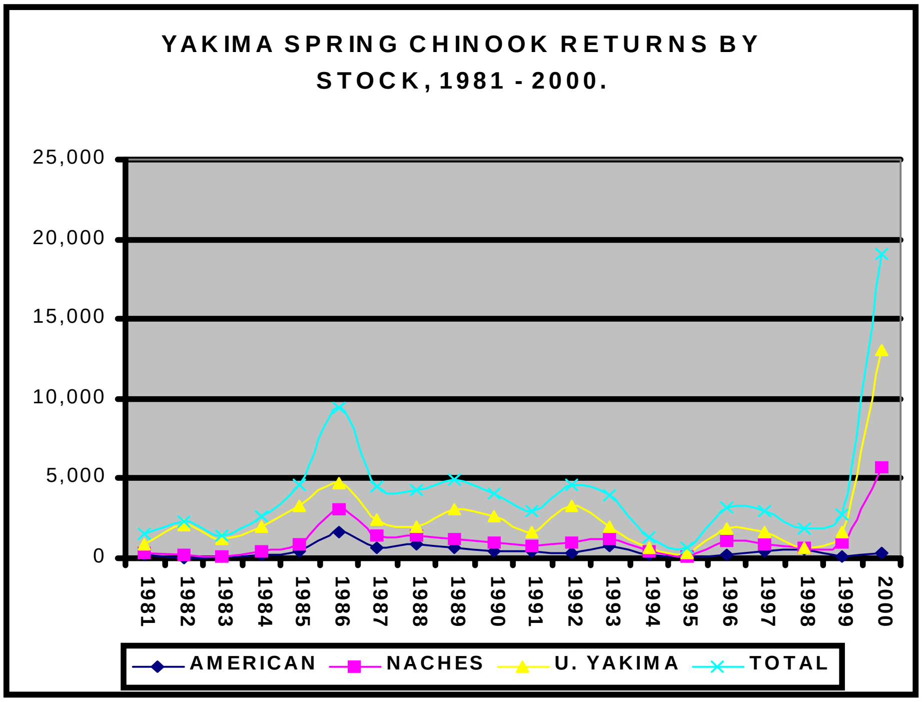


Figure 9. Estimated spring chinook returns by population in the Yakima Basin.

Top 15 Reaches for Preservation Value and Restoration Potential, Yakima Spring Chinook

• PRESERVATION		• RESTORATION	
1.	Yakima, Manastash-Taneum	1.	Yakima, Ahtanum-Naches
2.	Yakima, Marion Drain-S'side Dam	2.	Yakima, Manastash-Taneum
3.	American River	3.	Yakima, Wilson-Manastash
4.	Yakima, Ahtanum-Naches	4.	Yakima, Teanaway-Cle Elum
5.	Yakima, Wilson-Manastash	5.	Teanaway, mouth-NF T'way
6.	Yakima, Teanaway-Cle Elum	6.	Yakima, Naches-Wenas
7.	Yakima, Cle Elum-Little	7.	Naches, Cowiche-Wapatox
8.	Naches, Cowiche-Wapatox Dam	8.	Yakima, Cle Elum-Little
9.	Yakima, Swauk-Teanaway	9.	Prosser Dam
10.	Yakima, Roza-Umtanum	10.	Satus, Mule Dry-Dry
11.	Naches, Nile-L. Naches	11.	Wenas, mouth-NF Wenas
12.	Yakima, Umtanum-Wilson	12.	Cle Elum, mouth-Dam
13.	Yakima, Big-Easton Dam	13.	Sunnyside Dam
14.	Naches, Tieton-Rattlesnake	14.	Taneum, mouth-NF Taneum
15.	Yakima, Taneum-Swauk	15.	Cle Elum Dam

Figure 10. The top fifteen reaches in the Yakima Basin for restoration and preservation based upon the EDT analysis.

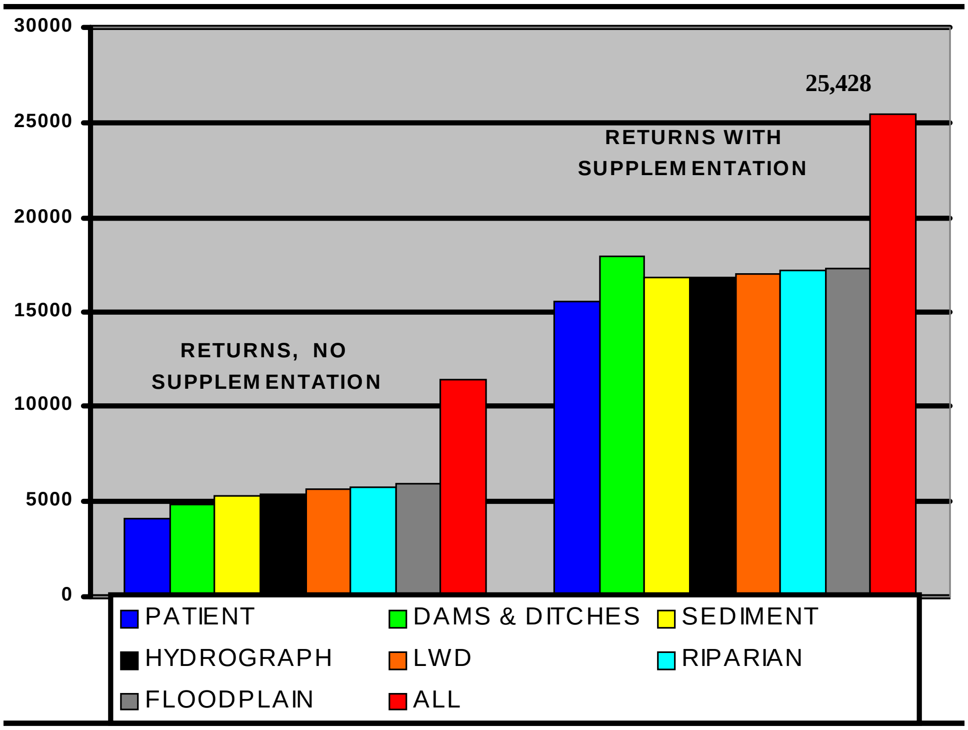


Figure 11. Expected equilibrium population estimates projected under various supplementation and habitat restoration scenarios in the Yakima Basin based upon the EDT analysis.

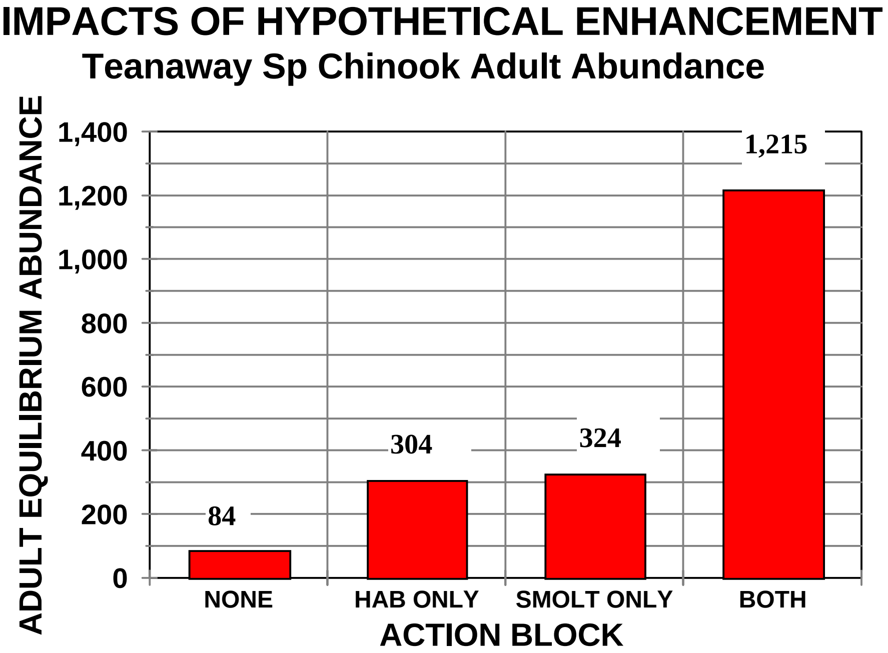


Figure 12. Comparison of hypothetical enhancement strategies on adult equilibrium abundance for spring chinook in the Teanaway River .

Personnel Acknowledgements: Jim Dunnigan is the Lead Biologist for this task.

Task 1.d Klickitat Juvenile Salmonid Population Surveys

Rationale: To determine the spatial distribution/relative abundance of salmonids throughout the Klickitat basin.

Methods: Summer and winter snorkel, and electrofishing surveys will be conducted in three mainstem reaches- McCormick Meadows to Castile Falls, Castile Falls (only summer surveys) to the WDF&W Klickitat Salmon Hatchery, and the WDF&W Klickitat Salmon Hatchery to Lyle Falls. Snorkel surveys will be direct counts, and electrofishing surveys will use catch per unit effort to estimate relative abundance. Summer electrofishing surveys will be conducted in selected reaches of the key tributaries to the Klickitat River using depletion estimates to determine absolute abundance.

Progress: Population estimates were conducted at 10 sites in selected tributaries and portions of the upper Klickitat mainstem using electrofishing and snorkeling. Population transects were located within TFW survey reaches, to allow for population estimates by habitat type. During closed area of the Yakama Reservation. Using USFWS bull trout inventory protocol crews conducted presence /absence, population density and habitat surveys at 13 sites. Additionally, 23 non-lethal DNA were collected. Bull trout were found exclusively within the West Fork system of the Klickitat Basin.

Personnel Acknowledgements: The Lead Biologist is Bill Sharp.

Task 1.e Yakima River Juvenile Spring Chinook Microhabitat Utilization

This Task has been assigned to WDFW, thus, they will report on its status.

Task 1.f Yakima River Juvenile Spring Chinook Marking

Rationale: Estimate hatchery spring chinook smolt-to-smolt survival at CJMF and Columbia River projects, and smolt-to-adult survival at Bonneville (PIT tags) and Roza (PIT and CWT) dams.

Method: To estimate smolt-to-smolt survival by rearing treatment (OCT/SNT), acclimation location and raceway, we PIT tagged and adipose clipped the minimum number to determine statistically meaningful differences detected at CJMF and lower Columbia River projects. The remaining fish will be adipose fin clipped and tagged with multiple body placement coded wire tags unique for rearing treatment, acclimation location, and raceway. Returning adults that are adipose clipped at Roza Dam Broodstock Collection Facility will be interrogated using a hand-held CWT detector to determine the presence/absence of body tags. We will recover CWT during spawning ground surveys (see Task A.17). We will use ANOVA to determine significant differences between groups for both smolt-to-smolt and smolt-to-adult survival.

Progress: Progress: Tagging began at the Cle Elum hatchery on October 16, 2000 and was completed on December 15, 2000. The marking consisted of all the fish being adipose clipped, with 2,225 fish from each raceway being CWT tagged in the snout and then PIT tagged. The remainder of the fish in each raceway had a CWT placed in their body and a colored elastomer dye placed into the adipose eyelid.

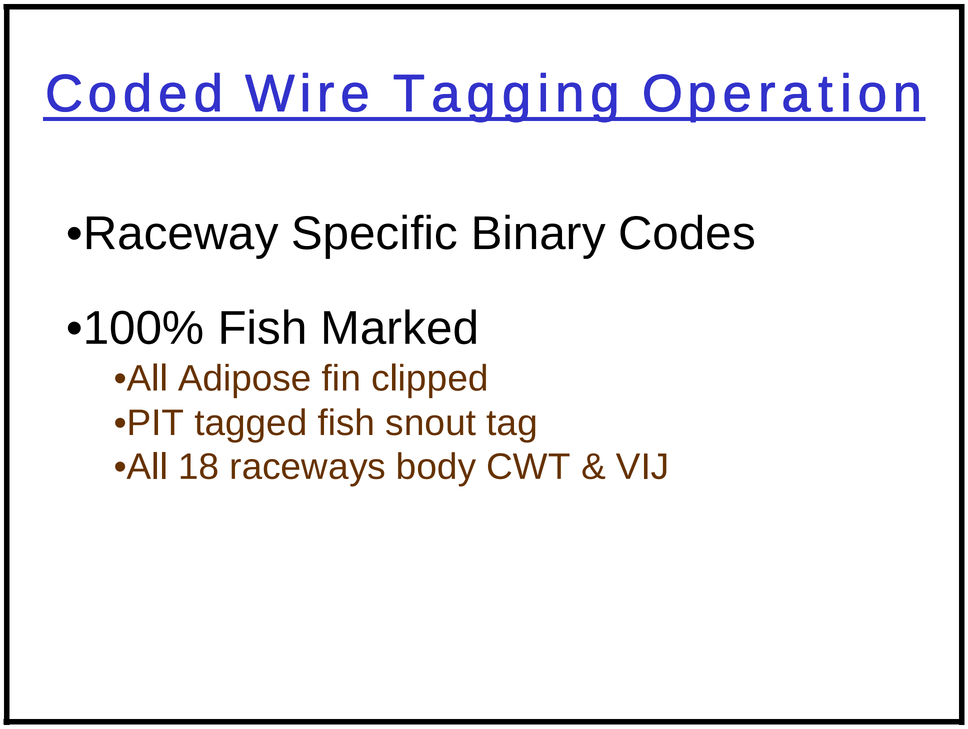
Personnel Acknowledgements (for 1.f, 1.g, 1.p): The Biologists assigned to these tasks include: Bruce Watson, Joel Hubble, Mark Johnston, Jim Dunnigan and John McConnaughey. The Technicians assigned are: Joe Hoptowit, Joe Jay Pinkham III, Leroy Senator, Gerry Lewis, Seymour Billy, Wayne Smartlowit, Tammy Swan, Morales Ganuelas, Michael Reyes, Ray Decoutea, Linda Lamebull, Wilson Lamere Jr., Sidney Wak Wak, Michael Polk, Isaiah Hogan, Phillip Smith, Shelia Decouteau and Steve Blodgett.

Cle Elum
PIT Tagging Operation

- 134 KHz (ISO) Tags
- Tagged ~ 5.6% Fish per Raceway (~ 2,225 per Raceway)
- 40,000 Fish PIT Tagged
- Selected 40,000 Total Marked to Rigorously Estimate Smolt-to-Adult Survival Rates.

Figure 13. Key points of the spring chinook PIT tagging operation at Cle Elum Supplementation and Research Facility.

Figure 14. Removal of the adipose fin is one of the first steps in the marking protocol at Cle Elum Supplementation and Research Facility.

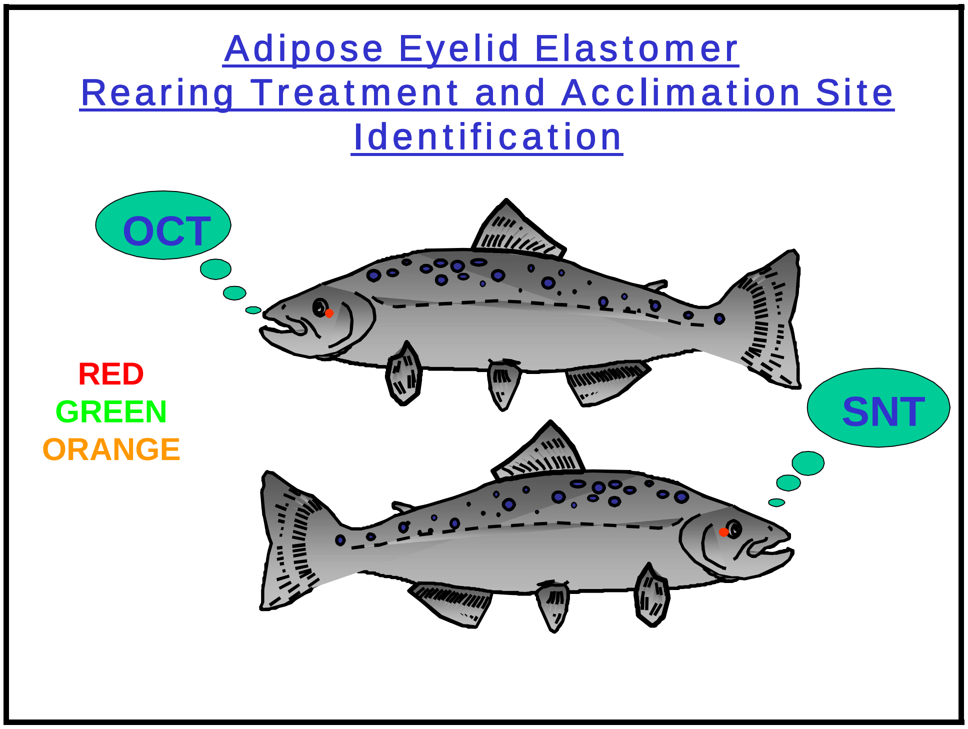


Coded Wire Tagging Operation

- •Raceway Specific Binary Codes
- •100% Fish Marked
  - •All Adipose fin clipped
  - •PIT tagged fish snout tag
  - •All 18 raceways body CWT & VIJ

Figure 15. Summary of the marking activities that occur at Cle Elum Supplementation and Research Facility for upper Yakima spring chinook.

Figure 16. A juvenile spring chinook being body tagged with a CWT.



Adipose Eyelid Elastomer Rearing Treatment and Acclimation Site Identification

OCT

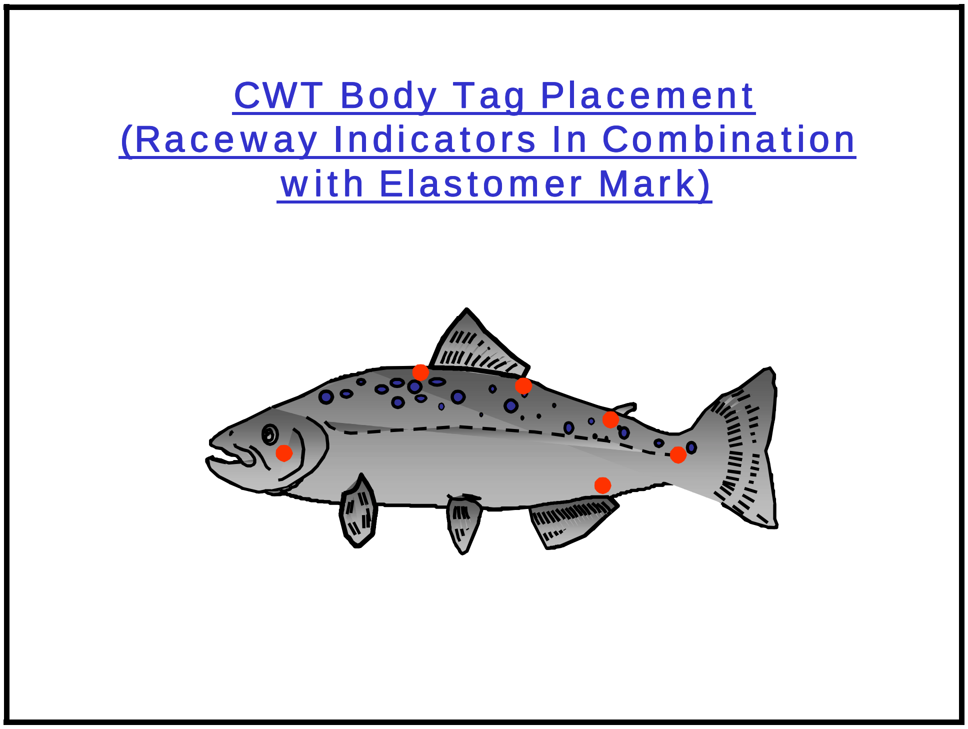
SNT

RED

GREEN

ORANGE

Figure 17. Depicts the use of elastomer marks to distinguish the OCT and SNT treatment groups.



CWT Body Tag Placement (Raceway Indicators In Combination with Elastomer Mark)

Figure 18. The locations used for CWT body tagging to identify each fish with a specific raceway, acclimation pond, and treatment.

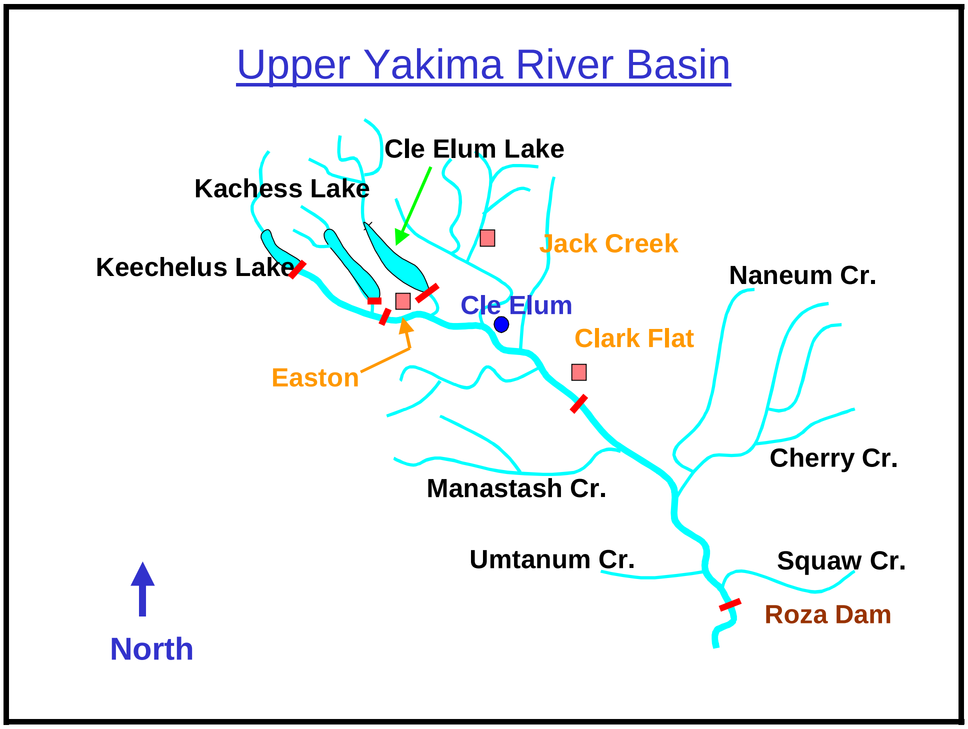


Figure 19. Map of the upper Yakima basin highlighting the location of the three Cle Elum Supplementation and Research Facility acclimation sites.

Figure 20. Aerial view of the Clark Flat acclimation site located near Thorp, Washington.

Figure 21. An upstream view at the Easton acclimation site of one of the SNT acclimation raceways.

Figure 22. Spring chinook smolts with PIT tags are interrogated as they exit from their respective acclimation sites (Easton, N.F.Teanaway and Clark Flat).

Task 1.g Roza Juvenile Wild/Hatchery Spring Chinook Smolt PIT Tagging

Rationale: To capture and PIT tag wild and hatchery spring chinook to estimate wild

and hatchery smolt-to-smolt survival to CJMF and the lower Columbia River projects.

Methods: Five rotary traps will be located below Roza dam to capture wild and hatchery spring chinook smolts. In addition the Roza juvenile fish bypass trap will also be used to capture smolts.

Progress: The Roza juvenile fish bypass trap began operation on January 31, 2001 and ended on April 24, 2001. We trapped a total of 10,241-spring chinook in the juvenile by-pass for the season. Of the 10,241, 8,062 were adipose clipped or hatchery fish, of those 307 already contained PIT tags from the hatchery. An additional 1,437 hatchery fish were subsequently PIT tagged and released. The remaining 2,179 wild spring chinook out of the 10,241 fish total were subsequently PIT tagged and released.

Task 1.h Yakima River Wild/Hatchery Salmonid Survival and Enumeration (Chandler Juvenile Monitoring Facility; CJMF)

Rationale: As referenced in the YKFP Monitoring Plan (Busack et al. 1997), CJMF is a vital aspect of the overall M&E for YKFP. The baseline data collected at CJMF includes: stock composition of smolts, outmigration timing, egg-to-smolt and/or smolt-to-smolt survival rates, hatchery-v-wild and hatchery optimum conventional treatment (OCT) reared fish-v-hatchery semi-natural treatment (SNT) reared fish survival rates (spring chinook). Monitoring of these parameters is essential to determine whether post-supplementation changes are consistent with increased natural production. This data can be gathered for all anadromous salmonids within the basin.

In addition, the ongoing fish entrainment study is used to refine smolt, both present and historic, as adjustments are made to the CJMF fish entrainment to river discharge logistical relationship.

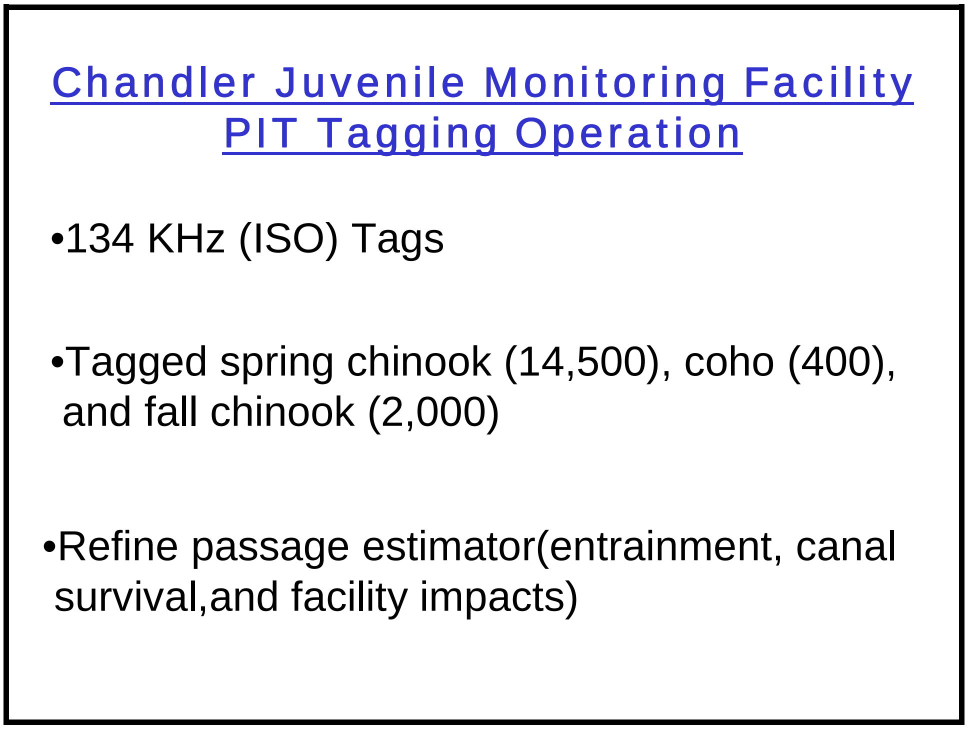
Methods: The CJMF operated on an annual basis, from the fall of 1998 through mid-July 1999, and was restarted December 7, 1999 through mid-July 2000. The CJMF ceased operation when the fall chinook smolt outmigration ended in June or mid-July, and began again in the fall after the annual canal maintenance is finished. Estimated fish passage was based on the experimentally derived fish-entrainment relationship. A sub-sample of salmonid outmigrants is biosampled on a daily basis and all PIT tagged fish interrogated.

Replicate releases of PIT tagged smolts were made in order to estimate the fish entrainment rate in relation to river discharge. The entrainment rate estimates were used in concert with a suite of independent environmental variables to generate a multi-variate smolt passage relationship used to develop current, future and passage estimates with confidence intervals.

Hand held CWT detectors were used to scan for body-tags on hatchery spring chinook smolts. This is a monitoring and evaluation protocol is built in as a backup in the event that the corresponding PIT tagged fish from each treatment group (OCT/SNT) failed to be accurately detected by the PIT detectors stationed at the CJMF. Fortunately, there was good correspondence between the detection rates between the two mark groups.

Progress: The final 2000 smolt outmigration numbers were as follows: wild spring chinook– 61,513; OCT spring chinook– 109,087; SNT spring chinook– 116,020; wild fall chinook– 198,002; Marion Drain hatchery fall chinook– 5,285; wild coho– 37,359; hatchery coho– 165,056; and wild steelhead– 42,696.

Personnel Acknowledgements: Biologist Mark Johnston and Fisheries Technician Leroy Senator are, respectively, the project supervisor and on-site supervisor of CJMF operations. Biologist John McConnaughey is responsible for the analysis of data collected at the facility. Other Technicians that assisted are Sy Billy, Joe Hoptowit, Jerry Evans, Morales Ganuelas, Tammy Swan and a varying number of seasonal temporary Fisheries Technicians.



Chandler Juvenile Monitoring Facility
PIT Tagging Operation

•134 KHz (ISO) Tags

•Tagged spring chinook (14,500), coho (400), and fall chinook (2,000)

•Refine passage estimator(entrainment, canal survival,and facility impacts)

Figure 23. A summary of the key points of the PIT tagging task that occurs at the Chandler Juvenile Monitoring Facility to estimate smolt entrainment rate.

Figure 24. Aerial view of the Yakima River at Prosser, Washington showing the dam and Chandler Canal (left bank) where the CJMF, video monitoring and Prosser Hatchery are located.

Figure 25. Composite photo depicting the key sampling components at the Chandler Juvenile Monitoring Facility.

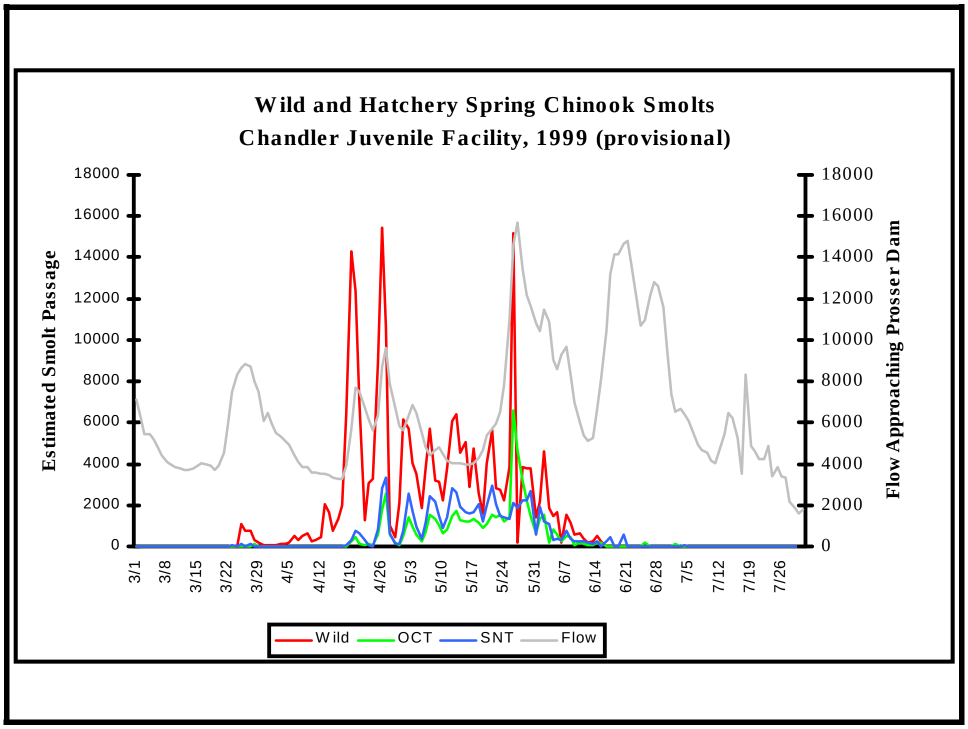


Figure 26. Spring chinook smolt outmigration timing at CJMF for wild, OCT and SNT type fish with respect to flow.

Task 1.i Yakima River Fall Chinook Optimal Rearing Treatment

Rationale: To determine optimal release timing to increase overall smolt and smolt-to-adult survival, and to investigate the general life history of wild Yakima River fall chinook.

Method: Approximately 325,000 fall chinook smolts were produced from fish spawned during the fall of 1999. These smolts were divided into two equal groups. One group was reared using conventional methods using ambient river temperature incubation and rearing profiles. The other group was incubated and reared using warmer well water to accelerate emergence and rearing and ultimately smoltification. Both groups of fish were spawned, incubated and reared at the Prosser Hatchery. Fish from both groups were 100% marked using ventral fin clips (pelvic fins), and approximately 2,000 fish from each group were PIT tagged to evaluate survival and migration timing to the lower Columbia River. Approximately 1,000 PIT tagged Marion Drain hatchery fall chinook juveniles were released to estimate survival from Marion Drain Hatchery to CJMF and McNary Dam. We monitored water temperature and the juvenile wild fall chinook growth profile within the mainstem Yakima River in the spring of 2000 to help determine whether or not temperature may be limiting fall chinook production above Prosser Dam.

Progress: Growth profiles of naturally rearing fall chinook juveniles in the lower Yakima River were successfully monitored via beach seining approximately 2-3 times per month. Juvenile fall chinook passage at the CJMF was used as an index of passage in order to direct the field sampling effort. The project successfully collected biological data from the approximately 138 fall chinook spawned at Prosser Hatchery during the fall of 2000. Juvenile survival indices for PIT tagged groups released from Prosser Hatchery in the spring of 2000 suggest that the conventional group survived at a higher rate than did the accelerated group (0.817 and 0.428 respectively). Survival of those juvenile chinook released from Marion Drain had the lowest index of survival (0.271). A detailed explanation and discussion of growth profiles of wild fall chinook rearing in monitoring sites in the lower Yakima River, and survival indices of hatchery fish are presented in the 2000 project annual report.

Task 1.j Yakima River Coho Optimal Stock, Temporal, and Geographic Study

Rationale: To determine the optimal location, date, and stock of release to maximize the feasibility of coho re-introduction into the Yakima Basin, and to determine the spawning distribution of returning adults.

Method: A nested factorial experimental design was intended to be used to test for survival differences between out of basin hatchery and Prosser Hatchery stocks; release location (upper Yakima and Naches subbasins); and release date (May 7 and May 31). A total of 485,000 and 15,000 smolts of out of basin and Prosser Hatchery stocks, respectively, were intended for release in the upper Yakima and Naches sub-basins (1,000,000 total). Each release date had two replicates per sub-basin (128,750 smolts per replicate). Within each replicate 2,500 coho smolts were PIT tagged (1,250 out of basin stock and Prosser Hatchery stock were intended to be PIT tagged) to evaluate survival to CJMF and lower Columbia projects. In addition to PIT tags to monitor juvenile survival, a portion of the smolts were CWT'ed in order to assess the survival of returning adult to Prosser Dam. The program had intended to 100% mark the 30,000 locally produced, and the 970,000 out of basin with CWT in order to monitor smolt-adult survival, and relative wild contribution of both smolt and adult coho production. In order to determine the relative abundance of hatchery coho smolt residuals, we conducted surveys in the upper Yakima and Naches rivers to enumerate coho that did not migrate during the spring.

Progress: Success of the Yakima/Klickitat Fisheries Program's (YKFP) efforts to re-introduce coho to the Yakima River is reliant upon the use of hatchery fish to develop naturalized spawning populations. The first milestone that must be achieved is the return of sufficient numbers of adults to either spawn naturally or to be spawned in a hatchery. Optimizing the date and location of release of hatchery coho may be a promising method of increasing returns of coho salmon. A literature review tends to indicate that survival increases with a later release date, and even though not definitive, previous results in the Yakima basin also suggest that later releases may out perform early releases in terms of juvenile survival (YN 1997). The optimal release date or location(s) for juvenile coho in the Yakima basin are not known at this time. Adult coho returns to the Yakima River have increased in recent years; however, the spawning distribution of returning adults is not well described.

Until recently, the project has relied entirely upon the transfer of lower Columbia River hatchery coho to produce adult coho returns in the Yakima basin. If viable self-sustaining populations of coho are to be re-established in the Yakima River, parent stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and the Yakima River. We are optimistic that the project will observe positive trends in coho survival in the Yakima basin as the program develops a localized broodstock.

- We estimated that smolt-to-adult survival rate for 1.4 million hatchery coho smolts released in the Yakima basin in 1999 was 0.567%.

- Survival estimates of juvenile coho released in the Yakima basin in the spring of 2000 to McNary Dam for eight groups of PIT tagged coho decreased compared to survival estimates from 1999 (2000 mean = 20.0%; 1999 mean= 40.2%). Although no significant differences between subbasin and time of release were indicated in 2000, the early releases had higher survival rates than late releases at all sites except Stiles site where significant mixing between early and late release groups occurred.

- PIT tagged juvenile coho released during the early (May 7) period generally passed McNary Dam earlier than those released during the late (May 31) period, even though mean travel time was generally lower for groups released during the late release.

- We collected and radio tagged 102 adult coho at the Prosser Dam right bank steep pass denil over the period September 14 – November 6. Prosser right bank worked relatively well for collection of coho for radio telemetry. However, relatively low efficiency at this facility (approximately 30%) would limit the effectiveness during low return years.

- Most radio tagged adult coho homed to the mainstem Yakima River below the city of Selah, Washington (Rkm 196) downstream to Rkm 80. Few adult coho homed back to acclimation sites, which juveniles were released from. Coho spawning in the Yakima peaked the first week of November and was generally complete by mid-November.

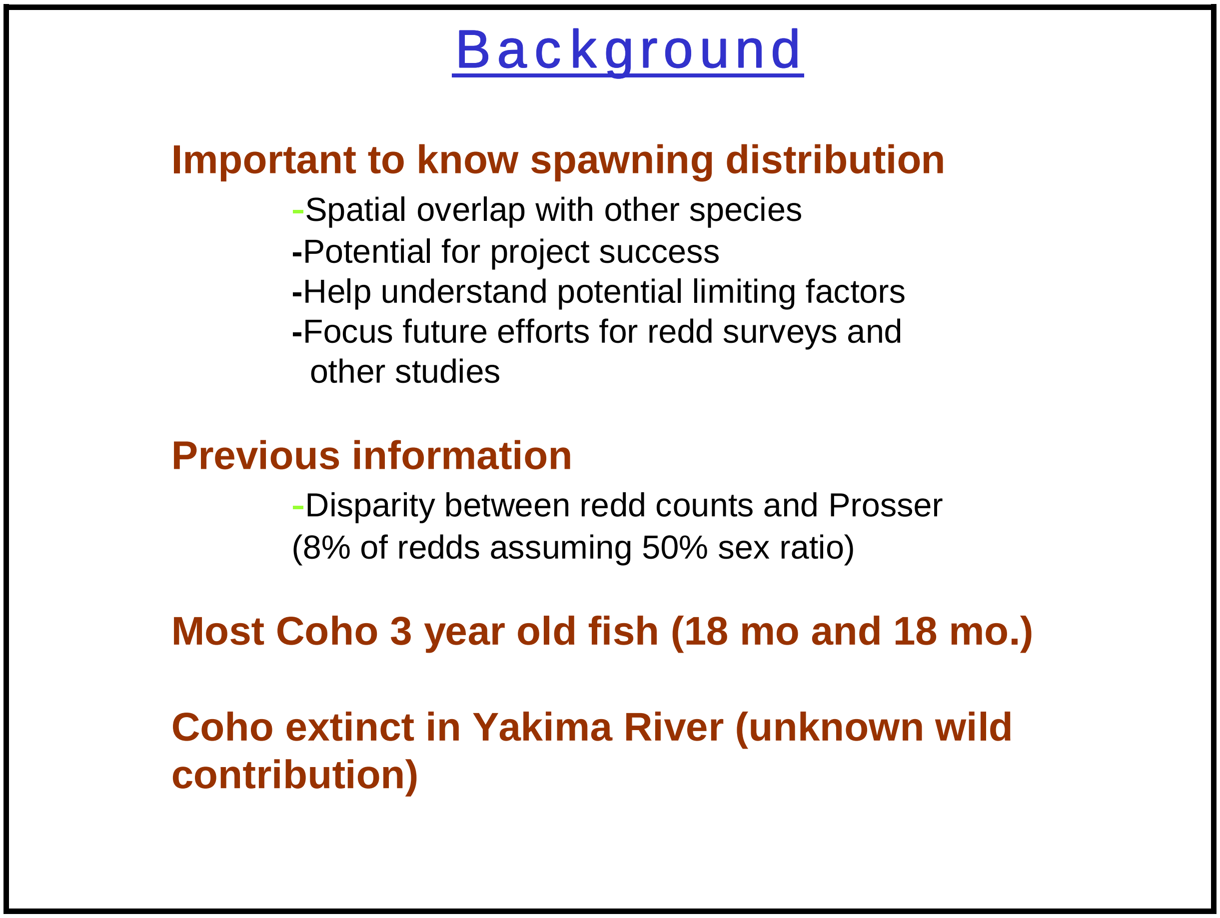
- Summer water temperatures may be an important limiting factor for the progeny of coho that spawned below Sunnyside Dam. The release of 100% marked hatchery coho in 2002 will aid in the estimation of the reproductive fish that spawned in 2000.

- Estimates of the average number of residual coho in the upper Yakima and Naches subbasins were relatively low in 2000. We estimated that more coho were present in the Naches Subbasin than the upper Yakima (67.8 and 14.7 coho per km respectively). We in part attribute the higher estimated number of coho in the Naches to natural coho production in that reach. Estimates of the number of coho residuals per km between 1999 and 2000 were similar when expressed as a per capita of coho released.

- The Yakama Nation estimated that a total of 6,138 adult coho passed Prosser Dam in 2000. We collected a total of 483 coho broodstock at the Prosser Dam right bank steep pass denil over the period September 11 – November 8. Fish were collected in relative proportion to the overall run passing Prosser Dam.

- We estimated that a total of 167,910 and 31,070 hatchery and natural origin coho smolts, respectively, passed Prosser Dam in the spring of 2000. Egg-to-smolt survival for natural origin coho from the 1998 brood year was 0.43%. We attribute the low egg-to-smolt survival to poor habitat conditions (especially summer rearing temperatures and gravel quality) in the mainstem Yakima River below Sunnyside Dam.

- Through a combination of weir trapping and electrofishing, we estimated that naturally spawning coho in Buckskin Creek had an average egg-to-fry survival rate of 1.2% (95% confidence interval 0.8 – 1.6%) for the 1999 broodyear. We attribute the low survival to poor quality and quantity of spawning habitat within this urban stream.



Background

Important to know spawning distribution

-Spatial overlap with other species
-Potential for project success
-Help understand potential limiting factors
-Focus future efforts for redd surveys and other studies

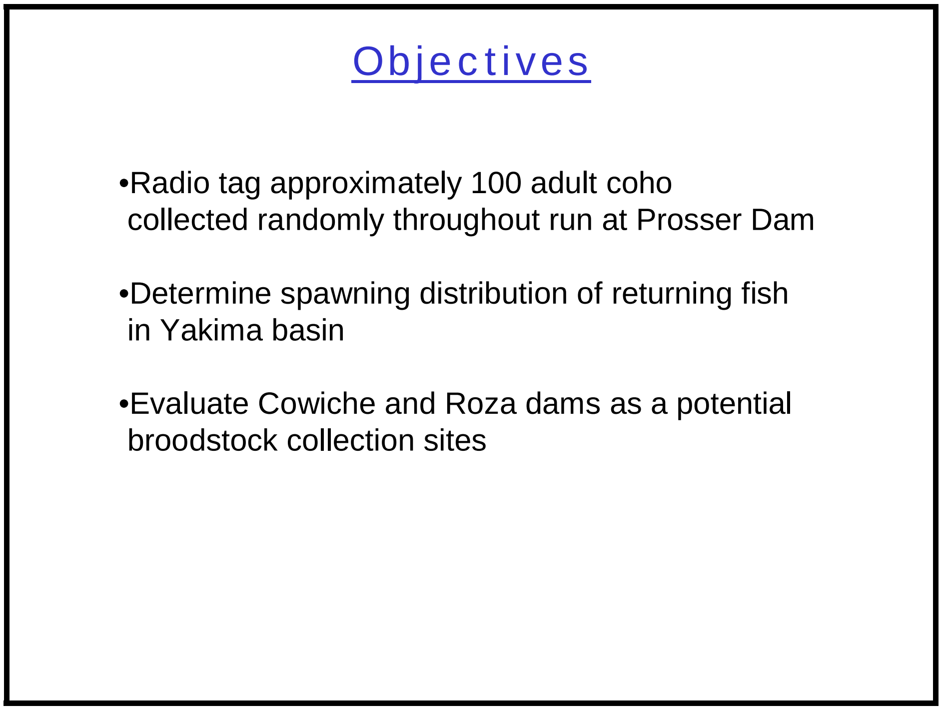
Previous information

-Disparity between redd counts and Prosser
(8% of redds assuming 50% sex ratio)

Most Coho 3 year old fish (18 mo and 18 mo.)

Coho extinct in Yakima River (unknown wild contribution)

Figure 27. Key reasons why the radio telemetry study is being conducted for Yakima Basin coho.



Objectives

- Radio tag approximately 100 adult coho collected randomly throughout run at Prosser Dam
- Determine spawning distribution of returning fish in Yakima basin
- Evaluate Cowiche and Roza dams as a potential broodstock collection sites

Figure 28. The three key objectives of the Yakima Basin coho radio telemetry study.

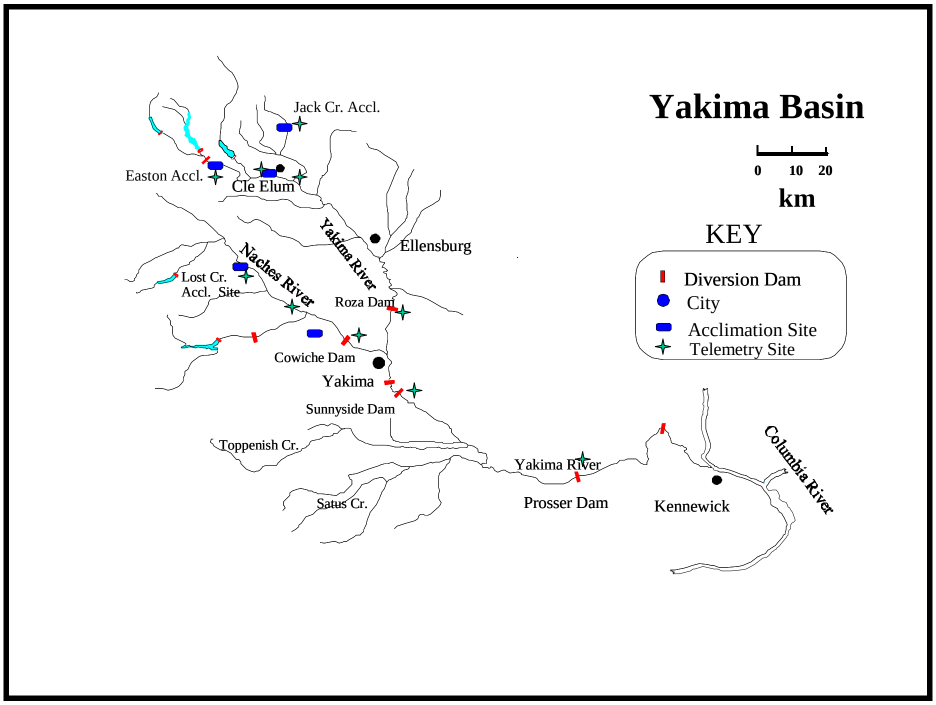
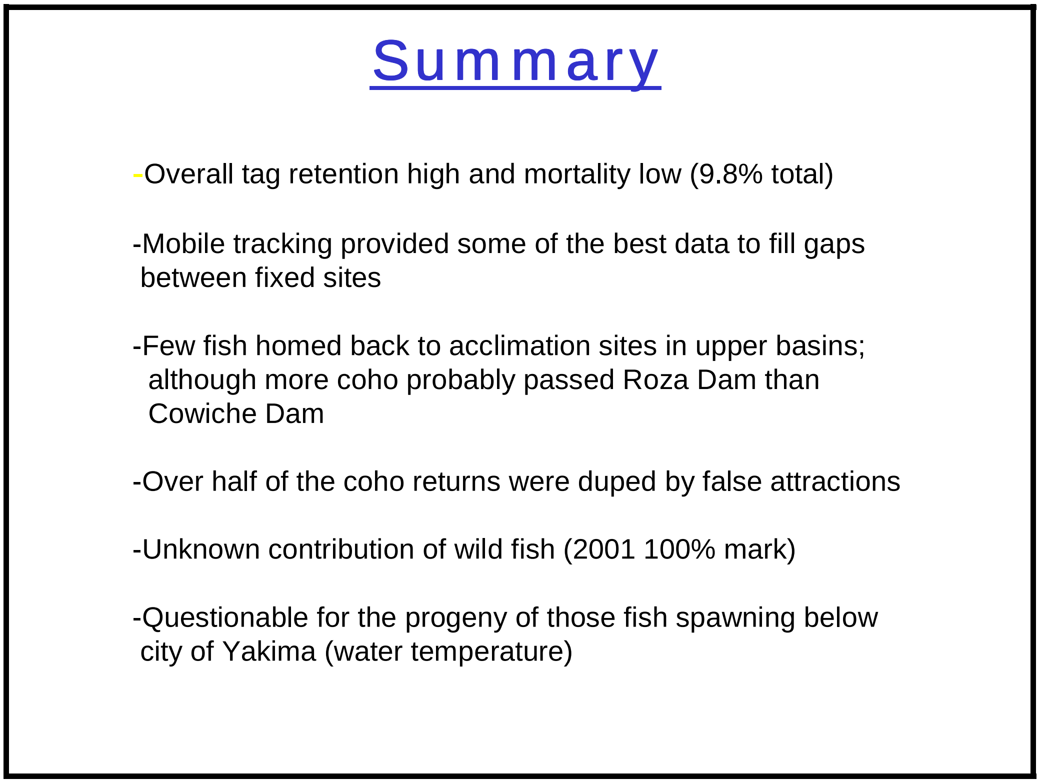


Figure 29. A map depicting the various radio telemetry monitoring sites within the Yakima Basin.



Summary

-Overall tag retention high and mortality low (9.8% total)

-Mobile tracking provided some of the best data to fill gaps between fixed sites

-Few fish homed back to acclimation sites in upper basins; although more coho probably passed Roza Dam than Cowiche Dam

-Over half of the coho returns were duped by false attractions

-Unknown contribution of wild fish (2001 100% mark)

-Questionable for the progeny of those fish spawning below city of Yakima (water temperature)

Figure 30. Key findings of the coho telemetry study being conducted in the Yakima Basin.

Task 1.k Yakima Spring Chinook Juvenile Behavior

Rationale: The present study is part of an effort to evaluate the rearing of Spring Chinook salmon (*Oncorhynchus tshawytsha*), at the Cle Elum Supplementation and Research Facility near the headwaters of the Yakima River in South Central Washington. Yearling smolts from two hatchery treatment groups OCT (Optimal Conventional Treatment) and SNT (Semi Natural Treatment) were compared to wild smolts in an experiment designed to assess differences in cover utilization, and survival to a predation threat.

Methods: The experiment was conducted at the Cle Elum Supplementation and Research Facility (CESRF). CESRF is a Spring Chinook hatchery located on the Yakima River near the headwaters on the eastern slopes of the Cascade Mountains in South Central Washington. CESRF is 832 river kilometers from the Pacific Ocean. The Yakama Nation operates CESRF, with funding provided by the Bonneville Power Administration. It's mission is help restore runs of Spring Chinook in the Yakima Basin by raising and releasing the progeny of wild fish into the Yakima River.

Pumped ground water from the CESRF's well field was used for the aquarium and fish holding tanks, the temperature was a nearly constant 9.8^{o} C. The water delivery system ensured the water was degassed and oxygenated. Water flow into the tanks was not measured, but flow through was sufficient to replace the total volume several times per day. A rack of four incandescent lights suspended over the aquarium provided lighting, which were controlled by both a dimmer and a timer switch. Some ambient light was also available through windows, and the blinds were left open to provide normal day lengths. A one HP irrigation pump was used to provide a current through the aquarium. Water was pulled from the drain at one end of the aquarium, and pumped into the headworks at the other end. The headwork consisted of two parallel two inch PVC pipes submerged at about 5 cm and 17 cm from the bottom. Water exited these pipes through a series of _mm holes pointed towards the drain.

Smolts from the three treatment groups (OCT, SNT and Wild) were introduced into a 10' x 4' x 3' aquarium containing cover objects (rocks, submerged snag) and a predator threat (Pikemouth minnows).

Elastomer marked OCT and SNT smolts, spawned and reared at the Cle Elum Facility, were used for ease of identification. OCT smolts were marked with an adipose fin clip and a red elastomer mark injected into the clear tissue behind the fish's left eye. SNT fish were also adipose fin clipped and had a green elastomer tag behind the right eye. These marks had been applied in October-November 1998 as a part of the marking program for all Cle Elum hatchery fish. Wild fish used in this experiment had no clips or marks, and were collected at a smolt enumeration and marking station at Roza Dam between 2 and 10 days prior to use in this experiment.

All surviving smolts were collected, anesthetized, and measured at the end of each replicate. Initially, we did not measure smolts at the start of the replicate due to fears that the stress and trauma would adversely affect the behavior study. This procedure, however, only gave us lengths of the surviving smolts, making it difficult to analyze length as a covariate to survival or time spent in cover. Beginning with replicate #10
we anesthetized and measured the smolts, and placed them in separate containers 24 hours prior to the start of the replicate. The container (20 liter bucket with lid and fitted with a hose and running water) was then lifted into the behavior arena, and lid removed to allow smolts to swim freely into the behavior arena. This gave the smolts a recovery period from the handling, and also eliminated netting and handling effects immediately prior to introduction into the behavior arena.

Northern Pikeminnows were used as the predator threat in this experiment. These were collected via boat electroshocking from the Zillah reach of the Yakima River in February 1999, and maintained in tanks at the Cle Elum facility, for the duration of this study. While in the holding tanks, the pikeminnows were not fed for up to a week before being used in a behavior trial. Seven to nine Pikeminnows were placed in the aquarium before the start of each replicate.

For each replicate, five smolts from each treatment were introduced in sequence, into the aquarium. The order of introduction of the smolts was completely counterbalanced yielding 6 orders in which one group was introduced and observed for 30 minutes before introducing the next group. The second group was introduced and observed for 30 minutes before the introduction and observation of the last group.

Typically, upon introduction, the smolts immediately dove to the bottom of the tank, and those that chose to hide under cover would do so in the first 10-15 seconds, where they would remain for periods up to an hour before immerging. Upon emergence smolts typically swam to an open area of the tank just downstream of the head box that had current provided by the recirculating pump. There they would maintain station 5 to 20 cm above the bottom. They generally remained in that area for the duration of the experiment, though sometimes would explore the rest of the tank. Occasionally the smolts would return to cover for periods of time, but this was the exception rather than the rule.

During the observation period we noted the position of each smolt, and the time when the smolt emerged from cover up to a maximum score of 30 minutes. The observation period for each replicate ended 30 minutes after the 5 smolts comprising the last group was added. At this point, approximately, 90 minutes 2 hours after the introduction of the first group of smolts, most or all of the 15 smolts would be out of cover and swimming in the tank with the majority of these schooling in an open area in the high velocity zone created by the recirculating pump.

Initially, we trapped the Pikemouth in an area at the rear of the aquarium with a sliding partition during our observations of the smolts, and then release them to begin the predation test. We had assumed that the Pikemouth would feed voraciously on the smolts, and planned to halt the replication when approximately half of the smolts had been eaten.preyed upon and we assumed that the Pikemouth would feed quickly on the smolts. This expectation was not born out. The Pikemouth showed little interest in the smolts while the room lights or aquarium lights were on, or when we were observing them. so we did not employ sliding partition thus allowing the Pikemouth access to the whole aquarium and smolts in the majority of the tests. Rather, we simply poured the smolts from a bucket directly into the aquarium containing the Pikemouth and assessed predation and the smolts reaction to cover simultaneously The Pikemouth showed little interest in the smolts during the observation periods and we never observed the Pikemouth to prey on the smolts. Except for one smolt that was eaten during a behavior replicate, all predation that occurred happened when the room lights were dimmed below the point where we could make observations, or when we were not present. during the daylight hours in which we observed the aquarium. Often we left smolts and Pikemouth in the aquarium for 48 to 96 hrs in order to obtain our target predation level (1/2 of the smolts). before we started another replication out of frustration as no predation had occurred or following actual predation by the Pikemouth during the dark cycle.

At the end of a replication, the tank was drained and cleaned and the survivors recorded as to which smolt group and belonged, and measured (fork length). Generally, a different batch of Pikemouth (held in a holding tank without food) was placed in the aquarium at the beginning of each new trial.

Progress: Typically, on introduction to the tank, smolts sought refuge in the cover provided, then emerged and moved to an open area more or less in the center of the tank where the current was the greatest. Observers noted the time smolts stayed in cover from the time of introduction until emergence. The order of introduction did not significantly affect the time the smolts remained in cover and no significant difference was found between OCT and SNT smolts in either time spent in cover or survival of the predation threat. In contrast, wild fish stayed in cover significantly longer than hatchery fish, and survived the predation challenge at significantly higher rates even though the surviving wild smolts were significantly smaller than the surviving smolts in the hatchery groups. Qualitative observations also revealed little difference between the OCT and SNT smolts. In comparison to wild smolts, the hatchery fish appeared less adept at concealing themselves in cover. Wild smolts also tended to swim less, i.e. when under a rock or in cover they appeared at rest on the substrate, whereas hatchery fish were almost always swimming.

Personnel Acknowledgements: John McConnaughey, (YKFP Research Center) and Terry DeVietti (CWU Psychology Dept), Jason Rau, (Cle Elum Research and Supplementation Facility).

Task 1.l Yakima Spring Chinook Juvenile Morphometric/Coloration

This task is assigned to WDFW and they will report on its status.

Task 1.m Yakima Spring Chinook Smolt Physiology

This task is assigned to NMFS and they will report on its status.

Task l.n Klickitat Feasibility Study of Mobile Juvenile Sites

Rationale: To determine the feasibility of using rotary traps to monitor long term juvenile salmonid outmigrants in the upper and lower Klickitat River.

Methods: Rotary traps located above Castile Falls, at the WDFW Klickitat hatchery and near RM 6 in the mainstem river were fished, as nearly as possible, on a year-round basis. Calibration releases were conducted for each trap to determine the feasibility of establishing a fish entrainment to river discharge relationship.

Progress:

Upper Trap

The upper trap was fished from June 21, 2000 to November 27, 2000 at RM 67. During this period the predominate species collected was resident rainbow trout followed by hatchery spring chinook. In addition to species abundance, the catch data was used to analyze two hatchery spring chinook releases into the upper basin. The two releases consisted of the annual release of fed fry into the upper Klickitat mainstem in May, followed by a second release of summer parr in upper Diamond Fork Creek in August. The trap data and tributary population surveys were used to assess release strategies.

Hatchery Trap

The hatchery trap was fished at RM 44 for the entire reporting period. During this period of operation the predominate species collected was rainbow/steelhead followed by hatchery spring chinook.

Lyle Trap

The Lyle trap was fished at RM 6 for the entire reporting period. During this period of operation the predominate species collected was hatchery fall chinook followed by hatchery coho.

Entrainment relationship

A total of 24 marked releases were conducted using hatchery spring and fall chinook and hatchery coho at the Lyle rotary trap. No analysis has been conducted to develop a flow to entrainment relationship on these releases during this reporting period. However, detailed flow, environmental and rotary trap rotation information was collected for future analysis. Previous releases and analysis have shown a poor release to recapture rate and poor statistical confidence.

Habitat Analysis

Two TFW habitat surveys were conducted during this reporting period. A site was selected on Brush Creek (a tributary of White Creek) to characterize habitat for future inclusion to the EDT model. To provide pre-habitat restoration documentation a TFW transect was conducted on the Little Klickitat River downstream of the town of Goldendale. This site was located within an area to receive riparian fencing and bank stabilization activities conducted under the Lower Klickitat Riparian and In-Channel Restoration Project #199705600. This information will provide both a per-habitat restoration baseline, as well as, future refinement of EDT analysis of the Little Klickitat River system.

Limited TFW were conducted during this reporting period while field crews concentrated on culvert inventory described under Task 1.B

Genetic Sampling

In both 2000 and 2001 the Lyle and Hatchery traps were used to collect non-lethal DNA/ allozyme tissue samples from wild steelhead smolts emigrating from the Klickitat basin (April to June). Analysis of these samples will be used to refine existing stock information of steelhead populations within the Klickitat basin.

Task 1.o Adult Salmonid Enumeration at Prosser Dam

Rationale: To estimate the total number of adult salmonids returning to the Yakima Basin by species (spring and fall chinook, coho and steelhead), including the estimated return of externally marked fish (i.e., CWT). In addition, biotic and abiotic data is recorded for each fish run. Various YKFP biologists and managers ultimately use this information for project monitoring and evaluation purposes, and for policy/management decisions.

Methods: Monitoring is accomplished through use of time-lapse video recorders (VHS) and a video camera located at each of the fishways. The videotapes are played back and various types of information/data are recorded for each fish that passes.

Progress:

Spring Chinook (2000 run)

An estimated 19,159 spring chinook were counted past Prosser Dam. The total adult count was 17,529 (91.7%) fish, while the jack count was 1,589 (8.3%) fish. Of the adult count, 41 were identified as hatchery origin. These were all assumed to be out-of-basin strays, given that only YKFP jacks were returning in 2000. The ratio of wild jacks to hatchery jacks was 59.5% to 40.5%, respectively. The hatchery jacks were of YKFP origin released as smolts in 1999. Sixty-one percent of the fish migrated through the left fishway, followed by 29% and 10%, respectively, at the center and right fishways.

The 25%, 50% and 75% dates of cumulative passage were May 5, May 11 and May 19, respectively.

The estimated mean fork length for adults (wild and hatchery) and jacks (wild and hatchery) was 64.3 cm and 45.6 cm, respectively. The estimated video fork length for adults was 7.2 cm smaller than that measured "hands-on" at Roza in the broodstock collection. The difference between jacks was less than one centimeter. This suggests that video based fork lengths measured at Prosser underestimate the true fork length. It's believed this is a result of a "mismatch" in the applied multiplier value (video length x multiplier value = true length) relative to the horizontal passage trajectory of the fish as it passes by the viewing window. This bias in underestimating the actual fork length is being examined for the 2001 spring and fall runs.

Fall Run (coho and fall chinook)

Coho (2000)

The estimated coho run was 6,138 fish. It should be mentioned that an undetermined number of fish "dropped out" below Prosser Dam and are not reflected in this count. Some fish were harvested while others were falsely attracted into tributaries such as Spring Creek. Adults comprised 95.2% and jacks 4.8% of the run. A total of 465 adipose clipped fish were counted, 445 were adults and 20 were jacks. Fish passage amongst the three fishways was as follows- right: 40.2% (of this the Denil was 10.2%), center: 26.8% and left: 33.0%.

The 25%, 50% and 75% dates of cumulative passage were September 30, October 10 and October 19, respectively.

The estimated mean adult and jack fork length was 59.2 cm and 38.4 cm, respectively. The adult length was 7.3 cm smaller than that measured for fish collected at the Denil for broodstock (66.5 cm average). The range in mean fork lengths between the three fishways was minimal (adults- 58.1 to 60.4 cm; jacks- 37.9 cm to 39.0 cm).

Fall Chinook (2000 run)

Estimated fall chinook passage at Prosser Dam was 2,413 fish. Adults comprised 79.3% of the run, and jacks 20.7%. Of the total number of fish, 247 were adipose clipped, 188 fish were adults and 59 fish were jacks. The median passage date was September 24, while the 25% and 75% dates of cumulative passage were September 6 and October 15, respectively.

Most fish passed through the left fishway (57.3%), followed by the center (27.1%) and right (15.6%; the Denil accounted for 5.6% of the 15.6%).

The mean adult and jack fork length was 76.9 cm and 46.4 cm, respectively. The mean fork length for adults and jacks at the three fishways was right- 74.8 cm and 46.6 cm; center- 78.7 cm and 45.1 cm; and left- 76.4 cm and 52.3 cm, respectively.

Steelhead (1999-00 run)

The estimated steelhead run was 1,611 fish. Of the total, 40 adipose clipped fish, which were all out-of-basin strays since no hatchery returns were expected to the Yakima River. The median passage date was October 14, 1999, while the 25% and 75% cumulative dates of passage were October 14 and December 1, respectively.

