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Run-timing, Escapement, and Harvest of Upriver Bright Fall Chinook Salmon in the Columbia River, 1998 and 2000-2005

Michael A. Jepson*, Matthew L. Keefer, George P. Naughton, Christopher A. Peery

Department of Fish and Wildlife Resources

University of Idaho

Moscow, ID 83844-3141

and

Brian J. Burke

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, WA 98112

*****Corresponding author. Tel.: 1-208-885-4224: fax: 1-208-885-9080

E-mail address: mjepson@uidaho.edu (M.A. Jepson)

Preface

Columbia River upriver bright fall Chinook salmon are a major contributor to Southeast Alaskan and Canadian fisheries and the status of these populations are a concern for Parties to the Pacific Salmon Treaty. The research objectives outlined here fall under consideration of Article X, Section 1, of the Pacific Salmon Treaty. This section addresses research to "investigate the migratory and exploitation patterns, the productivity and status of stocks of common concern and the extent of interceptions". The objectives additionally relate to Chapter 3 of Annex IV regarding management and regulation of Chinook salmon stocks by the United States Chinook Technical Committee (USCTC) of the Pacific Salmon Commission (PSC).

Acknowledgements

We are indebted to many people who provided time and assistance during the course of this study. We especially appreciate the contributions of T. Bjornn and L. Stuehrenberg, who led the early years of the research. K. Tolotti, R. Ringe, M. Morasch, T. Dick, D. Joosten, C. Williams, C. Nauman, S. Lee, C. Boggs, C. Morat, A. Pinson, T. Goniea, B. High, E. Johnson, P. Keniry, M. Feeley, B. Hastings, and M. Heinrich helped with field operations and the collection and processing of telemetry data at the University of Idaho. A. Matter, M. Moser, S. McCarthy, T. Bohn, and K. Frick, National Marine Fisheries Service, helped with data management. We thank E.O. Garton, University of Idaho, for his assistance with the statistical components of this report. We also thank personnel at the Grant, Chelan, and Douglas County Public Utility Districts for cooperation with telemetry data. C. Brun, Confederated Tribes of Warm Springs, Oregon, provided escapement estimates for the Deschutes River during 2001-2005. The Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife provided tag recovery information from their annual spawning ground surveys. Paul Hoffarth, WDFW, was particularly helpful in providing recent escapement estimates for the Yakima River and Hanford Reach. Stuart Ellis, Columbia River Inter-Tribal Fisheries Commission, provided information about the Zone 6 gillnet fisheries. The U.S. Army Corps of Engineers provided funding for years 1998 and 2000-2003; we thank D. Clugston, M. Shutters, R. Dach, M. Langeslay, and T. Mackey for their assistance. The USCTC and the Bonneville Power Administration provided funding for this research during 2004 and 2005 for which we are very grateful.

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Abstract

During 1998 and 2000-2005, we radiotagged a total of 6,079 adult fall Chinook salmon *Oncorhynchus tshawytscha* at Bonneville Dam and monitored them as they migrated to upstream spawning sites in the Columbia and Snake River basins. We divided the 'upriver bright' (URB) stock of fall Chinook salmon into five subgroups: the Deschutes, Yakima, and Snake rivers, the Hanford Reach, and sites upstream from Priest Rapids Dam. We calculated run-timing statistics past Bonneville Dam during 15-day intervals and estimated annual escapement and harvest values for each subgroup.

The relative abundance of adult fish returning to sites upstream from Priest Rapids Dam was as much as half of the run during early August but decreased steadily during the remainder of each migration season. Deschutes, Yakima, and Snake river subgroups typically comprised small (≤13%), but relatively constant proportions of fall Chinook salmon throughout each migration season. During all years, Hanford Reach fish made up increasingly large proportions of the run at Bonneville Dam as each migration season progressed, averaging over three-quarters of the run in early October.

Fall Chinook salmon from the Hanford Reach were estimated to be the most abundant of the five URB subgroups. All URB subgroups increased in abundance compared to estimated 1998 levels; the Snake River subgroup increased by as much as five times by 2004. Escapement estimates for the Hanford, Snake River, and 'above Priest Rapids' subgroups were estimated to have declined from 2004 to 2005 while those for the Deschutes and Yakima subgroups were estimated to have increased. The minimum coefficients of variation about escapement estimates were observed for the Hanford and 'above Priest Rapids Dam' subgroups, averaging approximately four and six percent, respectively, for the seven study years. Coefficients of variation about escapement estimates averaged approximately 10% for the Snake River subgroup, 18% for the Deschutes River subgroup, and 20% for the Yakima River subgroup.

Harvest estimates ranged between 5 and 41% among all year-subgroup combinations. With all years averaged, nearly one-third of most URB subgroups that passed Bonneville Dam were estimated to have been harvested in a mainstem Columbia River fishery. Fall Chinook salmon returning to sites upstream from Priest Rapids Dam were estimated to have been harvested at a lower mean rate (20%) during the seven study years, probably because of its relatively early run-timing, coupled with the start of the mainstem fishery in late August each year.

Introduction

Three Columbia River fall Chinook salmon populations are used as indicator stocks of escapement by the United States Chinook Technical Committee (USCTC) of the Pacific Salmon Commission (PSC): the Hanford Reach, the Deschutes River, and the Lewis River populations. Lewis River fall Chinook salmon are commonly referred to as "lower river brights" (Marshall et al. 1995). The Lewis River enters the Columbia River downstream from Bonneville Dam — the salmon collection site for our radiotelemetry research—so this stock was excluded from our analyses. We did collect and monitor fall Chinook salmon that migrated to the Hanford Reach of the Columbia River and to the Deschutes River. These two indicator stocks are considered "upriver brights" (URB) because their flesh is characterized by a bright color and high oil content during their upstream migration (Myers et al. 1998; Marshall et al. 1995). For this report, we further divided URB fall Chinook salmon into five subgroups: those returning to the Deschutes, Snake, and Yakima rivers, to the Hanford Reach, and to spawning sites upstream from Priest Rapids Dam (Figure 1). Information about these subgroups should assist management of the Southeast Alaska and northern British Columbia/Queen Charlotte Island Aggregate Abundance-based Management (AABM) fisheries.

During 1998 and 2000-2005, we radiotagged adult fall Chinook salmon at Bonneville Dam and monitored them as they migrated to upstream spawning sites. We used these telemetry data to address the research objectives outlined by the USCTC in 2003, which include Total Mortality Estimates (Theme 1), Improvement of Escapement Estimates to USCTC Standards (Theme 2), and Biologically-based Escapement Goals (Theme 3). Specifically, we present run-timing characteristics and escapement estimates for the five URB subgroups. We additionally address components of Themes 1 and 5 (Stock Composition) using a combination of telemetry monitoring and fishery recaptures to estimate the subgroup composition of adult fall Chinook salmon harvested downstream from McNary Dam during the seven study years.

Objectives

1. Use radiotelemetry to estimate total escapement of fall Chinook salmon to the Deschutes, Snake, and Yakima rivers, the Hanford Reach of the Columbia River, and areas upstream from Priest Rapids Dam on the Columbia River by monitoring adult fish collected and radiotagged at Bonneville Dam during 1998 and 2000-2005.
2. Use basin-wide monitoring of radio-tagged adult salmon and recoveries of radio transmitters obtained via a reward program to estimate contribution of fall Chinook salmon from indicator stocks to Columbia River mixed-stock fisheries during 1998 and 2000-2005.

Methods

Fish Trapping, Tagging, and Monitoring

Adult fall Chinook salmon were trapped at Bonneville Dam (river kilometer, rkm, 235) in the adult fish facility (AFF) adjacent to the Washington-shore fish ladder as they migrated upstream in the Columbia River (Figure 1). Each day that fish were tagged, a weir was lowered into the ladder to divert fish into the AFF via a short secondary ladder. Once inside the facility, fish were either diverted into anesthetic tanks for tagging or returned to the main ladder without handling.

During the seven study years, radio transmitters were placed in a total of 6,079 fall Chinook salmon (Table 1). On average, radio-tagged fish represented 0.3% of the fall Chinook salmon counted passing Bonneville Dam each year (USACE 2004; 2005 data were obtained from the DART web page - http://www.cbr.washington.edu/dart/adult.html). Fish were tagged throughout each run in approximate proportion to long-term average counts at Bonneville Dam; variability in daily counts and annual run timing precluded precise proportional sampling (Figure 2). Fall Chinook salmon were not tagged during August 1998 and were tagged on only five days during August 2004 and 2005 because of regulations restricting handling of adult fish during periods of high water temperatures (≥ 22.2 ºC; 72 ºF) at the Bonneville facility.

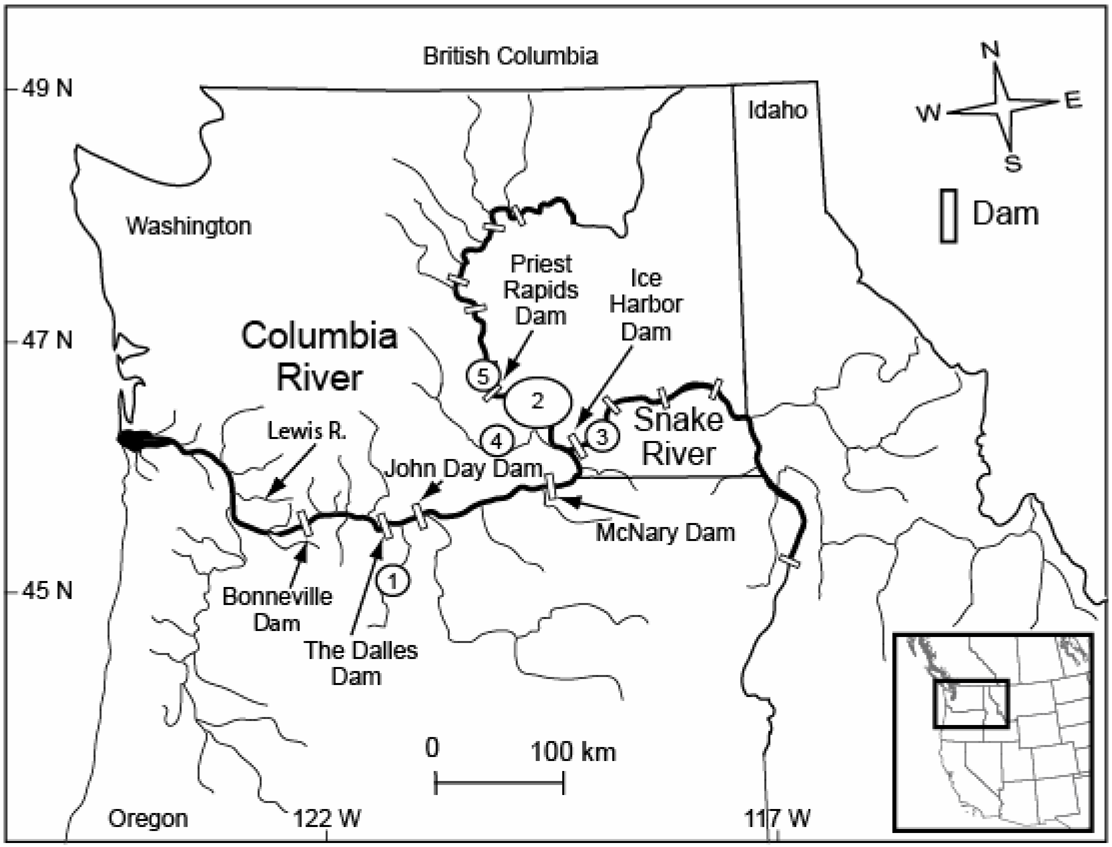

Figure 1. Map of the Columbia River basin study area including mainstem dams and major tributaries. Studied "upriver bright" fall Chinook salmon populations included: 1) Deschutes River, 2) Hanford Reach, 3) Snake River, 4) Yakima River, and 5) Columbia River upstream from Priest Rapids Dam. All major tributaries upstream from Bonneville Dam were monitored with radio-telemetry (see Appendix 1).

