PRELIMINARY RESEARCH PROPOSAL (FY07)

TITLE: A study to compare SARs of in-river migrating versus transported Snake River yearling anadromous salmonids

PROJECT LEADERS: Douglas M. Marsh
National Marine Fisheries Service
Northwest Fisheries Science Center
Fish Ecology Division
2725 Montlake Boulevard East
Seattle, Washington 98112
(206) 860-3251

ADMINISTRATIVE: Kurt Gores
National Marine Fisheries Service
Northwest Fisheries Science Center
Fish Ecology Division
2725 Montlake Boulevard East
Seattle, Washington 98112
(206) 860-3270

ADMIN. CODE: TPE-W-05-NEW (TPE-W-00-04)

DURATION OF PROJECT: 2000 to 2010

DATE OF SUBMISSION: July 2006

PROJECT SUMMARY

The goal of this project is to provide statistically valid comparisons of the smolt-to-adult return rates (SAR) of Snake River juvenile salmonids that migrate in-river compared to those transported around dams of the Federal Columbia River Power System (FCRPS). Wild yearling Chinook salmon (*Oncorhynchus tshawytscha*) and wild steelhead (*O. mykiss*) were PIT-tagged at Lower Granite Dam in 2000, 2002 and 2003 for this evaluation, with adults returning through 2006. Based on SARs to Lower Granite Dam, we will calculate a 95% confidence interval (CI) for the overall transport/in-river-adult-return-ratio (T/I). We will compare results from our studies (wild fish

marked at the dam) to results from hatchery fish PIT-tagged above the dam (Berggren et al. 2005). Beginning in 2004 and continuing through 2006, we marked a barge index group with no corresponding in-river group. Adult returns from this marking will continue through 2009.

A secondary goal of this project is to determine if differential post-hydrosystem mortality (*D*) of transported yearling Chinook salmon is related to their size and timing of arrival in the estuary/nearshore ocean. Results from recent transportation studies utilizing PIT tags have shown that transported yearling Chinook salmon return at lower rates then expected, based on their survival estimates through the hydropower system (to below Bonneville Dam) (Williams et al. 2005). One way this can occur is when transported fish have a lower survival rate below the hydropower system to return as adult than fish migrating in-river. Several hypothesis for $D < 1$ for transported fish have been proposed (Budy et al. 2002), some of which are being investigated through other research proposals. Here we will investigate possible effects due to differences in size and timing of fish from the two groups upon arrival below Bonneville Dam. Fish tagging efforts for this portion of the study will be combined with concurrent BPA funded (Project # 199302900) in-river smolt survival study tagging.

Analyses of data based on this and other research conducted under various contracts will provide critical information to compare overall SARs of transported and in-river-migrating or bypassed anadromous salmonids, to examine potential seasonal effects of transportation, to evaluate the effects of transportation on homing of adults, to estimate differential post-hydrosystem mortality (*D*) of transported fish, and mechanisms to explain *D*. The studies will be conducted using state-of-the-art facilities and technologies and under environmental conditions known to provide as favorable in-river passage conditions as possible through the FCRPS as it is currently configured and operated.

Relevance

This study addresses needs identified in NOAA's 2004 Biological Opinion (BiOp) "*The Action Agencies will continue to conduct RM&E to provide information on juvenile fish transportation and delayed mortality*", and the 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action of the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration (dated May 2005). Specifically, the Implementation Plan, under the Hydropower Action Effectiveness Research section (page 40), they state "*Advance the understanding of the effectiveness of flow augmentation, spill,* ***transportation****, and system configuration changes on fish survival for each ESU*".

This study also addresses RPAs identified in NOAA's 2000 BiOp including *Action 47* addressing the need for an evaluation of delayed mortality (D) of transported versus inriver migrating juvenile anadromous salmonids, *Action 48* addressing the effects of prior transport as smolts on the homing of adults, *Action 49* addressing the effects of the timing of transport release so that fish arrive at the estuary at the optimum time, *Action 185* aimed at defining juvenile migrant survival for both transported and nontransported migrants including a comparison of SARs of both groups to estimate D, and *Action 187* to evaluate relationships between ocean entry timing and SARs for transported and downstream migrants.

