Hood River Production Program Review

Final Report
1991 - 2001

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Hood River Production Program Review 1991-2001

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Note From The Authors:

This report reflects the authors' interpretation of data provided in annual reports and databases maintained by Oregon Department of Fish and Wildlife and the Confederated Tribes of the Warm Spring Reservation of Oregon during the summer of 2002. The Hood River Production Program (HRPP) continued to collect and refine data since the summer of 2002. As a result, new and updated data was provided to the authors by HRPP participant during the review phase of this document (September, 2003). The new and updated data was included in this document, only if updates substantially changed the conclusions drawn during this review.

EXECUTIVE SUMMARY

BACKGROUND

This document provides a comprehensive review of Bonneville Power Administration (BPA) funded activities within the Hood River Basin from 1991 to 2001. These activities, known as the Hood River Production Program (HRPP), are intended to mitigate for fish losses related to operation of federal dams in the Columbia River Basin, and to contribute to recovery of endangered and/or threatened salmon and steelhead, as directed by Nation Oceanic and Atmospheric Administration - Fisheries (NOAA Fisheries). The Environmental Impact Statement (EIS) for the HRPP, which authorized BPA to fund salmon and steelhead enhancement activities in the Hood River Basin, was completed in 1996 (BPA 1996). The EIS specified seven years of monitoring and evaluation (1996-2002) after program implementation to determine if program actions needed modification to meet program objectives. The EIS also called for a program review after 2002, that review is reported here.

The HRPP was designed to re-establish spring Chinook and supplement summer and winter steelhead populations in the Hood River Basin. Hatchery fish were used to accomplish this purpose. Through the course of the subbasin planning process in 1990, CTWSRO and ODFW recommended additional hatchery production for the Hood River Subbasin. The reason identified was poor in basin habitat conditions coming from natural and anthropogenic sources, which severely limited egg-smolt survival. In addition, the run sizes of steelhead and spring Chinook at the time were considered insufficient to reestablish historic runs. The 1990 Hood River Subbasin Plan argued that BPA had an obligation to restore natural runs of salmon and steelhead through the use of supplementation to meet the Northwest Power Planning Council's salmon and steelhead recovery goal. Through both the master planning process and the subbasin planning process, the HRPP established the goals identified in Table 1.

Table 1. Fish production objectives based on average adult returns to the mouth of the Hood River by 2016¹ (Coccoli 2000).

	Adult Run Size	Spawning Escapement	Broodstock to Hatcheries	In-Basin Harvest
Spring Chinook	1,700	400	220	1,080
Winter Steelhead	5,000	2,400	90	2,510
Summer Steelhead	8,000	2,400	160	5,440

¹ Time target estimates are based on the following assumptions (1) subbasin fish passage improvements including screen upgrades expected to reduce in-river smolt mortality are completed by spring 2004; (2) after 2004, several 4-year return cycles are needed to confirm a solid trend in increased adult returns given climate variation and other survival factors; (3) habitat conditions and water quality improve as projects are completed and stream segments restored-habitat redevelopments succeeds within several year after most riparian and instream restoration projects are completed; (4) supplementation succeeds in boosting natural spawning of spring Chinook and steelhead without altering genetic structure of target populations and (5) HRPP law enforcement and other (non-BPA) funding continues and is expanded to complete priority projects identified in the Hood River Habitat Protection, Restoration and Monitoring Plan and the Hood River Watershed Action Plan.

As part of the HRPP, an M&E plan was incorporated to measure progress towards goals and to address critical uncertainties that would potentially hinder the chances of the HRPP achieving its goals. This document explored the following questions with regard to the HRPP:

- Are program actions being implemented as planned?
- Are program goals being achieved?
- Are data sufficient to evaluate key aspects of program performance?
- What additional data was needed to resolve uncertainties for present and future actions?
- What was the cause of deviations from expected performance?
- What are the probable effects of new program actions?
- What are the costs and benefits of the program?
- What possible remedies might be employed to increase program success?

The HRPP was comprised of a number of actions all aimed at achieving the larger goals of the program. These BPA funded actions included habitat improvements, fish

supplementation, and M&E activities. M&E funded by BPA began in 1991. Responsibility for M&E was split between ODFW and the CTWSRO. The ODFW sampled adults at Powerdale trap, electrofished to determine juvenile densities, radio tracked adult returns, surveyed habitat, operated fish outmigrant screw traps at four locations, surveyed anglers, and monitored stream flow. The CTWSRO studied survival of spring Chinook reared in Pelton Ladder, radio tracked adult returns, surveyed spawning grounds, monitored water temperature, and monitored acclimation effectiveness.

The BPA-funded supplementation program for spring Chinook began in 1992, for winter steelhead began in 1991, and for summer steelhead began in 1997. Three hatcheries were used for these programs: two in the Deschutes Basin - Round Butte/Pelton Ladder and Oak Springs, and one in the Hood Basin - Parkdale Facilities. All rearing was completed at existing facilities in the Deschutes Basin, while only the collection of adults and final acclimation of smolts at the time of release were planned for the Hood River Basin. A summary of release goals, locations, and release strategies can be found in Table 2.

Table 2. Summary of fish release targets for the Hood River Basin from 1988 through 2001. BPA funded projects are in normal font. Programs funded through ODFW are in italics.

Species	Number	Size	Stock	Stream	Sites/Type	Release Duration
<i>Spring Chinook</i>	<i>140,00</i>	<i>Smolt</i>	<i>Carson</i>	<i>West Fork</i>	<i>1 site, direct release</i>	<i>1998-1992</i>
Spring Chinook	125,000	Smolt	Deschutes	West Fork	1 site, direct release	1993-1995
Spring Chinook	95,000	Smolt	Deschutes	West Fork	2 site, acclimation	1996-2001
Spring Chinook	30,000	Smolts	Deschutes	Middle Fork	1 site, acclimation	1997-2001
<i>Summer Steelhead</i>	<i>75,000</i>	<i>Smolt</i>	<i>Skamania</i>	<i>West Fork, Mainstem</i>	<i>1 site, direct release</i>	<i>1988-1997</i>
<i>Summer Steelhead</i>	<i>75,000</i>	<i>Smolt</i>	<i>Skamania</i>	<i>Mainstem RM 4.5</i>	<i>1 site, direct release</i>	<i>1998-2001</i>
Summer Steelhead	40,000	Smolt	Hood River	West Fork	2 sites, acclimation	1998-2001
<i>Winter Steelhead</i>	<i>30,000</i>	<i>Smolt</i>	<i>Big Creek</i>	<i>Middle and East Fork</i>	<i>1 site, direct release</i>	<i>1988-1992</i>
Winter Steelhead	30,000	Smolt	Hood River	East Fork	1 site, direct Release	1993-1995
Winter Steelhead	30,000	Smolt	Hood River	East Fork	1 site, acclimation	1996-2001
Winter Steelhead	30,000	Smolt	Hood River	Middle Fork	1 site, acclimation	1999-2001

PROGRAM CONSTRAINTS

The physical and biological characteristics of the Hood River Basin strongly influenced the potential to enhance anadromous salmonid populations. The Hood Basin is dynamic and harsh environment, and its ability to produce salmonids is limited by numerous natural and anthropogenic sources. The glaciers present atop Mt. Hood heavily influenced the Hood River and each of its three main forks (East, Middle and West). Several tributaries to these forks originated from glaciers on the north face of Mt. Hood. Glacial turbidity caused decreases in primary production and subsequently resulted in decreased macroinvertebrate (fish food)

production and abundance. This decrease in macroinvertebrate production resulted in limited fish growth and survival. Furthermore, channel morphology in the Hood River was not favorable for salmonid production as gradient was typically high (>2.5%). The East and Middle Forks were characterized by excessive fine sediments and a lack of deep pools. Cool temperatures in the upper portions of each of the main forks resulted in limited opportunities for growth in these reaches. Limited growth is significant because length at outmigration has been correlated to survival.

Anthropogenic hindrances included irrigation withdrawals that limited available

rearing space, influenced temperatures, and decreased freshwater survival through entrainment. Several dams, of which the most significant was Powerdale Dam (RM 4.5), altered flow, influenced temperatures, and hindered passage of both upstream and downstream migrating salmonids. Land use practices influenced freshwater habitat throughout the basin, including reduced riparian vegetation, severed floodplain interactions, and constructed barriers.

All of these factors influenced the capacity of the Hood River System to produce anadromous salmonids. Understanding the natural carrying capacity of the Hood Basin was important to the HRPP because it helped determine the juvenile production goals of the program. At the outset of the HRPP, the capacity of the Hood Basin to produce anadromous smolts was estimated with the data and tools available at the time. New data provided by the HRPP, and new tools were used to reassess the production potential of the basin. Habitat data provided by the M&E that quantified habitat factors influencing the production potential of the basin were used to estimate the smolt capacity of the Hood Basin. Capacity was estimated at 15,692 spring Chinook, 16,970 winter steelhead, and 13,860 summer steelhead smolts. These estimates were only 24%-37% of previous capacity estimates for the basin.

