Imnaha River Spring/Summer Chinook Salmon Hatchery Program Review

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This program is a cooperative effort of the Oregon Department of Fish and Wildlife, the Nez Perce Tribe and the Confederated Tribes of the Umatilla Indian Reservation. The program is funded by the Bonneville Power Administration and administered by the United States Fish and Wildlife Service under the Lower Snake River Compensation Plan.

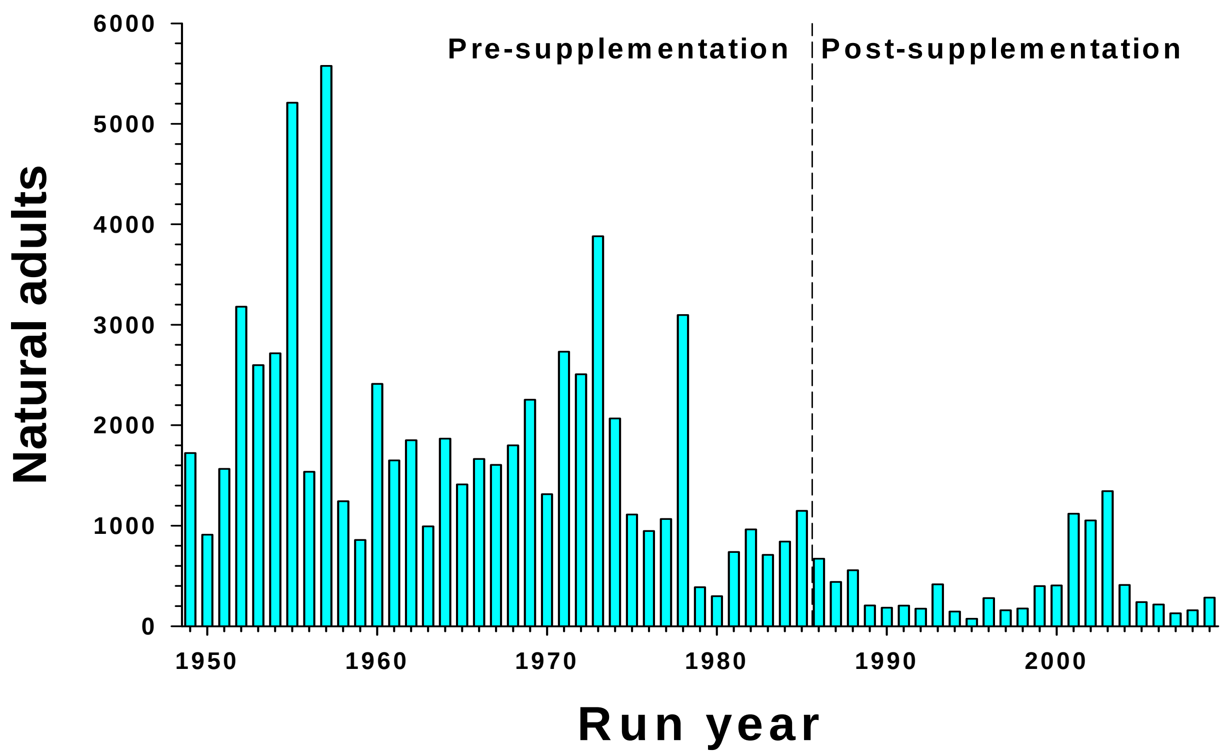
INTRODUCTION AND BACKGROUND

This paper provides background information, program development history, and an assessment of program performance for the Imnaha River spring/summer Chinook salmon *Oncorhynchus tshawytscha* hatchery program. We cover the period from program initiation in 1982 to the present (2010).

The Imnaha River basin historically supported an abundant run of spring/summer Chinook salmon. Tribal and recreational fisheries occurred throughout the basin. Recreational fisheries were closed in the mid-1970s due to the depressed status of the population and tribal fishing was limited in many years.

The Imnaha River basin is located in Northeastern Oregon. The basin originates in high elevation areas of the Eastern Wallowa Mountains and the plateau between the Wallowa River drainage and Hells Canyon. The Imnaha River enters the Snake River at rkm 309.9. Historically, the primary production areas included the upper mainstem of the Imnaha River and Big Sheep Creek.

The Lower Snake River Compensation Plan (LSRCP) Imnaha River spring/summer Chinook hatchery program was initiated in 1982 in response to severe abundance declines that occurred in the mid-1970s (Figure 1).



(Figure 1): Natural-origin adult abundance of Imnaha River spring/summer Chinook salmon population, 1949-2009.

Table 1. Lower Snake River Compensation Plan mitigation goals for Oregon's spring/summer Chinook salmon in the Imnaha River basin. Adult and survival goals are expressed for returns to the compensation area and total catch and escapement.

Category	Goal
Compensation Area	
Annual smolt goal	490,000 Smolts(360,000 interim)
Annual pounds of production	24,500 lbs.
Annual adult goal	3,210 Adults
Broodyear smolt–to-adult return rate (SAR)	0.65%
Total Catch & Escapement	
Annual adult goal	16,050 Adults
Brood year smolt-to-adult survival rate (SAS)	3.25%

Annual adult mitigation, brood year specific smolt-to-adult return and total survival rates, and annual smolt production goals were established to compensate for the estimated annual loss of 48% of the adult production (Table 1).

The adult return and smolt-to-adult return rate goals for the compensation area represent the required performance to the area above Lower Granite Dam. The total adult and smolt-to-adult survival rate goals were determined based on an assumed catch to escapement ratio of four-to-one that existed prior to construction of the dams. An interim smolt production goal of 360,000 has been adopted due to rearing space limitations and preferred density criteria at Lookingglass Fish Hatchery (LFH).

The implementation of LSRCP Imnaha Chinook salmon hatchery program has been guided by five priority management objectives: 1) establish an annual supply of broodstock capable of meeting production goals; 2) maintain and enhance natural production while maintaining long term fitness of the natural population; 3) re-establish historic tribal and recreational fisheries; 4) establish a total return number of spring Chinook salmon that meets the LSRCP compensation goal; 5) operate the hatchery program to maintain the genetic and life history characteristics of the natural population and have hatchery fish characteristics mimic wild fish, while achieving management objectives.

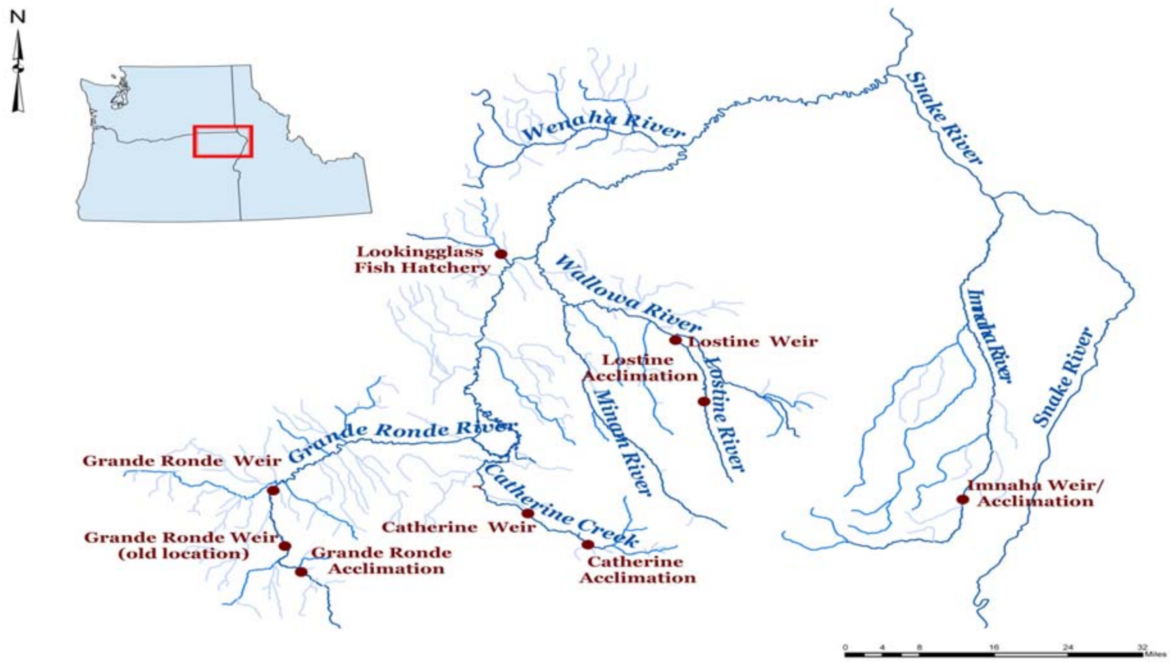


Figure 2. Map of the Grande Ronde Imnaha river basins including the Imnaha weir / acclimation site and Lookingglass Fish Hatchery.

The Imnaha River juvenile acclimation and adult weir/trapping facility is located at rkm 85 on the mainstem of the Imnaha River (Figure 2). The Imnaha weir/ acclimation site is operated as a satellite of LFH, which serves as the adult holding, spawning, incubation and rearing facility for the Imnaha Chinook program. A temporary facility was operated on the Imnaha River from 1982-1988 and a permanent facility was constructed in 1989.

A comprehensive research, monitoring, and evaluation (RM&E) program has been underway since 1984. The primary objectives of the RM&E are: 1) document and assess fish culture and hatchery operation practices and performance; 2) determine optimum rearing and release strategies that will produce maximum survival to adult; 3) determine total catch and escapement, smolt survival, and smolt-to-adult survival, and assess if adult production meets mitigation goals; 4) assess and compare recruits-per-spawner of hatchery and natural origin fish; 5) assess response in natural population abundance and productivity (adult recruits-per-spawner, smolts-per-spawner) to supplementation; 6) assess and compare life history characteristics (age structure, run and spawn timing, sex ratios, smolt migration, fecundity) of hatchery and natural fish; and 7) assess success in restoring fisheries.

PROGRAM ASSESSMENT

The uniqueness of the Imnaha spring/summer Chinook salmon population was recognized prior to the initiation of the hatchery program. This recognition led to the decision to use only endemic local broodstock for the hatchery program. Wild adults were collected for broodstock beginning in 1982. Natural-origin adults comprised a majority of the broodstock from 1982-1988. In recent years natural-origin adults have represented only a small proportion of the annual broodstock (Table 2).

Table 2. Hatchery broodstock history for the Imnaha River spring/summer Chinook salmon hatchery program.

	Number of females in broodstock		Percent natural origin adults in broodstock
Spawn years	Natural	Hatchery	
1982-1988	10-91	0-10	100-82.2
1989-2002	6-48	9-168	7.1-71.4
2003-2009	19-34	72-87	19.1-26.4

Few hatchery fish spawned naturally from 1982-1988. Hatchery fish have represented a high proportion of natural spawners in recent years and the Proportionate Natural Influence (PNI) has been low, ranging from 0.218-0.279 (Table 3). A sliding scale broodstock management plan has been used throughout most of the implementation time frame. The sliding scale has been modified through time and the current sliding scale management plan (Table 4).

Table 3. Vital statistics for natural spawning spring/summer Chinook salmon in the Imnaha River.

Spawn years	Total number spawning in nature	Percent hatchery spawning in nature	Percent natural retained for broodstock	PNI
1982-1988	539-1715	0-15.4	2.3-28.8	1-0.881
1989-2002	291-4643	24.4-75.8	3.0-28.9	0.161-0.781
2003-2009	804-3164	49.3-86.2	3.9-21.2	0.235-0.362

Table 4. Sliding scale broodstock and natural escapement management plan for the Imnaha River spring/summer Chinook salmon hatchery program.