Protocols for fish trapping, handling, intra-gastric insertion of radio transmitters, and fish recovery were the same in all years and are described in Keefer et al. (2004a). Samples were not truly random because only fish passing via the Washington-shore ladder were sampled, proportions sampled each day varied, and no fish were sampled at night. To accommodate transmitter sizes (see Keefer et al. 2004a for transmitter types and dimensions), we also did not tag jack (precocious adult) salmon with fork length < 50 cm. Among fall Chinook salmon, we selected for 'upriver bright' fish and limited our collection of sexually mature 'Tule' fall Chinook salmon. Tules return only a short distance upstream to Bonneville reservoir hatcheries (Myers et al. 1998), and during times of high Tule passage, we selected against these fish to maximize sample sizes destined for upstream locations.

Table 1. Number of adult fall Chinook salmon outfitted with radio transmitters at Bonneville Dam in 1998 and from 2000-2005 that were released downstream from the dam, into the Washington-shore ladder, or into the dam forebay.

Release Site	1998	2000	2001	2002	2003	2004	2005	**Total**
Downstream from Bonneville Dam	1,032	745	561	755	665	571	0	**4,329**
WA ladder	0	0	0	0	1	35	600	**636**
Bonneville Dam forebay	0	373	431	310	0	0	0	**1,114**
Total	**1,032**	**1,118**	**992**	**1,065**	**666**	**606**	**600**	**6,079**

Tagging methods were modified during 2000-2004 to include use of an automated system (McCutcheon et al. 1994) that identified fish with passive integrated transponder (PIT) tags as they passed through the AFF trap. PIT tags indicated if and where fish were tagged as juveniles. Only approved groups of PIT-tagged fish were available for radiotagging, and codes for those fish were imported into the automatic detection system in the trap. We attempted to radiotag as many PIT-tagged (referred to as known-source) fish as possible within the 2000-2004 tagging schedules but we did select for any known-source fish during 2005. The proportions of radio-tagged fall Chinook salmon that had been PIT-tagged as juveniles were: < 1% (2000), 13% (2001), 6% (2002), 4% (2003), and 4% (2004). Known-source fish were radiotagged as they were trapped and fish without PIT tags made up the remainders of each daily sample. We excluded known-source fish from run-timing and escapement analyses because they were sampled in disproportionate abundance to the run. Most known-source fall Chinook salmon were from the Snake River, and annual escapement and harvest estimates for these groups are reported in Keefer et al. (2005).

Radio-tagged fall Chinook salmon were monitored as they passed each of the eight Columbia and Snake river mainstem hydro-projects operated by the U.S. Army Corps of Engineers (USACE), and at Priest Rapids Dam, operated by Grant County Public Utility District. In addition, numerous receiver sites were used to monitor fish movements in and near the major tributaries of the lower Columbia and Snake rivers (Figure 1, Appendix 1). Three fixed receiver sites were used in the Deschutes River during 1998 and 2000-2003: one just upstream from the mouth of the river (rkm 329), the second just downstream from Sherar's Falls (rkm 396), and the third at the Oak Springs Hatchery (rkm 405). During 2004 and 2005, a fourth receiver was added approximately 30 km upstream from the mouth of the Deschutes River (rkm 359).

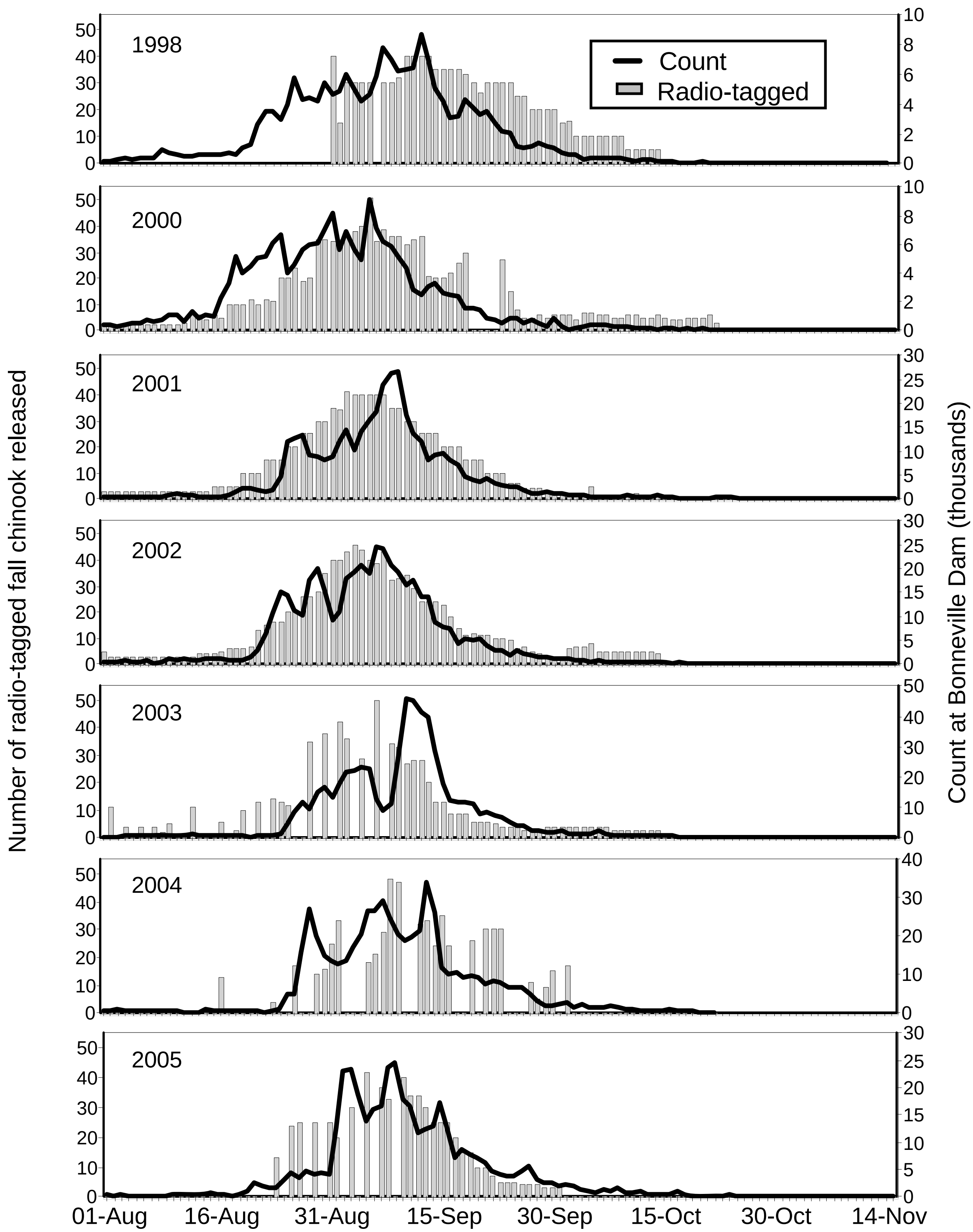

Figure 2. Counts of adult fall Chinook salmon passing Bonneville Dam from 1 August to 15 November 1998, 2000-2005 and the numbers radio-tagged at the dam each year.

Records of tags at the fixed sites within and outside the Deschutes River were used to determine which fish entered and remained in the river during spawning season. Periodic (approximately every two weeks) mobile tracking surveys were made of areas of the Deschutes River with road access during and following spawning periods to record final locations of radio-tagged fish. In 2004 only, a portion of the river not accessible by road (primarily a segment of river approximately 14 km in length just downstream from Mack's Canyon) was mobile tracked by boat. Tags were also retrieved from fish inspected during spawning and carcass surveys conducted by personnel from the Confederated Tribes of the Warm Springs Reservation, Oregon (CTWSRO) and Oregon Department of Fish and Wildlife (ODFW).

Salmon that entered the Hanford Reach of the Columbia River were monitored using two receivers near the upstream end of McNary reservoir, one on the west bank in Richland, WA and one on the east bank in Pasco, WA. Radio-tagged fish were assumed to have returned to the Hanford Reach if they were last recorded on either of these two receivers (i.e., they did not pass Priest Rapids or Ice Harbor dams, or enter the Yakima or Walla Walla rivers). Two tracking surveys were also conducted by boat throughout the Hanford Reach each study year to determine the number of tagged fish in that segment of river during traditional spawning periods. Transmitters were also recovered during Hanford Reach carcass surveys conducted by the Washington Department of Fish and Wildlife (WDFW) biologists each year. Movements of radio-tagged salmon into or from the Yakima River were monitored using a fixed-site receiver and a six-element yagi antenna deployed on the south side of the river, 5.6 km upstream from the mouth.

All fixed tributary sites had a single four-, six- or nine-element yagi antenna connected to an SRX radio receiver. Entrances into and exits from tributaries were inferred from the number and sequence of detections of individual fish at these sites. Typically, one set of detections (two records separated by 30 minutes or less) was interpreted to be an entrance. A second set of detections on the same site (at least 30 minutes later) by the same fish was construed to be an exit. Interpretations were often corroborated or refuted by mobile tracking records within tributaries or by detections at sites other than those within tributaries (i.e., at dams). Still, we could not infer swimming direction of individual migrants with complete certainty based on radio detections at fixed tributary sites alone.

We evaluated potential effects of the radiotagging on fish behavior by comparing the passage success of radio-tagged fall Chinook salmon to untagged fall Chinook salmon. We first calculated the percentage of untagged fish counted at Bonneville Dam (adjusted for fallback; see Boggs et al. 2004) that were also detected at upstream dams. Similarly, we calculated the percent of radio-tagged fish detected at Bonneville Dam that were also detected at an upstream dam. We made identical evaluations expressing values as percentages of counts or numbers of unique transmitters past The Dalles Dam.

Run Composition and Run-Timing Analysis

We assigned individual salmon to specific subgroups based on final locations as determined from telemetry monitoring (e.g., Keefer et al. 2004b). Fish were identified as belonging to individual subgroups either by the location of their final telemetry record in a tributary, or from recapture records from hatcheries, traps, counting weirs, or tributary fisheries. We assumed fish reported as harvested in tributary fisheries originated from those tributaries because Chinook salmon straying rates are generally low (Waples et al. 1991, but also see Quinn et al. 1991). Fish last recorded at the ladder exits of Bonneville, The Dalles, John Day, or McNary dams did not receive stock assignments. Similarly, fish reported to be recaptured in mainstem Columbia River fisheries downstream from McNary Dam did not receive stock assignments.