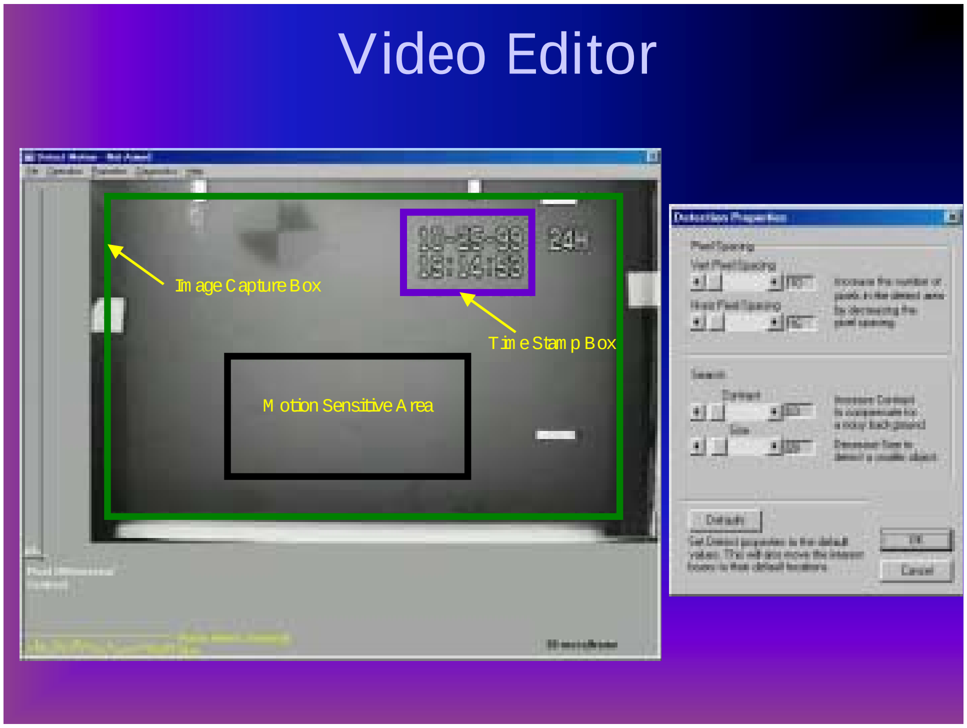
The mean fork length was 57.4 cm, and fish ranged in size from 42.1 cm to 88.3 cm.

Video Editor

Phase II work was completed and delivered by the subcontractor Vision1 in February 2000. The system consists of four units, with each unit including a PC, camera and support software. To date the video monitoring system has been tested in the office by playing existing video tapes with fish on them through the image capture software. Results from these tests are mixed. On the positive, the system is able to detect fish motion of interest and to some degree “filter out” fish of non-interest. The system appears it will work reasonably well on tapes with low numbers of fish on them. However, tapes will high numbers of fish may prove difficult to accurately count. The biggest drawback identified at this time is the inability to accurately determine the directional (up or down) movement of individual fish in order to conclude whether the fish actually passed or “fell back”. This problem was not anticipated at the outset. The problem is the result of the system outputting a time series of individual images (opposed to video clips, i.e. mpeg or avi files) taken in rapid succession. To overcome this problem Phase III work will consist of replacing the existing still frame capture card in the PC with a video motion card. I have been communicating with a biologist in the Great Lakes who is using this technology to count salmon in a river system similar to here in the Yakima. The video clips (avi file format) that he sent demonstrated that motion video allows for the reader to accurately determine the directionality of the fish. There also may be some structural changes that could be made at the fish ladders to improve the “possibility” of salmon, as well as, screen out non-target species. These will be discussed with the BOR in 2001.

Personnel Acknowledgements for 1.o & 1.p: Biologists, Melinda Davis and Joel Hubble, and Fisheries Technicians Winna Switzler and Florence Wallahee.

Figure 31. Shows the adult fish video monitoring video editor (Phase II), designed to capture and store to the PC harddisk target fish.



Video Editor

Figure 32. Depicts various components and filtering parameters of the video editor (I.e., detection box, time/date box, contrast and pixel density).

Task 1.p Adult Salmonid Enumeration and Broodstock Collection at Roza/Cowiche Dams

Rationale: To estimate the total number of adult salmonids returning to the upper Yakima Basin for spring and fall chinook, coho and steelhead) at Roza Dam, and for coho only into the Naches Basin at Cowiche Dam. This includes the count of externally marked fish (i.e., adipose clipped fish). In addition, biotic and abiotic data is recorded for each fish run.

Methods: Monitoring was accomplished through use of time-lapse video recorders (VHS) and a video camera located at each fishway. The videotapes were played back and various types of information/data are recorded for each fish that passes. Spring chinook passing Roza Dam are virtually entirely enumerated through the Cle Elum Supplementation and Research Facility broodstock activity.

Progress:

Roza Dam

Steelhead

A total of 108 steelhead were counted past Roza Dam for the 1999-00 run. Typical of past years, few fish migrated in the fall portion of the run through December 31 (3 fish), while 105 fish migrated from January 1 through June 30. Most fish (63%) migrated past Roza Dam in April.

Spring Chinook

At Roza Dam 12,327 (90% adults and 10% jacks) spring chinook were counted at the adult facility between April 26 and September 8, 2000. Of the jacks, 56% were hatchery origin and 44% natural. The hatchery jacks were the first returns from the Cle Elum Supplementation and Research Facility (BY1997). The mean passage date for adults and jacks was May 22 and June 17, respectively.

Cowiche Dam

Coho

Coho spawners were monitored at the dam from October 16, 2000 through January 29, 2001. The unusually low river discharge during the fall/winter allowed for an extended monitoring season.

A total of 184 coho were counted passing the fishway, and given the extreme low flow conditions it was assumed no fish were able to jump the dam. Because of the camera configuration at this facility no adult and jack breakdown is possible. The number of fish passing Cowiche Dam represented 3% of the Prosser count. The majority of fish (51%) migrated past the dam in a seven day period from October 27 through November 2. The 25%, 50% and 75% dates of cumulative passage were October 28, October 30 and November 7, respectively. The last fish was counted on December 19.

Personnel Acknowledgements for 1.o & 1.p: Biologists, Melinda Davis and Joel Hubble, and Fisheries Technicians Winna Switzler and Florence Wallahee.

Task 1.q Spawning Ground Surveys (Redd Counts, Yakima & Klickitat Basins)

Rationale: To enumerate the temporal-spatial distribution of spring chinook, fall chinook, steelhead and coho redd deposition in the Klickitat and Yakima basins. To collect biological information from spawned out carcasses.

Methods: Regular foot and/or boat surveys were conducted within the established geographic range for each species (this is increasing for coho as acclimation sites are located upriver and as the run increases in size). Redds were individually marked during each survey and carcasses are sampled to collect-egg retention, scale sample, sex, body length and to check for possible experimental marks.

Progress: **S**pawning ground surveys were completed for all steelhead stocks in the Klickitat and Yakima basins. Results are as follows:

Yakima

Steelhead: Steelhead surveys in Satus and Toppenish basins and Ahtanum Creek began in mid-March and end in late April. Total redd counts by subbasin were as follows: Satus basin-160, Toppenish basin- 185, and Ahtanum Creek- 11. For all three basins a total of 356 redds were counted.

Spring Chinook: Redd counts began in late July in the American River and ended in early October in the upper Yakima River. Total counts for the American, Bumping, Little Naches, Naches, Rattlesnake rivers, and Crow Creek (tributary to the Little Naches) were, respectively, 53, 278, 73, 441, 35 and 7 redds. Redds counts in the upper Yakima, Teanaway and the Cle Elum rivers were, 3,349; 499 and 21, respectively. The entire Yakima basin had a total of 4,723 redds (Naches- 887 redds, upper Yakima- 3,836).

Fall Chinook: Marion Drain fall chinook surveys were not conducted for CY2000.

Coho: Surveys began in early November and ended in late December in the Yakima River basin. A total of 346 redds were located in the Yakima Basin. Surveys were concentrated where radio telemetry fish were located to maximize survey effort. The redd distribution was as follows:

Yakima R.- 142 redds. Most redds were located between the Zillah Bridge and Roza Dam. Two redds were located in the upper Yakima Canyon.

Naches R.- 137 redds. Most redds were located from the confluence to below the Tieton River confluence.

Ahtanum Cr.- 26 redds.

Cowiche Cr.- 6 redds.

Buckskin Cr.- 32 redds.

Teanaway R.- 3 redds.

Klickitat

Steelhead:

2000 Steelhead spawning results

During 2000 survey period, steelhead surveys were conducted in the Klickitat River from RM 3 to RM 64, as well as, in 12 tributaries. A total of 199 redds were enumerated in the Klickitat basin. Of the total, 158 redds were observed in the Klickitat mainstem with the highest concentration of 32 redds (7.6 redds/mile) observed between RM 28.0 and RM 32.2. Tributary spawning accounted for the remaining 41 redds observed in five tributaries. Swale Creek contained the highest number of redds at 16.

2001 Steelhead spawning results

During 2001 survey period, steelhead surveys were conducted in the Klickitat River from RM 3 to RM 64, and in 6 tributaries. A total of 161 redds have been enumerated, of these 137 were located in the mainstem Klickitat River. The highest redd density (4.5 redds/mile) in the Klickitat River is found between RM 24.7 and RM 32.2). Spawner surveys were concluded on June 6th 2001 due to poor river conditions (visibility).

Spring Chinook: Spring chinook spawner surveys were initiated on August 10, 2000. Surveys continued through mid-September 2000. A total of 68 redds were enumerated within the index area of Castile Fall (RM 64) to Big Muddy Creek (RM 54). This year's redd count is 81% of the 12 year (1989-2000) average of 83 redds for the index reach. A total of 106 redds were enumerated through the entire surveyed area from RM 64 to RM 32. No spawning from natural production was observed above Castile Falls.

Results from the release of 220 surplus hatchery fish (60% female and 40% male) above Castile Falls resulted in a total of 64 redds between RM 71 and RM 85. Redds were distributed seven rivermiles upstream and eight rivermiles downstream from the point of release at rivermile 77. No natural origin spawners were found during carcass surveys conducted above Castile Falls in 2000.

Fall Chinook: During this reporting period spawners surveys were conducted bi-weekly from RM 42 to RM 5. A total of 1,627 redds were enumerated in the Klickitat River. This year's redd count is 145% of the six year average (1995-2000) of 1,120 redds.

Coho: During this reporting period coho surveys were conducted in the Klickitat River from RM 51 to RM 5. A total of 336 redds were enumerated between October 17, 2000 and January 24, 2001. No tributary spawning was observed this season as a result of unusually low stream flows that blocked access to spawning tributaries. The 336 redds observed were highest recorded to date. However, this could be a result of low flows and better than average visibility, which allowed for more thorough spawner survey coverage. During the 2000-2001reporting period, a total of 129 redds (155% of the 5 year average) were enumerated in the WDFW Hatchery to Summit Creek index reach.

Personnel Acknowledgements: Klickitat Basin: Lead Biologist, Bill Sharp assisted by Fisheries Technicians Sandy Pinkham, Greg Strom, Rodger Begay, Matt Tomaskin, Isadore Honanie, Roger Stahi and Robert Cruz. Yakima Basin: Lead Biologist, Mark Johnston assisted by Technicians Leroy Senator, Joe Hoptowit, Wayne Smartlowit, Gerald Lewis and Morales Ganuelas.

Figure 33. A pair of wild spring chinook spawners in the Yakima Basin.

Task 1.r Yakima Spring Chinook Spawning Behavior Observations

This task is assigned to WDFW and they will report on its status.

Task 1.s Yakima Spring Chinook Residuals/Precocials Studies

This Task is assigned to WDFW, they will be reporting on status of it.

Task 1.t Yakima River Relative Hatchery/Wild Spring Chinook and Coho Reproductive Success

This Task is assigned to WDFW, they will be reporting on status of it.

Figure 34. The fork length is one of several biotic parameters collected from spring chinook spawners at the Cle Elum Supplementation and Research Facility.

Task 1.u Yakima Spring Chinook Gamete Quality Monitoring

This Task is assigned to WDFW, they will be reporting on status of it.

Task 1.v Scale Analysis

Rationale: To determine age and stock composition of juvenile and adult salmonid stocks in the Yakima and Klickitat basins.

Methods: Scale analysis was used to accomplish this task.

Scale analysis was used to determine the proportion of hatchery vs. wild coho smolts and adult

Figure 35. Eggs from each female spawner are counted to determine fecundity and egg size at the Cle Elum Supplementation and Research Facility.

Figure 36. Each spawner is interrogated to record its PIT tag into the YKFP database.

in the Yakima Basin. Juvenile coho scales were randomly collected from smolts that entered the CJMF. Adult coho scales were taken from broodstock captured at Prosser Dam, right fishway, Denil ladder.

Progress: Scale samples were collected and subsequent analysis performed for several YKFP related tasks. Sample locations and species sampled are listed as follows:

Chandler Juvenile Monitoring Facility- random samples collected from spring and fall chinook, coho and steelhead smolts.
Roza Adult Broodstock and Monitoring Facility- samples from all spring chinook broodstock and returning hatchery adults.
Prosser Dam (Denil ladder)- samples from all coho broodstock.
Yakima spawner surveys- samples from spring chinook carcasses in the Naches and upper Yakima subbasins.
Klickitat basin- samples collected from juvenile salmonids captured in the rotary traps; and samples from fall chinook and coho collected during the spawning ground surveys.

Personnel Acknowledgement: Fisheries Technician Tammy Swan is the scale reader for the Yakama Nation and John Sneva is the scale reader for Washington Department of Fish and Wildlife.

Task 1.w Fish Health Monitoring

Rationale: To monitor and advise project personnel on the fish health issues associated with the adult capture, holding, and spawning, incubation, rearing, acclimation transport, and release of the spring chinook, fall chinook, and coho reared under the YKFP.

Methods: U.S. Fish and Wildlife Service Fish Health personnel conduct various fish health protocols on adults, eggs, juveniles, and pre-smolt releases at each of the YKFP fish rearing facilities: Cle Elum Research and Supplementation Facility and its associated acclimation sites, and Prosser and Marion Drain hatcheries.

Progress: This is a summary of fish health monitoring activities and brief results provided by USFWS.

Prosser fish
During the one year period ending March 31, 2001 a total of 484 fry, fingerling and yearling Prosser-Yakima stock coho were examined for routine fish health monthly monitoring, diagnostics for some mortality problems and extensive certification exams for virus and bacterial fish pathogens. A total of 444 male and female Prosser stock coho were also examined for certifiable virus and bacteria.

Yearling coho (brood year 2000) had a serious bacterial gill disease (Flavobacter) epizootic (December, 2000) but that was easily controlled with applications of the drug Chloramine T.

As fingerling, the 2000 brood coho suffered a bacterial Coldwater disease epizootic caused by *F. psychrophyllum* bacteria beginning in early spring 2000, which was controlled with increased sanitation and thinning the fish to reduce stress and horizontal transfer. A few fish with the slow chronic form of the disease continued to die until release.

Adult coho exam results are from six site visits from 10/17/00 to 12/21/00. No viruses were detected, but low-level Reinibacter salmoninarum (Kidney disease bacteria) and low *A. salmonicida* (Furunculosis bacteria) and normal *Ceratomyxa shasta* sporozoans were detected. These pathogens are fairly normal in most adult salmon and the fish were actually considered fairly healthy.

A total of 22 site visits for diagnostic, routine, and spawning sampling were made during the time period. Overall, the 1999 and 2000 brood coho Juveniles are essentially free of certifiable pathogens.

Marion Drain fish

Six adult fall chinook (brights) were spawned on 10/3 1/00 at Prosser. No virus and low to moderate levels of *R. salmoninarum* and *A. salmonicida* and normal *C. shasta* were detected.

Diagnostic services were performed on Marion Drain fall chinook on April 3, 2000, which verified the presence of gill disease bacteria (Flavobacters), but were much improved over the previous month. Increased sanitation and thinning the fish were low-tech, inexpensive solutions to the problem. A prerelease exam for certifiable fish pathogens was negative. No virus, no bacteria. Total, two site visits in time period, 75 fish examined.

Prosser fall chinook (1999 brood brights)

Fingerling chinook were sampled from 4/24/00 to 5/22/00. No pathogens were detected. Two site visits including one certification, one routine, and one diagnostic (fish smolting).

Prosser fall chinook (1999 brood, Little White Salmon stock)

One routine site visit was made, with no pathogens being found.

Prosser fall chinook (2000 brood adult)

A total of 216 adult male and female chinook were sampled from 10/19/00 to 11/07/00 on 4 sample days. No viruses detected, and low bacterial *A. salmonicida* numbers, moderate *R. salmoninarum* bacteria, and normal numbers *C. shasta* sporozoans.

Prosser fall chinook (2000 brood fingerling)

Two site visits, one certification, and two routine exams. No pathogens detected with the exception of a few myxobacteria in a tail rot lesion, no virus, 91 fish examined.

A total of 182 chinook juveniles of Prosser and Little White stock were examined. Fish were considered healthy.

Coho rearing sites

Sixty fish samples from each of five acclimation sites were examined for prerelease disease certification from 4/10/00 to 4/17/00. No viruses, and no other certifiable pathogens were detected. Sites were: Stiles pond (Willard stock); Naches-Lost Creek (Willard); Klickitat site (Washougal stock); Cle Elum (Willard stock); Easton Pond (Willard stock); and a diagnostic of Cascade coho stock at Leavenworth channel (six fish, low cold water disease bacteria).

Task l.x Habitat Monitoring Flights and Ground Truthing

Rationale: To measure a number of environmental variables by analyzing data extracted from periodic aerial videos.

Methods: An aerial flight using the BPA helicopter was conducted of the Klickitat subbasin in October 1999. A video camera was used to continuously record habitat conditions along the entire Klickitat mainstem and its major tributaries.

Progress: The resultant videotape was used in 2000 as a tool to make refinements to the habitat attributes for Stream Reach Analysis for the Klickitat steelhead, and for the Klickitat spring chinook and steelhead EDT models.

Personnel Acknowledgements: Project biologist Bill Sharp.

Task 1.y Out-of-Basin Environmental Monitoring

Rationale: To obtain and utilize information from outside sources, regarding environmental and harvest-related impacts on all anadromous salmonids occurring outside the Yakima and Klickitat subbasins.

Methods: The method entailed communicating (telephone, E-mail and occasional face-to-face meetings) with various state and federal agencies, other research programs, hatcheries, and university researchers and collecting information regarding out-of- basin environmental and harvest-related impacts on anadromous stocks.

Progress: To date, the only out-of-basin environmental monitoring that has occurred has been downloading data from on-line environmental data banks, especially the Columbia Basin "Data Access in Real Time" web site. Access to this data was free.

Task 1.z Trophic Enhancement Research

This task is assigned to WDFW, thus, they will be reporting on the status of it.

Task 1.A Sediment Impacts On Habitat

Rationale: To monitor stream sediment loads associated with the operation of dams and other anthropogenic factors (e.g. logging, agriculture and road building), which can increase sediment loads in stream utilized by all salmonids in the Klickitat and Yakima subbasins.

Methods: Representative gravel samples were collected from the upper Yakima River (upstream of the Cle Elum River), Little Naches basin, South Fork of the Tieton River, and in the Klickitat basin in the fall of 2000. Each sample was analyzed to estimate the percentage of fine or small particles present (<0.85 mm). The Washington State TFW program guidelines on sediments were used to specify the impacts estimated sedimentation levels have had on salmonid egg-to-smolt survival. These impacts will be incorporated in analyses of impacts of "extrinsic" factors on natural production.

Progress:

Upper Yakima

Sixty samples were collected; with the control reach located above Lake Easton and the treatment reaches extending from Easton to the Cle Elum River confluence. Percent fines ranged from 7% (in the control reach) up to 16.5%.

Naches

In the Little Naches basin 120 samples were collected from the mainstem and several of the tributaries. In addition, 12 samples were collected from the South Fork of the Tieton River. Percent fines between all these sites ranged from 8.4% up to 18%. Within the Little Naches basin the level of percent fines observed in 2000 was comparable to that observed in recent years.

Klickitat

Gravel samples collected during the 2000 season have been processed and the results will be reported during the FY2001 reporting period.

Personnel Acknowledgements for Tasks 1.A, 1.B, 1.C, & 1.D: Lead Biologist is Bill Sharp assisted by the following Technicians, Sandy Pinkham, Greg Strom, Rodger Begay, Matt Tomaskin, Isadore Honanie, Roger Stahi and Robert Cruz.

Task I.B Klickitat Fish Passage Obstruction Inventory Assessment

Rationale: To locate and describe existing salmonid fish migration barriers in the Klickitat basin.

Methods: Upon receiving in depth training by WDFW personnel in June 2000, YKFP field crews conducted Level A and Level B culvert inventory using the Fish Passage Barrier Assessment and Prioritization protocol. During this reporting period YKFP crews inventoried 59 culverts using this technique. The criteria used identifies culvert as barriers if they cannot effectively pass a 6-inch rainbow trout/steelhead.

Level A

The Level A analysis describes and determines if the culvert is a barrier or non-barrier. Culvert descriptors and core physical measurements required for a Level A analysis are: shape of the culvert, material of which the culvert is constructed, the horizontal and vertical dimensions of the culvert, and the depth of water inside of the culvert. Factors that determine if a culvert is a barrier are: Is there natural streambed material throughout the culvert? If yes, is the culvert width at least 75% of the average streambed toe width at the second riffle downstream of the culvert? If yes, the culvert is not a barrier, additional measurements not required, if no, Level B analysis is required. If there is no streambed material throughout the culver, is there an outfall drop > 0.24 meters? If yes, the culvert is a barrier, additional measurements not required. If no, is the culvert slope greater than or equal to 1%? If yes, the culvert is a barrier, additional measurements not required, if no, Level B analysis is required.

Level B

The Level B Analysis involves collecting more detailed information required to run a hydraulic model to determine the barrier status of the culvert. Physical measurements required to conduct a Level B Analysis are: the **reference point datum** and **location**; **the upstream and downstream** stream elevation; the **streambed culvert** elevation; the **downstream control cross section** measurements at the head of the first riffle, **downstream control water surface** and **ordinary high water** elevation; the **water surface** elevation 15 m downstream of **downstream control**; and the **channel dominant** substrate.

Progress:

Initial results of the 59 culverts inventoried show that 49 (83%) constitute fish barriers using this protocol. This information and additional culverts assessments will used to prioritize culverts for removal or modification.

Engineering subcontractors have completed hydraulic calculations and engineering design plans for modification of the falls #10 tunnel at Castile Falls. The subcontractor is coordinating final review with NMFS and WDFW engineers. Upon successful review, designs will be developed for bid purposes and notice to bid documents will be developed. The anticipated construction period will be September-October of 2001.

Task l.C Klickitat Water Quality Inventory

Rationale: Record water quality measurements at each habitat survey reach on a seasonal basis.

Methods: Mean daily water temperatures were monitored on an annual basis for several key tributaries and mainstem sites using Hobo thermographs.

Progress: A total of 29 Hobo thermographs were monitored over this reporting period. Thermographs were placed in 18 in tributaries throughout the basin, and four mainstem locations.

The period of record for most thermographs deployed by the YKFP extends back to November 1996. Temperature information from the three Little Klickitat River sites was shared with Washington Department of Ecology for the newly initiated TMDL study.

Task l.D Klickitat Habitat Production Assessment

Rationale: The near term objective is to collect baseline data on existing habitat conditions, fish populations, and existing passage conditions throughout the basin. This information will be incorporated into the Ecosystem Diagnosis and Treatment (EDT) model, as well as, to guide the decision making process towards future mainstem and tributary passage improvements.

The long-term objective is to implement habitat restoration, hatchery supplementation, and fish passage improvement projects in the basin. Outcomes from the EDT model will be used to prioritize the implementation of these projects. Associated with these projects will be ongoing monitoring ands evaluation (M&E) of the implemented projects.

Methods: The habitat inventories were conducted using the TFW methodology (modules-Stream Segment Identification, Reference Point Survey, Habitat Unit Survey, Large Woody Debris and Ambient Salmonid Spawning Gravel Composition).

Progress: During this reporting period habitat production assessment information was complied and used to populate the Phase 1 analysis of the EDT model. YKFP biologists and the data management team are currently compiling and synthesizing existing TFW habitat information into a relational database using MS-ACCESS. Once developed this information will be used to further refine the EDT level 2 habitat attribute values for both spring chinook and steelhead. Geographical Information System (GIS) mapping is being developed for the entire Klickitat Basin as a portion of Task 1.D. To date GIS coverage's include: topographic contour, hydro, roads, towns, vegetation, and salmonid species distribution. Project staff will be refining the GIS database to include all monitoring location (i.e. screw traps, thermographs, TFW transects, fish population transects, etc.).

Task 1.E Predator Avoidance Training

Rationale: Hatchery fish have been shown to be more susceptible to predation than wild counterparts and it has been suggested that hatchery fish lack skills required to avoid predators (Wiley et al. 1993; Olla et al. 1994; Maynard et al. 1995).

Progress: No activities were scheduled for this task in FY2000.

Task 1.F Data Management: This task is reported on in the Management 2000 annual report.

Task 1.G Biometrical Support:

Rationale: Dedicated biometrical support is required for four reasons: 1) there are a large number of monitoring measures in the monitoring plan that require power analyses to evaluate feasibility and sample size requirements, 2) several of these measures will involve sophisticated statistical analyses beyond the expertise of full-time YKFP staff, and 3) only a professional biometrician can provide the state-of-the-art analyses and experimental designs that a project the size of the YKFP requires.

Progress: The biometrician assisted MIPT with the design of the experiments called for by the YKFP's spring chinook, coho and fall chinook programs, as well as provided assistance in the analysis of data already collected by these programs in 2000 and 2001. This included development of statistical tools to ensure that experiments were designed to collect sufficient information to answer critical questions with a specified degree of statistical power. Specific items that were addressed in 2001 included:

1. Design and analysis of experimental releases of PIT-tagged smolts intended to improve estimates of smolt passage at the Chandler facility, especially during periods of high flow.
2. Determination of the relative survival of OCT and SNT hatchery-reared spring chinook released in 2001 to Chandler on the lower Yakima and to McNary Dam on the Columbia.
3. Determination of the relative survival of early- and late-released coho smolts from the upper Yakima and Naches in the spring of 2001 to the Chandler smolt trap on the lower Yakima and to McNary Dam on the Columbia.
4. Determination of the relative survival of accelerated, conventionally-reared and Marion Drain hatchery fall chinook smolts to McNary Dam and, in the case of Marion Drain releases, to Prosser.
5. Determination of the feasibility of discriminating the impact of environmental fluctuations vs supplementation on the natural production upper Yakima spring chinook smolts, or on the natural production of spring chinook smolts from the entire Yakima Basin (the so-called "extrinsic/intrinsic" issue).
6. Determination of the feasibility of estimating the impact of the instantaneous abundance of smolts commingled with experimental releases on the survival of the experimental fish from Chandler to McNary Dam, and estimating the degree to which such impacts can be distinguished from such confounding environmental factors as discharge, water temperature, and turbidity (the so-called "indirect predation" issue).
7. Determination of the relative survival to Prosser and McNary Dam of three groups of spring chinook outmigrants: "spring smolts", "winter migrants" and hatchery-reared smolts.
8. Determination of the relative smolt-to-adult and release-to-adult survival of OCT and SNT hatchery-reared spring chinook of the 1997 brood. "Release-to-adult" survival is based on the relative numbers of fish initially transferred to acclimation sites; "smolt-to-adult" survival is based on the relative numbers of fish of each group estimated to have passed Roza Dam.

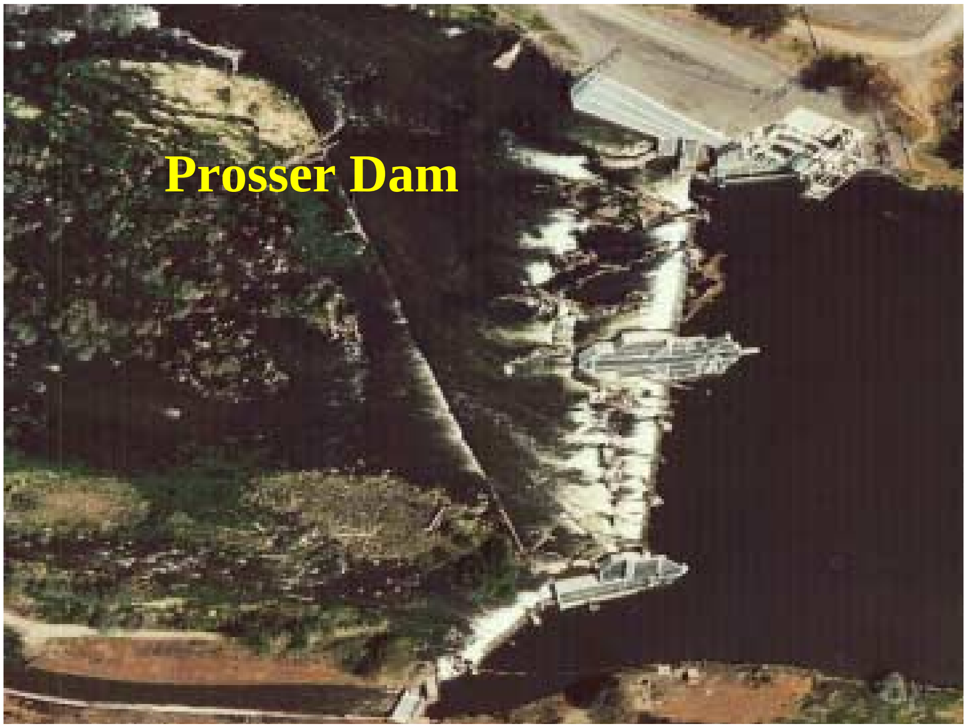


Figure 37. An aerial view of Prosser Dam where ongoing PIT tag studies are being conducted to refine the CJMF fish entrainment rate, and evaluate smolt-to-smolt survival through the lower Columbia River.

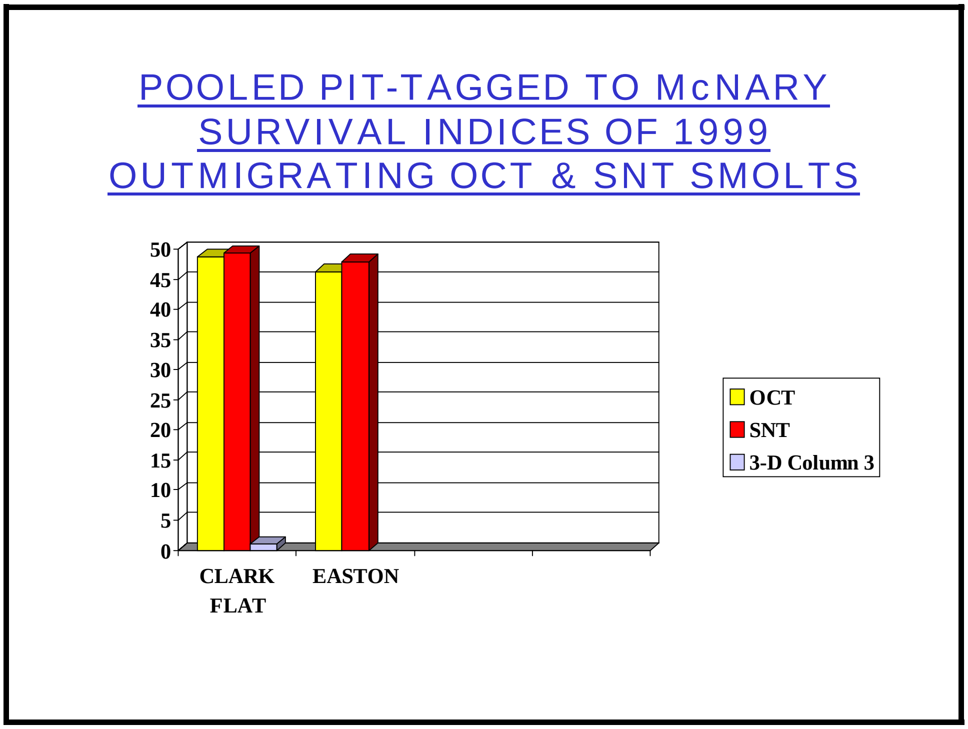


Figure 38. A comparison of survival (indices) between two of the three acclimation sites and between the OCT and SNIT treatments, 1999.

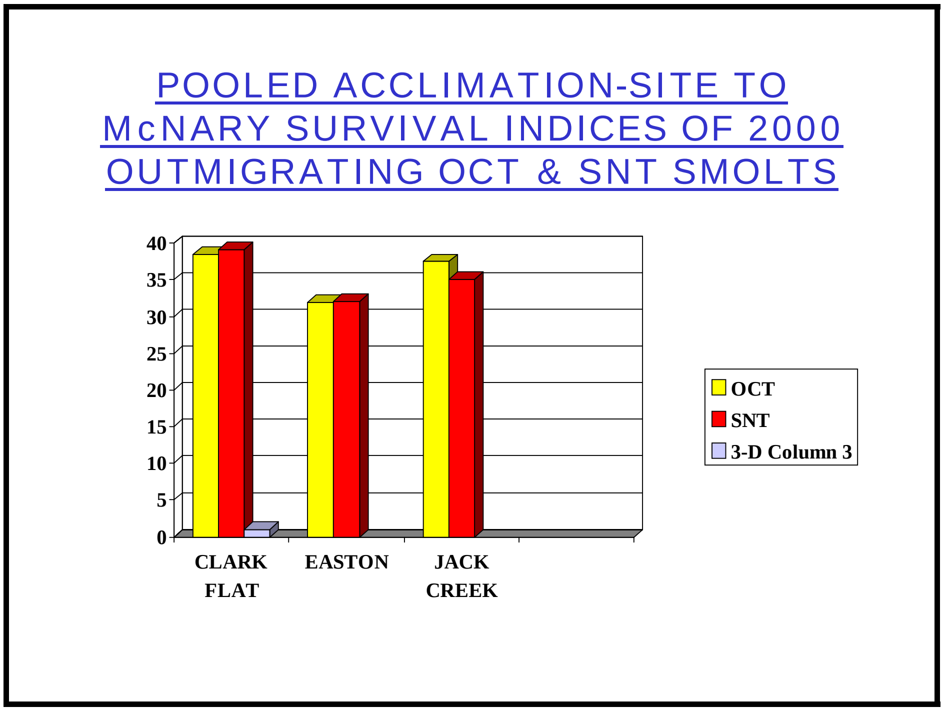

POOLED ACCLIMATION-SITE TO McNARY SURVIVAL INDICES OF 2000 OUTMIGRATING OCT & SNT SMOLTS

Figure 39. A comparison of survival (indices) between two of the three acclimation sites and between the OCT and SNIT treatments, 2000.

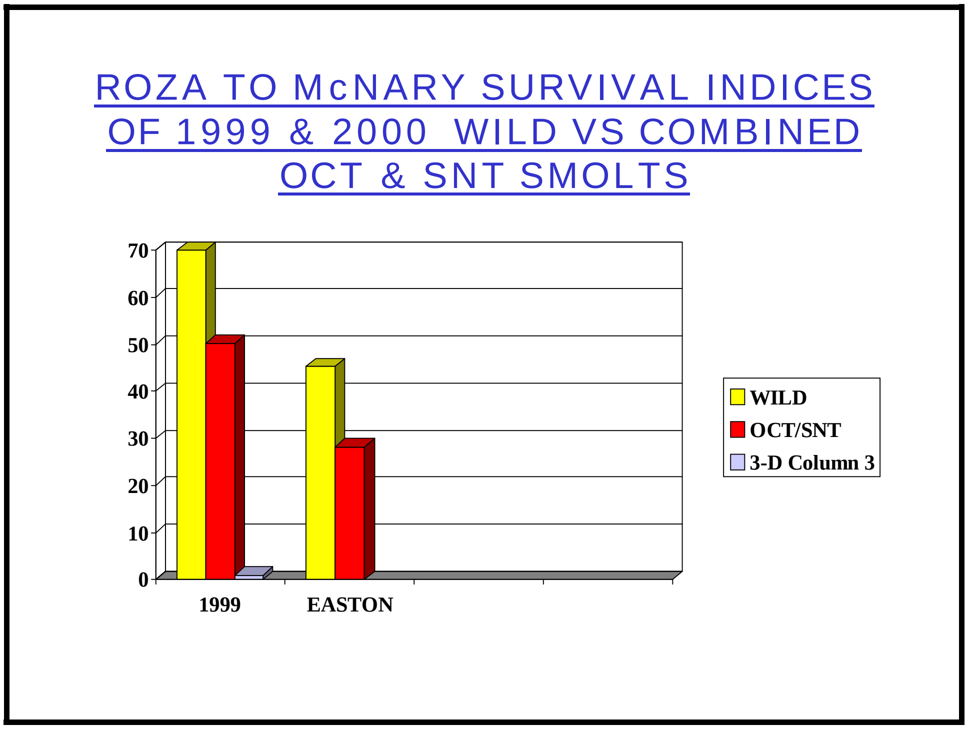

ROZA TO McNARY SURVIVAL INDICES OF 1999 & 2000 WILD VS COMBINED OCT & SNT SMOLTS

Figure 40. A comparison of survival (indices) between two of the three acclimation sites and between the OCT and SNIT treatments for 1999 and 2000 combined.

9. Determination of the relative Chandler-smolt-to-Roza-adult survival of wild spring chinook smolts, OCT hatchery-reared smolts and SNT hatchery-reared smolts. This smolt-to-adult survival rate will be based on the number of smolts of each type estimated to have passed Chandler trap. If possible, separate relative survival estimates should be developed for upper Yakima wild spring chinook smolts and for “all Yakima wild” spring chinook smolts.

Task 1.H MIPT Operations

This is referenced but was not implemented as a separate task. This task was implemented with participation realized through other existing M&E tasks.

2. HARVEST

Overall Objective: Develop methods for detecting increases in harvest of YKFP target stocks.

Task 2.a Out-of-Basin Harvest Monitoring

Rationale: Develop a database to track the contribution of target stocks to out-of-basin fisheries.

Method: Coordinate with agencies responsible for harvest management (WDFW, ODFW, USFWS, CRITFC, etc.) to estimate the harvest of target stocks.

Progress: It is difficult to obtain adequate information on out-of-basin fisheries due to the limited number of CWT recoveries from sampling programs for these fisheries. Out-of-Basin harvest of spring chinook in 2000 was estimated at about 1,200 Yakima River spring chinook using population proportions at Bonneville Dam.

However, standard run reconstruction techniques can be employed to derive reasonable estimates of harvest from the Columbia River mouth to the mouths of the Klickitat and Yakima Rivers. The *United States versus Oregon* Technical Advisory Committee (TAC) maintains databases of estimated Columbia River mouth run sizes for all species of salmon destined for tributaries above Bonneville Dam. These TAC databases contain Columbia River mainstem (river mouth to McNary Dam) harvest rate estimates for aggregate populations plus estimated passage losses due to the hydrosystem. The YKFP intends to use these TAC databases, in conjunction with estimated Yakima and Klickitat river mouth run size estimates, to derive Columbia River mouth run size estimates and Columbia River mainstem harvest estimates for Yakima and Klickitat salmon populations. The YKFP intends to develop this database for Yakima River spring chinook in time for the Project Annual Review in 2002. Work on similar databases for other species in the Yakima River and for all species in the Klickitat will continue as time allows.

It is anticipated that for the 2002 spring migration, adult PIT tag detection facilities at all ladders at McNary and Bonneville Dams will be operational. These facilities are expected to achieve nearly 100% efficiency in adult PIT tag detection. This will allow the YKFP to use run size proportions to estimate the catch of Yakima fish in Columbia River mainstem fisheries (using methods described in the preceding paragraph) and then use mainstem PIT tag detection data to derive the stock composition (OCT/SNT by acclimation site) of the estimated Cle Elum "hatchery" portion of the mainstem catch for Yakima River spring chinook.

Additionally, two other databases are available to retrieve data to complement the data that will be derived using run reconstruction. The Regional Mark Information System (RMIS) will be queried regularly for any CWT recoveries of YKFP releases in ocean or Columbia River mainstem fisheries. In addition, the commercial fish ticket database maintained by Washington and Oregon will be queried for recoveries of Klickitat River fall chinook and coho in non-Indian and Treaty Indian fall season commercial fisheries in the Columbia River.

Task 2.b Yakima and Klickitat Subbasin Harvest Monitoring

1.
2. **Rationale:** Develop a database to track the contribution of target stocks to in-basin fisheries.
3.
4. **Method:** The two co-managers, Yakama Nation and WDFW, are responsible for monitoring their respective fisheries in both the Klickitat and Yakima rivers. Each agency employs fish monitors dedicated to creel surveys and/or fisher interviews at the most utilized fishing locations and/or boat ramps. From these surveys, standard techniques are employed to expand fishery sample data for total effort and open areas and times to derive total harvest estimates. Fish are interrogated for various marks. This information is used along with other adult contribution data (i.e. broodstock, dam counts, spawner ground surveys) to determine overall project success.
5.
6. **Progress:**

Total estimates of Yakima and Klickitat River in-basin harvest for both tribal and sport fisheries are reported annually (since at least the early-to-mid 1980s) and are available through the YKFP, the *United States versus Oregon* TAC, the WDFW, and/or the U.S. Bureau of Indian Affairs.

Klickitat

The Treaty Indian harvest estimates for the Klickitat in 1999 and 2000 were as follows:

1999	2000
Spring Chinook- 111	Spring Chinook- 1,189
Summer Chinook- 36	Summer Chinook- 76
Fall Chinook- 356	Fall Chinook- 844
Steelhead- 160	Steelhead- 447
Coho- 1,456	Coho- 2,698

Yakima

Both non-Indian and Treaty Indian spring chinook fisheries occurred in the Yakima River in 2000. The sites monitored were those of traditional and historic fishing sites, they included, but were not limited to, Wapato, Parker, Prosser and Horn Rapids dams.

Monitor data indicate that approximately 2,460 spring chinook (2,360 adults, 100 jacks) were harvested in Treaty Indian fisheries from the mouth of the Yakima River to Union Gap, which equated to a 12.9% harvest rate. The first fish returning from the Cle Elum facility returned as jacks in 2000. A total of 43 marked jacks were sampled in the tribal fishery and the data from these recaptures have been logged in the YKFP database and is available on the YKFP web site.

The sport harvest was estimated at 100 spring chinook (92 adults, 8 jacks).

Personnel Acknowledgements: Biologist Mark Johnston and Fisheries Technician Steve Blodgett.

3. GENETICS

Overall Objective: Develop methods of detecting significant genetic changes in extinction risk, within-stock genetic variability, between-stock variability and domestication selection.

Progress: All Tasks within this Section are assigned to WDFW.

4. ECOLOGICAL INTERACTIONS

Overall Objective: To develop monitoring methods to determine if supplementation and enhancement efforts keep ecological interactions on non-target taxa of concern within prescribed limits and to determine if ecological interactions limit supplementation or enhancement success.

Task 4.a Avian Predation Index

Progress: Implemented and funded by WDFW in cooperation with U of W.

Task 4.b Fish predation index.

Rationale: Develop an index of the mortality rate of upper Yakima spring chinook attributable to non-salmonid piscivorous fish in the lower Yakima. This index will be used to estimate the contribution of in-basin predation to fluctuations in hatchery and wild smolt-to-adult survival rate.

Methods: The densities of all major piscivorous fish species were censused during the smolt outmigration in representative reaches of the lower Yakima (Benton City, Granger and near Parker Dam), and predator-specific smolt consumption data was recorded in the same reaches. From this data, we estimated both predator fish abundance and salmonid consumption. Population estimates were calculated using mark-recapture techniques, and consumption estimates were made using the meal over-turn method.

Progress: This task is reported on in the WDFW's annual report.

Personnel Acknowledgments: Jim Dunnigan was the lead biologist for this project. Joel Hubble, Linda Lamebull, Jerald Reed, and Jason Allen helped with the florescent grit marking of the fish.

Task 4.c Coho/chinook predation study.

There was no activity on this task for FY2000. Work for this task was complete in FY1999.

Task 4.d Indirect Predation

Rationale: The release of hatchery smolts may increase or decrease the survival of commingled wild smolts -- or of smolts of any origin -- by altering the behavior of predators. This hypothetical change in predation-related mortality attributable to the release of hatchery smolts has been termed "indirect predation". Although the term seems to imply hatchery releases indirectly increase losses to predators, the impact on commingled smolts, if any, may be either positive or negative.

An issue of considerable importance to the YKFP is the possibility that releases of hatchery fish might decrease the survival of any wild smolts that happen to move down the river along with the hatchery fish. Predators are generally attracted to concentrations of prey, such as areas in which hatchery fish are released. For example, bigmouth minnows were attracted to locations where hatchery releases occurred in Bonneville Pool (Collis et al. 1995), and piscivorous birds such as gulls and mergansers flock to the dense aggregations of fish that occur during and immediately after large hatchery releases (Ruggerone 1986; Wood 1987). This increase in the abundance of predators may increase predation on any *wild* smolts that happen to be moving through the release point, or on smolts of any type. Moreover, predators may become more piscivorous when fish are abundant (Collis et al. 1995; Shively et al. 1996). For example, bigmouth minnows consumed primarily invertebrates prior to the release of hatchery fish in the Chehalis River, but switched to fish after a release of hatchery smolts (Fresh et al. In review). A similar phenomenon may have occurred in Chandler Canal in 1998 (McConnaughey, 1998. Internal YKFP Progress Report). Finally, wild fish may be more susceptible to predators because they are generally smaller than hatchery fish (Hillman and Mullan 1989; Shively et al. 1996).

The YKFP is equally interested in the possibility that releases of hatchery smolts might *in-*

crease the survival of commingled smolts. Large numbers of hatchery and wild migrants may simply overwhelm the consumption capacity of a limited number of predators, or confuse predators such that their predation efficiency is impaired (Wood 1987). Moreover, hatchery fish may be more vulnerable to predators because of their conspicuous behavior and coloring (Berejikian 1995; White et al. 1995), and may act as "shields" for more cryptic wild fish.

The initial objective of this study is simply to determine whether a consistent relationship between smolt survival and total smolt abundance exists in the Yakima River. Because many factors can influence smolt survival – e.g., water temperature, flow, smolt size – it is critical that the analysis be capable of separating the survival impact of smolt abundance from the impacts of other factors that might be active at the time. If an "Indirect Predation" effect were to be thus established, it would then be necessary to investigate more specific and often mechanistic questions. These questions include:

- Is the effect the same for commingled hatchery and wild smolts, and how does relative hatchery/wild susceptibility vary across species?
- Is the effect consistent across a range of physical factors – flow, temperature and turbidity -- that might be expected to affect smolt survival or predation rates?
- If conclusively demonstrated, can it be equally conclusively demonstrated that the effect is caused by a change in predation?
- If demonstrated and conclusively attributable to predation, is it:
    - due to the attraction of predators to release sites?
    - due to a change in consumption rates among predators?
    - due to the greater conspicuousness or vulnerability of wild or hatchery smolts?
    - due to predator satiation?
    - due to size differences between test groups and the average outmigrant at the time?

A complete summary of methods and task results are discussed in Appendix E.

Personnel Acknowledgements: Bruce Watson, YN Biologist, is collaborating with Dr. Todd Pearsons, WDFW Biologist on this Task.

Task 4.e Yakima River Spring Chinook Competition/Prey Index

This Task is assigned to WDFW, thus, they will be reporting on it.

Task 4.f Upper Yakima Spring Chinook NTTOC Monitoring

This Task is assigned to WDFW, thus, they will be reporting on it.

Task 4.g Pathogen Sampling

This Task is assigned to WDFW, thus, they will be reporting on it.

APPENDICES

A. Yakima River Fall Chinook Monitoring And Evaluation 2000 Annual Report.

B. Yakima Coho Monitoring And Evaluation 2000 Annual Report.

C. Task 1.k . Yakima Spring Chinook Juvenile Behavior.

D. Annual Report: Outmigration Year 2000. Part 1. Supplemented Fish Survival To McNary Dam.

E. Annual Report: Outmigration Year 2000. Part 2. Chandler Certification And Calibration (Spring Chinook and Coho).

F. Task 4.d. Indirect Predation.

APPENDIX A

Yakima River Fall Chinook Monitoring and Evaluation

2000 Annual Report

YAKIMA RIVER FALL CHINOOK MONITORING AND EVALUATION

2000 ANNUAL REPORT

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Abstract

Water temperatures in the lower Yakima River during the late spring are often elevated to the point that they may limit the production of Yakima River fall chinook by decreasing survival of rearing and/or migrating juveniles. Aquacultural techniques that accelerate the smoltification process of hatchery fish have the potential of increasing fall chinook survival later in the outmigration season by limiting the exposure of juvenile fish to elevated and potentially lethal water temperatures. In the spring of 2000, the Yakama Nation acclimated and released a total of approximately 307,000 fall chinook that were spawned and reared at Prosser Hatchery. Fish were the progeny of Yakima River returning adults. Approximately 2,000 fish within each of the accelerated and control groups were PIT tagged. Additionally, the thermally accelerated and control groups were also marked by removal of a pelvic fin (right and left respectively), in order to estimate smolt-to-adult survival. Release dates for the thermally accelerated and control groups were April 20-21 and May 25-26 respectively. In the spring of 2000, the Yakama Nation also acclimated and released a total of approximately 10,000 fall chinook that were spawned and reared at Marion Drain Hatchery. These fish were the progeny of fish that returned to Marion Drain. We PIT tagged approximately 1,000 of these fish prior to release on April 10-11, 2000. Survival indices were estimated of all three groups of fall chinook to McNary Dam.

We used a pooled detection rate over treatments to estimate detection rate at McNary Dam to estimate passage of PIT tagged fall chinook. Relative survival indices were highest for fall chinook released from Prosser Hatchery in May (conventional), and lowest for those released from Marion Drain. Survival indices to McNary Dam were 0.428, 0.817, and 0.271 for the Prosser accelerated (April release), Prosser conventional (May release), and Marion Drain groups. Travel time analyses are also presented for each group.

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We are thankful to the many people that helped make this project a reality. Doug Neeley provided statistical consultation for survival estimates of PIT tagged fish. Joe Blodgett and Bill Fiander were responsible for the aquaculture and care of all the fish released, which made the research in this report possible. Melvin Sampson provided administrative support. This work was funded by the Bonneville Power Administration under the Yakima Klickitat Fisheries Project, and was administered by David Byrnes.

Introduction

The Yakima Klickitat Fisheries Project's (YKFP) ongoing fall chinook research program, aims to test the application of supplementation principles to the two lower Yakima River fall chinook stocks, the mainstem and Marion Drain stocks. The Marion Drain stock spawns in Marion Drain (Figure 1). However the full extent of the spawning distribution and origin of the Marion Drain stock is not known. Marion Drain is a man-made 19-mile irrigation return ditch constructed in the early 1900's. The other Yakima stock, the "mainstem stock", is the most abundant stock in the Yakima sub-basin. The mainstem stock is genetically similar to the composite stock of upriver bright (URB) fall chinook in the Columbia River, and the Marion Drain stock is similar to Snake and Dechutes River fall chinook (Busack et al. 1991).

Water temperatures in the lower Yakima River during the late spring are often elevated to the point that they may limit the production of Yakima River fall chinook by decreasing survival of rearing and/or migrating juveniles. Baker et al. (1995) concluded that the upper incipient lethal level for fall chinook was between 23 and 25°C. The mean daily temperatures at Prosser Dam during the period 1988-2000 (Table 1) are likely well above the preferred temperature for fall chinook, and in some instances approach or exceed the critical thermal maxima for most salmonids. Maximum instantaneous daily temperatures are undoubtedly higher than the mean daily maximum temperatures, and temperatures increase downstream of the Prosser Dam to the confluence. High and fluctuating temperature profiles have been shown to increase the susceptibility of disease (Holt et al. 1975; Udey et al. 1975) predation (Coutant 1973), competition (Reeves et al. 1987), and may be physiologically stressful for salmonids (Wedemeyer 1973; Thomas et al. 1986). Smallmouth bass are a significant predator on fall chinook below Prosser Dam (McMichael et al. 1999; Pearsons et al. 2001). McMichael et al. (1999) and Pearsons et al. (2001) estimated that in the Yakima River, smallmouth bass consumed approximately 358,208 and 145,679 salmonids in 1998 and 1999 respectively, most of which were fall chinook. Consumption rates of fall chinook by smallmouth bass in the lower Yakima River peaked between May 23 and June 1 in both 1998 and 1999. Peak consumption rates correspond to the historic fall chinook migration peaks at Prosser Dam (Figure 2).

Aquacultural techniques that accelerate the smoltification process of hatchery fish have the potential of increasing fall chinook survival later in outmigration season by limiting the exposure of juvenile fish to the latter portion of the outmigration period. By limiting the exposure of fall chinook to the latter portion of the typical outmigration period, juveniles may be spared from the lethal temperatures in the lower river that occur during some years, and the peak smallmouth bass consumption period. Temperature and photoperiod have been shown to be the most effective environmental conditions that are relatively easily manipulated in the hatchery environment (Muir et al. 1992; Poston 1978;

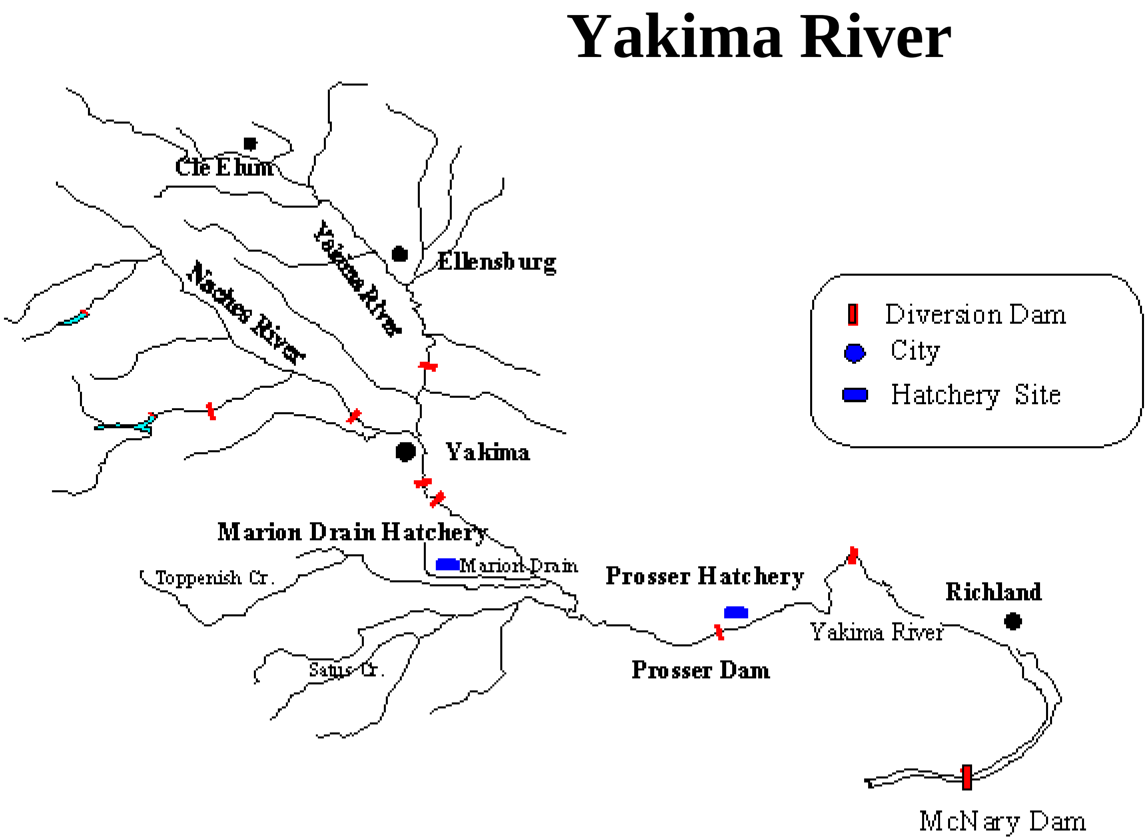

Figure 1. Map of the Yakima sub-basin, including the location of Prosser and Marion Drain hatcheries.

Table 1. The mean and maximum daily Yakima River water temperature (degrees C) at Prosser Dam during the period 1988-1999, 1999, and 2000.

	April	May	June	July	August
Prosser Dam Mean 1988-1999	10.9	14.5	17.7	21.1	21.4
Prosser Mean + 1 Standard Deviation 1988-1999	13.0	17.2	20.8	23.6	23.3
Prosser Dam Maximum 1988-1999	17.6	22.1	26.6	26.8	26.0
Prosser Dam Mean 1999	9.9	13.4	15.5	17.3	20.0
Prosser Dam Maximum 1999	12.8	15.6	17.1	20.9	23.2
Prosser Dam Mean 2000	11.5	15.2	18.0	22.7	22.0
Prosser Dam Maximum 2000	13.6	17.9	22.4	23.9	23.9

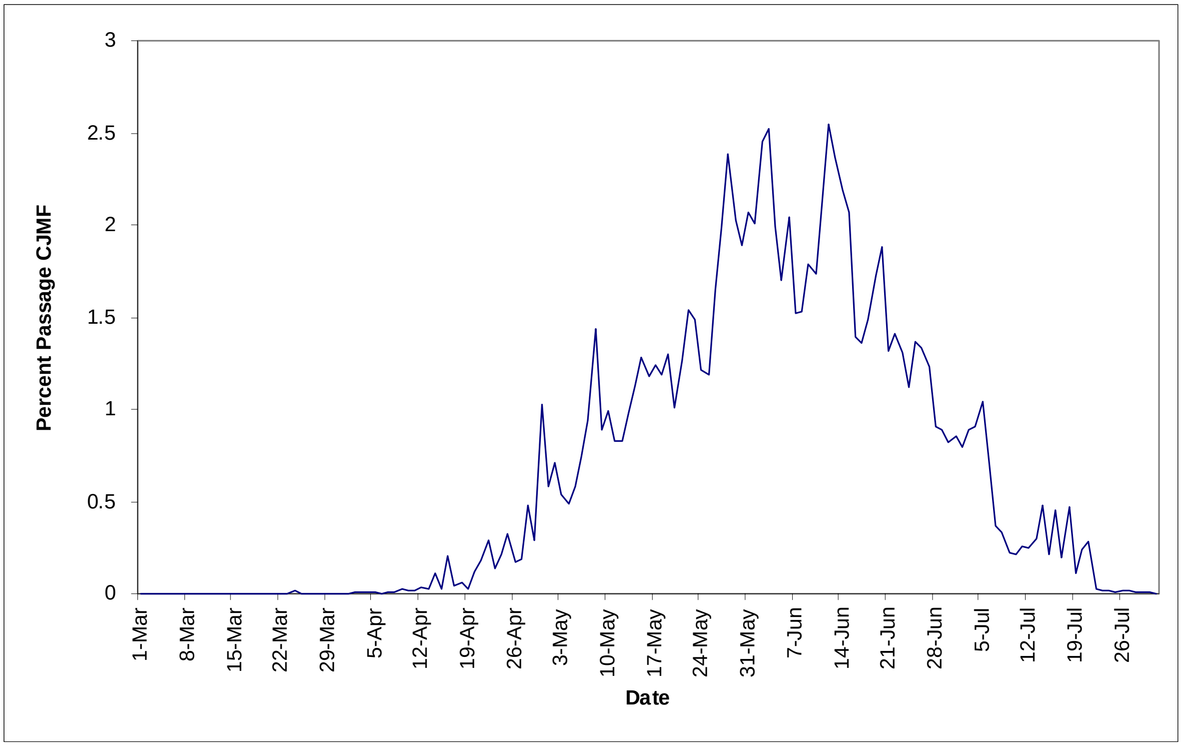

Figure 2. The mean daily seasonal passage of juvenile fall chinook at Chandler Juvenile Monitoring Facility at Prosser Dam, 1983-1998.

Wedemeyer et al. 1980). However, Clarke et al. (1992) suggest that the juvenile life history patterns of ocean and stream-type chinook may be under genetic control, and that artificial manipulation of photoperiod have little effect on the smoltification process of ocean-type chinook (Clarke et al. 1992; Clarke et al. 1981). Thus, the manipulation of ambient rearing temperature is likely the most promising method of advancing the smoltification process of fall chinook juveniles.

This report summarizes the results of the second year of a three year study intended to test the efficacy of thermally accelerating the growth and physiological development of Yakima River fall chinook in the fish's early life stages. Although results of this report will focus solely on juvenile survival, smolt-to-adult comparisons will be made when the first year adults return (jacks in 2001). In this report we will compare the juvenile survival rates to McNary Dam of a test and control group of fall chinook released from Prosser Hatchery. Survival estimates of Marion Drain Hatchery reared fall chinook released within Marion Drain are also presented.

Methods

Broodstock Collection and Culture

Yakama Nation spawned a total of 98, 121, and 122 female fall chinook in 1998-2000 respectively. Most fish were collected from fish entrained in Chandler Canal while the canal was drawn down for routine maintenance. Mean fecundity for the mainstem stock was 4,994, 4,737, and 4,254 eggs/ female in 1998-2000 respectively. Broodstock collection intentionally attempted to achieve a 50% sex ratio. Approximately half of the eggs collected were incubated and fry reared on a mixture of well and Yakima River water (mean temperature 13° C) intended to accelerate growth and physiological development. Remaining fish were incubated and reared on cooler ambient Yakima River water.

Yakama Nation spawned a total of 2, 7 and 5 female fall chinook collected via fish wheel operated in Marion Drain in 1998-2000 respectively. The fish wheel was operated near the State Highway 97 bridge on Marion Drain in all years. All eggs and fry were incubated and reared on ambient Marion Drain water.

Estimates of 2000 Juvenile Survival Indices

Prosser Hatchery Releases

In the spring of 2000, the Yakama Nation acclimated and released a total of approximately 307,000 fall chinook that were spawned and reared at Prosser Hatchery (Table 2). We PIT tagged approximately 2,000 within each of the accelerated and control groups (Table 2). Releases were replicated in order to estimate variation and perform statistical comparisons between groups. The thermally accelerated and control groups were also 100% marked by removal of a pelvic fin (left and right respectively; Table 2).

Release Dates for the thermally accelerated and control groups were April 20-21 and May 25-26, respectively.

Table 2. Release groups, dates, numbers, location and marks for mainstem Yakima River and Marion Drain fall chinook stocks in 2000.

Stock	**Incubation & Rearing Group**	**Release Date**	**Total Release Number**	**Release Location**	**Mark**	**Number PIT tagged**
Mainstem Yakima	Thermally Accelerated	4/20-21/00	146,086	Prosser Hatchery	Right Pelvic Fin Clip	2,033
Mainstem Yakima	Ambient River Water	5/25-26/00	160,747	Prosser Hatchery	Left Pelvic Fin Clip	2,018
Marion Drain	Ambient Marion Drain Water	4/10-11/00	10,000	Marion Drain Hatchery	None	1,003

Marion Drain Hatchery Releases

In the spring of 2000, the Yakama Nation acclimated and released a total of approximately 10,000 fall chinook that were spawned and reared at Marion Drain Hatchery (Table 2). We PIT tagged 1,003 of these fish prior to release on April 10-11, 2000, in order to estimate an index of survival to McNary Dam.

Estimates of Survival Indices for PIT Tagged Juveniles

Estimates of survival indices of 2000 PIT tagged fall chinook from releases at Prosser and Marion Drain Hatcheries was based on expanding (dividing) the detected fish at McNary by the McNary Dam detection rate (efficiency) and then dividing the expanded number by the number of PIT tagged fish released. Detection rates at McNary were estimated by dividing the number of fish detected at both McNary (McN) and John Day (JD) by the total number detected at John Day.

We found no statistical evidence that the JD-based daily McN-detection rates varied over passage time (Neeley 2001). Therefore there was no reason to stratify the outmigration season at McNary and John Day dams into strata, as was done in 1999 (Dunnigan 2000).

