ASSESSMENT OF LOSSES OF JUVENILE FALL CHINOOK IN THE HANFORD REACH OF THE COLUMBIA RIVER IN RELATION TO FLOW FLUCTUATIONS

Field Summary Report
(for Inclusion into Final Report)

Prepared for
Alaskan Fisheries
Columbia River Inter-Tribal Fish Commission

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Background

The Hanford Reach supports the larger of the only two remaining healthy naturally spawning fall chinook salmon populations in the Columbia River System (Huntington et al.1996). This population is a primary source of ocean and freshwater sport, commercial, and in-river tribal fisheries (Dauble and Watson 1997) and is a primary component of the Pacific Salmon Treaty between the United States and Canada. River flows for this section of the Columbia River are manipulated by discharge from Priest Rapids Dam. Flow fluctuations from Priest Rapids Dam occur rapidly due to changes in hydroelectric power generation (power peaking), irrigation, water storage, and flood control. These fluctuations have been observed to cause stranding and entrapment of juvenile fall chinook salmon on gently sloped banks, gravel bars, and in pothole depressions in the Hanford Reach area of the Columbia River (Page 1976, Becker et al. 1981, DeVore 1988, Geist 1989, Wagner 1995, Ocker 1996, Wagner et al. 1999, Nugent et al. 2001a and 2001b).

Stranding of juvenile fall chinook salmon occurs when the fish are trapped on or beneath the unwatered substrate as the river level recedes. Entrapment occurs when the fish are separated from the main river channel in depressions as the river level recedes. Entrapped fish may become stranded when depressions drain completely. Fish mortality occurs from stranding, thermal stress (warming of water in entrapments), and by piscivorous, avian, and mammalian predation in small shallow entrapments.

The impact of river fluctuations due to operation of hydroelectric facilities on rearing salmonids has been assessed on numerous Columbia River tributaries and other river systems (Thompson 1970, Witty and Thompson 1974, Phinney 1974a and 1974b, Bauersfeld 1978, Tipping et al. 1978 and 1979, Becker et al. 1981, Woodin 1984, and Beck 1989) but limited research has been conducted on the Hanford Reach prior to 1997. In 1997, the Washington Department of Fish and Wildlife (WDFW) was contracted through the Bonneville Power Administration (BPA) and the Grant County Public Utility District (GCPUD) to perform an evaluation of juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) stranding on the Hanford Reach. The multi-year study, has been developed to assess the impacts of water fluctuations from Priest Rapids Dam on rearing juvenile fall chinook salmon, other fishes, and benthic macroinvertebrates of the Hanford Reach and for directing the future management of flows from Priest Rapids Dam.

The Army Corps of Engineers was contracted in August 1998 to collect detailed bathymetry data on 35.1 km^2 of the Hanford Reach from Rkm 571.3 to Rkm 606.9 using Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS). This data was used in conjunction with the Modular Aquatic Simulation System 1D (MASS1) unsteady flow model to provide information on the Hanford Reach at a range of stage discharges. From this information, the extent of area of shoreline exposed by flow fluctuations and the configuration of the river channel could be determined. A sampling plan was designed by Pacific Northwest National Lab (PNNL) and WDFW prior to the 1999 field season to estimate the total number of juvenile fall chinook salmon killed or placed at risk due to flow fluctuations. The study area was confined to the portion of the Hanford Reach defined by the SHOALS bathymetry data at river elevations corresponding to Priest Rapids discharges from 40 kcfs to 400 kcfs.