New estimates of carrying capacity were generated using the Unit Characteristic Method (UCM) developed by Cramer (2001). This method is a habitat based method that uses stream survey data, water chemistry data, and relationships of rearing salmonids to their habitat described in the literature. Carrying Capacity estimates of the UCM compared favorably to maximum outmigration estimates seen in other basins throughout the Pacific Northwest.

PERFORMANCE AND ACHIEVEMENTS

Hatchery Program

Spring Chinook

The achievement of HRPP performance goals was contingent on the success of four subcomponents, including: hatchery contributions, habitat improvements, natural production, and minimized impacts on non-target populations. Review of program data showed that some program goals were met, others were not, and the status of others remains unknown. The review also identified critical uncertainties and potential road blocks to success of the program.

The assumed goal of the HRPP spring Chinook hatchery program to rely on Hood River returning adults for eggs was not met. Even if every Hood River returning adult allocated to the Parkdale Hatchery had provided eggs, the take would not have been sufficient. The exception was during 1997 when an adequate number of Hood River adults were held to meet brood goals. The release goal of 125,000 Deschutes stock smolts was met nearly every year since use of the stock began in 1993. Attempts to limit competition between released hatchery smolts and natural parr were successful.

Stray rates of Hood River hatchery spring Chinook were high. NOAA fisheries established 5% among ESUs as an acceptable stray rate goal, but only in 1997 was this goal met provided fish strayed beyond their ESU. High stray rates reduced the number of fish available for harvest and natural spawning and were a significant road block to achieving program objectives. Straying resulted in a low smolt to adult return for the Hood River than for the Deschutes River. Stray rates in the

Hood Basin could be reduced by acclimating hatchery juveniles to Hood River water earlier in the year. This action would likely facilitate the imprinting process.

The in-basin Hood River harvest goal was 1,080 adults with a total run size of 1,700; these goals were not achieved. From 1996 to 2000, marginal harvest occurred (ranging from 0 to 54 fish) and run size was below stated goals (ranging from 2 to 560 age 4 adults). Tribal harvest of spring Chinook above Powerdale Dam from 1999-2001 was not believed to exceed 100 fish per year.

Other uncertainties were identified as well. ODFW pathology data indicated spring Chinook returning to the Hood River contained high incidences of Infectious Hematopoietic Necrosis (IHN). The prevalence of IHN may impede the collection of the eggs and in turn provide an impediment to the success of the HRPP. Disease also limited success of the Round Butte/Pelton Ladder spring Chinook rearing program. BKD was a chronic problem at Round Butte Hatchery and Pelton Ladder. High levels of BKD were believed to have caused notable presmolt loss in the Pelton Ladder during the 1995-96 and 1996-97 rearing periods.

Rearing strategies may have also affected program success. Mortality differed

among spring Chinook rearing cells at Pelton Ladder. Juvenile mortality at Pelton Ladder increased from upstream to downstream cells. The cells were designed to minimize water usage by supplying water used in upstream cells to downstream cells (gravity feed to lower cells). The reason for the increased mortality of downstream cells may have to do with water quality or disease. Also, fish reared at Pelton Ladder had much higher mortality than fish reared at the Round Butte Hatchery reducing hatchery fish production.

Unusually high jack and mini-jack rates had a deleterious effect on achieving program goals. High composition of jacks and mini-jacks in the returning population do not accurately mimic most natural populations. Mini-jacks and jacks accounted for a near 10-fold greater proportion of hatchery spring Chinook than wild spring Chinook returning to Powerdale Dam. Mini-jacks composed an average of 46% of hatchery returns, compared to only 6.3% of wild returns from 1997-2001 (Figure 1). Frequency of jacks were also higher for hatchery fish than wild fish. Jacking and mini-jacking appeared to be a result of highly nutritional (i.e. high lipid) feed and the associated fast growth of fish reared in the hatchery than in the wild.

Figure 1. Average percentage of Deschutes hatchery and wild spring Chinook returning to Powerdale Fish Trap that were mini-jacks (age 2), jacks (age 3), and adults (age 4 or greater), 1997 through 2001. Data from Olson (2003).

Summer Steelhead

The summer steelhead program recently (1999) moved from releasing a non-indigenous-Skamania stock to releasing the progeny of wild summer steelhead collected in the Hood River. The indigenous program was not in operation for a sufficient period of time to allow for an in depth review. The HRPP initial releases goal of 40,000 hatchery reared smolts was met in 2000 and 2001. However, residualism was high ranging from 14%-23% indicating possible low adult returns in future years.

Spring migration timing was similar between hatchery and wild summer steelhead. Based on hatchery emigration data, the HRPP appeared to meet the unspecified goal of limiting competition between wild parr and hatchery smolts because hatchery fish appeared to migrate out of the system quickly limiting interactions with smaller and younger parr. However, the fork length of hatchery summer steelhead smolts captured and measured at the mainstem screw trap were significantly larger than wild smolts during the period from 1999 through 2001. Larger hatchery smolts may result in negative impacts to wild smolts through competitive

interactions throughout the migration. The degree of impact was unknown.

The non-indigenous Skamania stock of summer steelhead exhibited different adult return timing than the wild stock. A majority of the Skamania stock and wild adults entered the Hood River in May through June. Unlike the Skamania stock wild adults also showed a strong return in October and November. However, the size of returning wild and Skamania adults appeared to be similar. Return data for the Hood River hatchery stock were not yet sufficient to evaluate return timing.

Columbia River harvest of Hood River of Skamania summer steelhead ranged from 87 to 390 fish with an average of 207 fish. Hood River harvest ranged from 39 to 737 fish with an average of 412 fish. The Skamania summer steelhead harvest rate in the Hood River varied from 6% to 40% with an average of 29% during 1995-2001. The recycle program successfully enhance the number of fish harvested by Hood River anglers increasing harvest by an annual average of 26% with a range of 9%- 48% for the years 1996-2001.

However, the summer steelhead recycle program had some unintended consequences. An estimated 74% of recycled Skamania summer steelhead strayed, died, or spawned in the lower Hood River consisting of 41-1,918 fish between 1995 and 2001 (Figure 2). If all these fish were assumed to

have strayed, then an average of 56% of the entire return would have strayed. Similar problems were experienced with the winter steelhead recycle program, though at a lesser magnitude. The fate of unaccounted recycles should be determined

Figure 2. Number of summer steelhead recycled with number harvested and number unaccounted.

Winter Steelhead

Winter steelhead brood collection goals and collection criteria were met every year since 1995, and collection followed guidelines established by the HRPP. The winter steelhead release goal of 50,000 smolts was generally met in 1993 and after 1995, with releases ranging from 47,000 to 63,000 smolts. During 1994 to 1995 the release goal were not met with 38,000 and 43,000 released respectively. In most years, the winter steelhead program data indicated low residualism except for 1996 when 12% of the fish remained in the acclimation facility..

A goal of the HRPP was to minimize the possibility of competition between hatchery and wild parr by releasing hatchery fish ready

to migrate out of the Hood River. The screw trap data suggested the HRPP met the goal. As with spring Chinook and summer steelhead, hatchery winter steelhead smolts were larger than wild smolts at age 1. If competition occurred between the wild and hatchery smolts during out-migration, the hatchery smolts had the advantage based on size.

During the run years of 1996 through 1998, greater numbers of hatchery adults returned to the Powerdale Fish Trap than wild adults, but in the run year 1999 and 2000 wild fish dominated adult returns. The adult run goal was 5,000 fish and the actual returns from 1995 to 2000 were from 529 to 1,899 fish. Adult run goals were not met. The HRPP established an in-river winter steelhead harvest goal of 2,510 fish. Average harvest in

the Hood River was only 28% of this goal.

Smolt to adult survival was determined based on return of fish marked with CWTs. The average survival was 1.41% ranging from 0.29% to 2.89%. The HRPP program anticipated a 4% smolt to adult survival, which was not achieved. Since program adult return and harvest were based, in part, on smolt to adult, steps should be taken to identify why survival has been low and determine if, the 4% goal is appropriate.

The HRPP winter steelhead supplementation program resulted in low recruits per spawners as compared to wild stock (when out of basin hatchery stocks were used). However, when eggs from the indigenous stock were used in the hatchery, the hatchery fish performance was similar to the wild fish (Blouin 2003).

Habitat Restoration

A key component of the HRPP was improving habitat conditions within the Hood Basin. Improved freshwater conditions were intended to improve natural egg-to-smolt survival and aid in the recovery of natural populations. The HRPP devoted energy towards habitat improvement from the beginning of the program. The habitat programs focused on six habitat improvement actions: instream habitat renewal, riparian recovery, stream flow restoration, fish passage improvements, planning at the project and watershed level, and finally monitoring and evaluation of habitat activities.

Analysis of habitat data and UCM modeling showed that a lack of pool habitat, combined with low wood complexity, high fines, and high turbidity were key factors limiting freshwater capacity and survival. Many instream improvement activities were

aimed at alleviating one or several of these limitations.