Equations 1 through 3 below were used to estimate passage. In the equations, n() represents the number of detections at the dams indicated within the parentheses.

Equation 1. DR(k) - estimated JD-based McN Detection Rate:

$$DR = \frac{n(JD, \quad McN)}{n(JD)}$$

Equation 2. P - estimated McNary passage:

$$P = \frac{n(McN)}{DR}$$

Equation 3. S - estimated survival index from release to McN:

$$S = \frac{P}{N}$$

Wherein N is the number of released PIT tagged fish.

Results

Estimates of 2000 Juvenile Survival Indices

We compared pooled PIT tag detection rates at McNary Dam by treatment group (Table 3) using logistic analysis of variance and found no evidence that detection rate differed between treatment groups (p = 0.4078). Therefore, we used the mean McNary (John Day based) detection rate pooled over treatments (0.2907) to estimate survival indices for all treatment groups of PIT tagged fall chinook. The conventionally reared fall chinook out performed the accelerated group (survival indices for the conventional and accelerated groups were 0.817 and 0.428 respectively; Table 4). The Marion Drain fall chinook had the lowest survival index to McNary of all three treatment groups. Logistic analysis of variance indicated that at least two of the groups were significantly different (p = 0.0343). Pair wise comparisons showed that the conventional treatment group had a significantly higher survival index than either the accelerated or Marion Drain groups (survival index = 0.271).

Travel time to McNary Dam from release was longest for fall chinook released from Marion Drain, and shortest for the conventional group released from Prosser Hatchery (Table 6). Although travel time was longest for the Marion Drain fall chinook, date of mean arrival at McNary Dam was approximately the same for the Marion Drain and Prosser Hatchery accelerated groups (5/28 and 5/27 respectively; Table 6) due to a shorter travel time and distance of the Prosser Hatchery accelerated group. An analysis of variance (Table 7) suggested that the travel time to McNary for at least one pair of releases was significantly different, and multiple comparisons indicated that all comparisons had significantly different travel times to McNary Dam (Table 8).

Table 3. John Day (JD)-Based McNary (McN)-detection rates for sub-yearling chinook released into the Yakima River in 2000.

Release Site	**Treatment**	**Pooled Detection Rate**
Prosser Hatchery	Accelerated Rearing	0.2522
Prosser Hatchery	Conventional Rearing	0.3063
Marion Drain Hatchery	Conventional Rearing	0.3750
Pooled over Treatments		0.2907

Table 4. Logistic analysis of variation for groups of conventional, accelerated, and Marion Drain fall chinook released in the Yakima River, 2000.

Source	**Deviance (Dev)**	**Degrees of Freedom (DF)**	**Mean Deviance (DEV/DF)**	**F-ratio**	**Type 1 P**
Treatment	1079.89	2	539.95	12.70	0.0343
Error	127.59	3	42.53		

Table 5. Treatment comparisons of logistic coefficients for conventional, accelerated, and Marion Drain releases of PIT tagged fish to McNary Dam.

Treatment	**Treatment**	
Conventional	Accelerated	Control
t-test	-3.75	
Type 1 P	0.0331	
Marion Drain		
t-test	1.28	4.17
Type 1 P	0.2911	0.0251

Table 6. Mean travel time (days), date of arrival at McNary Dam, and number of detections (sample size) for PIT tagged juvenile fall chinook released from Prosser (accelerated and conventional groups) and Marion Drain hatcheries. Weighted means are weighted by sample size.

	Prosser Hatchery Accelerated			**Prosser Hatchery Conventional**			**Marion Drain**		
Replicate	**Travel Time (days)**	**McNary Arrival Date**	**Sample Size**	**Travel Time**	**McNary Arrival Date**	**Sample Size**	**Travel Time**	**McNary Arrival Date**	**Sample Size**
1	36.44	5/26/00	126	26.96	6/20/00	233	49.53	5/29/00	17
2	37.40	5/28/00	127	22.77	6/17/00	246	47.67	5/28/00	62
Weighted Mean*	36.92	5/27/00		24.81	6/19/00		47.67	5/28/00	

Table 7. Analysis of variance of PIT tagged fall chinook travel times to McNary Dam for groups released from Prosser (accelerated and conventional groups) and Marion Drain hatcheries.

Source	**Sums of Squares**	**df**	**Mean Square**	**F-ratio**	**P-value**
Among Treatments	49186.96	2	24593.48	33.05	0.0090
Within Treatments	2232.34	3	744.11		

Table 8. Mean comparisons of travel times to McNary Dam between treatment groups of PIT tagged fall chinook released from Prosser (accelerated and conventional groups) and Marion Drain hatcheries.

Comparisons	**Mean Difference (days)**	**Standard Error of Difference**	**t-ratio**	**P-value**
Accelerated vs. Conventional	12.12	2.120054	5.72	0.0106
Accelerated vs. Marion Drain	-10.75	3.515726	-3.06	0.0551
Conventional vs. Marion Drain	-35.55	3.312498	-10.73	0.0017

Discussion

Ultimately the survival parameter of most value to managers will be survival to returning adult, especially if ocean entry timing is a critical factor influencing smolt-to-adult survival. The project will estimate smolt-to-adult survival for both groups of fall chinook released from Prosser Hatchery, and although juveniles released in Marion Drain were not marked, the project will rely on redd counts within Marion Drain to determine changes in abundance through time. Nevertheless, our ability to partition mortality throughout the various life stages for each experimental group may provide valuable insight which will help fisheries managers better understand the ecology and potential limiting factors of fall chinook in the Yakima River.

The survival index for conventionally incubated and reared fall chinook outperformed both the thermally accelerated and Marion Drain fall chinook by approximately 2 and 3 fold respectively. Mean travel time of the accelerated treatment group released from Prosser Hatchery was approximately 49% longer than the conventional group. Estimates of juvenile fall chinook survival from release to McNary Dam for the 2000 outmigration contradict results from the 1999 outmigration (Dunnigan 2000). Two differences are apparent when comparing juvenile fall chinook survival indices from 1999 and 2000. First, in 1999 the thermally accelerated group of fall chinook released from Prosser Hatchery outperformed their counterparts released a month later, although the difference was generally small (< 5%) regardless of the method used to compare the two groups (Dunnigan 2000), but in 2000, the conventional group outperformed the accelerated group by 91%. Secondly, differences in the relative survival between the Marion Drain fall chinook juveniles and the two treatment groups released from Prosser Hatchery were higher in 2000 than compared to 1999. Although, in 2000 fall chinook released from Marion Drain were released 42 days earlier in 2000 than 1999.

Water temperature in the lower Yakima River during the migration period (May-July) for juvenile fall chinook in 1999 and 2000 does not readily explain relative differences between the treatment groups in 1999 and 2000. Mean daily water temperatures in 1999 were cooler than average during the period 1988-1999 (Table 1), and the accelerated release group had a survival index slightly higher than the conventional group (Dunnigan 2000). If water temperature limits survival of fall chinook released in May (conventional group), then one may expect that the April release group (accelerated) would have outperformed the conventional group in 2000. This was not the case even though water temperature in the lower Yakima River during the outmigration period was approximately 1-2 degrees C warmer in 2000 than the mean daily temperatures during the period 1988-1999, and in 1999 (Table 1). The warmer water temperatures in the lower Yakima River in 2000 also corresponded to lower flow conditions during the same period (Figure 3), especially during the migration period for the accelerated group of fall chinook (April 20 – May 27), which may have in part accounted for the lower relative survival of the accelerated group released from Prosser Hatchery in April.

Differences in fall chinook survival between release groups and between years may have been partially related to fish size. In both 1999 and 2000, the release group with the highest mean fork length had the highest relative survival to McNary (Table 9). This effect may have been highest for the groups of fall chinook released from Prosser Hatchery in May due to the greatest difference in size compared to the other two groups during both years. It is not possible to separate the effect of fish size from release date our study, however, future releases will attempt to minimize differences in fish size at time of release in an effort to better isolate the influence of aquacultural techniques and release timing on survival.

Table 9. Mean fork length (mm) for PIT tagged fall chinook released from Prosser (April and May) and Marion Drain Hatcheries in 1999 and 2000.

	1999	2000
Prosser April (accelerated)	83.9	82.5
Prosser May (conventional)	68.4	90.6
Marion Drain	80.9	73.4

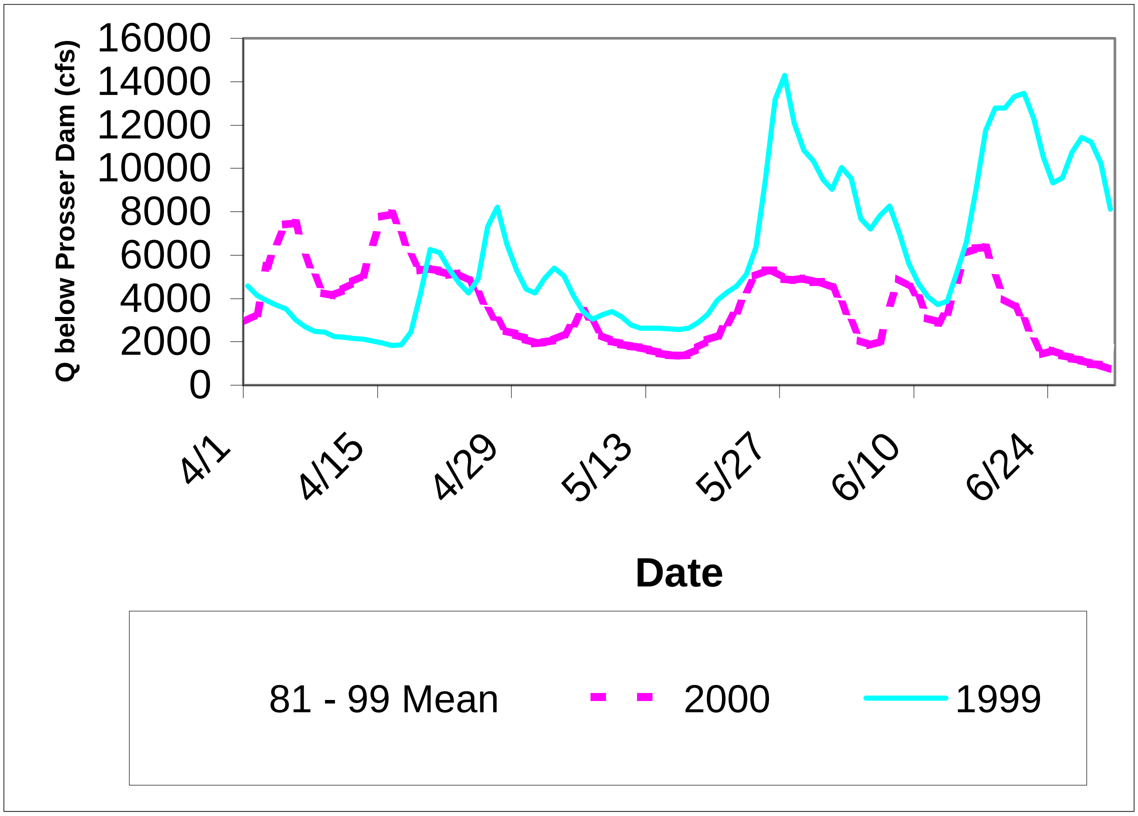

Figure 3. Mean daily May-July discharge (cubic feet per second; CFS) of the Yakima River below Prosser Dam during the period 1981-1999, 1999, and 2000.

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APPENDIX B

Yakima Coho
Monitoring and Evaluation

2000 Annual Report

YAKIMA COHO MONITORING AND EVALUATION
2000 ANNUAL REPORT

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EXECUTIVE SUMMARY

Success of the Yakima/Klickitat Fisheries Program's (YKFP) efforts to re-introduce coho to the Yakima River is reliant upon the use of hatchery fish to develop naturalized spawning populations. The first milestone that must be achieved is the return of sufficient numbers of adults to either spawn naturally or to be spawned in a hatchery. Optimizing the date and location of release of hatchery coho may be a promising method of increasing returns of coho salmon. A literature review tends to indicate that survival increases with a later release date, and even though not definitive, previous results in the Yakima basin also suggest that later releases may out perform early releases in terms of juvenile survival (YN 1997). The optimal release date or location(s) for juvenile coho in the Yakima basin are not known at this time. Adult coho returns to the Yakima River have increased in recent years; however, the spawning distribution of returning adults is not well described. Until recently, the project has relied entirely upon the transfer of lower Columbia River hatchery coho to produce adult coho returns in the Yakima basin. If viable self sustaining populations of coho are to be re-established in the Yakima River, parent stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and the Yakima River. We are optimistic that the project will observe positive trends in coho survival in the Yakima basin as the program develops a localized broodstock.

- We estimated that smolt-to-adult survival rate for 1.4 million hatchery coho smolts released in the Yakima basin in 1999 was 0.567%.

- Survival estimates of juvenile coho released in the Yakima basin in the spring of 2000 to McNary Dam for 8 groups of PIT tagged coho decreased compared to survival estimates from 1999 (mean = 20.0% and 40.2%, respectively). Although no significant differences between subbasin or time of release were indicated in 2000, the early releases had higher survival rates than late releases at all sites except Stiles site where significant mixing between early and late release groups occurred.

- PIT tagged juvenile coho released during the early (May 7) period generally passed McNary Dam earlier than those released during the late (May 31) period, even though mean travel time was generally lower for groups released during the late release.

- We collected and radio tagged 102 adult coho at the Prosser Dam right bank steep pass denil over the period September 14 – November 6. Prosser right bank worked relatively well for collection of coho for radio telemetry. However, relatively low efficiency at this facility (approximately 30%) would limit the effectiveness during low return years.

- Most radio tagged adult coho homed to the mainstem Yakima River below the city of Selah, Washington (Rkm 196) downstream to Rkm 80. Few adult coho homed to acclimation sites which juvenile were released from. Coho spawning in the Yakima peaked the first week of November and was generally complete by mid-November.

- Summer water temperatures may be an important limiting factor for the progeny of coho that spawned below Sunnyside Dam. The release of 100% marked hatchery coho in 2002 will aid in the estimation of the reproductive fish that spawned in 2000.

- Estimates of the average number of residual coho in the upper Yakima and Naches subbasins were relatively low in 2000. We estimated that more coho were present in the Naches Subbasin than the upper Yakima (67.8 and 14.7 coho per km respectively). We in part attribute the higher estimated number of coho in the Naches to natural coho production in that reach. Estimates of the number of coho residuals per km between 1999 and 2000 were similar when expressed as a per capita of coho released.

- The Yakama Nation estimated that a total of 6,138 adult coho passed Prosser Dam in 2000. We collected a total of 483 coho broodstock at the Prosser Dam right bank steep pass denil over the period September 11 – November 8. Fish were collected in relative proportion to the overall run passing Prosser Dam.

- We estimated that a total of 167,910 and 31,070 hatchery and natural origin coho smolts, respectively passed Prosser Dam in the spring of 2000 (Figure 1). Egg-to-smolt survival for natural origin coho from the 1998 brood year was 0.43%. We attribute the low egg-to-smolt survival to poor habitat conditions (especially summer rearing temperatures and gravel quality) in the mainstem Yakima River below Sunnyside Dam.

- Through a combination of weir trapping and electrofishing, we estimated that naturally spawning coho in Buckskin Creek had an average egg-to-fry survival rate of 1.2% (95% confidence interval 0.8 – 1.6%) for the 1999 broodyear. We attribute the low survival to poor quality and quantity of spawning habitat within this urban stream.

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General Introduction

Wild stocks of coho salmon *Oncorhynchus kisutch* were once widely distributed within the Columbia River Basin (Fulton 1970; Chapman 1986); however, coho salmon probably went extinct in the Yakima River in the early 1980s (YN 1997). Efforts to restore coho within the Yakima basin rely largely upon releases of hatchery coho. The feasibility of re-establishing coho in the Yakima basin may initially rely upon the resolution of two central issues: the adaptability of a domesticated lower river coho stock used in the re-introduction efforts and associated survival rates, and the ecological risk to other species associated with coho re-introduction efforts.

The Yakama Nation has released 85,000 to 1.4 million coho smolts annually in the Yakima Basin annually since 1985. However, prior to 1995, the primary purpose of these releases was harvest augmentation; after 1995, the primary purpose became a test of the feasibility of re-establishing natural production. Currently, the Yakima coho program is part of the Yakima Klickitat Fisheries Project (YKFP). The Yakama Nation is also the lead agency for coho re-introduction project in the Wenatchee and Methow sub-basins. Although the mid-Columbia coho re-introduction project and the YKFP are administered by separate entities within the Yakama Nation, each project relies on the transfer of information between basins to some degree to resolve critical uncertainties that are not considered basin-specific issues. For example, coho predation on spring chinook fry, coho hatchery smolt residualism, and the reproductive ecology of lower Columbia River hatchery coho were reported in the 1999 annual report for Mid-Columbia coho monitoring and evaluation (Dunnigan 1999). This report summarizes issues that are specific to the Yakima sub-basin, such as the survival and spawning distribution of hatchery fish and the development of a localized broodstock in the Yakima sub-basin.

The project will initially use early returning hatchery coho smolts from several state and/or federal facilities. Most of these facilities have a lengthy history of coho propagation activities, which may have the potential to subject these stocks to genetic changes due to selective effects, such changes are termed domestication selection (Busack et al. 1997). The genetic composition of the endemic and now extinct Yakima River coho is unknown, however it is likely that genotypic differences existed between the lower Columbia River hatchery coho and the original endemic stock. It is possible that phenotypic differences between endemic Yakima River coho populations and lower Columbia coho populations may have included maturation timing, run timing, stamina, or size of returning adults. Thus the development of a localized broodstock may ultimately determine if this project successfully re-establishes self sustaining populations of coho in the Yakima River.

If coho re-introduction efforts in the Yakima Basin are to succeed, lower Columbia River coho stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and the Yakima River.

We are optimistic that the project will observe positive trends in hatchery coho survival as the program transitions from the exclusive use of lower Columbia River hatchery coho to ultimately the exclusive utilization of in-basin returning broodstock during the development of a locally adapted broodstock. Therefore it is important to measure hatchery fish performance to not only use as an indicator of project performance but to track potential short and long term program benefits from the outlined project strategies. Additionally, if any re-introduction effort is to be successful, adult returns must be sufficient to meet stock replacement levels.

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Chapter 1

Survival of Hatchery Coho

Introduction

Efforts to re-introduce anadromous salmonids in basins that they have become extinct, must rely on project performance indicators to determine if progress toward re-establishing a sustainable population is being achieved. The first milestone that must be achieved is the return of sufficient numbers of adults to either spawn naturally or to be spawned in a hatchery. The project performance indicator of highest interest in the short term may be smolt-to-adult survival. Thus, a monitoring program that tracks smolt-to-adult survival rates of hatchery and wild fish through time is essential to track the project's long-term performance.

Even though adult returns to the Yakima basin have consistently increased since hatchery coho were first released in the Yakima basin (Figure 1), smolt-to-adult survival rates of hatchery coho in the Yakima basin are likely below replacement levels in the natural environment. The project is optimistic that development of a localized broodstock will improve survival rates. However, such changes may take many generations to realize substantial increases in smolt-to-adult survival rates. Optimizing the date of release of hatchery coho may be a promising method of increasing returns of coho salmon (Mathews and Ishida 1989; Bilton et al. 1982, 1984; Mathews and Buckley 1976; Gowan and McNeil 1984). Returns at maturity often increase with generally later releases in the out migration season (Bilton et al. 1982; Mathews and Ishida 1989). Although results in the Yakima River tend to show similar results (YN 1997), with survival increasing with later release date, an optimal date is not known at this time.

The project is not only interested in smolt-to-adult survival rates, but also in juvenile survival in order to parse out that portion of the smolt-to-adult mortality that is occurring in the freshwater lifestages. Juvenile coho released in the Yakima River must migrate past 4 hydroelectric dams on the mainstem Columbia River before reaching the Pacific Ocean. Dams have increased the total cross-sectional area of he Columbia River resulting in decreased water velocity and turbidity, which in turn has increased smolt travel time and generally subjected smolts to greater exposure to predators and other factors influencing survival (Raymond 1979; 1988; Williams 1989). Physical changes in the Columbia River environment attributable to hydro-projects may require salmonids to migrate under a different set of environmental conditions than they evolved.

Juvenile and adult coho survival in the Columbia River mainstem may be further depressed by the source of hatchery broodstock. Lower Columbia River stocks of coho may not be well adapted to migrate the long distances required for them to reach the ocean and return. Beginning in 2000, all hatchery smolt were marked with CWT, allowing estimation of naturalized smolt and adult production and survival. A baseline monitoring

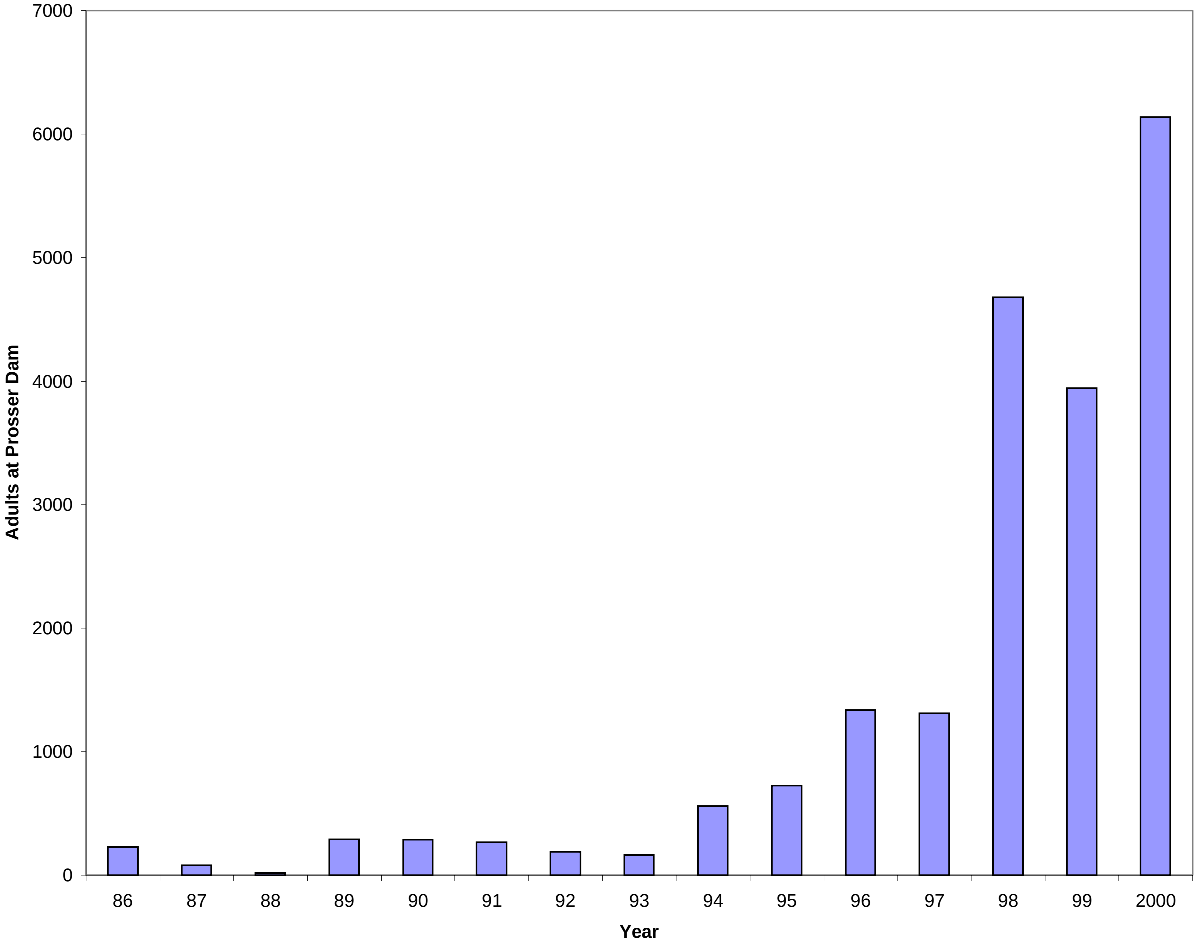

Figure 2. Adult coho returns (adults and jacks) at Prosser Dam, 1986-2000.

program that tracks both juvenile survival and smolt-to-adult rates will be important to determine if benefits are achieved from development of a locally adapted broodstock.

This report summarizes the second year of results from a four year study intended to determine optimal time of release for hatchery coho in the Naches and upper Yakima sub-basins. Comparisons between sub-basin will also be made. Results for 2000 will be limited to comparisons of juvenile survival using PIT tags. Comparisons of smolt-to-adult treatment groups will begin in 2001, the first year of returns from 100% marked hatchery smolts.

Methods

Smolt-to-Adult Survival Rates for Return Years 1996-2000

Yakama Nation acclimated and released between 700,000 and 1,400,000 yearling coho smolts in the Yakima basin during the period 1995-2000 at various locations throughout the basin (Table 1). We calculated smolt-to-adult survival by dividing the number of adults (outmigration year +1) and jacks (migration year) passing Prosser Dam as enumerated via video monitoring by the total number of hatchery smolts released for returns years 1996-2000.

2000 Juvenile Survival Estimates

We acclimated and released a total of approximately 1 million hatchery coho smolts in the Yakima basin in the spring of 2000 in the Naches and upper Yakima sub-basins. Each sub-basin had two release sites (Easton highway ponds and Cle Elum Hatchery Slough in the upper Yakima and Lost Creek and Stiles ponds in the Naches; Figure 2). Within each site there were two releases, which represented a complete factorial combination of time of release [May 7 (early) and May 31 (late)]. The program had planned to incorporate approximately 28,000 Yakima stock coho into the 2000 release (brood year 1998) experimental design, but a mechanical failure at the Prosser Hatchery on February 26, 2000 forced the premature release at that facility. None of the fish released were marked. At each acclimation/release site, release groups were confined in separate ponds, and consisted of approximately 1,200 PIT tagged progeny of Willard Hatchery stock (Table 2). The remainder of the release groups that were not PIT tagged were tagged in the snout with a coded wire tag that identified each fish to release group.

PIT tagged fish were detected at McNary and Bonneville dams, which allowed estimates of survival indices for the 8 coho release groups (2 release dates x 2 sites/river x 2 rivers) (Appendix A).

Table 1. A summary of hatchery coho release numbers and locations for the period 1995-2000.

	1995	1996	1997	1998	1999	2000
Wapato	45,000					
Roza Waste Way	196,000	562,700	674,500	700,000		
Granger	459,100	655,600				
Greenway		86,000		200,000		
Lost Creek.			370,000	300,000	320,000	247,780
Golf Coarse Springs				200,000		
Stiles Pond					226,000	249,087
Cle Elum Hatchery Slough					210,000	247,575
Jack Creek Spring Chinook Acclimation Site					226,000	
Easton Spring Chinook Acclimation Site					48,000	
Easton Highway Ponds						248,137
TOTAL	**700,100**	**1,304,300**	**1,044,500**	**1,400,000**	**1,030,000**	**992,579**

Table 2. Hatchery coho release locations, basin, river kilometer (Rkm), stock, release date, and number PIT tagged in Yakima sub-basin, 2000. The first number in the river kilometers is number of km from the Yakima River confluence, and numbers after the period are number of km from the confluence of the next tributary with the Yakima River.

Location	**Basin**	**Rkm**	**Stock**	**Release Date**	**PIT Tag Number Released**
Stiles Pond	Naches	187.14	Willard	5/7/99	1250
Stiles Pond	Naches	187.14	Willard	5/31/99	1277
Lost Creek	Naches	187.62	Willard	5/7/99	1160
Lost Creek	Naches	187.62	Willard	5/31/99	1220
Cle Elum Slough	Yakima	295	Willard	5/7/99	799
Cle Elum Slough	Yakima	295	Willard	5/31/99	809
Easton Ponds	Yakima	284.17. 9	Willard	5/7/99	1247
Easton Ponds	Yakima	284.17. 9	Willard	5/31/99	1246
Prosser Hatchery**	Yakima	75.6	Yakima	2/26/00	0

**On February 26, 2000 a pump failure at Prosser Hatchery forced premature release of ~28,000 unmarked coho from the facility.

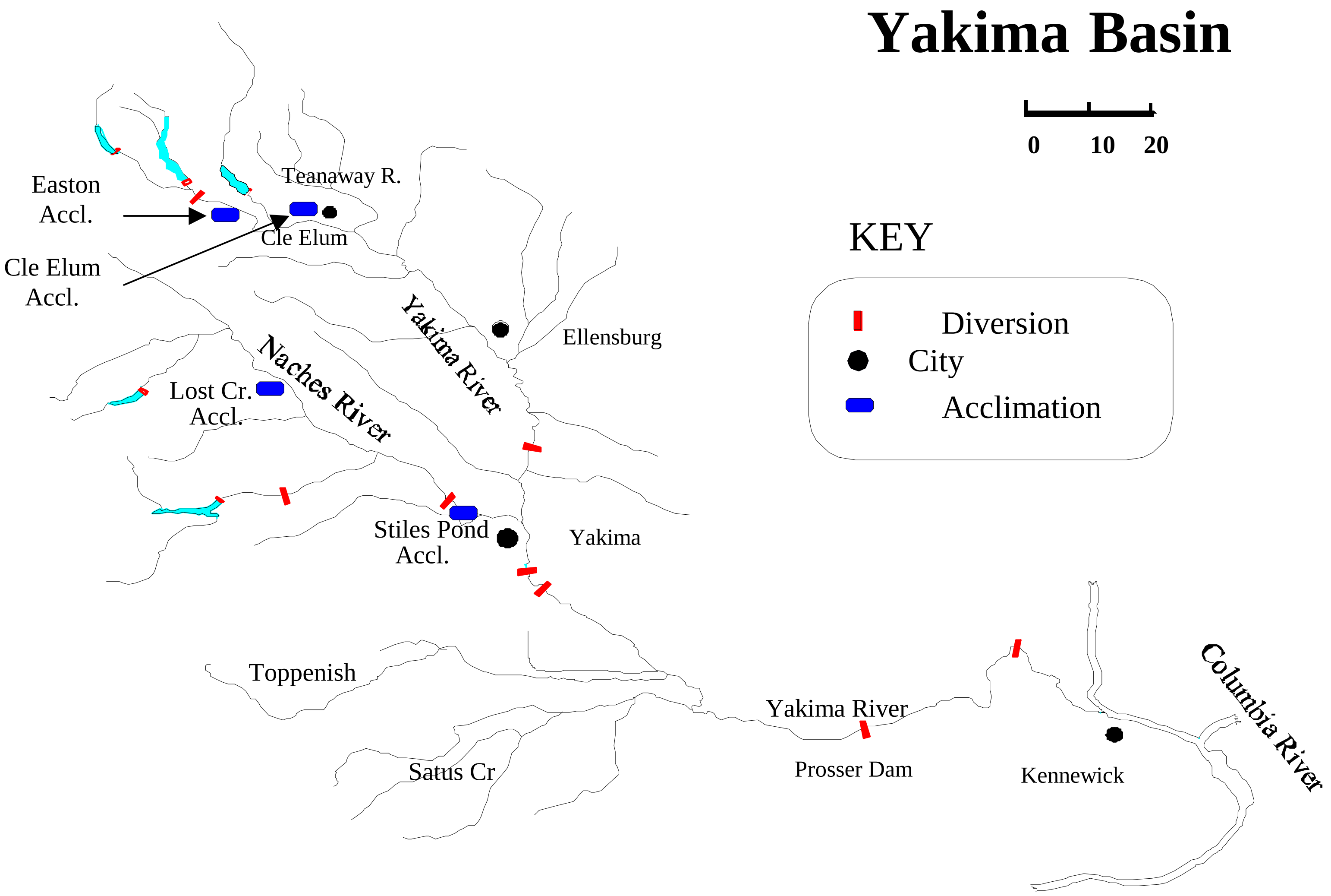

Figure 2. Map of the juvenile hatchery coho acclimation and release sites in 2000.

Estimates of Survival for PIT Tagged Juveniles

Survival of 2000 PIT tagged coho from releases in the upper Yakima and Naches to McNary Dam was based on expanding the detected fish at McNary by the McNary Dam detection rate and then dividing the expanded number by the number of released PIT tagged fish. Detection rates at McNary were estimated by dividing the number of fish detected at both McNary (McN) and Bonneville (BV) by the total number detected at Bonneville Dam.

McNary detection rates estimated from 1999 volitional releases of spring chinook in the upper Yakima were found to vary over passage time (Appendix A). In outmigration year 2000, there were only two detection rate strata for the upper Yakima PIT tagged spring chinook (there were 7 in 1999). In 2000, only 4 out of 286 total PIT-tagged coho detections at Bonneville were detected in the first stratum (on or before May 19); therefore strata partitioning for coho in 2000 did not make sense (see Appendix A).

Since travel time from McNary to Bonneville Dam was not stratified for PIT tagged coho in 2000, it was not necessary to offset the Bonneville date by the mean McNary-to-Bonneville-based travel time to obtain the McNary date of passage associated with Bonneville-based detection rate strata. Equations 1 through 3 below were used to estimate passage. In the equations, n() represents the number of detections at the dams indicated within the parentheses.

Equation 1. DR - estimated BV-based McN Detection Rate:

$$\mathrm{DR} = \frac{\mathrm{n(BV, McN)}}{\mathrm{n(McN)}}$$

Equation 2. P - estimated McNary passage:

$$\mathrm{P} = \frac{\mathrm{n(McN)}}{\mathrm{DR}}$$

Equation 3. S - estimated survival from release to McN:

$$\mathrm{S} = \frac{\mathrm{P}}{\mathrm{N}}$$

Wherein N is the number of released PIT tagged fish released.

The survival estimates were analyzed using a logistic analysis of variation that effectively uses number released as weights and assumes an underlying binomial distribution. The site-within-subbasin x time-of-release interaction served as the measure of error variation. We compared differences in mean travel time (days) between groups at each site using a t-test.

Results

Smolt-to-Adult Survival Rates for Return Years 1996-2000

We estimated that 5,843 adult coho and 411 jack coho returned to the Yakima sub-basin in the fall of 2000 and 1999 respectively, for an overall smolt-to-adult survival estimate of 0.607%. Smolt-to-adult survival (including jacks from the previous year) has increased nearly every year since 1996, with the 2000 return the highest observed in the Yakima River for hatchery coho (Table 3).

2000 Juvenile Survival Estimates

We used a pooled Bonneville powerhouse-based detection rate to estimate survival to McNary Dam. The mean Bonneville-based McNary detection rate over the coho migration was 0.2063. Survival indices from release to McNary Dam for the 8 groups of PIT tagged hatchery coho released in the Yakima basin in 2000 ranged from 2.0% to 35.8% (Table 4). Estimates of survival were lowest for those coho released at the Cle Elum acclimation facility (pooled site mean = 7.8%; Table 4).

Although the logistic analysis of variation (Table 5) indicates no significant differences between the subbasins or between the early and late releases, the early releases had higher survival rates than late releases at all sites other than Stile's as indicated in Table 4. There is strong evidence of mixing of early and late release fish prior to release at Stiles where there was only one pond with a net separating the early from the late release fish. Travel times of the releases are given in Table 6. More than 54% of the Stile's late release detections at McNary were detected before the late release date suggesting that there was a substantial mixing between the Stile's early and late release treatment fish prior to release. The small proportion of fish detected before release date for two of the five other releases might reflect a small proportion of escapees prior to release date.

Table 3. Smolt-to-smolt (based on smolts released to smolts at CJMF) and smolt-to-adult survival (based on smolts released and adults at Prosser Dam) statistics for hatchery coho released in the Yakima River Basin. Returns are adult returns 1 year following the release year plus jacks the year of the release. Years in the table represent year of smolt release.

Year of Release	Number of Smolts Released	Chandler Passage	Smolt Survival To CJMF (%)[1]	Adult Returns (Year+1) Jacks (Year+0)[2]	Smolt-Adult Survival (%)[3]	Release Date(s)	Release Site(s)
1985	260,690	117,558	45.1	230 (0)	0.088	5/28-5/31	Yakima River above Wapato Dam (unacclimated)
1986	84,879	48,349	57.0	82 (0)	0.100	4/1-5/23	Nile Pond on upper Naches River (acclimated, volitional release)
1987	492,415	193,777	39.4	18 (1)	0.004	4/1-4/20	Wapato Dam + mid-Yakima tributaries (MYTs)[4]: Ahtanum, Wide Hollow & Cowiche Creeks (unaccl.)
1988	828,269	606,926	73.3	282 (0)	0.034	4/29-5/7	MYTs (unaccl.)
1989	700,186	224,670	32.1	289 (9)	0.043	3/9-3/16	MYTs (unaccl.)
1990	505,263	158,305	31.3	230 (0)	0.046	3/9-3/14	MYTs (unaccl.)
1991	483,256	112,975	23.4	137 (39)	0.036	3/5-3/16	MYTs + Wanity Slough & Toppenish Cr. (unaccl.)
1992	631,358	110,999	17.6	162 (53)	0.034	3/1-3/7	MYTs (unaccl.)
1993	534,246	82,589	15.5	532 (3)	0.100	3/15-3/17 & late April	MYTs + Wapato & Horn Dams, lower Satus & Toppenish Cr., Granger Pond & Roza WW #3 (WW#3, Granger Pond & Wapato Dam acclimated; the rest unaccl.). Unaccl. releases in March, acclimated in late April.
1994	772,551	403,774	52.3	650 (28)	0.088	4/29	Granger Pond, Roza Wasteway #3, Wapato Dam (accl.)
1995	699,474	411,733	58.9	921 (75)	0.142	4/26	Granger Pond, Roza Wasteway #3, Wapato Dam (accl.)
1996	1,218,221	785,978	64.5	1241 (417)	0.136	4/10 & 5/6-5/15	Roza Wasteway #3 (May release), Granger Pond (April 10 release) (accl.)
1997	1,040,602	306,520	29.5	4625 (71)	0.451	5/15	Roza Wasteway #3, Lost Cr. Pond on the Naches (accl.)
1998	1,400,00	472,820	33.8	3532 (54)	0.256	5/15 & 5/30	Roza Wasteway #3, Lost Cr. Pond, Golf Course Springs, and Greenway Pond (accl.)
1999	1,030,000	117,107	11.7	5843 (411)	0.607	5/17 & 5/27	Stiles Pond & Lost Creek (Naches); Jack Cr. & Easton accl. sites & Cle Elum Hatchery Slough (upper Yakima) (acclimated)

Table 3. Smolt-to-smolt (based on smolts released to smolts at CJMF) and smolt-to-adult survival (based on smolts released and adults at Prosser Dam) statistics for hatchery coho released in the Yakima River Basin. Returns are adult returns 1 year following the release year plus jacks the year of the release. Years in the table represent year of smolt release.

Year of Release	Number of Smolts Released	Chandler Passage	Smolt Survival To CJMF (%)[1]	Adult Returns (Year+1) Jacks (Year+0)[2]	Smolt-Adult Survival (%)[3]	Release Date(s)	Release Site(s)
2000[5]	1,030,000	202,415	19.7	N/A (295)	N/A	5/7 & 5/31	Stiles Pond & Lost Creek (Naches); Jack Cr. & Easton accl. sites & Cle Elum Hatchery Slough (upper Yakima) (acclimated)

1 Smolt-to-smolt survival is based on smolts released to smolts at CJMF.

2 Returns are adult returns 1 year following the release year plus jacks the year of the release.

3 Smolt-to-adult survival is based on smolts released and adults at Prosser Dam.

4 MYTs = Mainstem Yakima River Tributaries.

5 2000 Coho information should be considered provisional at this time.

Table 4. Survival indices from release site to McNary Dam for coho released in the Naches and upper Yakima, 2000, calculated based on Bonneville Dam-based McNary detections.

Subbasin	Site	Early	Late	Pooled Site Mean	Subbasin Mean
Yakima	Cle Elum	0.136	0.020	0.078	0.154
	Easton	0.278	0.182	0.230	
Naches	Lost Creek	0.271	0.148	0.209	0.259
	Stiles	0.259	0.358	0.309	
Pooled Treatment Mean		0.236	0.177	0.207	

Table 5. Logistic analysis of variation in survival among 1999 coho releases in the Yakima River basin, 2000. Survival estimates are based on individual stratum detection rates pooled over releases.

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 P
Subbasin	335.24	1	335.24	2.41	0.2607
Site (within Subbasin)	581.27	2	290.64	2.09	0.3236
Time (of Release)	104.37	1	104.37	0.75	0.4776
Subbasin x Time	114.34	1	114.34	0.82	0.4602
Error (Site x Time)	278.12	2	139.06		

The estimated mean travel time to McNary Dam for the four release groups of juvenile coho released on May 7 ranged from 20.9 to 27.7 days (Table 6), with coho released from Stiles Pond having the shortest mean travel time, and Lost Creek having the longest travel time. Mean date of arrival at McNary Dam for these two groups was May 27 and June 3 respectively. Travel time for coho salmon released at every site was significantly longer for releases made on May 7 compared to May 31 releases (Table 6). In most cases release time was approximately reduced by about 50%. Mean travel times for groups of coho released on May 31 ranged from 1 to 28 days, for the Stiles and Lost Creek sites respectively. However, the short travel time for the Stiles site was strongly biased due to mixing between the May 7 and 31 release groups (see above).

Table 6. Travel time means and comparisons between early (May 7) and late (May 31) juvenile coho releases at four release sites, 2000.

May 7 Release Travel Time	Cle Elum	Easton	Lost Creek	Stiles
Mean	25.70	24.97	27.69	20.89
Standard Deviation	10.95	7.25	8.23	4.59
Number of Detections	70	142	139	133
May 31 Release Travel Time				
Mean	11.10	13.29	12.24	1.41
Standard Deviation	12.67	7.74	5.24	5.51
Number of Detections	10	93	76	184
Difference				
Estimate	14.60	11.68	15.45	19.49
Standard Error	4.215	1.007	0.921	0.569
Approximate DF	11	188	208	309
t-test	3.464	11.597	16.771	34.271
Computed Type 1 Error	0.0053	0.0000	0.0000	0.0000

Discussion

We estimated an average survival rate of 20.7% for the 8 coho release groups to McNary Dam in 2000. We believe that the observed survival indices of these mark groups accurately represented those groups they were intended to represent. We feel that environmental conditions in the Yakima River during the period of migration of these fish contributed to their performance. Environmental conditions in the Yakima River in 2000 were similar to average conditions during the period 1981 to present. The mean daily temperature difference between the mean (period 1987-1999) and 2000 between May 7 and June 30 was 1.2 C. However, discharge approaching Prosser Dam in 2000 between the period April 1 – June 30 was slightly higher than the mean flow during the period 1981-1999 (Figure 3). Given the somewhat typical conditions observed during the 2000 coho outmigration period, the estimated juvenile survival indices may be typical of what can be expected during most years, under the current coho program.

Although environmental conditions in the Yakima River in 2000 may have been somewhat typical compared to most years, conditions in 2000 were atypical compared to conditions and survival observed in 1999. Survival indices from release to McNary Dam for juvenile coho released in 1999 were approximately twice as high as survival indices for coho released in 2000. We believe that survival indices between years accurately represent survival trends in the Yakima and Columbia rivers. Environmental conditions in the Yakima River were likely responsible for differences in survival between 1999 and 2000. The mean daily difference in discharge approaching Prosser Dam between May 7 and June 30 was 4423 cubic feet per second higher in 1999 compared to 2000. Mean daily water temperature (measured at Prosser Dam) was also 2.2 C warmer in 2000 compared to 1999. While the temperature difference between the 1999 and 2000 coho outmigration period was relatively small (approximately 2.2 degrees C), the difference in temperature would have resulted in a substantial increase of the metabolic rate for many of the predator fish species present in the Yakima River (Brown and Moyle 1981; Vigg et al. 1991; Ferguson 1958; Barans and Tubb 1973).

Hatchery spring chinook salmon released in the upper Yakima in 2000 had slightly higher survival indices from release to McNary Dam than coho. The mean survival index for all PIT tagged hatchery spring chinook released in 2000 was 35.1% (see Appendix A). Survival indices from release to McNary Dam for hatchery spring chinook were also lower in 2000 than in 1999 (pooled survival index 0.351 and 0.526 respectively). Differences in migration timing and migration behavior may be responsible for differences in survival indices for each species.

Although the logistic analysis of variation indicates no significant differences between the sub-basins or between the early and late releases, the early releases had higher survival rates than late releases at all sites other than Stile's. It is possible that the significant mixing between early and late release groups at the Stiles site confounded the results. However, when results are pooled across 1999 and 2000, it is possible that early released fish have a greater survival rate than late released fish. In 1999 five out of six[1] paired releases had a higher survival index for the early release. For the combined years, the

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[1] Six pairs in 1999 were three sites (Cle Elum, Jack Creek, Stiles) x two stock (Cascade, Yakima). The late release of Yakima stock at Stiles had a higher survival index then the early.

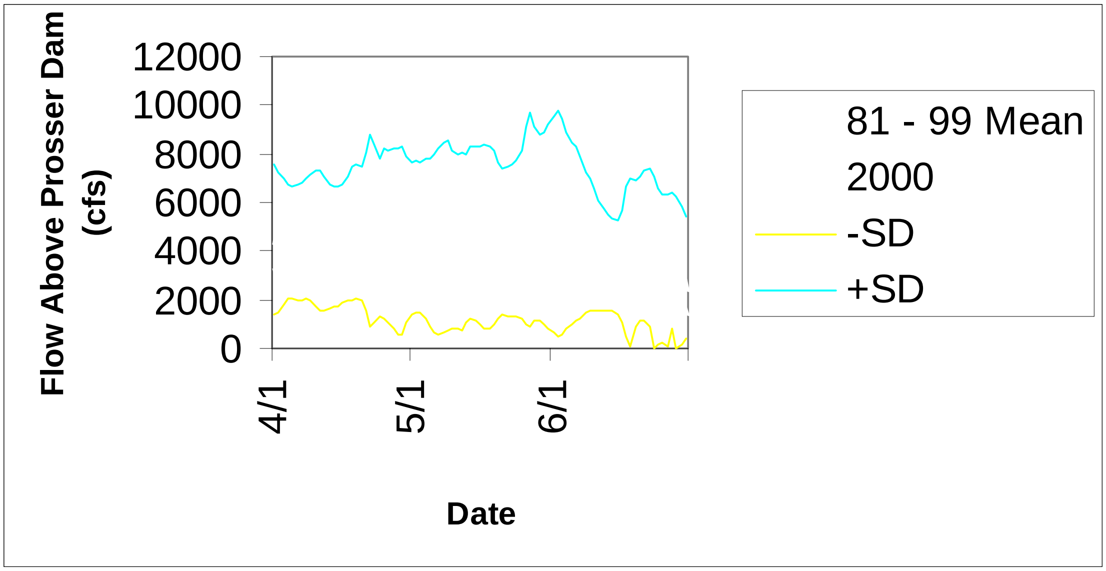

Figure 3. Mean discharge (cubic feet per second) approaching Prosser Dam for the mean (1981-1999), plus and minus one standard deviation (SD), and 2000 for the period April 1 – June 30.

probability of having just by chance a total of 8 (3 in 2000 and 5 in 1999) or more out of 10 paired releases (4 in 2000 and 6 in 1999) having one of the two treatments with the highest survival index is P = 0.11[2]. If the year-2000 Stiles' release were omitted (due to mixing between groups), the probability of having just by chance total of 8 or more out of 9 paired releases over two years having one treatment out of two with the highest survival index is 0.04. It is likely that the early coho release has a higher survival index than the late release.

While we believe that our estimates of the survival of PIT tagged coho accurately represented survival of the groups they were intended to represent, we feel that additional data will strengthen conclusions that will be critical for shaping the final Yakima River Coho Re-Introduction Program. Even though the results of the combined results from 1999 and 2000 juvenile survival estimates tended to suggest that early releases had higher survival rates to McNary Dam than the late releases, the most important survival parameter will inevitably be survival to returning adult. We were unable to find any studies that assessed juvenile survival related to release timing. In fact, juvenile coho survival from release to Chandler Juvenile Monitoring Facility (CJMF) is not correlated to adult and jack returns to Prosser Dam (YN 1997). Several studies have demonstrated that smolt to adult survival of coho salmon increases several-fold within a series of experimental releases over a period of several months (Mathews and Ishida 1989; Bilton et al. 1982, 1984; Mathews and Buckley 1976; Gowan and McNeil 1984). Although Mathews and Ishida (1989) found increasing trends in smolt to adult survival for groups of coho released from a Columbia River Hatchery (Big Creek) and an Oregon hatchery (Coos Bay), they were not able to substantiate either of the two most commonly supported hypotheses related to observed trends in ocean survival of juvenile coho: (1) intraseason variability of early ocean-life food supply for coho, and (2) intraseasonal variability of the physiological readiness of migrating coho to adapt to salt water. Bilton et al. (1982) also found significant trends of increasing adult returns for coho released as yearling smolts over four release periods ranging from April 14 – July 8 on Vancouver Island, British Columbia. However, Bilton et al. (1982) also noted a significant interaction between release time and size, and that generally adult returns were maximized with early releases of small fish (16-17 g) and later releases of larger (27-28 g).

All hatchery coho released in the spring of 2000 were marked with CWT, thus allowing us to assess differences in smolt-to-adult survival rates between release groups. The marking program initiated in the spring of 2000 will continue for the next several years, allowing us to assess the contribution of naturally spawning coho to smolt and adult production within the Yakima Basin (see Chapter 4). Operations at the CJMF will also enable us to enumerate naturally produced (non-marked) juvenile migrants, and the adult coho broodstock collection conducted at Prosser Dam will permit us to estimate the proportion of returning adults of natural origin. This combined effort will allow

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[2] Type 1 error probability based on sign test assuming binomial distribution

comparison of hatchery and naturally produced smolt-to-adult survival rates. Enumeration of naturally produced juvenile migrants at CJMF will also help us assess the reproductive success of naturally spawning coho in the Yakima Basin.

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Chapter 2

Adult Coho Radio-Telemetry

Introduction

In order to re-establish a self-sustainable population of coho salmon in the Yakima River, returning adults must successfully spawn in viable areas of the Yakima basin. Prior to juvenile releases in 1999, political constraints required that the majority of hatchery coho releases were restricted to below Wapato Dam. Tributaries available for coho spawning in this section of the Yakima River are limited, and the mainstem Yakima is generally larger than most streams that coho typically select to spawn in (Groot and Margolis 1991). Summer time rearing temperatures below Wapato Dam may also limit naturalized coho production in the Yakima River below the city of Yakima. The spawning distribution and spawning success of coho returning to the Yakima was previously unknown. Earlier attempts to determine the spatial distribution of spawning coho in the Yakima basin has been limited by our ability to locate significant numbers of redds. For example, the ratio of adults passing Prosser Dam to redds during the period 1989 – 1996 was approximately 25:1. Thus, assuming a 50% sex ratio on average we observed approximately 8% of the potential redds (YN 1997). The disparity between coho redds observed and Prosser adult counts could potentially be explained by three factors. Redd surveys may not have been conducted in appropriate areas to locate coho redds. The homing fidelity of adult coho to those acclimation sites they were released at as juveniles was also previously unknown. Previous surveys were generally conducted in the general vicinity to acclimation sites and those areas with anecdotal reports of spawning coho. It was also possible that previous surveys had been conducted in areas with low observer efficiency due to river conditions such as turbidity or depth. The final potential factor that may have accounted for low coho redd counts, was low reproductive success (redd construction) of hatchery coho. A preliminary reproductive success experiment conducted in Wenas Creek in 1998 suggest that most female hatchery coho construct redds (Dunnigan 1999), however the reproductive success of those individuals is unknown. In the fall of 1999 we initiated a three year adult coho radio telemetry study to determine the distribution of spawning coho in the Yakima basin. Dunnigan (2000) concluded that most coho returning to the Yakima in the fall of 1999 spawned below the city of Selah, Washington and that summer rearing temperatures would likely limit natural production below Wapato Dam. This report summarizes the results of the second year of the study.

Methods

The Yakama Nation released a total of approximately one million yearling hatchery coho smolts in May 1999 at five release locations (Table 1). The five acclimation and release locations were Lost Creek and Stiles Pond on the Naches River, Cle Elum Hatchery Slough, and the Jack Creek and Easton spring chinook acclimation Facilities on the upper Yakima (Figure 1). Most hatchery coho that returned to the Yakima River in 2000 were assumed to be three year old hatchery fish released in the spring of 1999. However, scale samples were collected from returning coho, but were not completed in time for this report. The proportion of naturally produced fish that constituted the outmigration in 1998 and the adult returns of 1999 were unknown.

Table 1. Hatchery coho release locations, basin, river kilometer (Rkm), and total release number in Yakima sub-basin, 2000. The first number in the river kilometers is number of km from the Yakima River confluence, and numbers after the period are number of km from the confluence of the next tributary with the Yakima River.

Location	**Basin**	**Rkm**	**Total Number Released**
Stiles Pond	Naches	187.14	226,000
Lost Creek	Naches	187.62	320,000
Cle Elum Slough	Yakima	295	210,000
Jack Creek	Yakima (Teanaway sub-basin)	284.17. 9	226,000
Easton Ponds	Yakima	327	48,000

Tagging Procedure

We estimated weekly run timing distribution for coho at Prosser Dam for return years 1994-1999 to generate an average weekly run timing distribution, in order to distribute the radio tags in proportion to fish passing Prosser Dam. We collected coho at Prosser Dam right bank steep pass denil. Fish ascended the denil to a flume that diverted all fish into an anesthesia tank containing a solution of tricaine methanesulfonate (MS-222). We examined fish for marks, tags, and injuries, and then measured and obtained scale samples. Radio transmitters were inserted through the mouth into the stomach (Mellas and Haynes 1985). Tagged fish were held in a recovery tank 4-10 hours in order to evaluate tag regurgitation. Age and hatchery/wild origin determination from scale samples was conducted by YN personnel, but was not completed in time for this report. We did not tag fish less than 350 mm fork length (FL) in order to minimize tag regurgitation and physical injury to fish. After recovery, we released tagged fish 0.5 miles upstream of Prosser Dam. The denil was operated throughout the coho run during the period September 30 – October 30 (Figure 2).

Radio Tags

We used 25 g tags manufactured by Advanced Telemetry Systems, Inc. Tags were powered by a single 3.6 V lithium battery and had a minimum life span of 155 days. Each transmitter had a 29 cm flexible external whip antenna attached to one end. The tags transmitted on one of eight frequencies spaces 10 kHz apart (30.17 to 30.25 MHz). We did not use frequency 30.22 MHz due to prior poor performance related to background noise in the area (Hockersmith et al. 1994). Each tag had unique bandwidth pulses that provided individual identification codes.

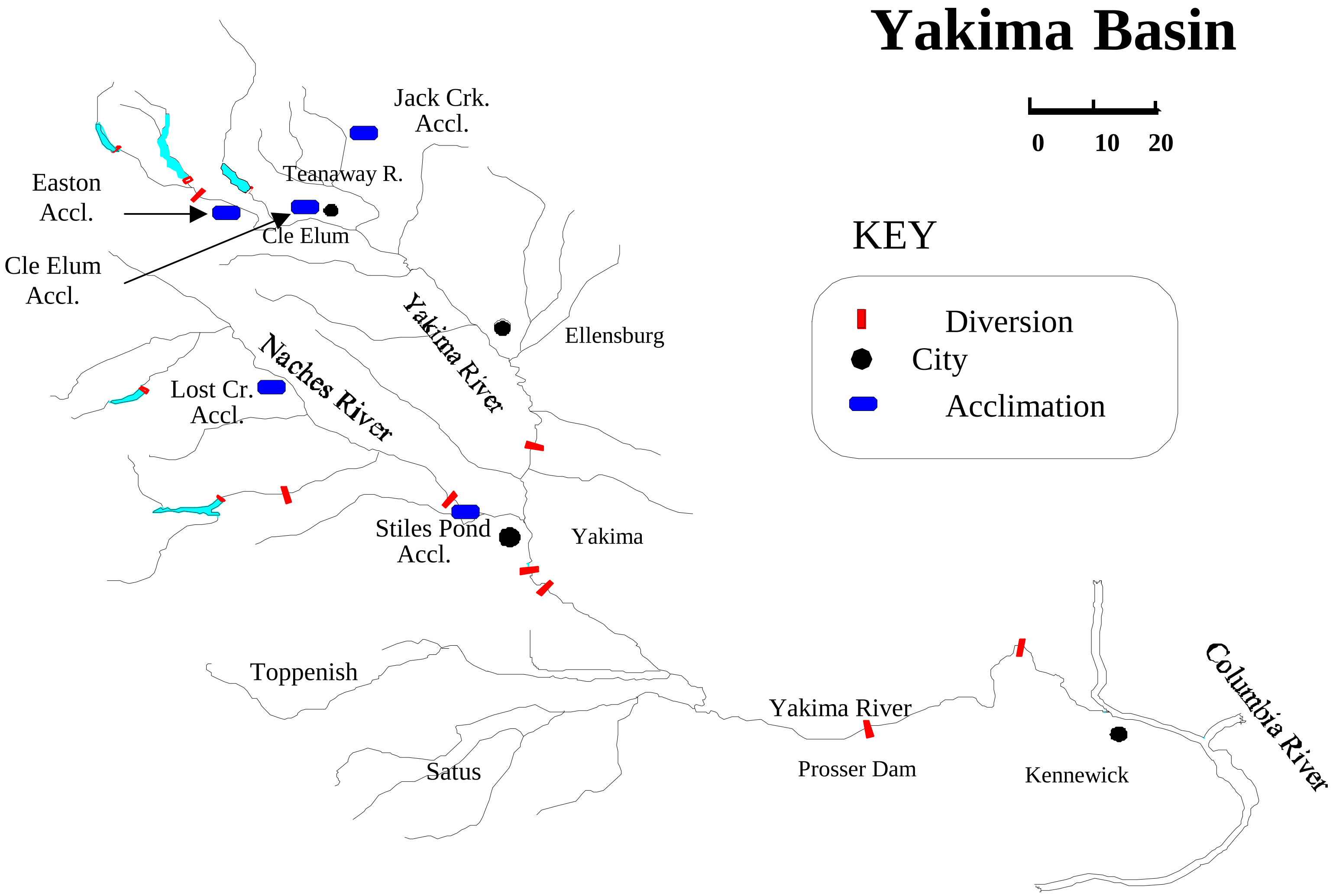

Figure 1. Map of the Yakima basin including juvenile hatchery coho acclimation and release sites for 1999.

Surveillance Equipment and Procedures

We used telemetry receivers manufactured by Lotek Engineering (Model SRX-400) for both fixed site and mobile monitoring activities. Each unit consisted of a radio receiver, data processor, internal clock, and data logger, and had a scanning rate of 13.5 seconds.

We established self-contained fixed site monitoring stations near the vicinity of Prosser, Sunnyside, Roza, Cowiche dams, the Jack Creek, Cle Elum, and Lost Creek acclimation sites, and the confluence of the Teanaway River (Figure 1) to record the presence and activities of tagged coho in the area, and collect run-timing information. At Cowiche Dam we were also interested in fish ladder utilization to determine the efficacy of this site for a future coho broodstock collection site. Fixed site monitors consisted of a receiver system, power supply, antenna switching box (for those sites with multiple antennae), and either a single or series of antennae. Data collected at fixed site monitoring stations was downloaded at least once per week.

We used two types of antennae. Tuned loop antennae were used for fixed site and mobile monitoring. At fixed sites we used either a single antenna to determine if fish were in the general area (Lost Creek and Roza Dam) or 2 antennae (one directed upstream and one directed downstream) to estimate passage (Sunnyside and Cowiche dams) (Table 2). Underwater antennae that consisted of coaxial cable, with 10 cm of shielding stripped from the distal end, were installed at Cowiche Dam in addition to the aerial antennae described above. Underwater antennae were intended to evaluate ladder passage.

Mobile tracking was conducted approximately 2-4 days per week to determine the location of tagged fish at sites outside the range of fixed monitoring sites. We relied primarily upon upstream movement and visual observations as indicators of live fish. Tags were recovered from dead fish whenever possible.

Results

The Yakama Nation estimated that a total of 6,138 coho passed Prosser Dam in 2000. We collected and radio tagged 102 coho at the Prosser Dam right bank steep pass denil over the period September 14 – November 6 (Figure 2). We estimated that the 2000 Yakima River coho return was comprised of 49.5% female, 46.9% adult male, and 3.6% precocial male (jacks). Adult males were slightly larger (mean FL = 67.4 cm) than females (mean FL = 66.1 cm; Figure 3). Prosser right bank worked relatively well for collection of coho for radio telemetry. Approximately 31.7% of the returning coho passed over the right bank ladder during the past 5 years of operation.

Based on the last radio signal recorded for individually tagged adult coho, we believe that most tagged coho homed to the mainstem Yakima River below the city of Selah, Washington (Rkm 196) downstream to Rkm 80 (Figure 1). We therefore concluded that most radio tagged coho homed with low fidelity to the release/acclimation sites in the Naches and upper Yakima sub-basins. Coho spawning in the Yakima peaked in early to

Table 2. Locations and antennae configuration for fixed site radio telemetry monitors.

Monitor Number	**Monitor Location**	**River**	**River Kilometer**	**Antenna Number**	**Antenna Orientation**
1	Prosser Dam	Yakima	75.6	1	Upstream
2	Sunnyside Dam	Yakima	165.7	1	Downstream
2	Sunnyside Dam	Yakima	165.7	2	Upstream
3	Cowiche Dam	Naches	5.8	1	Downstream
3	Cowiche Dam	Naches	5.8	2	Upstream
4	Cowiche Dam	Naches	5.8	1	Ladder Entrance
4	Cowiche Dam	Naches	5.8	2	Ladder Exit
5	Lost Creek Acclimation Site	Naches	61.8	1	Downstream
7	Roza Dam	Yakima	205.8	1	Downstream
8	Roza Dam	Yakima	205.8	2	Ladder Exit
9	Teanaway Confluence	Yakima	283.4	1	Downstream
10	Jack Creek Acclimation Site	North Fork Teanaway	17.0 (9.5)	1	Downstream
11	Cle Elum Hatchery Slough	Yakima	294.7	1	Downstream
12	Easton Acclimation	Yakima	325.1	1	Downstream

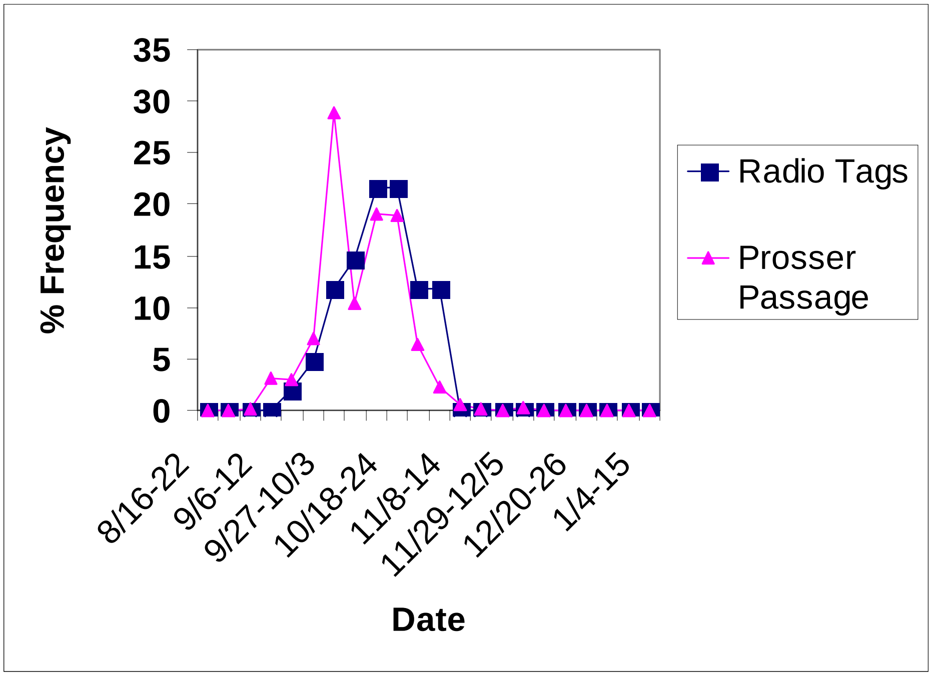

Figure 2. The cumulative passage of adult coho at all ladders at Prosser Dam, and radio tagged fish at right bank denil, 2000.