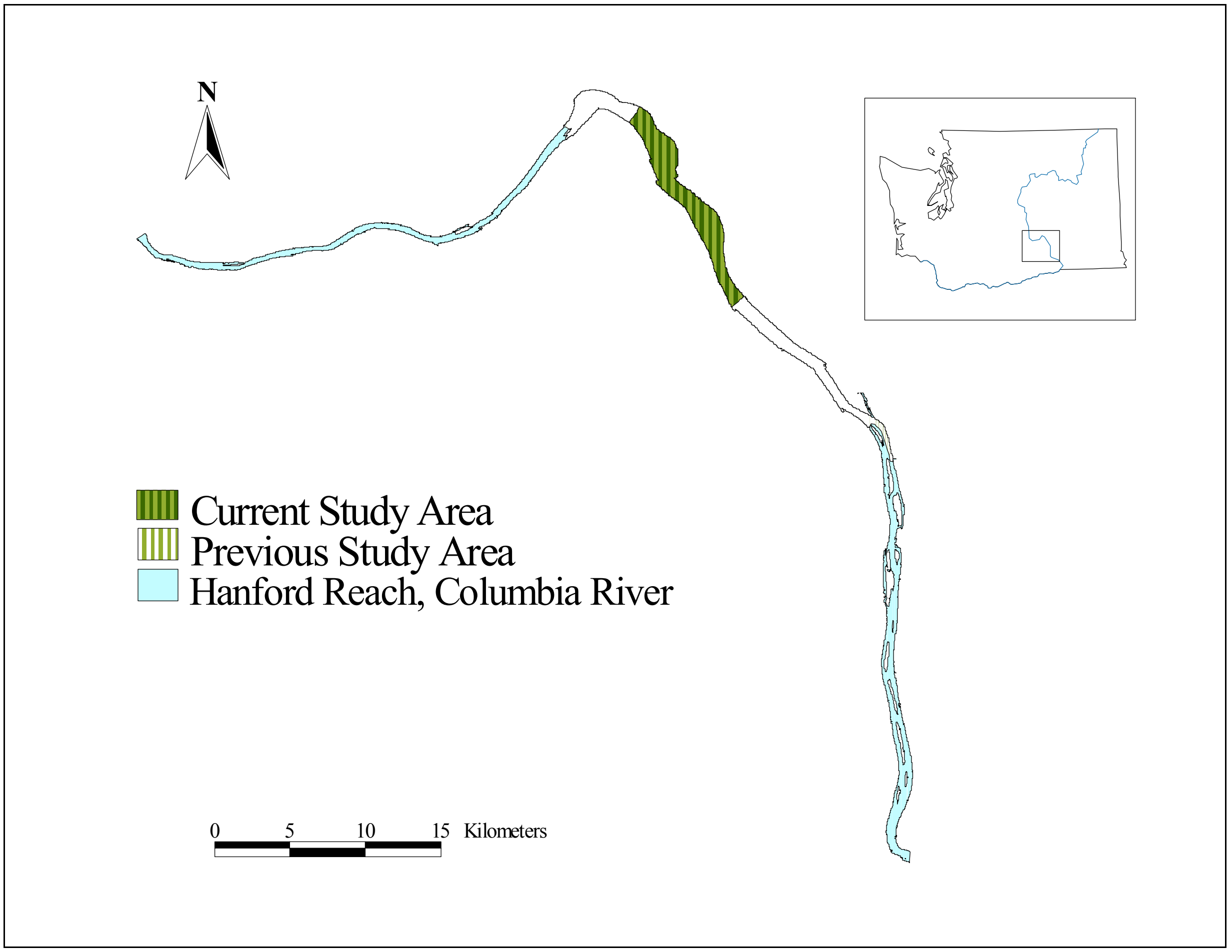

Figure 1. Study areas used for evaluation of impacts of hydroelectric operations on juvenile fall chinook in the Hanford Reach of the Columbia River.

The study area was stratified into 40 kcfs flow bands and divided into 3600 ft^2 (344.4 m^2) plots or sampling cells. The sample plot size was based on the mean size of entrapments found in 1998. A list of all cells contained within the study area was compiled and cells were randomly selected to use in daily field sampling activities. Daily sampling targeted random sampling locations within wetted flow bands identified in the previous 48-hour flow history. If entrapments were encountered, an assessment was made to determine the percentage of the entrapment contained within the sample plot. Entrapments with area of 50% or greater within the circle were sampled in their entirety. Entrapments with area of greater than 50% outside of the circle were not surveyed.

Evaluations were conducted for the same area in 2000 and 2001. In 2002 and 2003, the study area was reduced to an 8 mile section of the Reach (RM to RM). Sampling in the reduced study area would continue to provide in-season monitoring of impacts to juvenile fall chinook and a mortality and at risk estimate could be generated using only one 2-person crew. Mean mortality and "at risk"[1] estimates generated though the random sampling method ranged from a low of 45,487 mortalities in 2000 to 2,013,638 mortalities in 2001 (Table 1).

Table 1. Comparative impacts (mortality and at risk) to juvenile fall chinook in the Hanford Reach, 1999-2003.

2003 Field Season	Mean	Mean - 1.96 S.E.	Mean + 1.96 S.E.
Morts	154,853	83,903	225,802
Rev Morts	154,853	83,903	225,802
At Risk	164,643	91,093	238,192
2002 Field Season	Mean	Mean - 1.96 S.E.	Mean + 1.96 S.E.
Morts	67,409	28,623	106,195
Rev Morts	70,903	31,517	110,288
At Risk	144,249	28,813	259,685
2001 Field Season	Mean	Mean - 1.96 S.E.	Mean + 1.96 S.E.
Morts	2,013,638	-746,334	4,773,611
Rev Morts	2,013,638	-746,334	4,773,611
At Risk	2,013,638	-746,334	4,773,611
2000 Field Season	Mean	Mean - 1.96 S.E.	Mean + 1.96 S.E.
Morts	45,487	12,866	78,108
Rev Morts	192,824	-70,865	456,514
At Risk	199,534	-64,234	463,302
1999 Field Season	Mean	Mean - 1.96 S.E.	Mean + 1.96 S.E.
Morts	93,943	21,393	166,493
Rev Morts	NA	NA	NA
At Risk	320,650	-54,006	695,307

(Chris Murray, Pacific Northwest National Laboratory, July 2003)

Hourly flow fluctuations in low flow years have been shown to produce relatively significant mortality impacts on emerging and rearing fall chinook. Channel bathymetry at elevations corresponding to discharges of less than 110 kcfs results in large dewatered areas in response to even modest flow fluctuations. The combination of very high spawning escapements of fall chinook in 2002 and expected low flows in the Columbia River during emergence and rearing in 2003 provide optimum conditions for detecting the potential significance of stranding and entrapment due to fluctuations in discharge from Priest Rapids Dam. Large numbers of juvenile salmon emerging in 2003 will provide better identification of location and factors affecting susceptibility of fall chinook to stranding and entrapment. Thus, 2003 sampling might place a reasonable upper bound on impact estimates.

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[1] Juvenile fall chinook found alive in entrapments were categorized as "at risk" as these entrapments were subject to draining, lethal temperatures, or reflooding.

Improvements in sampling design can substantially improve accuracy and precision in estimates of stranded juvenile fall chinook in Hanford Reach rearing areas. Previous estimates based on a random design (among habitat types) produced highly uncertain estimates in part because of the expansion effects of high sample variance. Previous estimates may also have substantially underestimated actual stranding numbers by sampling only a segment of the entire reach, sampling only during daylight hours when some dewatered areas had already been reinundated[2], and inadequately representing large entrapment pools.

Study Objectives

1. To estimate numbers of juvenile fall chinook salmon entrapped and subject to mortality risks as a result of flow fluctuations in the Hanford Reach of the Columbia River between Priest Rapids Dam and McNary Reservoir.
2. To provide empirical data suitable for use in models of the effects of alternative flow operations on stranding and entrapment mortality risks.

Methods

The Hanford Reach encompasses the free flowing stretch of the Columbia River from Priest Rapids Dam to Richland, Washington. The magnitude and duration of reductions in discharge from Priest Rapids Dam determines the change in river elevation that occurs at areas downstream. Timing and river elevation changes in the upper portion of the Reach mirror the timing and magnitude of reductions occurring in the Priest Rapids Dam tailwater. The effect of fluctuations in discharge is dampened and delayed at locations further downstream. As the river reaches Richland the McNary Dam forebay elevation has increased influence on river elevation and reduces the effects of hydroelectric operations from Priest Rapids Dam. Previous studies were limited to the 17 mile area containing detailed bathymetry and focused on dewatered areas occurring between 9:00 am and 3:00 pm. The 17-mile study area was used as an indicator of the effects of hydroelectric operations on the Reach as a whole.