Instream improvements focused on the addition of large woody debris and boulders to the West Fork Hood River, Lake Branch, Clear Branch, and Robinhood and McGee Creeks, among other areas. While results varied, data indicated that the effects of restoration were generally positive. In McGee Creek, pool habitat increased from 6% pre-project to 35% post project during the year following USFS improvements. At the same site, density of large woody debris (LWD) increased from 4.2 to 17.4 pieces/100m. These results indicated that at least in the short-term, rearing capacity in McGee Creek was increased by restoration efforts. In McGee Creek monitoring methods did not allow a direct comparison of pre and post project conditions. However, results of surveys indicated that restoration activities increased available pool habitat area within the study site. A USFS stream survey report of McGee Creek in 1997 noted the continued existence of stream improvement structures indicating that improvements were continuing to function six years after restoration. Thorough examination of effects of instream restoration was hindered by inadequate pre and post project monitoring data, or a lack of reporting of that data. Such monitoring is needed to fully evaluate the benefits following improvement projects.

CTWSRO, with the assistance of landowners and other agencies, fenced, rip-rapped, and planted riparian vegetation along reaches of several streams in the Hood Basin equaling 1.2 miles. Many such efforts occurred in the lower basin, where livestock grazing prompted the need for such actions. Riparian habitat restoration occurred in the following streams: Neal Creek, Baldwin Creek, Tieman Creek, Rhoades Creek, Shelley Creek and Lenz Creek.

Livestock grazing has been implicated as a source of riparian habitat disturbance and a cause for diminished salmonid populations in western streams for several decades. The installation of livestock grazing exclosures, which eliminated livestock grazing in riparian zones, was a common technique for restoring ecological function and habitat quality in stream channels adversely affected by cattle grazing. CTWSRO installed nine exclosures between 1996 and 2001.

Data gathered during inspection of several livestock exclosures in the Hood River watershed by SPCA and CTWSRO staff indicated that exclosure sites in Shelley, Lenz, Tieman Creek and Baldwin Creeks were expected to respond positively to the exclosures over time by increasing pool habitat and a lower width-to-depth ratio. Two of the exclosures on Neal Creek may not have had the desired effects. As a result of channel incision, geomorphic adjustments in Neal Creek, may be limited because of a lack of interaction between the channel and newly established riparian vegetation.

Riparian habitat protection due to livestock exclusion is projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively. These increased parr density estimates were based on empirical juvenile density increases of nearly 30% resulting from similar cattle exclusion and fenced riparian zone protection in eastern Oregon. Restoration activities in non-anadromous reaches provided additional downstream benefits to water quality and habitat suitability for resident fish and native lower trophic level fauna in the individual streams where the projects occurred. Furthermore, reduced erosion and sediment loading rates and improved thermal and physical water quality conditions in areas “treated” with exclusion and protective

fencing also benefited higher-order streams and the downstream mainstem Hood River.

Several projects in the Hood Basin were aimed at minimizing the effects of water withdrawals at irrigation and hydroelectric diversions. Estimates were made of the number of additional parr that could be expected to rear in the Hood Basin, if the current withdrawals were reduced. Estimates were made using UCM estimates of parr capacity density as they related to August flow in reaches below each diversion. We assumed that the relationship between increased percent of flow and increased percent of capacity was positively linear and 1:1. Thus, reducing withdrawals in August by 10% in a reach below the East Fork Irrigation Diversion would result in a 10% increase in parr carrying capacity. This assumption was based on the belief that increased flow corresponds to increased depth and rearing area, and increased depth and rearing area resulted in increased rearing capacity. This was a simplistic method designed to illustrate the potential benefits of increasing water availability below diversions. More accurate estimates of increased capacity could be made if the relationship between flow conserved below diversions and increased depth and surface area in downstream reaches was understood.

Though estimates of increased rearing capacity were likely inaccurate due to the methods used to generate those estimates, they provided an order of magnitude reference for benefits from reducing water withdrawals. Restoration of 10cfs of flow at each of the major irrigation diversions (EFID, Dee, and FID) as well as returning 250 cfs at Powerdale was estimated to increase steelhead parr capacity by 10,000-20,000 parr, and spring Chinook capacity by 7,500-12,500 parr. Powerdale Dam was scheduled to be decommissioned in 2010 with all of the

associated water rights being returned to the state for fish and wildlife benefits. Efforts by the Irrigation districts are underway to improve water use efficiency and reduce water consumption.

A major fish protection action was conducted in 1996 by the East Fork Irrigation District (EFID). The EFID installed a fish screen at its diversion on the East Fork Hood River (RM 8.6)(Coccoli and Lambert 2000). This diversion was operated without a screen for decades despite the high proportion of flow removed by the diversion. The addition of this screen marked an important step in recovering natural steelhead populations in the Hood River Basin. Despite the importance of screens such as this one, many of the irrigation diversions in the Hood River Basin remain unscreened, or if present the screens were in poor working condition. Several projects proposed by Coccoli (2002) to improve anadromous populations in the Hood River Basin were targeted at installing or improving irrigation diversions. Some of these proposed projects are being addressed outside of the BPA funded HRPP.

The benefits of adding screens at major diversion sites were evaluated by estimating the number of mortalities that were prevented with screens of various efficiencies. Estimates of entrainment (fish loss) at Powerdale Dam indicated that up to 85,000 wild and hatchery juvenile salmonids (steelhead and spring Chinook) would be lost if there were no screen at the diversion. Screens of progressive efficiencies (increments of 20%) decreased the number of lost juveniles by 17,000. The number of juveniles lost in each group (origin, life stage, or species) was relative to their abundance passing the diversions. Losses were highest among hatchery spring Chinook smolts, with significant losses also occurring among hatchery and wild steelhead smolts.

Entrainment losses at the East Fork Irrigation Diversion were comprised solely of wild steelhead juveniles.

Under a no screening scenario, an estimated 7,200 wild steelhead juveniles were lost each year. Increased screen efficiencies of 20% decreased entrainment by 1,400 steelhead at each level of efficiency. Many of those lost were steelhead fry. Losses from entrainment at the Dee Irrigation Diversion were relatively minor with an estimated 86 juveniles lost annually. Diversions at the Farmers Irrigation Diversion were estimated to lose approximately 13,000 juveniles under no screen conditions. Additions of screens with increments of 20% efficiency decreased the loss by 2,600 juveniles for each increment.

Each habitat restoration action taken by the HRPP had positive effects on spring Chinook and steelhead habitat, and most likely benefited non-target populations. Quantification of benefits was hindered somewhat by a lack of pre and post-project monitoring and a limited understanding of how changes in habitat affect production potential and survival at different spatial and temporal scales. Of the improvements made, the projects that involved restoring flow or screening of diversions had the most positive effects on spring Chinook and steelhead production. Those projects influenced the primary migratory and rearing reaches within the basin, and thus impacted the most individuals.

Wild Production

Spring Chinook

Unmarked adult spring Chinook generally arrived at Powerdale Dam from mid-April to early October. The migration exhibited two distinct peaks, the first and

largest occurring in June and the second in September. On average, 4% of returning spring Chinook were mini-jacks (age-2), 3% were jacks (age-3), and 93% were adults (age 4 and older). Spawning ground surveys indicated that peak spring Chinook spawning occurred, on average, in mid-September (Lambert et al. 1999). A majority of redds were observed in the lower portion of the West Fork and recent limited spawning occurring in the Middle Fork in association with Parkdale Hatchery. The East Fork did not support Chinook spawning, as indicated by the absence of juvenile Chinook catches in the East Fork screw trap.

Emergence timing was not studied by HRPP, but thermograph data and spawn timing indicated that spring Chinook fry emerged beginning in mid March. In contrast, fry emergence from natural spawning in the Warm Springs River was slightly earlier, beginning in February. The difference in emergence times between the Hood River and Warm Spring River appeared to be driven by water temperature. Water temperature during incubation did not appear to be a factor directly affecting spring Chinook egg survival. However, peak flow events may have scoured pre-emergent fish out of the gravel, thus reducing survival.

Catches of wild juvenile spring Chinook in the West Fork screw trap indicated that most juveniles emigrated as fry (FL < 50 mm) in the spring or as pre-smolts in the fall. Trapping generally did not start until the last week of March, and it appeared that fry were migrating prior to trap installation. The much larger catch of age 1+ spring Chinook smolts in the spring at the mainstem trap indicated that many fish leaving the West Fork remained in the mainstem through winter. These fish then later emigrated as smolts in the spring.

Furthermore, it appears that a large percentage (greater than 50%) of the juveniles emigrating from the West Fork did not stop in the mainstem, rather they continued to the lower four miles of the mainstem or into the Columbia River. Captures of wild spring Chinook outmigrants in screw traps from 1994 to 2001 suggested that wild spring Chinook predominantly migrated out of the Hood River in the fall.

The UCM carrying capacity estimate was 44,835 spring Chinook parr, resulting in 15,692 smolts (based on 35% survival from parr to smolt). Smolt production as estimated from screw trap data indicated the basin was producing less than 10% of the estimated capacity.

The number of wild adult spring Chinook returning to Powerdale Dam on the Hood River ranged from 24 to 97 annually, with total wild and hatchery returns ranging from 53 to 647 adults. Based on the life cycle model, we estimated that roughly 125 adult spring Chinook were needed to fully seed the Hood River to carrying capacity. In only two of the years from 1996- 2001 did the number of adults passed above the dam exceed the number of predicted spawners needed to fully seed the basin.