Total escapement to river	Maximum % natural retained for broodstock	% Hatchery above weir	Minimum % of natural-origin broodstock
>15	0	NA	NA
15-159	50	NA	NA
150-299	40	70	20
300-499	40	60	25
500-999	30/40*	50	30
1000-1499	30/40*	40/30*	40
1500-1999	25	25	50
>2000	25	<10*	100

** 3 consecutive years with Minimum Abundance Threshold ≥ 1000*

One of the significant challenges that this program has faced is trapping adults throughout the entire run. The weir can be safely installed only when river discharge is $\leq$ 28 m^{3}/$_{5}$. There have been many years that a large proportion of the return has passed by the weir prior to weir installation (Figure 3). In addition, significant spawning occurs below the weir location.

Prespawning mortality of broodstock has been variable with some high mortality rates early in the program implementation. In recent years, prespawning mortality has been low (Figure 4). Green egg-to-smolt survival rates have been consistently high through time. The smolt production goal of 490,000 has not been achieved in any year. Since 2000, when the interim smolt production goal was adopted, the smolt production has met or exceeded the goal in six of nine years (Figure 5). Smolt survival to Lower Granite Dam has been relatively high (greater than 65%) for most recent brood years (Figure 6). The smolt migration pattern for hatchery fish is different than natural fish. Hatchery fish have a compressed distribution with later arrival timing and earlier migration completion (Figure 7).

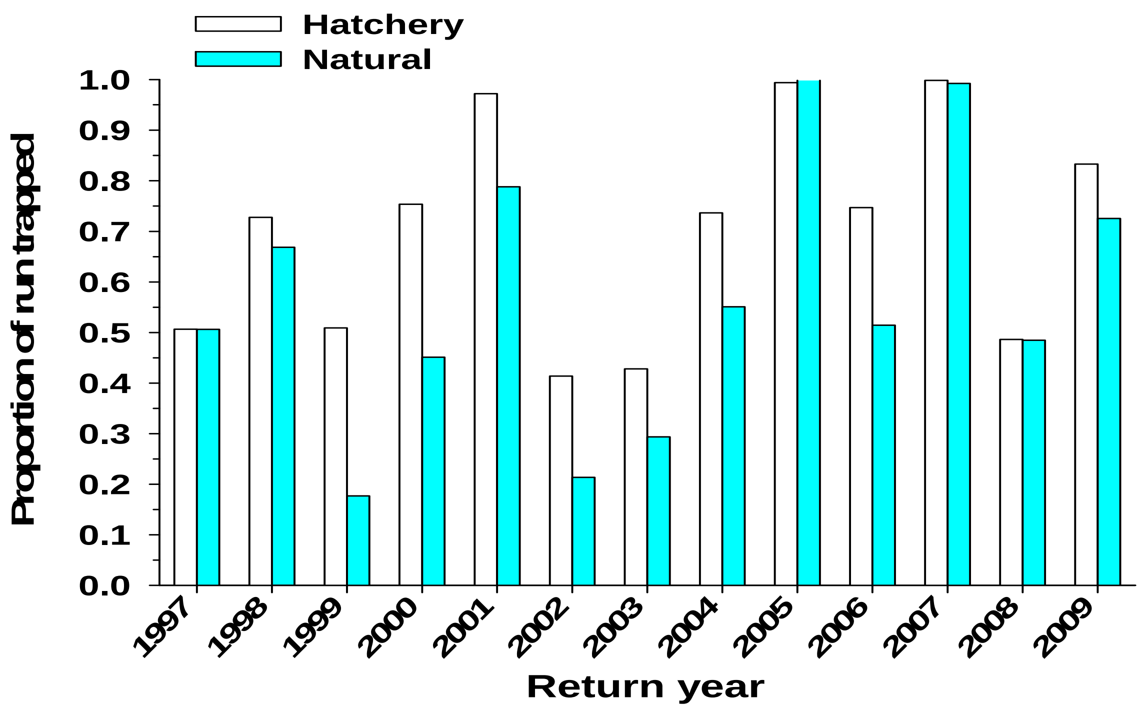


Figure 3. Estimated proportion of the Chinook salmon run trapped at the Imnaha River weir, 1997-2009.

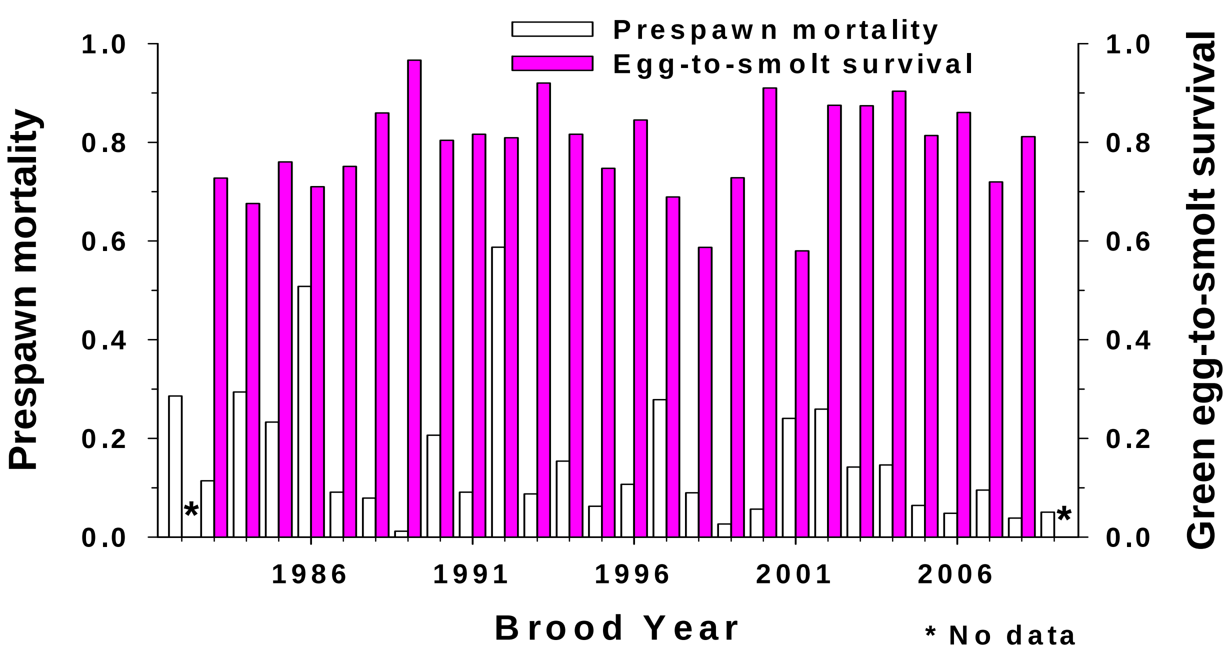


Figure 4. Prespawn mortality of broodstock collected and held for spawning and green egg-to-smolt survival, 1982-2009 brood
years.

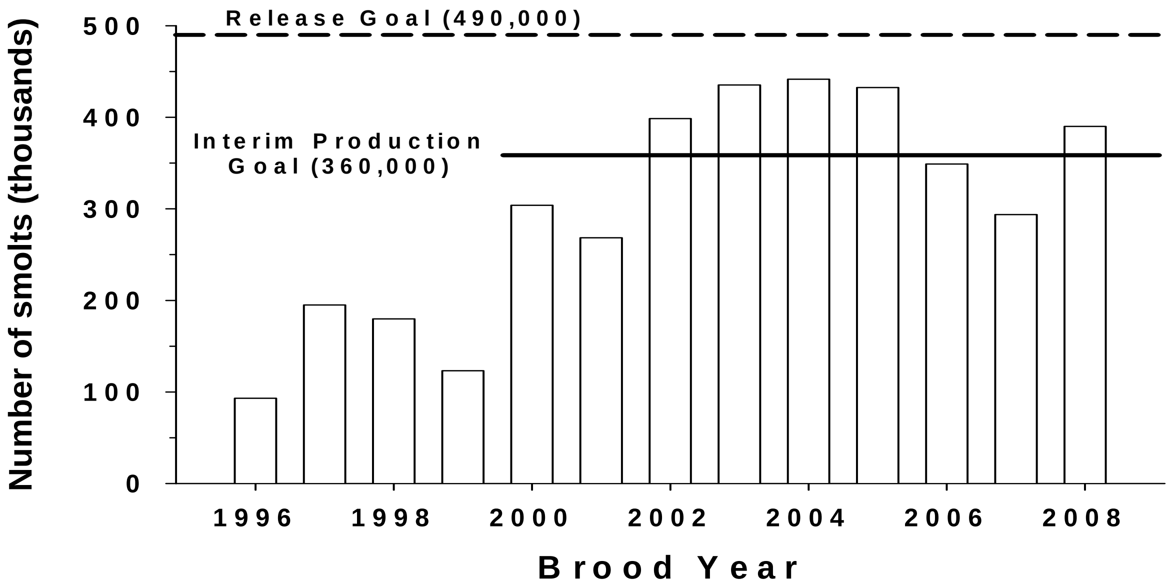


Figure 5. Chinook salmon hatchery smolt releases in the Imnaha River basin, 1996-2008 brood years.

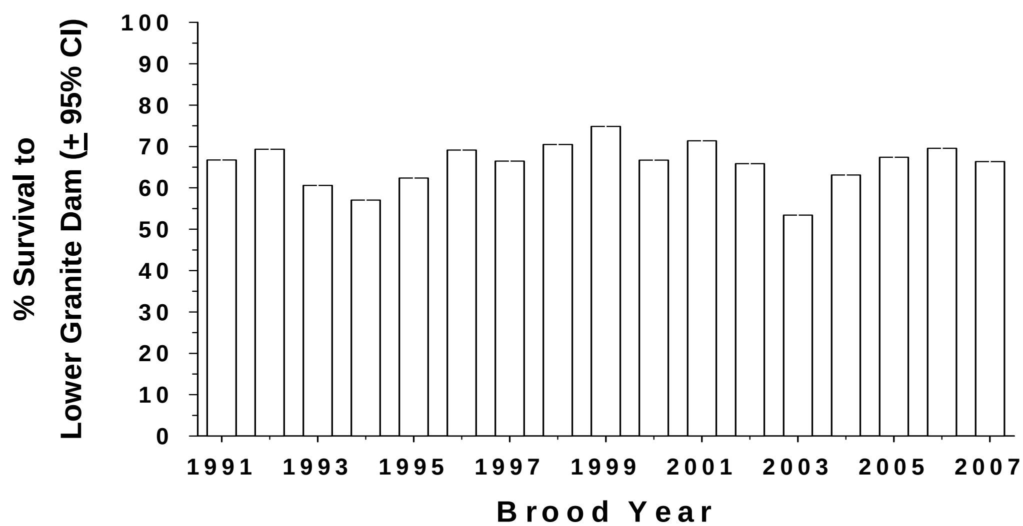


Figure 6. Mean Imnaha River hatchery smolt survival to Lower Granite Dam, 1991-2007 brood years.