BACKGROUND

Research to evaluate the effects of transporting juvenile salmonids around dams began over 30 years ago (Ward et al. 1997). Evaluations of transportation of yearling Chinook salmon and steelhead were conducted from various Snake River dams from 1968 through 1980. In addition, transportation of subyearling Chinook salmon and steelhead was evaluated at McNary Dam on the Columbia River from 1978 through 1983.

From these early studies, the apparent benefits of transportation varied by species. For subyearling Chinook salmon and steelhead, results consistently showed that more marked/transported fish returned to the point of release than did marked fish released to migrate in-river. However, for yearling Chinook salmon, study results were less consistent. Results from the earliest studies, during 1968-73, demonstrated conclusively that significantly more marked fish that were transported returned to the point of marking than did fish released to migrate in-river (Ebel et al. 1973, Slatick et al. 1975, Ebel 1980). However, studies conducted between 1976 and 1980 were inconclusive as very low numbers of marked adults returned from either group (Park 1985).

Matthews (1992) postulated that severe physical traumas suffered by smolts during collection and marking were a primary cause of low returns of marked yearling Chinook salmon adults during the 1976-80 studies. From 1981 through 1984, the COE and fisheries agencies addressed this problem by modifying or otherwise improving many features of the smolt collection and bypass systems at dams, particularly at Lower Granite Dam. Moreover, the preanesthetic system of handling and marking smolts (Matthews et al. 1997) was introduced at Lower Granite Dam in 1983. This system eliminated much of the major physical traumas associated with the handling and marking process. All indications suggest that the modifications and improvements increased survival substantially.

A study to re-evaluate smolt transportation of yearling Chinook salmon and steelhead migrants from the Snake River, after the substantial modifications to collection and bypass facilities were made, was initiated at Lower Granite Dam in 1986. Yearling Chinook salmon and steelhead smolts were marked in 1986 and 1989 at Lower Granite Dam. Approximately one-half of the smolts were placed in barges at Lower Granite Dam and released below Bonneville Dam. The remainder were trucked to a release site downstream from Little Goose Dam to continue their in-river migration. Although significantly more marked adults of both species returned from those fish barged compared to fish that migrated in-river, concern was raised that the studies were flawed because the in-river migrating fish were transported to below Little Goose Dam (Ward et al. 1997). Further, in-river conditions were not considered optimal for the survival of in-river migrating fish; therefore, efficacy of in-river migration was not fairly evaluated.

To address these concerns, we began a study on yearling Chinook salmon at Lower Granite Dam in spring 1995. In 1995, 1996, 1998, and 1999, we PIT tagged transport and in-river-migrating wild and hatchery yearling Chinook salmon smolts. No yearling fish were tagged in 1997 due to very depressed smolt numbers that year. By 2000, we had sufficient adult returns from fish PIT-tagged in 1995, 1996, and 1998 to suggest some relationship between SARs and detection histories. In general, the more often fish were detected (bypassed), the lower the SARs (Williams et al. 2005). Among in-river-migrating Snake River fish, those not detected at a transport collector dam generally had the highest SARs, except for fish bypassed only at Lower Granite Dam. We began the recent studies in 1995 without this knowledge. We adjusted our study design beginning in 2000, tagging and releasing more fish into the Lower Granite Dam tailrace to assure more fish in the non-detected or non-bypassed category. Additionally, in 2000, 2002, and 2003, we only PIT tagged transport and in-river groups of wild yearling Chinook salmon and steelhead smolts as sufficient numbers of hatchery fish were tagged above the dam to evaluate transportation of hatchery fish (Berggren et al. 2005). In 2001, due to extremely low flows, we only tagged transport groups of both species.

Results from our latest tagging efforts (2003) will provide new data to assess in-river migration and transportation to determine what strategies will provide the highest adult returns of anadromous salmonids to the Snake and Columbia Rivers. We will integrate results with concurrent in-river-smolt-survival studies (Muir et al. 2001), and using the results from these combinations of studies, provide estimates of *D* for the various groups of study fish. Furthermore, as *D* has been shown to vary temporally within the migration season (Williams et al. 2005, Muir et al. *In press*), we will estimate *D* on a weekly basis, as data allows.