Since 1994 the number of returning hatchery spring Chinook had increased, while the number of returning wild fish had decreased. A primary goal of supplementation is to enhance wild populations. In this respect, the current program was not meeting the supplementation goal. We hypothesized that since spring Chinook releases were from Deschutes River Stock rather than a Hood River derived stock, the hatchery fish may be maladapted to the Hood River and therefore those hatchery fish spawning in the wild result in limited success. As a result, a recommendation was made to collect

wild/naturally spawned Hood River returns for brood when adult return numbers are sufficient to support the hatchery and wild population.

Summer Steelhead

Adult summer steelhead began arriving at Powerdale Dam in mid-March, migration typically peaked in early July, and declined sharply during August. Passage peaked a second time during November. Summer steelhead returned to the Hood River at between 2 – 6 years of age. The predominant age of returning wild adults was age-4. Returning adults spent from 1 – 3 years in the ocean, with an average of 2 years. The average percentage of female summer steelhead returning to the Powerdale fish trap from 1994 to 2001 was 68%. Average fecundity was estimated at 4,100 to 4,400 eggs per female from 1997 through 2000.

The number of summer steelhead smolts migrating out of the Hood River from 1999 through 2001 differed greatly between hatchery and wild smolts. Hatchery releases ranged from roughly 15,000 to 30,000 smolts, while the number of wild smolts migrating past the screw trap ranged from 550 to 2,000.

ODFW estimated summer steelhead parr rearing densities in tributaries to the West Fork Hood River in 1994-1997. Comparisons of observed densities to predicted densities and standard parr densities used in the model indicated that the tributaries to the West Fork were probably seeded near capacity.

The recruits per spawner (R/S) averaged 0.18, and ranged from 0.38 to 0.09 for hatchery and wild summer steelhead passed above Powerdale Dam to spawn. The low R/S estimate indicated the natural spawning population was not replacing itself.

Since an entire brood year of the new indigenous hatchery program had not returned at the time of this review, it was too early to determine if supplementation was benefiting the wild population.

Winter Steelhead

Returning adult winter steelhead reached the Powerdale Dam fish trap beginning in February. The run rapidly increased throughout March, peaked during late April, and then rapidly declined in May. Winter steelhead spawned primarily in the mainstem, Middle Fork and East Fork of the Hood River (Coccoli 2000), while summer steelhead spawned in the West Fork Hood River.

Recent screw trap data suggested winter steelhead primarily migrated out of the East Fork in the fall instead of the spring. Emigrants moved into the upper mainstem and roughly 9% of the fall emigrants moved into the lower 4 miles of the Hood River or the Columbia River. The contribution of fall migrants to adult returns was unknown. Middle Fork and upper mainstem winter steelhead primarily smolted in the spring. The mean egg to smolt survival was 1.8% and the mean smolt to adult survival was 6.4%. The HRPP undocumented smolt to adult survival goal of 4% was exceeded.

Comparisons of observed rainbow/steelhead densities to UCM predicted carrying capacity indicated that Neal Creek was probably seeded near capacity, and that the East Fork and Middle Fork Basins were below carrying capacity.

Adult returns of wild winter steelhead to Powerdale Dam ranged from 194 to 1,002, during 1993 through 2000. The recruits per

wild winter steelhead spawner (R/S) averaged 1.98 and ranged from 0.87 to 3.71. The supplementation program appeared to meet the goal of stabilizing and increasing the wild population.

The hatchery program appeared to have benefited the wild population by increasing population size. The average smolt to adult survival for hatchery fish was lower (1.45%) than wild fish (6.4%). However, the mortality associated with both initial release and harvest appeared to account for a majority of the difference. This hatchery program met or exceeded program goals.

Non Target Fish Impacts

A primary objective of the HRPP was to minimize program affects on non-target populations. Non-target populations included species other than spring Chinook or steelhead within the Hood Basin, or any species outside of the Hood Basin.

Stray rates of Deschutes stock spring Chinook released into the Hood River from the 1993-1997 brood years ranged from 0% - 37% and averaged 18%. This compares to an average stray rate of 2% for Deschutes stock spring Chinook released into the Deschutes River from the 1980-1997 brood years. Given the low numbers of Deschutes stock Hood River returns from the pre-1997 broods (13-302 adults), the straying of hatchery spring Chinook into other basins was unlikely to have had a significant genetic influence on other populations. The effects were particularly muted since most of the fish that strayed (86%) strayed into the Deschutes River. Data from CWT recoveries and observations by local biologists suggested that straying of hatchery summer and winter steelhead from the Hood River was low, however, a potentially large source of stray hatchery steelhead came from the sport fishery

recycle program. The fate of unaccounted recycles was not known representing a critical uncertainty.

The affect of competition on non-target populations within the Hood River was difficult to assess from available data. Monitoring of juvenile production has focused on trapping outmigrants, so there was inadequate information to detect changes in resident populations. Genetic studies indicated that breeding with either resident rainbow or residual steelhead likely accounted for up to half of all steelhead adults returning to Powerdale Dam.

Cutthroat trout were present in the Hood Basin, but most populations were located upstream of anadromous populations (BPA 1996). Captures of cutthroat at screw traps within the basin were limited in number and insufficient to determine trends in abundance or condition. Bull trout were also present in the basin, but competition with anadromous hatchery fish was unlikely. This was because bull trout were found primarily in the upper Middle Fork, upstream of the steelhead production areas (BPA 1996).

Predation caused by the HRPP fish on non-target species or populations was unknown. Monitoring has not included stomach content analysis of HRPP fish. The largest source of predation would have likely come from residualized steelhead. Data regarding the degree of residualism of Hood River hatchery steelhead was not available.

Steelhead were diagnosed with diseases common to the region and therefore were not believed to transmit exotic diseases (i.e. Infectious Hematopoietic necrosis virus (IHN) and a "cold water" like disease). The incidence of illness was low and was not considered a reservoir of disease. Spring Chinook were infected with IHN, bacterial

kidney disease (BKD), fungus and Ceratomyxosis. Two out of eight years, the HRPP spring Chinook program released fish with high BKD levels, which could have served as a reservoir of disease transmittable to wild fish.

Very little harvest occurs on either natural fall Chinook or coho in the lower Hood River, so increased harvest on HRPP fish did not adversely affect these species. However, bull trout was a highly catchable species, and incidental hooking mortality likely occurred.

PERFORMANCE IMPROVEMENT

Cost and Benefits

The HRPP expended approximately \$28 million in pursuit of reintroducing spring Chinook and supplementing summer and winter steelhead for species conservation and harvest augmentation. The greatest program cost was associated with capital improvements. These expenditures accounted for approximately 44% of the total program cost by modifying Pelton Ladder and Oaks Springs Hatchery, altering the Powerdale Dam Fish Trap, and creating Parkdale Fish Facility. The Monitoring and Evaluation program accounted for 25%, Operation and Maintenance accounted for 23%, and Planning and coordination accounted for 8% of total expenditures.

Hatchery operations contributed greatly to the production of adult spring Chinook and winter steelhead stocks. Of the known spring Chinook and winter steelhead production throughout the Hood River Basin, 83% and 58% respectively were of hatchery origin. Another benefit of the HRPP was additional harvest opportunities. Hatchery winter steelhead allowed for a sport angler

harvest that averaged 277 adults annually for the period 1996-2000. Hatchery spring Chinook allowed for a harvest that averaged 53 adults annually for the period 1996-2000. Harvest of winter steelhead or spring Chinook would not have occurred without the hatchery program, owing to the fact that wild fish numbers were low and strict conservation measures for ESA species were in place.

Installation of new fish screens on irrigation withdrawal structures theoretically saved 1,255 summer steelhead, 7,169 winter steelhead and 5,693 spring Chinook juveniles. Cattle exclusion and riparian habitat protection fencing was projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively.

Future Program

The affects of both HRPP activities and environmental variation on adult returns and harvest were evaluated using a Life-Cycle model with carrying capacity estimates from the Unit Characteristic Method. Models were developed separately for spring Chinook, summer steelhead and winter steelhead. Physical factors and fish populations parameters used in the Life Cycle model were based primarily on data collected in the Hood River Basin.

The model begins with the number of adults spawning naturally. The number of parr that these spawners produce in the next generation was predicted according to a modified form of the Ricker stock-recruitment function and continues for 30 years to predict the final outcome. Baseline conditions were compared to alternative scenarios. The baseline scenarios reflected the 1990's averages. Subsequent scenarios were examined by altering 1 or 2 parameters from baseline conditions to study the potential changes in equilibrium values.

Assumptions in the Life Cycle Model were tested by using the hindcast method of comparing predicted to observed escapements of natural and hatchery fish to Powerdale Dam. The hindcast method involved using actual spawner escapement from the early 1990's, and applying year specific values of certain model parameters where data was available to populate the life cycle model. The hindcast analysis indicated the model performed within acceptable tolerances.

The baseline simulation of the Hood River spring Chinook population estimated equilibrium Powerdale Dam returns of 170 natural and 215 hatchery jacks and adults. In addition, it estimated returns of 23 natural and 52 hatchery precocials. Total harvest of spring Chinook was estimated at 258 fish, made up primarily of 145 above Powerdale Dam in the tribal fishery, and 58 in the lower Hood River sport fishery.