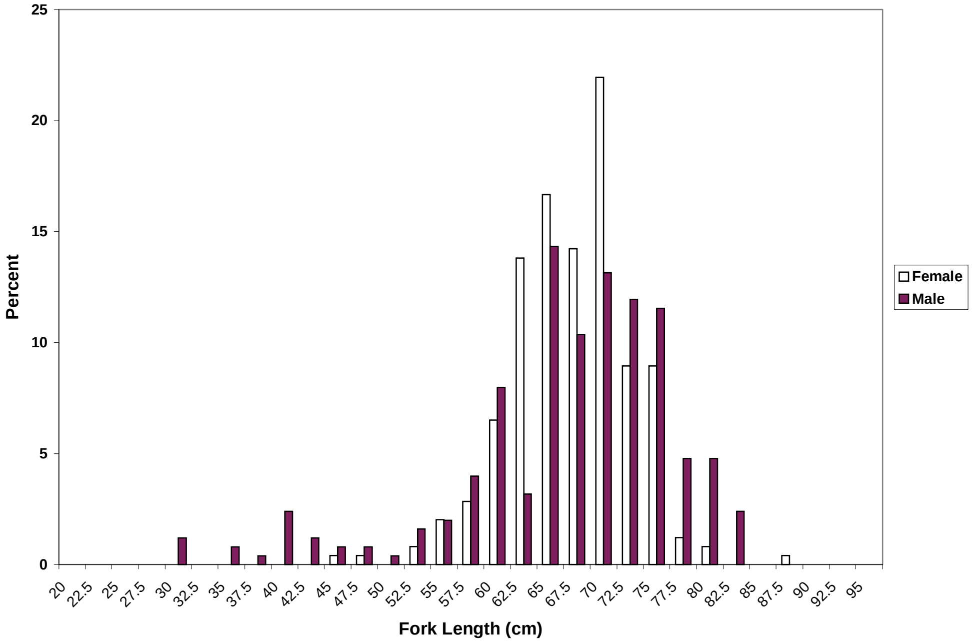

Figure 3. Length frequency distribution of adult coho collected at right bank denil trap at Prosser Dam, 2000.

mid-November and was generally complete by early December. Most radio tagged adult coho (62.7%; 64) did not pass Sunnyside Dam (Figure 4). We estimated that approximately 41% of the tagged coho spawned in Yakima mainstem between river kilometer 129 – 166. We believe most of these tagged coho likely spawned in the lower Yakima River mainstem and side channels.

We observed 38 (37.3%; Figure 4; Table 3) tagged coho above Sunnyside Dam (Rkm 166). Most of the coho that we believe spawned above Sunnyside Dam did so in the main stem Yakima and Naches rivers. We observed 10 (9.8%) radio tagged fish in the section of the Yakima River from Selah, Washington (Rkm 196) downstream to Union Gap (Rkm 172). Four (3.9%) radio tagged coho were last observed and believed to have spawned in the lower Ahtanum Creek. Three (2.9%) radio tagged coho were last observed in Wide Hollow Creek near Yakima. Only one (1%) of the radio tagged coho ascended Cowiche Dam, and was believed to have spawned in the mainstem Naches at approximately Rkm 21. Two other radio tagged coho approached Cowiche Dam, but did not pass the dam, and were believed to have spawned between the Naches confluence and Cowiche Dam (Rkm 6). Two of the radio tagged fish (2%) were last observed in the mainstem Yakima River between the Naches River Confluence (Rkm 187.1) and Roza Dam (Rkm 206). We observed 6 (5.9%) of the radio tagged coho upstream of Roza Dam (Rkm 206), with the furthest fish observed at Rkm 257.5. We did not observe any radio tagged coho in the vicinity of Lost Creek, Cle Elum, Easton, or Jack Creek acclimation/release sites in the Naches or upper Yakima sub-basins respectively. Over half (56.8%) of the radio tagged coho were last observed in the vicinity of four irrigation/hydro-electric waterways (Table 4).

Table 3. Distribution of the 38 out of 102 radio tagged adult coho captured at Prosser Dam in 2000 that migrated upstream of Sunnyside Dam (Percent of Total Released) and the distribution of the 38 out of 38 radio tagged coho that migrated upstream of Sunnyside Dam (Percent above Sunnyside Dam).

Location	**Percent of Total Released**	**Percent Above Sunnyside Dam**
Sunnyside Dam to Union Gap	6.8%	20.0%
Ahtanum Creek	3.9%	11.4%
Wide Hollow Creek	2.9%	8.6%
Union to Selah Gap	9.8%	28.6%
Naches Confluence to Roza Dam	2.0%	5.7%
Above Cowiche Dam	1.0%	2.9%
Naches Confluence to Cowiche Dam	2.0%	5.7%
Above Roza Dam	5.9%	17.1%
Total	37.3%	100%

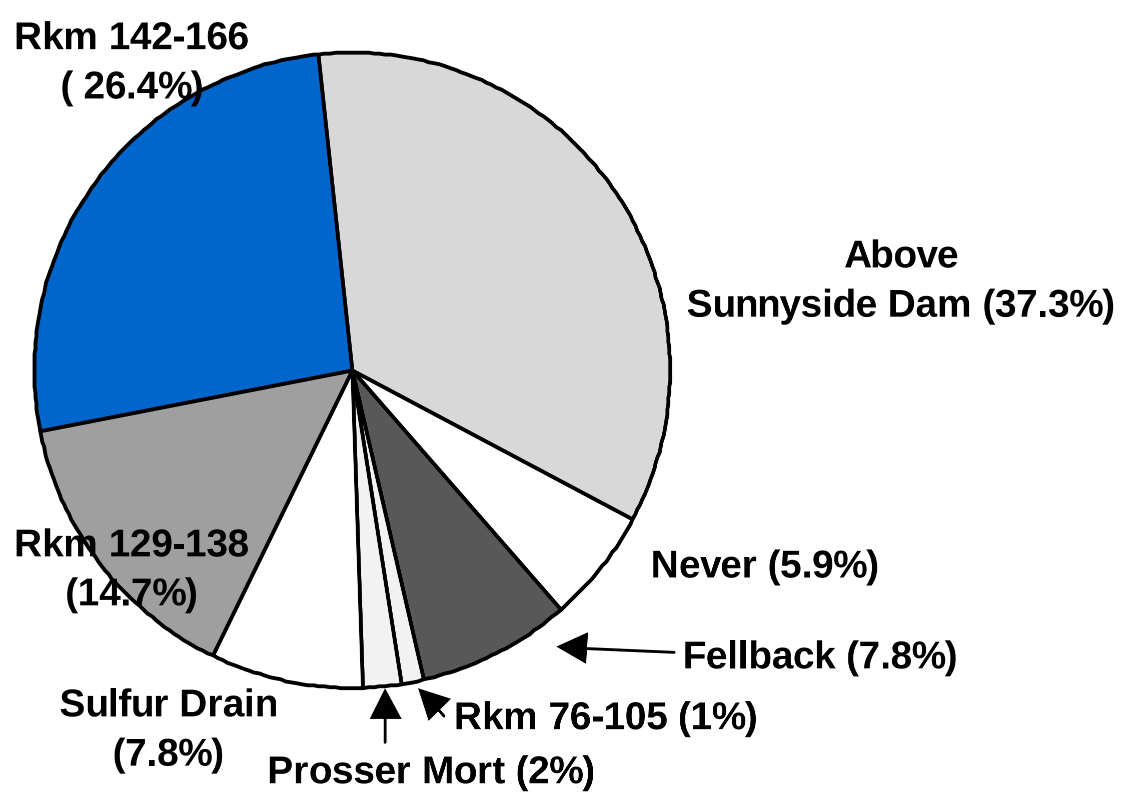

Figure 4. Spawning distribution in the Yakima River of 102 adult coho radio tagged at Prosser Dam, 2000.

Table 4. The distribution of 58 out of 102 radio tagged coho captured at Prosser Dam at various irrigation and hydro-electric outfalls throughout the Yakima Basin during the fall of 2000.

Location	**River kilometer**	**Percent of Total Released**	**Number**
Sulfur Drain	96.6	7.8%	8
Irrigation Ditch Outfall	143.2	14.7%	15
Roza Wasteway #3	157.7	26.5%	27
Roza Power Plant Outfall	181.9	7.8	8
Total		56.8%	58

A total of 8 (7.8%) radio tagged coho that were released above Prosser Dam were observed below Prosser Dam after release (fell back). Two of these fish later re-ascended the ladders at Prosser Dam and were later observed upstream in the mainstem Yakima River. Overall tagging mortality/tag loss throughout the study was relatively low (2; 2%). A total of 6 (5.9%) of the fish tagged and released near Prosser were never observed again.

Discussion

The results of our study conducted in 2000 indicate that most coho did not home back to the general vicinity of the four acclimation sites that coho smolts were released from in the spring of 1999. Even though the proportion of coho we radio tagged relative to the total number passing Prosser Dam in 1999 was low (~2.0%), we believe the results of this study accurately represent the spatial homing and spawning distribution of coho in the Yakima sub-basin. Video adult salmonid enumeration at Prosser, Roza and Cowiche dams in the fall of 2000 corroborates our conclusions. Based on video enumeration, YN estimated that approximately 2.5% (144) of the total coho return to the Yakima sub-basin passed Roza Dam, and at least 182 (3.2%) coho passed over Cowiche Dam. Coho spawning surveys conducted in the Yakima sub-basin in the fall of 2000 also indicated that most coho spawned in the mainstem Yakima River and associated tributaries below the city of Selah, Washington (Yakama Nation, unpublished data). Coho spawning in the mainstem Yakima River often occurred in side channels.

The results from the 1999 coho radio telemetry study and the 2000 results were relatively consistent even though acclimation/release locations were very different between years. During both years of the study over half of the radio tagged fish homed to areas downstream of Sunnyside Dam, and only 3.6% and 7.0% of the radio tagged coho passed either Cowiche or Roza dams in 1999 and 2000 respectively. We in part attribute the relatively low homing fidelity to acclimation sites in 2000 to false attractions at four locations in the lower mainstem Yakima River. These four locations (Table 4) accounted for the distribution of over half of the radio tagged adult coho. If we are correct in assuming that the radio tagged coho accurately represent the untagged coho in the 2000 return, then over half of the adult coho production may have also been present at these four locations. Ecological conditions, especially summer rearing temperatures in the mainstem Yakima River and quantity and quality of incubation and rearing habitats at these four locations will likely limit survival of naturally produced fish in these locations.

In order to re-establish a self-sustaining population of coho salmon in the Yakima sub-basin, returning adults must spawn in areas with sufficiently high incubation and rearing survival rates. Flow conditions below Sunnyside Dam most years during the period of coho spawning is relatively low but often decreases even further later during the coho incubation period (Figure 5). This scenario often results in the de-watering of many of the side channels that we observed coho spawning. Summer time water temperatures below Sunnyside Dam may also be a factor limiting natural coho production in this section of the Yakima River. The critical thermal maxima (CTM) is defined as the species specific temperature at which a fish loses equilibrium and dies (Konecki et al. 1995). Beschta et al. (1987) reviewed several studies that reported CTM for juvenile salmonids and concluded that most could not tolerate temperatures higher than 23-26°C. However, Becker and Genoway (1979) note that fish acclimated to warm water are more tolerant of high water temperatures than fish acclimated to colder water. DeHart (1975) found the incipient lethal level for juvenile coho acclimated to 20°C to be 25°C. However, Konecki et al. (1995) observed that mean CTM varied among 3 populations of coho in Washington State, ranging from 28.2-29.2°C. While the mean and maximum daily June, July, August

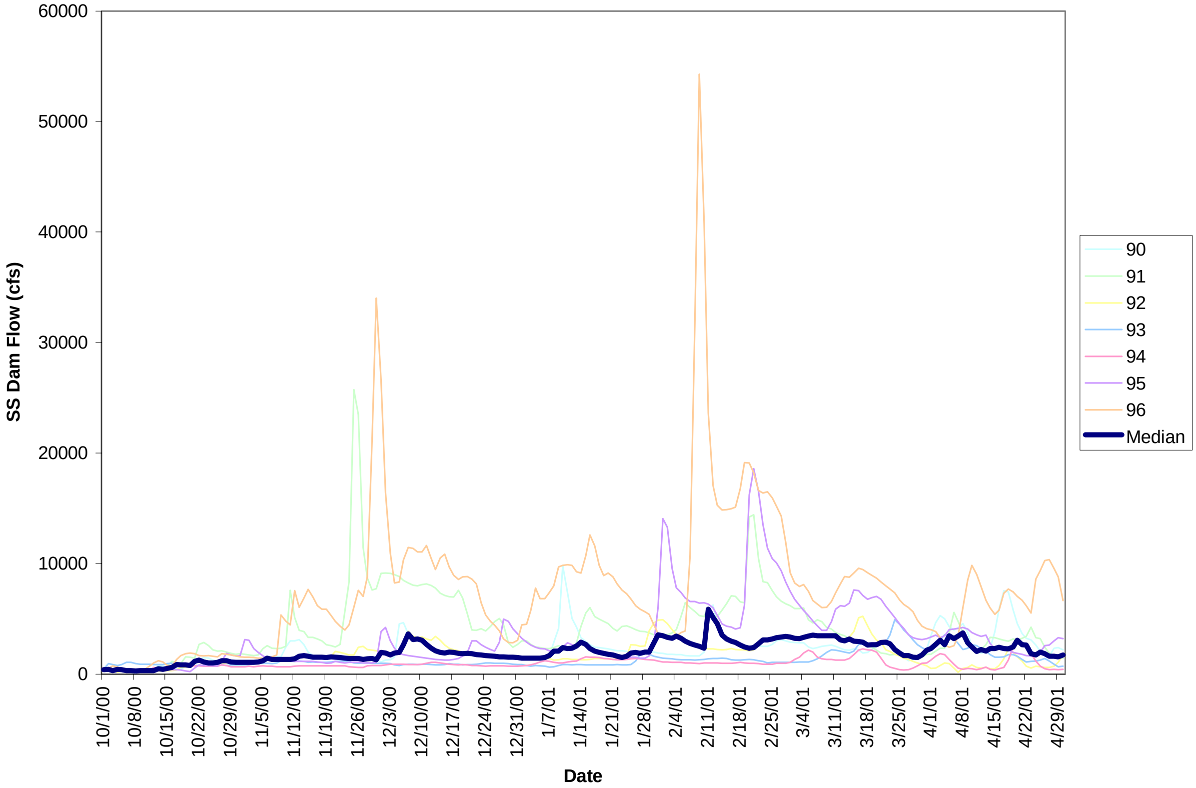

Figure 5. The mean daily flow (cubic feet per second) at Sunnyside Dam for the period 1990-1996, and the median daily flow for all years during that period.

and September water temperatures at Sunnyside Dam during the period 1984-1997 (Table 5) did not exceed the reported values of CTM for coho salmon, water temperature increases as you progress downstream towards Prosser Dam (Table 5). The mean daily temperatures at Prosser Dam during the period 1984-1997 also do not exceed the CTM for coho, however, the maximum daily temperatures during the same period approach or exceed that level (Table 5). All mean daily temperatures at Sunnyside and Prosser Dam greatly exceed the preferred temperature of juvenile coho salmon of 10-12°C (Brett 1952; Konecki et al. 1995a), and the maximum instantaneous daily temperatures are undoubtedly higher than the mean daily maximum temperatures. Even though the mean daily summer temperatures in the Yakima River between Sunnyside and Prosser dams may not consistently exceed the CTM for coho, we believe that the summer coho rearing temperatures in this area of the Yakima River are sufficiently high to impact the survival of coho inhabiting this section of the river in the summer months. High and fluctuating temperature profiles have been shown to increase the susceptibility of disease (Holt et al. 1975; Udey et al. 1975) predation (Coutant 1973), competition (Reeves et al. 1987), and may be physiologically stressful for salmonids (Wedemeyer 1973; Thomas et al. 1986).

Table 5. The mean and maximum daily Yakima River water temperature (degrees C) at Sunnyside Dam (SSD) and Prosser Dam (PD) during the period 1984-1997.

	June	July	August	September
Sunnyside Dam Mean	13.6	16.5	17.5	15.9
Sunnyside Dam Maximum	19.4	20.7	21.1	17.2
Prosser Dam Mean	18.0	21.4	21.5	17.9
Prosser Dam Maximum	26.6	26.8	26.0	23.8

The progeny of the 1999 and 2000 brood year will pass CJMF in 2001 and 2002 respectively, as migrating smolts. The experimental plan for the Yakima Coho Program requires that 100% of the juvenile hatchery coho released in the Yakima River during the period 2001-2003 be marked with coded wire tag. This situation allows the Program the opportunity to enumerate naturally produced juveniles, and thus indirectly assess the reproductive success of naturally spawning coho in the Yakima sub-basin.

Based on the distribution of spawning coho in 1999 and 2000, and the resulting limited temporal and spatial overlap between juvenile coho and other salmonids, we believe that limited potential for negative ecological interactions exist between coho and other salmonids. Other than fall chinook, most salmonids in the Yakima River do not rear or spawn below the city of Yakima. We believe that emergence timing and growth profiles for fall chinook (YN 1997) and coho are likely to be similar for both species below Sunnyside Dam. Any growth or size differentials are likely to be small, and would limit the physical capability of coho to prey upon fall chinook (Pearsons and Fritts 1999) juveniles before they migrate.

Our radio telemetry study will be continued in the fall of 2001. During this period, returning adult coho will be a combination of naturally produced and hatchery fish. Adult coho returning in the fall of 2001 will be a combination of hatchery and wild origin fish. The hatchery fish were released from similar acclimation sites as those that returned in 2000, thus giving an additional year as a replicate for 2000.

The relative proportion of hatchery and wild returning coho to the Yakima sub-basin during the 1999 and upcoming 2000 radio telemetry study is unknown. Estimates of the relative proportion will rely upon scale analysis and the presence of experimental marks (CWT) beginning in the fall of 2001 to differentiate between the two groups.

The right bank denil at Prosser Dam worked relatively well collecting adult coho for the radio telemetry study and broodstock collection. However, since the right bank ladder passes only approximately one quarter to one third of all coho passing Prosser Dam, during years with low numbers of returning adults, the Program may struggle to meet target collection numbers. It may be possible to use the existing adult collection facility at Roza Dam to collect adult coho that home back to the upper Yakima. A similar opportunity exists at Cowiche Dam. However, the feasibility of using Cowiche Dam as a broodstock collection and monitoring location warrants further investigation. Although all radio tagged coho that we observed passing Cowiche Dam in 1999 and 2000 used the ladder, additional observations are needed to determine if coho will consistently use the ladder. The long-term feasibility of utilizing Cowiche and Roza dams as coho monitoring and broodstock collection facilities will likely be determined by the spawning distribution of adult coho during the next few years. In 1999 and 2000 most natural spawning occurred below Cowiche and Roza dams, and therefore collection of adults at these two dams would have been largely ineffective.

The proportion of radio tagged coho that were released above Prosser Dam were observed below Prosser Dam after release (fell back) in 2000 (7.8%) was higher than observed during the 1999 study (4.7%). We adjusted our operating procedures during the mid-season collection at Prosser Dam. Prior to 10/11/00 released tagged coho at the Prosser boat ramp (Rkm 76.4), but after observing several fish fall back at Prosser Dam, we began releasing the tagged coho at the Mabton-Sunnyside Bridge (Rkm 96). We felt the change in release location (further upstream from Prosser Dam) allowed more time for fish recovery before potentially facing the stressful challenge of re-ascending Prosser Dam. The rate of fall back at Prosser Dam was substantially reduced by this operation change.

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Chapter 3

Relative Abundance of Residual Hatchery Coho in the Yakima Sub-basin

Introduction

Minimizing the levels of adverse ecological interactions of hatchery fish is one of the fundamental cornerstones of supplementation and the Yakima Klickitat Fisheries Project (YKFP; Busack et al. 1997). Fish that do not migrate after release are termed residuals, and fish that do not migrate and participate in spawning are termed precocials. Gross (1987) suggests that precocity may have evolved as an alternative life history pattern for Pacific salmon. However Mullan et al. (1992) indicated that often hatcheries release larger fish when compared to naturally produced fish, in order to increase survival, and that this practice may result in a higher numbers of precocial fish that are mostly males. The frequency of precocialism may range from 0-29% for anadromous salmonids (Mullan et al. 1992).

The abundance of residual coho in the Yakima sub-basin is important for two reasons. Residual hatchery coho do not contribute to anadromous adult production, and precocial fish may have the potential to significantly alter sex and anadromous versus precocial ratios on the spawning grounds (Mullan et al. 1992; Busack et al. 1997). Residual hatchery fish may also have the potential to either compete with or prey upon other species. Precocial salmonids are virtually all males (Mullan et al. 1992), and are typically larger than yearling parr. Larger fish have been shown to generally dominate smaller fish in studies that examined both inter- and intraspecific competition (Griffith 1972; Abbott et al. 1985; Hearn 1987; Chandler and Bjornn 1988; Hughes 1992).

This investigation was initiated to determine baseline levels of hatchery coho residuals in the upper Yakima sub-basin, Methow River, and Nason Creek a tributary of the Wenatchee River. Prior to this investigation no estimates of relative abundance of residual fish existed. After several years of gathering baseline hatchery coho residual data, YKFP managers will determine if densities of residual coho are high enough to warrant investigation of either residual hatchery coho ecological interactions with other species or abundance of precocials on the spawning grounds.

Methods

On May 7, approximately 125,000 yearling coho smolts were volitionally released after a period of approximately 5 weeks of acclimation at the Easton and Cle Elum and Lost Creek and Stiles Pond facilities in the upper Yakima and Naches sub-basins respectively (Figure 1). Identical volitional releases were made from each location on May 31, for a season total release of approximately 250,000 smolts from each facility for the season. Underwater snorkeling techniques as described in Thurow (1994) were conducted in the

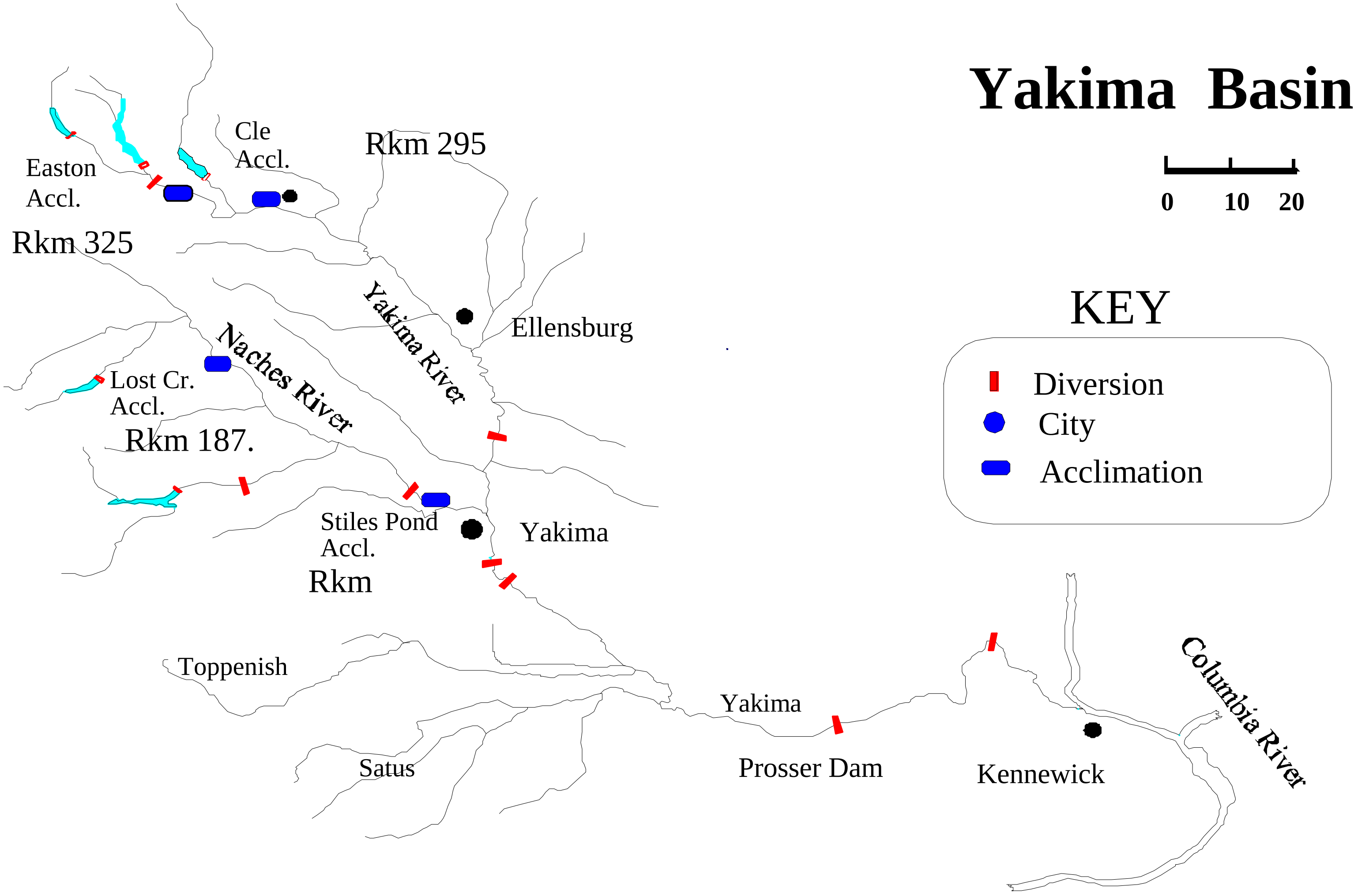

Figure 1. Acclimation and release locations for juvenile coho in the upper Yakima and Naches sub-basins, 2000.

Yakima and Naches rivers downstream of the Easton and Lost Creek acclimation sites to detect the presence of hatchery coho smolts that did not migrate during the May smolt releases. Snorkel observations were not conducted below the Stiles and Cle Elum acclimation/release sites due to excessive turbidity and stream width that limited snorkel efficiency. Surveys were conducted in the upper Yakima from July 10-17 and from July 18 –20, 2000 in the Naches sub-basin. We conducted snorkel surveys on the upper Yakima River from the Easton acclimation site (Rkm 325.4) to the confluence of the Cle Elum River (Rkm 294.6; Easton Reach). Snorkel surveys on the Naches River were conducted from the Lost Creek acclimation site (Rkm 61.8) to the confluence of Rock Creek (Rkm 53.9; Lost Creek Reach). Each study reach described above was divided into 500 m sections, with one 100 m sample unit randomly selected from each of each 500 m sections, resulting in a 20% sample rate. Within each 100 m sample unit, two observers snorkeled in a downstream direction between the hours of 10:00 and 16:00. All salmonids observed were enumerated by species and size class. Information regarding habitat type, pool, riffle, or glide (USFS 1996), and the presence and type of available cover, in each snorkeled unit was recorded.

We estimated the total number of residual coho in each study reach (T) using the following formula:

$$T = \overline{R} \times N$$

Where

$$\overline{R} = \frac{mean\#coho}{100m}$$

and N = number of 100 m sections in section of river.

We estimated the 95% confidence interval for the mean number of residual coho/100m using the following formula:

$$\overline{R} \pm 1.96 \times \sqrt{\frac{s^2}{n} \times \frac{N-n}{N}}$$

Where

s^2 = the sample variance,

and

n = the number of 100 m sections sampled within the study reach.

The upper and lower bounds of the 95% confidence interval for the mean number of residual coho per 100 m were used to estimate the upper and lower bounds of the total number of residual coho present within the Easton and Lost Creek reaches. We expanded snorkel counts by 100, 75, 50, 25, and 10% to reflect a range of snorkel efficiencies. The total number of residual hatchery coho smolts within the study reach was estimated by assuming a 100, 75, 50, 25, and 10% sampling efficiency. For each estimate of relative abundance of hatchery coho we calculated the estimated number per km within the study reach. We extrapolated results from the Easton Reach from the Easton acclimation site to Roza Dam, and the results from the Lost Creek Reach from the Lost Creek acclimation site to the Naches Confluence to estimate the total number of residual hatchery coho present in the entire Yakima sub-basin.

Results

We observed higher numbers of coho in the upper Yakima Easton Reach than we did in the Lost Creek Reach on the Naches River. We observed an average of 14.7 and 67.8 coho per km in the Easton and Lost Creek reaches respectively. We present the mean number of residual hatchery coho per mile and total number within the Easton and Lost Creek reaches for snorkel efficiencies ranging from 10-100% in Table 3.

Estimates of the total number of hatchery coho residuals from Roza Dam to the Easton Acclimation site in July, 2000 range from 243 to 65,394 fish (Table 2). We estimated similar numbers in the Naches River from the Naches River confluence to the Lost Creek acclimation site, which ranged from 1,645 to 66,473 fish, although the number per kilometer were higher in the Naches compared to the upper Yakima River.

Table 1. July, 2000 coho residual snorkel survey results. Total number and mean number of coho per kilometer for each given snorkel efficiency. Numbers in parentheses are 95% confidence intervals. Total coho smolt release numbers were approximately 250,000 each for Easton and Lost Creek acclimation facilities.

Study Reach	**Snorkel Efficiency Rates**				
	100%	**75%**	**50%**	**25%**	**10%**
Easton Reach Total*	455 (91-877)	607 (121-1170)	910 (182-1755)	1820 (364-3510)	4550 (910-8774)
Easton Reach #/km*	14.7 (2.9-28.4)	19.6 (3.9-37.8)	29.5 (5.9-56.8)	58.9 (11.8-113.6)	147.3 (29.6-284.0)
Lost Creek Reach Total	535 (212-585)	713 (283-1144)	1070 (425-1715)	2140 (849-3431)	5350 (2123-8577)
Lost Creek Reach #/km	67.8 (26.9-108.7)	90.5 (35.9-145.0)	135.7 (53.8-217.5)	271.4 (107.7-435.1)	678.4 (269.2-1087.6)

*note Yakima lower bound estimates based on number observed not actual lower 95% confidence bound.

Table 2. July, 2000 upper Yakima expanded coho residual estimates from Easton Acclimation site to Roza Dam using Easton, and Naches from Lost Creek Acclimation site to Naches River confluence. Numbers in parentheses are 95% confidence intervals.

	Snorkel Efficiency Rates				
	100%	**75%**	**50%**	**25%**	**10%**
Easton to Roza Dam*	3391 (243-6539)	4522 (324-8719)	6782 (486-13079)	13565 (972-26157)	33912 (2430-65394)
Lost Creek to Naches Confluence	4146 (1645-6647)	5528 (2194-8863)	8293 (3290-13294)	16585 (6581-26589)	41463 (16458-66473)

*note Yakima lower bound estimates based on number observed not actual lower 95% confidence bound.

Discussion

Based the results of this study, we believe that the overall proportion of hatchery coho that did not migrate during the spring of 2000 was relatively low. However, we were unable to determine actual snorkel efficiencies. The accuracy of underwater estimates is difficult to assess because the true population density is usually unknown (Hillman et al 1992). The accuracy of underwater estimates has been estimated by comparing snorkel counts with estimates derived from electrofishing (Griffith 1981; Hankin and Reeves 1988) and toxicants (Hillman et al 1992; Northcote and Wilkie 1963). Thurow (1994) reviewed 13 studies in which population estimates were compared with snorkeling estimates of fish abundance. In all but two cases, the snorkeling estimates were within 70% of the actual population estimates. Hankin and Reeves (1988) used multiple removal estimates to calibrate snorkel counts for juvenile coho salmon and steelhead *Oncorhynchus mykiss*. In this study, the correlation between snorkel counts and removal method population estimates exceeded 94% for coho salmon in both pools and riffles. On average, snorkel counts were reported similar to accurate population estimates for juvenile coho salmon (Hankin and Reeves 1988).

Water temperature influences fish behavior and may bias underwater counts (Thurow 1994). Thurow indicated that surveys of fish in summer rearing habitat should be conducted when stream temperatures exceed 9 C. We consistently snorkeled when water temperatures were well above this level. While residual coho abundance estimates reported here likely underestimate the true population density, we believe, based upon previously reported snorkel efficiencies (Griffith 1981; Hankin and Reeves 1988; Hillman et al 1992; Thurow 1994; Zubik and Fraley 1988) and good conditions at the time of the surveys (visibility and temperature) that the difference is likely small.

Under some conditions, nighttime surveys may be more effective for studying salmonid than daytime surveys (Thurow 1994). Often fish that remain concealed during the day, move out of cover and are visible at night (Griffith and Smith 1993). For these reasons, a comparison of night and day abundance estimates will be made during the 2001 field season.

We estimated the total numbers of residuals in the upper Yakima by extrapolating the Easton Reach data. We believe these estimates likely overestimate the number of residuals from the Easton Acclimation site to Roza Dam. We base this assumption on the high quality of habitat in the Easton Reach compared to the habitat from the Cle Elum River confluence downstream to Roza Dam. By concentrating out sampling in the Easton Reach, and the highest quality habitat, it is likely that we may have maximized the potential for coho to inhabit this area and therefore our potential to observe these fish in our surveys.

The number of coho observed per kilometer in the Naches was approximately 4.5 fold higher than observed in the upper Yakima. We believe that naturally produced coho in the Naches River may have inflated estimates of hatchery residuals. The absence of external marks on hatchery coho made differentiation between hatchery and wild fish impossible. Although we attempted to differentiate between yearling coho and sub-yearling parr based on size, this task was difficult due to overlapping length distributions between the two year classes.

The total number of residuals in the Easton Reach in 2000 was approximately 6 times higher than the total number of coho residuals we estimated present in early July of 1999 (Dunnigan 1999). However, approximately five times more coho were released at the Easton Acclimation site in 2000. Thus, estimates of the total number of residual coho present in the Easton Reach are very similar between 2000 and 1999 when compared on the basis of total number of coho smolts released. For example, if we express the total estimated number of coho present in 2000 (455) on the basis of numbers present per 50,000 smolts released (91 coho residuals), the results are similar to the early July estimates in 1999 (75 coho residuals; Dunnigan 1999).

Murdoch (2000) conducted similar field studies in the Wenatchee and Methow Rivers in 2000 to estimate the abundance of residual coho. Residual coho estimates on the Wenatchee and Methow Rivers in 2000 expressed as the number of residual coho per km per 50,000 smolts released were at least an order of magnitude lower than we observed on the upper Yakima and Naches rivers in 2000. For example, Murdoch (2000) estimated 0 residual coho present during surveys conducted from early July through August in Nason Creek, a tributary of the Wenatchee River where approximately 75,000 coho were released. Snorkel surveys conducted in the Methow River from July through August, estimated an average of 0.1 residual coho per kilometer per 50,000 smolts released. Murdoch (2000) observed the highest densities of residual coho in sections of the middle and lower Wenatchee River where sampling was intentionally biased toward the highest quality habitat, in an attempt to maximize the potential to detect residual coho. During sampling that occurred in these sections of the river, Murdoch estimated an average of approximately 0.7 residual coho per kilometer per 50,000 coho released, compared to our estimates of 2.9 and 13.6 residual coho per km per 50,000 smolts released in the upper Yakima and Naches rivers respectively.

Washington Department of Fish and Wildlife snorkel and electrofishing surveys in the upper Yakima sub-basin in the summer and fall of 2000 also collaborate our findings that hatchery coho smolt residual rates were low (T. Pearsons, personal communication). We attribute the observed low levels of hatchery coho residuals to sound fish cultural practices including good fish health prior to release, and an adequate acclimation period of 5-6 weeks prior to release. An acclimation period of 5-6 weeks for fish transported has been shown to increase post-release survival rates (Johnson, et al. 1990).

It is important to quantify the total number of hatchery coho residuals for 2 reasons. A high degree of residualism has the potential to negatively impact the program strictly from the aspect of production. Based on the low estimated number of residual hatchery coho observed in the Yakima and Wenatchee sub-basins, it is unlikely that residualism significantly impacted smolt survival estimates or future smolt-to-adult survival estimates.

It is also important to quantify the abundance of residual coho from the aspect of ecological interactions between hatchery coho and other species. As the total number of coho residuals increases so may the potential for ecological interactions such as competition and predation with other species. Although we did not directly investigate competition or predation between hatchery coho and other species, based on the low number of estimated residual coho in 2000, we believe that the potential for negative ecological interactions between coho and other species was minimal. In order for competition to occur, the common resource (space or food) must be in limited supply and important to the well being of each species. We believe that it is unlikely that the low estimates of hatchery coho residuals were ecologically capable of negatively impacting any species present unless the environment was at or exceeded the natural carrying capacity. Similarly, we believe that the potential for hatchery coho residual predation on other species was negligible due primarily to the low numbers of coho present after the spring migration.

We further believe that the potential for competition and predation between coho and other species was minimized due to habitat segregation and resource partitioning (Ross 1986). Recently emerged age 0 salmonids are those most likely to be vulnerable to predation due to their small size, and have been shown to typically utilize shallower and lower velocity microhabitats than do yearling salmonids (James et al. 1999; Hillman et al. 1989). Our observations were consistent with these findings, and further lead us to believe that minimal spatial overlap between hatchery coho residuals and recently emerged age 0 salmonids limits the opportunity for predation and competition between coho residuals and other species.

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Chapter 4

Development of a Locally Adapted Broodstock and Estimates of Naturally Produced Coho in the Yakima Basin

Introduction

Success of the Yakima/Klickitat Fisheries Program (YKFP) coho re-introduction program is reliant upon the use of hatchery fish to develop naturalized spawning populations. Until recently, the project has relied entirely upon the transfer of lower Columbia River hatchery coho to produce adult coho returns in the Yakima basin. If a viable self-sustaining population of coho is to be re-established in the Yakima River, parent stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and the Yakima River. Returning hatchery fish must also have sufficiently high productivity and survival rates to meet replacement levels. The project recognizes the need to ultimately eliminate the transfer of lower Columbia River hatchery transfers to the Yakima and transition to the exclusive use of returning fish as broodstock. We expect this transition will take place in two somewhat overlapping phases. The first step in the transition phase is to replace lower river smolt transfers with progeny from returning Yakima River coho. During the final phase of the project broodstock collection will be limited to naturally produced individuals (YN 1997). We are optimistic that the project will observe positive trends in hatchery coho survival as the program develops a localized broodstock.

The YKFP has generally two concerns using lower Columbia River hatchery coho for re-introduction efforts. Each concern is related to the feasibility of developing a truly localized broodstock source for coho re-introduction efforts in the Yakima basin. First, inter-basin coho salmon transfers throughout this century were common for most hatcheries in the lower Columbia River, with the exception of the Sandy River Hatchery (Currens and Farnsworth 1993). These transfers have the potential to reduce the genetic variability to the point that parent stocks may not have sufficient variability to allow adaptation to take place. Secondly, many of the lower Columbia River coho hatcheries have been in operation since the early 1900s. Given the lengthy culture history of these stocks it is likely that many have been subjected to intensive domestication selection for many generations. Domestication is usually attributed to the effects of genetic drift which may result from low founding broodstock numbers or selections pressures from rearing fish in the hatchery environment (Calaprice 1969; Cross and King 1983; Allendorf and Phelps 1980). Fish populations that have been subjected to artificial selection may perform well in the hatchery, but poorly in the wild (Busack et al. 1997). Although the Program is interested in the effects of domestication (see Dunnigan 1999), this report will focus solely on the monitoring efforts conducted in 1999 that are intended to provide a baseline data set to be used for comparison throughout the transitional broodstock development phases. We will track physical traits and demographics such as sex ratios, fecundity, age at return, and baseline genetic information through time for later comparison to donor hatchery stocks.

Methods

Estimates of Natural Coho Smolt Production in the Yakima Sub-basin

The Yakama Nation released approximately one million yearling hatchery coho smolts in May 2000 at four release locations (See Chapter 1). Although hatchery fish were not externally marked, all fish were tagged with a snout coded wire tag (CWT). We estimated the proportion of naturally produced fish at the Chandler Juvenile Monitoring Facility (CJMF) located on the fish bypass facility of Chandler Canal at Prosser Dam (Rkm 75.6). The CJMF serves as the cornerstone facility for the estimating smolt production in the Yakima sub-basin for several species and stocks of salmonids. Daily species counts in the livebox at the CJMF are expanded by the canal entrainment, canal survival, and sub-sampling rates in order to estimate daily passage at Prosser Dam. A detailed description of the methods used to estimate passage is explained in Neely (2001). All coho that entered the livebox at the CJMF during the 2000 outmigration season were interrogated for the presence of a CWT in the snout. Coho with a CWT present were enumerated as hatchery origin coho, and those without a CWT were enumerated as natural origin coho. Daily counts for each group were expanded to estimate daily passage.

We assumed that all coho smolts were age 1+ and therefore would represent cohorts of the 1998 broodyear. We estimated the total potential coho egg deposition above Prosser Dam in the fall of 1998 by expanding the total coho escapement obtained by video enumeration at Prosser Dam (Hubble 1999) by the estimated sex ratio and mean fecundity. Egg-to-smolt survival rate for naturally produced fish was estimated by dividing the estimated number of naturally produced coho passing Prosser Dam in the spring of 2000 by the estimated egg deposition in the fall of 1998.

Estimates of egg-to-fry survival rate for naturally produced coho in Buckskin Creek

We selected Buckskin Creek, a small tributary to the Naches River (Rkm 5.3) to perform a field study to investigate the egg-to-fry survival rates of naturally spawning hatchery coho for two reasons. Buckskin Creek is fed primarily from groundwater, and originates from two large ponds. Water level in Buckskin Creek fluctuates very little throughout the year, and therefore provided a relatively stable hydrograph for operation of a weir-type trap, and adult returns to Buckskin Creek were plentiful in the fall of 1999. We estimated the number of spawning female coho in Buckskin Creek during the fall of 1999 by conducting weekly redd surveys between October 1 and November 30. We estimated potential egg deposition in Buckskin Creek by multiplying the number of redds we observed by the mean fecundity we observed for coho that returned to the Yakima River in 1999. We installed a weir trap constructed out of framed panels faced with 6 mm sized mesh hardware cloth. A 15 cm plastic pipe funneled fish migrating downstream into a livebox constructed of plywood and lined with a 2 mm mesh net. The trap was checked daily until May 16, 2000. All fish captured in the trap were enumerated by species, measured (fork length; mm), weighed (g) and released downstream.

We conducted electrofishing surveys in Buckskin Creek between May 16 and 24, 2000 to assess the abundance of naturally produced coho fry still present in Buckskin Creek. The length of Buckskin Creek from the confluence to the source ponds was measured (m) with a hip-chain device. Fifteen 30-meter sites were randomly selected for multiple-pass electrofishing. We measured fork length (to 1 mm) and weighed (to 0.01 g) all salmonids, and we enumerated all other species. Estimates of coho abundance and capture efficiency were calculated for at each 30 m site using the maximum likelihood estimator (Van Deventer and Platts 1983).

We estimated the total number of juvenile coho present in Buckskin Creek (T) during the electrofishing surveys using the following formula:

$$T = N \times \bar{c}$$

Where

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{n}$$

N = the total number of 30 m sites in Buckskin Creek,
n = the number of 30 m sites sampled in Buckskin Creek, and
c_i = the estimated number of coho present in site *i* of Buckskin Creek.

We estimated the 95% confidence interval for the total number of coho present in Buckskin Creek using the following formula:

$$95\% CI = T \pm B$$

Where

$$B = 1.96 \times \sqrt{N^2 \times \frac{s^2}{n} \times \frac{N-n}{N}}$$

and s^2 = the sample variance of c

We estimated a minimal coho fry population estimate in Buckskin Creek by summing total coho fry passage at the weir up to May 16, 2000 and the coho fry population estimate obtained through electrofishing. We divided the fry population estimate by the potential coho egg deposition to estimate a minimum estimate of coho egg-to-fry survival rate in Buckskin Creek for the 1999 brood year.

Broodstock Collection Procedure

We estimated weekly run timing distribution for coho at Prosser Dam for return years 1994-1999 to generate an average weekly run timing distribution, in order to collect broodstock in proportion to fish passing Prosser Dam. We collected coho at Prosser Dam right bank steep pass denil. Fish ascended the ladder and entered the denil, and then entered into a flume that diverted all fish into an anesthesia tank containing a solution of tricaine methanesulfonate (MS-222). We examined fish for marks, tags, and injuries, and then measured fork and mid-eye to hypural plate length (mm), weighed (kg), obtained scale samples and PIT tagged each coho. When coho were collected at the denil, they were given a condition rating of either bright, medium or dark based on physical appearance. Fish were transported by truck to the Prosser Hatchery where they were held until spawned. Age and hatchery/wild origin determination from scale samples was conducted by YN personnel, and were not completed in time to include in this report.

Statistical Analyses

The use of PIT tagged broodstock allowed us to compare Prosser Dam passage date to sexual maturation timing for individual fish. We compared the physical condition of fish entering the denil (bright, medium, or dark) to Prosser Dam passage and spawn timing using analysis of variance, and a Tukey Test (Zar 1999) to make multiple comparisons. We used linear regression to determine the correlation of passage timing at Prosser Dam to sexual maturation timing.

Results

Estimates of Natural Coho Smolt Production in the Yakima Sub-basin

We estimated that a total of 4,679 coho passed Prosser Dam in the fall of 1998. Unbiased estimates of sex ratio are not available for the 1998 brood year for Yakima returns. We assumed a female sex ratio of 53% by averaging female sex ratios observed in two other lower Columbia River coho hatcheries for the 1998 brood year (Dunnigan 2000). We estimated a mean fecundity of 2,923 eggs/female for the 1998 coho Yakima brood year. Therefore, we estimate a total of 7,249,040 eggs were deposited in the Yakima River above Prosser Dam by naturally spawning coho. We estimated that a total of 167,910 and 31,070 hatchery and natural origin coho smolts, respectively passed Prosser Dam in the spring of 2000 (Figure 1). Egg-to-smolt survival for natural origin coho from the 1998 brood year was 0.43%.

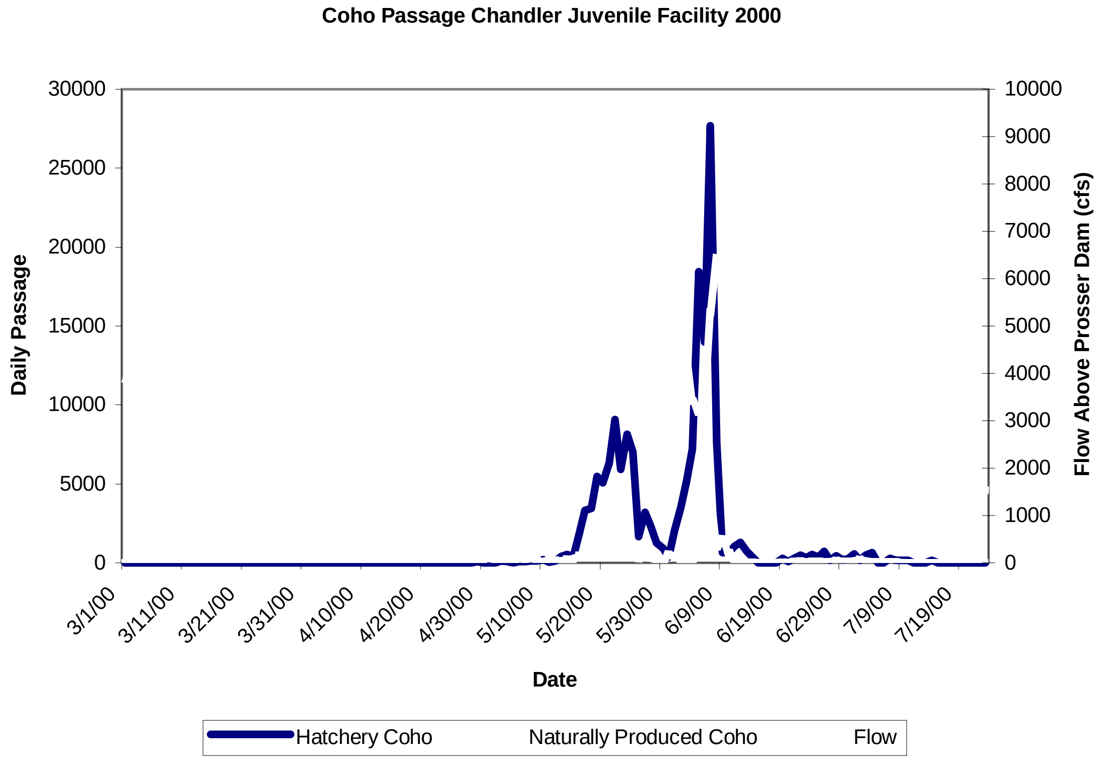

Figure 1. Daily passage of hatchery- and naturally produced-origin coho smolts passing Chandler Juvenile Monitoring Facility, 2000.

Estimates of egg-to-fry survival rate for naturally produced coho in Buckskin Creek

We counted a minimum of 48 coho redds in Buckskin Creek between September 1 and November 30, 1999. We estimated an average fecundity of 3,423 eggs/female for 156 female coho randomly collected at the Prosser Dam right bank denil in 1999. Therefore, potential coho egg deposition in Buckskin Creek for brood year 1999 was 163,304 eggs.

We estimated that a minimum of 576 juvenile coho emigrated from Buckskin Creek from February 18 to May 16, 2000. Daily passage estimates peaked during the first week of March at approximately 75 coho per day (Figure 2).

We randomly selected 14 sites in Buckskin Creek to perform multiple pass electrofishing. This represented a sampling rate of approximately 45% of the total linear habitat within the stream (Table 1).

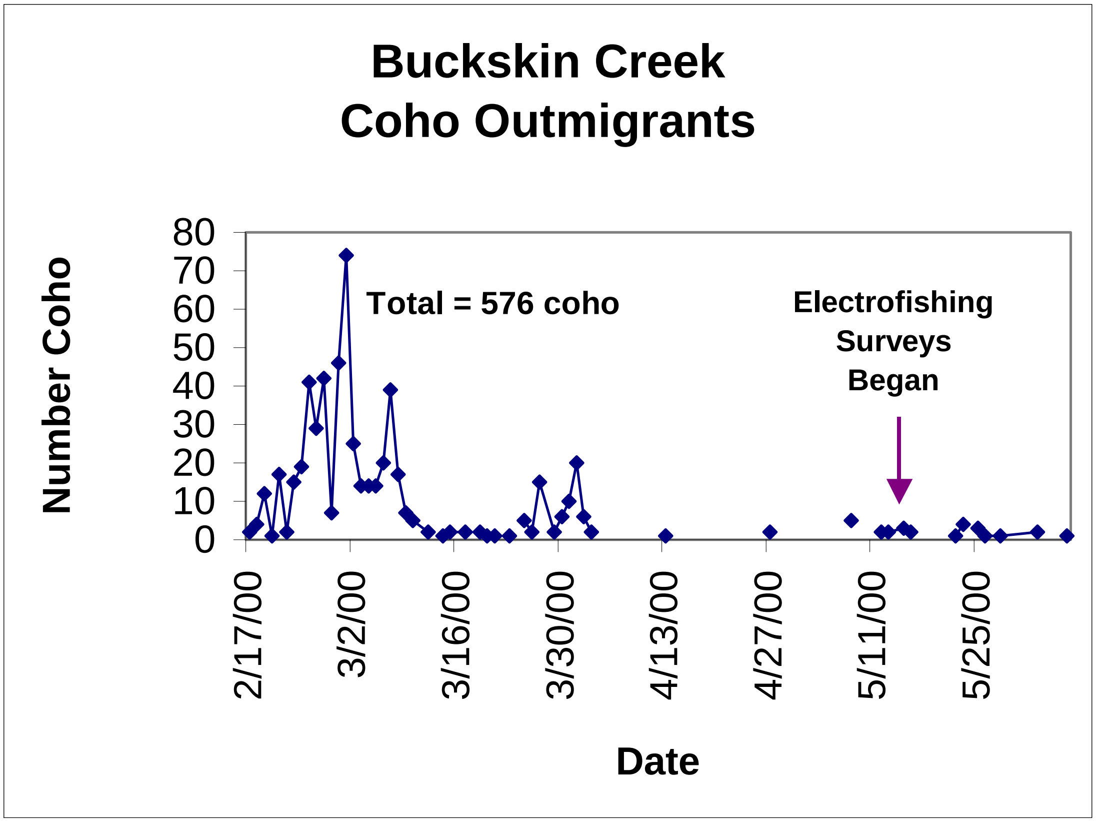

Figure 2. Number of age 0 coho passing the weir trap per day on lower Buckskin Creek during the period February 18 – May 16, 2000.

Table 1. Electrofishing population estimates and 95% confidence intervals (CI) for 14 sites in Buckskin Creek.

Site Number	**Length (m)**	**Estimated Coho**	**95% CI**
1	27.4	14	14 – 15
2	25.3	40	40 – 41
3	30.8	1	N/A*
4	30.2	54	43 – 72
5	17.1	62	62 – 63
6	29.0	102	101 – 105
7	30.2	207	195 – 219
8	27.4	32	32 – 34
9	22.6	21	21 – 22
10	18.9	13	13 – 14
11	11.6	3	3 – 6
12	42.7	13	12 – 18
13	23.8	4	N/A*
14	25.6	48	47 – 52

*Note: Confidence intervals could not be calculated with the maximum likelihood estimator because all coho were captured on the first electrofishing pass.

We estimated that a total of 1,340 (95% confidence interval 693 – 1986) juvenile coho were present in Buckskin Creek during the period May 16 – 24, 2000. Thus, by adding the electrofishing estimate to the total catch at the weir trap up to May 16, we estimated that a minimum of 1,916 coho fry were produced in Buckskin Creek from the 1999 brood year. Therefore, a minimum estimate of coho egg-to-fry survival in Buckskin Creek for the 1999 brood year was 1.2% (95% confidence interval 0.8 – 1.6%).

Broodstock Collection

The Yakama Nation estimated that a total of 6,138 coho passed Prosser Dam in 2000. We collected a total of 483 coho at the Prosser Dam right bank steep pass denil over the period September 11 – November 8 (Figure 3) in proportion to the run. We estimated that the 2000 Yakima River coho return was comprised of 49.5% female, 46.9% adult male, and 3.6% precocial male (jacks). Adult males were slightly larger (mean FL = 67.4 cm) than females (mean FL = 66.1 cm; Figure 4). Prosser right bank worked relatively well for broodstock collection of coho. Approximately 31.7% of the returning coho passed over the right bank ladder during the past 5 years of operation. Mean fecundity of for the 2000 Yakima coho broodyear was 2,869 eggs/female.

The ANOVA comparing mean passage date at Prosser Dam for bright, medium, and dark conditioned coho suggested that at least one comparison was significantly different ($p < 0.0000001$). Coho estimated to be in bright condition passed Prosser Dam significantly earlier ($p < 0.05$) when compared to coho salmon estimated to be in medium or dark condition. Mean passage date for all fish recorded in bright, medium and dark condition was October 5, 16 and 18, respectively. Mean passage date of medium condition coho was not significantly earlier when compared to the mean passage date of fish in dark condition. The ANOVA comparing mean spawning date of bright, medium, and dark fish indicated that at least one comparison was significantly different ($p = 0.025$). The mean spawn date for bright, medium, and dark coho was November 3, 3, and October 31 respectively. Dark fish spawned significantly earlier than did coho classified in medium condition ($p < 0.05$).

Although bright coho passed Prosser Dam significantly earlier than either medium or dark coho, and dark coho spawn significantly earlier than medium coho, passage timing at Prosser Dam was weakly correlated to spawn timing (Figure 5; $r^2 = 0.09$), suggesting that coho passage timing at Prosser Dam was a poor predictor of spawn timing.

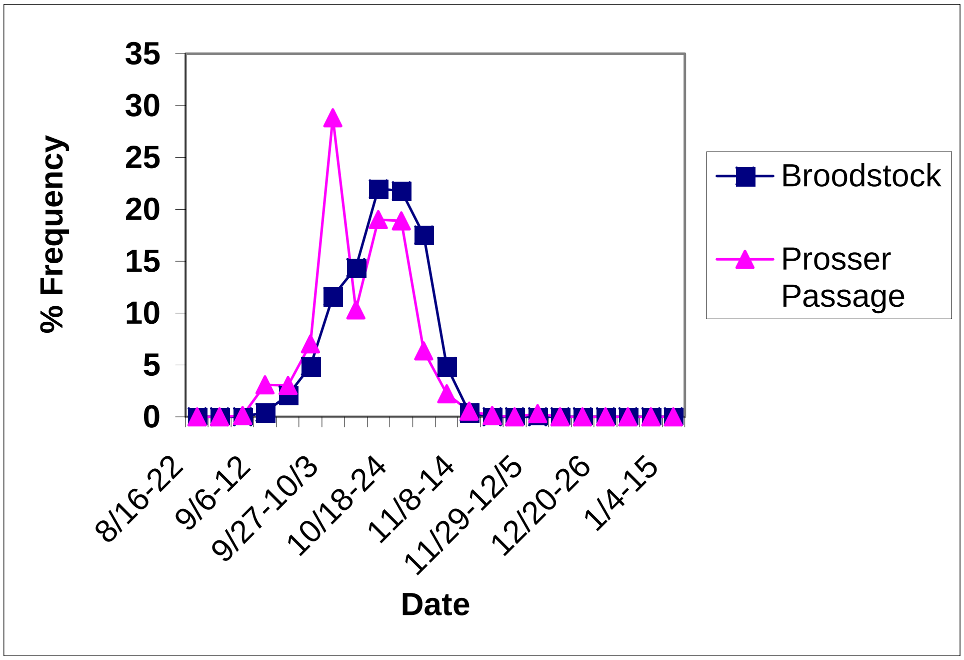

Figure 3. The cumulative passage of adult coho at all ladders at Prosser Dam and broodstock collected from right bank denil, 2000.

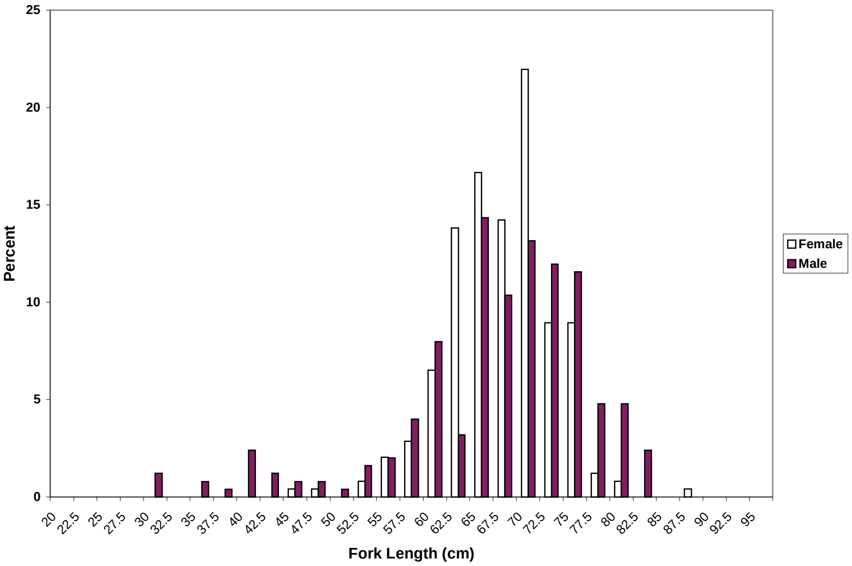

Figure 4. Length frequency distribution of adult coho collected at right bank denil trap at Prosser Dam, 2000.

Discussion

Based on our estimates of the total number of naturally produced coho smolts passing CJMF in the spring of 2000, we estimated that egg-to-smolt survival for broodyear 1998 was very low (0.43%) for returning coho spawning above Prosser Dam. The spring of 2000 was the first year the project was capable of estimating natural smolt production in the Yakima. However given the fact that the 1998 return was the second highest number of returning coho to the Yakima Basin during project history (see Chapter 1), and that release locations of during previous were similar (see Chapter 1), it may be likely that egg-to-smolt survival and total natural coho production was also low for previous broodyears. We attribute the low estimated egg-to-fry survival rate we observed in 2000 to poor spawning and rearing habitat conditions that exist below the city of Yakima. Primarily, high percentage of fines in spawning gravels and high summer rearing temperatures likely limit production of naturally produced coho in the lower Yakima River (see Chapter 2 discussion).

Given the observed low productivity of the naturally spawning 1998 coho broodyear, it is likely that the number of naturally produced smolts will not have a sufficiently high smolt-to-adult survival rate need to meet replacement levels. In order for smolts produced by the 1998 coho broodyear to meet replacement levels in terms of adult returns, a smolt-to-adult survival rate of approximately 15.05% must be observed. Mean smolt-to-adult survival rate for wild spring chinook in the Yakima Basin over the period 1983-present is 2.5% (range 0.5 – 8.1%; Yakama Nation, unpublished data). Operations at the Prosser Dam right bank denil trap in the fall of 2001 will allow an estimate of the total return number of naturally produced adult, and therefore an estimate of smolt-to-adult survival for hatchery- and natural-origin recruits.

Our estimate of egg-to-smolt survival for naturally produced coho may even lower than our estimated 0.43% due to misidentification of hatchery smolts as natural origin smolts at the CJMF. Differentiation between the groups relies on the use of a hand held CWT detector to identify the presence of a CWT in the snout of hatchery coho. We do not have an estimate of efficiency of this process. However, the migration patterns of hatchery and naturally produced coho are very similar (Figure 1), especially the bimodality of the hatchery fish that results from two release dates (May 7 and 31), suggesting that many of the fish may have been hatchery fish. If this is the case, we may have over-estimated the total number of naturally produced coho. In the future the project will attempt to quantify the bias associated with misidentification at the CJMF because this facility and technique will continue to provide our only estimates of the abundance and migration timing of naturally produced coho smolts in the Yakima Basin for the foreseeable future.

Based on counts of emigrating coho and electrofishing results in Buckskin Creek, we estimated that egg-to-fry survival rate was low (1.25%). We attribute low survival to the poor quality and quantity of spawning and rearing habitat in Buckskin Creek, and to frequent coho redd super imposition. Much of Buckskin Creek where coho spawned was either adjacent or downstream of Suntides Golf Course. Land use practices on the golf course contribute sediment and simplify habitat complexity, which in turn greatly diminishes the quality and quality of spawning and rearing habitat within Buckskin Creek. The low quantities of suitable spawning gravel in Buckskin Creek contributed to the relatively high frequency of redd superimposition. The degraded habitat conditions in Buckskin Creek and the spawning escapement of at least 48 female coho likely exceeded the carrying capacity for spawning and rearing coho. Despite the logistic reasons for selecting Buckskin Creek to conduct such a study, the poor habitat conditions likely offset those attractive qualities.

The estimates of egg-to-fry survival should be considered a minimum estimate due to the relatively long time period between emergence (February-March) and electrofishing surveys (May). Considerable mortality may have occurred between the period of emergence and sampling.

The sex ratio of returning hatchery fish to the Yakima River in 2000 was similar to the sex ratios observed at Cascade, Eagle Creek, or Little White Salmon hatcheries (Table 2), where the proportion of adult female coho was approximately equal to the proportion of adult male coho. Males typically out numbered females at Little White Salmon and Eagle Creek Hatcheries when precocious males were included with adult males (Table 2; USFWS, unpublished data). Hotlby and Healey (1990) concluded that the sex ratio of most coho populations is rarely biased toward females. They attribute differences in sex ratio to behavioral differences between sexes in the ocean environment, which allowed females to achieve large size. This was the second year that we were able to obtain estimates of the sex ratio of returning coho to the Yakima basin. Additional data will produce a better estimate in the variability of sex ratio for Yakima River coho.