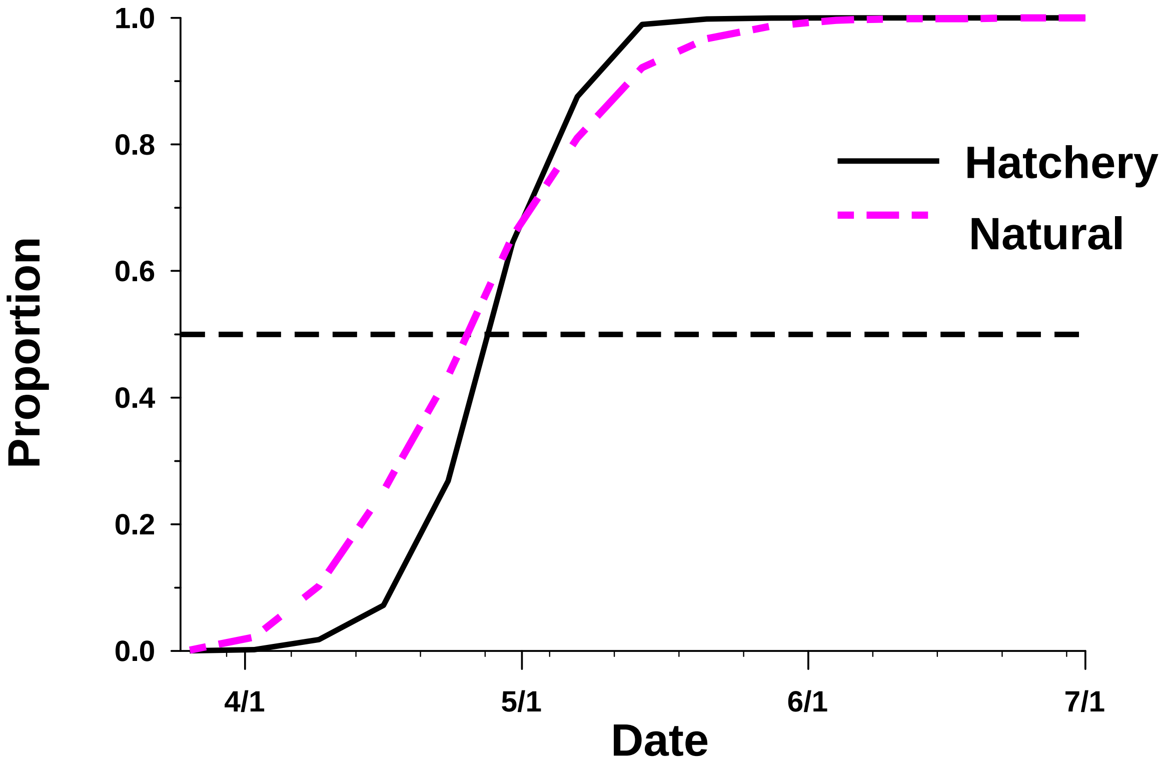


Figure 7. Mean migration timing at Lower Granite Dam of natural and hatchery-origin Imnaha River smolts, 1995-2009 migration years.

Prior to 2001, adult returns to the compensation area were well below the mitigation goal of 3,210. We reached the goal for the first time in 2001 and have met or exceeded the goal in three of the last nine years (Figure 8). One of the primary reasons we have not achieved adult return goals is because smolt production has been below the original goal of 490,000. One key measure of performance is the SAR relative to the program goal of 0.65%. Over the past 10 years the SAR has ranged from 0.03% to 2.5%. The SAR goal has been met or exceeded in eight of the last 10 years (Figure 9).

Imnaha River Chinook salmon are exploited at very low rates in the ocean, Columbia River and tributaries fisheries. On average, 88.3% of the adults produced escape to the Imnaha River (Table 5).

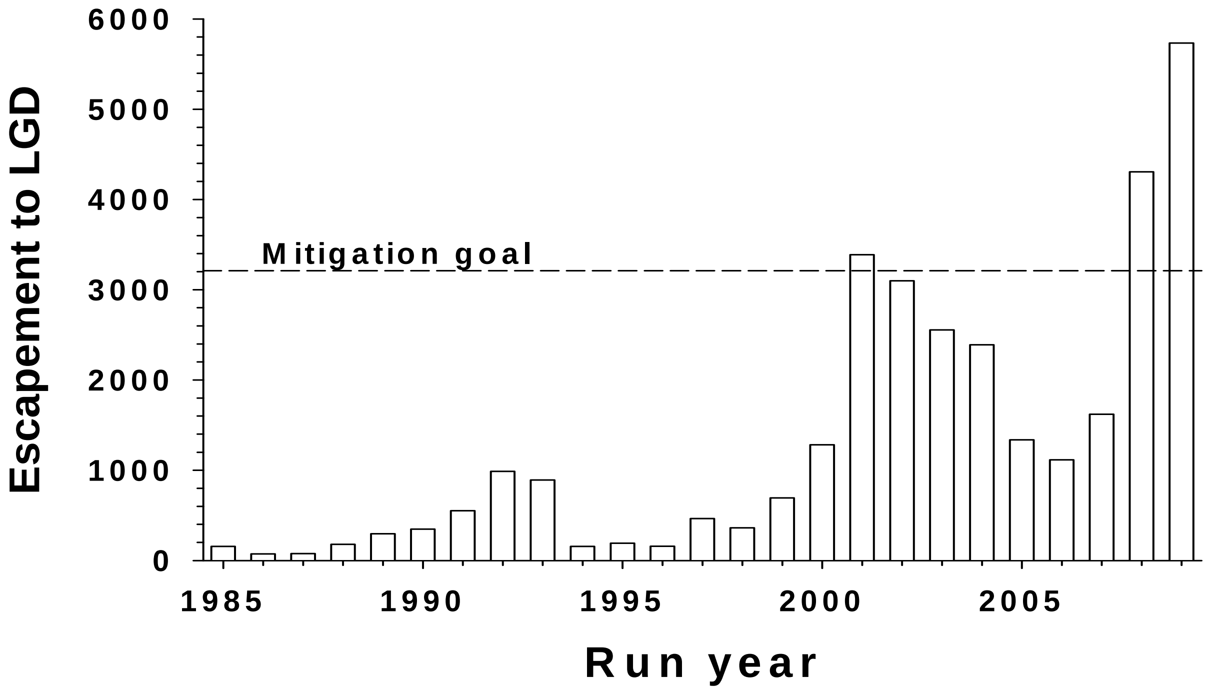


Figure 8. Adult returns to the LSRCP compensation area for hatchery-origin Imnaha River spring/summer Chinook salmon, 1985 – 2009 run years.

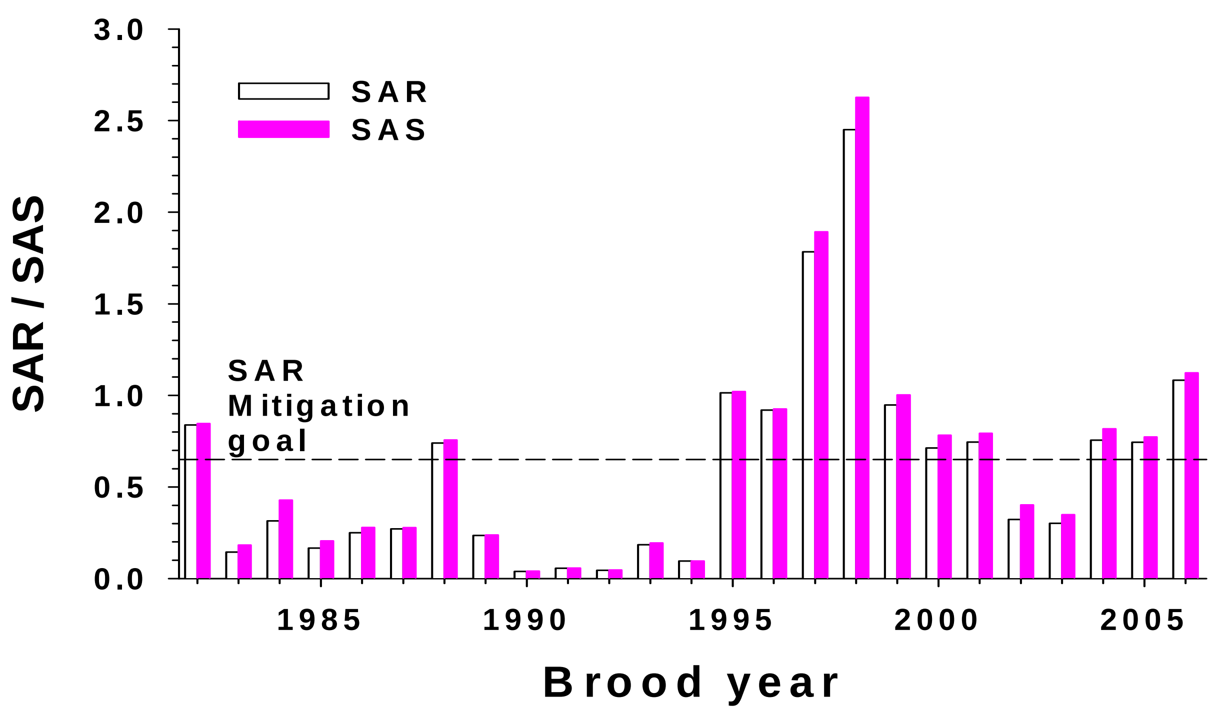


Figure 9. Smolt-to-adult survival (SAS) and return (SAR) rates for Imnaha River hatchery Chinook salmon, 1982 – 2006 brood years.

Table 5. Catch and escapement distribution (%) of Imnaha River hatchery spring/summer Chinook salmon.

Recovery Location	Percent of total				
	Brood Year				
	2001	2002	2003	2004	Mean
Ocean	0.6	0.2	0.1	0.4	0.3
Columbia River Harvest					
Tribal	1.3	3.5	7.4	1.5	3.4
Sport	3.0	12.1	4.5	4.6	6.1
Commercial net	0.8	2.0	0.6	0.3	0.9
Snake River					
Stray below LGD	0.3	0.2	0.4	0.6	0.4
Stray above LGD	0.0	0.4	0.3	0.1	0.2
Sport above LGD	0.2	1.3	0.0	0.0	0.4
Tribal above LGD	0.0	0.0	0.0	0.0	0.0
Escapement to River	**93.9**	**80.2**	**86.7**	**92.5**	**88.3**

Imnaha River hatchery Chinook that return to the Imnaha River have a diverse disposition profile. A high proportion of the returns spawn naturally, are outplanted to the Big Sheep Creek drainage or are used for broodstock. Smaller porporitions are harvested in tribal and recreational fisheries or are distributed to Oregon food banks or for tribal consumption (Figure 10).

One of the key indicators of the magnitude of full life cycle survival advantage that is provided by hatchery supplementation programs is the hatchery-to-natural ratio in adult recruits-per-spawner (R/S). For the ten most recent brood years the R/S for hatchery spawned fish averaged 9.3 and 1.4 for natural spawning fish. Natural spawner recruits-per-spawner exceeded 1 in only four of the last ten brood years and was below 0.5 for five most recent brood years (Figure 11).