Smolts that are transported typically take from 2 to 4 weeks to migrate from Lower Granite to Bonneville Dam, while barged fish take < 2 days (Williams et al. 2005). Thus, they likely face considerably different conditions upon ocean entry, a critical time in their life cycle (Percy 1992). Based on hatchery yearling Chinook salmon PIT-tagged above Lower Granite Dam or wild yearling Chinook salmon tagged at Lower Granite Dam, and either transported from Lower Granite Dam or returned to the river, *D* varies widely within a season as well as from year to year (Figs. 1) (Muir et al. *In press*). Similar findings were reported by Williams et al. (2005). However, data on wild fish is limited, particularly for steelhead.

Congleton et al (2005) reported that wild yearling Chinook salmon that migrated in-river grew 6 and 8 mm in 2002 and 2003, respectively during their migration from Lower Granite and Bonneville Dams, a migration that typically takes 2 to 4 weeks (Fig. 2). Hatchery yearling Chinook salmon were found to exhibit similar growth during their migration. This finding would differentially affect the vulnerability of transported and in-river migrating smolts to size-selective predation. Northern pikeminnow (*Ptychocheilus oregonensis*), the most abundant smolt predator in the Columbia River, particularly below Bonneville Dam (Ward et al. 1995), have been shown to be size selective predators (Poe et al.1 1991, Shively et al. 1996).

Thus, transported smolts arrvive to below Bonneville Dam at a different time and size than fish that migrate in-river and this likely affects their survival from below Bonneville Dam to return as adult (*D*).

APPROACH

Objective 1

Compare SARs of PIT-tagged wild yearling Chinook salmon and wild steelhead smolts barged from Lower Granite, Little Goose, and Lower Monumental Dams to below Bonneville Dam with those released into the Lower Granite Dam tailrace.

In 2000, we began marking wild yearling Chinook salmon and wild steelhead smolts for a 3-year study to compare the adult returns to Lower Granite Dam between marked smolts transported from Little Goose Dam to below Bonneville Dam and those allowed to migrate in-river from the tailrace of Lower Granite Dam. Because of low flows in 2001, we only marked wild yearling Chinook salmon and wild steelhead smolts for an index group of smolts transported from Lower Granite Dam (no in-river control group). In 2002 and 2003, we continued the study begun in 2000 and added a transport group from Lower Granite Dam. Adults from these juvenile marking years will return through 2006.

Task 1:

<u>Monitor PIT tag detections of wild adult Chinook salmon and steelhead and analyze adult return data.</u>

Lower Granite Dam will serve as the primary detection site for adults. Data acquired from other areas will be considered ancillary. To analyze results, statistical tests will be applied when adult returns for the study are complete. Confidence intervals for the T/I will be calculated using the ratio of SAR estimates (Burnham et al. 1987) and their associated empirical variance. The study will also produce seasonal trends in SARs and T/Is and an overall, statistically-bound T/I estimate for both wild species at Lower Granite Dam. Additionally, we will use regression analyses to correlate T/Is with a number of variables related to hydropower system operation and time of ocean-entry. We will integrate our SAR data with in-river survival estimates from BPA funded studies (using the Single-Release Model)(Muir et al. 2001) and use the information from these combination of studies to estimate *D*, on a weekly basis if data allows.

Task 2:

Examine PIT-tag detection histories of adults as they migrate upstream through the hydropower system.

Currently, Bonneville, McNary, Priest Rapids, Ice Harbor, and Lower Granite Dams are equipped with adult PIT-tag detection systems (Harmon et al. 2003) and detection systems are planned for installation in other dams in the future. At these dams, all PIT-tagged fish passing through the fish ladders will likely be detected. Detection systems are also in place at many hatcheries in the Columbia River Basin.

To evaluate if transportation affects the homing of returning adults, we will compare the PIT-tag detection histories of transported and non-transported adult study fish as they pass upstream through PIT-tag detection systems in the Basin.

Objective 2

PIT-tag transport index groups of wild yearling Chinook salmon and wild steelhead smolts at Lower Granite Dam.

In 2007, we propose to PIT tag wild Snake River yearling Chinook salmon and wild steelhead to provide statistically valid transport SARs on a temporal (e.g. weekly) basis. For both yearling Chinook salmon and steelhead, PIT-tagged fish will represent the composite population of wild fish collected and transported from Lower Granite Dam. This will provide a statistically-bound point estimate of transport SAR for each species, both a seasonal average as well as multiple estimates within the season.