All known locations[3] containing large numbers of pools formed by the reduction of discharge from Priest Rapids Dam within the Hanford Reach were designated as part of the study area for this evaluation. To cover such an extensive area, three two-person crews were scheduled to work seven days a week from April 1 through June 21. Utilizing a system that incorporated flexible Reach-wide designated random sampling locations and staggered shift times that encompassed all daylight hours, enabled the three crews to sample areas of the Reach where flow fluctuations were most likely to have produced entrapments based on the magnitude and duration of the reduction in discharge from Priest Rapids. The increased sampling power of the entrapment pool approach facilitated a wider distribution of effort because field crews are able to concentrate on problem sites rather than having to include homogenous beach sites that

[2] Reinundation may wash away fish left stranded on dewatered shorelines or entrapped in pools that drain prior to increases in water levels. Underestimation of mortality may result where reinundation occurs prior to sampling and entrapment surveys.
[3] Previous stranding/entrapment studies and fall chinook stock assessment surveys had identified areas where large numbers of isolated pools typically formed during reductions in discharge

contribute little to the problem but require time-consuming sampling efforts. The ability to sample every day is critical because of the unpredictable occurrence of flow fluctuation events.

To obtain information on fall chinook entrapment and mortality throughout the Reach under all operational changes in discharge, the study area was stratified into three reaches, each reach containing sampling sites that would be subject to river elevation changes of similar magnitude and timing.

Vernita - Priest Rapids Dam (RM 397) to Locke Island (RM 373), 27 sampling sites
Hanford[4] - Locke Island to Hanford Slough (RM 363), 26 sampling sites
Richland – Hanford Slough to Howard Amon Park (RM 338), 47 sampling sites

A total of 85 sampling sites were identified prior to the start of field sampling. Using a random number generator, the sites within each reach were randomly ordered and listed at the beginning of the study. The reach sampled on any given day was selected based on current flow events and the sampling location within the reach was selected from the list. The location was consequently crossed off the list. Only reaches affected by a given fluctuation event were sampled. Thus, sampling may be concentrated in upstream reaches when fluctuations are too small to affect downstream areas or sampling may be distributed among all reaches when events are large (Figure 2). Staggered shifts allowed crews to capitalize on event timing in each reach. All entrapments within the dewatered zone of each selected entrapment area were counted by field crews.

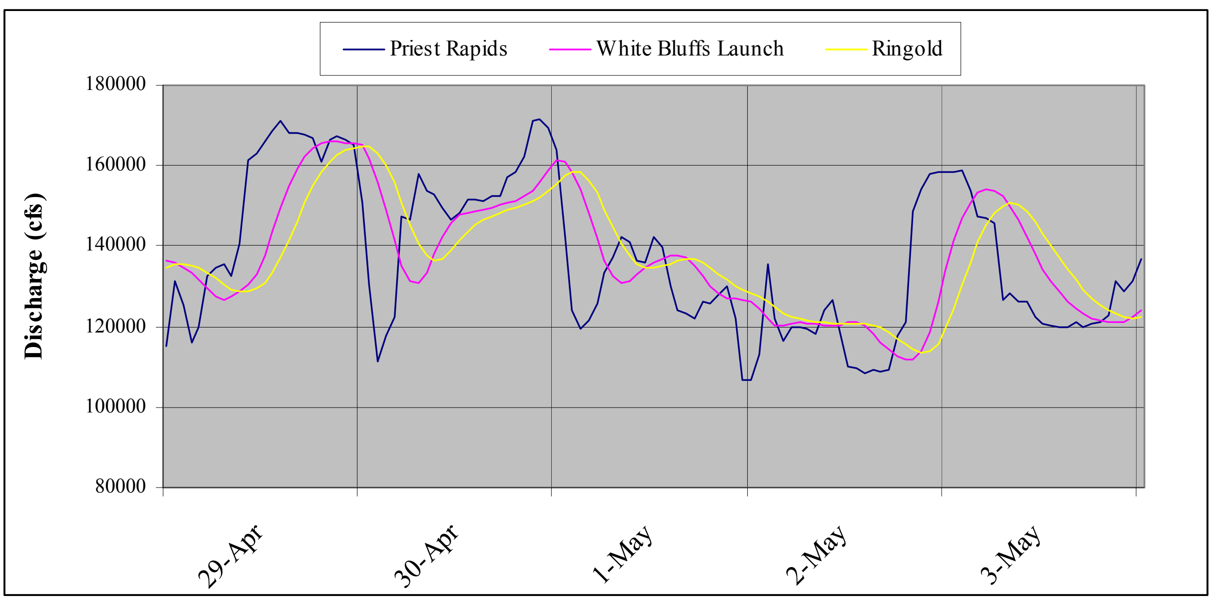

Figure 2. Hourly flow in the Hanford Reach below Priest Rapids Dam, and in the White Bluffs and Ringold areas, April 29 – May 3, 2003.

[4] The Hanford section of the Reach designated in this study is the same study area surveyed for the estimation of mortalities by the Hanford Stranding Study funded through GCPUD. This will allow direct comparison of impacts between studies.