Alteration of stream capacity, freshwater survival, or smolt-Age 2 survival (without altering other variables) resulted in a 1:1 change in natural returns to Powerdale Dam and harvest of natural fish. Combining the effects of both changes in capacity and freshwater and marine survival rates, resulted in total harvest and returns to Powerdale ranging from a high of 250% to low of 45% of baseline conditions.

Incorporating different supplementation levels into the model influenced harvest and returns of hatchery fish, but not natural fish. Increased supplementation did not reduce the natural population, because the allocation scheme mandated that of all fish passed above Powerdale Dam in excess of spawner capacity was harvested by anglers. Changes in harvest below Powerdale Dam affected returns to Powerdale Dam and harvest above Powerdale

Dam, but did not affect the number of available spawners. Increased hatchery stray rates had a negative effect on hatchery returns to Powerdale and harvest of hatchery fish, but had no effect on natural fish. Increased hatchery precocial rates caused a decrease in jack and adult in-basin harvest and returns to Powerdale Dam.

The baseline simulation of the Hood River summer steelhead population estimated equilibrium Powerdale Dam returns of 238 natural and 470 hatchery jacks and adults. Harvest of summer steelhead was estimated at 506 fish, made up primarily of in-Hood River harvest of hatchery fish.

The baseline simulation of the Hood River winter steelhead population estimated equilibrium Powerdale Dam returns of 241 natural and 475 hatchery jacks and adults. Harvest of winter steelhead was estimated at 307 fish, made up primarily of in-Hood River harvest of hatchery fish.

Combining the effects of both changes in capacity and freshwater and marine survival rates, resulted in total harvest and returns to Powerdale of steelhead ranging from a high of 250% to low of 45% of baseline conditions. Incorporating different steelhead supplementation levels into the model influenced both hatchery and natural fish. Hatchery returns were positively correlated at a 1:1 ratio with supplementation. Wild fish were negatively affected by increased supplementation.

Changes in steelhead harvest below Powerdale Dam affected hatchery returns to Powerdale Dam and the number of fish recycled, but did not affect the number of available spawners. Increased steelhead residualism reduced both harvest and the number of wild and hatchery fish returning to Powerdale Dam. Increased residualism had a

more pronounced effect on wild fish than on hatchery fish.

Recommendations

The following bullet points summarize recommendations resulting from the review of the HRRP.

- Review and adjust program goals and objectives based on new information gathered over the last 10 years. Create short and long term goals and associated performance standards, crafted in a manner that allows the M & E program to measure progress.
- Develop, implement and evaluate means to reduce the release of residual hatchery fish.
- Test the efficacy of reducing precocity rates of spring Chinook by releasing smaller hatchery fish, while considering trade offs such as smolt survival.
- The utility of acclimating spring Chinook smolts in the Hood River earlier and for a longer period should be evaluated and tested.
- Hatchery brood should come from Hood River returns over Deschutes River returns.
- Methods to reduce Spring Chinook disease (i.e. BKD) at Pelton Ladder should be explored and implemented.
- The effect of Powerdale Dam removal on the goals, objectives and protocols of the HRPP should be estimated, assessed and evaluated in terms of potential program changes.
- Place the highest priority on irrigation withdrawal screening and withdrawal structural improvements. The next highest priority should focus on stream flow restoration activities.
- Conduct fencing projects only in core anadromous fish rearing habitat that has poor riparian vegetation and appropriate geologic conditions.
- Prior to conducting habitat improvement projects estimate impacts of degraded condition and the benefit of the project in terms of fish, and conduct M&E activities to measure realized benefits.
- Determine stray rates of recycled fish and adjust harvest management strategies to meet stray rate goals.
- Determine the contribution of fall outmigrants to adult returns.
- Refocus screw trap efforts to attain spring Chinook migration estimates for spring and fall migrants. Furthermore, attempt to increase precision of screw traps by improving trap catch performance and analyze data in biweekly to monthly time-steps for all migrating size classes.
- If Coded Wire Tagging (CWT) Programs continue, create a five year mark and recovery plan, which is updated annually. ”
- Studies measuring the affect of habitat factors limiting egg to smolt survival should be conducted. Studies such as bed-load movement and sediment transport may explain the low egg to smolt survival and lead the HRPP to

implement novel strategies for increasing wild fish survival.

- Annually review HRPP successes and failures, reprioritize M&E activities,

and report findings in summary reports focusing on monitored performance indicators, which are tied to goals.

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SECTION I INTRODUCTION & ENVIRONMENTAL CONSTRAINTS

CHAPTER 1: INTRODUCTION

This document provides a comprehensive review of Bonneville Power Administration (BPA) funded activities within the Hood River Basin from 1991 to 2001. These activities, known as the Hood River Production Program (HRPP), are intended to mitigate for fish losses related to operation of federal dams in the Columbia River Basin, and to contribute to recovery of endangered and/or threatened salmon and steelhead, as directed by National Oceanic and Atmospheric Administration - Fisheries (NOAA Fisheries). Hood River originates from the glaciers of Mount Hood and flows into the Columbia River at River Mile 168. One federally operated dam lies between the mouth of the Hood River and the Pacific Ocean, Bonneville Dam at river mile 146. The HRPP is a collection of fish rearing, habitat improvement, and monitoring and evaluation (M&E) projects. The Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) are the Fish Managers responsible for the implementation and success of the HRPP. Since this program conducts activities in the presence of Endangered Species listed fishes, steelhead (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*), the NOAA Fisheries and United States Fish and Wildlife Service (USFWS) consult with ODFW and CTWSRO on program goals and activities.

The EIS for the HRPP, which authorized BPA to fund salmon and steelhead enhancement activities in the Hood River Basin, was completed in 1996 (BPA 1996). The EIS specified seven years of monitoring and evaluation (1996-2002) after program implementation to determine if program actions needed modification to meet program objectives. That EIS also called for the program review after 2002 that is reported here. Monitoring and evaluation of the project began in late 1991, as described in the "Hood River Master Plan" (O'Toole and ODFW 1991). Monitoring has included upstream trapping of adults, downstream trapping of juveniles, spawning surveys, rearing surveys, genetic analyses, temperature monitoring, and habitat surveys. Results from this monitoring in addition to monitoring by other resource agencies working in the Hood River Basin provide the basis for this independent analysis of program effectiveness to date, and identification of needs or opportunities for adaptive management of the program.

HRPP OVERVIEW

Program Need

The historical significance (during the early 1900's) of the Hood River salmon and steelhead fishery is not recorded in readily available literature. The Hood River Subbasin Plan (O'Tool 1990) did present an incomplete escapement or harvest estimates from data collected during 1960s through 1980s. Data available for wild spring Chinook suggested that by the early 1960s this species was functionally extinct in the Hood River. O'Tool (1991) reported steelhead harvest during the period 1977 to 1987 ranged between 1,105 and 3,626 for summer steelhead

and between 86 and 1,593 for winter steelhead. As with spring Chinook, steelhead escapement in years prior to substantial human impact was unavailable. As a result, Fish Managers were unable to rely on historic adult return records to formulate an appropriate adult return and population goal for the basin. Although, Fish managers were sure the number of adult Chinook and steelhead returning to the Hood River in the 1980's was far below the historical return. In an effort to estimate the carrying capacity of the Hood River was estimated using the Smolt Density Model (NWPPC 1990). Model results, indicated the Hood River was far below carrying capacity.

Through the course of the 1990 subbasin planning process, the CTWSRO and ODFW recommended additional hatchery production for the Hood River Subbasin. The reason identified was poor in basin habitat conditions coming from natural and anthropogenic sources, which severely limited egg-smolt survival. In addition, the run sizes of steelhead and spring Chinook at the time were considered insufficient to reestablish historic runs. CTWSRO and ODFW believed that instream habitat restoration would improve run sizes, but would not result in substantially improved adult returns (NWPPC 1990). The 1990 Hood River Subbasin Plan argued BPA had an obligation to restore natural runs of salmon and steelhead through the use of supplementation to meet the Northwest Power Planning Council's salmon and steelhead recovery goal. Pursuant to meeting the NWPPC goals, the Hood River Production Program was initiated through funding by BPA.

In order for the NWPPC to recommend BPA to fund the HRPP, the NWPPC policies indicated the purpose, hypotheses, critical uncertainties and implementation strategy of the HRPP was required. The document satisfying these criteria was crafted and called the Hood River Master Plan (O'Toole 1991). Based on this document, we extracted hypotheses to better understand the rationale behind the HRPP. The Master Plan did not directly state the hypotheses by which the program was created. Thus, we translated the strategies and justification for the strategies into the following hypotheses:

- The Hood River is a dynamic glacier driven system that provides poor habitat conditions (i.e. high sediment load and high gradient) for juvenile salmonids resulting in below average egg-to-smolt survivals.
- Egg-to-smolt survival is the limiting factor controlling population size of summer/winter steelhead and spring Chinook, because capacity was under used.
- A hatchery program will increase the egg-to-smolt survival resulting in harvestable numbers while maintaining a healthy wild population (Table 1).
- Hood River program will rebuild naturally self-sustaining spring Chinook summer/winter steelhead populations.
- The hatchery program will be of sufficient size to meet both harvest goals and fully seed the Hood River with wild fish
- Capacity to sustain natural production is accurately estimated from the NWPPC smolt density model.
- Hatchery smolts releases have no significant impacts on wild juveniles.
- Acclimated releases result in greater survival than direct releases.
- Hatchery smolt releases have little effect on wild smolts, because these fish do not compete for food or space.