We calculated the proportion of each URB subgroup passing Bonneville Dam during 15-day intervals (starting 1 August; fall-run start dates are later at upstream dams) to describe changes in proportionate abundance of the subgroups during each tagging season. We used these 15-day proportions to estimate harvest of URB subgroups described later in this report. We calculated migration-timing statistics for individual URB subgroups for each year, all years combined, and all years combined excluding 1998 and 2004-2005 (years when sampling was restricted due to high water temperatures). Specific parameters included: median, mean, quartile, 5^{th} and 95^{th} percentile, coefficient of variation, skewness, and kurtosis (Wuttig and Everson 2001). All variables were based on the date each fall Chinook salmon was radiotagged at Bonneville Dam. We compared run-timing distributions among URB subgroups within and among years using Kruskal-Wallis one-way analyses of variance.

Annual Escapement Estimates

We defined any radio-tagged fall Chinook salmon recaptured or last recorded in a specified tributary or river section as having escaped there. For each URB subgroup, we used the number of fish that passed the nearest downstream dam as the starting population. For example, we used counts of tagged fish that passed The Dalles Dam for estimating escapement to the Deschutes River. We estimated total annual escapement for each URB subgroup using:

$$\hat{E} = \left[\frac{(R+1)}{(M+1)} * (C+1) \right] - 1$$

where $\hat{E}$ is total estimated escapement, *R* is the number of tagged fish last detected ("recaptured") at one of the five subgroup sites, *M* is the number of tagged fish that passed the nearest downstream dam to a URB subgroup, and *C* is the total number of fall Chinook salmon counted at the nearest downstream dam. We adjusted dam counts for fallback and re-ascension events according to Boggs et al. (2004) because these events artificially inflate counts at dams.

Just as we calculated escapement of fall Chinook salmon to the Deschutes River using detections and adjusted counts at The Dalles Dam, we calculated escapement for Yakima River and Hanford Reach fall Chinook salmon using these metrics from McNary Dam. Detections and adjusted counts from Ice Harbor Dam were used to estimate escapement for the Snake River subgroup and escapement to sites upstream from Priest Rapids Dam was estimated using the adjusted counts and number of radio-tagged fall Chinook salmon known to have passed that dam. To estimate escapement upstream from Sherar's Falls in the Deschutes River, we multiplied our annual escapement estimate to the Deschutes River by the proportion of tagged fish last recorded in the Deschutes River upstream from the falls.

We estimated the variance about the proportion of radio-tagged fish migrating to one of the five URB subgroups ($\hat{p} = R/M$) using the formula:

$$v(\hat{p}) = \frac{\hat{p}(1-\hat{p})}{M-1}$$

We estimated the variance about escapement estimates using the formula:

$$v(\hat{E}) = v(\hat{p})C^2$$

We calculated coefficients of variance about escapement estimates using the formula:

$$CV(\hat{E}) = \left(\sqrt{v(\hat{E})} / \hat{E}\right) * 100$$

Finally, we estimated 95% confidence intervals about escapement estimates using the formula:

$$\hat{E} \pm 1.96 * \sqrt{v(\hat{E})}$$

We used bootstrapping with replacement to create an estimated distribution of escapement for each year-subgroup combination. Specifically, we multiplied the unadjusted dam count by two proportions, the proportion of radio-tagged fish both which were assumed to behave binomially.

Composition of Harvested Fish from URB Subgroups

We estimated the number of subgroup-specific fall Chinook salmon harvested in mainstem fisheries between Bonneville and McNary dams (fish recaptured downstream from Bonneville Dam were excluded) using the subgroup-specific proportion of the run that escaped (from run-timing analysis) and the ratio of radio-tagged salmon recaptured in mainstem fisheries downstream from McNary Dam to radio-tagged salmon released at Bonneville Dam. Specifically, we used the formula:

$$H_S = (N_H / N_R) * P_S * C$$

where H_S is the number of subgroup-specific fall Chinook salmon harvested in mainstem fisheries, N_H is the number of tagged fish harvested downstream from McNary Dam, N_R is the number of tagged fish released at Bonneville Dam, P_S is the subgroup-specific proportion of each 15-day block that escaped (from run timing analysis), and C is the total number of fall Chinook salmon counted at Bonneville Dam adjusted for fallback and reascension events. We estimated H_S for each 15-day block throughout the entire run and then summed the estimates across blocks. We added the subgroup-specific harvest to corresponding annual escapement estimates and calculated the percentage of URB subgroups passing Bonneville Dam that were harvested in mainstem fisheries between Bonneville and McNary dams (i.e., $H_S/(H_S + E)$).

Rewards were paid for transmitters voluntarily returned from commercial, sport, and tribal fisheries. The standard reward value printed on all transmitters was US$25 in all years. US$100 rewards were offered for return of a sub-sample of 12 to 19% of the transmitters used in 2000-2002.

Results

Assessment of Tagging Effects

Fall Chinook salmon radiotagged at Bonneville Dam passed dams upstream from Bonneville in higher proportions than did untagged salmon (Figure 3), but we believe this was an artifact of our selecting against Tules and for URBs. When we used adjusted counts (for fallback and re-ascension events according to Boggs et al. 2004) and the number of unique radio-tagged salmon past The Dalles Dam as the denominator (which removed most Tules from the analyses), passage percentages at upstream dams were similar for tagged and untagged salmon (Figure 4).

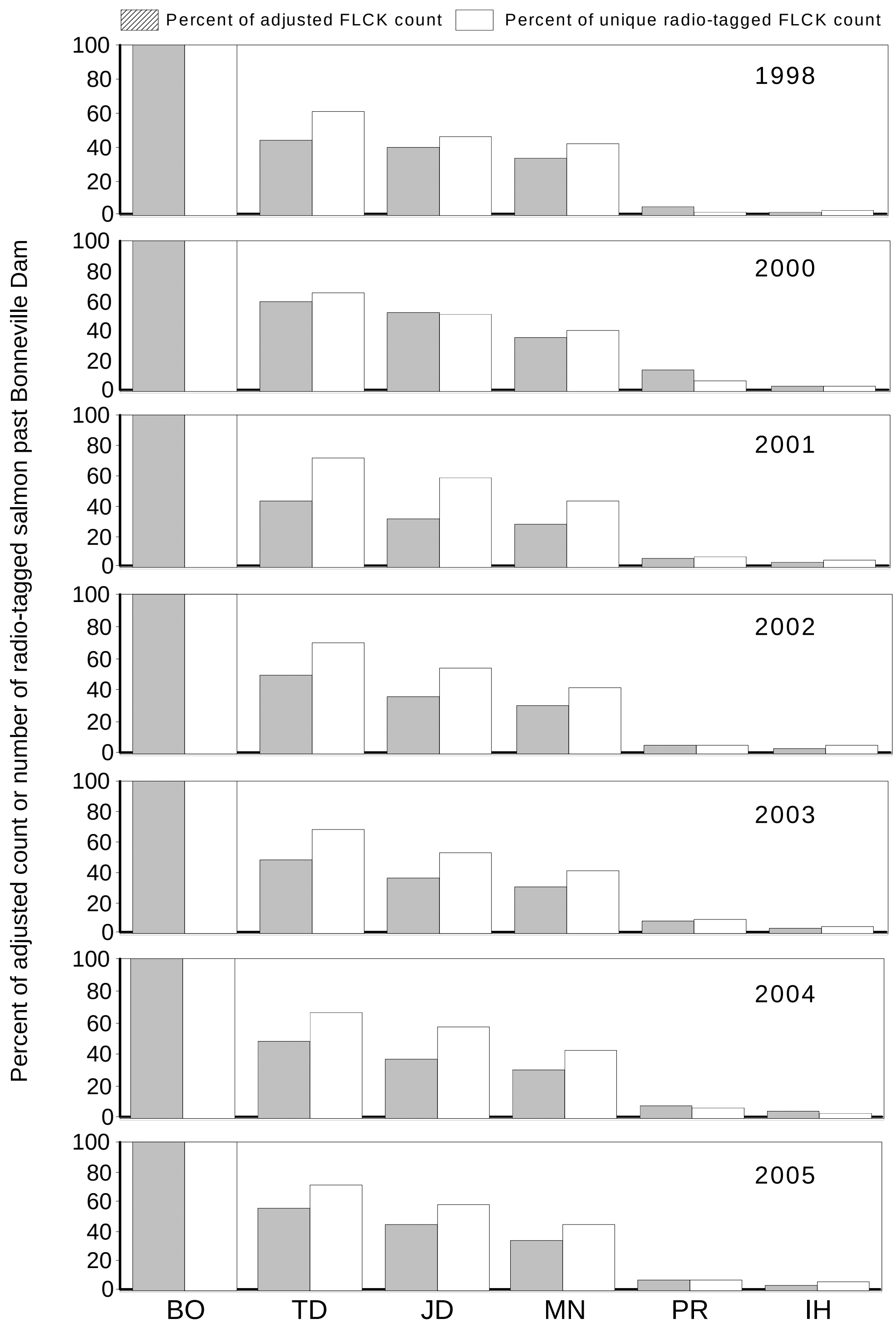

Figure 3. Percentages of adjusted counts or numbers of unique radio-tagged fall Chinook salmon at Bonneville Dam (BO) that passed upstream dams during 1998 and 2000-2005. TD = The Dalles Dam, JD = John Day Dam, MN= McNary Dam, PR = Priest Rapids Dam, IH = Ice Harbor Dam, and FLCK = fall Chinook salmon.