Fecundity of hatchery coho that returned to the Yakima River was higher than the hatchery fish that return to the donor hatcheries in the lower Columbia River for broodyears 1999 and 1998. However this trend was not consistent for the 2000 broodyear (Table 2). Future data collected in the Yakima will help determine if this trend is consistent. A review by Beacham (1982) found that stocks of coho from Alaska to the coast of Washington state exhibit both regional and annual variability of fecundity. Selection for large female coho size (and presumably fecundity) within a population may be influenced by gravel quality, frequency of flood events, and competition for nest sites (Holtby and Healey 1986; van den Berghe and Gross 1984). However, since the hatchery fish that return to the Yakima have not undergone

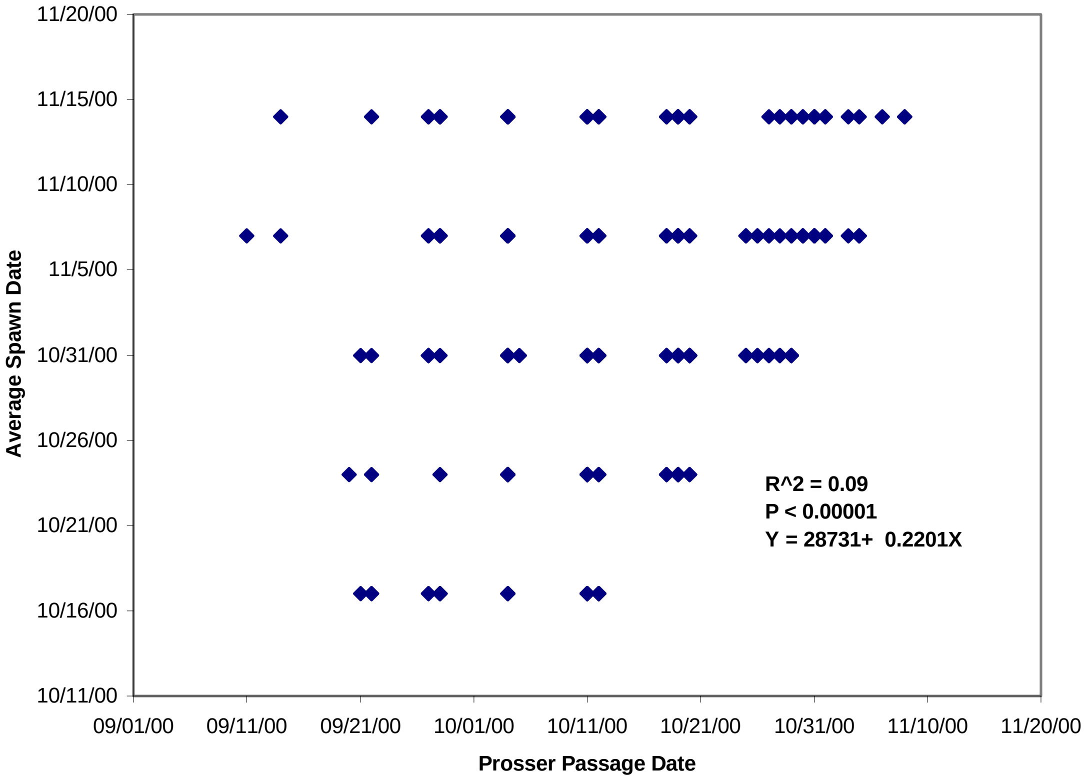

Figure 5. Passage timing at Prosser Dam right bank denil compared to average spawn date for all coho broodstock collected in 2000.

Table 2. The annual fecundity (eggs/female), sex ratio (Female:Male:Jack) for Cascade, Little White Salmon (LWSH), Eagle Creek (ECNFH), and Yakima early run coho stocks 1996-2000 broodyears. Sex ratios for Cascade Hatchery for the 1996-1999 broodyears were not available.

Broodyear					
	2000	1999	1998	1997	1996
Cascade Hatchery Fecundity	2,700	2,588	2,926	2,445	2,932
Cascade Hatchery F:M:J	47:48:5	N/A	N/A	N/A	N/A
LWSH Fecundity	2,600	2,962	2,783	2,557	2,762
LWSH F:M:J	44:45:11	26:29:45	54:46:1	44:36:20	32:33:35
ECNFH Fecundity	3,229	3,288	2,808	3,023	2,895
ECNFH F:M:J	38:48:14	42:49:9	52:44:4	43:46:11	40:43:16
Yakima Fecundity	2,869	3,423	2,923	N/A	N/A
Yakima F:M:J	49:47:4	59:37:5	N/A	N/A	N/A

selective pressure of mating in the natural environment, other factors must be responsible to any shifts in female size or fecundity from their donor hatcheries. We suggest that migration distance may be the influencing factor. Fish that migrate back to the Yakima River must travel at least 355 km further than fish returning to the closest hatchery that our program receives juvenile fish. We suggest that longer migration distances may select for larger and therefore more fecund females. It is possible that either low stamina or early sexual maturation may prevent a portion of hatchery coho released in the Yakima from returning to spawn (Dunnigan 2000).

Our study demonstrated that although passage timing was a poor predictor of spawn timing, there was a tendency for the earliest returning coho in 2000 to spawn earlier than those coho passing Prosser Dam at later dates. These results were consistent with observations for the 1999 broodyear (Dunnigan 2000). The fish weighted mean passage date at Prosser Dam in 2000 was October 8, and the mean maturation date for all adults collected and spawned at the Prosser Hatchery was November 5. Given the relatively short duration between the mean passage date and the mean maturation date, returning coho may have an insufficient length of time to migrate to the upper Yakima, construct a redd and spawn successfully. Therefore, we expect that maturation timing may be one of the most important factors in the development of a localized broodstock in the Yakima basin, and a factor expected to diverge from the donor lower Columbia River hatcheries. The maturation timing we observed for coho returning to the Yakima basin in 1999 and 1998 was similar to maturation timing for Cascade (ODFW, unpublished data) and Little White Salmon Hatcheries (USFWS, unpublished data). Local adaptation of traits such as endurance, run timing and sexual maturation timing may take several generations to occur, therefore a long-term monitoring effort will be continued to track changes over several generations.

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Appendix

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ANNUAL REPORT: OUTMIGRATION YEAR 2000

Part 1. SUPPLEMENTED FISH SURVIVAL TO McNARY DAM

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1. Introduction

Survival to McNary Dam of PIT-tagged hatchery fish released into the Yakima basin was assessed for year 2000 outmigrants. The general method used was first to expand the number of fish detected at McNary (McN) by diving by the McN-detection rate (estimated proportion of the release's McNary passage that were detected at that site). The McN-detection rate was based on the number of the target group's PIT-tags jointly detected at McNary and a downstream dam (DSD) divided by the total number of the target group's PIT-tags detected at that downstream dam. The resulting expanded number detected at McNary was then divided by the number of fish released as an estimate of the release-to-McN survival index. The estimation method involved stratification of passage days based on estimated daily detection rates and involved an independent stratification of McN-to-DSD travel times. Since McN-detection-rate estimates were based on downstream dam detections, the date of downstream detection had to be offset by the travel time from McNary to be applied to a date of McNary detection. See Appendix A's Section A.1 for a detailed discussion.

Logistic analysis of variation was used to make comparisons among survival rates. The logistic analysis effectively operates on the transformation $b = \ln[sr/(1-sr)]$ where sr is the survival index which is assumed to be binomially distributed. Estimates of standard errors of b, given tables, are adjusted for the failure of binomial to hold by multiplying the binomially-based standard error by the square root of the mean deviance. The deviance and the mean deviance are respectively analogous to the residual sums of squares and mean square in conventional (least squares) analysis of variance. If the distribution of the survival rate were actually binomial, the mean square would be expected to be greater than 1.0. Under logistic analysis, the retransformed estimate of mean the survival index[3] is an unbiased estimate.

NOTE: In this report, table and figure numbers are associated with the numbering of the sections of the report.

2. Optimum Conventional Treatment (OCT) and Simulated Natural Treatment (SNT) Spring Chinook Survival

2.a. Survival from Raceway Release to McNary Dam

Table 2.a.1 gives the estimated logit coefficients (b), their standard errors, and the associated estimated survival index from volitional acclimation-raceway release to McNary Dam, and Table 2.a.2 gives the associated logistic analysis of variation using raceway within treatment within site as a measure of "error" variation against which Site (release site--Clark Flat, Easton, and Jack Creek), Treatment (OCT and SNT), and Site x Treatment interaction effects were tested. Figure 2.a graphically presents the survival indices given in Table 2.a.1.

As can be seen from the logistic analysis of variation in Table 2.a.2, neither significant treatment nor site x treatment interaction effects were detected. The significant site effect in the table was driven by a significantly lower survival index from Easton compared those from other release sites. Comparisons among the estimated logistic coefficients from Table 2.a.1 are given in Table 2.a.3 along with their estimated standard errors. It is worth noting that the mean travel time from volitional raceway release to McNary detection was an average of 7.5 days longer for Easton releases than for Clark Flat releases, and this may explain the significantly lower survival index of Easton releases relative to Clarks Flats (Table 2.a.4). However, even though the Easton survival index was also significantly less than that for Jack Creek (Table 2.a.3), the average travel time for Easton releases was less than two days greater for Jack Creek (Table 2.a.4, note for OCT releases, the mean travel time was actually less for than for Jack Creek).

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[3] Retransform of logit is

$$\mathrm{sr} = \frac{\exp(\mathrm{b})}{1+\exp(\mathrm{b})} = \frac{1}{1+\exp(-\mathrm{b})}$$

Table 2.a.1. **Survival indices from acclimation site's volitional release to McNary Dam of PIT-tagged OCT and SNT fish (outmigration year 2000, brood-year 1998)**

OCT Survival Indices

Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4845	0.05922	0.381
Easton (3 raceways/Trt)	-0.7885	0.06163	0.312
Jack Creek (2 raceways/Trt)	-0.5139	0.08444	0.374
Pooled Mean	-0.6100	0.0380	0.352

SNT Survival Indices

Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4577	0.05920	0.388
Easton (3 raceways/Trt)	-0.7834	0.06173	0.314
Jack Creek (2 raceways/Trt)	-0.6207	0.07527	0.350
Pooled Mean	-0.6184	0.0371	0.350

Survival Indices Pooled

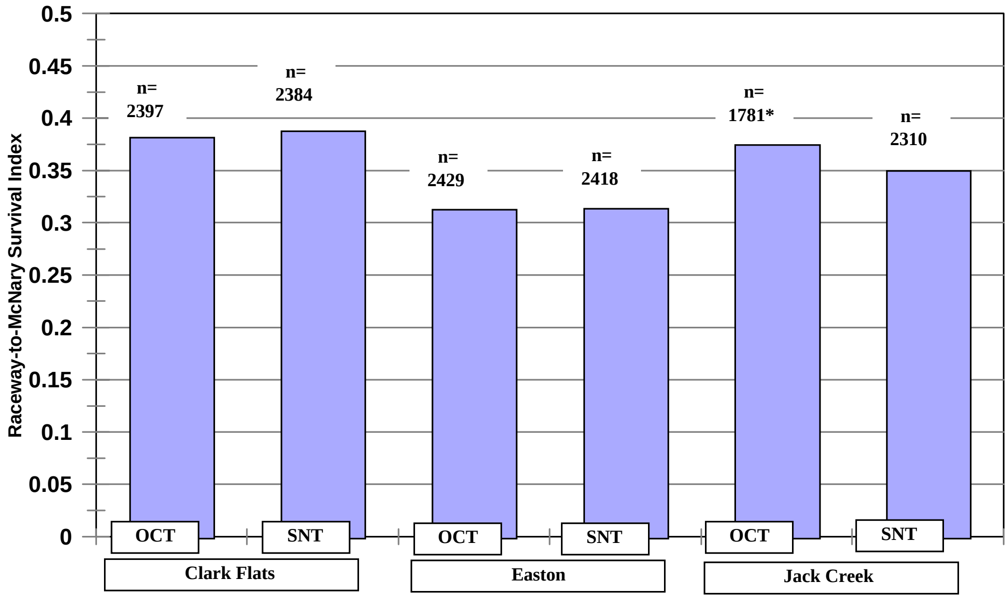
Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4711	0.0419	0.384
Easton (3 raceways/Trt)	-0.7860	0.0436	0.313
Jack Creek (2 raceways/Trt)	-0.5738	0.0562	0.360
Pooled Mean	-0.6143	0.0265	0.351

Table 2.a.2. **Logistic analysis of variation of survival indices from acclimation site's volitional release to McNary of PIT-tagged OCT and SNT fish (outmigration year 2000, brood-year 1998)**

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error
Site	165.88	2	82.94	13.94	0.0013
Treatment (OCT vs SNT)	0.15	1	0.15	0.03	0.8770
Site x Treatment	5.78	2	2.89	0.49	0.6290
Error	59.49	10	5.95		

Table 2.a.3. **Comparisons of the acclimation site logistic coefficients.**

Comparison	Difference	SE	t-ratio[4]	P
Clark Flats versus Easton	-0.3148	0.06046	-5.21	0.0004
Clark Flats versus Jack Creek	-0.1027	0.07006	-1.47	0.1734
Easton versus Jack Creek	0.2121	0.07111	2.98	0.0137



*** n is mean detected fish leaving raceways. For Jack Creek, SNT, there were 2 raceways, one with 1109 and the other with 2279 detected fish leaving raceway**

Figure 2.a. **Pooled acclimation-site-to-McNary survival indices of OCT and SNT fish.**

Table 2.a.4. **Mean travel time in days from volitional release to McNary Dam first detection.**

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[4] The t-test is not a truly appropriate statistical test, but the degrees of freedom were too small for the often-used asymptotic z-test to be appropriate; therefore the more conservative t-test was used.

Site	OCT	SNT	Average
Clark Flat	16.3	18.4	17.4
Easton	22.5	27.1	24.8
Jack Creek	24.1	22.1	23.1

Outmigration year 1999 gave higher survival indices than but similar comparative results to year 2000. Using Bonneville-based estimates of McNary detection rates, year 2000 had a Clark-Flat-to-McN survival index that was 78.4% of that in 1999 and a Easton-to-McNary survival index that was 66.5% of that in 1999. In 1999 there were no acclimation raceways at Jack Creek, and there were only two raceways per treatment at Easton. (In year 2000 there were three raceways/treatment at Easton and Clark Flats and two raceways/treatment at Jack Creek.) The survival indices in 1999 were based on time of tagging-to-McN survival instead of time-of-volitional-release-to-McN survival because the PIT-tag detectors in the raceway outfalls were not functioning properly in 1999; therefore, survival-index estimates in 2000 would have been even relatively lower than those in 1999 had raceway outfall detections been used for the release numbers in that year.

As in year 2000, there were no significant differences among treatments in year 1999 (Type 1 P = 0.42) or between site x treatment interaction effects (Type 1 P = 0.65). And as in year 2000, Easton had a smaller 1999 Bonneville Dam-based McNary survival index (0.471) than Clark Flats (0.490). The Type 1 error probability of P = 0.14 for this 1999 Easton versus Clark Flats comparison was much larger than in 2000 (Type 1 P = 0.14 in 1999)[5]. Since the raceway outfall detectors were malfunctioning in 1999, it was not possible to assess travel times for the volitional releases in that year.

More detailed descriptions of the estimation of the OCT-SNT survival indices are given in Appendix A, Section A.2.a.

2.b. Survival from Rosa to McNary

Wild and OCT-SNT hatchery fish passing Rosa Dam were sampled, PIT-tagged if not previously PIT-tagged, and then released for the purpose of comparing wild to hatchery Rosa-to-McN survival indices. Releases were grouped into strata in a manner to either 1) attain a minimum of 5 McN detections for each release group (wild, previously tagged OCT-SNT fish, and not-previously tagged OCT-SNT fish) or 2) have a reasonably consolidated period of release days within strata. The number of fish released at Rosa, survival index estimates, and unexpanded detections at McNary within strata are presented in the Table 2.b.1 and subsequent Figure 2..b. In the case of sampled untagged OCT-SNT fish, not all sampled fish were PIT-tagged prior to Rosa release. For this group the total number of sampled fish is given under the heading "Weight" in Table 2.b.1 and the number of those fish that were PIT-tagged at Rosa prior to release is given under the heading "Number Released". In the case of wild and previously tagged fish, the pooled mean is weighted by the "Number Released", all sampled fish being tagged or already having tags; whereas, in the case of previously untagged fish, the pooled mean is weighted by the "Weight" (total fish sampled at Rosa).

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[5] The OCT-SNT survival indices estimates presented in this report are based on Bonneville-based McN detection rates for reasons discussed later. In 1999, both Bonneville-based and John Day-based estimates were used. The Type I error probability associated with the John Day Dam-based 1999 Easton versus Clark Flats survival index comparison was P = 0.09

A logistic analysis of variation for wild and OCT-SNT hatchery fish is given in Table 2.b.2. During the period of the hatchery outmigration, the survival index of wild fish significantly exceeded that of OCT-SNT hatchery fish ($P < 0.01$, wild and OCT-SNT survival indices being 0.452 and 0.282[6], respectively). The hatchery survival rate is 62% of that of the wild. Rosa-to-McN survival rates for 1999 outmigrants were higher than in 2000. The 1999 wild survival index was 0.699, and the pooled hatchery survival index of 0.502 was 72% that of the wild (Type 1 $P = 0.07$).

The wild-fish survival index during the period preceding the outmigration of hatchery fish (early strata: 1 through 4, first four release periods in Table 2.b.1) was significantly less (Type 1 $P < 0.0001$) than the wild-fish survival index during the outmigration of hatchery fish (late strata: 5 through 10, last six release periods in Table 2.b.1). The wild fish pooled mean of 0.299 over early strata was 66% of the wild pooled survival index of 0.452 over late strata. The logistic analysis of variation comparing these two periods of wild outmigration past Rosa is given in Table 2.b.3.

More detailed descriptions of the estimation of the wild versus OCT-SNT survival indices are given in Appendix A, Section A.2.b.

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[6] OCT-SNT estimates were pooled over previously tagged and untagged fish because survival indices of two groups pooled over strata were almost identical: survival indices for previously tagged and untagged equaled 0.281 and 0.283, respectively ($P = 0.97$).

Table 2.b.1 Rosa release numbers, Rosa-to-McNary survival-index estimates, and McNary unexpanded detections for wild, previously tagged, and previously untagged fish that were released at Rosa (outmigration year 2000)

Release Period 1999 - 2000		Wild Number Released	Wild Survival Index	Wild Detections[1]	OCT-SNT Previously Tagged Number Released	OCT-SNT Previously Tagged Survival Index	OCT-SNT Previously Tagged Detections[1]	OCT-SNT Previously Untagged Number Released	OCT-SNT Previously Untagged Survival Index	OCT-SNT Previously Untagged Detections[1]	Weight[2]
7-Dec	2-Jan	158	0.320	18							
3-Jan	9-Jan	1575	0.306	171							
10-Jan	17-Jan	845	0.307	92							
18-Jan	24-Jan	435	0.252	39							
25-Jan	7-Mar	2401	0.446	381	111	0.286	11	86	0.304	9	1733
8-Mar	22-Mar	333	0.431	51	116	0.203	8	454	0.291	46	1057
23-Mar	30-Mar	191	0.519	35	141	0.496	24	381	0.246	32	1986
31-Mar	13-Apr	171	0.564	34	328	0.201	23	351	0.226	27	3920
14-Apr	26-Apr	51	0.364	6	226	0.296	21	401	0.379	48	2990
27-Apr	6-May	49	0.318	5	127	0.298	11	277	0.251	21	1633
Strata 1-4 Pooled		3013	0.299	320							
Strata 5-10 Pooled		3196	0.452	512	1049	0.282	98	1950	0.282	183	13319
Strata 5-10, OCT-SNT tagged and Untagged Pooled								2999	0.282	281	14368

[1] Unexpanded Detections

[2] Not all trapped untagged OCT-SNT fish were tagged. The weight represents all fish trapped, and the pooled mean survival is a weighted mean using these weights

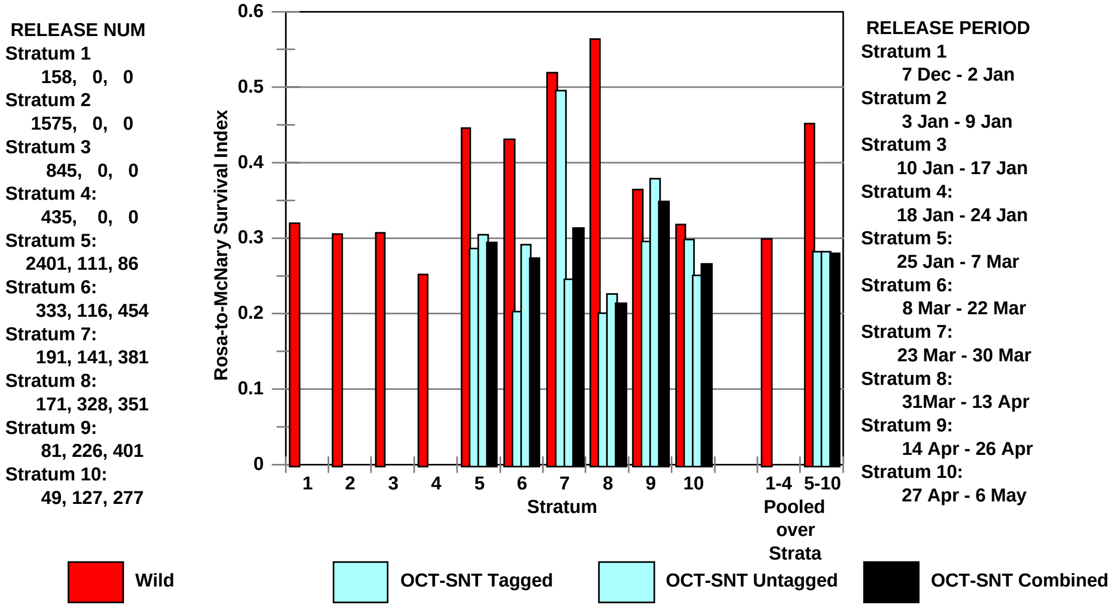

Figure 2.b. Rosa-to-McNary survival indices of wild and previously tagged, untagged, and combined OCT-SNT fish within release strata.

Table 2.b.2. **Logistic analysis of variation of Rosa-to-McNary survival-indices estimates among strata 5 through 10 and among wild and previously tagged and untagged hatchery fish released at Rosa**

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance Dev/DF	F-Ratio	Type 1 P
Among Late Strata	99.93	5	19.99	2.98	0.0666
Wild versus OCT-SNT	190.79	1	190.79	28.45	0.0003
OCT versus SNT	0.01	1	0.01	0.00	0.9700
Error	67.05	10	6.71		

Table 2.b.3. **Logistic analysis of variation of Rosa-to-McNary survival-indices estimates between wild spring Chinook passing during time-strata 1 through 4 and those passing during time-strata 5 through 10**

Wild Only Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance Dev/DF	F-Ratio	Type 1 P
Early versus Late Strata	155.15	1	155.15	51.93	0.0000
Among Strata within Early and Late	23.90	8	2.99		

3. Early and Late Coho Releases' Release-Site-to-McNary Survival

Early and late releases of coho were made at two sites (Cle Elum and Easton) on the Upper Yakima and at two sites (Lost Creek and Stiles) on the Naches. Survival indices from time of PIT-tagging to McNary passage and an associated logistic analysis of variation are given in Table 3.a. McNary detection-rate estimates were based on the proportion of the Bonneville Dam detections that were previously detected at McNary.

Although the logistic analysis of variation indicates no significant differences between the subbasins or between the early and late releases, the early releases had higher survival rates than late releases at all sites other than Stile's as indicated in Figure 3. There is strong evidence of mixing of early and late release fish prior to release at Stiles where there was only one pond with a net separating the early from the late release fish. Travel times of the releases are given in Table 3.b. More than 54% of the Style's "late release" detections at McNary were detected before the "late release" date suggesting that there was a substantial mixing between the Stile's early and late release treatment fish prior to release. The small proportion of fish detected before release date for two of the five other releases might reflect a small proportion of escapees prior to release date.

It is possible that early released fish have a greater survival rate than late released fish. In 1999 five out of six[7] paired releases had a higher survival index for the early release. For the combined years, the probability of having just by chance a total of 8 (3 in 2000 and 5 in 1999) or more out of 10 paired releases (4 in 2000 and 6 in 1999) having one of the two treatments with the highest survival index is P = 0.11[8]. If

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[7] Six pairs in 1999 were three sites (Cle Elum, Jack Creek, Stiles) x two stock (Cascade, Yakima). The late release of Yakima stock at Stiles had a higher survival index then the early.

[8] Type 1 error probability based on sign test assuming binomial distribution

the year-2000 Stiles' release were omitted, the probability of having just by chance total of 8 or more out of 9 paired releases over two years having one treatment out of two with the highest survival index is 0.04. It is likely that the early coho release has a higher survival index than the late release.

More detailed descriptions of the estimation of the wild versus OCT-SNT survival indices are give in Appendix A, Section A.2.b.

Table 3.a. Survival Indices from release site to McNary of early and late year 2000 released coho smolt

a. McNary Survival Indices

Subbasin	Site	Early	Late	Pooled Site Mean	Subbasin Mean
Yakima	Cle Elum	0.136	0.020	0.078	0.154
	Easton	0.278	0.182	0.230	
Naches	Lost Creek	0.271	0.148	0.209	0.259
	Stiles	0.259	0.358	0.309	
Pooled Treatment Mean		0.236	0.177	0.207	

b. Logistic Analysis of Variation

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 P
Subbasin	335.24	1	335.24	2.41	0.2607
Site (within Subbasin)	581.27	2	290.64	2.09	0.3236
Time (of Release)	104.37	1	104.37	0.75	0.4776
Subbasin x Time	114.34	1	114.34	0.82	0.4602
Error (Site x Time)	278.12	2	139.06		

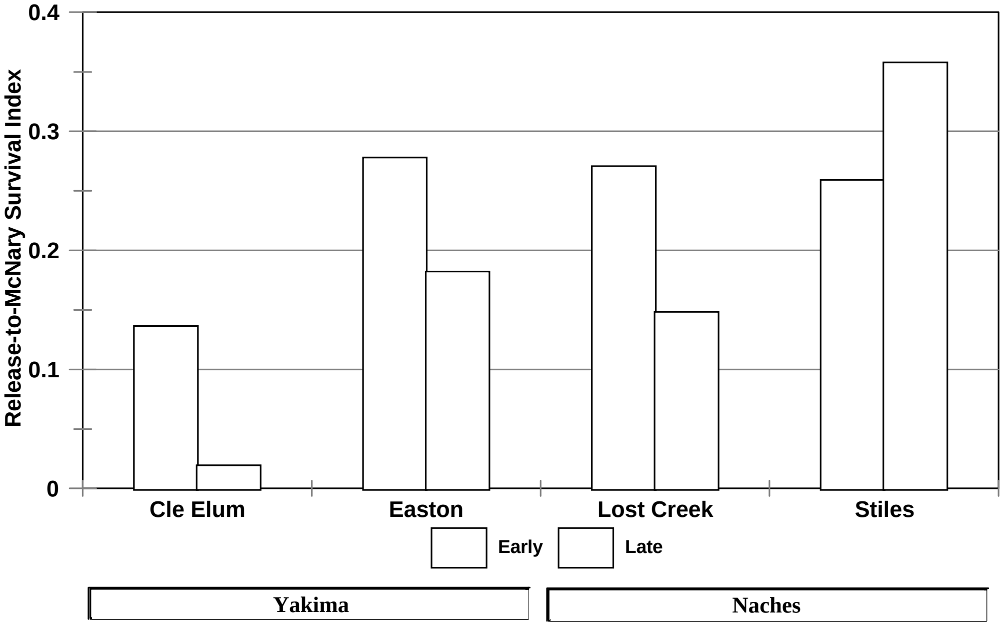

Figure 3. Release-to-McNary survival indices of early and late releases of coho from two sites within the Upper Yakima and from two sites within the Naches subbasins

Table 3.b. Travel time summaries from release to McNary of early and late release coho

	Upper Yakima				Naches			
	Cle Elum		Easton		Lost Creek		Styles	
	Early	Late	Early	Late	Early	Late	Early	Late
Total Released	70	10	142	93	139	76	133	184
Release Date	7-May-00	31-May-00	7-May-00	31-May-00	7-May-00	31-May-00	7-May-00	31-May-00
Mean Detection Date	1-Jun-00	11-Jun-00	31-May-00	13-Jun-00	3-Jun-00	12-Jun-00	27-May-00	1-Jun-00
Mean Travel Time (Days)	26	11	25	13	28	12	21	1
Proportion of fish detected before release date	0.029	0.000	0.000	0.022	0.000	0.013	0.000	0.543

4. Fall Chinook Releases' Release-Site-to-McNary Survival

Replicated releases of accelerated and conventionally reared fall Chinook were made below Prosser Dam in the Yakima. A replicated release was also made in the Yakima near the Marion Drain confluence. There is no particular reason to compare the Marion releases' survival indices to those of the Prosser releases, but the data from all releases were analyzed together to increase the power of the test by increasing the degrees of freedom. McNary detection-rate estimates used for expanded survival indices were based on the proportion of the John Day Dam coho detections that were previously detected at McNary.

Table 4 presents: a. estimated logistic coefficients, their standard errors, and the survival indices (retransformed logit); b. the logistic analysis of variation; and c. "t-tests" associated with comparisons of the logistic coefficients. The accelerated treatment has a substantially and significantly smaller survival index than the conventional treatment (survival indices for accelerated and control respectively are 0.428 and 0.817, Type 1 P = 0.03). It turns out the release near Marion Drain has the smallest survival index (survival index = 0.271) which is substantially but not significantly less than that of the accelerated treatment released below Prosser Dam (survival index = 0.428, Type 1 P = 0.29) but is significantly less than that of the conventional treatment released below Prosser (survival index = 0.817, Type 1 P = 0.03).

Table 4. **Survival Indices from release site to McNary of year 2000 released fall Chinook smolt**

a. Logistic Coefficients and Retransformed Release-to-McNary Survival Indices

Treatment	Logistic Coefficient [(Coef)]	Standard Error [SE(Coef)]	Mean Survival Index
Accelerated	-0.290	0.2923	0.428
Control	1.493	0.3745	0.817
Marion Drain	-0.990	0.4633	0.271

b. Logistic Analysis of Variation

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 P
Treatment	1079.89	2	539.95	12.70	0.0343
Error	127.59	3	42.53		

c. Treatment Comparisons of logistic coefficients

	Treatment	
Treatment	Accelerated	Control
Control		
"t"-test	-3.75	
Type 1 P	0.0331	
Marion Drain		
"t"-test	1.28	4.17
Type 1 P	0.2911	0.0251

APPENDIX A. DETAILED DISCUSSION ON ESTIMATION

A.1. General Estimates of Passage

McNary Detection Rate based on Downstream Dam Detections: The McNary (McN) detection rate was estimated by using detections at dams downstream of McNary. The detection-rate estimate was the number of fish jointly detected at McNary and the downstream dam (DSD) divided by the total number detected at that downstream dam. The McNary detection rate was not uniform over the outmigration; therefore the outmigration was stratified in manner that minimized the among-day variation when pooled over strata. The expansions of the McNary detections were performed within strata and then cumulated over strata before dividing by the number of fish released to estimate the survival indices.

The McNary detection rate within detection-rate stratum i [DR(McN; i)] is estimated by Equation A.1.a.

Equation A.1.a. $$\mathrm{DR(McN\ ;\ i)} = \frac{\sum_{j} \mathrm{N(McN,\ \ DSD;\ \ i, j)}}{\sum_{j} \mathrm{N(DSD;\ \ i, j)}}$$

wherein N(McN,DSD; i,j) is the number of fish detected at the downstream dam on day j within stratum i that were previously detected at McNary and N(DSD; i,j) is the total[9] number of fish detected at the downstream dam on that day.

Detection-rate strata were determined by applying a weighted stepwise logistic linear regression of the logit-transform of the detection rate (Equation A.1.b) on all possible continuous day strata indicator variables, the weight being the daily total detection number at the downstream dam. To the extent a reasonably small number of strata could be accommodated, the goal was to make the logistic regression residual mean deviance[10] adjusted for the stratum indicator variables as near to what would be expected if the distribution of the detection rates among days within strata were binomial.

Equation A.1.b. $$\mathrm{Logit(DR)} = \ln\left[\frac{\mathrm{DR}}{1-\mathrm{DR}}\right] \text{wherein ln is the natural log}$$

Downstream Dam Date Offset to Correspond to McNary Passage Date. Daily McNary detection rates were estimated at the downstream dam on the day (j) of downstream dam passage. The day of McNary passage to which the detection rates applied was offset from the day of downstream dam

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[9] Total number of detections is the number of detected fish whether previously detected at McNary or not.

[10] The logistic regression procedure followed assumed that the underlying distribution of the detection rates is binomial. The residual deviance and the residual mean deviance are respectively analogous to the residual sums of squares and the residual mean square in least squares analysis. If the distribution is truly binomial then the mean deviance is expected to be 1. If the residual mean square is not substantially or significantly different than 1, then the fit is regarded as being very good. (Tests for expected mean square equaling 1 is a chi-square test on the residual deviance.)

detection using mean McN-to-DSD travel time in days based on first day[11] of detections. Mean travel times as well as travel-time medians and distributions were computed within travel time strata, which were developed independently of detection rate strata[12]. The offset-time within travel-time stratum k is given in Equation A.1.c.

Equation A.1.c.

$$j'(\text{McN}) = j(\text{lower Dam}) - \text{Mean}\,[TT(k)]$$

or

$$j(\text{lower Dam}) = j'(\text{McN}) + \text{Mean}\,[TT(k)]$$

Wherein j is the downstream dam day of passage and Mean[TT(k)] is the mean travel time within stratum k containing day j, j' being the estimated day of passage at McNary.

Travel strata were determined by applying a weighted stepwise least squares linear regression using mean travel time of fish passing McNary on day j' as the response variable and all possible continuous-day-strata indicator variables as predictor variables, the weights being the number of detections on day j' at McNary that were subsequently detected at the downstream dam (i.e., the number of observations going into the daily mean travel time). The stepwise process was terminated when either 1) certain statistical criteria were met[13], 2) a step produced equal travel times (in rounded days) between two adjacent strata in which case the previous step was the last used, or 3) when the last strata produced a mean travel time that was greater than that for a stratum that included earlier passage dates in which case the previous step was the last used. Regarding the last two termination criteria, the assumption is that travel-time will not increase with later outmigration.

Assignment of McNary passage to a given McNary detection rate. The stratified offset used to assign a downstream dam's detection date to a McNary passage date is somewhat biased because of miss-assignment of fish. Not all fish passing the downstream dam on a given date took the same number of days to travel from McNary. Say, as an artificial example, that the last downstream dam day for the first **detection-rate stratum** (Stratum 1) was May 29 and the mean travel time used for that day was 3 days, making the offset McNary passage date May 26 (May 29 - 3). However, some fish passing McNary after May 26 would have actually passed the downstream dam on or before May 29 (the last downstream-dam date for the Stratum 1) and contributed to the wrong stratum (McN Stratum 2 passing during downstream dam's Stratum 1). Likewise, some fish passing McNary on or before May 26 would have actually passed the downstream dam after May 29 contributing to the wrong stratum (McN "Stratum" 1 passing during downstream dam's Stratum 2) . Therefore, the individual stratum detection rates, based on date of downstream detection, are somewhat biased.

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[11] Travel time = Time of first detection at McNary - Time of first detection at downstream dam.

[12] In outmigration year 1999, mean travel-time was computed separately for each detection-rate stratum and the resulting value was used to offset the McNary detection date from the downstream-dam detection date. However, mean travel time varied within detection rate strata, so in year 2000 the decision was made to stratify the travel time as well. The travel-time offset was then independent of the detection rate strata.

[13] In the step-up procedure an indicator variable was included if the associated F-ratio exceeded 4, corresponding to an approximate Type 1 Error probability of 0.05; the dropping of already included variables in the model occurred when the associated F-ratio fell below 4.

No method was developed for adjusting for this bias. However, efforts were made to assign the McNary passage to the correct stratum. For each travel-time stratum, this was done by estimating the distribution of travel-times and then applying this distribution to the total[14] daily McNary detections within this stratum. As an artificial example, say that distribution in travel times for the **travel-time stratum** that contained McNary passage date May 25 were as given in Table A.1.a.

Table A.1.a. Artificial example: Relative frequency of travel-times for travel-time stratum containing off-set McNary passage date May 25 (travel time based on joint McNary and downstream dam detections)

	McN-to-DSD Travel Time and Relative Frequencies					
Travel Time (TT)	1	2	3	4	5	6
Relative Frequency	0.1	0.2	0.3	0.15	0.15	0.1
Mean TT =	3.35					
Median TT =	3					

If a total if 200 fish were detected at McNary on May 25, the travel-time frequency of those fish to the downstream dam would be 200*relative frequency; e.g., for 1 travel-time day from Table A.1.a, 200*0.1 = 20, estimated fish passing McN on May 25 taking 1 day to travel to downstream dam. The estimated frequencies are given Table A.1.b. The McNary May 25 estimated travel-time frequency was assigned to the corresponding downstream-dam offset day (May 25 + travel time, also given in Table A.1.b). Referring to Table A.1.b, McN's sequential travel-time frequencies 20,40, 60, and 30 were respectively assigned to downstream dam detections day May 26, May 27, May 28, and May 29 which are within detection-rate Stratum 1; and sequential travel-time frequencies 30 and 20 were respectively assigned to downstream dam detection days May 39 and May 29 which are within the next detection-rate stratum.

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[14] Total at McNary detections whether or not detected at the downstream dam.

Table A.1.b. **Artificial example: Distributed travel times for 200 fish passing McNary on May 25 (last stratum date) using Table A.1.a.'s travel-time relative frequencies**

	McN-to-DSD Travel Time (TT in days)					
Travel Time (TT)	1	2	3	4	5	6
TT Frequency	20	40	60	30	30	20
Lower Dam Date = May 25+TT	May 26	May 27	May 28	May 29	May 30	May 31
Mean TT =	3.35					
Median TT =	3					

Expanding the passage to obtain survival indices. The frequencies from all McNary passages contributing to a given downstream-dam date are cumulated. These are in turn are cumulated over all downstream dam dates within each detection-rate stratum. Each cumulated stratum count is then expanded by the respective detection-rate estimate, and the expanded values are in turn added over strata to obtain an index of the total passage. This passage index is then divided by the release number as a survival-index estimate which is summarized in an oversimplified form in equation A.1.d.

Equation A.1.d. $$\text{Survival Rate Index} = \frac{\sum_i \frac{\text{N (McN,i)}}{\text{Detection Rate (i)}}}{\text{Number Released}}$$

Wherein N(McN,i) is the number of McNary detections allocated to stratum i by relative travel-time distributions; Detection Rate (i) is the downstream-dam-based McNary detection-rate for stratum i, and Number Released is the total number of released fish that contributed to that passage.

A.2. Optimum Conventional Treatment (OCT) and Simulated Natural Treatment (SNT) Spring Chinook Survival

A.2.a. Survival from Raceway Release to McNary Dam

McNary detection rate based on downstream dam-detections: The number of detections of OCT-SNT dams was approximately 80% lower in 2000 than in 1999 even though approximately the same total number of OCT-SNT fish were tagged (approximately 40,000). Doubtlessly this was do to the relatively lower survival in 2000. However, the relative number of John Dam detections in 2000 was far lower (less than 20% lower) than was the case for either McNary Dam or the two Bonneville Dam power houses. Figure A.2 presents the actual total number of 1999 and 2000 OCT-SNT detections at the four detection sites as well as the pooled detections from the two Bonneville powerhouses and also presents 2000/1999 detection ratios. As can be seen, the ratio for John Day is far less than that those for McNary and Bonneville. The 1999/2000 John day ratio as a proportion was 0.182 compared to 0.801 at McNary and to 0.625 at Bonneville (pooled estimate). The discrepancy could not be explained in terms of mean daily spill. The weighted mean of the percentage of flow spilled[15] at John Day was 28% in 1999 and 32% in 2000, the weights being the daily number of detections at John Day. Based on this relatively low number of John Day detections, the decision was made to use Bonneville detections to estimate the McNary detection rate.

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[15] Percent flow being the daily flow spilled divided by the total discharge. U.S.Corps of Engineers data provided by Henry Franzoni, Fish Passage Center, Portland, Oregon.

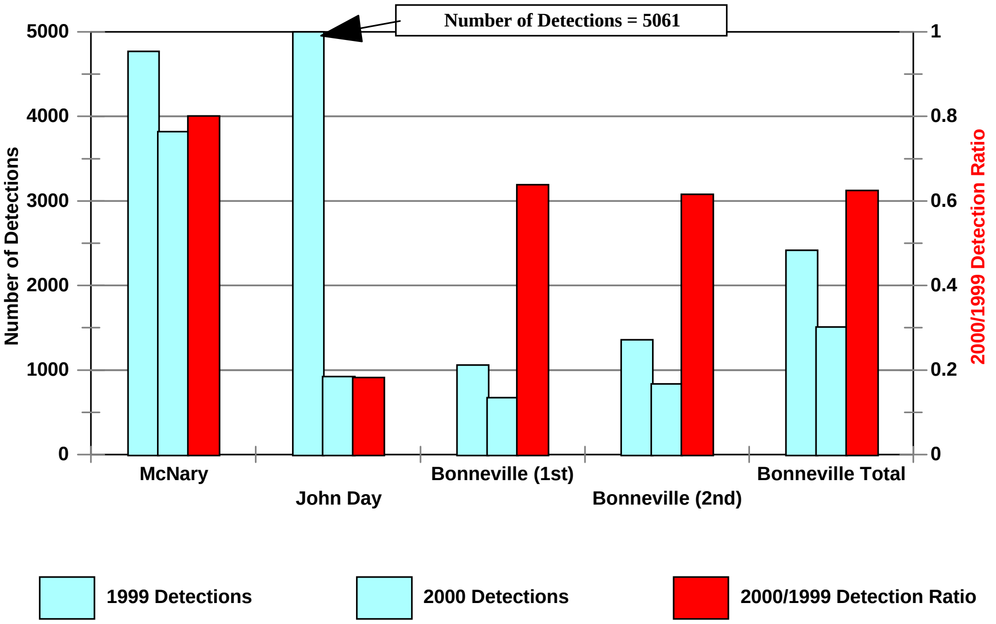

Figure A.2.a. **Total detections of OCT-SNT fish at McNary, John Day, and Bonneville Dams in 1999 and 2000 and associated 2000/1999 detection ratios as proportions.**

The Bonneville-detections were pooled over the two powerhouses. The Bonneville-based daily McNary detection rates, when logistically regressed against all possible indicator variables to separate continuous days into two strata resulted in strata detection rates separated by Bonneville dates May 20 and 21 leading to the smallest pooled within-day mean deviance. The mean deviance, based on 55 degrees of freedom, was 1.07 which is not significantly different than 1 based on a chi-square test on the deviance; this implies that no further stratification is necessary. Two strata were thus established, the first stratum ending with May 20, and the second, beginning with May 21. The estimated detections rates for the two strata are given below in Table A.2.a.1[16].

It should be noted that, according to the Bonneville event log on June 19, 2000, the flow through the Powerhouse 2 was reduced to near 0 and the detections dramatically dropped, but by that date the number of detections of OCT/SNT fish at Powerhouse 1 had also dramatically dropped and the outmigration was nearly finished. Further, since the detection rate in stratum 2 through June 18 were essentially the same for the two power house (0.2803 for Powerhouse 1 and 0.2703 for Powerhouse 2), the detection rates from Powerhouse 1 after July 18 were deemed to representative of both powerhouses.

Table A.2.a.1. **Bonneville-based McNary detection rates by identified strata**

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[16] The full Stratum 1 detection rate estimates were 0.3415 based on 284 total detections for Powerhouse 1 and 0.3709 based on 275 total detections for Powerhouse 2, the full Stratum 2 detection rate estimates were 0.2788 based on 391 total detections for Powerhouse 1 and 0.2696 based on 560 total detections for Powerhouse 2. The within stratum rates for the two powerhouse did not significantly differ from each other based on z z-test (Type 1 P = 0.40 for Stratum 1 and Type 1 P = 0.73 for Stratum 2). The detection rates given in Table A.2.a.1 are the within-stratum pooling of the two powerhouse's detection rates.

Stratum	Bonneville Dates First Date[1]	 Last Date[2]	Pooled Detection Rate (DR)
1	4/30/00	5/20/00	0.3560
2	5/21/00	7/4/00	0.2734

[1] First day of first stratum is day of first OCT-SNT detection

[2] Last day of last stratum is day of last OCT-SNT detection

Downstream Dam Date Offset to Correspond to McNary Passage Date. The weighted stepwise least-squares regression procedures described earlier produced the five travel-time strata in Table A.2.a.2. along with their respective travel time means.

Table A.2.a.2. Bonneville-to-McNary travel-time strata along with pooled travel-time means

Travel Time Stratum	McNary Dates		Mean Travel Time	Bonneville Date	
	First	Last		First	Last
1		4/27/00	11.3		5/8/00
2	4/28/00	5/1/00	9.5	5/7/00	5/10/00
3	5/2/00	5/4/00	8.4	5/10/00	5/12/00
4	5/5/00	5/16/00	7.3	5/12/00	5/23/00
5	5/17/00		5.9	5/23/00	

Travel-time distributions were then developed within time-travel strata and are given around the strata medians[17] in Table A.2.a.3. Because of the limited number of detections within the distribution frequency classes in the first three strata and because of the similarity of their distributions around their respective medians[18], the first three strata distributions were pooled; however, the pooled distributions were centered around the respective medians within the three classes. The last two strata were not pooled. These distributions were applied to each OCT-SNT raceway's McNary daily detections with the medians centered on the detection date.

Expanding the passage to obtain survival indices. For each OCT-SNT raceway, Table A.2.a.4 gives the unexpanded and expanded recoveries for each stratum, the pooling of those recoveries over strata, and the estimated survival index (the pooled expanded recoveries divided by the total number of fish detected leaving the raceway outfall). Of the total of 3,820 OCT-SNT fish detected at McNary, only 24 were not previously detected at raceway outfalls. This gives a raceway detection efficiency of (3,820 - 24)/3,280 = 0.993. With an over-99% detection efficiency, no attempt was made to adjust for efficiency, neither in terms of release numbers nor detection numbers. The logistic analysis of variation provided earlier in the main text's Table 2.a was performed on the raceway survival indices, the mean deviance among raceway survival indices within treatment within site serving as the measure of error.

A.2.b. Survival from Rosa to McNary

The same detection-rate strata and rates and the same travel-time strata, means, medians, and distributions that were used for estimating survival from individual raceway releases to McNary Dam were also applied to McNary detections of fish released at Rosa. Wild fish and previously untagged OCT-SNT fish were tagged at Rosa, and previously tagged fish were re-released. The basic description is given in the main text's Section 2.b.

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[17] It should be noted that the median values did not differ from the mean travel times by more than 0.5 days.

[18] As an example for the similarity, the strata 1, 2, and 3 variances of the distributions around their respective <u>medians</u> were almost identical (7.1, 7.0, and 7.2, respectively); whereas the variances for strata 4 and 5 differed (3.0 and 2.4, respectively).

Table A.2.a.3. Travel time distribution around median travel time (median set at 0 for table presentation).

	McN Stratum Dates			Median Travel Time										
STRATUM 1	**15-Mar**	**27-Apr**		**11 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	2	5	5	5	7	1	1	0	0	1	0	0	0	1
Proportion	0.071	0.179	0.179	0.179	0.250	0.036	0.036	0.000	0.000	0.036	0.000	0.000	0.000	0.036
Cumulative Proportion	0.071	0.250	0.429	0.607	0.857	0.893	0.929	0.929	0.929	0.964	0.964	0.964	0.964	1.000
	McN Stratum Dates			**Median Travel**										
STRATUM 2	**28-Apr**	**30-Apr**		**9 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	3	2	3	5	2	2	1	3	0	0	1	0	0	0
Proportion	0.136	0.091	0.136	0.227	0.091	0.091	0.045	0.136	0.000	0.000	0.045	0.000	0.000	0.000
Cumulative Proportion	0.136	0.227	0.364	0.591	0.682	0.773	0.818	0.955	0.955	0.955	1.000	1.000	1.000	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 3	**1-May**	**4-May**		**8 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	0	3	13	6	6	1	2	1	0	0	0	0	0	1
Proportion	0.000	0.091	0.394	0.182	0.182	0.030	0.061	0.030	0.000	0.000	0.000	0.000	0.000	0.030
Cumulative Proportion	0.000	0.091	0.485	0.667	0.848	0.879	0.939	0.970	0.970	0.970	0.970	0.970	0.970	1.000
STRATUM 1-3	**McN Stratum Dates**			**Median Travel Time**										
POOLED	**15-Mar**	**4-May**		**POOLED**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	5	10	21	16	15	4	4	4	0	1	1	0	0	2
Proportion	0.060	0.120	0.253	0.193	0.181	0.048	0.048	0.048	0.000	0.012	0.012	0.000	0.000	0.024
Cumulative Proportion	0.060	0.181	0.434	0.627	0.807	0.855	0.904	0.952	0.952	0.964	0.976	0.976	0.976	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 4	**5-May**	**16-May**		**7 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	1	8	46	34	18	13	7	4	0	2	1	0	0	0
Proportion	0.007	0.060	0.343	0.254	0.134	0.097	0.052	0.030	0.000	0.015	0.007	0.000	0.000	0.000
Cumulative Proportion	0.007	0.067	0.410	0.664	0.799	0.896	0.948	0.978	0.978	0.993	1.000	1.000	1.000	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 5	**17-May**	**31-Jul**		**6 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	0	18	93	74	35	15	4	1	0	0	1	0	0	1
Proportion	0.000	0.074	0.384	0.306	0.145	0.062	0.017	0.004	0.000	0.000	0.004	0.000	0.000	0.004
Cumulative Proportion	0.000	0.074	0.459	0.764	0.909	0.971	0.988	0.992	0.992	0.992	0.996	0.996	0.996	1.000

Table A.2.a.4. **Detection rates and unexpanded detections (Unexp[19]), expanded detections (Exp), release numbers, and survival indices for each raceway**.

Detection Rate Stratum Information				Clark Flats											
	Bonneville		Bonn-Based	Raceway 1		Raceway 2		Raceway 3		Raceway 4		Raceway 5		Raceway 6	
Detection Rate	Starting	Ending	McNary	SNT		OCT		SNT		OCT		SNT		OCT	
Stratum	Date	Date	Detection Rates	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	98.0	275.4	57.2	160.6	88.8	249.5	34.1	95.9	94.7	266.1	74.6	209.5
2	5/21/00	7/31/00	0.2734	179.0	654.6	196.8	720.0	188.2	688.3	242.9	888.3	174.3	637.4	182.4	667.2
	Total			277	930.0	254	880.5	277	937.8	277	984.2	269	903.5	257	876.7
	Release Number (Rel Num)				2343		2404		2392		2349		2416		2439
	Survival Index = (Exp Total)/(Rel Num)				0.3969		0.3663		0.3921		0.4190		0.3740		0.3595

Detection Rate Stratum Information				Easton											
	Bonneville		Bonn-Based	Raceway 1		Raceway 2		Raceway 3		Raceway 4		Raceway 5		Raceway 6	
Detection Rate	Starting	Ending	McNary	SNT		OCT		SNT		OCT		SNT		OCT	
Stratum	Date	Date	Detection Rates	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	69.7	195.7	80.0	224.7	96.4	270.9	46.3	130.0	183.7	515.9	56.7	159.4
2	5/21/00	7/31/00	0.2734	134.3	491.3	144.0	526.7	149.6	547.1	186.7	683.0	69.3	253.6	151.3	553.3
	Total			204	687.0	224	751.4	246	818.0	233	813.0	253	769.5	208	712.6
	Release Number (Rel Num)				2426		2453		2429		2423		2398		2411
	Survival Index = (Exp Total)/(Rel Num)				0.2832		0.3063		0.3367		0.3355		0.3209		0.2956

Detection Rate Stratum Information				Jack Creek							
	Bonneville		Bonn-Based	Raceway 1		Raceway 2		Raceway 3		Raceway 4	
Detection Rate	Starting	Ending	McNary	SNT		OCT		SNT		OCT	
Stratum	Date	Date	Detection Rates	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	63.3	177.9	33.9	95.3	20.7	58.2	32.9	92.5
2	5/21/00	7/31/00	0.2734	181.7	664.6	234.1	856.2	195.3	714.3	79.1	289.2
	Total			245	842.4	268	951.5	216	772.5	112	381.7
	Release Number (Rel Num)				2340		2453		2279		1109
	Survival Index = (Exp Total)/(Rel Num)				0.3600		0.3879		0.3390		0.3442

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[19] Because of the allocation of daily detections by estimated travel-time distribution, the within-strata unexpanded detections are usual not a whole number; however, their totals over strata will equal the total detections at McNary.

A.3. Early and Late Coho Releases' Release-Site-to-McNary Survival

McNary Detection Rate based on Downstream Dam Detections: In 1999 the same detection-rate strata that were used for OCT-SNT fish were used for coho. This was because there were many more OCT-SNT fish available for identifying the strata and because the within-strata detection-rate trend for coho over strata were the same as those for the OCT-SNT fish. The detection rates were not the same for the two species (in fact the coho detection rates were greater than that of the OCT-SNT fish over all strata in 1999), but the trends were the same--if the detection rate for the OCT-SNT fish went up (or down) from one stratum to another, so did the coho detection rate.

In outmigration year 2000, there were only two detection rate strata for the OCT-SNT fish (there were 7 in 1977). Only 4 out of 286 total PIT-tagged coho detections at Bonneville were detected in the first stratum (on or before May 19, 2000); therefore strata partitioning for coho did not make sense.

As was the case for OCT-SNT spring Chinook, the decision for coho was to base the McNary-detection rates on Bonneville detections rather John Day. However, the reason for doing so is different than was the case for OCT-SNT fish. For coho, non-stratified McNary detection rates were initially estimated using John Day and separately using McNary's two power houses. Weighted detection-rate means over passage days are given in Table A.3.a along with mean comparisons, the weights being the daily number of detections at the respective downstream dam site. The two Bonneville power-house-based detection-rate means did not differ substantially or significantly from each other (P = 0.72, Table A.3.a), and there were greater differences between the polled Bonneville-power-house-based estimates and the John-Day-based estimate (Type 1 P = 0.13).

One of the assumptions for the detection rates to be unbiased is that fish passing through the McNary's bypass system and those not passing through the bypass mix well with each other both temporally and spatially before being detected at the downstream dam from where the detection rates are estimated. The near equality of the two Bonneville-based detection rates could result from such mixing prior to reaching Bonneville since the two power houses from where the data was collected were on opposite sides of the river. The difference between the Bonneville and John Day estimates may result from the failure of fish to spatially mix well by the time they reached John Day. For this reason, the pooled detection rate estimate from the two Bonneville power houses was used. A weighted logistic regression of Bonneville-based detection rate on a simple indicator variable to estimate the logit-transform's mean and mean deviance was performed. The resulting among-day mean deviance of 0.8758 based on 38 degrees of freedom did not differ substantially or significantly from 1 (Type 1 P =0.69). This suggests that the among-day variation was what would be expected from a binomial distribution and that stratification was not necessary because of the homogeneity of the detection rates over outmigration days.

It should be noted that the number of detections at Powerhouse 2 after the dramatic Jun 19 reduction in flow went down to near zero. Only 0.59 % of the total 169 Powerhouse 2 coho detections were made after June 18; whereas 8.55% of the total 117 Powerhouse 1 coho detections were made after that date. Powerhouse 1 is still regarded as representative of both powerhouses after that date because the estimated detection rates up through June 18 were very similar for the two powerhouse (0.2056 for Powerhouse 1 and 0.2083 for Powerhouse 2).

Expanding the passage to obtain survival indices. With no stratification, it was not necessary to offset the Bonneville date by the mean McNary-to-Bonneville travel time to obtain the McNary day of passage associated with Bonneville-based detection-rate strata. Referring to A.3.b, the single Bonneville-based detection rate of 0.2063 was used to expand the total McNary detections of each of the eight coho releases (2 times of releases x 2 sites/river x 2 rivers); each of these expanded McNary detections were then divided their respective release sizes to obtain the estimated survival indices used in obtaining the estimates and logistic analysis of variation given in Table 3.a.

Table A.3.a. **Bonneville-based and John-Day-based McNary detection rate estimates and estimate comparisons for year-2000 coho release outmigrants**

Downstream-dam-based McNary detection rate estimates

	Bonnevile Power House			John
	1	2	Pooled	Day
Detection Rate	0.1966	0.2130	0.2063	0.1518
Standard Error (SE)	0.03453	0.02928	0.02119	0.02913
Degrees of Freedom (DF)	28	26	38	36

Table A.3.a. **Bonneville-based and John-Day-based McNary detection rate estimates and estimate comparisons for year-2000 coho release outmigrants (continued)**

Comparisons among downstream-dam--based McNary detection rate estimates

Bonneville Powerhouse 1 versus 2

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
-0.0164	0.045273	-0.36	53	0.7180

Bonneville Powerhouse 1 versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0448	0.045176	0.99	59	0.3252

Bonneville Powerhouse 2 versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0613	0.041302	1.48	60	0.1432

Bonneville Powerhouses Pooled versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0545	0.036022	1.51	67	0.1348

[1] SE(Diff) = $[SE(1)^2 + SE(2)^2]^{1/2}$

[2] DF (approximate) = $[SE(Diff)]^4/\{[SE(1)^4/DF(1) + SE(2)^4/DF(2)]$

Table A.3.b. **Unexpanded and expanded McNary detections, release numbers, and survival indices of year 2000 coho releases used in Table 3.a .**

			McNary Detections		Number	Survival
River	Site		Unexpanded	Expanded[1]	Released	Index[2]
Upper Yakima	Cle Elum	Early	70	339.3	2487	0.1364
		Late	10	48.5	2462	0.0197
	Easton	Early	142	688.4	2476	0.2780
		Late	93	450.8	2476	0.1821
Naches	Lost Creek	Early	139	673.8	2489	0.2707
		Late	76	368.4	2488	0.1481
	Stiles	Early	133	644.7	2488	0.2591
		Late	184	891.9	2493	0.3578

1 Expanded = Unexpanded/0.2063

2 Survival Index = Expanded/Number Released

A.4. Fall Chinook Releases' Release-Site-to-McNary Survival

McNary Detection Rate based on Downstream Dam Detections: Unlike the case for year-2000 spring Chinook and coho outmigrants, John Day, not Bonneville, was the downstream site used to estimate the McNary detection rate for fall Chinook. The reason for this is that, with the severely reduced flows through Bonneville Powerhouse 2 after June 18, the proportion of fall Chinook detected at Bonneville after that date[20] was far less than the proportion at John Day (proportions being 0.256 based on 258 total detections at John Day but being only 0.108 based on 130 total detections at Bonneville). Since at both downstream dams a majority of the late releases below Prosser Dam (conventional rearing) passed after June 18, the John Day detections were regarded as more representative of the late migrant passage.

A weighted logistic regression of John Day-based detection rate on an indicator variable to estimate the logit-transform's mean and mean deviance. The resulting among-day mean deviance of 1.275 based on 41 degrees of freedom did not differ substantially from 1; however, the computed Type 1 Error probability was high enough to consider stratification (Type Error 1 P =0.11). The main question would be whether the estimated detection rates differed over treatments since certain treatments' passage was later in the season. The mean treatment detection rates and a logistic analysis of variation over treatments are given in Table A.4.a. The logistic analysis of variation of non-stratified detection-rate estimates indicated no significant difference over treatments (Type 1 P = 0.41). The error mean deviance of 0.827 did not differ substantially or significantly from 1 (Type 1 Error P= 0.48 based on chi-square test of deviance). Based on these high p values, the decision was made to use the non-stratified pooled estimate of the detection rate over treatments (detection rate = 0.2907).

Table A.4.a. John Day-based McNary detection rate estimates for fall Chinook, analyzed over treatments

Pooled Detection Rates over Treatments

Release Site	Treatment	Pooled Detection Rate
Prosser Release	Accelerated Rearing	0.2522
	Conventional Rearing	0.3063
Marion Drain Release		0.3750
Pooled over Treatments		0.2907

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[20] The July 18th date at John Day is really comparable to the July 18th date at Bonneville because of travel time. However, any travel-time adjustment would have created an even earlier John Day date, and the resulting proportion after the time-adjusted July 18th John Day date would have further exceeded that on Bonneville.

Table A.4.a. **John Day-based McNary detection rate estimates for fall Chinook, analyzed over treatments (continued)**

Logistic Analyis of Variation

Source	Deviance	D.F.	Dev/D.F.	F	Type I P
Treatment	2.03	2	1.015	1.23	0.4078
Error	2.48	3	0.827		

APPENDIX C

Yakima Spring Chinook Juvenile Behavior: Comparisons of Wild and Hatchery Spring Chinook (*Oncorhynchus tshawytsha*) Smolts In Cover Utilization and Avoidance of Predation by Northern Pikeminnows (*Ptychocheilus oregonensis*)

Task 1.k Yakima Spring Chinook Juvenile Behavior:

Comparisons of Hatchery and Wild Spring Chinook ***Oncorhynchus tshawytsha*** Smolts in Cover Utilization and Avoidance of Predation by Northern Pikeminnows, ***Ptychocheilus oregonensis***

Personnel Acknowledgements: John McConnaughey, MS Fisheries (YKFP Research Center) and Dr.Terry DeVietti, pHD (CWU Psychology Dept), Jason Rau, (Cle Elum Research and Supplementation Facility).

Abstract

The present study is part of an effort to evaluate the rearing of Spring Chinook salmon (Oncorhynchus tshawytsha), at the Cle Elum Supplementation and Research Facility near the headwaters of the Yakima River in South Central Washington. Yearling smolts from two hatchery treatment groups OCT (Optimal Conventional Treatment) and SNT (Semi Natural Treatment) were compared to wild smolts in an experiment designed to assess differences in cover utilization, and survival to a predation threat. Five smolts from each of the three treatment groups (OCT, SNT and Wild) were introduced into a 3400-liter observation tank at 30-minute intervals with the order of introduction counterbalanced across replicates. The tank bottom was covered with flat river gravel measuring from 5 to 15 cm, and a small dead pine tree, arranged to provide cover for smolts seeking refuge. A 1hp-recirculating pump provided a water current from front to back of the tank. Several Northern Pikeminnows were present in the tank and served as the predation threat. Typically, on introduction to the tank, smolts sought refuge in the cover provided, then emerged and moved to an open area more or less in the center of the tank where the current was the greatest. Observers noted the time smolts stayed in cover from the time of introduction until emergence. The order of introduction did not significantly affect the time the smolts remained in cover and no significant difference was found between OCT and SNT smolts in either time spent in cover or survival of the predation threat. In contrast, wild fish stayed in cover significantly longer than hatchery fish, and survived the predation challenge at significantly higher rates even though the surviving wild smolts were significantly smaller than the surviving smolts in the hatchery groups.. Qualitative observations also revealed little difference between the OCT and SNT smolts. In comparison to wild smolts, the hatchery fish appeared less adept at concealing themselves in cover. Wild smolts also tended to swim less, i.e. when under a rock or in cover they appeared at rest on the substrate, whereas hatchery fish were almost always swimming.

Introduction

Chinook salmon culture efforts in the Northwest have produced only very modest returns. The high cost of operating hatchery facilities, combined with their low returns and uncertainties concerning their impacts on wild stocks have led some to question their effectiveness as a tool in salmon restoration efforts (Winton and Hilborn, 1994).

The low levels of returning fish of hatchery origin is due largely to the much lower survival of hatchery smolts compared to their wild counterparts. For example, in sub basins of the Columbia River, depending upon the race of the species and the particular sub basin, between 8 and 100 times the numbers of wild chinook salmon return to spawn compared to hatchery-reared fish (Fast, Hubble, Kohn, & Watson, 1991; Mullan, Williams, Rhodus, Hillman, & McIntyre, 1992).