Task 1.1:

PIT tag wild yearling Chinook salmon and wild steelhead smolts in spring 2006 to establish transport index groups at Lower Granite Dam.

Sample Size Calculation

For a transport index group at Lower Granite Dam, the number of PIT-tagged fish required to estimate the SAR of the group can be determined from the following equation:

$$N = (z_{\alpha/2})^2 * SAR * (1 - SAR) / w^2$$

where:

N = the number of PIT-tagged juveniles required in the transport group at Lower Granite Dam.

SAR = the expected smolt-to-adult return rate.

w = desired precision of the estimate, expressed as ½ the width of a (1- α) x 100% confidence interval.

Thus, with α = 0.05 and expected SAR for the transport group of 0.01 (1.0%), the following table gives the number of PIT-tagged fish required to achieve various levels of precision:

Half-width of 95% confidence interval on estimated SAR	Number of PIT-tagged fish required in release group
0.0020	9,508
0.0025	6,085
0.0030	4,226
0.0035	3,105

Therefore, we will PIT tag and release a transport index group of each species each week at Lower Granite Dam in spring 2007 as long as sufficient numbers of fish are available. Based on availability of fish passing Lower Granite Dam in past years, we anticipate that we can tag 6,000-fish groups of wild Chinook salmon for four or five weeks at the peak of the migration. Wild steelhead migration patterns are more variable from year to year, but barring a very large spike in the migration corresponding to a large runoff event, we anticipate tagging four or five weekly groups of 4,000-6,000 wild steelhead.

The population collected at Lower Granite Dam will be sampled at levels to permit marking a constant rate of fish throughout the entire outmigration. The percentage of the daily collection we handle will depend upon the number of fish collected. Hatchery smolts of both species will be sorted and returned to the Lower Granite Dam raceways for transport.

As in the past, all handling/marking will be done using preanesthesia techniques (Matthews et al. 1997). After the fish are anesthetized, they will be gravity-transferred in water into the sorting building as is done at the primary fish-sampling facilities at dams.

Objective 3

Recapture in-river migrants at Bonneville Dam that have been previously PIT-tagged and measured at Lower Granite Dam and re-measure to estimate growth during migration.

During 2007, studies funded by Bonneville Power Administration will include wild and hatchery yearling Chinook salmon and steelhead tagged and measured at Lower Granite Dam and released into the tailrace (i.e., "in-river", not transported). We will enter the PIT-tag codes of these fish into the sort-by-code system (Marsh et al. 1999) at Bonneville Dam for recapture. We will record the date of recapture and the fork length (mm) for each recaptured fish and compare these with date and length at Lower Granite Dam to calculate growth (mm) and travel time (days) between Lower Granite Dam and Bonneville Dam. Mean growth and travel time will be calculated for the season as a whole and for segments of the season (at least early, middle, and late and probably weekly).

Sample sizes

We anticipate that around 10,000 PIT-tagged wild Chinook salmon and 40,000 PIT-tagged hatchery Chinook salmon will be released into the tailrace of Lower Granite Dam in 2007. Based on detection rates in 2005, we anticipate that 5% of these fish (500 wild and 2,000 hatchery fish) will encounter the sort-by-code system at Bonneville Dam. Based on growth data for wild Chinook salmon sampled in 2002 and 2003, we anticipate that a sample of 100 fish will provide a mean growth estimate with a 95% confidence interval of +/- 1 mm. Thus, by sampling every wild Chinook salmon (from above) that encounters the sort-by-code system and one of every four hatchery

Chinook salmon, we anticipate that we can make estimates of mean growth with this precision for five temporal groups within the migration season.

FISH REQUIREMENTS FOR FY 2007

Lower Granite Dam

We will PIT tag 4,000 to 6,000 wild yearling Chinook salmon and wild steelhead smolts each week (as long as sufficient numbers are available to monitor the temporal smolt-to-adult return rates of transported fish (Objective 2).