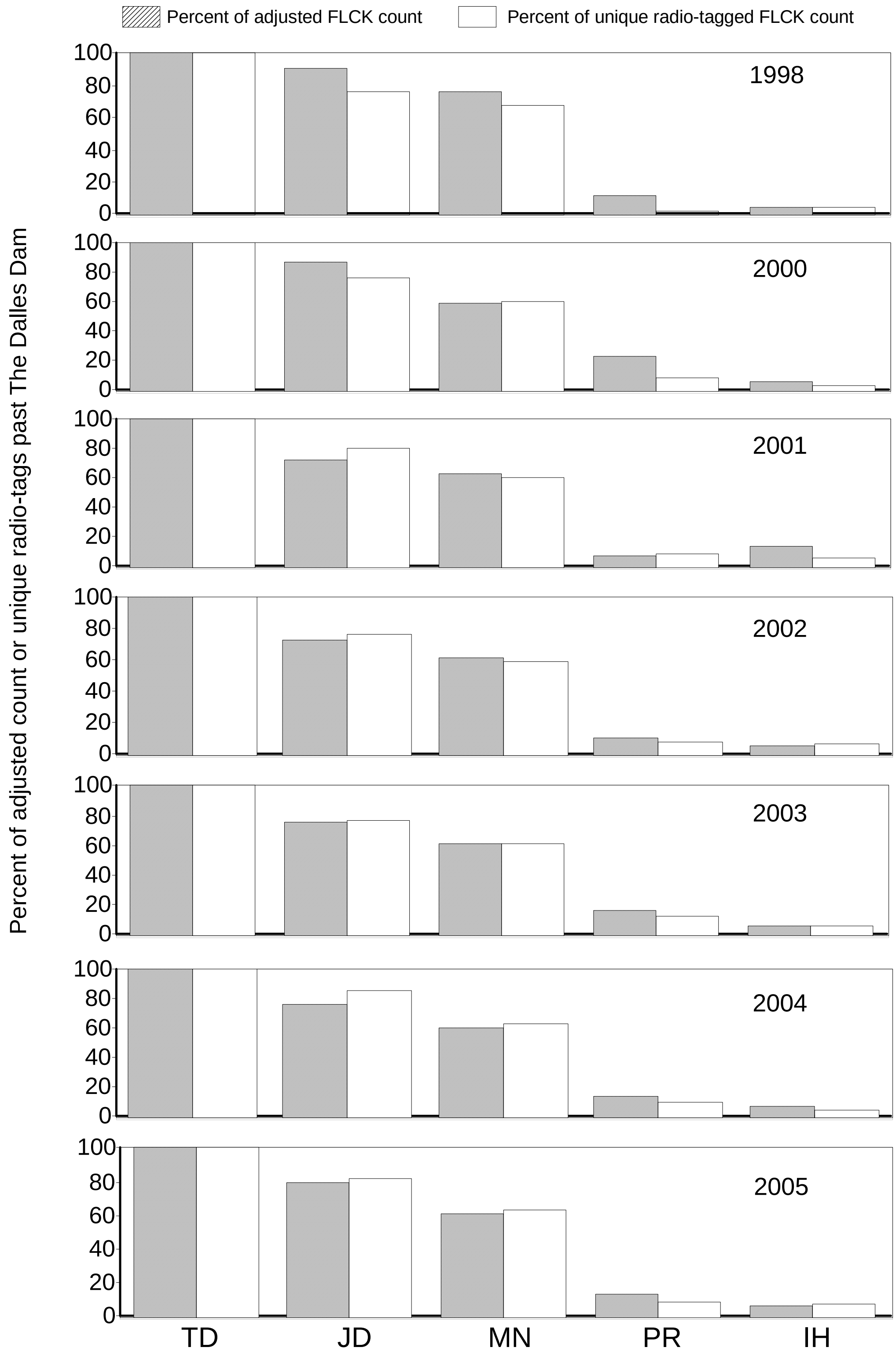

Figure 4. Percentages of adjusted counts or numbers of unique radio-tagged fall Chinook salmon at The Dalles Dam (TD) that passed upstream dams during 1998 and 2000-2005. JD = John Day Dam, MN= McNary Dam, PR = Priest Rapids Dam, IH = Ice Harbor Dam, and FLCK = fall Chinook salmon.

Run Composition and Run-Timing Analyses

The five URB subgroups described in this report were represented by a total of 2,568 radio-tagged fish during the seven years (Table 2), with an average of 73 tagged fish per stock per year (*median* = 46, *SD* = 87). The Hanford Reach subgroup averaged 241 tagged fish per year and the Snake, Yakima, and Deschutes subgroups had means of 25, 27, and 34 tagged fish per year, respectively. The subgroup from above Priest Rapids Dam averaged 40 tagged fish per year. The remainder of each run (labeled as 'Other' in Table 2) was comprised of tagged fish with final observations in Eagle and Herman creeks, the Hood, Wind, Little White Salmon, White Salmon, Klickitat, Umatilla, and Walla Walla rivers as well as at Spring Creek Hatchery. This final group averaged 109 tagged fish per year and represented 23% of all tagged fish that were last recorded at potential spawning sites ('escaped').

The most abundant URB subgroup was from the Hanford Reach and it comprised 46-56% of the run for each year, with an average of 51% for all years combined. The Deschutes, Yakima, and Snake River subgroups each comprised < 10% of any year's run. When all years were combined, the Deschutes, Yakima, and Snake River subgroups averaged 7, 6, and 5% of the run, respectively. The relative abundance of fall Chinook salmon from above Priest Rapids Dam ranged from 2-15% of the run passing Bonneville Dam in any year and averaged 8% for all years combined.

Fish returning to spawning sites upstream from Priest Rapids Dam made up relatively large proportions of tagged Chinook salmon passing Bonneville Dam during early August of years for which we had samples (Figure 5). This group constituted as much as 50% of the run during the first half of August (e.g., in 2001) but that may reflect a strong component of late 'summer-run' fish heading for mid- and upper-Columbia sites. The relative abundance of fish returning to sites upstream from Priest Rapids Dam decreased steadily through each migration season. Deschutes, Yakima, and Snake River subgroups comprised small, but relatively constant proportions of fall Chinook salmon throughout the migration seasons. During all years, Hanford Reach fish comprised increasingly large proportions of the run at Bonneville Dam as the migration season progressed, making up an average of over three-quarters of the run during early October. The remaining stocks, grouped into a single 'Other' category, exhibited mild peaks during early September of most years.

Table 2. Final known distribution of fall Chinook salmon radiotagged at Bonneville Dam in 15 d blocks starting 1 August that returned to the Deschutes, Snake, and Yakima rivers, the Hanford Reach of the Columbia River, upstream from Priest Rapids Dam (> PR), or elsewhere (Other), 1998 and 2000-2005.

Year	15 d Block	Deschutes	Hanford	Snake	Yakima.	> PR	Other	Total
1998	3	31	103	11	4	6	79	234
	4	16	168	7	10	3	76	280
	5	3	84	7	2	1	20	117
	6	1	3					4
	Total	51	358	25	16	10	175	635
2000	1		10	2	1	7	9	29
	2	6	53	2	9	16	32	118
	3	20	150	4	8	20	74	276
	4	10	76	6	2	2	21	117
	5	4	24	2	1		6	37
	6	2	12	1	1	1	1	18
	Total	42	325	17	22	46	143	595
2001	1	7	4	2		15	2	30
	2	10	40	5	10	18	23	106
	3	26	131	24	28	13	68	290
	4	4	76	2	8	4	18	112
	5	3	5			1	3	12
	6		1					1
	Total	50	257	33	46	51	114	551
2002	1	3	7	1	4	14	5	34
	2	12	42	11	13	20	29	127
	3	16	120	18	30	18	68	270
	4	5	71	7	6	3	20	112
	5	2	28	2		1	6	39
	6		2					2
	Total	38	270	39	53	56	128	584
2003	1	3	2	3	1	12	5	26
	2	6	14	5	5	18	15	63
	3	5	84	10	12	21	56	188
	4	2	36	1	2	2	7	50
	5	3	27				2	32
	6		1					1
	Total	19	164	19	20	53	85	360
2004	2		7	1	1	9	6	24
	3	5	76	8	4	13	43	149
	4	6	54	5	4	9	21	99
	5	2	20			1	2	25
	Total	13	157	14	9	32	72	297
2005	2	7	16	4	3	9	6	45
	3	8	85	18	15	21	32	179
	4	6	53	7	3	4	10	83
	5	1	3				1	5
	Total	22	157	29	21	34	49	312
	Grand Total	235	1,688	176	187	282	766	3,334

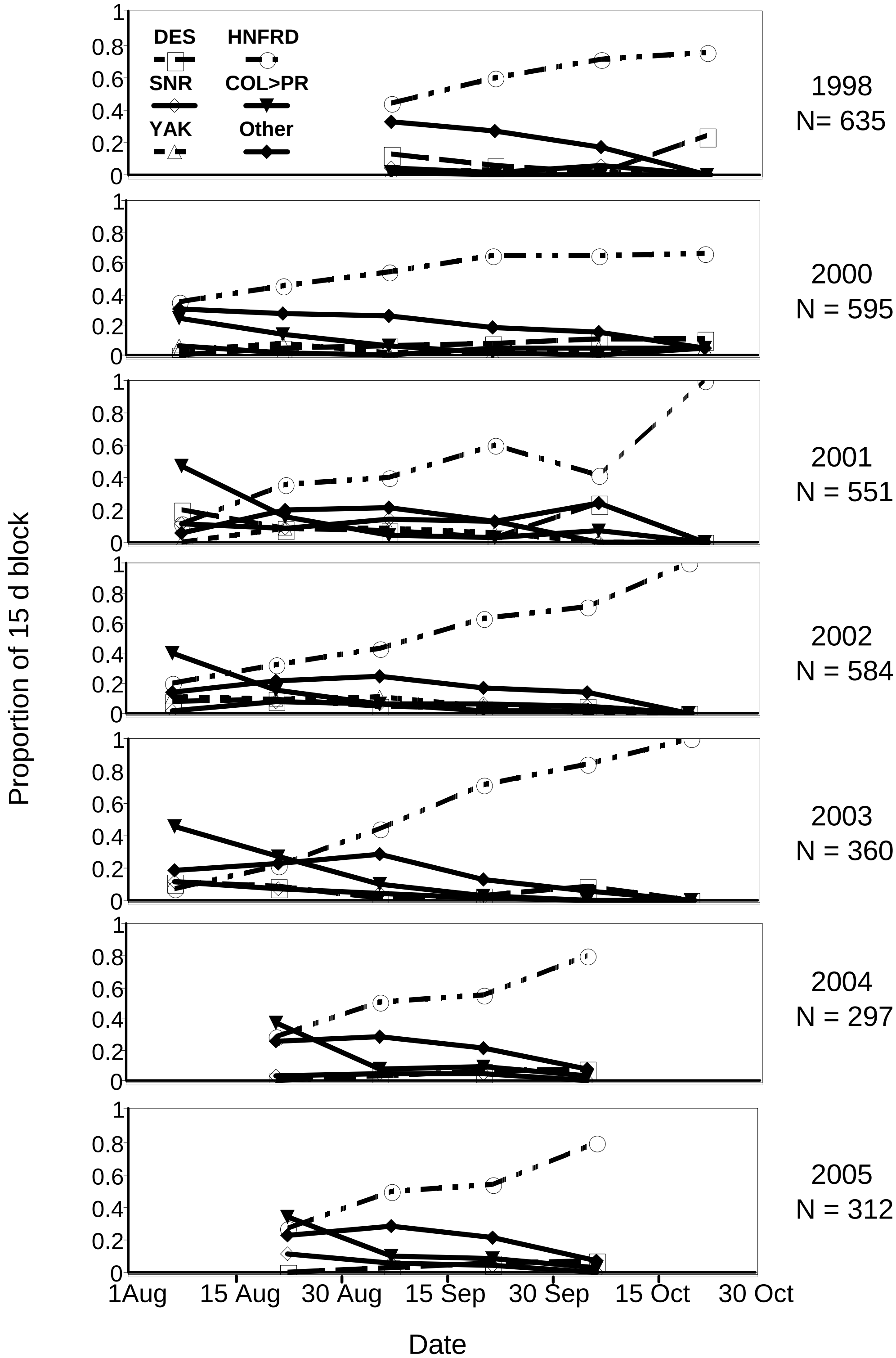

Figure 5. Proportions of fall Chinook salmon radiotagged at Bonneville Dam in 15-day blocks that returned to the Deschutes River (DES), the Snake River (SNR), the Yakima River (YAK) the Hanford Reach (HNFRD), upstream from Priest Rapids Dam (COL>PR), and all others, 1998 and 2000-2005. Sample sizes are presented in Table 2.