At the site, field crews recorded the GPS coordinates at the center of all isolated pools, took four measurements to determine surface area of the pool, and numbered and flagged each pool. An entrapment was designated as an isolated pool with a minimum wetted surface area of one meter. Information was recorded on surface area of the entrapment including estimation of the initial size of the pool when it isolated from the river. If no entrapments were present at the designated site, crews moved to the closest adjacent site. Visual observations of fish presence, drainage, and re-inundation by the river were also recorded. After completing the initial survey identifying all entrapments in the area, entrapments were subsampled based on time remaining in shift. When all sites could not be subsampled with the time remaining every n^{th} site was sampled. For example, if 3 of the 22 entrapments could be sampled in the time remaining, every 7^{th} site would be sampled. Flip of a coin or roll of dice was used to select the first site. If #2 was selected as the start point, entrapments 2, 9, 16 would be sampled. All sites are flagged and enumerated in the initial survey and flags are not removed until the subsamples are completed. Detailed sampling of the entrapments included a surface area and depth measurement, maximum water temperature, drainage rates, fate of the entrapment[5], substrate, embeddedness, vegetation, and enumeration of fish species present and fork length. Fish were collected from entrapments by seining or back pack electrofishing. On sites where fates could not be determined by the end of shift, flags were left at the site and subsequent crews would revisit the locations to determine the fate of the entrapment.

Assessment of Juvenile Fall Chinook Salmon Relative Abundance and Fish Size

Juvenile fall chinook salmon were seined from 15 nearshore sampling sites in the Hanford Reach once a week during the emergence and rearing period to assess relative abundance and fish size. The 15 sites were dispersed throughout the study area from Howard Amon Park in Richland (RM 338) to Vernita Bar (RM 395) (Table 2). Seining techniques were similar to methods described by Key et al. (1994). A beach seine, 21.3 m x 1.8 m with a 1.8 m^2 bag, 4.8 mm diamond mesh, and 15.2 m leads, was used to collect juvenile fall chinook salmon and other fish species from the designated nearshore sampling sites. One lead of the seine was cleated to the bow of a 5.5 m boat, the seine was folded and laid on the bow, and the other lead was held by a person on shore. The boat was then backed perpendicular to shore to a distance of 15.2 m and then backed upstream allowing the seine to be fed out parallel to shore. Once the seine was deployed, the boat was maneuvered back into shore. Both ends of the seine were then simultaneously hauled to shore. The area sampled in this manner was approximately 320 m^3.

When samples contained less than 100 juvenile fall chinook salmon, all fish were anesthetized with tricaine methanesulfonate (MS 222), measured, and fork lengths were recorded. If samples had over 100 chinook but less than 1,000, all fish were counted and fork lengths on a subsample of 100 chinook were recorded. Samples with over 1,000 salmon fry were subsampled to estimate total numbers and obtain length frequency information. Sub-sampling was necessary to reduce holding time and stress. Sub-sampling protocol consisted of returning two nets of fish from the holding container to the river, and counting one net. The count from the retained chinook was multiplied by 3 to estimate the total number of chinook at the location. All fish were released back into the river after sampling. River temperature, relative velocity, dominant

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[5] Fates were categorized into reflooded, reached lethal temperature for fall chinook (25°C), drained, large entrapment of sufficient size and depth that draining or reaching lethal temperatures was unlikely, and undetermined for those sites whose fate could not be determined by the end of the designated sampling period.

and subdominant substrate size (modified Wentworth code; Platts et al. 1983), substrate embeddedness (Platts et al. 1983), and vegetation density (absent, sparse, medium, or dense) were recorded for each site (Appendix A).

Table 2. Nearshore sites used to determine relative abundance and length frequency of fall chinook in the Hanford Reach.

Reach	Site	Location	Reach	Site	Location
Vernita	1	Below Vernita Bar	Hanford	9	Upstream of Hanford Slough
	2	China Bar		10	Hanford Slough
	3	Coyote Rapids	Richland	11	Lower end of Savage Island
	4	Island #1		12	Homestead Island
	5	Island #2		13	Wooded Island
Hanford	6	Locke Island		14	North Richland
	7	DOE ferry landing		15	Howard Amon Park
	8	100 F Area			

Aerial Counts of Entrapment

Weekly flights were scheduled on Saturdays, corresponding to expected reductions in discharge from Priest Rapids Dam. Flights were conducted to determine the number of entrapments that typically form during these weekend decreases in flow and identify critical locations where large numbers of entrapments form. Each shoreline was videotaped so that accurate counts of entrapments in each reach could subsequently be enumerated. The exercise was similar to that used to estimate fall chinook redd production in the Hanford Reach. Flights were conducted at 9:00 am on April 12, 19, 26, May 10, 17, and 24. Only entrapments isolated from the river were included in these counts.

Results

A total of 1,257 isolated pools[6] formed by decreases in discharge from Priest Rapids Dam were surveyed between April 1 and June 21, 2003. Mean surface area of these pools at formation was 197 m^2. Of the entrapments surveyed, 934 (74%) were sub-sampled for detailed information related to impacts to juvenile fall chinook rearing and survival. Of the entrapments sub-sampled, 179 entrapments contained fish (19.2%) and 164 contained juvenile fall chinook (17.6%). Fish were observed in an additional 46 entrapments (4.9% of sub-sampled pools) but were not recovered during seining. A total of 33,177 chinook were collected and sampled from the 164 entrapments containing chinook. Mean surface area and depth of entrapments at the time of sub-sampling was 88.8 m^2 and 7.6 cm, respectively.

Entrapment sampling began well after the estimated start of fall chinook emergence in 2003. In the first week of sampling, April 1 - 6, 1,682 chinook were recovered from the 47 entrapments sampled. The mean number of chinook per entrapment was 35.8 with 19 (40.4%) of the 47 entrapments containing chinook (Table 3). Chinook presence in entrapments continued to be relatively high through mid-May (Figure 3). During the first week of May the number of

[6] Pools isolated from the river and formed by the reduction in discharge will be referred to as entrapments. These isolated pools are potential entrapment areas for fall chinook fry and other fish species.

chinook per entrapment began to decrease in the middle and upper areas of the Reach whereas there was an increase in chinook in entrapments in the lower reach (Figure 4). There was a similar trend in the abundance of chinook in nearshore areas. By mid-June few chinook were found in these isolated pools throughout the Reach.

Table 3. Weekly percent of entrapments with chinook and mean number of chinook per entrapment by area, Hanford Reach, April 1 – June 21, 2003.