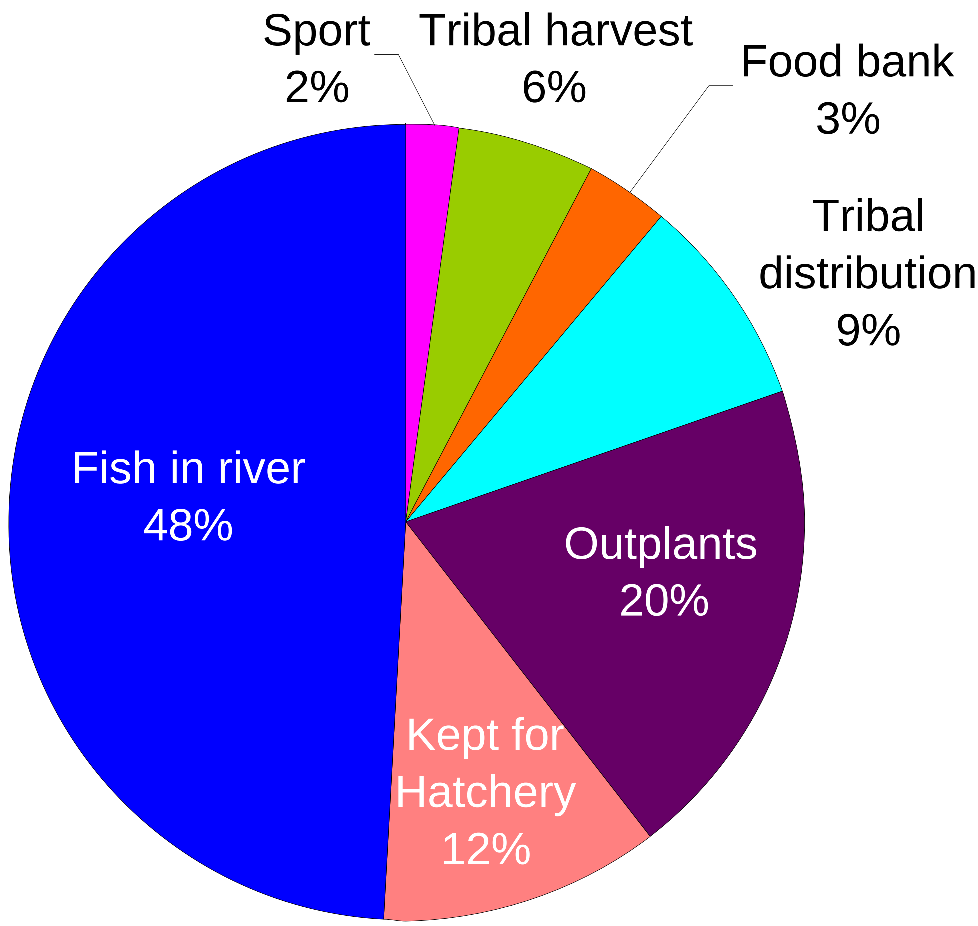


Figure 10. Disposition of Imnaha River hatchery Chinook salmon that returned to the Imnaha River, 2001-2004 return years.

We have consistently observed differences in run timing between hatchery and natural adults. Hatchery fish pass through the Lower Snake River dams later that natural fish and also have a later run timing distribution at the weir (Figure 12). This difference in timing is likely a result of broodstock collection that selects the later returning fish in most years. Consistent with later run timing for hatchery females we have also observed a later spawn timing for hatchery females. We have observed complete overlap in spawning range, however the hatchery fish distribution is concentrated more downstream around the release location (Figure 13). Hatchery fish return at an earlier age than natural-origin fish with a very high proportion of age 3 males and few age 5 fish (Figure 14). Age 3 males make up about 50% of the males that return for a brood year.

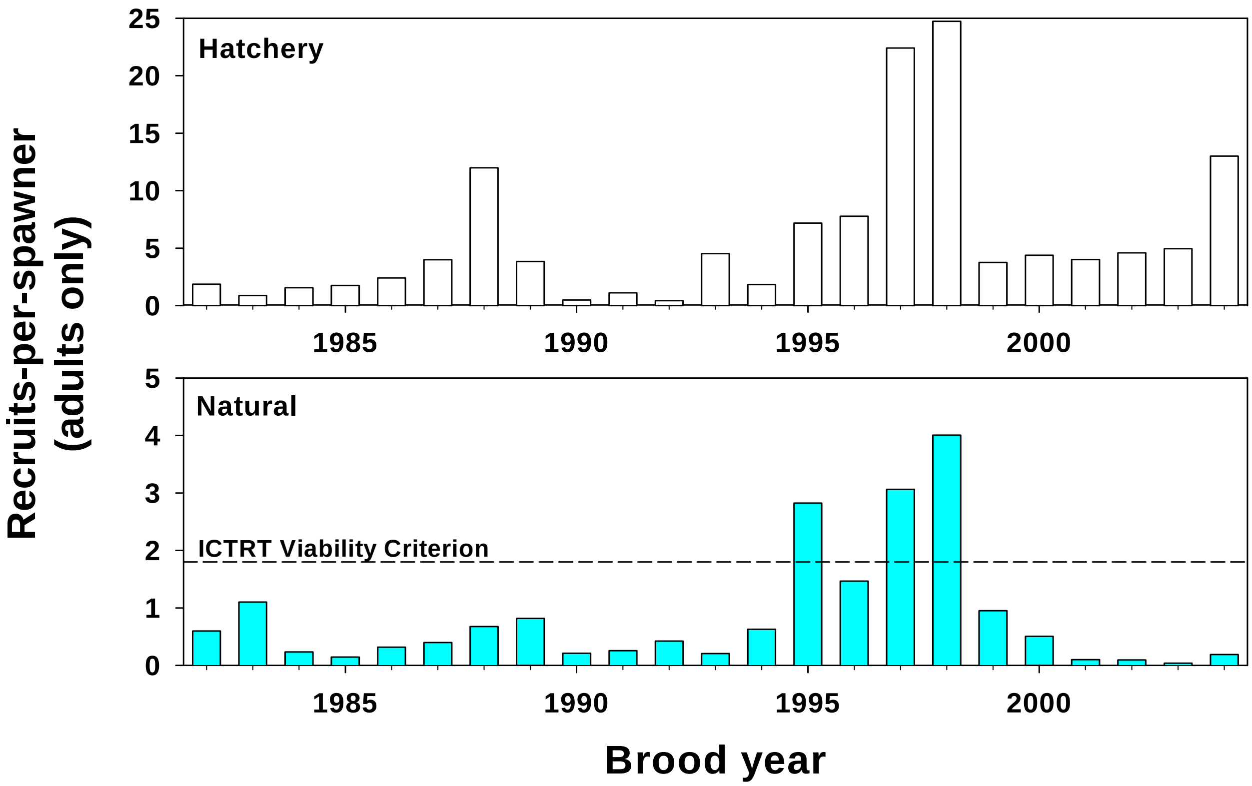


Figure 11. Imnaha River Chinook salmon recruits-per-spawner (jacks omitted) for hatchery spawned adults and natural spawning (natural-origin and hatchery-origin) adults, 1982-2004 brood years.

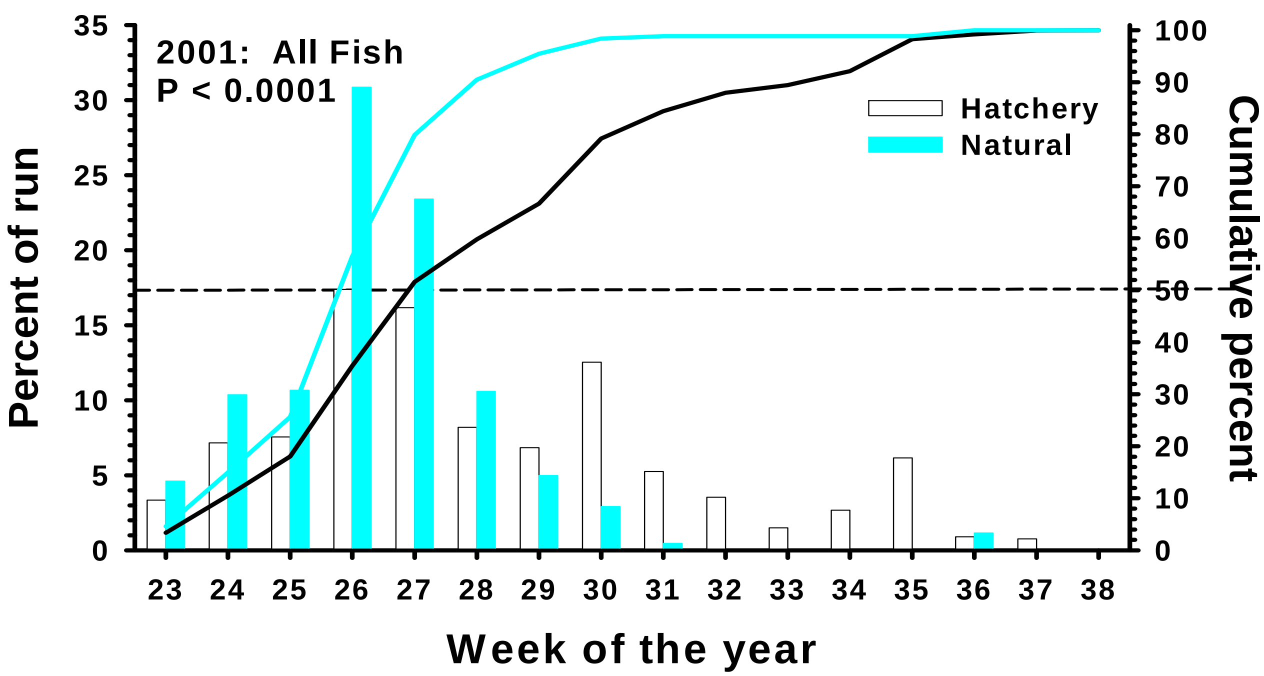


Figure 12. Run timing of hatchery and natural-origin Imnaha River Chinook salmon at the Imnaha River Weir, 2001-run year.

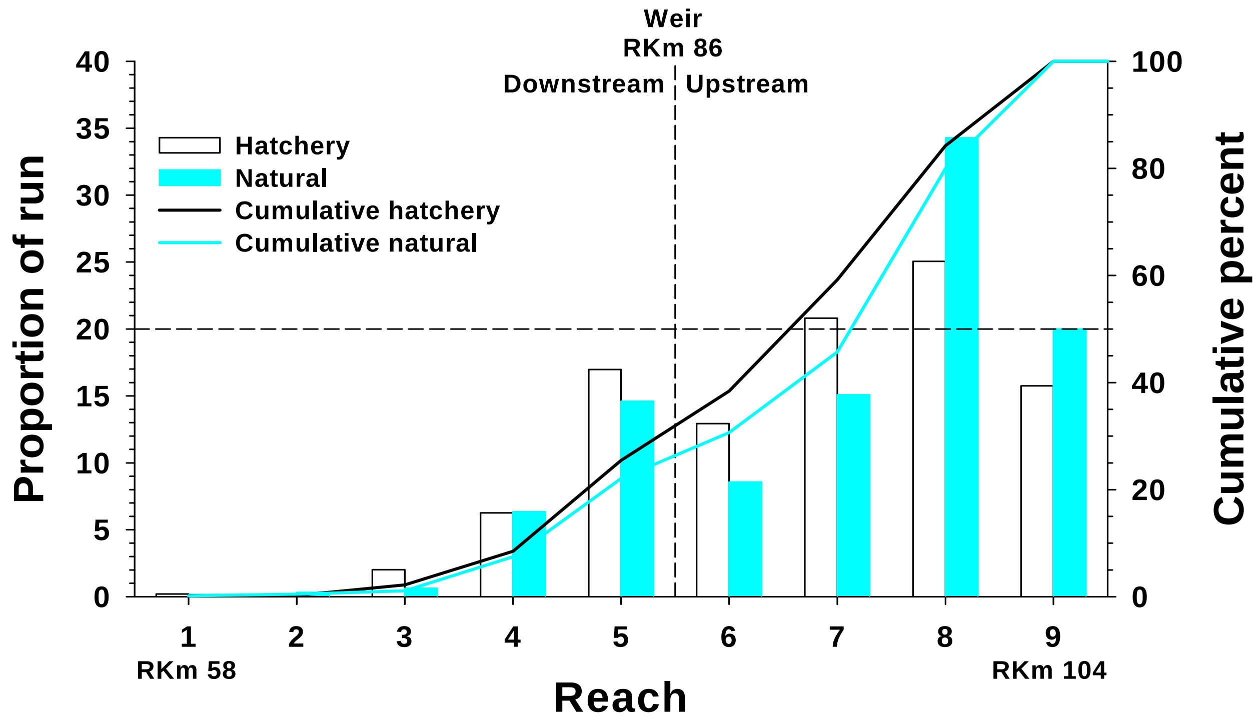


Figure 13. Spawning distribution of hatchery and natural-origin females in the Imnaha River.