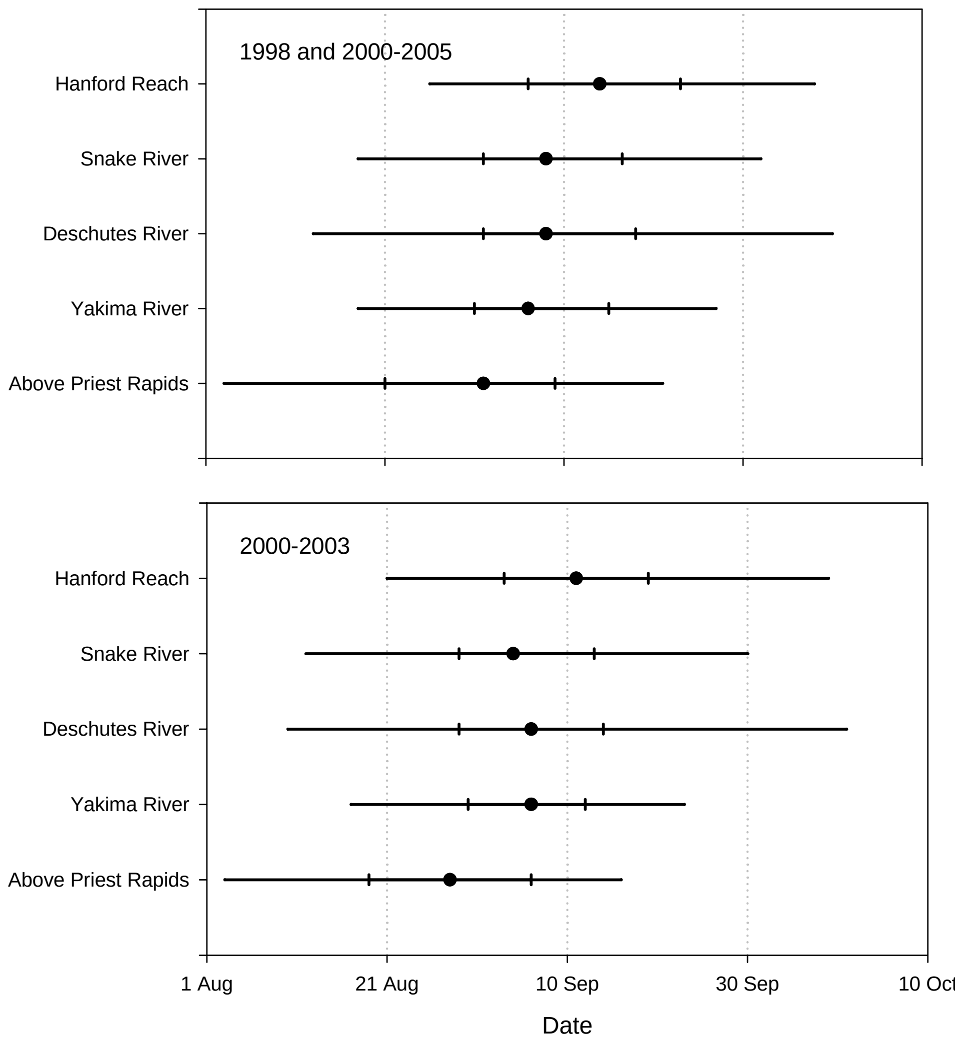

Figure 6. Run-timing distributions for "upriver bright" subgroups at Bonneville Dam, 1998 and 2000-2005 (upper panel), and 2000-2003 (lower panel), including median, quartiles, and 5th and 95th percentile dates.

Across all years, URBs returning to sites upstream from Priest Rapids Dam had the earliest median passage date at Bonneville Dam (Figure 6). Fall Chinook salmon from the Yakima, Deschutes, and Snake River subgroups had median Bonneville Dam passage dates approximately six days later than the subgroup from above Priest Rapids Dam. The Hanford Reach subgroup had the latest median passage date, approximately six days after the medians for the Yakima, Deschutes, and Snake subgroups. When years with limited samples were excluded (i.e. 1998, 2004, and 2005), median dates for all subgroups averaged 2.8 days earlier.

We found significant differences among subgroup migration timing distributions during each individual year ($P \leq 0.003$, Kruskal-Wallis tests). We also found significant differences among years within each subgroup ($P \leq 0.001$, Kruskal-Wallis tests) when we included all years. When we included years 2000-2003 only, we found significant differences among years for the Deschutes River, Hanford Reach, and Snake River subgroups ($P < 0.05$) but found none for the Yakima subgroup or the subgroup from above Priest Rapids Dam. Median Bonneville Dam passage dates for all subgroups in 1998, 2004, and 2005 tended to be later than those during 2000-2003, most likely reflecting our limited sampling during August of those three years (Figure 7, Table 3).

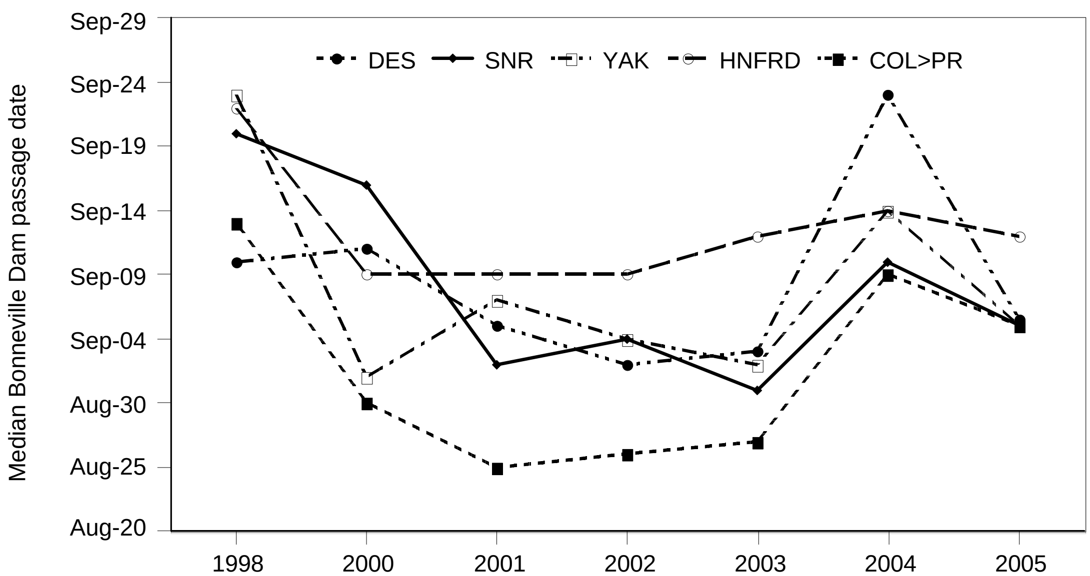

Figure 7. Median Bonneville Dam passage dates for radiotagged fall Chinook salmon that returned to the Deschutes River (DES), the Snake River (SNR), the Yakima River (YAK) the Hanford Reach (HNFRD), and upstream from Priest Rapids Dam (COL>PR) in 1998 and 2000-2005.

Mean Bonneville Dam passage dates differed from median dates by four days or less for all year-subgroup combinations (Table 3). For all years combined, inter-quartile ranges for all URB subgroups at Bonneville Dam were about 16 days. Annual inter-quartile ranges for each subgroup tended to be slightly narrower than the multi-year values.

Table 3. Annual migration timing statistics, including median and mean dates, inter-quartile ranges, coefficients of variation (CV), skewness ($\gamma 1$), and kurtosis ($\gamma 2$), for Columbia River basin Chinook salmon URB subgroups at the time of radio-tagging at Bonneville Dam for individual years (1998, 2000-2005). In a normal distribution, both (γ_1) and (γ_2) are zero. Negative γ_1 indicates skewness to the left; positive γ_1 indicates skewness to the right. Negative γ_2 indicates a flat distribution with thin tails; positive γ_2 shows a high-peaked distribution and/or fatter tails. All[1]= 1998 and 2000-2005, All[2]= 2000-2003.

URB subgroup	Year	Median date	Mean date	Inter-quartile range (d)	CV (%)	Skewness (γ_1)	Kurtosis (γ_2)	n
Deschutes R.	1998	Sep 10	Sep 14	14	25	1.07	0.61	51
	2000	Sep 11	Sep 14	21	33	0.74	-0.03	42
	2001	Sep 05	Sep 03	15	44	0.11	0.72	50
	2002	Sep 02	Sep 03	17	43	0.78	1.20	38
	2003	Sep 03	Sep 02	28	62	0.31	-0.52	19
	2004	Sep 23	Sep 19	14	20	-0.34	-0.89	13
	2005	Sep 05	Sep 08	19	28	0.42	-1.21	22
	All[1]	Sep 07	Sep 08	17	38	0.18	0.35	235
	All[2]	Sep 05	Sep 06	16	44	0.35	0.34	149
Snake R.	1998	Sep 20	Sep 20	17	21	0.30	-0.89	25
	2000	Sep 16	Sep 12	14	45	-0.18	-0.07	17
	2001	Sep 02	Sep 02	7	29	-1.19	2.22	33
	2002	Sep 04	Sep 05	17	34	0.46	0.02	39
	2003	Aug 31	Aug 31	13	43	-0.28	1.00	19
	2004	Sep 11	Sep 11	7	24	-1.05	1.90	14
	2005	Sep 05	Sep 08	11	23	0.64	-0.54	29
	All[1]	Sep 07	Sep 08	16	34	0.10	0.55	176
	All[2]	Sep 03	Sep 04	15	38	0.25	1.04	108
Yakima R.	1998	Sep 23	Sep 21	12	20	-0.63	0.25	16
	2000	Sep 01	Sep 04	20	47	1.15	1.20	22
	2001	Sep 07	Sep 07	14	21	0.18	-0.86	46
	2002	Sep 04	Sep 03	11	32	-0.26	0.24	53
	2003	Sep 02	Sep 03	12	29	-0.01	0.71	20
	2004	Sep 14	Sep 10	15	20	-0.75	-1.37	9
	2005	Sep 05	Sep 06	9	19	0.17	-0.49	21
	All[1]	Sep 05	Sep 06	15	31	0.30	0.69	187
	All[2]	Sep 05	Sep 04	13	31	0.34	1.28	141
Hanford	1998	Sep 22	Sep 21	16	21	0.04	-0.76	358
	2000	Sep 09	Sep 11	18	37	0.47	0.17	325
	2001	Sep 09	Sep 09	13	27	-0.09	0.32	257
	2002	Sep 09	Sep 11	18	33	0.28	0.04	270
	2003	Sep 12	Sep 14	16	29	0.43	-0.11	164
	2004	Sep 14	Sep 15	16	22	0.18	-0.90	157
	2005	Sep 12	Sep 11	12	20	-0.21	-0.07	157
	All[1]	Sep 13	Sep 14	17	29	0.17	0.07	1688
	All[2]	Sep 10	Sep 11	16	33	0.38	0.35	1016
Above Priest Rapids Dam	1998	Sep 13	Sep 15	7	22	1.56	3.42	10
	2000	Aug 30	Aug 29	17	49	0.26	2.03	46
	2001	Aug 25	Aug 25	23	57	0.22	-0.47	51
	2002	Aug 26	Aug 26	20	59	0.15	-0.40	56
	2003	Aug 27	Aug 25	14	52	-0.45	-0.74	53
	2004	Sep 09	Sep 07	18	34	-0.07	-0.92	32
	2005	Sep 05	Sep 05	14	23	0.01	-1.18	34
	All[1]	Aug 31	Aug 29	19	49	-0.06	-0.07	282
	All[2]	Aug 27	Aug 26	18	54	0.07	0.03	206

Sixty-nine percent (24/35) of the individual year-subgroup passage date distributions at Bonneville Dam were right-skewed (Table 3). During at least five of the seven study years, passage date distributions for each of the Deschutes, Hanford, and above Priest Rapids Dam subgroups were right-skewed. With all years combined, four of the five subgroups had timing distributions with high peaks and fat tails (leptokurtosis) and all subgroups exhibited these characteristics when 1998 and 2004-2005 data were excluded. Over half (19/35) of the distributions for individual year-subgroup combinations exhibited platykurtosis with the Deschutes River, Hanford Reach, and 'above Priest Rapids' subgroups doing so during at least four of seven years each. The distributions for the Snake and Yakima River subgroups had high peaks with fat tails during four of the seven study years.