Week	**% Entrapments with Chinook**				**Chinook per Entrapment**			
Ending	V	H	R	Total	V	H	R	Total
Apr 6	50%	67%	20%	40%	4.5	69.3	16.6	35.8
Apr 13	23%	59%	48%	48%	2.2	309.7	6.7	129.6
Apr 20	31%	44%	33%	37%	32.5	28.9	5.9	20.5
Apr 27	17%	26%	4%	17%	0.5	439.7	3.8	166.7
May 4	35%	23%	33%	33%	7.6	2.2	10.8	7.2
May 11	44%	29%	44%	37%	9.2	27.7	88.8	37.6
May 18	14%	10%	3%	8%	0.1	1.6	1.3	1.4
May 25	13%	0%	6%	5%	0.7	0.0	0.9	0.5
Jun 1	3%	9%	14%	7%	0.1	7.0	62.6	8.9
Jun 8	0%	10%	0%	4%	0.0	15.7	0.0	6.4
Jun 15	0%	0%	0%	0%	0.0	0.0	0.0	0.0
Jun 22	0%	0%	8%	3%	0.0	0.0	0.9	0.3
Overall	17%	19%	17%	18%	4.0	74.9	10.8	35.5

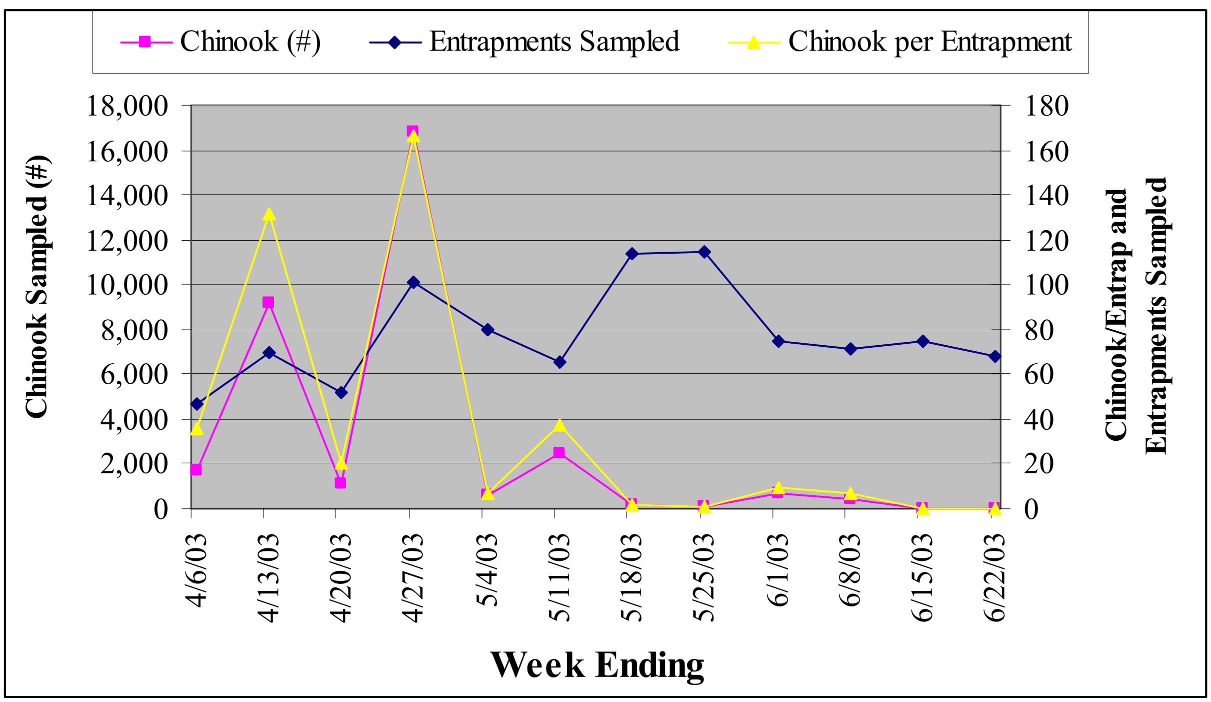

Figure 3. Weekly summary of juvenile chinook recorded in entrapments, number of entrapments sampled, and the mean number of chinook per entrapments sampled.

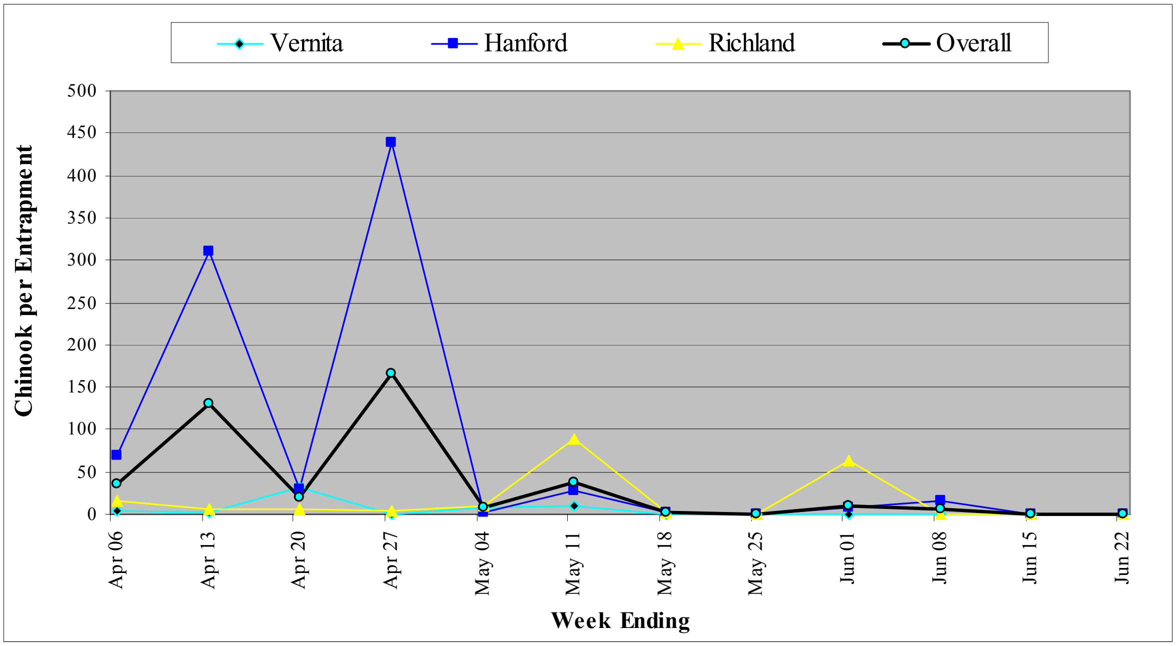

Figure 4. Weekly summary of juvenile chinook per entrapment for the Vernita, Hanford, and Richland areas, April 1 – June 21, 2003.