- The hatchery program will not significantly affect the genetic fitness of the wild population as long as 10% of the brood comes from wild fish, and breeding protocols were followed. The protocol includes taking of eggs throughout the run, mating randomly, maintaining male-to-female ratio appropriate for breeding population size (1:1), and using all ages of returning fish for breeding.
- The Deschutes River Spring Chinook Stock at Round Butte released into the Hood River will adapt and result in a wild self sustaining population in the West Fork Hood River.
- Rearing steelhead and spring Chinook in a Deschutes River Hatchery and in water different from Hood River will not affect performance of hatchery fish.
- Indigenous stocks of summer and winter steelhead reared in the hatchery will out perform out-of-basin stocks reared in the hatchery.

Although hypotheses were not listed, the Master Plan did list critical uncertainties arguing that a Monitoring and Evaluation Program was required in order to resolve these uncertainties, thereby greatly improving the probability of HRPP success (O'Toole 1991). Critical uncertainties were:

- What is the current status of summer and winter steelhead in the Hood River?
- Can natural production of spring Chinook and summer and winter steelhead be restored or enhanced with releases of hatchery-reared smolts?
- Can natural production of spring Chinook and summer and winter steelhead be sustained using supplementation with hatchery-reared smolts?
- To what extent will acclimation of spring Chinook and summer steelhead smolts, prior to release influence smolt-to-adult survival, homing ability, migration patterns, and spawning distribution?
- To what extent will length of acclimation time best enhance smolt-to-adult survival, migration patterns, and spawning distribution for spring Chinook and summer steelhead?
- To what extent will the release location of hatchery spring Chinook and summer and winter steelhead smolts influence smolt-to-adult survival, migration patterns and spawning distribution?
- Will environmental factors preclude restoration of sustained, natural production at an acceptable level?
- To what extent will releases of hatchery-reared spring Chinook, and summer and winter steelhead smolts influence natural production of resident fish?
- To what extent will releases of hatchery-reared spring Chinook smolts and restoration of natural production influence natural production of summer and winter steelhead?
- To what extent will release of hatchery-reared summer and winter steelhead, and enhancement of natural production, influence natural production of spring Chinook?
- What contribution will spring Chinook and summer and winter steelhead smolts releases make to adult harvest?

The HRPP chose to address these uncertainties with a Monitoring and Evaluation Program (M&E). Beginning in 1991, ODFW and CTWRO began implementing an M&E Program through BPA funding. The purpose of the program was to reduce the number of critical uncertainties hindering HRPP success through data collection and synthesis, evaluate HRPP relative to its performance objectives (Olsen 2000), and provided data vital to the preparation of an Environmental Impact Statement (EIS; Bonneville Power Administration 1996a; Bonneville Power Administration 1996b), completed in 1997

Program Goals

The HRPP was designed to re-establish spring Chinook and supplement summer and winter steelhead populations in the Hood River Basin. Hatchery fish were used to accomplish this purpose. Four primary goals were developed by the HRPP:

- 1) Re-establish naturally sustaining runs of spring Chinook salmon in the Hood River,
- 2) Re-build naturally sustaining runs of summer and winter steelhead in the Hood River,
- 3) Maintain genetic characteristics of the various Hood River fish populations, and
- 4) Produce fish that will contribute to tribal and non-tribal fisheries.

The HRPP focused activities on enhancement of spring Chinook salmon, winter steelhead and summer steelhead, although other significant fish species also inhabit the Hood River: fall Chinook, coho, pacific lamprey, sea-run cutthroat trout, bull trout, coastal cutthroat trout and rainbow trout. This review focuses on spring Chinook and winter and summer steelhead owing to the fact that BPA has focused funding on these fishes, and that they are the focus of the HRPP.

Project Objectives

The HRPP believed the goals would be met, if the following objectives were sought, as described in the Hood River Fisheries Project EIS (BPA 1996):

- 1) Help mitigate the losses of fish and wildlife associated with the construction and operation of Federal hydropower facilities in the Columbia River Basin.
- 2) Supplement naturally spawning spring Chinook populations with fish from a hatchery program, consisting of Deschutes River stock returning to the Hood River. (The indigenous populations were extirpated during the late 1960s).
- 3) Supplement the indigenous wild winter and summer steelhead populations with a hatchery program consisting of local brood stock to enhance natural production.
- 4) Monitor the abundance, distribution and life history of anadromous and resident fish and instream and riparian habitat conditions within the Hood River Subbasin to enable determination of trends.

- 5) Protect, enhance and restore indigenous anadromous and resident fish habitat in the Hood River subbasin
- 6) Protect and/or maintain the genetic characteristics of the populations.
- 7) Protect federal and state threatened and sensitive fish species in the subbasin
- 8) Be cost-prudent and environmentally sound.

Objectives 1 and 2 were the foundation to the production objectives presented in Table 1. In addition, the program was designed to achieve and maintain self-sustaining populations of other indigenous anadromous and resident fish within the subbasin by a target date of 2016 or earlier.

Table 1. Fish production objectives based on average adult returns to the mouth of the Hood River by 2016¹ (Coccoli 2000).

	Adult Run Size	Spawning Escapement	Broodstock to Hatcheries	In-Basin Harvest
Spring Chinook	1,700	400	220	1,080
Winter Steelhead	5,000	2,400	90	2,510
Summer Steelhead	8,000	2,400	160	5,440

¹ Time target estimates is based on the following assumptions (1) subbasin fish passage improvements including screen upgrades expected to reduce in-river smolt mortality are completed by spring 2004; (2) after 2004, several 4-year return cycles are needed to confirm a solid trend in increased adult returns given climate variation and other survival factors; (3) habitat conditions and water quality improve as projects are completed and stream segments restored-habitat redevelopments succeeds within several year after most riparian and instream restoration projects are completed; (4) supplementation succeeds in boosting natural spawning of spring Chinook and steelhead without altering genetic structure of target populations and (5) HRPP law enforcement and other (non-BPA) funding continues and is expanded to complete priority projects identified in the Hood River Habitat Protection, Restoration and Monitoring Plan and the Hood River Watershed Action Plan.

Project Components

BPA's EIS (1996) supported the strategies designed by the fish managers and outlined the following activities:

Spring Chinook (from Deschutes River stock)

- Incubate and hatch at Round Butte Hatchery,
- Rear to smolt stage in modified Pelton Ladder,
- Acclimate at Dry Run Bridge (West Fork Hood River) 3-4 weeks in April and early May,
- Exit volitionally (on their own) into West Fork Hood River,
- Leave Hood River Basin in 1 - 3 days, and
- Release 125,000 annually 1996 - 2002

BPA committed to funding spring Chinook activities related to:

- Production
- Parkdale facilities (adult holding and spawning facility), and
- Acclimation facilities at Dry Run Bridge (Pelton Ladder modifications completed)

Steelhead - summer and winter (naturally produced Hood River broodstock)

- Hatch and rear at Oak Springs Hatchery
- Acclimate:
 - Summer steelhead at Dry Run Bridge site 2 weeks in April and early May
 - Winter steelhead at EFID site 4 weeks in April and early May
- Exit volitionally
 - Summer steelhead into West Fork Hood River
 - Winter steelhead into East Fork Hood River
 - Leave Hood River system in 4 to 6 weeks
- Release annually:
 - Summer steelhead: 40,000/year 2000 - 2002
 - Winter steelhead: 50,000/year 1996 - 2002

BPA agreed to fund steelhead activities related to:

- New pond and associated facilities at existing Oak Springs Hatchery,
- Acclimation facilities at Dry Run Bridge, EFID and Parkdale,
- But did not agree to paying for production

The EIS identified a phased approach to the HRPP. Phase I, was baseline studies, Phase II was projected to last seven years, to provide a reasonable length of time to insure that the effects observed were the result of the actions taken and not a function of environmental variation between years. Phase III was projected to be an in-depth evaluation and analysis to determine whether operations should change in order to meet project goals (this review). The EIS anticipated that while self-sustaining populations were unlikely to be established by the end of Phase II, the monitoring and evaluation program was designed to provide appropriate feedback to indicate whether the project was moving in the right direction. Finally, the EIS identified Phase III (and additional phases if necessary) could incorporate an increased level of production, if the data indicate that under seeded habitat remains and additional NEPA review was to be completed prior to any increases in fish production by the HRPP.

SCOPE AND ORGANIZATION OF THIS REVIEW

As describe by the BPA EIS (1996) this document is the culmination of the Phase III review. Representatives of the ODFW and CTWSRO involved in the writing of the EIS (BPA 1996) for the HRPP recognized a need to review the status, progress, and the possible need for modification of the program (adaptive management) after a reasonable period of program implementation. A determination was made that a reasonable period of program implementation had passed, and S. P. Cramer and Associates (SPCA) were contracted by BPA to conduct the assessment. The purpose of this review was:

To independently review the effectiveness of all fish habitat and production actions of the HRPP, and determine the need for change.