Annual Escapement Estimates

Among the seven study years, escapement estimates for all URB subgroups varied considerably (Table 4, Figure 8). Minimum escapement estimates were observed during 1998 or 2000 but estimates typically increased each study year during 2001 and 2002. Maximum estimates for the Snake River and Hanford Reach subgroups were during 2004 while the maximum estimate for the Deschutes River subgroup was during 2001. The maximum estimates for the Yakima and 'above Priest Rapids' subgroups were during 2002 and 2003, respectively.

Escapement estimates for the Deschutes River subgroup during 2001-2003 were relatively homogenous, averaging 12,776 fish each year. During 2004, the escapement estimate for this subgroup decreased to 9,527 fish but rebounded to over 12,000 fish during 2005. Like escapement estimates for the Deschutes subgroup, those for the Yakima River subgroup decreased from 2003 to 2004 but increased (to approximately 11,000 fish) during 2005. In contrast, estimates for the Hanford Reach were similar during 2003 and 2004 and those for the Snake River subgroup increased by more than 50%. From 2004 to 2005, escapement estimates for the Hanford Reach, the Snake River, and the 'above Priest Rapids' subgroups all decreased, with the Snake River subgroup decreasing by approximately 40% of its 2004 estimate.

Table 4. Dam counts, adjustment factors, and adjusted dam counts for The Dalles (TD), McNary (MN), Ice Harbor (IH), and Priest Rapids (PR) dams, and annual escapement estimates, coefficients of variation (CV), and 95% confidence intervals for fall Chinook salmon (FLCK) upriver bright subgroups from the Deschutes, Snake, and Yakima rivers, the Hanford Reach, and the subgroup returning to sites upstream from Priest Rapids Dam on the Columbia River, 1998 and 2000-2005.

URB subgroup	Year	FLCK dam count	Dam	Adj. fact.	Adj. FLCK count	Unique radiotags past dam	Unique radiotags 'escaped'	Estimated escapement (number of FLCK)	CV (%)	+/- 95% C.I.
Deschutes R.	1998	92,932	TD	0.941	87,449	629	51	7,217	13.2	1,867
	2000	124,967		0.913	114,095	729	42	6,720	14.7	1,931
	2001	181,316		0.919	166,629	651	50	13,033	13.4	3,411
	2002	245,938		0.901	221,590	695	38	12,416	15.4	3,748
	2003	313,697		0.895	280,759	435	19	12,878	21.4	5,399
	2004	303,998		0.900	273,599	401	13	9,527	25.4	4,749
	2005	234,042		0.940	219,999	420	22	12,018	19.9	4,693
Snake R.	1998	4,220	IH	0.931	3,929	29	25	3,405	7.5	502
	2000	6,652		0.970	6,452	28	17	4,005	15.1	1,189
	2001	13,516		0.884	11,948	45	33	8,831	9.0	1,561
	2002	15,248		0.890	13,571	50	39	10,643	7.5	1,574
	2003	20,998		0.854	17,932	27	19	12,808	12.5	3,147
	2004	21,104		0.963	20,323	14	14	20,323	0.0	0
	2005	14,677		0.909	13,341	32	29	12,128	5.8	1,369
Hanford	1998	63,791	MN	0.984	62,770	428	358	52,528	2.1	2,202
	2000	67,572		0.998	67,437	449	325	48,854	2.9	2,792
	2001	110,517		0.961	106,207	428	257	63,872	3.9	4,934
	2002	141,682		0.963	136,440	442	270	83,465	3.8	6,209
	2003	178,951		0.966	172,867	276	164	102,971	5.0	10,033
	2004	171,048		0.975	166,772	252	157	104,150	4.9	9,999
	2005	134,876		0.992	133,797	265	157	79,473	5.1	7,931
Yakima R.	1998	63,791	MN	0.984	62,770	428	16	2,486	23.2	1,129
	2000	67,572		0.998	67,437	449	22	3,446	20.0	1,348
	2001	110,517		0.961	106,207	428	46	11,635	13.7	3,120
	2002	141,682		0.963	136,440	442	53	16,631	12.7	4,137
	2003	178,951		0.966	172,867	276	20	13,104	20.6	5,297
	2004	171,048		0.975	166,772	258	9	6,591	29.6	3,829
	2005	134,876		0.992	133,797	265	21	11,065	20.1	4,360
Upstream from Priest Rapids Dam	1998	9,662	PR	1.000	9,662	10	10	9,662	0.0	0
	2000	38,813		0.690	26,781	68	46	18,242	8.4	3,000
	2001	24,225		0.921	22,311	61	51	18,712	5.7	2.090
	2002	24,898		1.000	24,898	56	56	24,898	0.0	0
	2003	48,261		0.919	44,352	58	53	40,593	4.1	3,232
	2004	43,513		0.907	39,466	36	32	35,200	6.0	4,109
	2005	31,289		0.919	28,755	37	34	26,484	4.9	2,564

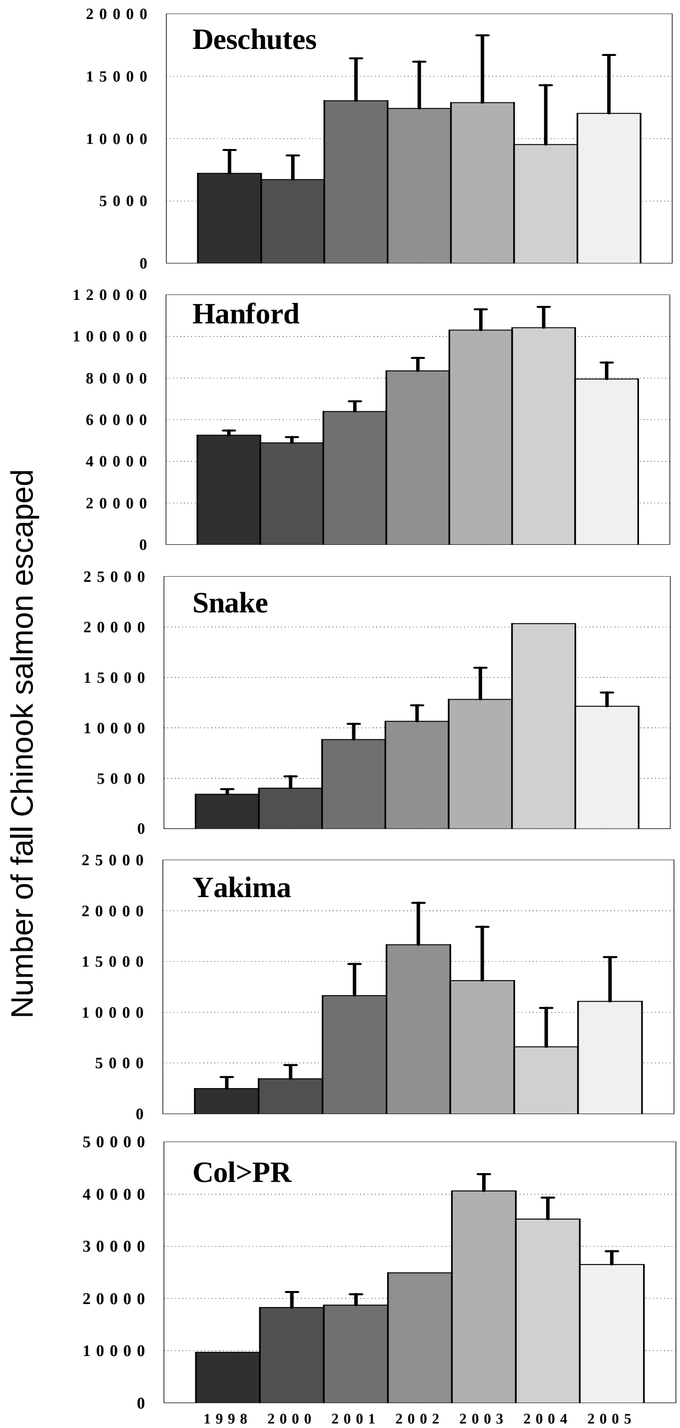

Figure 8. Estimated annual escapement of fall Chinook salmon and 95% confidence intervals for the Deschutes, Snake, and Yakima rivers, the Hanford Reach, and sites upstream from Priest Rapids Dam, 1998 and 2000-2005.

Among all URB subgroups, escapement estimates of fall Chinook salmon returning to the Hanford Reach were the highest during all years, followed by those for the subgroup returning to sites upstream from Priest Rapids Dam. Over the seven study years, annual escapement estimates for the Deschutes, Snake, and Yakima river subgroups each averaged between 9,280 and 10,540 fish. Among the five subgroups, minimum coefficients of variation about escapement estimates were observed for the Hanford and ‘above Priest Rapids Dam subgroups, averaging approximately four and six percent, respectively, for the seven study years. We were unable to estimate coefficients of variation and confidence intervals for some subgroups during years in which all radio-tagged fish passing Ice Harbor or Priest Rapids dams were estimated to have escaped. We believe this is a mathematical artifact and don’t wish to imply we have absolute confidence in these estimates. For all study years, coefficients of variation about escapement estimates averaged approximately 10% for the Snake River subgroup (excluding years where C.I. =0), 18% for the Deschutes River subgroup, and 20% for the Yakima River subgroup.

Mean and median escapement estimates generated from 1,000 bootstrapped sub-samples of the data were similar to the annual escapement estimates. On average, bootstrapped escapement estimates were two percent less on average than corresponding annual estimates and four percent less than median escapement estimates.

Within the Deschutes River, the percentage of radio-tagged salmon last detected at or upstream from Sherar’s Falls ranged between 5 and 21% during all years and escapement estimates above the falls averaged 1,627 fish per year (Table 5).

Table 5. Number of unique radio-tags last detected in the Deschutes River, the number of radiotags last detected at or upstream from Sherar's Falls, the total estimated escapement to the Deschutes River, and the estimated escapement above Shear's Falls, 1998 and 2000-2005.