Field crews recorded information on the survival of fall chinook (fate) within entrapments based on water temperature, size and depth of entrapment, drainage, and re-inundation of entrapment with increases in discharge. Entrapments where water temperatures reach 25°C were listed as lethal. A separate category was created to account for large, deep, entrapments that were unlikely to result in mortality from increased water temperatures or drainage. All entrapments where fates could not be determined during sampling were initially listed as unknown. Fates for these unknown entrapments were assigned post-field season based on water temperature, depth, and flow history. There were 198 (21.2%) entrapments categorized as unknowns by the end of the field season.

Criteria for assigning fates to unknown entrapments was:

All entrapments with water temperatures at or above 23°C were listed as thermal;

All entrapments with mean depth of less than 5 cm were listed as drained;

All entrapments with mean depth greater than 5 cm were listed as either drained or reflooded based on a drainage rate of 0.19 cm per minute and the flow history for the closest transect to the entrapment.

A drainage rate of 0.019 cm per minute was the median drainage rate for monitored entrapments in 2003. Median drainage rate was used to estimate mortality/survival instead of mean as it was the more conservative rate. Mean drainage rate was higher than median at 0.03 cm per minute. Flow history (river elevation and discharge) for closest transect was calculated by hourly discharge from Priest Rapids Dam and use of the MASS1 flow model. Of the entrapments sub-sampled 195 (20.9%) reflooded, 303 (32.4%) reached lethal water temperature, 432 (46.3%) drained, and 4 (0.4%) were large entrapments. Combined mortality rates for sub-sampled entrapments was 78.7% and 82.3% for entrapments containing chinook in 2003. The estimated mortality rates for juvenile chinook in entrapments in 2003 was similar to those observed during revisitation of entrapments during the evaluation of juvenile fall stranding in the Hanford Reach in 2000 (82.3%).

Assessment of Juvenile Fall Chinook Salmon Relative Abundance and Fish Size

Sampling to assess juvenile fall chinook salmon abundance and fish size began on February 19, one day prior to the estimated start of emergence and ended on June 23. For the first six weeks, February 19 through March 24, only six nearshore locations within the middle section of the Hanford Reach from Locke Island (RM 373) to the 100F area (RM 366) were sampled following the standard protocol from prior years evaluations of juvenile fall chinook stranding. From March 31 through June 23, nearshore sampling was expanded to 15 sites from Vernita Bar (RM 393) downstream to Howard Amon Park (RM 338).

A total of 42,588 juvenile fall chinook salmon were seined during nearshore seining in 2003. Collections of chinook in the weekly sample began to increase the first week of April and abundance of juvenile fall chinook was relatively high throughout the period from April 21 through May 19 (Figure 5). Peak abundance was recorded on May 5 when a total of 5,840 juvenile chinook were collected. Numbers of juvenile fall chinook in the collections declined to minimal numbers by June 16.

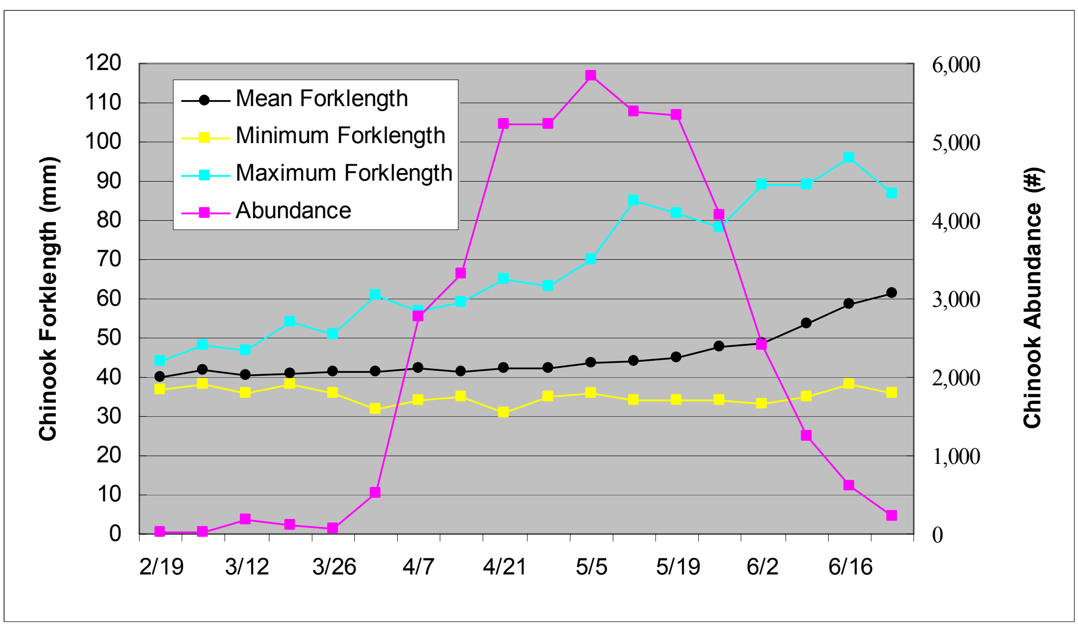

Figure 5. Juvenile fall chinook abundance and size in nearshore areas of the Hanford Reach, February 19 – June 23, 2003.