The phenotypic expression of wild fish differs from that of their hatchery reared counterparts. In salmonids, a host of investigations have reported differences in behavior, (e.g., Bachman, 1984; DeVietti, 1992; Dickson & MacCrimmon, 1982; Miller, 1958; Vincent, 1960), physiology (e.g., Miller, Sinclair, & Hochachka, 1959; Vincent, 1960), and morphology (e.g., Sosiak, 1982; Swain, Riddell, and Murray, 1991) between wild and hatchery-reared fish (See White, Karr, & Nohlson, 1995 for a review).
In anadromous fish, these differences in traits correlate with a large survival advantage favoring the wild fish. Traits of the wild fish have evolved through natural selection over generations from the genesis of anadromy to the present time. It follows that traits in hatchery-reared fish that differ from the wild fish offer little or no survival advantage. Moreover, some have argued that these different traits established through hatchery rearing are actually counterproductive to survival in the wild (DeVietti, 1992; Dickson & MacCrimmon, 1982; Fast, et al. 1991; Hilborn, 1992; Mullan, at al. 1992, While et al., 1995).

Variances in behaviors between species and systems are large, however. The recommendation by two reviewers is that the lessons learned in one system are not necessarily transferable to another, thus culture strategies may have to be investigated and tailored to the system they are applied, (Winton and Hilborn, 1994).

There is growing interest in the innovative rearing of hatchery fish in which the specific aim is to increase the return to spawn numbers and thus, explicitly or implicitly, to alter the traits of the cultured fish toward those shown by the wild fish. One such effort is currently underway at the Cle Elum Supplementation and Research Facility. In the Spring of 1999, this facility made it's first release of 400,000 spring chinook (*Oncorhynchus tshawytscha*) smolts that were reared in one of two treatments, 1) Optimum Conventional Treatment (OCT), or 2) Semi-Natural Treatment (SNT). In brief, OCT smolts are raised according to conventional hatchery practices, in a barren concrete raceway and surface fed by hand. SNT smolts are raised in similar raceways, with the raceway walls and floors painted to provide a varied colored background. Floating and submerged cover is provided, and feeding is accomplished using an underwater feed delivery system. The objective for SNT is to attempt to produce smolts that are more similar to their wild counterparts in terms of coloration, utilization of cover, and feeding behaviors. A detailed description and rational of the OCT and SNT treatments can be found in spring chinook monitoring plan, (Busack et. all., 1997).

As part of the overall monitoring efforts associated with the Yakima spring chinook supplementation effort, it is important to quantify and qualify differences produced by the various experimental regimes being tested at the Cle Elum Supplementation and

Experimental Facility. The present experiment addresses these needs by assessing the behavior of the Cle Elum Hatchery experimental hatchery smolts, and wild spring chinook smolts.

Results from this and other studies are to be used in evaluating the effectiveness of the SNT treatment, and in guiding fish culturists in raising a “better fish”, one with behavioral adaptations making it better adapted to survive in the wild.

The goal of the present study was: 1) to quantify the time spent by smolts in cover after introduction into the tank, 2) to qualify the effectiveness of cover utilization by the smolts, 3) to determine if the time the smolts spent in cover was influenced by the presence of other smolts already swimming in open areas of the tank, and 4) to quantify the smolts susceptibility to a predator threat by Pikemouth Minnows.

Methods

The experiment was conducted at the Cle Elum Supplemtation and Research Facility (CESRF). CESRF is a Spring Chinook hatchery located on the Yakima River near the headwaters on the eastern slopes of the Cascade Mountains in South Central Washington. CESRF is 832 river kilometers from the Pacific Ocean. CESRF is operated by the Yakima Nation, with funding provided by the Bonneville Power Administration. It's mission is help restore runs of Spring Chinook in the Yakima Basin by raising and releasing the progeny of wild fish into the Yakima River.

Pumped ground water from the CESRF’s well field was used for the aquarium and fish holding tanks, the temperature was a nearly constant 9.8oC. The water delivery system ensured the water was degassed and oxygenated. Water flow into the tanks was not measured, but flow through was sufficient to replace the total volume several times per day. Lighting was provided by a rack of 4 incandescent lights suspended over the aquarium which were controlled by both a dimmer and a timer switch. Some ambient light was also available through windows, and the blinds were left open to provide normal day lengths. A 1HP irrigation pump was used to provide a current through the aquarium. Water was pulled from the drain at one end of the aquarium, and pumped into the headworks at the other end. The headwork consisted of two parallel 2” PVC pipes submerged at about 5cm and 17cm from the bottom. Water exited these pipes through a series of _mm holes pointed towards the drain.

Smolts from the three treatment groups (OCT, SNT and Wild) were introduced into a 10’ x 4’ x 3’ aquarium containing cover objects (rocks, submerged snag) and a predator threat (Pikemouth minnows).

Elastomer marked OCT and SNT smolts, spawned and reared at the Cle Elum Facility, were used for ease of identification. OCT smolts were marked with an adipose fin clip and a red elastomer mark injected into the clear tissue behind the fish’s left eye. SNT fish were also adipose fin clipped and had a green elastomer tag behind the right eye. These marks had been applied in October-November 1998 as a part of the marking program for all Cle Elum hatchery fish. Wild fish used in this experiment had no clips or marks, and were collected at a smolt enumeration and marking station at Roza Dam between 2 and 10 days prior to use in this experiment.

All surviving smolts were collected, anesthetized, and measured at the end of each replicate. Initially, we did not measure smolts at the start of the replicate due to fears that the stress and trauma would adversely affect the behavior study. This procedure, however, only gave us lengths of the surviving smolts, making it difficult to analyze length as a covariate to survival or time spent in cover. Beginning with replicate #10 we anesthetized and measured the smolts, and placed them in separate containers 24 hours prior to the start of the replicate. The container (20 liter bucket with lid and fitted with a hose and running water) was then lifted into the behavior arena, and lid removed to allow smolts to swim freely into the behavior arena. This gave the smolts a recovery period from the handling, and also eliminated netting and handling effects immediately prior to introduction into the behavior arena.

Northern Pikeminnows were used as the predator threat in this experiment. These were collected via boat electroshocking from the Zillah reach of the Yakima River in February 1999, and maintained in tanks at the Cle Elum facility, for the duration of this study. While in the holding tanks, the pikeminnows were not fed for up to a week before being used in a behavior trial. Seven to nine Pikeminnows were placed in the aquarium before the start of each replicate.

For each replicate, five smolts from each treatment were introduced in sequence, into the aquarium. The order of introduction of the smolts was completely counterbalanced yielding 6 orders in which one group was introduced and observed for 30 minutes before introducing the next group. Typically, upon introduction, the smolts immediately dove to the bottom of the tank, and those that chose to hide under cover would do so in the first 10-15 seconds, where they would remain for periods up to an hour before immerging. Typically once emerged, the smolts would swim to an open area of the tank just downstream of the head box that had current provided by the recirculating pump. There they would maintain station 5 to 20cm above the bottom. They generally remained in that area for the duration of the experiment, though sometimes would explore the rest of the tank. Occasionally the smolts would return to cover for periods of time, but this was the exception rather than the rule.

During the observation period we noted the position of each smolt, and the time when the smolt emerged from cover up to a maximum score of 30 minutes. The observation period for each replicate ended 30 minutes after the 5 smolts comprising the last group was added. At this point, approximately 90 minutes after the introduction of the first group of smolts, most or all of the 15 smolts would be out of cover and swimming in the tank with the majority of these schooling in an open area in the high velocity zone created by the recirculating pump.

Initially, we trapped the Pikemouth in an area at the rear of the aquarium with a sliding partition during our observations of the smolts, and then release them to begin the predation test. We had assumed that the Pikemouth would feed voraciously on the smolts, and planned to halt the replication when approximately half of the smolts had been eaten. This expectation was not born out. The Pikemouth showed little interest in the smolts while the lights were on, or when we were observing them. so we did not employ sliding partition thus allowing the Pikemouth access to the whole aquarium and smolts in the majority of the tests. The Pikemouth showed little interest in the smolts during the observation periods and we never observed the Pikemouth to prey on the smolts. Except for one smolt that was eaten during a behavior replicate, all predation that occurred happened when the room lights were dimmed below the point where we could make observations, or when we were not present. Often we left smolts and Pikemouth in the aquarium for 48 to 96 hrs in order to obtain our target predation level (1/2 of the smolts). At the end of a replication, the tank was drained and cleaned and the survivors recorded as to which smolt group and belonged, and measured (fork length). Generally, a different batch of Pikemouth (held in a holding tank without food) was placed in the aquarium at the beginning of each replicate.

RESULTS

In general, wild smolts tended to be in or close to cover more often during the observation periods than the two hatchery groups following introduction into the aquarium. Also, wild smolts were observed to lay on the substrate more and thus swim less than the other groups when close to cover. No attempt was made to quantify this latter observation as we also observed members of the OCT and SNT groups, on occasion, to rest on the substrate. Thus the difference appeared to be one of degree, not kind.

Time to leave cover.

The time for the smolts to leave cover during the 30 minutes following their introduction to the aquarium was rounded to the nearest minute and analyzed with a 3 X 6 factorial analysis of variance which combined the three rearing conditions (Wild, SNT, and OCT) with the 6 counterbalanced orders of placement into the aquarium (for example, Wild, SNT, OCT was one order, Wild, OCT, SNT was another). The resulting 18 conditions each contained 5 smolts[1] A summary of these data is shown in Figure 1. A weighted means analysis indicated no main effect of the order of presentation of the three groups of smolts into the aquarium (F(1,72)= 1.81, p = .12. Also, the interaction between the smolts and the order of presentation failed to reach statistical significance (F (10,72) = 1.47, p = .17. Thus, the order in which the fish were introduced into the tank had no influence on how quickly they left cover. However, the main effect of smolt type

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with the exception that 6 wild fish and 4 OCT fish were run in the OCT, Wild, SNT order owing to the fact that a wild smolt apparently jumped from the Wild holding tank to the OCT tank, and was selected as one of the nominal 5 OCT fish.

approached statistical significance (F (2,72) = 2.84, p = .06). Subsequent analyses with the t-test revealed no difference between the two hatchery groups in the time to leave cover but a contrast between the mean performance of the wild smolts to the two hatchery groups pooled together revealed that the wild fish remained in cover significantly longer than the hatchery groups (p < .02).

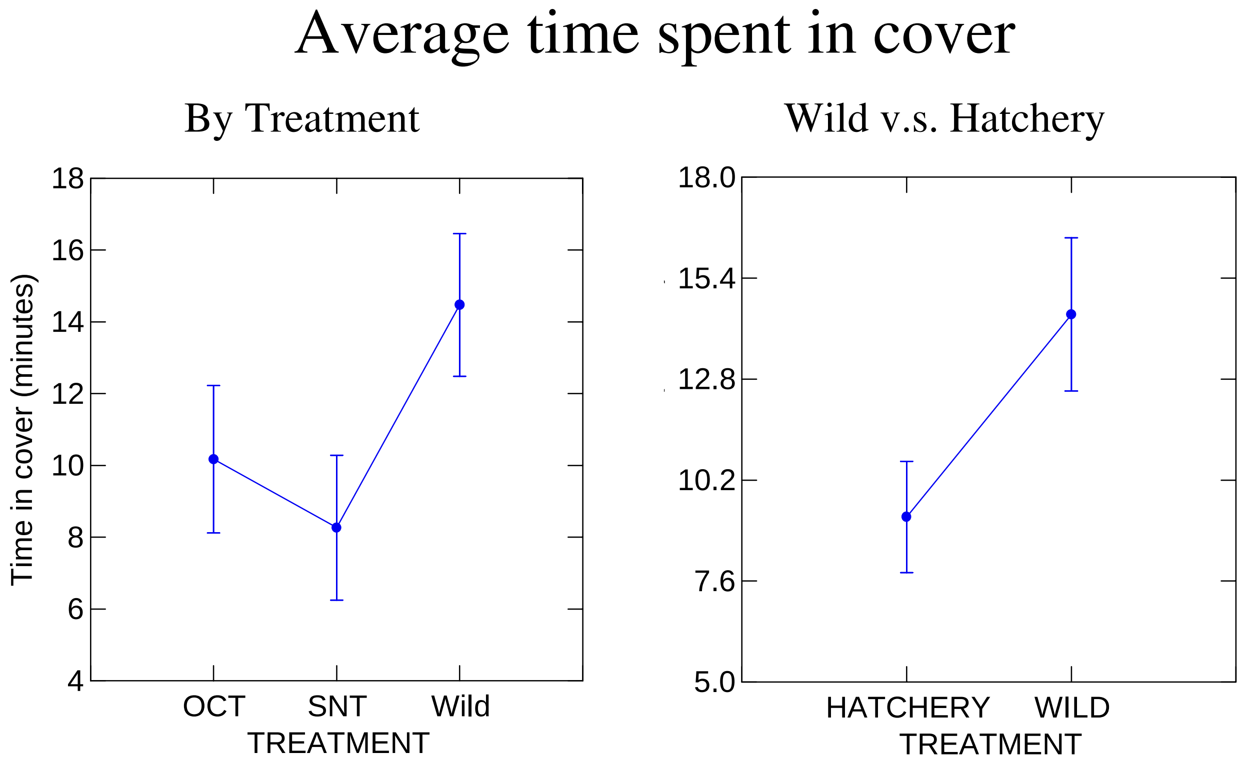

Figure 1. Comparison of mean time spent in cover by treatment group. Left shows the three treatment groups treated separately, right shows OCT and SNT combined into a single "Hatchery" group.

<u>Predation by the Pikeminnows.</u>

A total of 9 replications of 5 smolts each from the three rearing conditions were run to assess the for predation by the Pikeminnows. This procedure resulted in a total of 46 WILD, 45 SNT, and 44 OCT smolts facing the predation challenge. The unequal Ns resulted from the error noted above in which a wild smolt was placed with 4 OCT fish in one replication. Predation by the Pikeminnows occurred in 6 of the 9 replications. Surviving smolts were given a score of 1 and missing (eaten) or mortally wounded smolts a score of 0. Figure 2 summarizes the data from the original 9 replications where the sample size in each group was approximately equal. Although the wild fish had a superior survival rate to the two hatchery-reared smolts, no significant differences were obtained among the three groups (F (2,132) < 1 p > .10).

Subsequently, although we were unable to maintain equal numbers of smolts in the groups as the wild smolts had largely left the system by this time, we added additional replications. Figure 3 shows these data pooled with the original 9 replications. Analysis of these data revealed that the wild smolts were preyed upon significantly less than the two hatchery groups (p's < .02) and that the two hatchery groups did not differ from each other (p > .05).

Inclusion of the replicates where no predation occurred had no effect on the outcome of the significance test of the ANOVA, however inclusion of these replicates would shift the survival of all groups upwards by a constant amount.

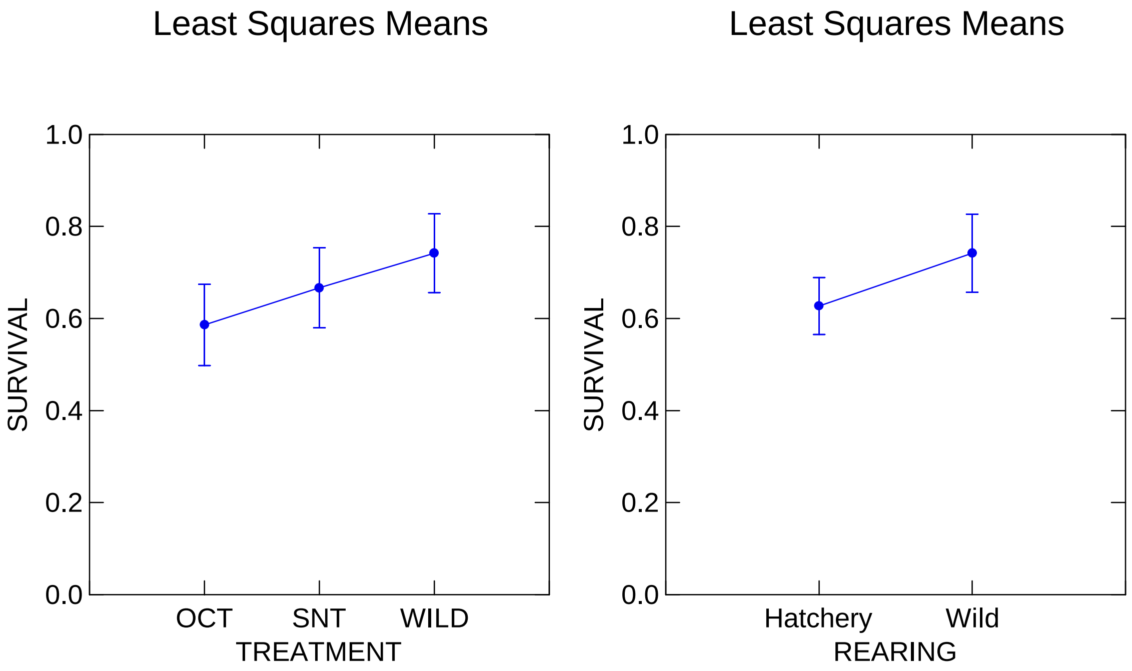

Figure 2 Spring Chinook smolt survival to a predation challenge (Pikeminnows). Only first 9 replications where equal numbers of wild, OCT and SNT smolts were available are included, and only replications where predation actually occurred (Reps 5, 7 & 8 excluded). Left plot compares each group separately, right plot shows OCT and SNT combined.

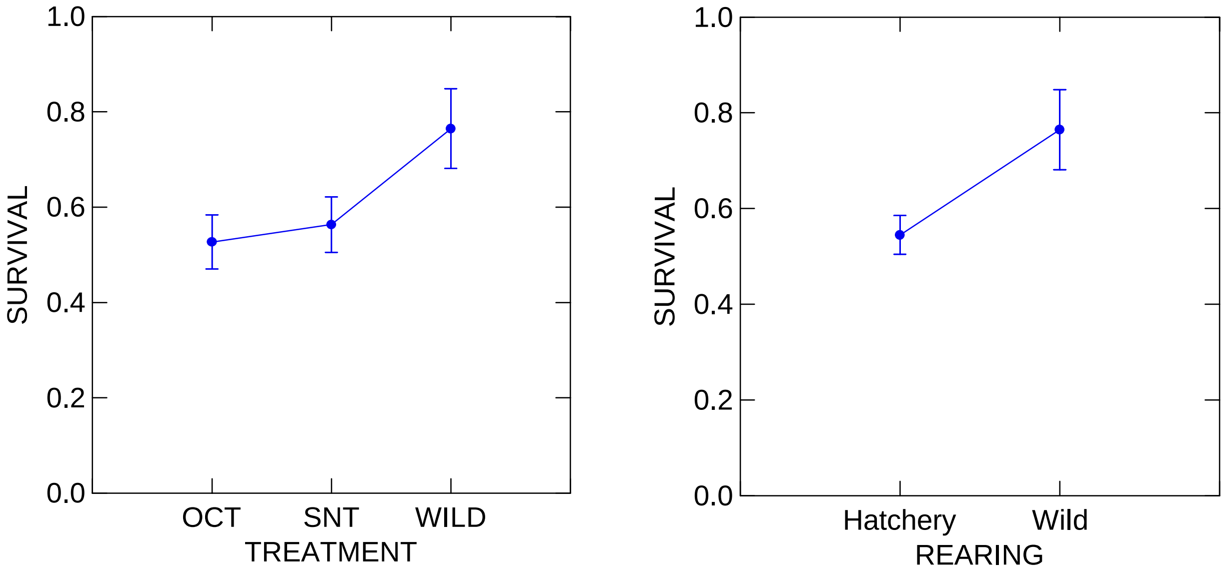

Figure 3. Spring Chinook smolt survival to a predation challenge (Pikeminnows). All replications where predation occurred are included.). Left plot compares each group separately, right plot shows OCT and SNT combined.

Fork-length of surviving smolts.

Figure 4 shows the fork-length (in mm) of the surviving smolts across the first 10 replications where we had equal numbers of smolts from each treatment. Replications 4-9 (blue shaded) were used for the cover trial experiments, the rest were run as survival only trials. Replications 5, 7 and 8 (yellow shaded) are the replications in which predation by the Pikeminnow did not occur. Analysis of variance of these data revealed differences in length among the smolts (F (2,103) = 12.35, p < .001). Subsequent pairwise comparisons with t-test indicated that wild smolts were significantly shorter than either the OCT or SNT smolts (p's < .001). and no difference was obtained between the two hatchery-reared smolts.

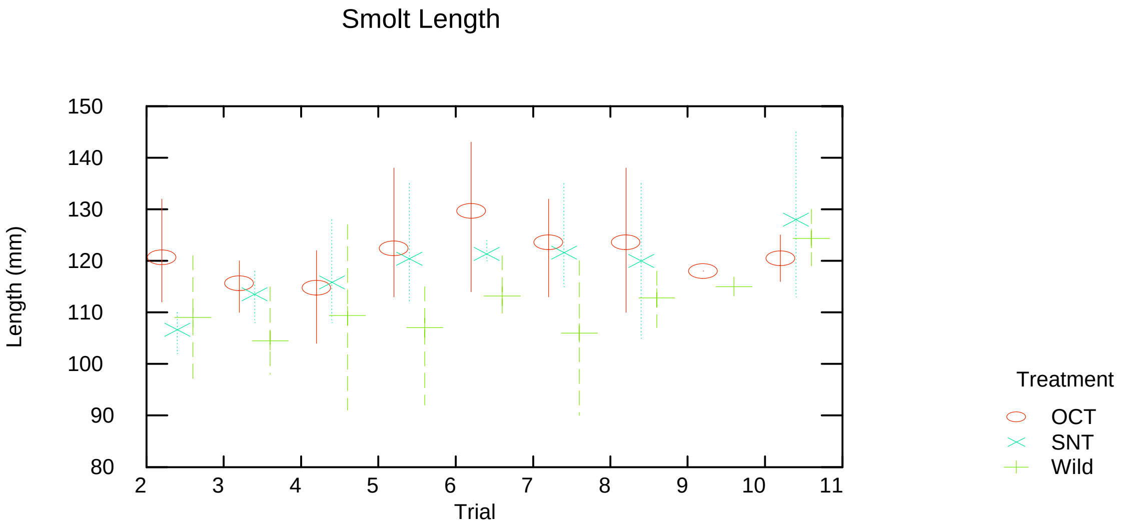

Figure 4. Lengths of surviving smolts replicates with equal numbers of fish from each treatment. Bars indicate minimum and maximum lengths, with symbols showing the average length of each group.

The Pikeminnow proved to be very hearty and resistant to handling mortality. Of the 16 original minnows captured in February 2000, as of December 2000, the only mortalities have been from jumping out of their tank. This is in spite of repeated netting, handling, and transport, irregular feedings, changes in water temperature and holding facilities, and periods of starvation. In June 2000, the 14 surviving minnows were also PIT tagged, photographed, measured, and injected with a florescent elastomer tag in various body locations. No diseases have been noted, although a couple fish were observed with injuries, (a torn maxillary on one, which healed eventually, and a bad abrasion on the chin of another. The chin injury appeared to be healing after 2 weeks, but that fish died after jumping from the tank.

DISCUSSION

The analysis of the time for the smolts to leave cover after introduction into the test tank revealed no significant effect of order of introduction and no interaction between rearing condition and order. Thus, smolts of a specific rearing group were not influenced to leave cover by the presence of other smolts swimming out of cover. However, this analysis did show that the wild smolts stayed in cover longer than either the OCT or SNT fish and the two hatchery-reared smolts did not differ from one another on this measure. In addition to this quantitative evidence of superior use of cover by the wild smolts, several qualitative observations also support the view that the wild smolts are more adept at using cover relative to their hatchery-reared counterparts. For example, wild smolts were observed to be in tight proximity to cover, often under cover objects, more often than hatchery smolts who tended, in the main, only to be close to cover rather than “in it.” Also, when in cover, wild smolts tended to remain motionless, resting on the substrate, whereas hatchery smolts tended to swim most of the time and were thus were more likely to be observed because of the movement.

The initial analysis of the survival data showed a strong trend for better survival in the wild smolts relative to the two hatchery groups. When further replications were conducted these apparent differences reached statistical significance. The PMM were more successful preying on the hatchery smolts than the wild smolts. Again, no difference was obtained with this measure between the two hatchery groups.

For trials 1 through 9 we only measured surviving smolts, and only beginning with trial 10 did we obtain both initial and final measurements. Thus we did not measure enough smolts to evaluate size differences in the three groups. However, the survival data clearly indicated that the wild smolts which survived predation by the PMM were smaller than the surviving hatchery smolts. Thus, the superior survival of the wild smolts is all the more striking as it appears that the NPM preferentially preys on the smaller smolts (see Figure 5).

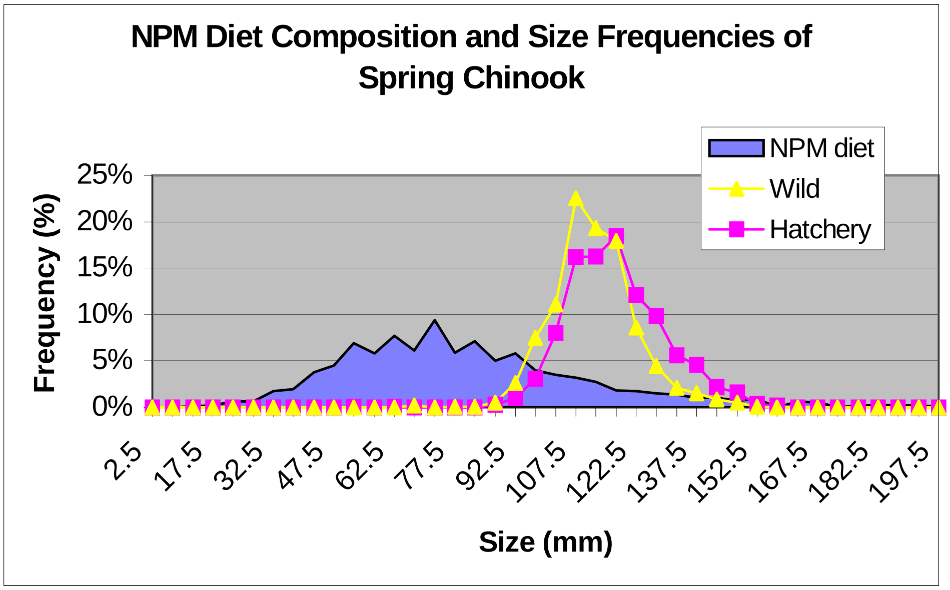

Figure 5 Predicted size frequency distribution of all fish consumed by Northern Pikeminnows in the Yakima, and the size frequency distribution of wild and hatchery spring chinook salmon passing over Roza Dam between March and June of 2000. The predicted size distribution for NPM diet was estimated by taking the observed distribution of the ratio of the prey to predator body lengths in a sample of 571 NPM fish prey items and applying those frequencies to the predicted size frequency distribution of NPM in the Yakima in June of 2000.

The Cle Elum hatchery OCT and SNT smolt population, are in fact larger than the wild smolt population. Of fish passing Roza in March through May of 2000, hatchery smolts averaged 116.9mm, and wild smolts were 111.5mm, a small, but statistically significant difference. By the time they reached Prosser Dam, the fish averaged 137.8 and

128.1mm. The increase in size is due in part by growth of fish as they migrate downstream, but may also be affected by differential mortality on smaller fish. Future work assessing survival of these groups would do well to use size as a covariate in the analysis as this would accentuate any superior survival tendencies by the smaller smolts, which, in the main, would be the wild smolts.

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APPENDIX D

Annual Report: Outmigration Year 2000
Part 1. Supplemented Fish Survival To Mc Nary Dam

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ANNUAL REPORT: OUTMIGRATION YEAR 2000

Part 1. SUPPLEMENTED FISH SURVIVAL TO McNARY DAM

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1. Introduction

Survival to McNary Dam of PIT-tagged hatchery fish released into the Yakima basin was assessed for year 2000 outmigrants. The general method used was first to expand the number of fish detected at McNary (McN) by diving by the McN-detection rate (estimated proportion of the release's McNary passage that were detected at that site). The McN-detection rate was based on the number of the target group's PIT-tags jointly detected at McNary and a downstream dam (DSD) divided by the total number of the target group's PIT-tags detected at that downstream dam. The resulting expanded number detected at McNary was then divided by the number of fish released as an estimate of the release-to-McN survival index. The estimation method involved stratification of passage days based on estimated daily detection rates and involved an independent stratification of McN-to-DSD travel times. Since McN-detection-rate estimates were based on downstream dam detections, the date of downstream detection had to be offset by the travel time from McNary to be applied to a date of McNary detection. See Appendix A's Section A.1 for a detailed discussion.

Logistic analysis of variation was used to make comparisons among survival rates. The logistic analysis effectively operates on the transformation $b = \ln[sr/(1-sr)]$ where sr is the survival index which is assumed to be binomially distributed. Estimates of standard errors of b, given tables, are adjusted for the failure of binomial to hold by multiplying the binomially-based standard error by the square root of the mean deviance. The deviance and the mean deviance are respectively analogous to the residual sums of squares and mean square in conventional (least squares) analysis of variance. If the distribution of the survival rate were actually binomial, the mean square would be expected to be greater than 1.0. Under logistic analysis, the retransformed estimate of mean the survival index[1] is an unbiased estimate.

NOTE: In this report, table and figure numbers are associated with the numbering of the sections of the report.

2. Optimum Conventional Treatment (OCT) and Simulated Natural Treatment (SNT) Spring Chinook Survival

2.a. Survival from Raceway Release to McNary Dam

Table 2.a.1 gives the estimated logit coefficients (b), their standard errors, and the associated estimated survival index from volitional acclimation-raceway release to McNary Dam, and Table 2.a.2 gives the associated logistic analysis of variation using raceway within treatment within site as a measure of "error" variation against which Site (release site--Clark Flat, Easton, and Jack Creek), Treatment (OCT and SNT), and Site x Treatment interaction effects were tested. Figure 2.a graphically presents the survival indices given in Table 2.a.1.

As can be seen from the logistic analysis of variation in Table 2.a.2, neither significant treatment nor site x treatment interaction effects were detected. The significant site effect in the table was driven by a significantly lower survival index from Easton compared those from other release sites. Comparisons among the estimated logistic coefficients from Table 2.a.1 are given in Table 2.a.3 along with their estimated standard errors. It is worth noting that the mean travel time from volitional raceway release to McNary detection was an average of 7.5 days longer for Easton releases than for Clark Flat releases, and this may explain the significantly lower survival index of Easton releases relative to Clarks Flats (Table 2.a.4). However, even though the Easton survival index was also significantly less than that for Jack Creek (Table 2.a.3), the average travel time for Easton releases was less than two days greater for Jack Creek (Table 2.a.4, note for OCT releases, the mean travel time was actually less for than for Jack Creek).

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[1] Retransform of logit is

$$\mathrm{sr} = \frac{\exp(\mathrm{b})}{1+\exp(\mathrm{b})} = \frac{1}{1+\exp(-\mathrm{b})}$$

Table 2.a.1. **Survival indices from acclimation site's volitional release to McNary Dam of PIT-tagged OCT and SNT fish (outmigration year 2000, brood-year 1998)**

OCT Survival Indices

Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4845	0.05922	0.381
Easton (3 raceways/Trt)	-0.7885	0.06163	0.312
Jack Creek (2 raceways/Trt)	-0.5139	0.08444	0.374
Pooled Mean	-0.6100	0.0380	0.352

SNT Survival Indices

Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4577	0.05920	0.388
Easton (3 raceways/Trt)	-0.7834	0.06173	0.314
Jack Creek (2 raceways/Trt)	-0.6207	0.07527	0.350
Pooled Mean	-0.6184	0.0371	0.350

Survival Indices Pooled

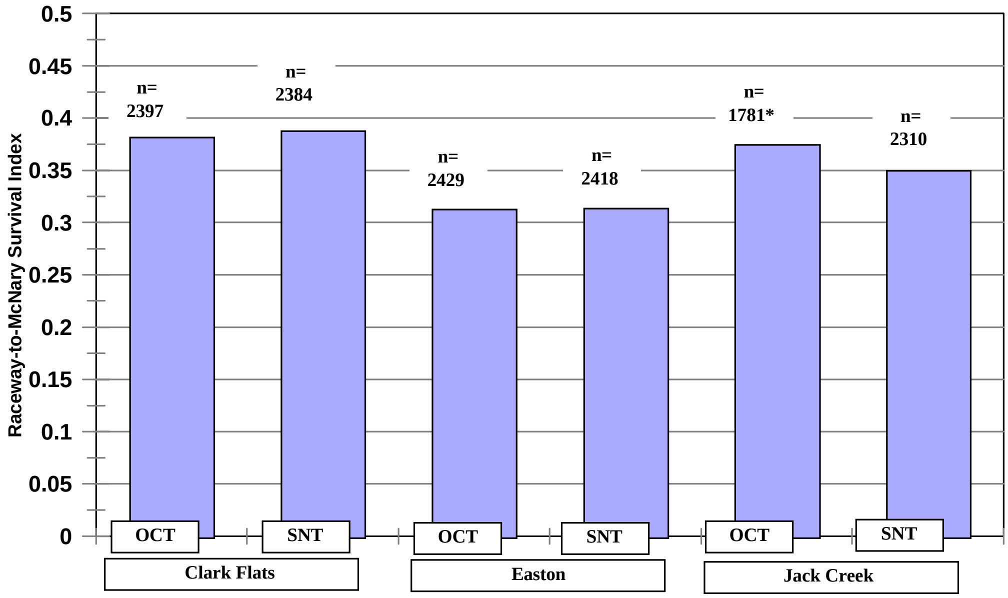
Site	Logistic Coefficient (b)	Standard Error [SE(b)]	Survival Index 1/[1+exp(-b)]
Clark Flat (3 raceways/Trt)	-0.4711	0.0419	0.384
Easton (3 raceways/Trt)	-0.7860	0.0436	0.313
Jack Creek (2 raceways/Trt)	-0.5738	0.0562	0.360
Pooled Mean	-0.6143	0.0265	0.351

Table 2.a.2. Logistic analysis of variation of survival indices from acclimation site's volitional release to McNary of PIT-tagged OCT and SNT fish (outmigration year 2000, brood-year 1998)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error
Site	165.88	2	82.94	13.94	0.0013
Treatment (OCT vs SNT)	0.15	1	0.15	0.03	0.8770
Site x Treatment	5.78	2	2.89	0.49	0.6290
Error	59.49	10	5.95		

Table 2.a.3. Comparisons of the acclimation site logistic coefficients.

Comparison	Difference	SE	t-ratio[2]	P
Clark Flats versus Easton	-0.3148	0.06046	-5.21	0.0004
Clark Flats versus Jack Creek	-0.1027	0.07006	-1.47	0.1734
Easton versus Jack Creek	0.2121	0.07111	2.98	0.0137



*** n is mean detected fish leaving raceways. For Jack Creek, SNT, there were 2 raceways, one with 1109 and the other with 2279 detected fish leaving raceway**

Figure 2.a. Pooled acclimation-site-to-McNary survival indices of OCT and SNT fish.

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[2] The t-test is not a truly appropriate statistical test, but the degrees of freedom were too small for the often-used asymptotic z-test to be appropriate; therefore the more conservative t-test was used.

Table 2.a.4. Mean travel time in days from volitional release to McNary Dam first detection.

Site	OCT	SNT	Average
Clark Flat	16.3	18.4	17.4
Easton	22.5	27.1	24.8
Jack Creek	24.1	22.1	23.1

Outmigration year 1999 gave higher survival indices than but similar comparative results to year 2000. Using Bonneville-based estimates of McNary detection rates, year 2000 had a Clark-Flat-to-McN survival index that was 78.4% of that in 1999 and a Easton-to-McNary survival index that was 66.5% of that in 1999. In 1999 there were no acclimation raceways at Jack Creek, and there were only two raceways per treatment at Easton. (In year 2000 there were three raceways/treatment at Easton and Clark Flats and two raceways/treatment at Jack Creek.) The survival indices in 1999 were based on time of tagging-to-McN survival instead of time-of-volitional-release-to-McN survival because the PIT-tag detectors in the raceway outfalls were not functioning properly in 1999; therefore, survival-index estimates in 2000 would have been even relatively lower than those in 1999 had raceway outfall detections been used for the release numbers in that year.

As in year 2000, there were no significant differences among treatments in year 1999 (Type 1 P = 0.42) or between site x treatment interaction effects (Type 1 P = 0.65). And as in year 2000, Easton had a smaller 1999 Bonneville Dam-based McNary survival index (0.471) than Clark Flats (0.490). The Type 1 error probability of P = 0.14 for this 1999 Easton versus Clark Flats comparison was much larger than in 2000 (Type 1 P = 0.14 in 1999)[3]. Since the raceway outfall detectors were malfunctioning in 1999, it was not possible to assess travel times for the volitional releases in that year.

More detailed descriptions of the estimation of the OCT-SNT survival indices are given in Appendix A, Section A.2.a.

2.b. Survival from Rosa to McNary

Wild and OCT-SNT hatchery fish passing Rosa Dam were sampled, PIT-tagged if not previously PIT-tagged, and then released for the purpose of comparing wild to hatchery Rosa-to-McN survival indices. Releases were grouped into strata in a manner to either 1) attain a minimum of 5 McN detections for each release group (wild, previously tagged OCT-SNT fish, and not-previously tagged OCT-SNT fish) or 2) have a reasonably consolidated period of release days within strata. The number of fish released at Rosa,

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[3] The OCT-SNT survival indices estimates presented in this report are based on Bonneville-based McN detection rates for reasons discussed later. In 1999, both Bonneville-based and John Day-based estimates were used. The Type I error probability associated with the John Day Dam-based 1999 Easton versus Clark Flats survival index comparison was P = 0.09

survival index estimates, and unexpanded detections at McNary within strata are presented in the Table 2.b.1 and subsequent Figure 2..b. In the case of sampled untagged OCT-SNT fish, not all sampled fish were PIT-tagged prior to Rosa release. For this group the total number of sampled fish is given under the heading "Weight" in Table 2.b.1 and the number of those fish that were PIT-tagged at Rosa prior to release is given under the heading "Number Released". In the case of wild and previously tagged fish, the pooled mean is weighted by the "Number Released", all sampled fish being tagged or already having tags; whereas, in the case of previously untagged fish, the pooled mean is weighted by the "Weight" (total fish sampled at Rosa).

A logistic analysis of variation for wild and OCT-SNT hatchery fish is given in Table 2.b.2. During the period of the hatchery outmigration, the survival index of wild fish significantly exceeded that of OCT-SNT hatchery fish ($P < 0.01$, wild and OCT-SNT survival indices being 0.452 and 0.282[4], respectively). The hatchery survival rate is 62% of that of the wild. Rosa-to-McN survival rates for 1999 outmigrants were higher than in 2000. The 1999 wild survival index was 0.699, and the pooled hatchery survival index of 0.502 was 72% that of the wild (Type 1 $P = 0.07$).

The wild-fish survival index during the period preceding the outmigration of hatchery fish (early strata: 1 through 4, first four release periods in Table 2.b.1) was significantly less (Type 1 $P < 0.0001$) than the wild-fish survival index during the outmigration of hatchery fish (late strata: 5 through 10, last six release periods in Table 2.b.1). The wild fish pooled mean of 0.299 over early strata was 66% of the wild pooled survival index of 0.452 over late strata. The logistic analysis of variation comparing these two periods of wild outmigration past Rosa is given in Table 2.b.3.

More detailed descriptions of the estimation of the wild versus OCT-SNT survival indices are given in Appendix A, Section A.2.b.

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[4] OCT-SNT estimates were pooled over previously tagged and untagged fish because survival indices of two groups pooled over strata were almost identical: survival indices for previously tagged and untagged equaled 0.281 and 0.283, respectively ($P = 0.97$).

Table 2.b.1 **Rosa release numbers, Rosa-to-McNary survival-index estimates, and McNary unexpanded detections for wild, previously tagged, and previously untagged fish that were released at Rosa (outmigration year 2000)**

Release Period 1999 - 2000		Wild			OCT-SNT Previously Tagged			OCT-SNT Previously Untagged			
		Number Released	Survival Index	Detections[1]	Number Released	Survival Index	Detections[1]	Number Released	Survival Index	Detections[1]	Weight[2]
7-Dec	2-Jan	158	0.320	18							
3-Jan	9-Jan	1575	0.306	171							
10-Jan	17-Jan	845	0.307	92							
18-Jan	24-Jan	435	0.252	39							
25-Jan	7-Mar	2401	0.446	381	111	0.286	11	86	0.304	9	1733
8-Mar	22-Mar	333	0.431	51	116	0.203	8	454	0.291	46	1057
23-Mar	30-Mar	191	0.519	35	141	0.496	24	381	0.246	32	1986
31-Mar	13-Apr	171	0.564	34	328	0.201	23	351	0.226	27	3920
14-Apr	26-Apr	51	0.364	6	226	0.296	21	401	0.379	48	2990
27-Apr	6-May	49	0.318	5	127	0.298	11	277	0.251	21	1633
Strata 1-4 Pooled		3013	0.299	320							
Strata 5-10 Pooled		3196	0.452	512	1049	0.282	98	1950	0.282	183	13319
Strata 5-10, OCT-SNT tagged and Untagged Pooled								2999	0.282	281	14368

[1] Unexpanded Detections

[2] Not all trapped untagged OCT-SNT fish were tagged. The weight represents all fish trapped, and the pooled mean survival is a weighted mean using these weights

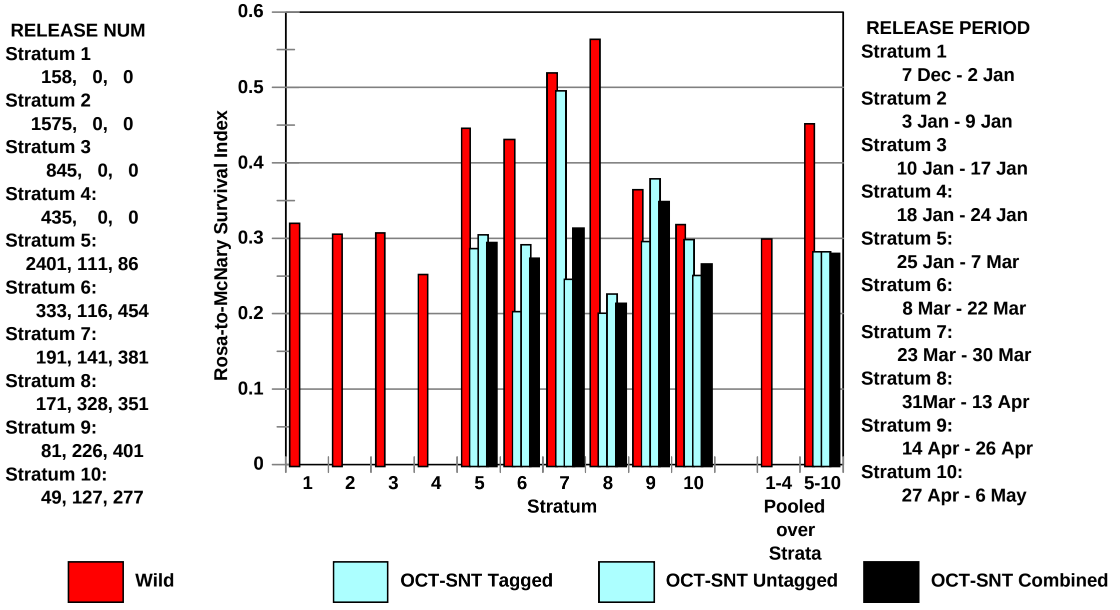

Figure 2.b. **Rosa-to-McNary survival indices of wild and previously tagged, untagged, and combined OCT-SNT fish within release strata.**

Table 2.b.2. Logistic analysis of variation of Rosa-to-McNary survival-indices estimates among strata 5 through 10 and among wild and previously tagged and untagged hatchery fish released at Rosa

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance Dev/DF	F-Ratio	Type 1 P
Among Late Strata	99.93	5	19.99	2.98	0.0666
Wild versus OCT-SNT	190.79	1	190.79	28.45	0.0003
OCT versus SNT	0.01	1	0.01	0.00	0.9700
Error	67.05	10	6.71		

Table 2.b.3. Logistic analysis of variation of Rosa-to-McNary survival-indices estimates between wild spring Chinook passing during time-strata 1 through 4 and those passing during time-strata 5 through 10

Wild Only Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance Dev/DF	F-Ratio	Type 1 P
Early versus Late Strata	155.15	1	155.15	51.93	0.0000
Among Strata within Early and Late	23.90	8	2.99		

3. Early and Late Coho Releases' Release-Site-to-McNary Survival

Early and late releases of coho were made at two sites (Cle Elum and Easton) on the Upper Yakima and at two sites (Lost Creek and Stiles) on the Naches. Survival indices from time of PIT-tagging to McNary passage and an associated logistic analysis of variation are given in Table 3.a. McNary detection-rate estimates were based on the proportion of the Bonneville Dam detections that were previously detected at McNary.

Although the logistic analysis of variation indicates no significant differences between the subbasins or between the early and late releases, the early releases had higher survival rates than late releases at all sites other than Stile's as indicated in Figure 3. There is strong evidence of mixing of early and late release fish prior to release at Stiles where there was only one pond with a net separating the early from the late release fish. Travel times of the releases are given in Table 3.b. More than 54% of the Style's "late release" detections at McNary were detected before the "late release" date suggesting that there was a substantial mixing between the Stile's early and late release treatment fish prior to release. The small proportion of fish detected before release date for two of the five other releases might reflect a small proportion of escapees prior to release date.

It is possible that early released fish have a greater survival rate than late released fish. In 1999 five out of six[5] paired releases had a higher survival index for the early release. For the combined years, the probability of having just by chance a total of 8 (3 in 2000 and 5 in 1999) or more out of 10 paired releases (4 in 2000 and 6 in 1999) having one of the two treatments with the highest survival index is P = 0.11[6]. If the year-2000 Stiles' release were omitted, the probability of having just by chance total of 8 or more out of 9 paired releases over two years having one treatment out of two with the highest survival index is 0.04. It is likely that the early coho release has a higher survival index than the late release.

More detailed descriptions of the estimation of the wild versus OCT-SNT survival indices are give in Appendix A, Section A.2.b.

Table 3.a. Survival Indices from release site to McNary of early and late year 2000 released coho smolt

a. McNary Survival Indices

Subbasin	Site	Early	Late	Pooled Site Mean	Subbasin Mean
Yakima	Cle Elum	0.136	0.020	0.078	0.154
	Easton	0.278	0.182	0.230	
Naches	Lost Creek	0.271	0.148	0.209	0.259
	Stiles	0.259	0.358	0.309	
Pooled Treatment Mean		0.236	0.177	0.207	

b. Logistic Analysis of Variation

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 P
Subbasin	335.24	1	335.24	2.41	0.2607
Site (within Subbasin)	581.27	2	290.64	2.09	0.3236
Time (of Release)	104.37	1	104.37	0.75	0.4776
Subbasin x Time	114.34	1	114.34	0.82	0.4602
Error (Site x Time)	278.12	2	139.06		

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[5] Six pairs in 1999 were three sites (Cle Elum, Jack Creek, Stiles) x two stock (Cascade, Yakima). The late release of Yakima stock at Stiles had a higher survival index then the early.

[6] Type 1 error probability based on sign test assuming binomial distribution

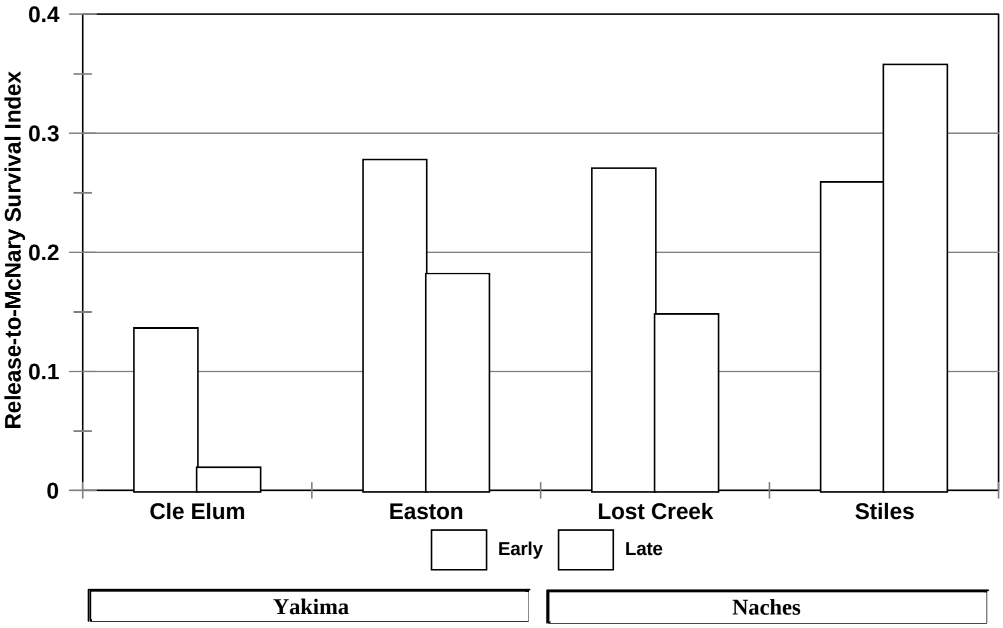

Figure 3. **Release-to-McNary survival indices of early and late releases of coho from two sites within the Upper Yakima and from two sites within the Naches subbasins**

Table 3.b. **Travel time summaries from release to McNary of early and late release coho**

	Upper Yakima				Naches			
	Cle Elum		Easton		Lost Creek		Styles	
	Early	Late	Early	Late	Early	Late	Early	Late
Total Released	70	10	142	93	139	76	133	184
Release Date	7-May-00	31-May-00	7-May-00	31-May-00	7-May-00	31-May-00	7-May-00	31-May-00
Mean Detection Date	1-Jun-00	11-Jun-00	31-May-00	13-Jun-00	3-Jun-00	12-Jun-00	27-May-00	1-Jun-00
Mean Travel Time (Days)	26	11	25	13	28	12	21	1
Proportion of fish detected before release date	0.029	0.000	0.000	0.022	0.000	0.013	0.000	0.543

4. Fall Chinook Releases' Release-Site-to-McNary Survival

Replicated releases of accelerated and conventionally reared fall Chinook were made below Prosser Dam in the Yakima. A replicated release was also made in the Yakima near the Marion Drain confluence. There is no particular reason to compare the Marion releases' survival indices to those of the Prosser releases, but the data from all releases were analyzed together to increase the power of the test by increasing the degrees of freedom. McNary detection-rate estimates used for expanded survival indices were based on the proportion of the John Day Dam coho detections that were previously detected at McNary.

Table 4 presents: a. estimated logistic coefficients, their standard errors, and the survival indices (retransformed logit); b. the logistic analysis of variation; and c. "t-tests" associated with comparisons of the logistic coefficients. The accelerated treatment has a substantially and significantly smaller survival index than the conventional treatment (survival indices for accelerated and control respectively are 0.428 and 0.817, Type 1 P = 0.03). It turns out the release near Marion Drain has the smallest survival index (survival index = 0.271) which is substantially but not significantly less than that of the accelerated treatment released below Prosser Dam (survival index = 0.428, Type 1 P = 0.29) but is significantly less than that of the conventional treatment released below Prosser (survival index = 0.817, Type 1 P = 0.03).

Table 4. Survival Indices from release site to McNary of year 2000 released fall Chinook smolt

a. Logistic Coefficients and Retransformed Release-to-McNary Survival Indices

Treatment	Logistic Coefficient [(Coef)]	Standard Error [SE(Coef)]	Mean Survival Index
Accelerated	-0.290	0.2923	0.428
Control	1.493	0.3745	0.817
Marion Drain	-0.990	0.4633	0.271

b. Logistic Analysis of Variation

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 P
Treatment	1079.89	2	539.95	12.70	0.0343
Error	127.59	3	42.53		

c. Treatment Comparisons of logistic coefficients

	Treatment	
Treatment	Accelerated	Control
Control		
"t"-test	-3.75	
Type 1 P	0.0331	
Marion Drain		
"t"-test	1.28	4.17
Type 1 P	0.2911	0.0251

APPENDIX A. DETAILED DISCUSSION ON ESTIMATION

A.1. General Estimates of Passage

McNary Detection Rate based on Downstream Dam Detections: The McNary (McN) detection rate was estimated by using detections at dams downstream of McNary. The detection-rate estimate was the number of fish jointly detected at McNary and the downstream dam (DSD) divided by the total number detected at that downstream dam. The McNary detection rate was not uniform over the outmigration; therefore the outmigration was stratified in manner that minimized the among-day variation when pooled over strata. The expansions of the McNary detections were performed within strata and then cumulated over strata before dividing by the number of fish released to estimate the survival indices.

The McNary detection rate within detection-rate stratum i [DR(McN; i)] is estimated by Equation A.1.a.

Equation A.1.a. $$\mathrm{DR(McN\;\;;\,i)} = \frac{\sum_{j} \mathrm{N(McN,\;\;DSD;\;\;i,j)}}{\sum_{j} \mathrm{N(DSD;\;\;i,j)}}$$

wherein N(McN,DSD; i,j) is the number of fish detected at the downstream dam on day j within stratum i that were previously detected at McNary and N(DSD; i,j) is the total[7] number of fish detected at the downstream dam on that day.

Detection-rate strata were determined by applying a weighted stepwise logistic linear regression of the logit-transform of the detection rate (Equation A.1.b) on all possible continuous day strata indicator variables, the weight being the daily total detection number at the downstream dam. To the extent a reasonably small number of strata could be accommodated, the goal was to make the logistic regression residual mean deviance[8] adjusted for the stratum indicator variables as near to what would be expected if the distribution of the detection rates among days within strata were binomial.

Equation A.1.b. $$\mathrm{Logit(DR)} = \ln\left[\frac{\mathrm{DR}}{1-\mathrm{DR}}\right] \text{wherein ln is the natural log}$$

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[7] Total number of detections is the number of detected fish whether previously detected at McNary or not.

[8] The logistic regression procedure followed assumed that the underlying distribution of the detection rates is binomial. The residual deviance and the residual mean deviance are respectively analogous to the residual sums of squares and the residual mean square in least squares analysis. If the distribution is truly binomial then the mean deviance is expected to be 1. If the residual mean square is not substantially or significantly different than 1, then the fit is regarded as being very good. (Tests for expected mean square equaling 1 is a chi-square test on the residual deviance.)

Downstream Dam Date Offset to Correspond to McNary Passage Date. Daily McNary detection rates were estimated at the downstream dam on the day (j) of downstream dam passage. The day of McNary passage to which the detection rates applied was offset from the day of downstream dam detection using mean McN-to-DSD travel time in days based on first day[9] of detections. Mean travel times as well as travel-time medians and distributions were computed within travel time strata, which were developed independently of detection rate strata[10]. The offset-time within travel-time stratum k is given in Equation A.1.c.

Equation A.1.c.

$$j'(\mathrm{McN}) = j(\mathrm{lower\ Dam}) - \mathrm{Mean}\,[\mathrm{TT}(k)]$$

or

$$j(\mathrm{lower\ Dam}) = j'(\mathrm{McN}) + \mathrm{Mean}\,[\mathrm{TT}(k)]$$

Wherein j is the downstream dam day of passage and Mean[TT(k)] is the mean travel time within stratum k containing day j, j' being the estimated day of passage at McNary.

Travel strata were determined by applying a weighted stepwise least squares linear regression using mean travel time of fish passing McNary on day j' as the response variable and all possible continuous-day-strata indicator variables as predictor variables, the weights being the number of detections on day j' at McNary that were subsequently detected at the downstream dam (i.e., the number of observations going into the daily mean travel time). The stepwise process was terminated when either 1) certain statistical criteria were met[11], 2) a step produced equal travel times (in rounded days) between two adjacent strata in which case the previous step was the last used, or 3) when the last strata produced a mean travel time that was greater than that for a stratum that included earlier passage dates in which case the previous step was the last used. Regarding the last two termination criteria, the assumption is that travel-time will not increase with later outmigration.

Assignment of McNary passage to a given McNary detection rate. The stratified offset used to assign a downstream dam's detection date to a McNary passage date is somewhat biased because of miss-assignment of fish. Not all fish passing the downstream dam on a given date took the same number of days to travel from McNary. Say, as an artificial example, that the last downstream dam day for the first **detection-rate stratum** (Stratum 1) was May 29 and the mean travel time used for that day was 3 days, making the offset McNary passage date May 26 (May 29 - 3). However, some fish

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[9] Travel time = Time of first detection at McNary - Time of first detection at downstream dam.

[10] In outmigration year 1999, mean travel-time was computed separately for each detection-rate stratum and the resulting value was used to offset the McNary detection date from the downstream-dam detection date. However, mean travel time varied within detection rate strata, so in year 2000 the decision was made to stratify the travel time as well. The travel-time offset was then independent of the detection rate strata.

[11] In the step-up procedure an indicator variable was included if the associated F-ratio exceeded 4, corresponding to an approximate Type 1 Error probability of 0.05; the dropping of already included variables in the model occurred when the associated F-ratio fell below 4.

passing McNary after May 26 would have actually passed the downstream dam on or before May 29 (the last downstream-dam date for the Stratum 1) and contributed to the wrong stratum (McN Stratum 2 passing during downstream dam's Stratum 1). Likewise, some fish passing McNary on or before May 26 would have actually passed the downstream dam after May 29 contributing to the wrong stratum (McN "Stratum" 1 passing during downstream dam's Stratum 2) . Therefore, the individual stratum detection rates, based on date of downstream detection, are somewhat biased.

No method was developed for adjusting for this bias. However, efforts were made to assign the McNary passage to the correct stratum. For each travel-time stratum, this was done by estimating the distribution of travel-times and then applying this distribution to the total[12] daily McNary detections within this stratum. As an artificial example, say that distribution in travel times for the **travel-time stratum** that contained McNary passage date May 25 were as given in Table A.1.a.

Table A.1.a. Artificial example: Relative frequency of travel-times for travel-time stratum containing off-set McNary passage date May 25 (travel time based on joint McNary and downstream dam detections)

	McN-to-DSD Travel Time and Relative Frequencies					
Travel Time (TT)	1	2	3	4	5	6
Relative Frequency	0.1	0.2	0.3	0.15	0.15	0.1
Mean TT =	3.35					
Median TT =	3					

If a total if 200 fish were detected at McNary on May 25, the travel-time frequency of those fish to the downstream dam would be 200*relative frequency; e.g., for 1 travel-time day from Table A.1.a, 200*0.1 = 20, estimated fish passing McN on May 25 taking 1 day to travel to downstream dam. The estimated frequencies are given Table A.1.b. The McNary May 25 estimated travel-time frequency was assigned to the corresponding downstream-dam offset day (May 25 + travel time, also given in Table A.1.b). Referring to Table A.1.b, McN's sequential travel-time frequencies 20,40, 60, and 30 were respectively assigned to downstream dam detections day May 26, May 27, May 28, and May 29 which are within detection-rate Stratum 1; and sequential travel-time frequencies 30 and 20 were respectively assigned to downstream dam detection days May 39 and May 29 which are within the next detection-rate stratum.

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[12] Total at McNary detections whether or not detected at the downstream dam.

Table A.1.b. Artificial example: Distributed travel times for 200 fish passing McNary on May 25 (last stratum date) using Table A.1.a.'s travel-time relative frequencies

	McN-to-DSD Travel Time (TT in days)					
Travel Time (TT)	1	2	3	4	5	6
TT Frequency	20	40	60	30	30	20
Lower Dam Date = May 25+TT	May 26	May 27	May 28	May 29	May 30	May 31
Mean TT =	3.35					
Median TT =	3					

Expanding the passage to obtain survival indices. The frequencies from all McNary passages contributing to a given downstream-dam date are cumulated. These are in turn are cumulated over all downstream dam dates within each detection-rate stratum. Each cumulated stratum count is then expanded by the respective detection-rate estimate, and the expanded values are in turn added over strata to obtain an index of the total passage. This passage index is then divided by the release number as a survival-index estimate which is summarized in an oversimplified form in equation A.1.d.

Equation A.1.d.

$$\text{Survival Rate Index} = \frac{\sum_{i} \frac{\text{N (McN,i)}}{\text{Detection Rate (i)}}}{\text{Number Released}}$$

Wherein N(McN,i) is the number of McNary detections allocated to stratum i by relative travel-time distributions; Detection Rate (i) is the downstream-dam-based McNary detection-rate for stratum i, and Number Released is the total number of released fish that contributed to that passage.

A.2. Optimum Conventional Treatment (OCT) and Simulated Natural Treatment (SNT) Spring Chinook Survival

A.2.a. Survival from Raceway Release to McNary Dam

McNary detection rate based on downstream dam-detections: The number of detections of OCT-SNT dams was approximately 80% lower in 2000 than in 1999 even though approximately the same total number of OCT-SNT fish were tagged (approximately 40,000). Doubtlessly this was do to the relatively lower survival in 2000. However, the relative number of John Dam detections in 2000 was far lower (less than 20% lower) than was the case for either McNary Dam or the two Bonneville Dam power houses. Figure A.2 presents the actual total number of 1999 and 2000 OCT-SNT detections at the four detection sites as well as the pooled detections from the two Bonneville powerhouses and also presents 2000/1999 detection ratios. As can be seen, the ratio for John Day is far less than that those for McNary and Bonneville. The

1999/2000 John day ratio as a proportion was 0.182 compared to 0.801 at McNary and to 0.625 at Bonneville (pooled estimate). The discrepancy could not be explained in terms of mean daily spill. The weighted mean of the percentage of flow spilled[13] at John Day was 28% in 1999 and 32% in 2000, the weights being the daily number of detections at John Day. Based on this relatively low number of John Day detections, the decision was made to use Bonneville detections to estimate the McNary detection rate.

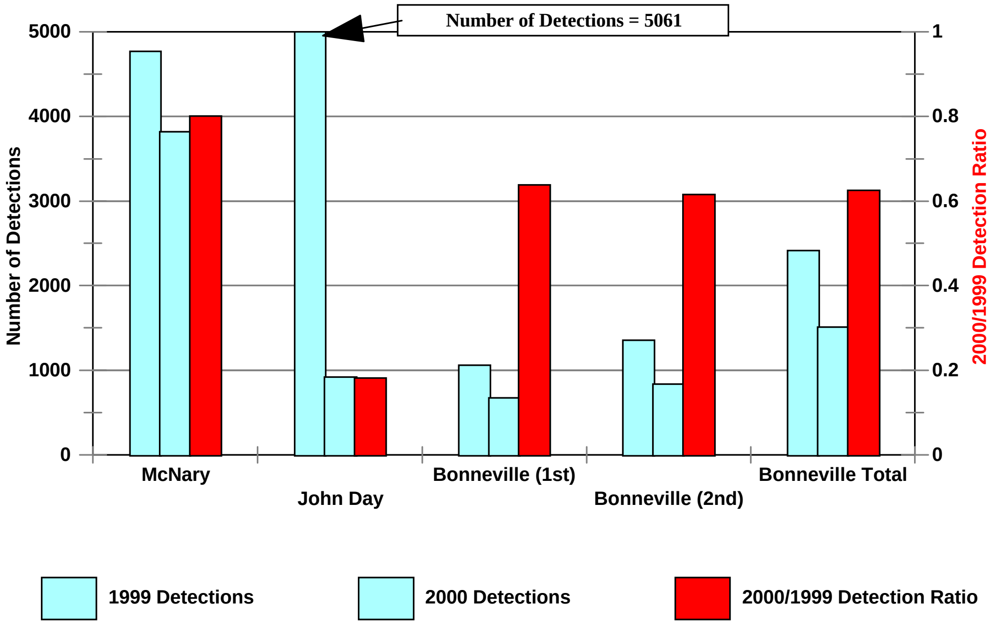

Figure A.2.a. Total detections of OCT-SNT fish at McNary, John Day, and Bonneville Dams in 1999 and 2000 and associated 2000/1999 detection ratios as proportions.