Year	Total radio-tags last detected in Deschutes R.	Total radio-tags last detected upstream from Sherar's Falls	Percentage of radio-tags last detected upstream from Sherar's Falls	Total estimated escapement (number of fall Chinook)	Estimated escapement above Sherar's Falls (number of fall Chinook)
1998	51	5	10	7,217	708
2000	42	3	7	6,720	480
2001	50	14	20	13,033	3,649
2002	38	4	9	12,416	1,307
2003	19	1	5	12,878	678
2004	13	4	21	9,527	2,931
2005	22	3	12	12,018	1,639

Composition of Harvested Fish from URB Subgroups

For all but the Deschutes River subgroup, total estimated harvest of URBs in mainstem fisheries increased steadily during the first four study years, peaked during 2002 or 2003, then decreased during 2004 (Table 6). Estimated harvest of the Hanford and 'above Priest Rapids' subgroups during 2005 decreased compared to 2004 estimates whereas those for the Snake and Yakima subgroups increased during 2005. The estimated number of harvested fall Chinook salmon from the Deschutes River peaked during 2001, remained steady during 2002, decreased during 2003 and 2004, then increased slightly during 2005. Harvest estimates from 1998 and 2004-2005 were generally lower than those from other years, probably reflecting the limited sampling during August of those years.

Table 6. Estimated number of "upriver bright" subgroup-specific fall Chinook salmon harvested in mainstem fisheries of the Columbia River downstream from McNary Dam, 1998 and 2000-2005.

Year	Deschutes	Hanford	Snake	Yakima	> PR	Other	Total
1998	2,394	9,899	878	439	462	6,739	20,758
2000	3,435	27,548	1,038	2,426	5,118	14,192	53,757
2001	6,819	34,437	5,367	7,242	6,078	17,321	77,264
2002	6,486	44,756	7,047	10,531	8,050	24,340	101,210
2003	4,216	52,524	5,241	6,327	12,726	26,911	107,945
2004	2,668	34,916	3,392	2,239	9,293	17,579	70,087
2005	3,120	23,506	4,702	3,623	5,771	7,982	48,704

When subgroup-specific recapture estimates were added to corresponding annual escapement estimates, expressed as percentages, and averaged across all study years, almost one in three (*range* 27-31%) of the URBs passing Bonneville Dam was estimated to have been harvested in a mainstem fishery for four of the five URB-subgroups (Table 7). The exception was the 'above Priest Rapids Dam' subgroup which had an average of one in five fish (20%) estimated to have been harvested in mainstem fisheries. Among years, harvest estimates varied considerably within subgroups (Table 7).

Table 7. Estimated percentages of subgroup-specific fall Chinook salmon harvested in mainstem fisheries of the Columbia River downstream from McNary Dam, expressed as a percentage of the summed number of fish recaptured and the annual subgroup-specific escapement estimates, 1998 and 2000-2005.

Year	Deschutes	Hanford	Snake	Yakima	> PR
1998	25	16	21	15	5
2000	34	36	21	41	22
2001	34	35	38	38	25
2002	34	35	40	39	24
2003	25	34	29	33	24
2004	22	25	14	25	21
2005	21	23	28	25	18
Mean	**28**	**29**	**27**	**31**	**20**

Discussion

Ensuring adequate adult escapement to natal spawning grounds is critical for managing Columbia and Snake river fall Chinook salmon stocks, which are vulnerable to both in-river and ocean fisheries. From this study, we were able to divide the URB stock into five subgroups, describe their run-timing characteristics past Bonneville Dam, and produce annual harvest and escapement estimates for each. Specific conclusions include:

1) The relative abundance of salmon returning to sites upstream from Priest Rapids Dam was highest in early August and decreased steadily through the migration seasons. Deschutes, Yakima, and Snake River subgroups typically comprised small (≤13%), but relatively constant proportions of fall Chinook salmon throughout the migration seasons. Within each season, Hanford Reach fish comprised increasingly large proportions of the run past Bonneville Dam and was the most abundant overall, making up to 46-56% of the run each year.

2) While there was considerable variation within subgroups among years, escapement estimates for all URB subgroups were generally higher than estimates from 1998. Estimates for

the Snake River subgroup increased by five times from 1998 to 2004. During 2005, however, estimates for subgroups from the Snake River, Hanford Reach, and sites above Priest Rapids Dam were less than those estimated for 2004. Estimates for the Deschutes and Yakima rivers increased from 2004 to 2005 after exhibiting modest decreases from 2003 to 2004.

3) Harvest estimates for all subgroups varied considerably among years. With all years averaged, nearly one-third of most URB subgroups that passed Bonneville Dam were estimated to have been recaptured in a mainstem Columbia River fishery. Fall Chinook salmon returning to sites upstream from Priest Rapids Dam were estimated to have been harvested at a lower mean rate (20%) during the six study years, probably because of its relatively early run-timing, coupled with the start of the mainstem fishery in late August each year.

Fish counts at hydroelectric dams are good relative indicators of annual aggregate run size in the Columbia River basin (Dauble and Mueller 2000) but the use of radiotelemetry in this study allowed us to address some of their shortcomings. Specifically, we were able to adjust dam counts based on fallback and reascension events and to quantify inter-dam turnoff into tributaries where spawning occurred downstream from impoundments (e.g., the Deschutes and Yakima rivers). Moreover, we were able to use the transmitter reward program to estimate annual subgroup-specific harvest rates in mainstem fisheries.

Radiotelemetry has been a useful tool for determining passage timing, spatial distribution and movement patterns, and ultimate fates of large numbers of individually-marked, adult migratory salmonids in the Columbia River Basin (Stuehrenberg et al. 1995; Bjornn et al. 2000; Keefer et al. 2004b). Mobile and fixed radio-telemetry arrays can passively monitor tagged fish at sites where access is difficult or traditional sampling methods are impractical (Eiler 1990 and 1995). Telemetry methods are particularly effective in river systems where upstream migrants pass through constricted areas like fish ladders at hydroelectric dams (Gerlier and Roche 1998; Gowans et al. 1999) or when fish disperse over wide, but accessible geographic areas (Milligan et al. 1985; Keefer et al. 2002).

We assumed that tagged fish represented sampled populations and that tagged fish behaved similarly to untagged fish. Strict representative sampling was not possible because of run size and timing, the location of the trapping facility (Washington-shore only), and tagging stoppages (no fall Chinook in August 1998 and only five days of tagging in August 2004 and 2005). On balance, however, we believe radio-tagged samples were reasonable surrogates for the runs and that tagged fish behaved similarly to untagged fish. The evidence of limited tagging effects we observed is consistent with other adult anadromous salmonid telemetry research in the Columbia and Snake rivers (Matter and Sanford 2003) and other drainages (Burger et al. 1985; Thorstad et al. 2000; Jokikokko 2002).

Four to nine percent of the salmon we radio-tagged annually were last recorded downstream from Bonneville Dam. We attribute this in part to our imprecise method of discriminating between Tules and URBs at Bonneville Dam. Escapement and harvest estimates were calculated only after fish had resumed upstream migrations and passed Bonneville Dam. To this extent, we believe downstream movements of tagged fish did not substantively affect our estimates of escapement or harvest. Downstream movements of fish following tagging can affect study results (Bernard et al. 1999; Mäkinen et al. 2000), particularly for studies assessing migration rates or abundance of migrants.

The escapement estimates we present are not estimates of spawning escapement. Some URBs that reached spawning grounds likely died prior to spawning or were harvested and not reported. We considered fish passing Priest Rapids, being last recorded at Lyons Ferry Hatchery, or passing Lower Granite Dam as being successful migrants but spawning grounds for some fish may be over 200 km upstream from these sites.

Overview of the URB Stock and Individual Subgroups - The native fall Chinook salmon populations in the Columbia River and major tributaries upstream from The Dalles Dam provide the basis of the current URB stock with most of the population produced naturally in the Hanford Reach. The "upriver bright" broodstock for hatchery programs represents a composite of Columbia and Snake River populations that were generally founded by random samples of fall-run Chinook salmon intercepted at a number of mainstem dams (Howell et al. 1985). The relative contribution of URB stocks to fall Chinook salmon runs in the Columbia River system increased from approximately 24% of the total in the early 1980s to about 50-60% of the total into the mid-1990s (WDFW and ODFW 1994).

Deschutes River Fall Chinook Salmon - Estimates of adult escapement to the Deschutes River between 1977 and 1995 have ranged between 2,813 and 8,250 individuals (CTWRSO and ODFW 1995). Beaty (1996) characterized the run as generally declining and variable on a cycle of approximately five years but suggests there are reasons to question the accuracy of the estimates. Run size estimates hinge on estimates of escapement past Sherar's Falls and the redd counts above and below the falls. Specifically, the estimated number of fish per redd above the falls is multiplied by the number of redds counted downstream from the falls to estimate the below-falls component of the run. Because the technique uses fish trapped and tagged during upstream migration at the falls, resulting estimates are less accurate and precise when the relative and absolute sizes of the above-falls component are low (Beaty 1996).

Our escapement estimates for the Deschutes River subgroup in 2001-2003 were 2-17% higher than estimates derived using the techniques employed by CTWSRO and ODFW (1995) [cited in Brun (*in prep*) and labeled as 'existing estimates']. During 2004 and 2005, however, estimates based on telemetry data were 20 and 11% lower than those produced with this technique, respectively.

Estimates of fall Chinook salmon escapement into the Deschutes River produced by Brun (*in prep*) were three percent lower than the one produced from telemetry data during 2001 but 21, 33, and 35% higher during 2002-2004, respectively. The mark-recapture estimate from 2005 was 23% less than the estimate from the telemetry study but the mark-recapture estimate was adjusted downward for temporary strays, or salmon that "dipped into" the Deschutes. Without the adjustment, the mark-recapture estimate was approximately 10% higher than the telemetry estimate. It is unclear what may have caused the large discrepancies between estimates during 2002-2005 but we may have failed to representatively radiotag Deschutes River fish at Bonneville Dam or the mark-recapture study may have tagged a proportionately high number of fish that left the Deschutes River after being marked.

Estimates of Deschutes 'fall' Chinook salmon escapement during all study years may have been low because some fish spawning in the fall pass Bonneville Dam during June-July, a period designated as summer-run fish (Howell et al. 1985). Telemetry data from summer Chinook salmon tagged at Bonneville Dam during 1996-1998 and 2000-2004 suggest an average of three percent (*maximum* = 6%) of the summer Chinook run that passed Bonneville Dam return to the Deschutes River (University of Idaho, unpublished data), but their contribution to fall spawning is uncertain.

The Deschutes River subgroup does not have a PSC-accepted escapement goal but uses a local management agency goal of 4,000 adults, including 2,000 fish from above Sherar's Falls (CTC 2004). Escapement goals were reached for the river as a whole during all study years based on our estimates. Based solely on the ratio of transmitters last detected upstream from

Sherar's Fall to the total number of transmitters last detected in the Deschutes River, the goal for the component from above Sherar's Falls was met during 2001 and 2004 only.

Yakima River Fall Chinook Salmon - Two genetically distinct groups of fall Chinook salmon occur in the Yakima River, the lower mainstem group and the Marion Drain group. The Marion Drain is a 19-mile-long, large irrigation return that enters the Yakima River 135 km upstream from the mouth. Several million juvenile URBs and smaller numbers of lower Columbia River fall-run hatchery Chinook salmon have been released into the Yakima River (Howell et al. 1985) and the majority of introductions occurred below Prosser Dam (rkm 76). Marshall et al. (1995) speculate these introductions may be responsible for genetic differences between Marion Drain and lower Yakima River fall-run fish. Based on redd counts and passage at Prosser Dam, the stock composition of the run is approximately 10% Marion Drain, 20% mainstem fish above Prosser Dam and 70% mainstem fish below Prosser Dam (Yakama Nation 2000).