Of the fall chinook fry sampled in nearshore areas, 24% were collected in the upper (Vernita) section of the Reach and roughly equal numbers were collected in the middle and lower sections (37% and 38%). By late May, numbers of chinook fry in the collection at locations in the middle and upper sections of the Reach began to decline and had decreased markedly by the second week of June with only 4% of the collection in the upper seven sampling locations (Figure 6).

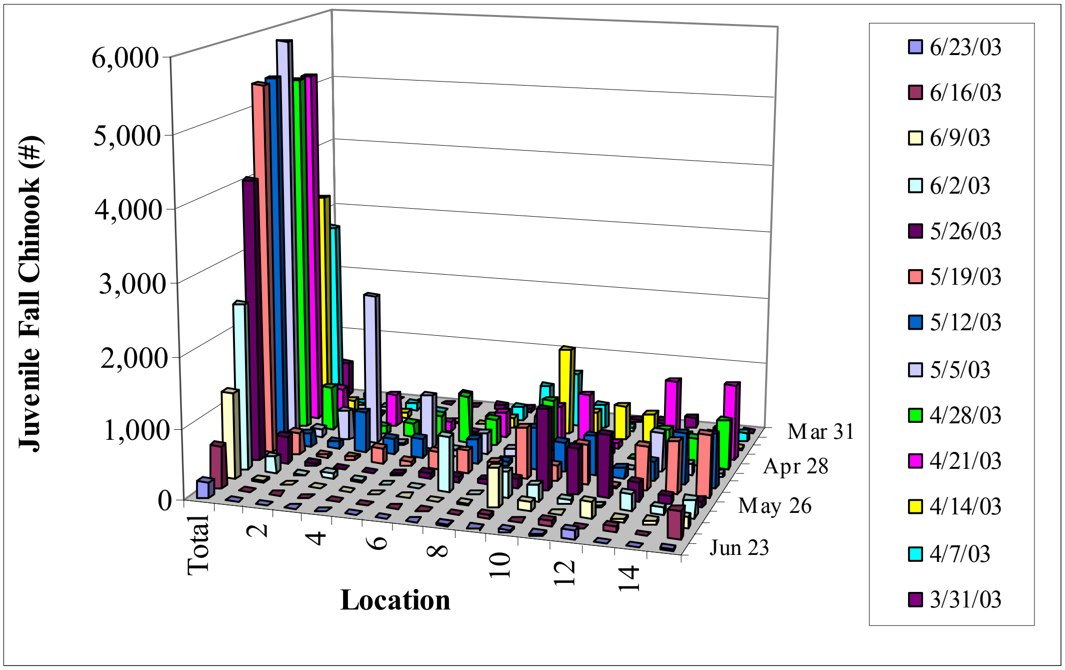

Figure 6. Abundance of juvenile fall chinook in 15 nearshore locations in the Hanford Reach, March 31 – June 23, 2003.

Susceptibility of juvenile fall chinook to stranding/entrapment typically decreases as fork length reaches 50 mm. Mean fork length of chinook reached 50 mm (53.8 mm) on June 9 in 2003. Minimum fork length for chinook sampled along nearshore areas in the Reach continued to be less than 40 mm through the final survey on June 23, however, the composition of newly emergent fry (<42 mm) in the sample had decrease markedly by June 9 (7.2% of sample). Also by June 9, 4 days after the end of the Protection Plan, abundance in nearshore areas had declined to 21.5% of peak abundance. The week prior, fall chinook continued to be abundant with 2,402 chinook in the collection (41.1% of peak abundance) and fork length was 5 mm lower at 48.5 mm.

Aerial Counts of Entrapment Areas

A total of 5,758 isolated entrapments were identified during the six aerial flights in 2003 (Table 4). The largest number of entrapments of the three sections was recorded in the upper section (Vernita) of the Hanford Reach with 2,478 entrapments, 43% of the overall. The lower section was second with 34% of the identified entrapments.

Table 4. Summary of aerial video counts of entrapments, Hanford Reach 2003.

Date	Apr 12	Apr 19	Apr 26	May 10	May 17	May 24
Discharge (kcfs)						
Start	115	120	170	145	175	207
End	90	95	123	120	135	120
Change	25	25	47	25	40	87
Total Entrapments	**1,036**	**420**[1]	**2,019**	**753**	**795**	**735**
Priest Rapids Dam to Vernita Bridge						
Franklin shore	28	1	27	9	2	6
Benton shore	111	27	104	37	33	18
Vernita Bar	3	1	28	1	9	0
China Bar	12	2	133	70	76	100
Vernita Bridge to Locke Island						
Franklin shore.	162	51	203	95	53	76
Benton shore	116	37	238	120	146	159
Coyote Rapids	11	0	5	3	0	5
Island #1	2	0	12		0	1
Island #2	0	0	11	1	2	2
Skull Island	4	3	51	13	6	49
Long Island	0	0	3	0	0	0
Vernita (total)	**449**	**122**	**815**	**349**	**327**	**416**
Locke Island to Ferry Landing						
Franklin shore.	30	0	0	0	0	0
Benton shore	6	1	48	6	3	14
Locke Island (Upper)	23	7	49	19	16	8
Locke Island (Lower)	70	15	43	26	12	8
White Bluffs Slough	17	9	35	51	18	16
Ferry Landing to Wooden Power Lines						
Franklin shore.	20	7	55	15	10	20
Benton shore	99	13	45	11	17	19
F-Islands	87	28	32	48	22	44
Hanford Slough	10	5	33	23	32	53
Hanford (total)	**362**	**85**	**340**	**199**	**130**	**182**
Wooden Power Lines to Ringold (canal)						
Franklin shore.	2	7	153	7	0	17
Benton shore	42	19	2	15	7	11
Savage	6	3	159	13	27	0
Ringold to Wooded Island (bottom)						
Franklin shore.	13	8	86	0	45	0
Benton shore	37	32	18	15	22	25
Island at Ringold	18	0	3	20	0	9
Homestead Island	17	21	24	22	40	24
Lower Homestead Island	21	66	360	57	145	17
Fir Island	8	3	3	0	3	0
Wooded Island	36	23	48	34	40	12
Wooded Island to Howard Amon Park						
Franklin shore.	0	23	0	10	9	4
Benton shore	18	8	5	5	0	16
Johnson Island	7	0	0	7	0	0
Refuge Island #1	0	0	0	0	0	0
Refuge Island #2	0	0	0	0	0	0
Refuge Island #3	0	0	0	0	0	2
Nelson Island	0	0	3	0	0	0
Richland (total)	**225**	**213**	**864**	**205**	**338**	**137**