SCHEDULE

Activity	FY07	Outyears
Objective 1		
Adult detection monitoring	Mar-Dec	Same
Objective 2		
Juvenile fish Tagging and release	April-June	Same
Objective 3		
Recapture fish at Bonneville Dam	April-June	Same

PROJECT IMPACTS, FACILITIES, AND EQUIPMENT

1. COE shall provide maintenance and repair of the adult collection facility at Lower Granite Dam.
2. Coordination with operations for smolt marking will be required at Lower Granite.
3. We will require exclusive use of at least three (possibly four) of the upstream raceways at Lower Granite Dam to collect and hold study fish.
4. Use of the sort-by-code system at Bonneville Dam will be required.

PROJECT PERSONNEL AND DUTIES

Jerrel Harmon--biologist in charge of all field duties.

Douglas M. Marsh--biologist and principal investigator.

Neil Paasch--biological technician.

Kenneth McIntyre--biological technician.

Kenneth Thomas--biological technician.

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. A draft report for spring/summer Chinook salmon will be provided to the COE by 15 November each year, with a final report provided by 15 March the following spring. A draft report for steelhead will be provided to the COE by 15 August each year, with a final report provided by 15 December. In this way, complete returns for each age class of adults can be included in the final report for each study year. Results will also be published in appropriate scientific journals.

REFERENCES

Action Agencies (U. S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration). 2004. Final Updated Proposed Action for the FCRPS Biological Opinion. November 24, 2004. Available at http://www.salmonrecovery.gov/

Berggren, T., H. Franzoni, L. Basham, P. Wilson, H. Schaller, C. Petrosky, K. Ryding, E. Weber, and R. Boyce. 2005. Comparative survival study (CSS) of PIT tagged spring/summer Chinook, 2003/04 Annual Report, Migration years 1997-2002, Mark/recapture activities and bootstrap analysis. Report to the Bonneville Power Administration, Portland, OR.

Budy, P., G. P. Thiede, N. Bouwes, C. E. Petrosky, and H. Schaller. 2002. Evidence linking delayed mortality of Snake River salmon to their earlier hydropower system experience. North American Journal of Fisheries Management 22:35-51.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5:1-437.

Congleton, J. L., J. Evavold, D. Jones, M. Santora, B. Sun, and T. Wagner 2005. Evaluation of physiological condition of transported and inriver migrating juvenile salmonids and effects on survival (DACW68-00-C-0030) Annual Report, 2003. Report of Idaho Cooperative Fish and Wildlife Research Unit to the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.

Ebel, W. J. 1980. Transportation of chinook salmon, *Oncorhynchus tshawytscha*, and steelhead, *Salmo gairdneri*, smolts in the Columbia River and effects on adult returns. Fish. Bull. 78:491-505.

Ebel, W. J., D. L. Park, and R. C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull. 71:549-563.

Harmon, J. R. 2003. A trap for handling adult anadromous salmonids at Lower Granite Dam on the Snake River, Washington. North American Journal of Fisheries Management 23:989:992.

Marsh, D. M., G. M. Matthews, S. Achord, T. E. Ruehle, and B. P. Sandford. 1999. Diversion of salmonid smolts tagged with passive integrated transponders from an untagged population passing through a juvenile collection system. North American Journal of Fisheries Management 19:1142-1146.

Matthews, G. M. 1992. Potential of short-haul barging as a bypass release strategy. Unpublished issue paper, 56 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, Washington 98112-2097.)

Matthews, G. M., N. N. Paasch, S. Achord, K. W. McIntyre, and J. R. Harmon. 1997. A technique to minimize the adverse effects associated with handling and marking salmonid smolts. Prog. Fish Cult. 59:307-309.

Muir, W. D, S. G. Smith, J. G. Williams, and E. E. Hockersmith. 2001. Survival estimates for migrant yearling Chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia Rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

Muir, W. D., D. M. Marsh, B. P., Sandford, S. G. Smith, and J. G. Williams. *In press*. Post-hydropower system delayed mortality of transported Snake River stream-type Chinook salmon: Unraveling the mystery. Transactions of the American Fisheries Society.