The remainder of the document seeks to answer the following questions in subsequent chapters:

- Are program actions being implemented as planned?
- Are program objectives being achieved?
- Are data sufficient to determine key aspects of program performance?
- What further data are needed to resolve uncertainties for present and future actions?
- What have been the causes of deviations from expected performance?
- What possible remedies might correct performance, and to what degree?
- What are the probable effects of new actions being proposed?
- What are the costs and benefits of the program, of new proposals, and of alternatives for adaptive change?

We present this review following the hierarchy of logic displayed in Figure 1. The report was organized in three sections corresponding to the second tier of this hierarchy, and the third tier of logic represents chapters of the report.

Figure 1. Diagram of logic steps covered by this review of the HRPP.

CHAPTER 2: HOOD RIVER BASIN CHARACTERISTICS

KEY FINDINGS IN CHAPTER 2

- The Hood River has a mainstem and three major forks (East, Middle and West). The system was heavily influenced by glacial recession and rain-on-snow events, causing a dynamic hydrograph and high turbidity during summer.
- The West Fork supplied 51% of the annual stream flow, but only covers 30% of the Hood River watershed. The East and Middle forks contributed 25% and 22% of stream flow, and cover 33% and 13% of the watershed area, respectively.
- Seven-day average temperatures in the Hood Basin typically ranged from 3 to 16°C. . Although there appears to be no thermal problems for eggs in the areas where spawning of salmon and steelhead is expected, cold temperatures through the summer in upper areas of the Hood River forks limited growth opportunities for juvenile salmon and steelhead in reaches where spawning and rearing occurred.
- The West Fork was least influenced by glacial melting, whereas the East Fork and Middle forks were heavily influenced. Literature demonstrated that high levels of glacial turbidity, like that found in the Hood River, are sufficient to substantially decrease primary production, macroinvertebrate (fish food) production, and subsequently, fish growth and survival.
- Channel morphology in the Hood River limits salmonid production. Gradient was typically high (>2.5%), pools were few, and loads of glacial fine sediment were high.
- Powerdale Dam (RM 4.5) and irrigation withdrawals were the most significant hydromodifications in the Hood Basin. Powerdale Dam impeded upstream and downstream migration. Both Powerdale dam and irrigation withdrawals remove water from the natural channel, altering flow and temperature and reducing rearing habitat.
- The environment during the review period fell outside the norm with very high and very low water years, and poor and excellent years of ocean conditions

The physical and biological character of the Hood River Basin strongly influence the potential to enhance anadromous salmonid populations. Before evaluating progress toward program goals, we describe those characteristics of the basin that play a role in determining the quantity and quality of fish habitat, and the types of species that can

be supported. First, physical factors are described that influence the fish and their habitat, including geography, land use, climate, and hydrology. Then, we describe how these factors shaped existing stream morphology. Substantial portions of this information were not available at the time the Hood River Production Master Plan (O'Toole 1992) was developed, but have since been gathered by natural resource agencies or through the HRPP Monitoring and Evaluation program. Thus, the new basin descriptors provide new opportunity to examine how the proposed Master Plan and results of its implementation fit revised understandings of watershed characteristics.

GEOGRAPHY

The Hood River is contained within the Hood River Subbasin, which covers approximately 216,957 acres (Figure 2). The Hood River flows northeasterly into the Columbia River at RM 168, twenty-two miles upstream from Bonneville Dam. The headwaters of the Hood River are derived from glaciers on the north and east slopes of Mt. Hood. The river has a mainstem and three major forks (East, Middle and West). The Hood River system is heavily influenced by glacial recession and rain-on-snow events, causing a dynamic hydrograph and high turbidity. This system frequently experiences catastrophic landslides and dam-break floods originating on the moraines and steep slopes of Mt. Hood. The Hood River system includes 695 stream miles with 108 miles accessible to anadromous fish (Coccoli 2000).

The mainstem Hood River is approximately 14.6 miles long with six primary tributaries and passes through the City of Hood River. This subbasin covers 50,618 acres. The mainstem stream flow is primarily derived from the three major forks.

Land Use & Vegetation Types Hood River Watershed

Figure 2. Shaded relief and vegetation map of the Hood River Basin.

The West Fork of the Hood River is 14.6 miles long, entering the mainstem at RM 12. This watershed covers 65,465 acres, of which 65% is National Forest Lands (Forest Service 1996). The West Fork Subbasin is on the northern slope of Mount Hood, reaching the crest of the Cascade Range. This fork is the least affected by glacial runoff and contributes approximately half of the flow of the mainstem. Of the 14 tributaries, Ladd Creek is the only major tributary fed by a glacier and entering the West Fork at river mile 13 leaving roughly 1.6 miles of accessible fish habitat upstream without influence of glacial caused disturbances; this area provides important spawning habitat for summer steelhead and spring Chinook. This subbasin provides a total of approximately 33 miles of spawning habitat for anadromous salmonids (Forsgren et al. 1988).

The Middle Fork of the Hood River is 10.2 miles long. The confluence of the Middle and East Forks form the mainstem, which begins at RM 14.6. This watershed covers 28,640 acres of which 74% is contained within National Forest Lands (Forest Service 1996a). The Middle Fork subbasin lies on the Northeast slope Mt Hood and is bordered by West and East Fork drainages. The Middle Fork is strongly influenced by glacial recession in Elliot and Coe Creeks causing abundant silt and sand delivery. The Middle Fork and its 10 tributaries contribute roughly 24% of the annual mainstem flow. The Middle Fork is primarily used by winter steelhead.

The East Fork is the longest fork stretching 28.8 miles up to the Clark, Newton and Polallie Glaciers. This fork is strongly influenced by glacial recession and rain-on-snow events. The East Fork and its associated 27 tributaries contribute approximately 26% of the annual mainstem flow. The East Fork Subbasin spans over 72,233 acres, with approximately 66% contained within National Forest Lands. The East Fork is primarily used by winter steelhead.

LAND OWNERSHIP

In the Hood River Subbasin, over 75% of the land ownership is by forest management (roughly 111,000 acres National Forest, 22,000 acres Longview Fibre and 30,000 acres is County-Owned Forest). Another dominant industry is irrigated agriculture, predominately orchards occupying approximately 15,000 acres. A smaller portion is managed as irrigated pasture (~2,000 acres). Remaining lands (~37,000 acres) are managed for a combination of forest, agriculture, and other uses (Figure 3).

CLIMATE

Hood River occurs within Oregon High Desert, Coastal Marine, and Mountain climate regimes. Annual rainfall within the Hood River subbasin was variable, decreasing north and east of Mount Hood with decreased elevation. On average, the West Fork receives the greatest amount of precipitation followed by the Middle Fork and East Fork (Forest Service 1996 and 1996a). The ten-year average annual (1991-2001) precipitation was highly variable with 34 inches at the cities of Hood River and Parkdale, 112 inches in the upper watershed of the West Fork, and 107 inches on Mt. Hood (Snotel, 2003). Temperature was equally diverse with an average daily maximum temperature range during August from 83°F in the City of Hood River to 64°F on Mt. Hood and average annual minimum temperature during the January ranging from 27°F in the City of Hood River to 24°F on Mt. Hood (Snotel, 2003). The spring and fall months

are the most variable climatic periods with frequent rain-on-snow events causing floods and associated debris torrents. The climate during the last ten years has exhibited extreme precipitation in excess of 135% of average snow pack and rainfall. These conditions had significant effects of the steam flow of the Hood River as evidenced in the following section.

Figure 3. General Land use in the Hood River Watershed by proportion (Reproduced from Coccoli 2001).

HYDROLOGY

A variety of hydrologic factors influence fish production and distribution in the basin, so we describe several factors within this category of basin characters. These factors include stream flow, water temperature, turbidity, sediment, and hydro-modification.

Stream Flow

Rainfall, snow pack and air temperature were major predictors of stream flow. Over, the past ten-year period (1991-2001), Hood River annual stream flow varied from below median (59-79% of the 34 year average) to significantly above median (102 -177% of the 34 year average) (Figure 4). Above average years had dramatic effects on the geomorphology of the river by resorting streambed substrate materials and displacing woody debris downstream. Fish survival during extreme flow events was expected to drop because of fish being flushed out of the river (Bell et al 2001, Giannico and Healey 1998, and Tschaplinski and Hartman 1983).

Fish were also expected to exhibit lower survival rates during extremely low flow years. Spring Chinook parr abundance was shown by Don Chapman Consultants (1989) to decrease as stream flow decreases in the summer. The observed exodus of juvenile Chinook was greatest in

June and July. Hillman et al. (1987) observed a similar decline in abundance of juvenile spring Chinook through the early summer in the Red River, Idaho. The continuing decrease in abundance during early summer (June to August) as juveniles grew and stream flow decreased indicated that density dependent mechanisms may be operating.

Figure 4. Median daily stream flow per year in the mainstem Hood River measured at Tucker Bride (RM 6.1). Annual median as percentage of the 34-year daily median (USGS station 14120000) shown above bars.