Flights were scheduled at 9:00 am on Saturdays from April 12 through May 24. Flights were scheduled based on anticipated decreases in discharge that typically occur on weekends due to decreased power demands. Entrapments counted should be considered minimum estimates as a single aerial flight can only capture a portion of the isolated pools formed during a given event. Many pools will drain prior to scheduled flight times are others continue to form as river elevations decrease in downstream areas as illustrated in Figures 7, 8, and 9.

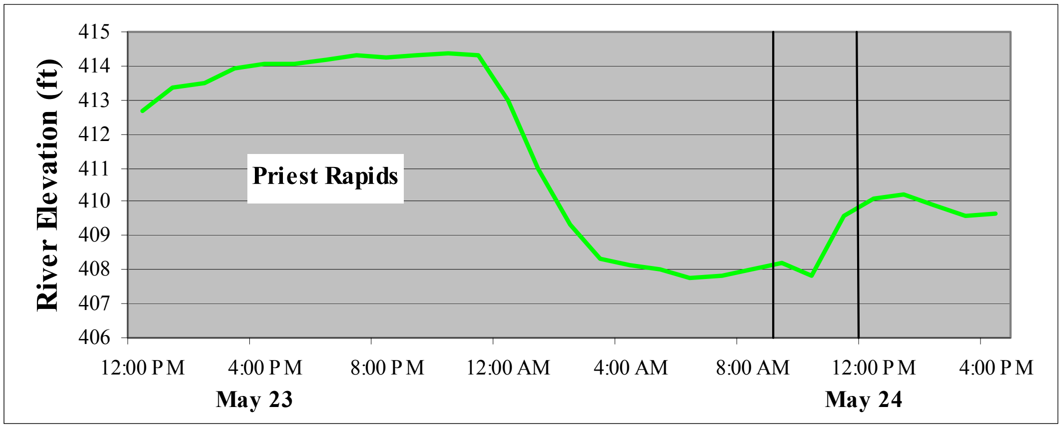

Figure 7. River elevation at Priest Rapids Dam, May 23-24, (flight 9am – noon, May 24).

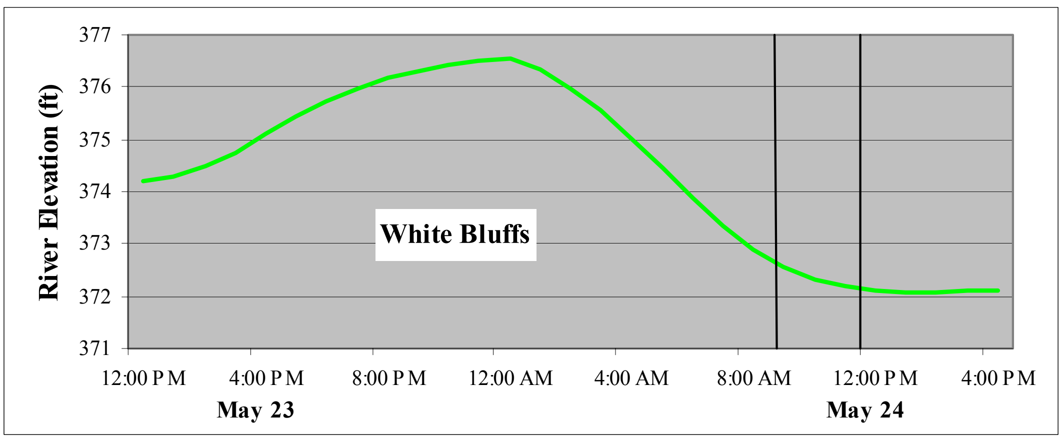

Figure 8. River elevation at White Bluffs boat launch, May 23-24, (flight 9am – noon, May 24).

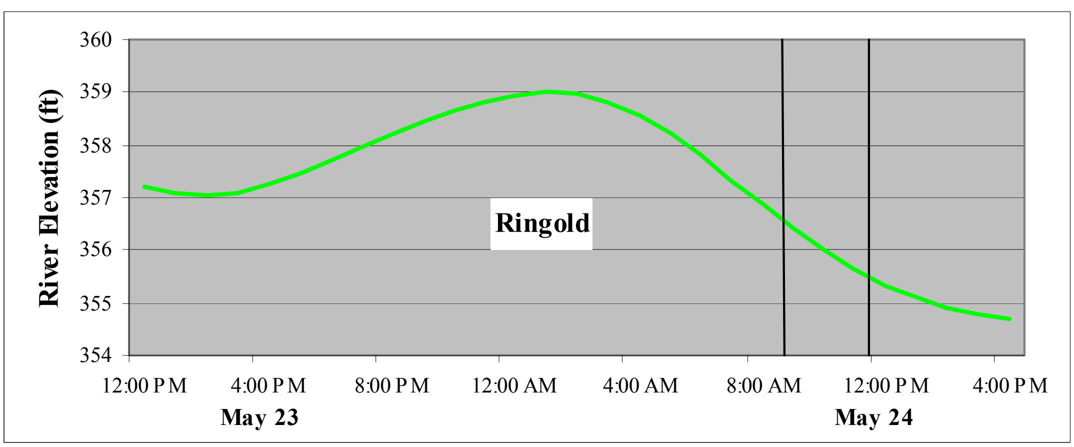

Figure 9. River elevation at Ringold , May 23-24, (flight 9am – noon, May 24).