The Bonneville-detections were pooled over the two powerhouses. The Bonneville-based daily McNary detection rates, when logistically regressed against all possible indicator variables to separate continuous days into two strata resulted in strata detection rates separated by Bonneville dates May 20 and 21 leading to the smallest pooled within-day mean deviance. The mean deviance, based on 55 degrees of freedom, was 1.07 which is not significantly different than 1 based on a chi-square test on the deviance; this implies that no further stratification is necessary. Two strata were thus

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[13] Percent flow being the daily flow spilled divided by the total discharge. U.S.Corps of Engineers data provided by Henry Franzoni, Fish Passage Center, Portland, Oregon.

established, the first stratum ending with May 20, and the second, beginning with May 21. The estimated detections rates for the two strata are given below in Table A.2.a.1[14].

It should be noted that, according to the Bonneville event log on June 19, 2000, the flow through the Powerhouse 2 was reduced to near 0 and the detections dramatically dropped, but by that date the number of detections of OCT/SNT fish at Powerhouse 1 had also dramatically dropped and the outmigration was nearly finished. Further, since the detection rate in stratum 2 through June 18 were essentially the same for the two power house (0.2803 for Powerhouse 1 and 0.2703 for Powerhouse 2), the detection rates from Powerhouse 1 after July 18 were deemed to representative of both powerhouses.

Table A.2.a.1. Bonneville-based McNary detection rates by identified strata

Stratum	Bonneville Dates First Date[1]	 Last Date[2]	Pooled Detection Rate (DR)
1	4/30/00	5/20/00	0.3560
2	5/21/00	7/4/00	0.2734

[1] First day of first stratum is day of first OCT-SNT detection

[2] Last day of last stratum is day of last OCT-SNT detection

Downstream Dam Date Offset to Correspond to McNary Passage Date. The weighted stepwise least-squares regression procedures described earlier produced the five travel-time strata in Table A.2.a.2. along with their respective travel time means.

Table A.2.a.2. Bonneville-to-McNary travel-time strata along with pooled travel-time means

Travel Time Stratum	McNary Dates First	 Last	Mean Travel Time	Bonneville Date First	 Last
1		4/27/00	11.3		5/8/00
2	4/28/00	5/1/00	9.5	5/7/00	5/10/00
3	5/2/00	5/4/00	8.4	5/10/00	5/12/00
4	5/5/00	5/16/00	7.3	5/12/00	5/23/00
5	5/17/00		5.9	5/23/00	

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[14] The full Stratum 1 detection rate estimates were 0.3415 based on 284 total detections for Powerhouse 1 and 0.3709 based on 275 total detections for Powerhouse 2, the full Stratum 2 detection rate estimates were 0.2788 based on 391 total detections for Powerhouse 1 and 0.2696 based on 560 total detections for Powerhouse 2. The within stratum rates for the two powerhouse did not significantly differ from each other based on z z-test (Type 1 P = 0.40 for Stratum 1 and Type 1 P = 0.73 for Stratum 2). The detection rates given in Table A.2.a.1 are the within-stratum pooling of the two powerhouse's detection rates.

Travel-time distributions were then developed within time-travel strata and are given around the strata medians[15] in Table A.2.a.3. Because of the limited number of detections within the distribution frequency classes in the first three strata and because of the similarity of their distributions around their respective medians[16], the first three strata distributions were pooled; however, the pooled distributions were centered around the respective medians within the three classes. The last two strata were not pooled. These distributions were applied to each OCT-SNT raceway's McNary daily detections with the medians centered on the detection date.

Expanding the passage to obtain survival indices. For each OCT-SNT raceway, Table A.2.a.4 gives the unexpanded and expanded recoveries for each stratum, the pooling of those recoveries over strata, and the estimated survival index (the pooled expanded recoveries divided by the total number of fish detected leaving the raceway outfall). Of the total of 3,820 OCT-SNT fish detected at McNary, only 24 were not previously detected at raceway outfalls. This gives a raceway detection efficiency of (3,820 - 24)/3,280 = 0.993. With an over-99% detection efficiency, no attempt was made to adjust for efficiency, neither in terms of release numbers nor detection numbers. The logistic analysis of variation provided earlier in the main text's Table 2.a was performed on the raceway survival indices, the mean deviance among raceway survival indices within treatment within site serving as the measure of error.

A.2.b. Survival from Rosa to McNary

The same detection-rate strata and rates and the same travel-time strata, means, medians, and distributions that were used for estimating survival from individual raceway releases to McNary Dam were also applied to McNary detections of fish released at Rosa. Wild fish and previously untagged OCT-SNT fish were tagged at Rosa, and previously tagged fish were re-released. The basic description is given in the main text's Section 2.b.

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[15] It should be noted that the median values did not differ from the mean travel times by more than 0.5 days.

[16] As an example for the similarity, the strata 1, 2, and 3 variances of the distributions around their respective medians were almost identical (7.1, 7.0, and 7.2, respectively); whereas the variances for strata 4 and 5 differed (3.0 and 2.4, respectively).

Table A.2.a.3. Travel time distribution around median travel time (median set at 0 for table presentation).

	McN Stratum Dates			**Median Travel Time**										
STRATUM 1	**15-Mar**	**27-Apr**		**11 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	2	5	5	5	7	1	1	0	0	1	0	0	0	1
Proportion	0.071	0.179	0.179	0.179	0.250	0.036	0.036	0.000	0.000	0.036	0.000	0.000	0.000	0.036
Cumulative Proportion	0.071	0.250	0.429	0.607	0.857	0.893	0.929	0.929	0.929	0.964	0.964	0.964	0.964	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 2	**28-Apr**	**30-Apr**		**9 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	3	2	3	5	2	2	1	3	0	0	1	0	0	0
Proportion	0.136	0.091	0.136	0.227	0.091	0.091	0.045	0.136	0.000	0.000	0.045	0.000	0.000	0.000
Cumulative Proportion	0.136	0.227	0.364	0.591	0.682	0.773	0.818	0.955	0.955	0.955	1.000	1.000	1.000	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 3	**1-May**	**4-May**		**8 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	0	3	13	6	6	1	2	1	0	0	0	0	0	1
Proportion	0.000	0.091	0.394	0.182	0.182	0.030	0.061	0.030	0.000	0.000	0.000	0.000	0.000	0.030
Cumulative Proportion	0.000	0.091	0.485	0.667	0.848	0.879	0.939	0.970	0.970	0.970	0.970	0.970	0.970	1.000
STRATUM 1-3	**McN Stratum Dates**			**Median Travel Time**										
POOLED	**15-Mar**	**4-May**		**POOLED**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	5	10	21	16	15	4	4	4	0	1	1	0	0	2
Proportion	0.060	0.120	0.253	0.193	0.181	0.048	0.048	0.048	0.000	0.012	0.012	0.000	0.000	0.024
Cumulative Proportion	0.060	0.181	0.434	0.627	0.807	0.855	0.904	0.952	0.952	0.964	0.976	0.976	0.976	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 4	**5-May**	**16-May**		**7 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Frequency	1	8	46	34	18	13	7	4	0	2	1	0	0	0
Proportion	0.007	0.060	0.343	0.254	0.134	0.097	0.052	0.030	0.000	0.015	0.007	0.000	0.000	0.000
Cumulative Proportion	0.007	0.067	0.410	0.664	0.799	0.896	0.948	0.978	0.978	0.993	1.000	1.000	1.000	1.000
	McN Stratum Dates			**Median Travel Time**										
STRATUM 5	**17-May**	**31-Jul**		**6 Days**										
Days From Median	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	>=10
Frequency	0	18	93	74	35	15	4	1	0	0	1	0	0	1
Proportion	0.000	0.074	0.384	0.306	0.145	0.062	0.017	0.004	0.000	0.000	0.004	0.000	0.000	0.004
Cumulative Proportion	0.000	0.074	0.459	0.764	0.909	0.971	0.988	0.992	0.992	0.992	0.996	0.996	0.996	1.000

Table A.2.a.4. Detection rates and unexpanded detections (Unexp[17]), expanded detections (Exp), release numbers, and survival indices for each raceway.

Detection Rate Stratum Information				Clark Flats											
	Bonneville		Bonn-Based McNary Detection Rates	Raceway 1 SNT		Raceway 2 OCT		Raceway 3 SNT		Raceway 4 OCT		Raceway 5 SNT		Raceway 6 OCT	
Detection Rate Stratum	Starting Date	Ending Date		Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	98.0	275.4	57.2	160.6	88.8	249.5	34.1	95.9	94.7	266.1	74.6	209.5
2	5/21/00	7/31/00	0.2734	179.0	654.6	196.8	720.0	188.2	688.3	242.9	888.3	174.3	637.4	182.4	667.2
	Total			277	930.0	254	880.5	277	937.8	277	984.2	269	903.5	257	876.7
	Release Number (Rel Num)				2343		2404		2392		2349		2416		2439
	Survival Index = (Exp Total)/(Rel Num)				0.3969		0.3663		0.3921		0.4190		0.3740		0.3595

Detection Rate Stratum Information				Easton											
	Bonneville		Bonn-Based McNary Detection Rates	Raceway 1 SNT		Raceway 2 OCT		Raceway 3 SNT		Raceway 4 OCT		Raceway 5 SNT		Raceway 6 OCT	
Detection Rate Stratum	Starting Date	Ending Date		Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	69.7	195.7	80.0	224.7	96.4	270.9	46.3	130.0	183.7	515.9	56.7	159.4
2	5/21/00	7/31/00	0.2734	134.3	491.3	144.0	526.7	149.6	547.1	186.7	683.0	69.3	253.6	151.3	553.3
	Total			204	687.0	224	751.4	246	818.0	233	813.0	253	769.5	208	712.6
	Release Number (Rel Num)				2426		2453		2429		2423		2398		2411
	Survival Index = (Exp Total)/(Rel Num)				0.2832		0.3063		0.3367		0.3355		0.3209		0.2956

Detection Rate Stratum Information				Jack Creek							
	Bonneville		Bonn-Based McNary Detection Rates	Raceway 1 SNT		Raceway 2 OCT		Raceway 3 SNT		Raceway 4 OCT	
Detection Rate Stratum	Starting Date	Ending Date		Unexp	Exp	Unexp	Exp	Unexp	Exp	Unexp	Exp
1	3/15/00	05/20/00	0.3560	63.3	177.9	33.9	95.3	20.7	58.2	32.9	92.5
2	5/21/00	7/31/00	0.2734	181.7	664.6	234.1	856.2	195.3	714.3	79.1	289.2
	Total			245	842.4	268	951.5	216	772.5	112	381.7
	Release Number (Rel Num)				2340		2453		2279		1109
	Survival Index = (Exp Total)/(Rel Num)				0.3600		0.3879		0.3390		0.3442

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[17] Because of the allocation of daily detections by estimated travel-time distribution, the within-strata unexpanded detections are usual not a whole number; however, their totals over strata will equal the total detections at McNary.

A.3. Early and Late Coho Releases' Release-Site-to-McNary Survival

McNary Detection Rate based on Downstream Dam Detections: In 1999 the same detection-rate strata that were used for OCT-SNT fish were used for coho. This was because there were many more OCT-SNT fish available for identifying the strata and because the within-strata detection-rate trend for coho over strata were the same as those for the OCT-SNT fish. The detection rates were not the same for the two species (in fact the coho detection rates were greater than that of the OCT-SNT fish over all strata in 1999), but the trends were the same--if the detection rate for the OCT-SNT fish went up (or down) from one stratum to another, so did the coho detection rate.

In outmigration year 2000, there were only two detection rate strata for the OCT-SNT fish (there were 7 in 1977). Only 4 out of 286 total PIT-tagged coho detections at Bonneville were detected in the first stratum (on or before May 19, 2000); therefore strata partitioning for coho did not make sense.

As was the case for OCT-SNT spring Chinook, the decision for coho was to base the McNary-detection rates on Bonneville detections rather John Day. However, the reason for doing so is different than was the case for OCT-SNT fish. For coho, non-stratified McNary detection rates were initially estimated using John Day and separately using McNary's two power houses. Weighted detection-rate means over passage days are given in Table A.3.a along with mean comparisons, the weights being the daily number of detections at the respective downstream dam site. The two Bonneville power-house-based detection-rate means did not differ substantially or significantly from each other (P = 0.72, Table A.3.a), and there were greater differences between the polled Bonneville-power-house-based estimates and the John-Day-based estimate (Type 1 P = 0.13).

One of the assumptions for the detection rates to be unbiased is that fish passing through the McNary's bypass system and those not passing through the bypass mix well with each other both temporally and spatially before being detected at the downstream dam from where the detection rates are estimated. The near equality of the two Bonneville-based detection rates could result from such mixing prior to reaching Bonneville since the two power houses from where the data was collected were on opposite sides of the river. The difference between the Bonneville and John Day estimates may result from the failure of fish to spatially mix well by the time they reached John Day. For this reason, the pooled detection rate estimate from the two Bonneville power houses was used. A weighted logistic regression of Bonneville-based detection rate on a simple indicator variable to estimate the logit-transform's mean and mean deviance was performed. The resulting among-day mean deviance of 0.8758 based on 38 degrees of freedom did not differ substantially or significantly from 1 (Type 1 P =0.69). This suggests that the among-day variation was what would be expected from a binomial distribution and that stratification was not necessary because of the homogeneity of the detection rates over outmigration days.

It should be noted that the number of detections at Powerhouse 2 after the dramatic Jun 19 reduction in flow went down to near zero. Only 0.59 % of the total 169 Powerhouse 2 coho detections were made after June 18; whereas 8.55% of the total 117 Powerhouse 1 coho detections were made after that date. Powerhouse 1 is still regarded as representative of both powerhouses after that date because the estimated detection rates up through June 18 were very similar for the two powerhouse (0.2056 for Powerhouse 1 and 0.2083 for Powerhouse 2).

Expanding the passage to obtain survival indices. With no stratification, it was not necessary to offset the Bonneville date by the mean McNary-to-Bonneville travel time to obtain the McNary day of passage associated with Bonneville-based detection-rate strata. Referring to A.3.b, the single Bonneville-based detection rate of 0.2063 was used to expand the total McNary detections of each of the eight coho releases (2 times of releases x 2 sites/river x 2 rivers); each of these expanded McNary detections were then divided their respective release sizes to obtain the estimated survival indices used in obtaining the estimates and logistic analysis of variation given in Table 3.a.

Table A.3.a. Bonneville-based and John-Day-based McNary detection rate estimates and estimate comparisons for year-2000 coho release outmigrants

Downstream-dam-based McNary detection rate estimates

	Bonnevile Power House			John
	1	2	Pooled	Day
Detection Rate	0.1966	0.2130	0.2063	0.1518
Standard Error (SE)	0.03453	0.02928	0.02119	0.02913
Degrees of Freedom (DF)	28	26	38	36

Table A.3.a. Bonneville-based and John-Day-based McNary detection rate estimates and estimate comparisons for year-2000 coho release outmigrants (continued)

Comparisons among downstream-dam--based McNary detection rate estimates

Bonneville Powerhouse 1 versus 2

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
-0.0164	0.045273	-0.36	53	0.7180

Bonneville Powerhouse 1 versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0448	0.045176	0.99	59	0.3252

Bonneville Powerhouse 2 versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0613	0.041302	1.48	60	0.1432

Bonneville Powerhouses Pooled versus JD

Difference	SE(Diff)[1]	t-ratio	DF[2]	Type 1 P
0.0545	0.036022	1.51	67	0.1348

[1] SE(Diff) = $[SE(1)^2 + SE(2)^2]^{1/2}$

[2] DF (approximate) = $[SE(Diff)]^4/\{\{SE(1)^4/DF(1) + SE(2)^4/DF(2)]$

Table A.3.b. Unexpanded and expanded McNary detections, release numbers, and survival indices of year 2000 coho releases used in Table 3.a .

			McNary Detections		Number	Survival
River	Site		Unexpanded	Expanded[1]	Released	Index[2]
Upper Yakima	Cle Elum	Early	70	339.3	2487	0.1364
		Late	10	48.5	2462	0.0197
	Easton	Early	142	688.4	2476	0.2780
		Late	93	450.8	2476	0.1821
Naches	Lost Creek	Early	139	673.8	2489	0.2707
		Late	76	368.4	2488	0.1481
	Stiles	Early	133	644.7	2488	0.2591
		Late	184	891.9	2493	0.3578

1 Expanded = Unexpanded/0.2063

2 Survival Index = Expanded/Number Released

A.4. Fall Chinook Releases' Release-Site-to-McNary Survival

McNary Detection Rate based on Downstream Dam Detections: Unlike the case for year-2000 spring Chinook and coho outmigrants, John Day, not Bonneville, was the downstream site used to estimate the McNary detection rate for fall Chinook. The reason for this is that, with the severely reduced flows through Bonneville Powerhouse 2 after June 18, the proportion of fall Chinook detected at Bonneville after that date[18] was far less than the proportion at John Day (proportions being 0.256 based on 258 total detections at John Day but being only 0.108 based on 130 total detections at Bonneville). Since at both downstream dams a majority of the late releases below Prosser Dam (conventional rearing) passed after June 18, the John Day detections were regarded as more representative of the late migrant passage.

A weighted logistic regression of John Day-based detection rate on an indicator variable to estimate the logit-transform's mean and mean deviance. The resulting among-day mean deviance of 1.275 based on 41 degrees of freedom did not differ substantially from 1; however, the computed Type 1 Error probability was high enough to consider stratification (Type Error 1 P =0.11). The main question would be whether the estimated detection rates differed over treatments since certain treatments' passage was later in the season. The mean treatment detection rates and a logistic analysis of variation over treatments are given in Table A.4.a. The logistic analysis of variation of non-stratified detection-rate estimates indicated no significant difference over treatments (Type 1 P = 0.41). The error mean deviance of 0.827 did not differ substantially or significantly from 1 (Type 1 Error P= 0.48 based on chi-square test of deviance). Based on these high p values, the decision was made to use the non-stratified pooled estimate of the detection rate over treatments (detection rate = 0.2907).

Table A.4.a. John Day-based McNary detection rate estimates for fall Chinook, analyzed over treatments

Pooled Detection Rates over Treatments

Release Site	Treatment	Pooled Detection Rate
Prosser Release	Accelerated Rearing	0.2522
	Conventional Rearing	0.3063
Marion Drain Release		0.3750
Pooled over Treatments		0.2907

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[18] The July 18th date at John Day is really comparable to the July 18th date at Bonneville because of travel time. However, any travel-time adjustment would have created an even earlier John Day date, and the resulting proportion after the time-adjusted July 18th John Day date would have further exceeded that on Bonneville.

Table A.4.a. John Day-based McNary detection rate estimates for fall Chinook, analyzed over treatments (continued)

Logistic Analyis of Variation

Source	Deviance	D.F.	Dev/D.F.	F	Type I P
Treatment	2.03	2	1.015	1.23	0.4078
Error	2.48	3	0.827		

APPENDIX E

Annual Report: Outmigration Year 2000
Part 2. Chandler Certification and Calibration (spring chinook and coho)

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ANNUAL REPORT: OUTMIGRATION YEAR 2000

Part 2. CHANDLER CERTIFICATION AND CALIBRATION (Spring Chinook and Coho)

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1. Introduction

In 1998, an index of daily juvenile outmigration past Prosser Diversion Dam (Prosser) on the lower Yakima River was developed. It involved the expansion of counts of fish subsampled at the Chandler Juvenile Monitoring Facility (Facility). The outmigrating passage index (op) for a given stock on day j was the estimated using Equation 1:

Equation 1.

$$op_j = \frac{c_j}{er_j * cs_j * sr_j}$$

wherein

c is the count of sampled juvenile fish for the stock of interest at the facility;

er is the stock's predicted juvenile entrainment rate into Chandler canal approaching Prosser (proportion of fish entering the canal);

cs is the stock's predicted juvenile canal-survival rate from the head gate to the main PIT-tag detector toward the beginning of the bypass; and

sr is the stock's predicted juvenile sample rate.

Figure 1 presents a schematic flow chart of the movement of outmigrants passing Prosser (OP in Figure 1) which are either entrained into Chandler Canal or not (ER and 1-ER respectively, ER being entrainment rate in Figure 1). Those that are entrained may survive the canal (CS being canal survival in Figure 1) to the canal bypass's main PIT-tag detector (PR(1) in Figure 1). They may then be sampled or not (SR and 1-SR respectively, SR being sample rate in Figure 1). The sampling mechanism is a timed gate that opens to a live box for a programmed proportion of time. All sampled fish are passed through a second PIT-tag detector (PR(2) in Figure 1) after being counted--enumerated according to stock [species, run (spring or fall) , and source (hatchery or wild)].

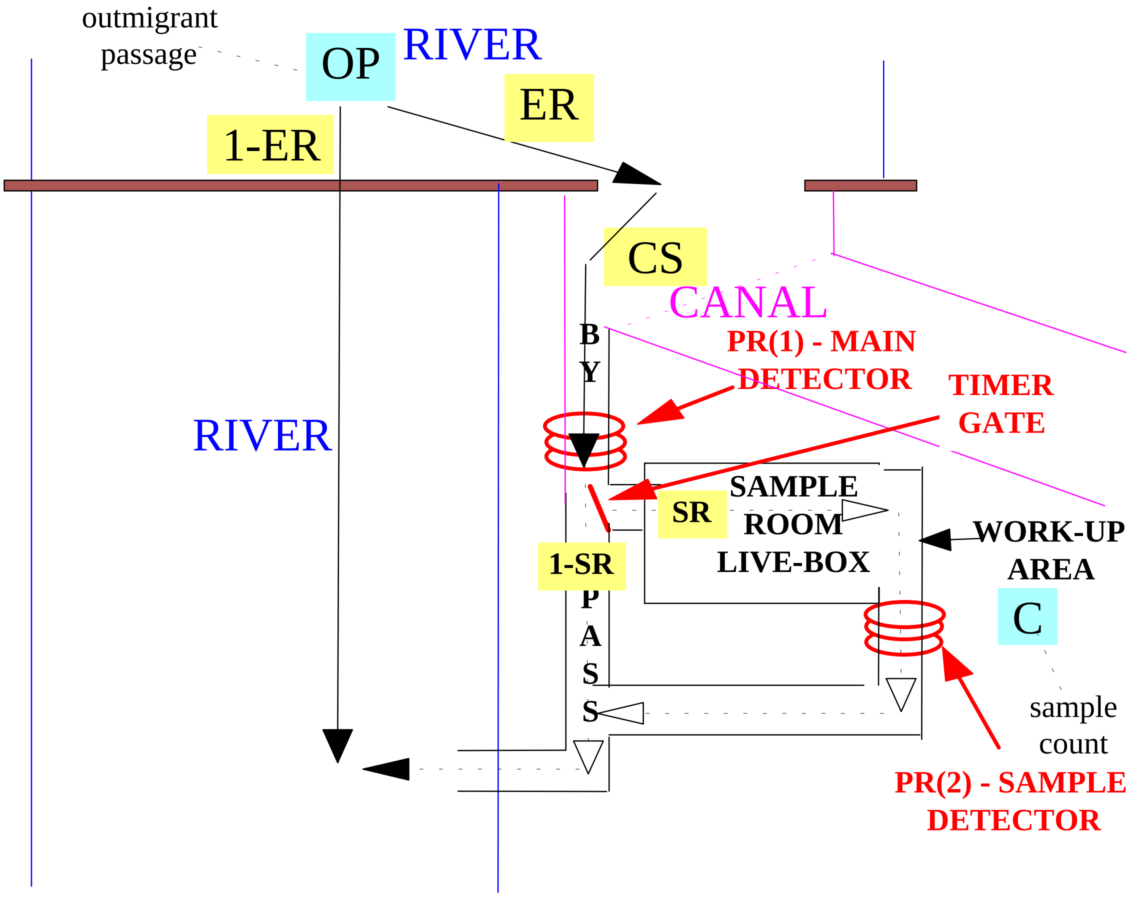

Figure 1. **Schematic diagram of movement of fish passing Prosser Diversion Dam and associated entrainment, canal-survival, and sample rates.**

2. Parameter Estimation

In 1998, entrainment-, canal-survival-, and sample-rate estimates predictors were developed using data from releases made by the National Marine Fisheries Service (NMFS) in 1991 and 1992 and by the Yakima Nation (YN) in 1997 and 1998[1]. These data-bases have subsequently been restructured by David Lind (YN) using PARADOX (Microsoft's Office 2000) queries of the PTAGIS files (Pacific States Marine Fisheries Commission, PSMFC, Gladstone, Oregon). These restructured 1991-1998 data bases along with David Lind's queries of PTAGIS files associated with additional releases made in 1999 and, to a lesser degree, 2000 by YN were used to produce estimates presented in this report, which focuses on spring Chinook and coho.

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[1] Neeley, Doug. 1998. Chandler Certification 1. Chandler Entrainment, Canal Survival, and Subsampling Rate Predictors for Estimating Relative Outmigration Indices over Years. Annual Report to the Yalima Nation.

Daily estimates are derived from PIT-tagged releases from days when sufficient numbers of fish were available for tagging, but fish are sampled for enumeration every day for an extended period, and expansion of these daily counts is required whether there were PIT-tagged releases or not. It was therefore necessary to develop predictors for the expansion parameters for every day of passage, and the prediction sections of this report discuss the development of these predictors and present summaries of the estimated predicted prediction parameters for canal survival, entrainment, and sample rate.

2.a. Canal Survival

2.a.1) Canal Survival Estimation: PIT-tagged releases designed to estimate expansion parameters (canal survival, entrainment, and sample rate) were made. Releases were made on days when a sufficient number of fish were available from the sample for PIT-tagging. Therefore, estimates are daily estimates for only a portion of the outmigration season, and they are not necessarily representative of the overall outmigration.

For a given date of PTT-tagging, the canal survival estimator, given in Equation 2, is the expanded proportion of fish released just below the headgates of Chandler Canal that are subsequently detected by the PR(1) PIT-tag detector; the unexpanded proportion being Equation 2's numerator (defined in Equation 2.a), and the expansion factor being PR(1)'s detection efficiency, Equation 2's denominator (defined in Equation 2.b).

Equation 2.

$$\mathrm{cs}\,[\mathrm{canal\,survival}] = \frac{\mathrm{p[PR(1)\,|\,canal]}}{\mathrm{e[PR(1)\,|\,canal]}}$$

wherein

Equation 2.a.

$$\mathrm{p[PR(1)\,|\,canal\;release]} = \frac{\mathrm{n[PR(1)\,|\,canal]}}{\mathrm{n[canal]}}$$

Equation 2.b.

$$\mathrm{e[PR(1)\,|\,canal\;release]} = \frac{\mathrm{n[PR(1),PR(2)\,|\,canal]}}{\mathrm{n[PR(2)\,|\,canal]}}$$

Within Equation 2.a, n[canal] is the number of fish released into the canal, and n[PR(1) | canal] is the number of those canal-released fish that are detected by the PR(1) detector; within Equation 1.b., n[PR(2) | canal] is the number of canal-released fish that is detected by sample detector PR(2), and n[PR(1),PR(2) | canal] is the number of canal released fish that is detected by both the PR(1) and PR(2) detectors. Since all fish detected by PR(2) should have been previously detected by PR(1), the estimate in Equation 2.a. is an estimate of PR(1) efficiency.

Several canal releases were made in 1999 and 2000. Canal release estimates were omitted for predictive purposes whenever there was a high pre-release mortality or whenever the efficiency estimate based on the PR(2) detector was significantly different from a second efficiency estimate based on McNary Dam (McN) detections on the lower Columbia River. The number of canal released fish detected at both PR(1) and McN divided by the total number detected at McN served as the second estimate of efficiency. If this McN-based estimate was substantially and significantly less than that based on PR(2), then it was possible that either the release was made into the river instead of the canal or that some canal-released fish entered the river without going through the bypass system. In either case, the estimate from Equation 2 would not be an unbiased estimate of canal survival..

Canal survival estimates are plotted against the Julian date of release in Figure 2.a for spring Chinook and Figure 2.b. for Coho. As can be seen in Figure 2.a, in year 2000 there were more releases of spring Chinook having canal-survival estimates substantially less than 90% than was the case in previous years. As might be inferred from the previous paragraph, there may have been quality-control problems associated the omitted releases in 2000. To what extent the un-omitted 2000 releases with low canal survival estimates in Figure 2.a reflected true poor canal-survival conditions or were associated with undetected quality control problems is unknown.

Table 1. presents the yearly mean canal-survival estimates and comparisons for spring Chinook. Logistic analysis of variation was used to produce the summary[2]. The computer

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[2] Logistic analysis is effectively a weighted regression of the logit transform of a proportion on predictor variables, the logit transform being ln[p/(1-p)], p being an estimated proportion (e.g., canal survival). The untransformed model being of the form:

$$p = \frac{\exp[b(0)*x(0)+b(1)*x(1)+b(2)*x(2)+...]}{1+\exp[b(0)*x(0)+b(1)*x(1)+b(2)*x(2)+...]} = \frac{1}{1+\exp[-b(0)*x(0)-b(1)*x(1)-b(2)*x(2)-...]}$$

and the logit transform being

$$\ln\left[\frac{p}{1-p}\right] = b(0)*x(0) + b(1)*x(1) + b(2)*x(2)+...$$

The weights are the effective number of released fish on which the proportion is based. In the above equations p is a proportion, “exp[…]” represents the exponential constant raised to the power given within the brackets and “ln” represents the natural log, b(j) is a logistic coefficient linearly relating the logit transform of p to the associated predictor variable, x(j). The first coefficient in the equation, b(0), is associated with the intercept value of the logit transform when x(0) = 1; the untransformed intercept being p(0) = 1/{1 + exp[-b(0)]}. If means are being compared, then the x's are indicator variables. A special case is when a common mean is estimated, in which case the intercept value estimates the pooled mean of all of the p’s which occurs only when b(1) = b(2) = … = 0 and x(1) = 1; i.e.:

$$p(0) = 1/\{1 + \exp[-b(0)]\} = \text{pooled mean of the } p\text{'s}$$

The logistic fitting procedure used assumes that the underlying distribution of the estimated proportions around the expected predictor is binomial. Logistic computer output of variances/covariances and the standard errors of coefficients also assumes that the underlying distribution is binomial. If the binomial distribution is the true distribution, the logistic mean deviance, which analogous to mean square from linear least squares regression, is expected to equal 1. In analyses performed for this report, the mean deviances were significantly greater than 1; therefore computer-output of variances/covariances of the logistic coefficient were multiplied by mean deviance to correct for the failure of the binomial to hold (correction for overdispersion) , and the associated standard errors were adjusted accordingly. Variances-covariances and standard errors presented in this report have already been adjusted unless otherwise indicated.

package used was STATISTIX[3]. As can be seen in the table, except for 1997, all years' canal survival estimates differed significantly from that in 1991. There were no significant differences among the 1992 through 2000 canal survival estimates. The low canal-survival-rate estimates for some of the 2000 releases did not reduce the 2000 mean canal survival enough to result it in differing significantly from the mean canal survivals of most other years. However, when the years' canal survivals were analyzed separately, the mean deviance for 2000 was greater than for other years, indicating the greater variability among the estimates in year 2000. The mean deviances for spring Chinook were 2.03, 2.07, 1.61, 2.66, 2.78, and **4.39** respectively for 1991, 1992, 1997, 1998, 1999, and **2000** with respective degrees of freedom 13, 9, 4, 12, 11, and **37**.

2.a.2) Canal Survival Prediction:

It can be seen by comparing Figure 2.b to 2.a that coho tend to pass later than spring Chinook, and that, later on in the outmigration, the coho's canal survival rate drops. This would probably be true of spring Chinook as well, but there were insufficient numbers of spring Chinook available for PIT-tagging at this time of poor canal survival To predict canal survival during the period of low canal survival, the spring Chinook and Coho canal survival estimates were analyzed together. A logistic spline fit was performed wherein, prior to a critical date, survival rates were pooled for a "good" canal-survival-period estimate, and after that critical date, a logistic slope estimating a decline in canal survival with increasing Julian Date[4] (JD) was used as a predictor for the "poor" canal-survival period. The critical Julian date was established by finding the Julian date that minimized the mean deviance fitting of the model:

Before Critical Julian Date (JD'): $CS = 1/\{1 + \exp[-b(0)]\}$

After Critical Julian Date (JD'): $CS = 1/\{1 + \exp[-b(0) - b(1)*(JD-JD')]\}$

wherein b(0) is the logistic intercept and b(1) is the slope of the logit transform of canal survival on Julian date (for JD <= JD' the value $CS = 1/\{1 + \exp[-b(0)]\}$ is the same as the pooled canal survival estimate from all releases up to JD = JD').

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[3] Analytical Software, Tallahassee Florida

[4] Other variables such as canal flow and canal temperature were used as potential predictor variables, but Julian Date proved to be a better predictor (resulted in a smaller mean deviance).

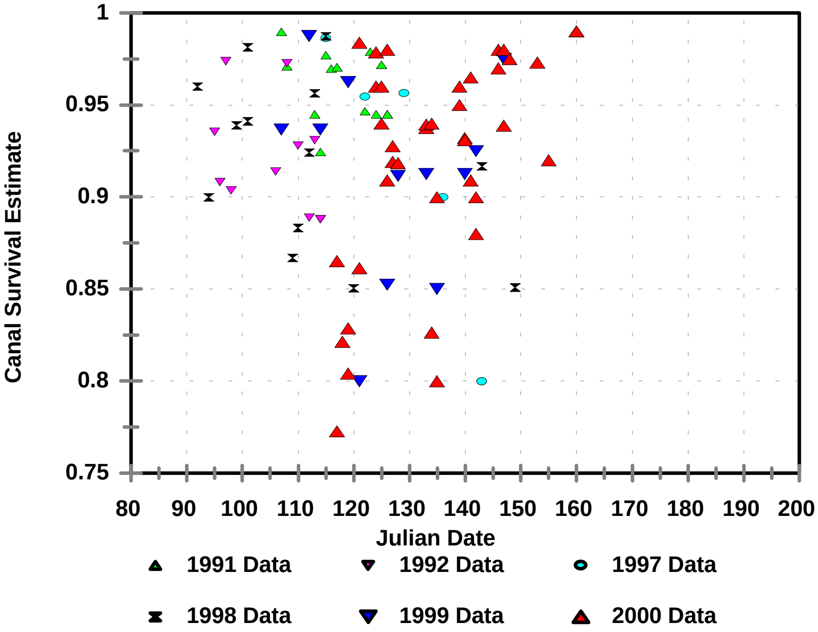

Figure 2.a. Chandler Canal-Survival Estimates from Individual 1991, 1992, 1997-2000 PIT-tagged Spring Chinook Releases

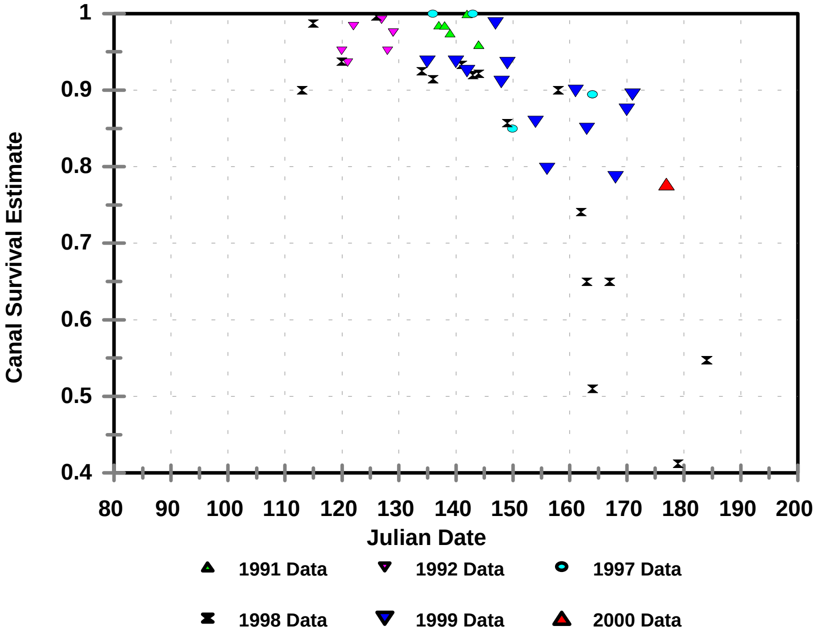

Figure 2.b. Chandler Canal-Survival Estimates from Individual 1991, 1992, 1997-2000 PIT-tagged Coho Releases

Table 1. Pooled Yearly Estimates of Spring Chinook Canal Survival and Comparisons among Estimates over Years

Summary from Logistic Analysis of Canal Survival

Year	Mean Canal Survival*	Mean of Logit	Standard Error (SE) of mean logit based on Binomial	adjusted**
1991	0.963	3.256	0.0983	0.1762
1992	0.925	2.506	0.1028	0.1841
1997	0.953	3.002	0.3824	0.6852
1998	0.918	2.419	0.1040	0.1863
1999	0.917	2.404	0.1190	0.2132
2000	0.917	2.396	0.0612	0.1097

Deviance (Dev)	276.16
Degrees of Freedom (DF)	86
Mean Deviance Dev/DF	3.211

* Mean canal Survival = 1/{1+ exp[-(mean logit)]}

** SE(adjusted) = SE(binomial)*(Mean Deviance)$^{1/2}$

"t-test" P based on
"t" = [mean logit(i) - mean logit(j)]/[SE^2(i) + SE^2(j)]

Year versus Year	1991	1992	1997	1998	1999
1992	0.0041				
1997	0.7203	0.4857			
1998	0.0016	0.7416	0.4136		
1999	0.0028	0.7201	0.4070	0.9589	
2000	0.0001	0.6102	0.3846	0.9154	0.9721

The critical date, JD', was established by estimating the separate b(0) values for each species within each year but a common logistic b(1) slope over all species and years. The date that minimized the logistic mean deviance was the estimated critical date. . This was a somewhat different method than was used in the 1998 analysis in which three parameter types were estimated instead of the two [b(0) and b(1)]; the three being an estimate for the mean before JD' and independent estimates for the intercept and the slope after JD'. The estimated critical Julian date was JD' = 148 based on the current analysis[5]. (The estimate from the analysis conducted in 1998 was between Julian dates 140 and 141). Using the current method, once the critical date was established, separate yearly slopes were estimated where possible.

The same within-year slope was used for spring Chinook and coho because of the limited number of spring Chinook during the poor survival period. In year 2000, the estimated slope was positive but not significantly so; therefore the slope was taken to be 0, and all spring

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[5] Julian Date 148 corresponds to May 28 in non-leap years

Chinook estimates, irrespective of Julian date went into the computation of spring Chinook canal survival for the good survival period.

For years in which no releases were made after the critical date, a pooled estimate of b(1) was used based on years when releases were available. The responses are plotted in Figure 3.a for spring Chinook and Figure 3.b for coho. The parameter estimates are presented in Table 2. Since almost all spring Chinook releases were made before JD' = 148, the mean canal estimates for spring Chinook in Table 1 equal or nearly equal Table 2's pre-critical date estimates.

It can be seen in Table 2 that the estimated pre-JD' canal survival of coho exceeded that of spring Chinook in every year for which estimates were available, significantly[6] so in 1992 (P = 0.05). There was no estimate of Pre-JD' coho canal survival in year 2000 because the only retained estimate was on Julian Date 176 in that year, substantially later than JD' = 148. When this point was included with the spring Chinook's post JD' = 148 releases, a positive slope resulted, even though the single coho estimate canal-survival estimate (cs = 0.778) was substantially less than the spring Chinook's mean (0.917); as mentioned earlier, the year-2000 slope was taken to be 0. Coho canal survival should be regarded as being unestimated for 2000, and perhaps a pooled coho b(0) over all other years should be considered for the year 2000 coho b(0) and the pooled b(1) = -0.0703 estimate should be used for the year 2000 coho b(1) [the single coho estimate was used along with all other retained JD > 148 estimates in the pooled b(1) prediction].

Comparing coho canal survival estimates over years, the higher survivals of 1991, 1992, and 1997 did not differ significantly[7] from each other, nor did the lower canal survivals of 1998 and 1999 differ significantly from each other (P>0.25). There were some significant differences between the 1991-1997 and the 1998-1999 sets of estimates; specifically, 1991 versus 1998 (P<0.01), 1991 versus 1999 (P<0.01), 1992 versus 1998 (P=0.05), 1992 versus 1999 (P<0.08).

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[6] Based on

$$\text{"t-test"} = [b(0,\text{coho})-b(0,\text{spr.Chin.})]/\{\text{Var}[[b(0,\text{coho})]+\text{Var}[b(0,\text{spr.Chin.})]-2*\text{Cov}[b(0,\text{coho}),b(0,\text{spr.Chin.})]\}^{1/2}$$

[7] Based on

$$\text{"t-test"} = [b(0,\text{year } i)-b(0,\text{year } j)]/\{\text{Var}[[b(0,\text{year } i)]+\text{Var}[b(0,\text{year } j)]\}^{1/2}$$

2.a.3) Canal survival estimation/prediction assumptions and biases:

a) The canal survival of PIT-tagged fish which were previously sampled equals that of the non-PIT-tagged fish. The PIT-tagged fish had been subjected to multiple stresses: Confined to livebox, crowded, anesthetized, handled and PIT-tagged, and held in small containers prior to release. There would be no way to assure that this assumption holds even with the elimination of releases that experienced high pre-release mortality.

b) There are no alternative routes from the point of canal release to the river other than through the bypass system. The elimination of releases when the two sets of efficiency estimates, one from PR(1) and the other from McN, should have protected against the failure of this assumption.

c) The logistic model used and the associated adjustment for over-dispersion are appropriate. If the overdispersion is not constant over the domain of the predictor variable, biases could result.

d) Using a common fit during the "poor" canal-survival period years when PIT-tagged fish were available and applying that fit to years when PIT-tagged fish were not available results in no bias. This assumption is not likely to be true

e) The fits can be extrapolated over periods when no PIT-tag estimates were available.

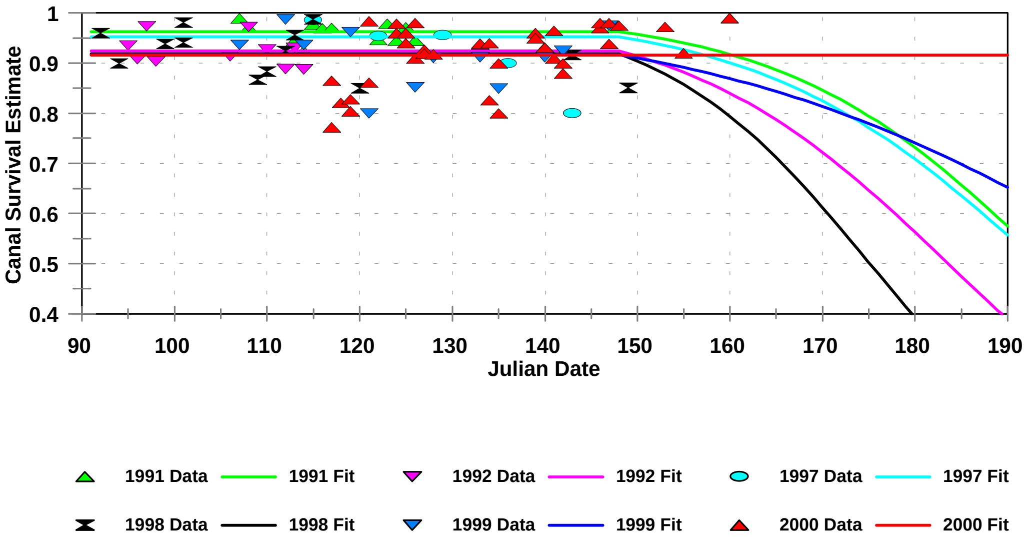

Figure 3.a. Spring Chinook canal survival response over Julian dates for PIT-tagged yearling smolt released in 1991, 1992, 1997-2000.

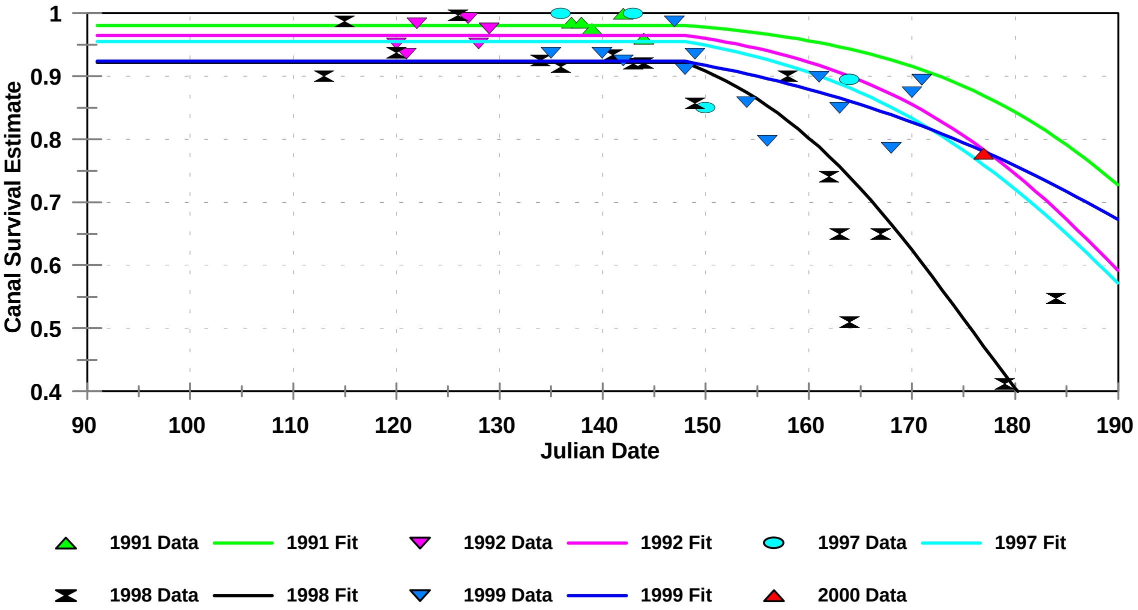

Figure 3.b. Coho canal survival response over Julian dates for PIT-tagged yearling smolt released in 1991, 1992, 1997-2000.

Table 2. Logistic canal-survival predictor coefficients relating canal survival (CS) to Julian date (JD) and associated statistics

$$CS = 1/\{[1 + \exp(-b(0)]\} \text{ for } JD < 148$$

$$CS = 1/\{1 + \exp(-b(0) - b(1)*(JD-148)]\} \text{ for } JD => 148$$

	Coefficient Estimate [b]	Standard Error SE[b]	**Pre-Julian Date 147 Canal Survival**	Variance-Covariance Matrix			
					Coho Intercept	Spr.Chin. Intercept	Slope
1991							
Coho Intercept	3.9383	0.43395	**0.9809**	Coho	0.18832		
Spring Chinook Intercept	3.2565	0.18422	**0.9629**	Spr.Chin.	0.00000	0.03394	
Common Slope*	-0.0703	0.01017		Slope	0.00000	0.00000	1.0353E-04
Degrees of Freedom	108						
1992							
Coho Intercept	3.3263	0.37378	**0.9653**	Coho	0.13971		
Spring Chinook Intercept	2.5055	0.19287	**0.9245**	Spr.Chin.	0.00000	0.03720	
Common Slope*	-0.0703	0.01017		Slope	0.00000	0.00000	1.0353E-04
Degrees of Freedom	108						
1997							
Coho Intercept	3.0642	1.14771	**0.9554**	Coho	1.31724		
Spring Chinook Intercept	3.0026	0.68730	**0.9527**	Spr.Chin.	0.00000	0.47239	
1997 Slope	-0.0660	0.10886		Slope	-0.08665	0.00000	1.1851E-02
Degrees of Freedom	106						
1998							
Coho Intercept	2.4738	0.20628	**0.9223**	Coho	0.04255		
Spring Chinook Intercept	2.4226	0.18484	**0.9185**	Spr.Chin.	0.00008	0.03417	
1998 Slope	-0.0892	0.01202		Slope	-0.00189	-0.00001	1.4436E-04
Degrees of Freedom	106						
1999							
Coho Intercept	2.4959	0.27976	**0.9239**	Coho	0.07826		
Spring Chinook Intercept	2.4043	0.18484	**0.9172**	Spr.Chin.	0.00000	0.03417	
1999 Slope	-0.0422	0.02086		Slope	-0.00432	0.00000	4.3497E-04
Degrees of Freedom	106						
2000							
Coho Intercept**				Coho			
Spring Chinook Intercept	2.3959	0.12824	**0.9165**	Spr.Chin.		0.01645	
2000 Slope***	0			Slope			
Degrees of Freedom	37						

* Common Slope was estimated from years 1997-2000 for which there were releases after Julian Date 147

** Only one coho release. Made after Julian Date 147. Single canal survival estimate = 0.778

*** Slope positive but not significantly greater than 0, Spring Chinook intercept based on all values with slope = 0

2.b. Entrainment Rate

2.b.1) Entrainment Rate Estimation: Two point releases were made for the purpose of estimating entrainment, and occasionally a third release point was included to test the an assumption required for the two-point release estimate of entrainment. Figure 4 schematically presents the release points and the associated downstream parameters associated with releases at the time of detection. The first point (f - forebay release) was about one-half mile upstream of Prosser Dam at a boat ramp on the right-hand side of the river. The second point (c - canal release) was the same release used to estimate canal survival. The third point (o - outfall release) was into the river downstream of the dam near the outfall of the facility bypass into the river. In terms of those listed parameters, the expected proportions, E[p(…)], of the forebay and canal releases detected at PR(1) are respectively given in Equation 3.a. and Equation 3.b. The Equations 3.a/3.b ratio is given in Equation 3.c.

Equation 3.a.

$$E\{p[PR(1)|f]\} = FS{*}ER{*}CS$$

wherein, FS is forebay survival, ER is the entrainment rate, and CS is canal survival.

Equation 3.b.

$$E\{p[PR(1)|c]\} = CS$$

Equation 3.c.

$$\frac{E\{p[PR(1)|f]\}}{E\{p[PR(1)|c]\}} = FS{*}ER$$

$$= ES \text{ if forebay survival is } 100\%$$

As was done for estimating canal survival, the detected proportions at Prosser were expanded by dividing by the estimated efficiency; therefore, Equations 3.a., 3.b., and 3.c. are modified to accommodate this adjustment, the adjusted two-point release estimates being respectively presented in Equations 4.a, 4.b, and 4.c.

Equation 4.a.

$$\text{adjusted}\, p[PR(1)|f] = \frac{\dfrac{n[PR(1)|f]}{n[f]}}{\dfrac{n[PR(1),PR(2)|f]}{n[PR(2)|f]}}$$

Equation 4.b.

$$\text{adjusted}\, p[PR(1)|c] = \frac{\dfrac{n[PR(1)|c]}{n[c]}}{\dfrac{n[PR(1),PR(2)|c]}{n[PR(2)|c]}}$$

Equation 4.c.

$$er = \frac{\text{adjusted}\, p[PR(1)|f]}{\text{adjusted}\, p[PR(1)|c]}$$

or

$$er = 1.0 \quad \text{whichever is smaller if in both cases, forebay survival} = 100\%$$

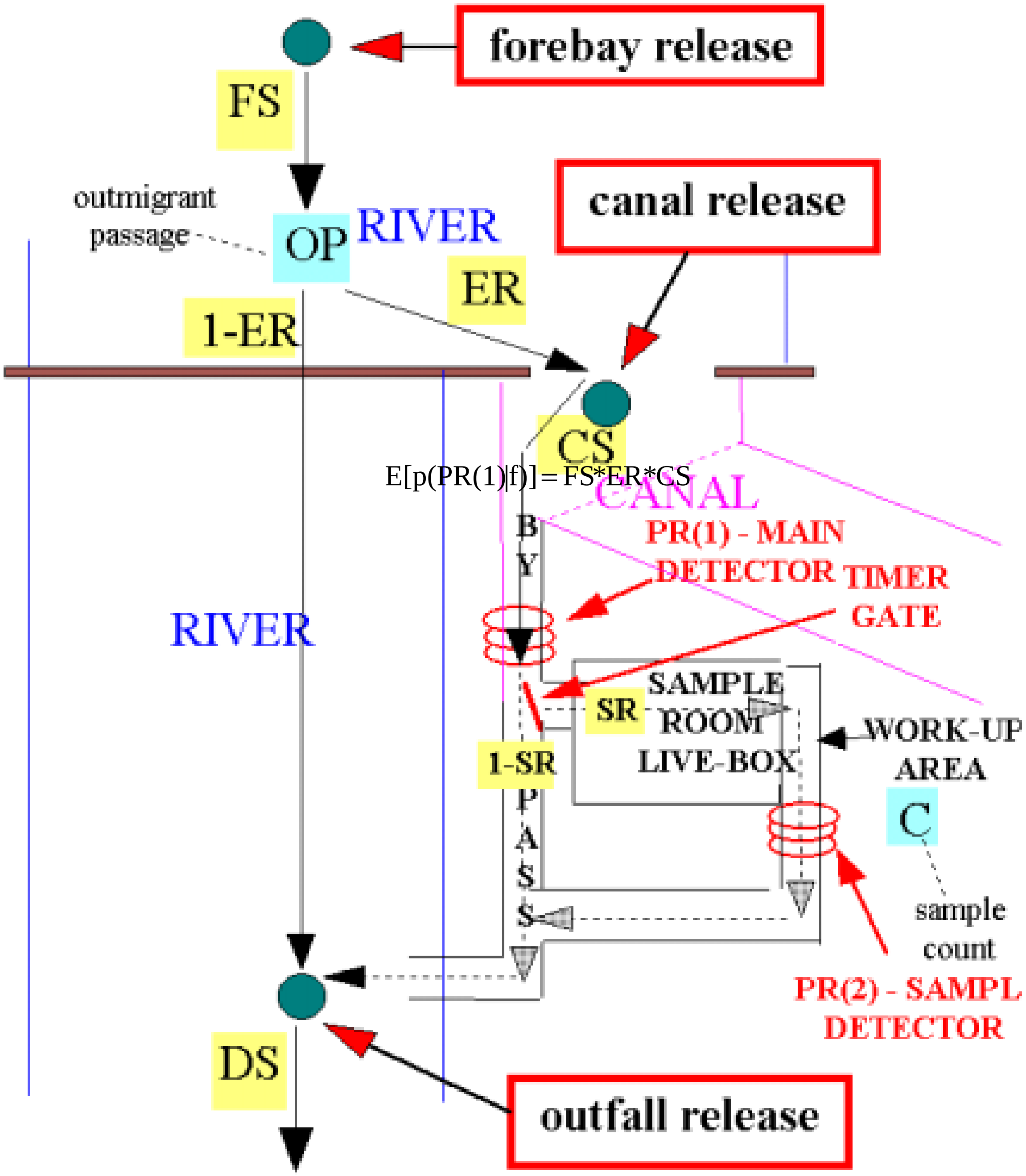

Figure 4. Schematic diagram of three points of release (forebay, canal, outfall) and associated relative survival and entrainment parameters.

Equation 4.b is the estimate of canal survival. I should note that the efficiency adjustments in Equations 4.a and 4.b are different than in the 1998 report. In the 1998 report for two-point releases, the efficiency rates of the forebay and canal releases used in Equations 4.a and 4.b were pooled into a single efficiency estimate for the release pair. This affected the canal survival estimate, but the entrainment estimate was not adjusted at all since the same efficiency estimate would have been used in computing both the numerator and denominator of equation 4.c, and would, therefore, have canceled each other.

Equation 4.c. as an estimate of entrainment depends on several assumptions, discussed later, one of which is that forebay-survival rate is 100% (FS = 1). To test the assumption of 100% forebay survival, a third release point is included (the one at the outfall) and is used with the other releases to estimate forebay survival. The proportion of the forebay release not detected at PR(1) but detected at McNary (McN) is taken to have the expected proportion given in Equation 5.a, and the proportion of the outfall release detected at McN is taken to have the expected proportion given in Equation 5.b. In Equations 5.a and 5.b, DS is a composite parameter--the product of the outfall-to-McN survival rate and McN detection efficiency, the efficiency being the proportion of those PIT-tagged fish passing through the McN bypass system that are actually detected. The Equations 5.a/5.b ratio is given in Equation 5.c.

Equation 5.a.

$$\mathrm{E\{p[McN, not\ PR(1)\,|\,f]\} = FS{*}(1\text{-}ER){*}DS}$$

Equation 5.b.

$$\mathrm{E\{p[McM\,|\,o]\} = DS}$$

Equation 5.c.

$$\frac{\mathrm{E\{p[McN,not\ PR(1)\,|\,f]\}}}{\mathrm{E\{p[McN\,|\,o]\}}} = \mathrm{FS{*}(1\text{-}ER)}$$

The sum of equations 3.c. and 5.c. equals the forebay survival (Equation 6.a), and the Equation 3.c/Equation 6.a ratio is an estimate of entrainment that does not depend on the assumption of 100% forebay survival (Equation 6.b)[8].

Equation 6.a.

$$\frac{\mathrm{E\{p[PR(1)\,|\,f]\}}}{\mathrm{E\{p[PR(1)\,|\,c]\}}} + \frac{\mathrm{E\{p[McN,not\ PR(1)\,|\,f]\}}}{\mathrm{E\{p[McN\,|\,o]\}}} = \mathrm{FS}$$

Equation 6.b.

$$\frac{\dfrac{\mathrm{E\{p[PR(1)\,|\,f]\}}}{\mathrm{E\{p[PR(1)\,|\,c]\}}}}{\dfrac{\mathrm{E\{p[PR(1)\,|\,f]\}}}{\mathrm{E\{p[PR(1)\,|\,c]\}}} + \dfrac{\mathrm{E\{p[McN, not\ PR(1)\,|\,f]\}}}{\mathrm{E\{p[McN\,|\,o]\}}}} = \mathrm{ER}$$

The three-point releases gave no statistical evidence of the forebay survival differing substantially or significantly from 1. However, in most years, the proportion of detections at

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[8] The reasons for not using this three-point-release entrainment form as an estimator are that the estimate depends on all three releases having the same passing-time distribution at McNary and that the inclusion of the more limited number of McNary detections in the form of the equation used (Equation 6.b) is less precise than the two-point-release estimator (Equation 4.c).

McN dramatically decreased toward the end of the season, indicating that in-stream conditions were deteriorating. Under those conditions, the estimates for entrainment were dropped because under deteriorating in-river conditions, the forebay survival may also be declining If canal releases were omitted for the purpose of estimating canal survival, the associated entrainment estimates were also omitted since the canal-survival estimate was used in the entrainment estimate (canal-survival estimate is the denominator in equation 4.c, the two-point-release entrainment estimator). Any releases based on fish not sampled at Prosser for PIT-tagging were also dropped for both canal-survival and entrainment estimation purposes. In only one case was an entrainment estimate dropped based on its own value. For a two-point release made on May 26, 2000, the estimated entrainment rate was 0.99 (an estimated 99% of the fish passing Prosser was entrained into the canal) when only 22% of the river flow was being diverted into the canal (canal diversion rate = 0.22). In none of the other two-point releases from any of the other release sets from any of the years did the entrainment rate exceed 0.5 when the canal flow diversion was this low. Therefore, the May 26th release of that year was dropped for the purpose of estimating entrainment. [The canal release was retained for the purpose of estimating canal survival because the canal-release estimates of efficiency based on both PR(2) and McN detections were equal to 1. It should be noted that the forebay-release efficiency estimates from both PR(1) and McN detections were also both equal to 1. While this would be expected if the entrainment were truly equal to 1 since all surviving forebay-released fish should pass through PR(1); it would also occur if the canal release and, erroneously, the intended forebay release were both released into the canal.]

2.b.1) Entrainment Rate Prediction: Logistic predictors were developed for entrainment, the response variable being the logit transform of entrainment estimates and the predictor variable being canal diversion. Weighted logistical curvilinear fits were made using the following untransformed predictive models given in equations 7.a. through 7.e.

Equation 7.a.

$$\mathrm{er} = \frac{1}{1 + \exp[\text{-b}(0)]}$$

Equation 7.b.

$$\mathrm{er} = \frac{1}{1 + \exp[\text{-b}(0) - \mathrm{b}(1)^{*}\mathrm{cd}]}$$

Equation 7.c.

$$\mathrm{er} = \frac{1}{1 + \exp[\text{-b}(0) - \mathrm{b}(1)^{*}\mathrm{cd} - \mathrm{b}(2)^{*}\mathrm{cd}^{2}]}$$

Equation 7.d.

$$\mathrm{er} = \frac{1}{1 + \exp[\text{-b}(0) - \mathrm{b}(1)^{*}\mathrm{cd} - \mathrm{b}(3)^{*}\mathrm{cd}^{3}]}$$

Equation 7.e.

$$\mathrm{er} = \frac{1}{1 + \exp[\text{-b}(0) - \mathrm{b}(1)^{*}\mathrm{cd} - \mathrm{b}(2)^{*}\mathrm{cd}^{2} - \mathrm{b}(3)^{*}\mathrm{cd}^{3}]}$$

Wherein er, the response variable, is the estimated entrainment rate from equation 4.c and cd, the predictor variable, is the canal diversion rate, the proportion of Yakama flow that is diverted into

Chandler Canal. The weight used was the harmonic mean[9] of the number released into the forebay and the number released into the canal.

Canal diversion rate is based on flows measured in cubic-feet/second (cfs) at two flow-monitoring stations: One monitoring river flow (gauged river flow) at the I-82 bridge downstream of Prosser and downstream of the Chandler bypass outfall into the river, and the other monitoring canal flow (gauged canal flow) at a location in the canal downstream of the bypass system. The gauged canal flow is less than the canal flow between the headgates and the bypass by the amount of canal flow that is bypassed to the river (bypassed flow,); similarly, the gauged river flow is more than the river flow in Prosser's tailrace by bypass flow. Canal flow through the headgates, river flow through the tailrace, total flow approaching the dam, and canal diversion raet adjusted for bypass flow are estimated as follows:

canal flow = gauged canal flow + bypass flow

tailrace river flow = gauged river flow – bypass flow

total flow = canal flow + river flow
= gauged canal flow + gauged river flow

cd (canal diversion) = (canal flow)/(total flow)

The bypassed flow after 1987 depends on gauged rive flow:

bypass flow = 32 cfs when gauged river flow < 2132 cfs

= 132 cfs gauged river flow ≥ 2132 cfs

The difference between the two bypass-flow values (32 and 132 cfs) is based on a pump-back scenario. From 1987 on, the amount of bypassed water entering the facility is designed to be 132 cfs. However, if the gauged river flow is 2132 cfs or less, 100 cfs of 132 cfs is pumped back into the canal.

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[9] The harmonic mean was used because, ignoring the detection efficiency of the PR(1) detector, the expected variance of the estimated entrainment can be approximated by

$$\sigma^2(\mathrm{er}) = \sigma^2\left(\frac{\mathrm{p[PR(1)\,|\,f]}}{\mathrm{p[PR(1)\,|\,c]}}\right) = \mathrm{ER}^2\left(\frac{\mathrm{1\text{-}P[PR(1)\,|\,f)]}}{\mathrm{P[PR(1)\,|\,f]^{*}n(f)}} + \frac{\mathrm{1\text{-}P[PR(1)\,|\,c]}}{\mathrm{P[PR(1)\,|\,c]^{*}n(c)}}\right)$$

under the binomial distribution of p[PR(1) | f] and p[PR(1) | c], lower case p being the estimate and upper case P being the parameter value. In the case where E = 1, implying P[PR(1) | f] = P[PR(1) | c] = P, variance reduces to

$$\sigma^2(\mathrm{er}) = \mathrm{ER}^2\left[\frac{\mathrm{1\text{-}P}}{\mathrm{P}} {*} \left(\frac{1}{\mathrm{n(f)}} + \frac{1}{\mathrm{n(c)}}\right)\right] = \mathrm{E}^2\left[\frac{\mathrm{1\text{-}P}}{\mathrm{P}} {*} \frac{2}{\mathrm{harmonic\ mean}\left[\mathrm{n(f),\,n(c)}\right]}\right]$$

The harmonic mean will generally produce a more conservative estimate of the standard error of entrainment because the effective sample size is more influenced by the smaller of the two releases size.