NOAA Fisheries. 2004. Biological Opinion: Consultation on Remand for Operation of the Columbia River Power System and 19 Bureau of Reclamation Projects in the Columbia Basin. November 30, 2004. Available at http://www.salmonrecovery.gov

Park, D. L. 1985. A review of smolt transportation to bypass dams on the Snake and Columbia Rivers. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H-0034, 66 p. (Available from Northwest Fisheries Center, 2725 Montlake Blvd. E., Seattle, Washington 98112-2097.)

Percy, W. G. 1992. Ocean Ecology of North Pacific Salmonids. Univ. Wash., Seattle. 179 p.

Poe, T. P., h. C. Hansel, S. Vigg, D. E. Palmer, and L. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Shively, R. S., T. P. Poe, and S. T. Sauter. 1996. Feeding response by northern squawfish to a hatchery release of juvenile salmonids in the Clearwater River, Idaho. Transactions of the American Fisheries Society 125:230-236.

Slatick, E., D. L. Park, and W. J. Ebel. 1975. Further studies regarding effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull. 73(4):925-931.

Ward, D. L., R. R. Boyce, F. R. Young, and F. E. Olney. 1997. A review and assessment of transportation studies for juvenile chinook salmon in the Snake River. North American Journal of Fisheries Management 17:652-662.

Ward, D. L., J. H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and Lower Snake River. Transactions of the American Fisheries Society 124:321-334.

Williams, J. G., S. G. Smith, R. W. Zabel, W. D. Muir, M. D. Scheuerell, B. P. Sandford, D. M. Marsh, R. McNatt, and S. Achord. 2005. Effects of the federal Columbia River power system on salmon populations. NOAA Technical Memorandum, NMFS-NWFSC-63.