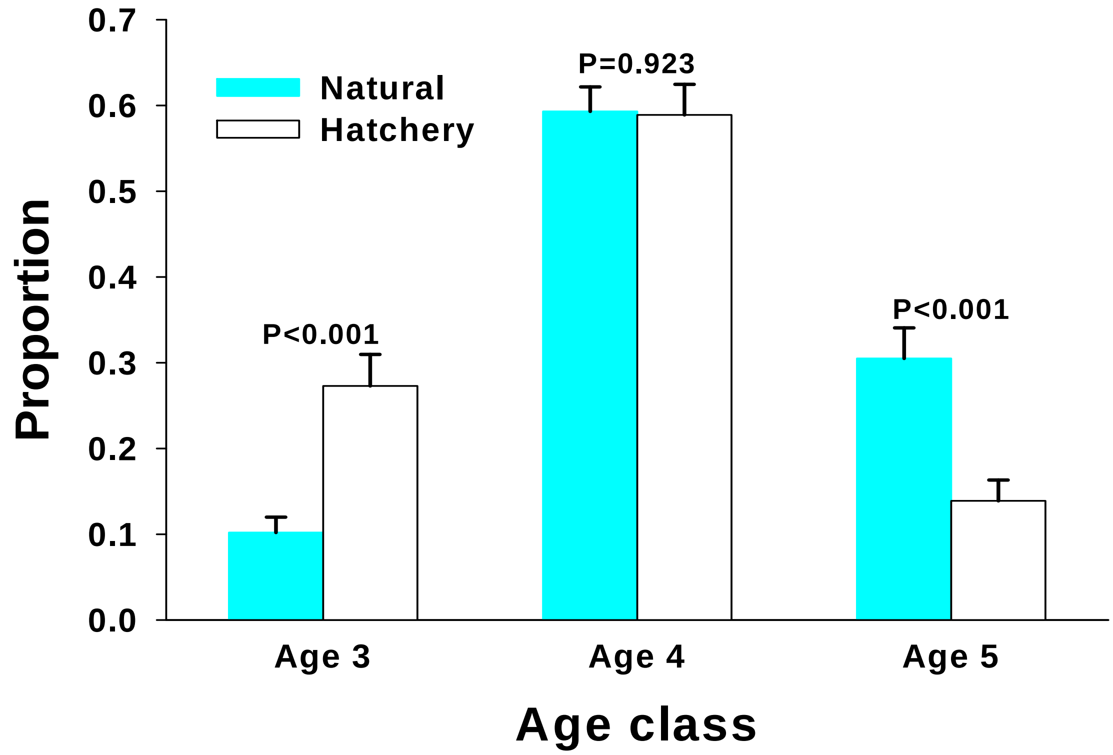


Figure 14. Mean age-at-return distribution for hatchery and natural-origin Imnaha River Chinook salmon, brood years 1982-2004.

The most common accepted definition of supplementation was developed by Regional Assessment of Supplementation Project (RASP) many years ago: "the use of artificial propagation to maintain or increase natural production to maintain long-term fitness of the target population …" We have estimated the abundance of natural spawning hatchery and natural origin fish for many years (Figure 15). However, this information alone provides little insight into the effectiveness of supplementation. For supplementation to be successful, natural-origin abundance must increase to levels above that which would have occurred without supplementation and productivity must not decrease. Approaches to assessing supplementation success are challenging, primarily due to the lack of availability of data for reference populations that are unsupplemented. The compilation of long-term abundance and productivity datasets by IDFG, ODFW, and the ICTRT for Snake River spring/summer Chinook salmon populations provided the unsupplemented reference population data to allow us to conduct a unique comprehensive analyses of the Imnaha Chinook supplementation program.

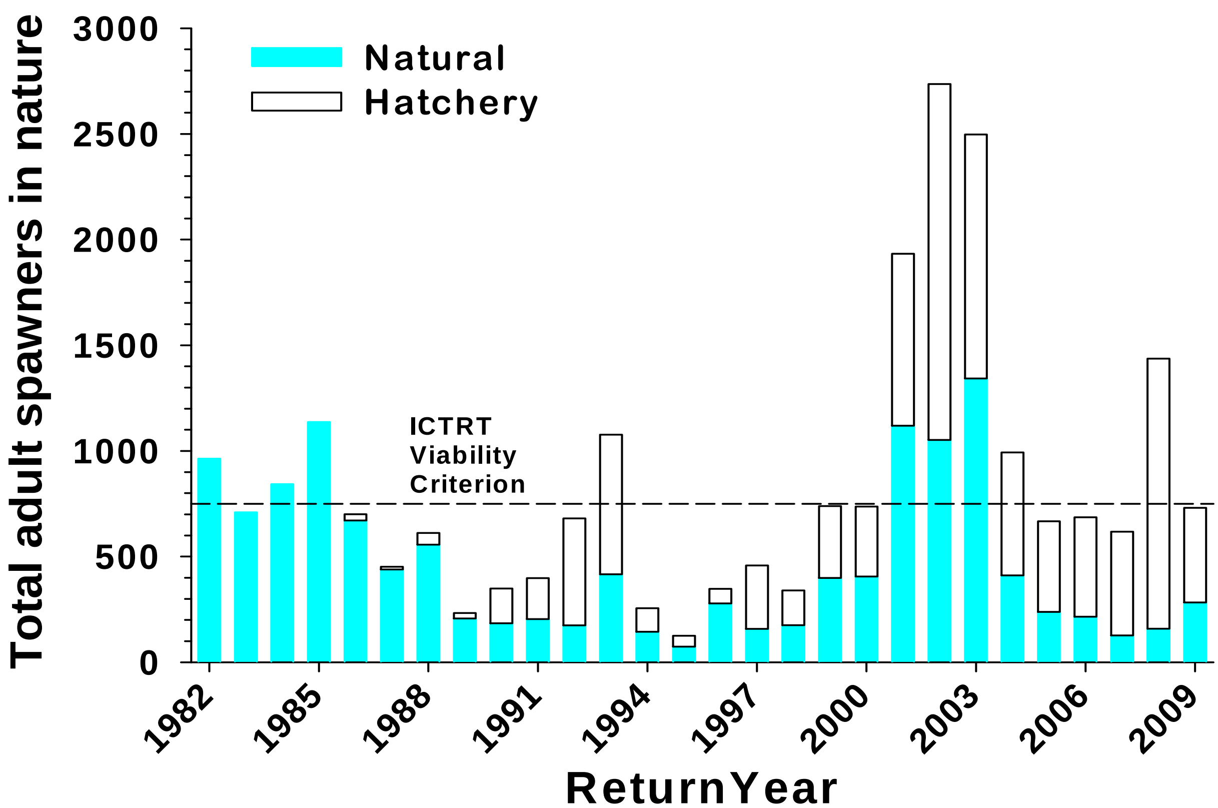


Figure 15. Abundance of naturally spawning hatchery and natural-origin adults in the Imnaha River Chinook salmon population, 1982-2009.

To assess the natural-origin abundance and productivity response of the Imnaha River population we acquired and compiled adult spawners and recruit abundance and productivity (R/S) time series datasets for the supplemented Imnaha River population and eight unsupplemented Idaho Salmon River basin populations (Figure 16). We determined the level of correlation (Pearson's) in abundance and productivity (R/S) between the Salmon River basin and Imnaha River populations for the pre-supplementation time period (late 1950s-1985 for abundance and late 1950s-1981 for productivity) to evaluate the adequacy of the Salmon River populations as reference populations. We calculated year-specific and mean year-specific pre-and post-treatment ratios (Imnaha / reference population) for total spawners, natural-origin spawners, and productivity. We conducted t-tests to compare means for pre-and post-time-periods. We designed our analysis to test the following assumptions and hypotheses:

1) Total spawner abundance should increase. Therefore, the post-supplementation total abundance ratio should be greater than the pre-supplementation ratio.

2) Natural-origin spawner abundance should increase. Therefore, the post-supplementation abundance ratio should be greater than the pre-supplementation ratio.

3) Productivity should remain the same. Therefore, the post-supplementation R/S ratio should be equal to or greater than the pre-supplementation ratio.

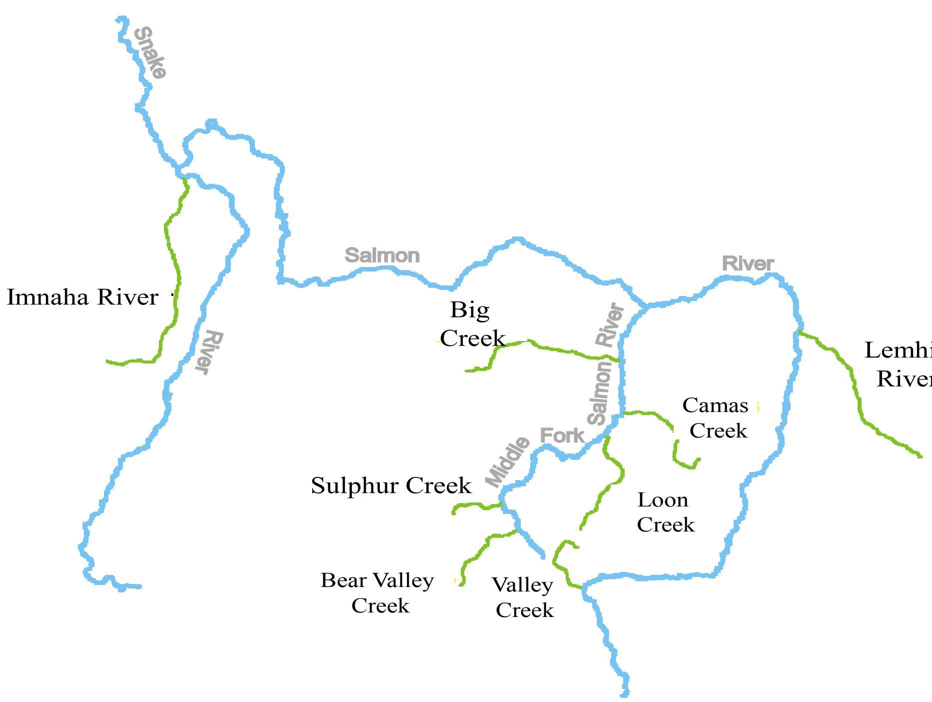


Figure 16. Map showing the locations of Snake River basin spring/summer Chinook salmon populations used for analyzing supplementation responses in the Imnaha River.