The analysis performed in 1998 suggested that the best model was that given in Equation 7.d., repeated as equation 8. The analysis was rerun using the restructured data bases, and the same model form was selected for both spring Chinook and Coho. The analysis of variance for the respective species is given in Tables 3.a and 3.b, respectively. For both species, CD contributed significantly in reducing the mean deviance, and CD^3 adjusted for CD also contributed significantly to reducing the mean deviance. Although CD^2 adjusted CD for also contributed significantly to the reduction in the residual mean deviance, its level of significance was less that that of CD^3 adjusted for CD, and the contribution of CD^2 adjusted for both CD and CD^3 was not significant.

Equation 8.

$$er = \frac{1}{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]}$$

The plots of the responses from the pooled 1991-1998 restructured data set and from the analysis performed in 1998 reveals little difference for spring Chinook (Figure 5.a) and no perceptible difference for Coho (Figure 5.b).

An analysis was then performed to assess whether the variation in entrainment responses differed over years, not only among years 1991, 1992, 1997, and 1998 (referred to now as 1991-1998) but also among the 1991-98, 1999, and 2000 fit of the model specified in Equation 8. There were no retained coho entrainment estimates in 2000. Recall that there was a single retained year-2000 canal survival estimate; however, the associated date of release was late in the season and the McNary detection numbers from that date's releases were so low, that the assumption of near 100% forebay survival could not be assured; therefore, the single 2000 coho estimate of entrainment was dropped). The among-year analysis of variation of Equation 8 entrainment fits for spring Chinook is given in Table 4.a and that for coho is given in Table 4.b

The differences among the 19991-1998 fits did not differ significantly for either spring Chinook ($P = 0.45$) or for coho ($P = 0.85$). Therefore, the fits were pooled over those years within species, and the 1999 fits were compared to the pooled 1991-1998 fits. Again there was no significant difference ($P = 0.91$ for spring Chinook and $P = 0.31$ for coho). The 1999 fit was pooled with that for 1991-1998, and the 2000 fir was compared with the 1991-1999 pooled fit (available only for spring Chinook). Here there was a significant and substantial difference. In fact the difference was so dramatic, had the 2000 data been pooled with the 1991-1999 data, and the model refit, then all of the coefficients [b(0), b(1), b(2), and b(3)] would have been included in the model [recall that only b(0), b(1), and b(3) were included in the model].

Table 3.a. Analysis of variation to select entrainment model for pooled 1991, 1992, 1997, and 1998 spring Chinook.

1991, 1992, 1997, 1998 Pooled Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance	F-Ratio to Error (Full Model)	Type 1 P
Selected: Canal Diversion (CD)	1488.32	1	1488.32	159.27	0.0000
CD^2 adjusted for CD	31.87	1	31.87	3.41	0.0730
Selected: CD^3 adjusted for CD	41.74	1	41.74	4.47	0.0416
CD^2 adjusted for CD and CD^3	14.09	1	14.09	1.51	0.2274
CD^3 adjusted for CD,CD^2	23.96	1	23.96	2.56	0.1181
Error (Full model CD,CD^2,CD^3)	336.41	36	9.34		
Selected Model Error: (CD,CD^3)	350.50	37	9.47		

Table 3.b. Analysis of variation to select entrainment model for pooled 1991, 1992, 1997, and 1998 Coho.

1991, 1992, 1997, 1998 Pooled Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance	F-Ratio to Error (Full Model)	Type 1 P
Selected: Canal Diversion (CD)	1211.40	1	1211.40	257.67	0.0000
CD^2 adjusted for CD	15.60	1	15.60	3.32	0.0828
Selected: CD^3 adjusted for CD	17.44	1	17.44	3.71	0.0677
CD^2 adjusted for CD and CD^3	3.64	1	3.64	0.77	0.3889
CD^3 adjusted for CD,CD^2	1.80	1	1.80	0.38	0.5427
Error (Full model CD,CD^2,CD^3)	98.73	21	4.70		
Selected Model Error: (CD,CD^3)	100.53	22	4.56954545		

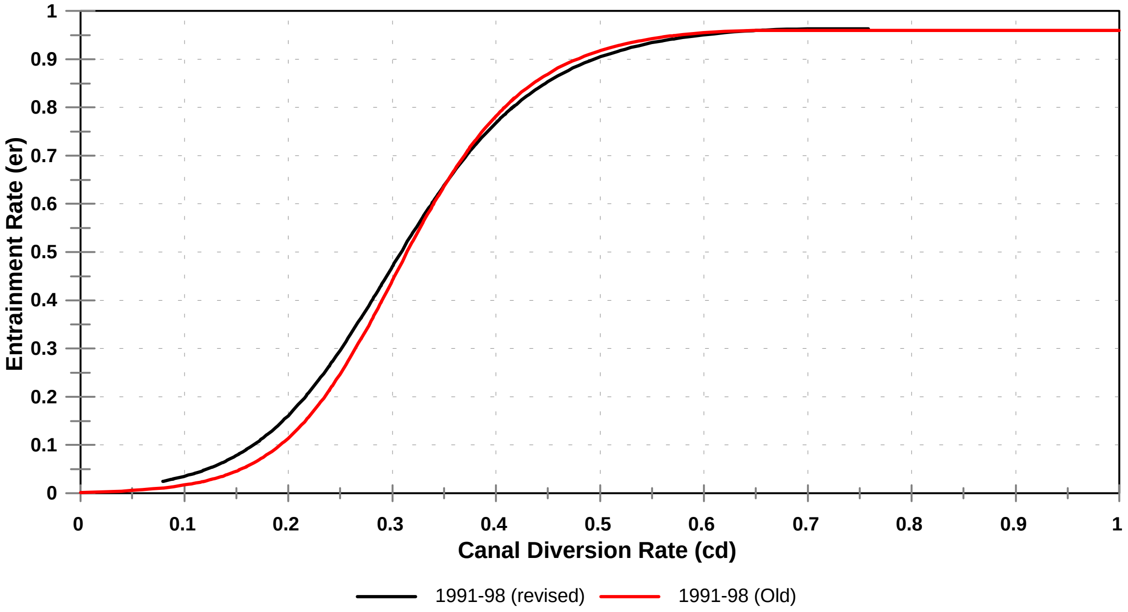

Figure 5.a. Plots of pooled 1991-1998 spring Chinook entrainment model based on restructured data base and based on data base used in 1998 analysis:

	b(0)	b(1)	b(2)
Current Restructured:	**-5.041**	**17.401**	**-11.285**
1998 Report :	**-6.151**	**21.138**	**-16.073**

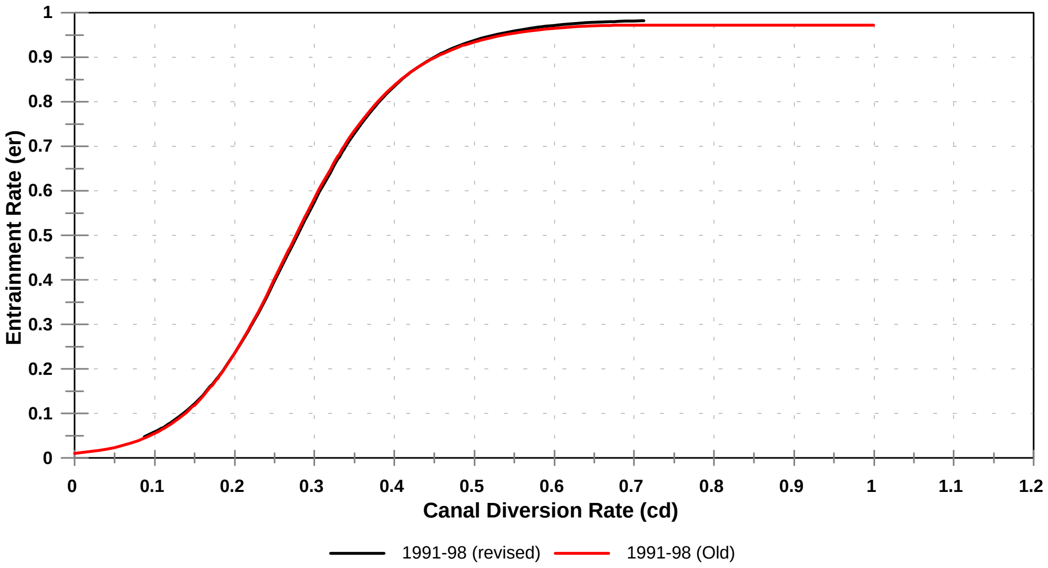

Figure 5.b. Plots of pooled 1991-1998 coho entrainment model based on restructured data base and based on data base used in 1998 analysis:

	b(0)	b(1)	b(2)
Current Restructured:	**-4.439**	**16..643**	**-9.333**
1998 Report :	**-4.575**	**17.429**	**-11.870**

Figure 6 presents the retained entrainment data points for all release years with the superimposed 1991-1998 fit (the fit not including the retained 1999 and 2000 entrainment estimates). The scatter of year-2000 data points clearly illustrates the difference. Entrainment estimates in the neighborhood of canal diversion cd = 0.4 mostly exceed the 1991-1998 predictor fit and the few available year-2000 estimates in the neighborhood of cd = 0.2 fall below the 1991-1998 predictor fit. Inclusion of the 2000 estimates would result in a more rapid change in the entrainment rate in the domain of canal flow diversion rates for which there were estimates in 2000. This can be seen by separately graphing the Equation 7 pooled 1991-1998, the 1999, and 2000 predictor fits (Figure 7) over areas of shared domains (the ending points of the 1999 and the 2000 fits indicate the lowest and highest canal-diversion rates for which entrainment estimates were available within the respective years). The 1999 fit tracts the 1991-1998 fit through most of the 1999 domain, whereas the 2000 fit exceeds the 1991-1998 fit over most of the 2000 domain, and falls below it over the remainder of its domain.

The decision has been made to pool the 1999 with the 1991-1998 entrainment estimates for estimating entrainment fit to be applied to outmigration counts prior to year 2000 and not to expand the 2000 counts until 2001 estimates are available to determine whether there has actually been a shift in the entrainment response or the 2000 fit is aberrant, perhaps due to possible quality control problems alluded to earlier. The pooled 1991-1999 coefficient estimates are given in Table 5.a for spring Chinook and Table 5.b for coho along with the estimated variances and covariances associated with these coefficients.

It should be noted that the year 2000 data sets included both hatchery and wild releases of spring Chinook. The hatchery and wild releases did not differ substantially nor significantly between their entrainment predictors (P = 0.78, Table 6.a). Further, the within-day variation between wild and hatchery entrainment variation[10]:

1) was not substantially nor highly significantly different than the value expected by chance (P = 0.10 associated with Chi-square difference of mean deviance of 1.67 from the expected value of 1.0 expected under the binomial distribution, Table 6.b), but

2) was substantially less than the residual associated with the fit comparisons (Table 6.a. Mean Deviance = 4.77, substantially and highly significantly greater what would be expected from a binomial distribution , P <0.0001).

In fitting the year-2000 data, the hatchery and wild entrainment rates were pooled. Further, whenever there was more than one release at a given release site on the same day, the information from those releases were pooled prior to estimating canal survival and entrainment (and forebay survival). If, instead of pooling, the individual multiple daily estimates were used in the Equation 8 fit, the resulting mean deviance would be smaller than it should be, and the precisions of the estimates (as measured by their standard errors) would appear to be better than they should.

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[10] Paired release sets of hatchery and wild fish were made on the eight different days. There were other days when only hatchery fish were released, and other days when only wild fish were released.

Table 4.a. **Among year comparisons for $er = 1/\{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]\}$ fits for spring Chinook smolt.**

Among Year Comparisons For Selected Model Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev [Dev/DF]	F-Ratio	Type 1 Error P
Among 1991,92,97,98 Fits	66.06	8	8.26	1.00	0.4498
1999 versus 1991-98 Fits	4.62	3	1.54	0.19	0.9053
2000 versus 1991-1999 Fits	74.29	3	24.76	2.99	0.0399
Pooled Residuals over Years	397.09	48	8.27		

Table 4.b. **Among year comparisons for $er = 1/\{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]\}$ fits for coho.**

Among Year Comparisons For Selected Model Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev [Dev/DF]	F-Ratio	Type 1 Error P
Among 1991,92,97,98 Fits	27.34	9	3.038	0.50	0.8523
1999 versus 1991-98 Fits	23.15	3	7.717	1.28	0.3107
Pooled Residuals over Years	108.34	18	6.019		

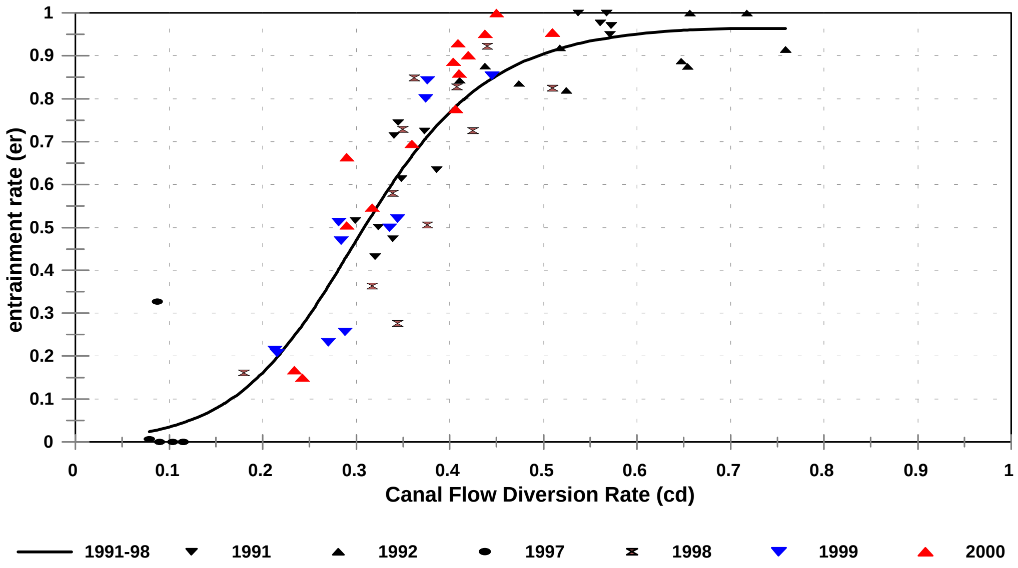

Figure 6. **Retained entrainment estimates from all release years and the pooled logistic fit $er = 1/\{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]\}$ from release years 1991, 1992, 1997, and 1998 for spring Chinook.**

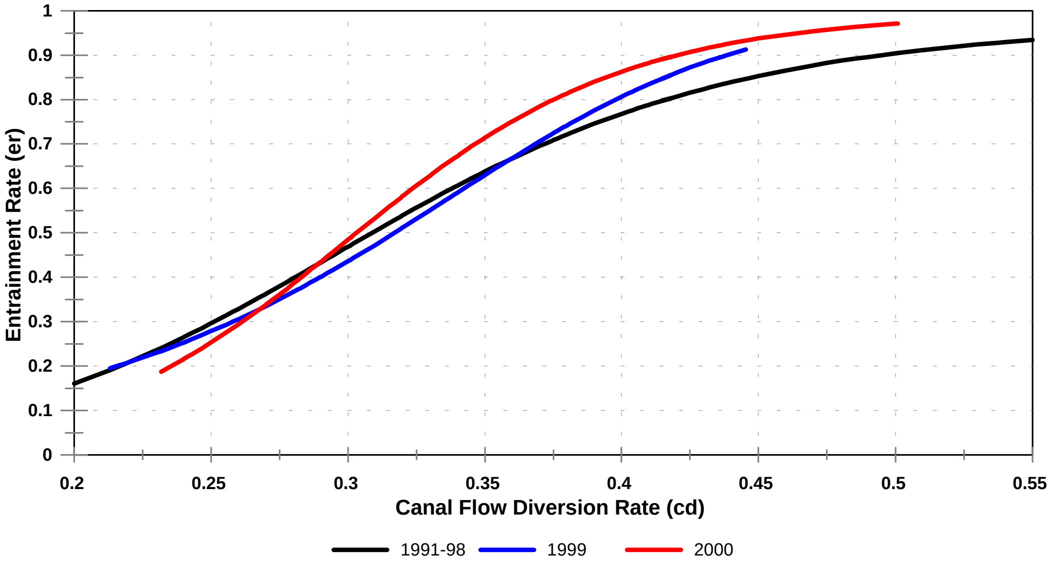

Figure 7. **Entrainment fit from pooled 1991, 199, 1997, and 1998 entrainment estimates and separate entrainments fits for 1999 and 2000 entrainment estimates using the model er = 1/{1 + exp[-b(0) - b(1)*cd - b(3)*cd^3]} for spring Chinook.**

Table 5.a. **Estimated logistic coefficients and associated variances-covariances using the spring Chinook 1991, 1992, 1997, 1998, 1999 estimates for the entrainment model**

er = 1/{1 + exp[-b(0) - b(1)*cd - b(3)*cd^3]}

Coefficient	Estimate (Est)	Standard Error (SE)	"t-Ratio" (Est/SE)	Type 1 P
b(0)	-5.196	0.8030	-6.47	0.0000
b(1)	17.901	2.8450	6.29	0.0000
b(3)	-11.862	4.4670	-2.66	0.0107
Deviance	399.59			
D.F.	48			
Dev/DF	8.32			
Type 1 P	0.0000			

	Variance-Covariance		
	b(0)	b(1)	b(3)
b(0)	0.644755		
b(1)	-2.25385	8.094195	
b(3)	3.18698	-11.9537	19.95378

Table 5.b. Estimated logistic coefficients and associated variances-covariances using the <u>coho</u> 1991, 1992, 1997, 1998, 1999 estimates for the entrainment model $er = 1/\{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]\}$

Coefficient	Estimate (Est)	Standard Error (SE)	"t-Ratio" (Est/SE)	Type 1 P
b(0)	-5.153	0.5806	-8.88	0.0000
b(1)	18.630	2.2721	8.20	0.0000
b(3)	-11.259	4.4696	-2.52	0.0173
Deviance	158.83			
D.F.	30			
Dev/DF	5.29			
Type 1 P	0.0000			

	Variance-Covariance b(0)	b(1)	b(3)
b(0)	0.337143		
b(1)	-1.268840	5.162399	
b(3)	2.007399	-9.047857	19.977055

Table 6.a. Comparisons between year-2000 wild and hatchery spring Chinook smolt fits of the entrainment model $er = 1/\{1 + \exp[-b(0) - b(1)*cd - b(3)*cd^3]\}$

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev [Dev/DF]	F-Ratio	Type 1 Error P
2000 Hatchery versus Wild FIT	5.29	3	1.76	0.37	0.7758
Residual	76.28	16	4.77		0.0000
					Chi-square Test

Table 6.b. Within-day variation between year-2000 wild and hatchery spring Chinook smolt Equation 8 estimates for eight days when both sources of fish were released.

Comparsion	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev [Dev/DF]	Type 1 Error P
2000 within-Day Hatchery versus Wild Estimates	13.39	8	1.67	0.0991
				Chi-square Test

2.b.3) Entrainment rate estimation/prediction assumptions and biases:

a) Experienced fish which have already been entrained and released into the forebay will have the same chance of being entrained as naïve fish that have never been entrained before. All PIT-tagged fish used for predicting entrainment are experienced. Attempts to trap a sufficient number of naïve fish approaching Prosser dam for release have failed. Releases of naïve fish in the past were of fish trapped far enough upstream of Prosser to raise the untestable question as to whether they would have been representative of fish passing Prosser.

b) There are no alternative routes from the point of canal entrainment to the river other than through the bypass system. The division of the adjusted forebay-released proportion detected by PR(1) by the adjusted canal proportion in estimating entrainment would not completely cancel out the effect of this bias, if it exists, because of the inability to separately enumerate un-entrained forebay-released fish from those that are entrained but escape to the river before entering the bypass.

c) The logistic model used and the associated adjustment for over-dispersion are appropriate. If the overdispersion is not relatively constant over the domain of the predictor variable, biases could result. The binomial distribution for the entrainment estimate is known to fail. Even if the proportion of forebay-released fish detected at PR(1) and that for the canal release were binomially distributed, the ratio of the proportions would not be binomially distributed. Further, the equating of entrainment values greater than 1 to 1 will result in bias.

d) The release-day values of the canal diversion (cd) is an appropriate measure of canal diversion. This may not be the case. Not all fish were detected on the release day, and the cd values change from day to day. If all forebay-released fish entered the canal on the day of release, then the use of the release-day cd value would be appropriate. But if some of the forebay-released fish entered the canal on days subsequent to release, then the release would have experienced the varying cd values over the time of its entrainment. However, there is no way to test where the PIT-tagged fish were holding after release, in the forebay or in the canal.

e) The entrainment-rate function applies to the full canal-diversion-rate domain within all years to which the fit will be applied. The pooling of the 1991-1999 entrainment estimates for prediction purposes is appropriate only if the entrainment function is the same over all years for which the fit was to apply. Although significant differences years were not detected among entrainment rates among those years, this does not mean differences do not exist. Further, the extrapolation of the predictor beyond the realized domain of the predictor variable is always problematic.

f) Canal survival for forebay-released and canal-released fish are equal.

g) Forebay survival equals 100% (discussed earlier).

2.c. Sample Rates

Referring back to Figure 4, any fish that enter the bypass and that pass though the PR(1) PIT-tag detector may be sampled by a programmed timed gate which, when opened to the sampling facility, diverts fish into a livebox. From the livebox, the sampled fish are periodically grounded together; captured; anesthetized, enumerated according to stock; and then passed through a second PIT-tag detector and routed to a recovery tank. After recovery, the fish are sent back to the bypass below the timed gate and out through the outfall to the river. The programmed time that the timed gate is opened was changed during the season to keep the facility from being overwhelmed by fish during periods of high passage or high entrainment rate while, at the same time, sampling a sufficient number of fish to estimate outmigrant passage..

2.c.1) Sample-Rate Estimation. The daily sample rate for a given stock is estimated using Equation 9.

Equation 9. $$\text{p[sampled]} = \frac{\text{n[PR(1),PR(2)]}}{\text{n[PR(1)]}}$$

Wherein n[PR(1)] is the number of all PIT tagged fish of a given stock, irrespective of release, that are detected by the bypass detector, PR(1), on that day; and n[PR(1),PR(2)] is the number of those PR(1)-detected fish that are subsequently detected by the sample-facility detector, PR(2), through which the sampled fish are passed. In 1998 it was determined from PIT-tagged releases into the livebox that fish jump out of the livebox into the outfall flume from the bypass, go back into the bypass, swim upstream past the bypass detector PR(1). Many of these PR(1)-detected fish were never detected at the sample facility detector. There may be other ways that fish diverted to the livebox are never captured and enumerated. The overall result is that the expected sample rate is less than the programmed timed gate rate.

2.c.2) Sample Rate Prediction. In the 1998 report a predictor was presented that related the daily sample rate to the timed gate rate using the following model.

Equation 10. $$sr = B*TR$$

The model was fit using weighted least squares regression without fitting the intercept, sr being the estimated sample rate on a given day and TR the recorded programmed timed gate rate for that day, the weight being the number of fish detected at the PR(1) detector on that date. The estimated regression coefficient is an estimate of the sample-rate/timed gate-rate ratio (sr/TR).

The reason for developing such a common predictor is that no estimates of sample rate were available for the many years when the facility was operating [either PR(1) was not installed (before 1990), PR(2) was not installed (1990), or PIT-tagged fish were not released (before 1990 and 1993-1996)]. Further, within years when estimates were available, there were occasional programmed timed gate rate settings during which fish were enumerated but no PIT-tagged fish were detected. Sample rates could be estimated with an Equation 10 predictor under such situations.

The daily detections of yearling salmon smolt (spring Chinook and coho combined) were used from PIT-tag releases in 1991, 1992, 1997, and 1998 to develop the common predictor presented in the 1998 report, and every days' detections were utilized in developing the predictor with the exception of three days within which the sample rate was known to have been changed within the day.

In this report the 1999 data sets are analyzed along with those from previous years. The year 2000 data set was incomplete, and a detailed analysis will be performed once the complete 2000 data set available. However, later in this section, there will be an informal discussion of 2000 sample rates based on the incomplete data set. Unlike the 1998 analysis, Coho and spring Chinook are evaluated separately, and, if two adjacent days have different TR settings, they are omitted from the data base for the purpose of estimating and predicting the sample rates. They are omitted because our recorded days of sr estimates are separated from each other at midnight, and timed gate rate changes were not performed at midnight. Therefore, the timed gate rate of record on a given day of such an adjacent day pair may actually be a combination of two timed gate rates. The desire was to include only those days for which it was known that the timed gate was functioning at a given setting for the whole day.

***Spring Chinook*.** Analyses were separately performed on the 1991, 1992, 1997, 1998, and 1999 data sets. The sr/TR ratio was computed for each detection day, a weighted analysis of variance was performed to see whether this ratio differed over the different timer-rate settings within years, the weight being the daily number of PR(1) detections used to compute the daily sampling-rate estimates. Tables 7.a-7.e respectively present for 1991-1999 PIT-tag releases: 1) sr and sr/TR estimates for each timed gate rate, the pooled estimate over the timed gate rates[11], and the Equation 10 coefficient estimate, and 2) the analysis of variance of sr/TR ratios over timed gate rates.

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[11]

$$\mathrm{sr/TR(pooled)} = \frac{\sum_{i} \mathrm{n[PR(1)_{i}]*(sr_{i}/TR}_{i})}{\sum_{i} \mathrm{n[PR(1)_{i}]}}$$

$$\mathrm{SE[sr/TR(pooled)]} = \frac{\sum_{i} \left\{\mathrm{n[PR(1)_{i}]*SE[sr_{i}/TR}_{i}]\right\}^{2}}{\left\{\sum_{i} \mathrm{n[PR(1)_{i}]}\right\}^{2}}$$

$$\mathrm{DF} = \frac{\left[\sum_{\mathrm{i}} \left\{\mathrm{n[PR(1)_{i}]*SE[sr_{i}/TR_{i}]}\right\}^{2}\right]^{2}}{\sum_{\mathrm{i}} \frac{\left\{\mathrm{n[PR(1)_{i}]*SE[sr_{i}/TR_{i}]}\right\}^{4}}{\mathrm{DF_{i}}}}$$

sr_i/TR_i being the ratio for TR setting I, n[PR(1)] the number of bypass detections, and $SE[sr_i/TR_i]$ being its estimated standard error and DF_i the associated degrees of freedom. The DF equation is Satterthwaite's approximate degrees of freedom.

For all 1991-1999 years except 1977, the sr/TR ratios did not differ significantly over timed gate rates (P > 0.47 for all but 1997 for which P =0.01). In the case of 1997, there were only two evaluated two timed gate rates, one with only one day of detections, and the other with only 6 days of detections. It is possible that the data set for that year was aberrant. The 1991-1999 data sets were pooled over years to determine which estimate, the estimate pooled over timer rates and years or the coefficient estimate would be the most precise (Table 7.f). The pooled estimate (0.800) and the coefficient estimate (0.813) were nearly identical. The standard error of the pooled estimate (SE = 0.0164) was larger than that of the coefficient estimate (SE = 0.0139); therefore, the coefficient estimate is taken to be the more precise estimate.

To determine whether this estimate could be applied over years, a weighted analysis of variance was performed to compare the coefficient estimates over 1991, 1992, 1997, and 1998, and then the pooled 1991-1998 pooled estimate was compared to the 1999 estimate within that analysis of variance (Table 8.a). The reason that the 1999 data set was treated separately is that modifications were made toward the beginning of the 1999 outmigration season in an attempt to increase the sample rate by restricting access of fish from the livebox to the outfall flume from the bypass. There were no substantial nor significant differences among the coefficients (P = 0.58 for comparing 1991-1998 estimates and P = 0.38 for comparing the 1999 estimate to the pooled 1991-1998 estimate). However, comparisons between individual yearly regression coefficient estimates using their own respective standard errors revealed two differences with relatively low p values (Table 8.b): 1992 versus 1999 (P = 0.16) and 1998 versus 1999 (P = 0.11). Since 1999 had the largest coefficient, which would be expected if the corrective action were successful, I recommend not pooling the 1999 data with that from previous years. The pooled 1991-1998 predictor can be applied to pre-1999 expansions. It may be necessary to combine the 1991-1998 estimates with the 1999 estimates up to the date when modifications were made and refit Equation 10, and then refit the 1999 estimates from after that modification date. This will require a more refined assessment of the 1999 data which will be performed from April-June, 2000. A summary of the yearly and pooled coefficients are given in Table 9

Regarding the 2000 sample rate, the only fish that were entered into the data base were releases made as part of the Chandler certification effort (i.e., releases into Prosser's forebay and Chandler Canal). Interrogations of fish released upstream of the Prosser forebay (including 2000-release OCT-SNT PIT-tagged fish) were inadvertently left out of the year-2000 data base. The result is that the number of PR(1) detections is smaller than it should be and probably the number of days of PR(1) detections is also smaller than it should be.. While the incomplete 2000 detections may be comparable to those experienced before 1998 when hatchery spring Chinook were not being released, they may still not be representative of the 2000 run. Nonetheless, the information on the existing data base is discussed here without a detailed analysis. Table 7.g presents 1) the timed gate rate, sample rate, and sr/TR ratios, and 2) the analysis of variance of those ratios among timed gate rates. Of particular interest is the fact that the sr/TR ratio for TR = 0.33 and 0.5 are comparable to what was seen in previous years (Table 7.f), but the year-2000 ratio for TR = 1.0 is not similar to that of previous years: The year-2000 sr/TR ratio was 0.762 for timed gate rate 0.33 and was 0.787 for timed gate rate 0.5, but for timed gate rate 1.0, the sr/TR ratio was 0.910.

Table 7. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b)

a. YEAR 1991

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Erro SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.1	0.167	1.6667	2.35702	1	6
0.33	0.225	0.6818	0.20348	6	813
0.5	0.402	0.8033	0.01709	5	1178
0.75	0.671	0.8953	0.01821	3	387
Pooled Estimate*		0.7790	0.07022	6	2384
Coefficient Estimate		0.8188	0.04906	18	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	3	6.11	0.39	0.7645
Days within TRs	15	15.83		

b. YEAR 1992

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Erro SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.2	0.000	0.0000		0	2
0.33	0.259	0.7856	0.03242	24	2208
Pooled Estimate*		0.7849	0.03239	24	2210
Coefficient Estimate		0.7855	0.03189	25	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	1.23	0.53	0.4737
Days within TRs	24	2.32		

c. YEAR 1997

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Erro SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.155	0.4690		0	72
1.00	0.766	0.7660	0.06050	5	124
Pooled Estimate*		0.6239	0.06050	5	196
Coefficient Estimate		0.7430	0.06532	6	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	6.83	15.05	0.0117
Days within TRs	5	0.45		

* Refer to Footnote 10

Table 7. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b) (continued)

d. YEAR 1998

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.260	0.7868	0.03039	28	1691
0.5	0.374	0.7485	0.09882	7	139
Pooled Estimate*		0.7839	0.02907	32	1830
Coefficient Estimate		0.7807	0.03019	36	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	0.19	0.12	0.7259
Days within TRs	35	1.52		

e. YEAR 1999

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.271	0.8217	0.03236	34	2110
0.5	0.422	0.8444	0.02147	40	2303
Pooled Estimate*		0.8335	0.01910	64	4413
Coefficient Estimate		0.8379	0.01768	75	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	0.57	0.36	0.5511
Days within TRs	74	1.59		

* Refer to Footnote 10

Table 7. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b) (continued)

f. POOLED OVER YEARS 1991, 1992, 1997, 1998, 1999

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.1	0.167	1.6667	2.35702	1	6
0.2	0.000	0.0000		0	2
0.33	0.258	0.7804	0.02458	96	6894
0.5	0.414	0.8273	0.01691	54	3620
0.75	0.671	0.8953	0.01821	3	387
1	0.766	0.7660	0.06050	5	124
Pooled Estimate*		0.8000	0.01641	121	11033
Coefficient Estimate		0.8133	0.01388	164	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	5	2.96	0.96	0.4476
Days within TRs	159	3.09		

g. YEAR 2000

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.252	0.7622	0.03193	11	2115
0.5	0.393	0.7869	0.01853	20	1863
1	0.910	0.9098	0.02011	3	388
Pooled Estimate*		0.7859	0.01746	17	4366
Coefficient Estimate		0.8257	0.01650	36	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	2	3.5712	3.28	0.0497
Days within TRs	34	1.0878		

* Refer to Footnote 10

Table 8.a. Among Year Analysis of Variance of Sample-Rate/Timed gate-Rate Ratio Estimates

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among 1991, 1992, 1997, 1998	3	0.2537	0.66	0.5784
Between 1999 and 1991-1998	1	0.8161	2.12	0.3677
Error	160	0.3849		

Table 8.b Individual Sample-Rate/Timer-Rate Coefficient Estimate Comparisons over Years

Years Compared	Coefficient Difference	SE of Difference	t-ratio	Degrees of Freedom (DF)	Type 1 Error P
1991 vs 1992	0.0334	0.0585	0.57	32	0.5726
1991 vs 1997	0.0758	0.0817	0.93	13	0.3703
1991 vs 1998	-0.0191	0.0521	-0.37	32	0.7171
1991 vs 1999	-0.0191	0.0521	-0.37	23	0.7181
1992 vs 1997	0.0425	0.0727	0.58	9	0.5736
1992 vs 1998	0.0048	0.0365	0.13	58	0.8962
1992 vs 1999	-0.0524	0.0365	-1.44	41	0.1581
1997 vs 1998	-0.0377	0.0677	-0.56	9	0.5913
1997 vs 1999	-0.0949	0.0677	-1.40	7	0.2037
1998 vs 1999	-0.0572	0.0350	-1.63	61	0.1072

Table 9. Summary of Sample-Rate/Timer-Rate Coefficient Estimates

Year	Estimate	Standard Error	Degrees of Freedom
1991	0.8188	0.04906	18
1992	0.7854	0.03189	25
1997	0.7430	0.06532	6
1998	0.7807	0.03019	36
1991-1998 Pooled	0.7967	0.02035	88
1999.0000	0.8379	0.01768	75
1991-1999 Pooled	0.8133	0.01388	164
2000	0.8257	0.01650	36

One rationale for a higher sr/TR ratio when TR = 1.0 is that, if fish return from the livebox to the bypass, they would still be ultimately forced into the livebox since the timed gate is always open to the livebox. When the timed gate rate is less than 1, then the fish could avoid the livebox by passing the timed gate when the timed gate is closed to livebox and open to the lower bypass and on to the river. However, prior to 2000, the sr/TR ratio at TR = 1.0 was substantially less than it was in 2000 (0.766 in 1997 and 0.910 in 2000; Tables 7.c and Table, respectively). It should be noted that, for TR = 1.0, the 1997 sr/TR estimate was based on only 6 PR(1)-detection days and the year-2000 sr/TR estimate was based on only 4 PR(1)-detection days.

Coho. As was done with spring Chinook, analyses were separately performed on the 1991, 1992, 1997, 1998, and 1999 data sets. Tables 10.a-10.e presents for the 1991-1999 PIT-tag releases 1) sr/TR estimates for each timed gate rate, the pooled estimate over the timed gate rates, and the Equation 10 coefficient estimate, and 2) the analysis of variance of sr/TR ratios over timed gate rates.

Within years, the PIT-tagged coho only experienced one or two TR settings. In 1991 and 1997 only one TR setting was experienced; therefore no sr/TR comparisons over settings were possible. In 1992, one of the sr/TR estimates was based on only two days' information. There was little information on which to base within-year comparisons of sr/TR ratios. The pooled 1991-1999 estimates revealed no significant differences among the timer rate settings and the pooled sr/TR ratio estimate and the sr/TR coefficient estimate did not differ greatly from each other (Table 11.f). However, there large differences over years among the coefficient estimates (Tables 11.a and 11.b). Comparisons among the coefficient estimates over years indicate that differences not only involved a difference between the 1999 detections and the 1991-1998 pooled estimate, possibly because of modifications made in 1999 to inhibit the escape of fish from the livebox through the outfall from the bypass, but also involved differences among the 1991-1998 coefficients. Table 12 summarizes the sr/TR coefficient estimates, and, as can be seen from the table, the 1999 sr/TR coefficient estimate was actually smaller than that of any other year, which was the opposite of what was experienced for the spring Chinook and opposite from what was expected; the modifications in 1999 were expected to result in the sample rate being closer to the timed gate rate and, therefore, result in the sr/TR coefficient being nearer to 1.

There was only one year when PIT-tagged coho experienced a TR = 1.0 setting, and that was 1997. The sr/TR coho estimate for that setting was 0.917 (Table 10.c) which was very near 1.0. Recall from the previous discussion under spring Chinook that the only value near 1 occurred in 1999, also for TR = 1.0. A higher sr/TR value was expected if a major loss of fish from the live box occurred through the outfall from the bypass. What is somewhat disconcerting is that higher sr/TR estimate for coho in 1997, the year when the spring Chinook estimate was only 0.77 for TR = 1.0.

It can be seen in Table 13 that there were several years when the sr/TR coefficient estimates differed significantly between spring Chinook and coho. It was probably inappropriate to combine spring Chinook and coho to estimate the sr/TR ratio in the 1998 report.

Even though the sr/TR sample rates do not appear to be constant over timed gate rates for coho (they appeared to be constant for spring Chinook). The sample rates do appear to be reasonably consistent over those years sharing the same TR values as can be seen from Table 14. For TR = 0.33 and TR = 0.5, for which there was more than one year of retained PIT-tag detections, there were no significant differences among the sample rates among years within each TR setting (Tables 15.a and 15.b respectively for TR = 0.33 and TR = 0.5).

NOTE: There were not enough detections of year-2000 PIT-tagged coho from the incomplete data set to permit any meaningful assessment of sample rates.

2.b.3) Entrainment rate estimation/prediction assumptions and biases:

a) For spring Chinook, the sample-rate/timed gate-ratio holds over all timed gate rates over all years through 1998 (the 1999 sr/TR estimate possibly being different and the 2000 sample rate estimates being incomplete).

For coho, the sample rates are the same for a given timer rate for all years through 1999 (the year 2000 sample rate estimates being incomplete), and any extrapolations developed for timed gate rates for which their were no PIT-tagged fish read will be unbiased. The method of extrapolating sr/TR estimates for TR values for which sr/TR estimates do not exist still must be worked out.

b) The proportion of those PIT-tagged fish read by the PR(1) detector that were later read by the PR(2) detector is the same as the proportion of all fish (PIT-tagged or not) passing the PR(1) detector that were later sampled and enumerated.

Table 10. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b)

a. YEAR 1991

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.2797971	0.84787	0.08204	8	1788
Pooled Estimate		0.84787	0.08204	8	1788
Coefficient Estimate		0.84787	0.08204	8	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	not applicable			
Days within TRs	8	12.0339		

b. YEAR 1992

1) Estimates

Timer Rate (TR)	Sample Rate	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.2	0.148296	0.74148	0.14542	1	27
0.33	0.234927	0.71190	0.04942	10	685
Pooled Estimate		0.71302	0.04786	3	712
Coefficient Estimate		0.71232	0.04508	12	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	0.0220	0.01	0.9080
Days within TRs	11	1.5728		

c. YEAR 1997

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
1.00	0.91711	0.91711	0.03040	8	157
Pooled Estimate		0.91711	0.03040	8	157
Coefficient Estimate		0.91711	0.03040	8	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	not applicable			
Days within TRs	8	0.1451		

* Refer to Footnote 10

Table 10. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b) (continued)

d. YEAR 1998

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.225093	0.68210	0.05319	9	391
0.5	0.375495	0.75099	0.05914	38	1414
Pooled Estimate		0.73607	0.04774	42	1805
Coefficient Estimate		0.74359	0.05038	48	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	1.4540	0.35	0.5596
Days within TRs	47	4.2103		

e. YEAR 1999

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.33	0.2406987	0.72939	0.05102	22	947
0.5	0.31194	0.62388	0.04267	25	561
Pooled Estimate		0.69014	0.03576	32	1508
Coefficient Estimate		0.66859	0.03329	48	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	1	3.9220	2.31	0.1351
Days within TRs	47	1.6970		

f. POOLED OVER YEARS 1991, 1992, 1997, 1998, 1999

***** Refer to Footnote 10

Table 10. Sample-Rate and Sample-Rate/Timer-Ratio Estimates (a) and Associated Analyses of Variance (b) (continued)

f. POOLED OVER YEARS 1991, 1992, 1997, 1998, 1999

1) Estimates

Timer Rate (TR)	Sample Rate (sr)	Sample-Rate/TR (sr/TR ratio)	Standard Error SE(sr/TR)	Degrees of Freedom	PR(1) Detections
0.2	0.148296	0.74148	0.14542	1	27
0.33	0.2564034	0.77698	0.03135	52	3811
0.5	0.357445	0.71489	0.04171	64	1975
1	0.91711	0.91711	0.03040	8	157
Pooled Estimate		0.75996	0.02433	96	5970
Coefficient Estimate		0.76883	0.02455	128	

2) Analysis of variance

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among TRs	3	3.001	0.90	0.4429
Days within TRs	125	3.331328		

***** Refer to Footnote 10

Table 11.a. Among Year Analysis of Variance of Sample-Rate/Timed gate-Rate Ratio Estimates

Source	Degrees of Freedom	Mean Square	F-Ratio	Type 1 Error P
Among 1991, 1992, 1997, 1998	3	1.4800	2.9754	0.0349
Betweem 1999 and 1991-1998	1	3.1682	6.3696	0.0131
Error	108	0.4974		

Table 11.b Individual Sample-Rate/Timer-Rate Coefficient Estimate Comparisons over Years

Years Compared	Coefficient Difference	SE of Difference	t-ratio	Degrees of Freedom (DF)	Type 1 Error P
1991 vs 1992	0.1356	0.0936	1.45	13	0.1713
1991 vs 1997	-0.0692	0.0875	-0.79	10	0.4471
1991 vs 1998	0.1043	0.0963	1.08	15	0.2958
1991 vs 1999	0.1793	0.0885	2.02	11	0.0678
1992 vs 1997	-0.2048	0.0544	-3.77	19	0.0013
1992 vs 1998	-0.0313	0.0676	-0.46	44	0.6460
1992 vs 1999	0.0437	0.0560	0.78	27	0.4420
1992 vs 1998	0.1735	0.0588	2.95	50	0.0048
1992 vs 1999	0.2485	0.0451	5.51	31	0.0000
1998 vs 1999	0.0750	0.0604	1.24	83	0.2177

Table 12. Summary of Sample-Rate/Timer-Rate Coefficient Estimates

Year	Estimate (Est)	Standard Error SE)	Degrees of Freedom
1991	0.8479	0.0820	8
1992	0.7123	0.0451	12
1997	0.9171	0.0304	8
1998	0.7436	0.0504	48
1991-1998 Pooled	0.7985	0.0319	79
1999	0.6686	0.0333	48
1991-1999 Pooled	0.7688	0.0246	128

Table 13. Comparisons between spring Chinook and coho survival rate estimates

Year	Spring Chinook - Chinook Difference	Standard Error (SE)	Approximate Degrees of Freedom	t-ratio (Est/SE)	Type 1 P
1991	-0.0291	0.09559	14	-0.30	0.7660
1992	0.0731	0.05522	24	1.32	0.1983
1997	-0.1741	0.07205	9	-2.42	0.0421
1998	0.0371	0.05873	76	0.63	0.5296
1991-1998 Pooled	-0.0018	0.03783	136	-0.05	0.9625
1999	0.1693	0.03769	75	4.49	0.0000
1991-1999 Pooled	0.0445	0.02820	206	1.58	0.1164

Table 14. Summarized estimated sample rate

Timer-Gate Rate Setting	1991	1992	1997	1998	1999	Mean
0.2		0.1483				0.1483
0.33	0.2798	0.2349		0.2251	0.2407	0.2564
0.5				0.3755	0.3119	0.3574
1			0.9171			0.9171

Table 15. **Logistic analysis of variation among years for each applicable timed gate-rate setting (TR = 0.33, TR = 0.5)**

a. Timer Gate Rate = 0.33

Source	Deviance	Degrees of Freedom	Mean Deviance	F-Ratio	Type 1 P
Among Years	10.03	3	3.34	1.47	0.2335
Within Years	111.24	49	2.27		

b. Timer Gate Rate = 0.33

Source	Deviance	Degrees of Freedom	Mean Deviance	F-Ratio	Type 1 P
Among Years	7.16	1	7.16	1.77	0.1882
Within Years	254.85	63	4.05		

APPENDIX F

Task 4.d
Indirect Predation

Research Task Funding Packages in YKFP
M&E 2000 Budget

Task 4.d Indirect Predation.

Cost: $30,980

Rationale: The release of hatchery smolts may increase or decrease the survival of commingled wild smolts -- or of smolts of any origin -- by altering the behavior of predators. This hypothetical change in predation-related mortality attributable to the release of hatchery smolts has been termed "indirect predation". Although the term seems to imply hatchery releases indirectly increase losses to predators, the impact on commingled smolts, if any, may be either positive or negative.

An issue of considerable importance to the YKFP is the possibility that releases of hatchery fish might decrease the survival of any wild smolts that happen to move down the river along with the hatchery fish. Predators are generally attracted to concentrations of prey, such as areas in which hatchery fish are released. For example, bigmouth minnows were attracted to locations where hatchery releases occurred in Bonneville Pool (Collis et al. 1995), and piscivorous birds such as gulls and mergansers flock to the dense aggregations of fish that occur during and immediately after large hatchery releases (Ruggerone 1986; Wood 1987) This increase in the abundance of predators may increase predation on any *wild* smolts that happen to be moving through the release point, or on smolts of any type. Moreover, predators may become more piscivorous when fish are abundant (Collis et al. 1995; Shively et al. 1996). For example, bigmouth minnows consumed primarily invertebrates prior to the release of hatchery fish in the Chehalis River, but switched to fish after a release of hatchery smolts (Fresh et al. In review). A similar phenomenon may have occurred in Chandler Canal in 1998 (McConnaughey, 1998. Internal YKFP Progress Report). Finally, wild fish may be more susceptible to predators because they are generally smaller than hatchery fish (Hillman and Mullan 1989; Shively et al. 1996).

The YKFP is equally interested in the possibility that releases of hatchery smolts might *increase* the survival of commingled smolts. Large numbers of hatchery and wild migrants may simply overwhelm the consumption capacity of a limited number of predators, or confuse predators such that their predation efficiency is impaired (Wood 1987). Moreover, hatchery fish may be more vulnerable to predators because of their conspicuous behavior and coloring (Berejikian 1995; White et al. 1995), and may act as "shields" for more cryptic wild fish.

The initial objective of this study is simply to determine whether a consistent relationship between smolt survival and total smolt abundance exists in the Yakima River. Because many factors can influence smolt survival – e.g., water temperature, flow, turbidity, smolt size – it is critical that the analysis be capable of separating the survival impact of smolt abundance from the impacts of other factors that might be active at the time. If an "Indirect Predation" effect were to be thus established, it would then be necessary to investigate more specific and often mechanistic questions. These questions include:

- Is the effect the same for commingled hatchery and wild smolts, and how does relative hatchery/wild susceptibility vary across species?
- Is the effect consistent across a range of physical factors – flow, temperature and turbidity -- that might be expected to affect smolt survival or predation rates?
- If conclusively demonstrated, can it be equally conclusively demonstrated that the effect is caused by a

change in predation?

- If demonstrated and conclusively attributable to predation, is it:
    - due to the attraction of predators to release sites?
    - due to a change in consumption rates among predators?
    - due to the greater conspicuousness or vulnerability of wild or hatchery smolts?
    - due to predator satiation?
    - due to size differences between test groups and the average outmigrant at the time?

Methods: Survival from Prosser Dam to McNary Dam was estimated for 157 groups of PIT-tagged spring chinook and coho smolts and for 51 groups of PIT-tagged fall chinook smolts. Test fish included both wild and hatchery smolts and no attempt to analyze fish of different origins separately has yet been made. Spring chinook and coho were combined because they are both yearling smolts of approximately the same size, and the behavior of yearling smolts differs considerably from the much smaller fall chinook subyearlings. The test groups were released in 1998, 1999 and 2000, and were analyzed as a pooled total over all years, and for 1998-99 and 2000 separately. The analysis was broken down across years in this way because flows were relatively high in 1998 and 1999 and relatively low in 2000.

The current analysis includes only actively migrating smolts, including both groups released at Prosser Dam and "self-selected" releases. The test fish that were released at Prosser Dam were initially captured at the Chandler smolt facility at Prosser Dam after having migrated considerable distances (usually 50 miles or more). "Self-selected" releases were subsets of PIT-tagged fish released *above* Prosser Dam that were detected and bypassed at the Chandler facility over a 3-day period. The number of fish in such a test group was the total number of fish detected over the three days, and the release date was considered to be the "middle day" (day two). A total of 82 and 75 yearling releases of these types (self-selected and on-site releases) were analyzed in 1998-99 and 2000, respectively. Comparable figures for 1998-99 and 2000 fall chinook releases were 40 and 11.

Multiple logistic regression was used to correlate survival with a number of factors acting both just below Prosser Dam and in the forebay of McNary Dam. The variables examined were: flow (below Prosser and in the McNary forebay); flow acceleration (Prosser and McNary); water temperature (Prosser and McNary); and smolt abundance (daily passage estimates at Prosser and Fish Passage Indices [FPI] at McNary). The potential impact of test fish size (mean fork length) will be analyzed in the near future[1]. Flow and temperature data for the Yakima River below Prosser Dam were obtained from the Bureau of Reclamation's Yakima Project Hydromet Web site; flow, temperature and FPI data for McNary were obtained from the University of Washington's DART Web site.

The analytical procedure employed assumes a number of factors affect smolt survival simultaneously, and that if smolt abundance is one of them, *its impact should be statistically significant after the effects of the other factors have been accounted for.*

Because test fish were detected at McNary over a number of days, values given to various independent variables were means averaged over the passage period. Specifically, they were "passage-weighted means", defined as the sum over the entire passage period of the product of the daily percent passage and the daily value of the independent variable. Independent variables measured at Prosser Dam were also expressed as passage-weighted means for self-selected releases.

Survival to McNary was estimated as N_{MCJ}/N_{REL}, where N_{MCJ} is the estimated passage at McNary and N_{REL} is the release number. McNary passage was estimated by the following expression:

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[1] The mean size of self-selected test groups can only be estimated by reference to similar types of fish that were examined at the Chandler smolt facility at the same approximate time as the test groups was being detected. The best data to estimate the mean size of certain 2000 self-selected releases is still being assembled.

$$N_{MCJ} = \sum_i D_i / dr_i$$

where D_i is the number of tagged fish detected on the ith day of passage at McNary, and dr_i is the detection rate at McNary on the ith day of passage.

McNary detection rates during various time periods in 1998 and 1999 were based on detections of tagged fish at John Day Dam. Let N(MCJ, JDJ) be the number of detections at John Day of fish previously detected at McNary, and N(JDJ) be the number of fish detected only at John Day. Assuming McNary detection affects neither travel rate nor survival, if detection rate were constant over the entire season, N(MCJ,JDJ)/N(JDJ) would give the constant detection rate at McNary Dam. McNary detection rate does, however, vary over the course of an outmigration. Therefore, daily detection rate estimates were plotted against date and an initial visual estimate of periods of relatively constant detection rate was made. The beginning and ending dates of these subjective constant detection rate periods were then varied and the pooled within-group variance was calculated. The partitioning that was used was the one that generated the minimum pooled variance.

A logistic regression package (Statistix, 1999) was then used to determine the independent variables that were, individually, significantly correlated with survival, as well as those that explained a significant portion of the variation even when paired with other significant variables and the contribution of the other variable was accounted for.

The significance of the correlation of single variables acting in the presence of other significant variables was determined as follows. In logistic regression, Deviance (Dev) is analogous to the sum of squares of deviations in a linear regression. The Deviance of factor A given the impact of factor B, Dev(A|B), is Dev(B) - Dev (A,B), where Dev(A,B) is the Deviance of the multiple logistic regression of A and B on survival. The ratio of the Dev(A|B) to Dev(A,B) represents an F-test of the significance of A's correlation after accounting for factor B.

Progress: When the spring chinook and coho data were combined over all years, the following six factors correlated significantly with survival from Prosser to McNary:

Flow in kcfs at McNary (Q_{MCJ}): $S = -1.88 + .0104(Q_{MCJ})$ p = .00001

Water temperature (deg F) at Prosser (PTEM): $S = 5.95 - .089(PTEM)$ p = .00021

Flow in cfs below Prosser (PFLOW): $S = .201 + 1.6*10^{-4} (PFLOW)$ p = .00042

Water temperature (deg F) McNary Pool (MTEMP): $S = 1.74 - .107(MTEMP)$ p = .00068

Flow acceleration McNary (ACC_{MCJ}): $S = 0.732 + 6.62(ACC_{MCJ})$ p = .00864

Flow acceleration below Prosser (ACC_{PRJ}): $S = .830 - .995(ACC_{PRJ})$ p = .02544

Test fish mean length (LENGTH)[2]: $S = -.784 + .013(LENGTH)$ p = .002

Neither the abundance of all smolts combined (ALLSMLT) nor the abundance of hatchery smolts only (HATSMLT) correlated significantly with Prosser-to-McNary survival, but HATSMLT was nearly significant:

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[2] Only includes 122 cases – 35 releases omitted until lengths can be estimated.

Abundance of all smolts at Prosser (ALLSMLT): $S = .901 - 9.56 \times 10^{-6}$ (ALLSMLT) p = .1729

Abundance of hatchery smolts at Prosser (HATSMLT): $S = .906 - 1.47 \times 10^{-5}$(HATSMLT) p = .0746

Interestingly, when paired with Prosser flow, both ALLSMLT and HATSMLT became significant. The sign of the coefficient for both measures of smolt abundance was always negative, indicating that the survival of commingled yearling smolts fell as total or hatchery smolt abundance below Prosser increased.

Prosser flow, McNary flow, Prosser temperature and McNary temperature were very robust predictors, in that each of them still explained a significant proportion of survival variability when adjusted for the contribution of other individually significant variables. This was interpreted as fairly strong evidence that these factors are truly correlated with survival, and that these relationships are not due to circumstantial correlation between one of the tested variables and some other factor that actually impacts survival. The single strongest bivariate survival prediction equation involved Prosser flow and McNary temperature.

The factors that did not correlate with Prosser-to-McNary survival at all were smolt abundance at McNary -- either hatchery-only or wild plus hatchery -- and percent spill at McNary (SPILL).

Analysis of 1998-99 yearling data separately. A different picture emerges when yearling data are analyzed separately for the high-flow period 1998-99. The five significant survival predictor variables for 1998-99 are: **McNary flow, McNary spill, total smolt abundance at Prosser and hatchery smolt abundance at Prosser**:

$S = -1.37 + .0095$(MFLOW) p = .0046

$S = -1.20 + 6.52$(SPILL) p = .0070

$S = .553 + 6.2 \times 10^{-5}$(ALLSMLT) p = .0084

$S = .753 + 8.0 \times 10^{-5}$(HATSMLT) p = .0108

No Yakima physical variable affected survival, although Prosser flow was borderline (p=.14) and the coefficient was, as would be expected, positive. No temperature variable was significant either in the Yakima or McNary pool, but both measures of smolt abundance in the Yakima were significant. Interestingly, the sign of the relationship between survival and Prosser smolt abundance is positive, indicating that at least in these high flow years, yearling smolt survival increased with smolt abundance.

Hatchery smolt abundance and total smolt abundance still explained a significant portion of survival variation after adjustment for the contributions of McNary flow and McNary spill, and their coefficients remained positive in multiple regressions with other independently significant variables. The same was true for McNary flow and McNary spill: they continued to explain a significant portion of survival variance when adjusted for HATSMLT and ALLSMLT and always had positive coefficients. McNary temperature became significant when paired with McNary flow, and the coefficient was negative, as one would expect. This multiple regression had the lowest residual Deviance/df (analogous to residual sum of squares) of all, possibly indicating that physical conditions in the Columbia were the dominant factors affecting survival from Prosser to McNary during this period.

Variables which never significantly correlated with survival in 1998 and 1999, either singly or when paired with other variables, included PTEM, ACCMCJ, ACCPRJ, FPI, Julian date and LENGTH.

Analysis of 2000 yearling data separately. The data for the low-flow year of 2000 are strikingly different than for 1998 and 1999. Physical factors in the lower Yakima were relatively more important, and while smolt abundance at Prosser was still significantly correlated with survival, the nature of the relationship is reversed: for 2000, survival from Prosser to McNary *decreased* as smolt abundance at Prosser increased.

The seven variables that were significantly correlated with yearling smolt survival from Prosser to McNary were McNary temperature (MTEM), Prosser temperature (PTEM), total smolt abundance at Prosser (ALLSMLT), Julian date (JULDATE), flow acceleration at Prosser (ACCPRJ), hatchery smolt abundance at Prosser (HATSMLT) and Prosser flow (PFLOW):

$S = 6.47 - .108\ (\text{MTEM})$ $\quad p = .0039$

$S = 5.07 - .0776(\text{PTEM})$ $\quad p = .0043$

$S = .688 - 1.79 \text{ X } 10^{-5}(\text{ALLSMLT})$ $\quad p = .0054$

$S = 3.05 - .019(\text{JULDATE})$ $\quad p = .0055$

$S = .525 - 1.06(\text{ACCPRJ})$ $\quad p = .0127$

$S = .632 - 1.86 \text{ X } 10^{-5}(\text{HATSMLT})$ $\quad p = .0132$

$S = -.221 + 2.22 \text{ X } 10^{-4}(\text{PFLOW})$ $\quad p = .0150$

McMary flow was borderline significant (p = .06) and positive in sign, and smolt abundance at McNary (FPI) was also borderline significant (p = .08) and negative in sign. McNary spill and flow acceleration at McNary were not significantly correlated with Prosser-to-McNary survival.

Total smolt abundance at Prosser and hatchery smolt abundance at Prosser remained significantly or almost significantly (p < .1) correlated with survival when adjusted for all other significant variables except for hatchery smolt abundance and flow acceleration at Prosser. Here again, the fall from significance is attributable to the fact that flow acceleration and total smolt abundance at Prosser are positively correlated, as are total and hatchery smolt abundance at Prosser.

McNary temperature remained significant when paired with other significant variables except for Prosser temperature and Julian date. These three variables are obviously interrelated, so such a finding is not surprising. The same is true of Prosser temperature and Julian date: they remained significantly correlated with all other significant variables except the "thermal complex" of McNary temperature, Prosser temperature and Julian date.

Perhaps the most robust predictor of Prosser-t-o-McNary survival was Prosser flow, which remained significant when paired with all of the other significant variables, and always retained its positive sign in bivariate multiple regressions.

The most significant bivariate regression involved **total smolt abundance at Prosser and Prosser flow**, perhaps indicating that the dominant factors controlling Prosser-to-McNary survival in the low-flow year of 2000 occurred inside the Yakima.

Preliminary conclusions for yearling smolts. From the data available, it appears as though the dominant factors controlling Prosser-to-McNary survival for yearling smolts are determined by the runoff pattern. In low-flow years, Yakima conditions – especially flow and smolt abundance at Prosser – are dominant, and Columbia conditions are dominant in high flow years, especially McNary flow and McNary temperature. It is interesting that the impact of smolt abundance at Prosser changes sign, being associated with increased survival in high-flow years and decreased survival in low-flow years (and, not surprisingly, showing no correlation when assessed over all years). At this point there is no clear explanation for this change.

Analysis of fall chinook data, all years. Compared to yearling smolts, fall chinook survival over all years was much more affected by McNary spill, was not significantly affected by flow below Prosser, and much more and more consistently affected by smolt abundance at Prosser -- Prosser smolt abundance always was positively correlated with survival. The seven variables that significantly correlated with fall chinook survival over all years were spill, McNary temperature, McNary flow, Prosser temperature, Julian date, total smolt abundance at Prosser and hatchery smolt abundance at Prosser:

$S = -1.97 + 6.88(\text{SPILL})$ $p = .000004$

$S = 7.24 - .117(\text{PTEM})$ $p = .00002$

$S = 7.85 - .128(\text{MTEM})$ $p = .0009$

$S = -2.45 + .009(\text{MFLOW})$ $p = .0013$

$S = 3.62 - .0222(\text{JULDATE})$ $p = .0025$

$S = -.242 + 7.8 \text{ X } 10^{-5}(\text{HATSMLT})$ $p = .0037$

$S = -.469 + 6.13 \text{ X } 10^{-5}(\text{ALLSMLT})$ $p = .0049$

No other variable remained significant when adjusted for the impact of either spill and Prosser temperature, although the abundance of hatchery smolts at Prosser came close to being significant when adjusted for Prosser temperature (p = .108). The meaning of the very strong positive relationship between spill and Prosser-to-McNary survival for fall chinook smolts is puzzling, as it is hard to see how spill would be capable of affecting survival *to* McNary Dam (as opposed to survival from McNary to some point downstream). Prosser abundance of hatchery smolts was significant at the .1 level when adjusted for McNary flow and Prosser temperature, and the .05 level when adjusted for Julian date and McNary temperature.

Analysis of fall chinook data, 1998-99 and 2000. Although the significance levels changed, exactly the same factors were significant for the high-flow years of 1998 and 1999. These relationships were:

$S = -3.14 + .101(\text{SPILL})$ $p = 5 \text{ X } 10^{-7}$

$S = 8.61 - .141(\text{PTEM})$ $p = .00003$

$S = -3.47 + .0121(\text{MFLOW})$ $p = .00085$

$S = 8.41 - .138(\text{MTEMP})$ $p = .0028$

$S = 3.60 -.022(\text{JULDATE})$ $p = .0072$

$S = -.245 + 7.7 \text{ X } 10^{-5}(\text{HATSMLT})$ $p = .0100$

$S = -.437 + 5.8 \text{ X } 10^{-5}(\text{ALLSMLT})$ $p = .0138$

As was the case for the all-years' analysis, no other variable remained significant when paired with spill, and only hatchery smolt abundance below Prosser remained significant when paired with Prosser temperature. Abundance of hatchery smolts at Prosser remained significant when adjusted for McNary temperature and Julian date, and total Prosser smolt abundance did also at the .1 level. Prosser flow was not significant, either by itself or when paired other significant or marginal factors.

In 2000, only 11 fall chinook releases were made, so it is not surprising that only two factors were significant: Prosser flow and Prosser temperature:

$S = 20.8 - .030(PTEMP)$ $p = .0017$

$S = -2.45 + .00167(PFLOW)$ $p = .0179$

No other variables except Prosser hatchery smolt abundance and Prosser total smolt abundance were close to being significant for 2000 fall chinook. The probability value of Prosser total smolts was .14, the probability value for Prosser hatchery smolt abundance was .24 and both were positively correlated with survival.

Preliminary conclusions, fall chinook. The relationship between fall chinook survival and Prosser smolt abundance was significant in 1998-99, but not 2000. Nevertheless, both for 1998-99 and 2000, the n*ature* of the relationship was the same: survival increased with smolt abundance (total and hatchery only). It might also be surmised that the relationship for 2000 would have been significant had sample size been larger. Another somewhat surprising difference between yearling smolts and fall chinook was that Prosser flow was a significant factor only in the low-flow year of 2000, but not for 1998-99 or for all years combined.

Preliminary conclusions, yearlings and fall chinook. Data collected to date suggests the following:

1. The survival of fall chinook from Prosser to McNary seems to be consistently improved by the abundance of smolts at Chandler, whereas the impact of Prosser smolt abundance on the survival of yearling smolts depends on flow conditions. The reason for such a switch is not currently evident.

2. Smolt abundance in the McNary pool, at least as indexed by the Fish Passage Index, does not seem to be correlated with the survival of either yearling or subyearling smolts.

3. Increases in Prosser flow are significantly correlated with Prosser-to-McNary survival only in low-flow years. In high-flow years, the flow in the McNary forebay is more significant.

4. Conditions in the Columbia appear to be more important in determining survival in years of high flow in the Yakima and, conversely, conditions in the Yakima appear to be more important during years of low flow in the Yakima.

This analysis was prepared by Bruce Watson, a YN biologist.