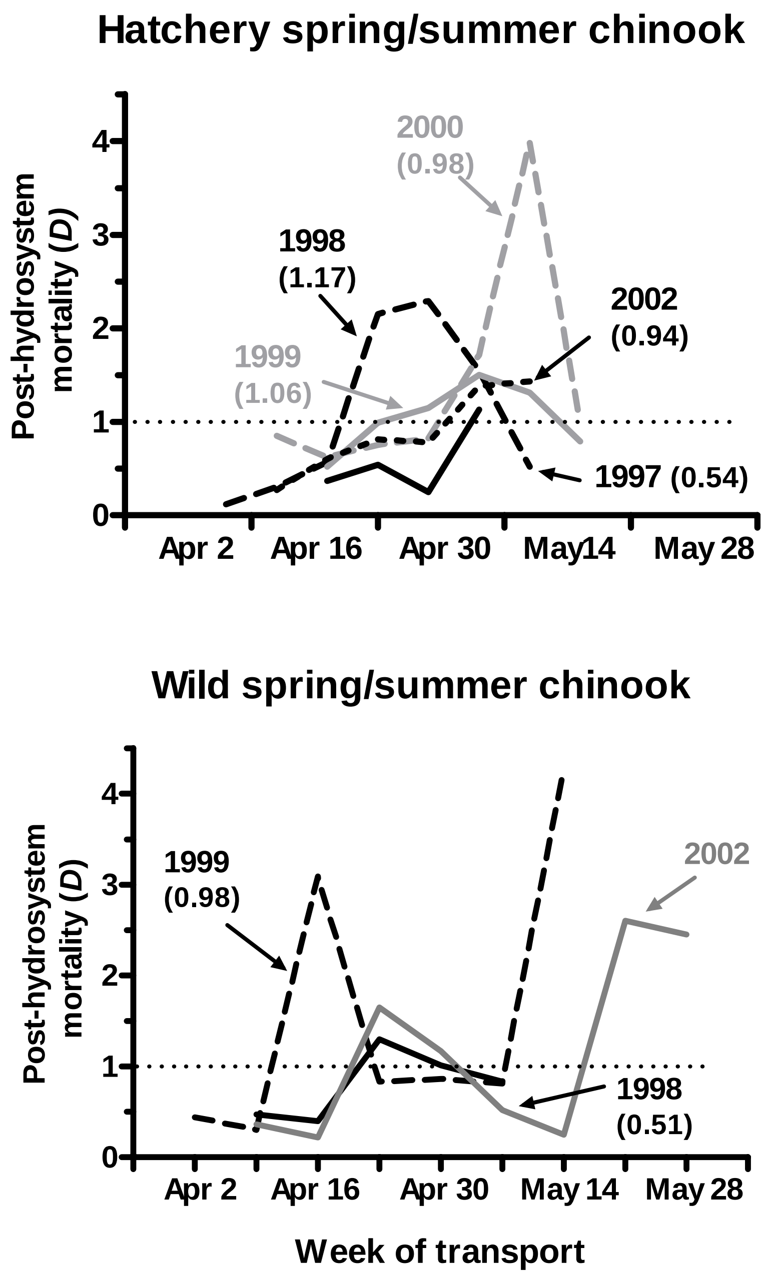

Figure 1. Weekly estimates of post-hydrosystem mortality (*D*) for hatchery (tagged above) and wild (tagged at) yearling Chinook salmon that were transported or returned to the river at Lower Granite Dam. Annual average estimate of *D* in parenthesis.

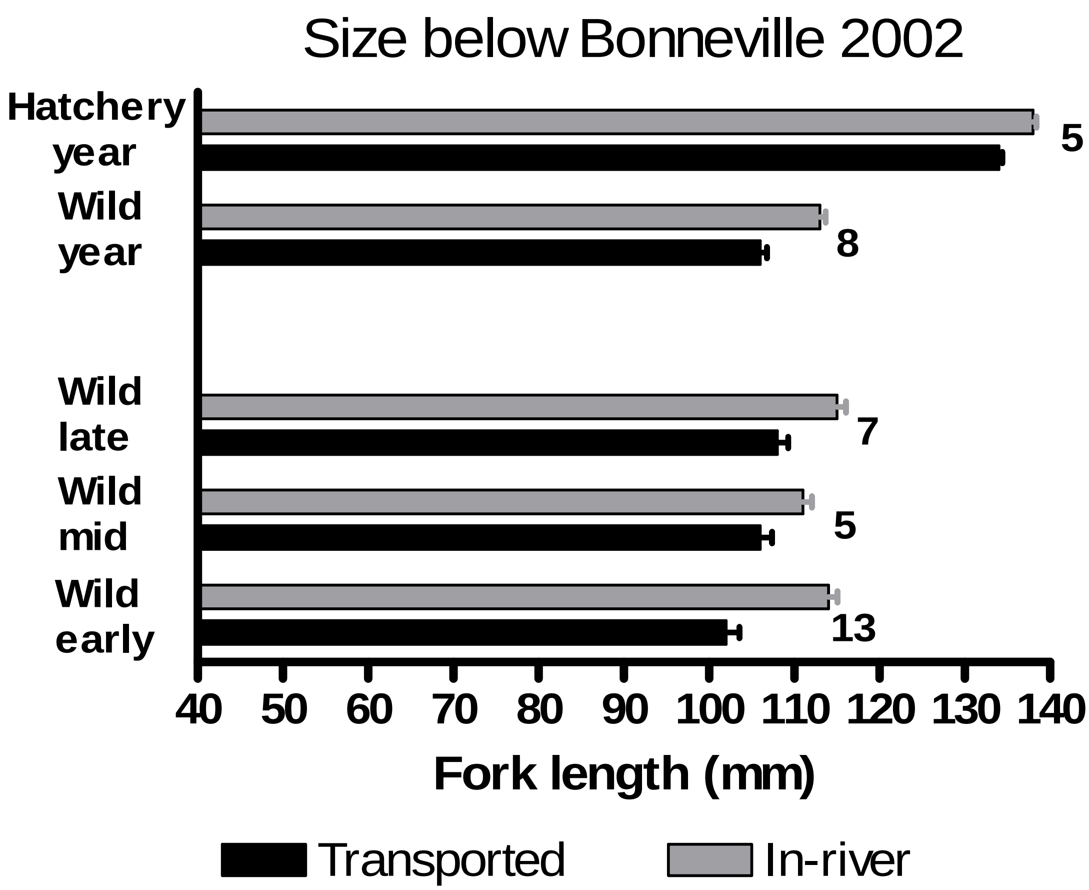

Figure 2. Fork length (mm) of wild yearling Chinook salmon on arrival below Bonneville Dam in 2002 that were transported or migrated in-river. The yearly average (top of graph), seasonal average (bottom), and change in length (number next to bars) are shown. Data provided by J. Congleton, UofI.