We found a high degree of correlation between the Imnaha river population and Salmon River reference populations for natural-origin abundance and adult R/S in the pre-supplementation time period (Table 6). We have provided time series comparisons (examples) between the Imnaha River and the Bear Valley Creek populations for total spawners, natural-origin spawner abundance, and R/S as well as year specific ratios, (Figures 17-22).

Table 6. Pre-supplementation natural-origin abundance correlations, Imnaha population vs. Idaho populations.

	Natural origin abundance		Recruits per spawner	
Idaho stream	rho	P-value	rho	P-value
Bear Valley Creek	0.56501	0.0026	0.47290	0.0262
Big Creek	0.53876	0.0026	0.36653	0.0715
Camas Creek	0.67431	0.0004	0.65674	0.0023
Lemhi River	0.47824	0.0087	0.40587	0.0441
Loon Creek	0.64394	0.0002	0.60903	0.0016
Marsh Creek	0.62440	0.0003	0.53570	0.0058
Sulphur Creek	0.52331	0.0043	0.35625	0.0805
Valley Creek	0.75378	<0.0001	0.58447	0.0027

Mean total spawner abundance ratio increased from the pre-to the post-time period for all eight pairwise comparisons. Three of the eight increases were significant (Table 7). The response in natural-origin abundance was much more variable. Natural-origin abundance ratios increased in three and decreased in five comparisons, with no consistent pattern in the response (Table 8). There was a consistent response pattern in the R/S ratio. The mean R/S ratio showed a significant reduction for all eight pairwise comparisons indicating a significant reduction in productivity for the post-supplementation time period (Table 9).

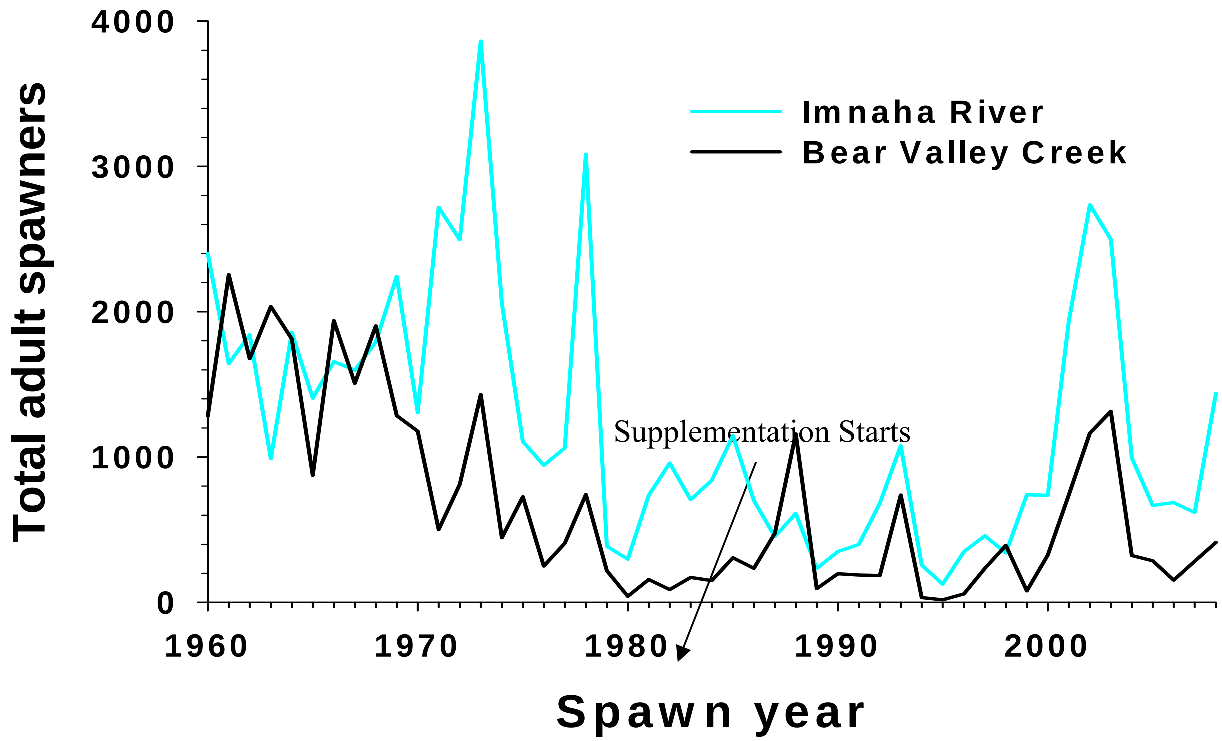


Figure 17. Abundance of total spawners for the Imnaha River and Bear Valley Creek Cinook salmon populations, 1960-2009.

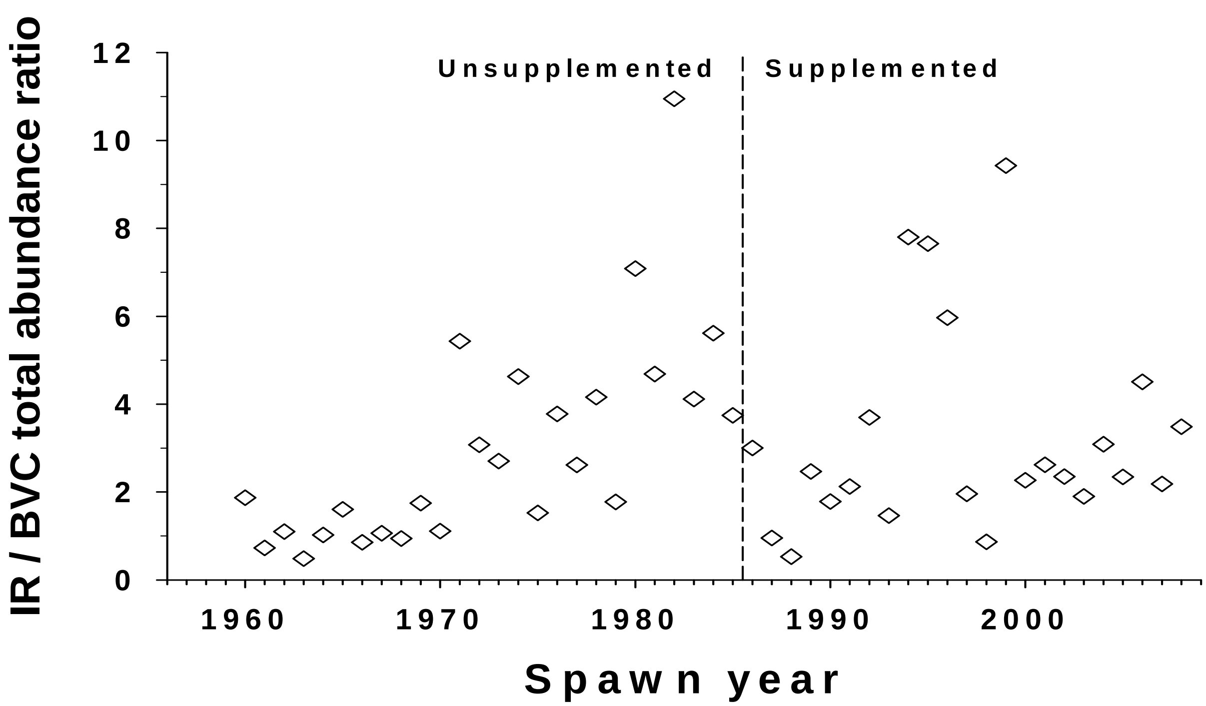


Figure 18. Total Chinook salmon spawner abundance ratios (Imnaha River / Bear Valley Creek), 1960-2009.

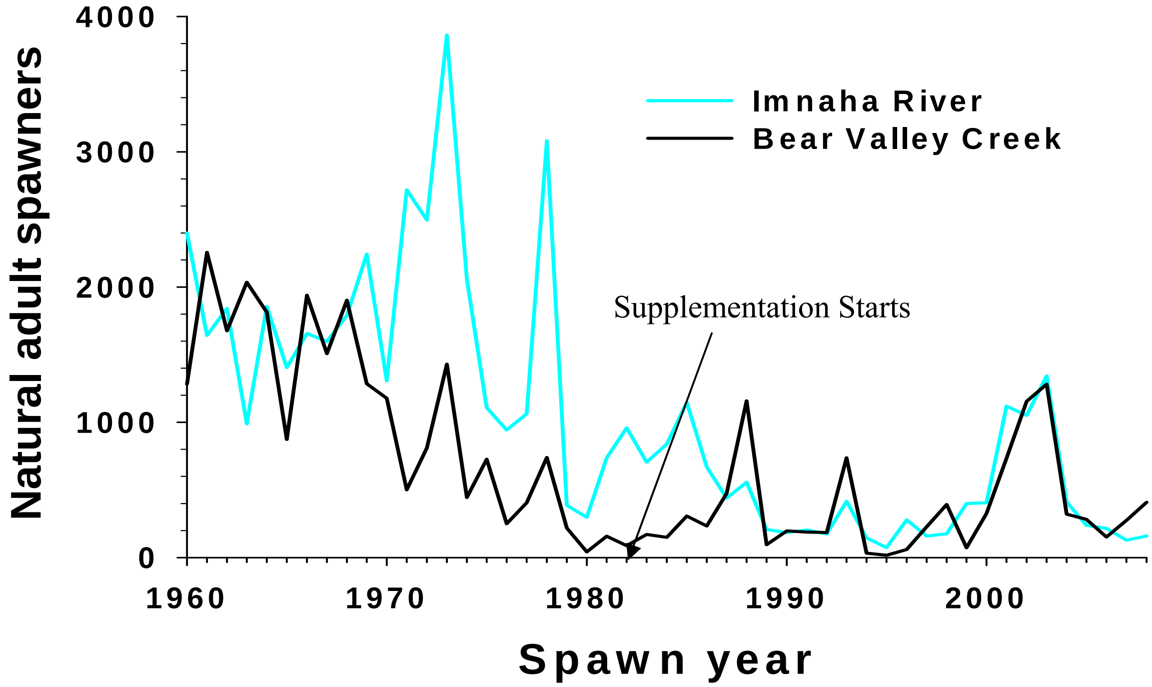


Figure 19. Abundance of natural-origin spawners in the Imnaha River and Bear Valley Creek Chinook salmon populations, 1960-2009.