Historic estimates of fall Chinook production in the Yakima River have been as many as 50,000 fish (Kreeger and McNeil 1993). The Yakima Subbasin Salmon and Steelhead Production Plan of 1990 set a goal of 8,410 returning adults for fall Chinook salmon and a spawning escapement of 4,351. Estimates from our radio-tagging study suggest their total escapement goal was met during four (2001-2003, and 2005) of the seven study years. WDFW estimated escapement of fall Chinook salmon into the Yakima River during 1998, and 2000-2005 based on redd counts downstream from Prosser Dam, reported sport harvest, and the count at Prosser Dam (Watson and LaRiviere 1999; Hoffarth, 2005, 2006). Estimates from the WDFW studies were 11-72% lower than the estimates produced from our radiotelemetry studies during 1998 and 2001-2005 but approximately 90% higher during 2000. Any apparent decrease in escapement during 2004 was attributed in part to a decreased sampling effort (four weekly surveys were conducted during 2004 as opposed to the customary six weekly surveys) and poor visibility resulting from the encroachment of aquatic vegetation into the primary spawning areas (Hoffarth 2005). High turbidity was also cited as a likely cause for low redd counts and thereby, low escapement estimates during 1998 (Watson and LaRiviere 1999). Errors in redd counts can result from a number of sources including inter-observer variability, variation in habitat characteristics, and incomplete sampling of spawning areas, either in space or time (Dunham et al. 2001).

Snake River Fall Chinook Salmon – Adult fall Chinook salmon abundance in the Snake River was estimated to be around 72,000 fish per year during the 1930s and 1940s (Myers et al. 1998). The Snake River URB subgroup has steadily declined since the completion of Hells Canyon complex (i.e. Hells Canyon, Brownlee, and Oxbow dams) in 1967 which prompted their being listed as threatened under the U.S. Endangered Species Act (ESA) in 1992. Fall Chinook salmon that spawn in the Snake River do so mainly in the Hells Canyon Reach (Groves and Chandler 1999) but some spawning has been documented in the tailraces of Ice Harbor, Little Goose, and Lower Granite dams (Dauble et al. 1999). Tributary populations are found in the Clearwater, Imnaha, Grand Ronde, Salmon, and Tucannon rivers (Dauble et al. 2003).

Cramer and Vigg (1996) suggest an escapement goal should be established for naturally spawning Snake River fall Chinook salmon at Lower Granite Dam in addition to the broodstock management goal at Lyons Ferry Hatchery because the spawning escapement goal past McNary Dam does not ensure adequate escapement to the Snake River. An interim abundance target established by NOAA Fisheries for the Snake River fall Chinook evolutionarily significant unit (ESU) is an 8-year geometric mean of 2,500 naturally-produced spawners (Lohn 2002).

Hanford Reach Fall Chinook Salmon – The Hanford Reach URBs represent a healthy population of salmonids, defined as being one-third as abundant as would be expected without human impacts (Huntington et al. 1996). While this may be an arguably low standard, the Hanford Reach URBs were consistently the most abundant subgroup among those examined for this report. Escapement estimates produced by WDFW (Watson and LaRiviere 1999; Watson and Hoffarth 2001, 2002; Watson 2003; Hoffarth, 2005, 2006) were 5-9% lower than those produced from this study during 1998 and 2000 but were 1-7% higher during 2002-2004. The maximum difference between estimates was during 2005 when WDFW estimated 102,312 fish escaped while this study estimated 79,473 fish escaped (22% less). Overall, trends in escapement estimates among studies during the seven study years were similar.

The Columbia River Fisheries Management Plan established an escapement goal of 40,000 naturally spawning URBs past McNary Dam based on a Ricker stock-recruitment function in 1988 and this goal was accepted by the CTC as an interim, biologically-based escapement goal for PSC purposes in 2002 (CTC 2004). While escapement estimates from this study are not estimates of spawning escapement, we believe it likely the goal was met during all study years except 1998 (Hoffarth 2005; Watson and LaRiviere 1999).

Fall Chinook Salmon Returning Upstream from Priest Rapids Dam – Fall Chinook salmon have been documented to spawn in the Wenatchee, Methow, Okanagan, and Chelan rivers (Chapman et al. 1994), although the authors were unable to distinguish summer- and fall-run Chinook of the mid-Columbia River on the basis of isozymes or other characteristics. Spawning sites have been reported in tailraces downstream from Wanapum (Rogers et al. 1989), Rock Island (Horner and Bjornn, 1979), and Wells dams (Giorgi 1992).

An average of 18% of the McNary Dam count from 1970 to 1988 was destined for spawning sites upstream from Priest Rapids Dam (Dauble and Watson 1997). Adjusted counts past Priest Rapids Dam comprised 15-26% (*mean* 24%) of the adjusted count past McNary Dam during this study. Within years, estimates of escapement past Priest Rapids Dam produced from telemetry data were within -11% to 18% of estimates by WDFW (Hoffarth 2006). We observed the same pattern of increasing escapement during 1998-2003, followed by a decrease during 2004 and 2005, as did Hoffarth (2006).

Harvest - Data from the transmitter reward program suggested the Zone 6 harvest rate for Snake River fall Chinook salmon was as much as 41% during 2002, questionably high for a stock currently listed as threatened. Moreover, the actual harvest rates of all subgroups were likely higher than our estimates because we could only account for voluntarily reported harvest. Illegal harvest also occurred but was difficult to detect using telemetry data.

Because fish bound for sites upstream from Priest Rapids Dam comprised relatively large portions of the run early in the fall migration, harvest of this subgroup might be minimized by delaying the opening of the Zone 6 fishery until late August or early September. Zone 6 gillnet fisheries have typically begun in the last week of August during the last five years (Stuart Ellis, Columbia River Inter-Tribal Fishery Commission Harvest Manager, personal communication) and this may explain the comparably low harvest rates we estimated for the subgroup returning to sites above Priest Rapids Dam. In contrast, harvest of Hanford Reach fall Chinook might selectively be minimized with a relatively early closure of the Zone 6 fishery. Minimizing harvest of salmon from the Deschutes, Yakima, and Snake rivers may not be so easily accomplished with fisheries timing because they make up relatively small, but constant proportions of the run past Bonneville Dam throughout the migration season.

Cramer and Viggs (1996) concluded estimates of harvest rates for URBs should be accepted as the best estimates for Snake River fall Chinook salmon because they found the timing of Zone

6 catch was similar. This is consistent with the reasonable agreement we observed among harvest rates within years for all but the URB subgroup from above Priest Rapids Dam. The West Coast Salmon Biological Review Team (BRT) (2003) suggests that harvest impacts on Snake River fall Chinook salmon have approximated 35-40% of the run in recent years. They further suggest that in-river gillnet and sport fisheries are 'shaped' in time and space to maximize exploitation of harvestable hatchery and natural (Hanford Reach) stocks while minimizing impacts on inter-mingled Snake River fall Chinook salmon. Estimates of in-river harvest rates were consistent with those of the BRT for Snake River fall-run salmon, but it was not clear how the 'shaping' of fisheries was minimizing impacts on this group as opposed to other URB subgroups.

Summary - Overall, the status of the Columbia River URB stock appears reasonably good considering the loss of spawning and rearing habitat (Dauble et al. 2003), a history of over-harvest (Van Hyning 1973), and deterioration of the river environment (National Research Council 1996). Prospects for meeting PSC-accepted escapement goals in the short-term seem most optimistic for the Hanford Reach and Deschutes River subgroups although based on radiotelemetry data alone, the above-Sherar's Falls component of the Deschutes run appeared to have fallen short of its 2,000 fish goal during most study years. The subgroup migrating to sites upstream from Priest Rapids Dam appears to have experienced some of its best adult returns since the late 1980s and to this extent, prospects for its continued success also appear good. In contrast, the near 50% reduction in estimated escapement for the Yakima River subgroup from 2003 to 2004 and the sometimes large discrepancies between estimates based on telemetry and redd counts make it difficult to speculate on this subgroup's future with confidence. Similarly, we believe continued increases in escapement and decreases in estimated harvest need to be demonstrated before making any conclusions about the prospects for the ESA-listed Snake River subgroup, particularly given the decrease in estimated escapement from 2004 to 2005. Despite the relatively optimistic outlook for most URB subgroups in the short-term, we are served well to critically evaluate estimates of escapement and harvest of this limited natural resource.

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Appendix 1. Summary of locations of fixed aerial and underwater antennas at dams, mainstem Columbia and Snake River sites, and tributaries in 1998 and 2000-2004. Exact configurations differed in each study year to accommodate evolving research objectives.

		River
Site	Antennas[1]	kilometer
Dams[2]		
Bonneville Dam	81	~235
The Dalles Dam	28	~308
John Day Dam	28	~346
McNary Dam	39	~470
Ice Harbor Dam	23	~538
Lower Monumental Dam	24	~589
Little Goose Dam	20	~635
Lower Granite Dam	25	~695
Priest Rapids Dam	3	~639
Other mainstem Columbia and Snake River sites		
Fort Rains	1	235
Bridge of the Gods	1	239
Stevenson boat launch	1	243
Carson Depot Road	1	247
Across from Depot Road	1	247
Hood River Bridge boat launch	1	273
Bingen Marina	1	276
Mayer State Park	1	293
Lone Pine	1	308
Avery boat launch	1	320
Wishram	1	325
Biggs Bridge	1	335
John Day Dam boat launch	2	~345
John Day River boat launch	1	351
Pasture Point boat launch	1	364
Sundale Park	1	382
Roosevelt	1	390
Pine Creek boat launch	1	401
Alder Creek	1	415
Patterson	1	443
Irrigon Hatchery	1	452
Fish Hook Park	1	550
Hanford	2	~553
Walker	1	570
Ayers boat launch	1	604
Willow Creek boat launch	1	659
Asotin	1	762
Heller's Bar	1	792

Eye of the Needle Rapids	1	826
Doug's Bar	1	838
Pittsburg landing	1	867
Hells Canyon Dam	1	918
Tributaries[2]		
Willamette River	1	169
Washougal River	1	193
Sandy River	1	194
Tanner Creek BNFH	1	232
Herman Creek	1	243
Wind River	2	~249
Little White Salmon River	3	~260
White Salmon River	4	~270
Hood River	1	273
Klickitat River	1	291
Deschutes River	2	~328
Nookie Rock	1	359
Sherars Falls	1	396
Oak Springs	1	405
John Day River	1	356
Rock Creek	1	370
Umatilla River	1	467
Walla Walla River	1	526
Yakima River	1	546
Prosser Dam	1	615
Sunny Side Dam	1	706
Naches River	1	732
Roza Dam	2	745
Wenatchee River	1	763
Methow River	1	850
Lyons Ferry Hatchery	1	616
Clearwater River	1	753
SF Clearwater River	1	868
Lochsa River	1	904
Selway River	1	906
Grande Ronde River	1	795
Salmon River	1	826
Lower Salmon River	1	963
SF Salmon River	1	1,095
MF Salmon River	1	1,144
Upper Salmon River	1	1,204
Imnaha River	1	853

[1] aerial and underwater combined
[2] additional sites at upper Columbia River dams and tributaries monitored by Public Utility Districts