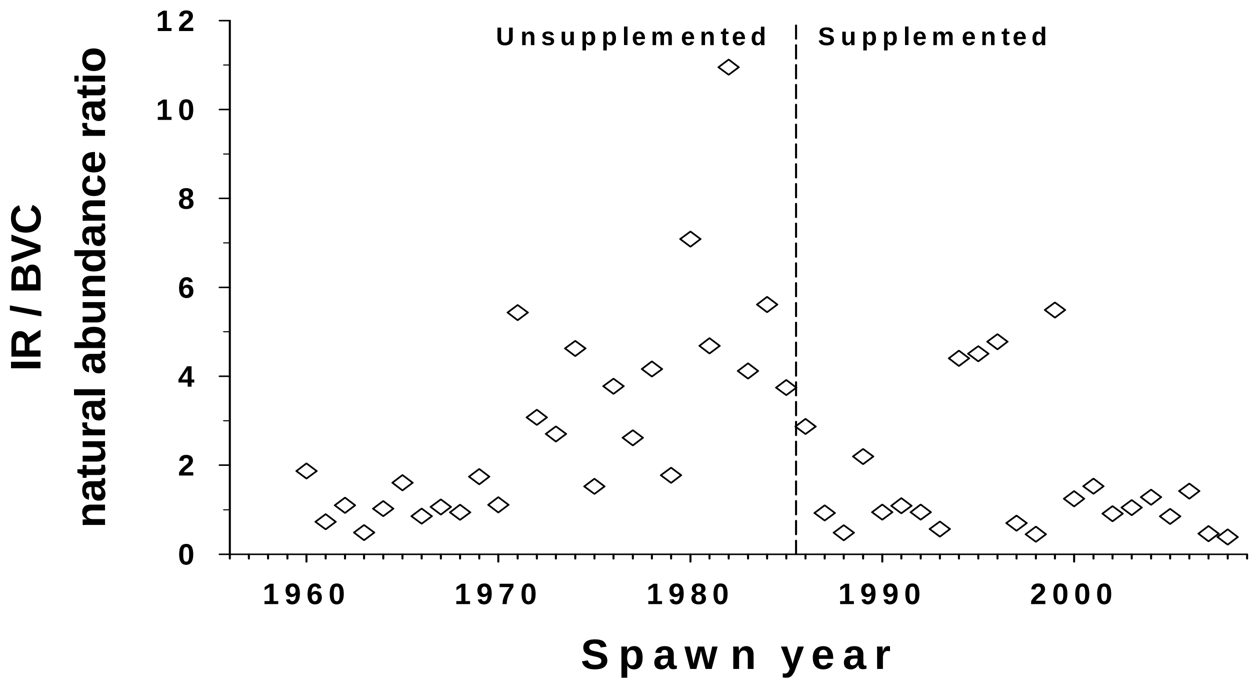


Figure 20. Chinook salmon ration of natural-origin abundance (Imnaha River / Bear Valley Creek), 1960-2009.

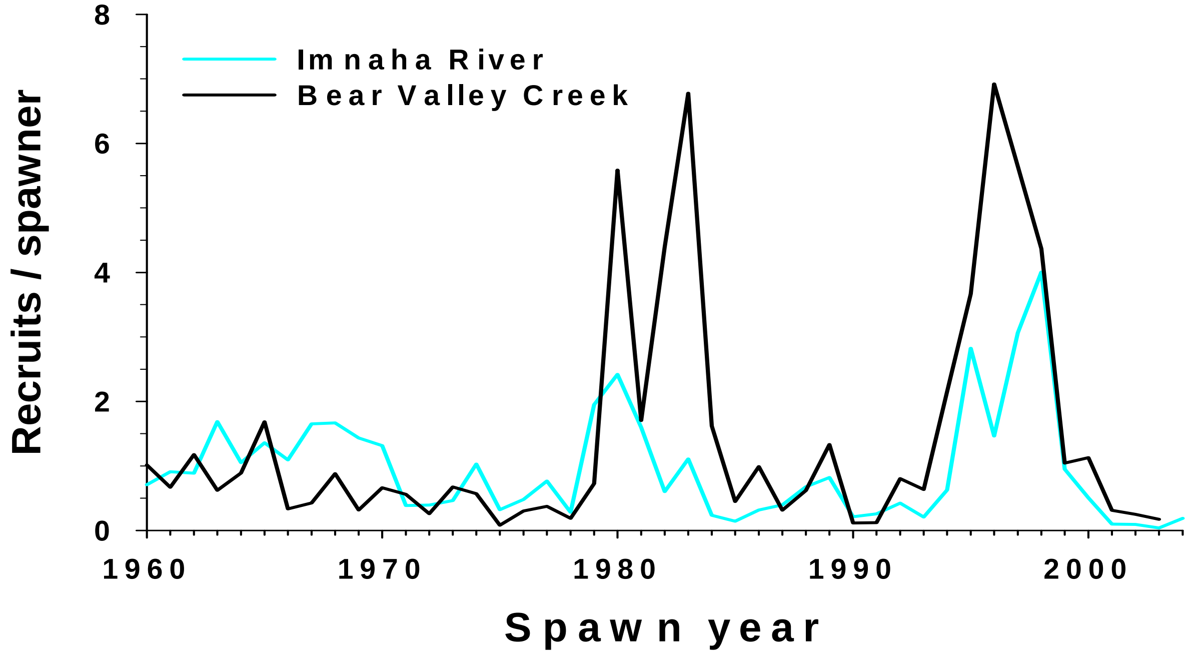


Figure 21. Recruits-per-spawner (spawner-to-spawner) for the Imnaha River and Bear Valley Creek Chinook salmon populations, 1960-2004.

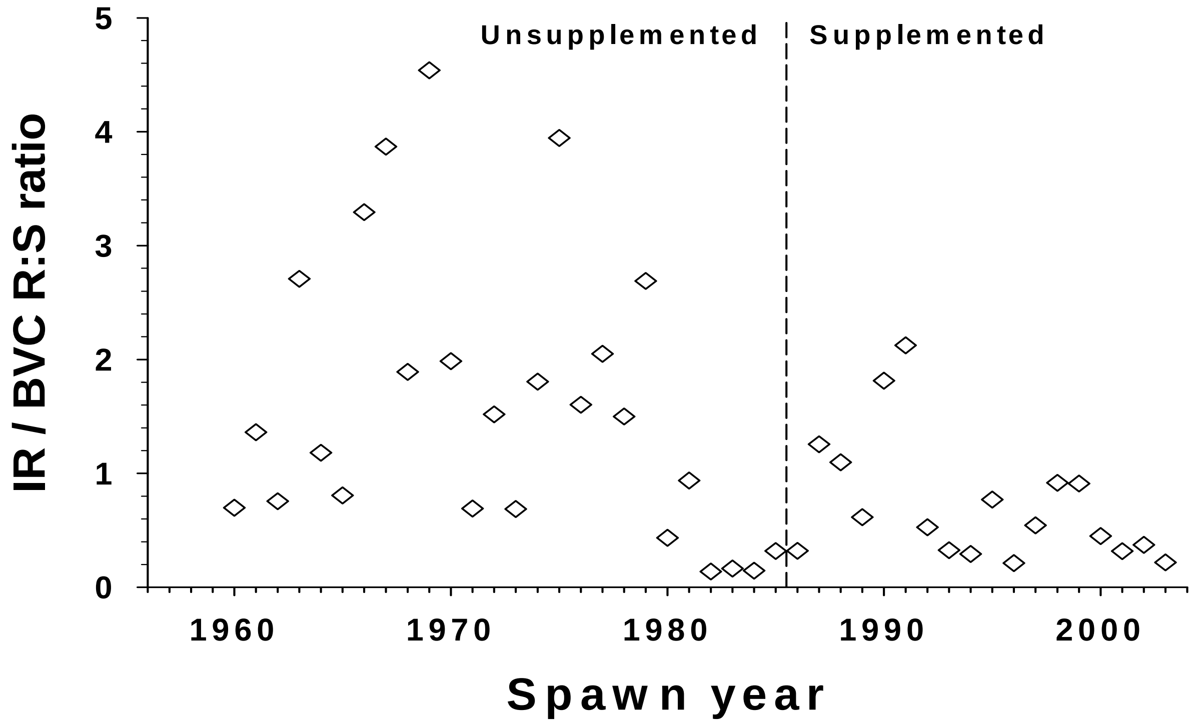


Figure 22. Chinook salmon ratio of recruits-per-spawner (Imnaha River R:S / Bear Valley Creek R:S), 1960-2003 brood years.

Table 7. Total Chinook salmon spawner abundance ratios (Imnaha abundance / reference abundance) for pre-and post-supplementation time periods. P values represent t-test results.

	Mean			
Stream	Pre-supplementation	Post-supplementation	Difference	P-value
Bear Valley Creek	3.02	3.24	0.22	0.568
Big Creek	7.54	9.89	2.35	0.796
Camas Creek	10.18	27.76	17.58	0.007
Lemhi River	2.84	10.84	8.01	<0.001
Loon Creek	14.23	29.17	14.94	0.065
Marsh Creek	3.77	5.80	2.03	0.146
Sulphur Creek	10.92	21.05	10.13	0.096
Valley Creek	13.74	16.65	2.90	0.002

Table 8. Natural-origin Chinook salmon spawner abundance ratios (Imnaha abundance / reference abundance) for pre-and post-supplementation time periods. P values represent t-test results.

	Mean			
Stream	Pre-supplementation	Post-supplementation	Difference	P-value
Bear Valley Creek	3.02	1.72	-1.30	0.013
Big Creek	7.54	5.68	-1.85	0.006
Camas Creek	10.18	16.08	5.90	0.783
Lemhi River	2.84	4.49	1.65	0.019
Loon Creek	14.24	16.66	2.42	0.437
Marsh Creek	3.77	2.84	-0.93	0.049
Sulphur Creek	10.92	9.79	-1.13	0.337
Valley Creek	13.74	8.45	-5.29	0.318

Table 9. Chinook salmon recruit-per-spawner ratios (Imnaha R/S / reference R/S) for pre-and post-supplementation time periods. P values represent t-test results.

	Mean			
Stream	Pre-Supplementation	Post-supplementation	Difference	P-value
Bear Valley Creek	1.86	0.63	-1.23	<0.001
Big Creek	1.71	0.81	-0.90	0.012
Camas Creek	1.94	1.48	-0.45	0.062
Lemhi River	1.72	1.04	-0.68	0.005
Loon Creek	2.32	1.44	-0.87	0.002
Marsh Creek	1.56	1.15	-0.41	0.026
Sulphur Creek	2.13	1.54	-0.59	0.031
Valley Creek	1.66	0.85	-0.81	<0.001

One important management objective for this program is to restore and sustain tribal and recreational fisheries. Recently, a harvest management framework has been adopted to guide annual tributary harvest decisions. Essential elements of the tributary harvest management strategy include the following: 1) Allowable natural origin impact is conservative and scaled relative to “critical and viable levels”; 2) Each population is considered separately in fishery decisions; 3) Fishery protects any population below “critical” threshold from impact; 4) Generally, hatchery fish harvest is limited by resulting incidental impact on natural origin adults; 5) Hatchery fish escapement must meet broodstock and supplementation needs; 6) Monitoring allows impact tracking and in-season adjustment.

The critical and viable thresholds for the Imnaha River population are listed in (Table 10). Tribal and recreational fisheries are regulated based on allowable impact on the margin of natural-origin fish between the run prediction and the critical abundance threshold. The maximum natural-origin allowable sport fishing impact ranges from 0% at 300 natural-origin adults to 5.5% at 2000 natural-origin adults allowable tribal allocations are higher at each escapement level. The sport fishery has been managed for marked selective harvest and catch-release for all unmarked fish. The tribal fishery has been non-selective.

Table 10. List of Grande Ronde / Imnaha Chinook MPG salmon populations and associated interim critical and viable thresholds.

Natural Population	Critical abundance threshold	Viable abundance threshold
Wallowa/ Lostine Rivers	225 adults/yr	750 adults/yr
Catherine Creek	150 adults/yr	500 adults/yr
Upper Grande Ronde River	150 adults/yr	500 adults/yr
Imnaha River	300 adults/yr	1000 adults/yr
Wenaha River	225 adults/yr	750 adults/yr
Minam River	225 adults/yr	750 adults/yr

As stated previously, the recreational fishery was closed from the late 1970s through 2000. Sport fisheries have occurred in eight of the last ten years. The number of fish harvested has generally been below the historical value, however harvest in 2009 exceeded the 1959-69 mean value (Figure 23). Catch rates have been highly variable since the fishery was reopened. Season length has also been variable, but well below the traditionally season length in the 1960s (Figure 24). The tribal fishery has been conducted on a more regular basis than the sport fishery.

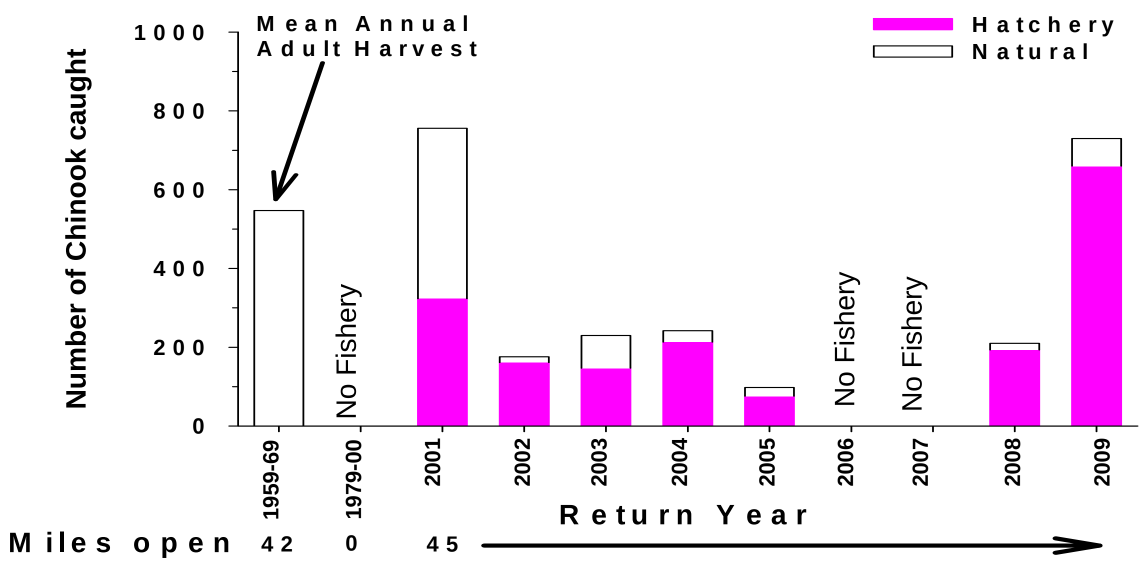


Figure 23. Number of hatchery fish harvested and natural-origin fish caught and released in the Imnaha River Chinook salmon sport fishery (ODFW Wallowa Fish District).

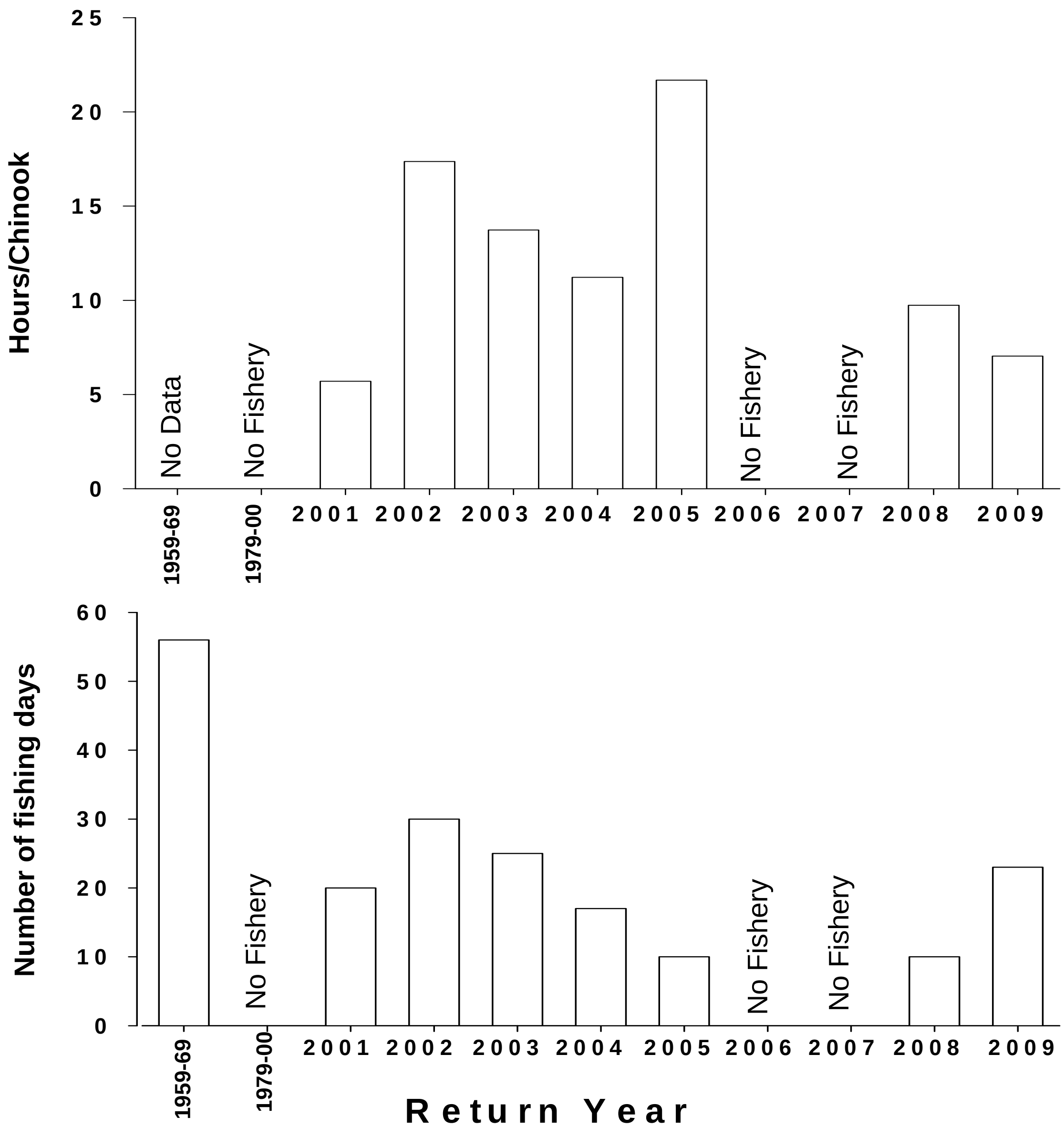


Figure 24. Catch rate and season length for the Imnaha River Chinook salmon recreational fishery.

SUMMARY AND CONCLUSIONS

Broodstock Development and Management

The low abundance of natural-origin adults limited program success throughout the early years and to some extent in recent years. Smolt production goals were not reached due to availability of natural-origin broodstock. The low abundance of natural-origin returns has resulted in a high proportion of hatchery-origin fish in the broodstock and spawning naturally, resulting in low PNIs. The inability to install the weir prior to arrival of the first fish and resulting selective broodstock collection of late returning fish has created significant problems for the program. Uncontrolled escapement of hatchery fish occurs for the early part of the run in many years, resulting in high hatchery proportions on the spawning grounds.

In-Hatchery Performance

Pre-spawning mortality and egg-to-smolt survival rates have been variable. However, pre-spawning mortality is generally low and egg-to-smolt survival has been high. With the exception of a few years, in-hatchery performance has not limited program success.

Production, Survival and Adult Return Performance

We have reached our interim smolt production goal of 360,000 in most of the recent years. Smolt survival to Lower Granite Dam is among the highest observed for Oregon's Snake River hatchery programs. Adult returns have improved substantially in the past ten years and we have reached our return goal to the compensation area in 30% of the recent years. Smolt-to-adult return rates have also improved greatly and we have met the return rate goal of 0.65% in 80% of the recent years. Although we have seen improvement in total smolt-to-adult survival rates, we are a long way from reaching the original goal of 3.25%.

Imnaha River hatchery Chinook salmon are exploited at very low rates. Few fish are harvested in ocean or mainstem Columbia River fisheries. Greater than 80% of the adults produced escape to the Imnaha River basin. We have observed very low stray rates consistently through time. In recent years stray rates have not exceeded 2% in any year. Recreational fishing opportunity has been restored to the Imnaha River in recent years. Although seasons are short and harvest rates are low in most years, the fishing is a welcome and popular addition to recreational opportunities in N.E. Oregon. Tribal fishing now occurs on a consistent and regular basis.

Supplementation: Life History and Spawning Characteristics

Hatchery fish return at an earlier age than natural-origin fish with far more age 3 males and fewer age 5 adults. Adult return timing to the weir is later for hatchery fish compared to natural-origin fish and hatchery fish spawn later. The run timing and spawn timing differences are likely a result of unintentional selective broodstock collection. The spawning distribution of hatchery females is distributed more downstream than natural females, concentrated near the release location. We have not observed differences in size-at-age or age specific fecundity between hatchery and natural-origin fish.

Supplementation: Abundance and Productivity

The Imnaha hatchery program has demonstrated a significant full life cycle survival advantage over naturally spawning fish with a R/S advantage of over 10:1. We have not observed an increasing trend in natural-origin abundance since we started the hatchery program. R/S for mixed hatchery and natural-origin fish spawning naturally has averaged less that 1.0 and has only exceeded 1.0 in 5 of the last 20 complete brood years. We have significantly increased the total number of spawners, but it does not appear that we have increased the number of natural-origin recruits. The natural productivity of mixed hatchery and natural-origin spawners in the Imnaha River population has decreased significantly since supplementation was initiated.

We have conducted an initial qualitative assessment to assess potential reasons why we have not seen an increase in natural-origin abundance and why productivity has declined.

1) *Poor reproductive success of hatchery fish*: We do not have any direct measures of relative reproductive success. Given the results of other studies, the low PNI for this program, selective broodstock collection, and divergent life history characteristics (spawn timing and younger age at return) it is likely that hatchery fish have reduced reproductive success.
2) *Competitive and other ecological effects:* We have no information to assess these types of effects. Therefore, we are highly uncertain of the implications.
3) *Other genetic and ecological effects:* Given the combination of selective broodstock collection, high proportion of hatchery fish spawning naturally, differences in spawn timing and spawning distribution, unnaturally high proportions of jacks spawning naturally and potential weir effects on adult distribution, we hypothesize that these effects may be important.
4) *Density dependent effects of increased total spawners:* We demonstrated that the hatchery program significantly increased total spawners, and increased spawner density. This increase could result in decreased observed productivity; however, we have a substantial number of low spawner abundance years in the post-supplementation time period and post-supplementation abundance has not reached historical abundance levels. Although density may be a factor depressing observed productivity, it does not provide any explanatory power for the lack of response in natural-origin abundance.

FUTURE PROGRAM CHALLENGES AND NEEDS

The Imnaha River Chinook salmon hatchery program could benefit greatly from a new weir and adult collection system that would allow adult collection across the entire run. A new weir would provide be better application of the sliding scale management plan, improved PNI, and improvement in similarity of life history characteristic between hatchery and natural fish.

The low productivity of natural spawning fish as well as the low abundance of natural-origin adults are major challenges for achieving management objectives. These factors limit the ability to improve PNI and also limit access to harvest of surplus hatchery fish, which is regulated based on natural-origin fish impacts.

The lack of detailed understanding of why productivity has declined and why more natural-origin fish have not been produced by supplementation limits our ability to make sound decisions on how best to modify the program. We will continue studies to better understand how hatchery operations, density dependence, life history divergence, and hatchery fish performance are influencing overall program success.