Cramer et al. (1985) found only a slight indication of density dependence in survival of Chinook parr, but strong density dependence in growth rate between the life stages of fry and smolt in the Rogue River. Growth rates were lower in years of higher parr abundance. Somewhat in contrast, Bjornn (1978) found from extended studies on the Lemhi River that a wide range of fry, parr, and smolt abundances were linearly related to spawner abundance. However, Bjornn (1978) did observe density dependent growth of juveniles, such that parr were smaller in years of high abundance. This density-dependent reduction in growth commonly observed among juvenile Chinook probably translates into a density dependent effect on survival, because virtually every Chinook hatchery has demonstrated from varying size at release of smolts that smolt-to-adult survival increases as size at ocean entry increases.

Data from studies by Bjornn (1978) on the Lemhi River show a classic difference between juvenile steelhead and Chinook in their response to high density. Juvenile steelhead survival decreased at highest juvenile densities, but growth changed little. In contrast, juvenile Chinook survival was not affected by increasing density, but there was a negative linear

relationship between length in the fall and density during summer. This was also the finding from a long term study of salmon and steelhead in the Rogue River (Cramer et al. 1985). This difference relates to behavioral differences between Chinook and steelhead in their defense of rearing territories. Snorkel observations of rearing steelhead consistently showed that they defend individual territories, associated with the substrate, and are seldom found in schools. In contrast, juvenile Chinook were frequently found in schools well up in the water column off of the substrate (Everest and Chapman 1972; Hillman et al. 1987; Don Chapman Consultants 1989). These behavioral differences would be likely to lead to displacement of juvenile steelhead when space or food was limited, but to reduced growth of Chinook that aggregate in schools. Thus, density dependence resulted in a limit on numbers of juvenile steelhead, but in smaller size at smolting among Chinook.

Average daily stream flow within years was a coarse predictor of water passing through the river. It does not indicate whether the flow was distributed evenly over the year or whether a majority of the flow rushed through the river in a couple of months (i.e. the “shape” of the annual hydrograph). The Hood River was a very dynamic system that typically experienced rain-on-snow events. To illustrate this fact, Figure 5 displays the daily average stream flow during ten-year period (1991-2001) and Figure 6 presents the ten-year averages. Note the extreme and rapid stream flow peaks between November and May of each year; such peaks were likely caused by characteristic rain-on-snow events.

Figure 5. Average daily stream flow of the mainstem Hood River measured at Tucker Bridge (RM 6.1, USGS Station 14120000), 1991-2001.

Figure 6. Daily mean, minimum and maximum average stream flow during the period 1991-2001 in the mainstem Hood River at Tucker Bridge (RM 6.1, USGS Station 14120000).

The West, Middle and East Forks supplied a majority of the stream flow to the mainstem Hood River. Stream flow data for the forks was limited. The West Fork had a USGS gauge station in operation from 1932 to 1999 at Dee approximately 0.25 miles upstream from the mouth. No long term data existed for the East and Middle Forks resulting in ODFW installing gauge staffs in the East Fork in 1994 and in the Middle Fork in 1996. ODFW obtained daily staff readings from March through November (Olsen 2000). Based on a combination of USGS and ODFW data, we estimated the contribution of stream flow by each fork to better understand this system. On a monthly basis, the percent contribution did change slightly among forks. However, the West Fork contributed the greatest percentage of flow during all months (Figure 7). The Forks appeared to follow similar peak stream flow events as exhibited in Figure 8. However, the East Fork had a greater likelihood of providing catastrophic flood events caused by dam-break floods during fall, associated with glacier recession and rain-on-snow events. An example of a catastrophic event occurred on September 30, 2000. The Hood River News reported a flood originating from the headwaters of the East Fork that closed Powerdale Dam for a month and damaged Highway 35 with associated debris flows (Gill 2000).

Figure 7. Average daily stream flow for West, East and Middle Forks by month based on data provided by East Fork, 1994-2001 and Middle Fork, 1996-2001 from ODFW gauge stations (2001) and USGS Stations 14118500 (Dee) and 14120000 (Tucker Bridge), 1991-2001.

Figure 8. Average daily stream flow among West, East and Middle Forks and Mainstem during 1996 - 1999 based on data provided by ODFW (2001) and USGS (2003) Stations 14118500 (Dee) and 14120000 (Tucker Bridge).

Water Temperature

The East Fork maintained the warmest water temperatures throughout a majority of the year followed by the mainstem, Middle and West Forks based on data from the CTWSRO (personal communication, Alexis Vaivoda, Figure 9). The Hood River was listed on the Clean Water Acts 303(d) for violating temperature criteria. Temperature standards were based partly on the species of fish residing in a steam system, because the Hood River supported anadromous salmonids and bull trout. Maximum water temperature standards were set at 64°F 7-day maximum during juvenile fish rearing and 55°F for 7-days during spawning of anadromous salmonids in a majority of the subbasin. Furthermore streams supporting bull trout were not to exceed 50°F, which includes selected tributaries of the Middle and West Fork. The Oregon Department of Environmental Quality (ODEQ 2001) conducted a Total Maximum Daily Load (TMDL) study and determined that stream shading by riparian vegetation and decreased water withdrawals would cool the river to meet in-river temperature standards. Thus, ODEQ (2001) created a management plan largely dependent on riparian management and increased in-river flows to meet mandated thermal conditions.

Figure 9. Average 7-Day maximum temperature in the West, Middle and East Forks and Mainstem Hood River (river miles 1.8, 4.8, 0.8, 3.9 respectively), for the period 1990-2001 except for Middle Fork period was 1994-2001 (data provided by CTWSRO).

Seven-day average temperatures in the Hood Basin typically ranged from 3 to 16°C. The lower East Fork and lower mainstem were influenced by irrigation withdrawals throughout the summer and accordingly had the highest temperatures of any reaches in the Hood Basin. Both of these reaches experienced 7-day average temperatures that peaked at near 16°C in mid-summer, while typical high temperatures reach only 12°C at other gauges in the forks (Figure 10).

Survival and growth of Chinook and steelhead is affected by water temperature. The available temperature data did not indicate thermal problems for eggs in the areas where spawning of salmon and steelhead was expected. Published studies on the thermal tolerances of salmon eggs showed that mortality of freshly spawned Chinook and steelhead eggs begins when temperatures rise above 13°C, or drop to 4°C (Beacham and Murray 1990). However, the tolerance range of temperatures increased by the time the eggs reached the eyeing stage. Spring Chinook spawning must occur sufficiently early for eggs to develop to a cold water temperature (below 4-5°C) tolerant life stage (eyed eggs). On the other hand, fish must spawn sufficiently late in the year to avoid exposing eggs to high water temperatures of approximately 14°C (Beacham and Murray 1990), Hood River temperature data suggested that spring Chinook spawning in the lower portion of the basin during September would subject the egg to temperatures above 14°C reducing survival. In contrast, fall Chinook spawn in the lower river because they spawn later in the year after the river has cooled below upper tolerances.

Temperature data indicated limited growth opportunities for juveniles in upper spawning and rearing areas of the Hood River forks. Temperature has a strong influence on growth rate of juvenile salmonids. In streams where food was a limiting factor, Bisson and Davis (1976) found that juvenile Chinook grew best at temperatures from 9-15° C. Data from the Rogue River indicated a similar preference range for growth of steelhead of 11-15°C (Fustish et al. 1988). Temperatures in the West Fork Hood River in the primary spring Chinook spawning reaches only remain above 9° C from early July to late September, allowing roughly 3 months of optimal growth (Figure 10). Tributaries to the West Fork had less optimal growing opportunity at 1.5-2 months of temperatures of 9°C or greater (Figure 10).

Figure 10. Thermal regimes of reaches within the Hood River Basin with elevation above mean sea level provide in feet.

Cool temperature may be limiting growth opportunities for juvenile spring Chinook and steelhead in the West Fork Hood River. The length at outmigration of West Fork spring Chinook was compared to those in the Warm Springs River to determine, if growth appeared to be limited in the Hood River as compared to the Warm Springs. Temperature regimes were similar in the two basins, but the elevation of monitoring in the Warm Springs River was 900ft higher than in the West Fork Hood River. Fall outmigrating spring Chinook from the Hood River averaged 108mm compared to 98mm (Olsen and Spateholts 2003) for the Warm Springs River fall outmigrants. Spring outmigrants were similar between the two rivers at 108mm for the Hood River fish, and 112mm (Olsen and Spateholts 2003) for the Warm Spring River fish. These results did not take into account that competition for food among juveniles was greater in the Warm Springs River. That Warm Springs River frequently had spawning escapements near capacity, while those in the Hood River had been below capacity (see chapter 6). Expectations were for juvenile Chinook in the Hood River to out-grow Warm Spring River fish, because the Hood River fish were far below carrying capacity. The effect of intraspecific competition within a species has been related to growth in numerous studies (Krebs 1985).

Steelhead growth opportunities were temperature limited in several areas. The lower East Fork maintains temperatures in the optimal growth range from mid-June to mid-September, but above RM 13, the 7-day average temperatures never exceeded 11°C, likely reducing growth above that altitude (Figure 10). The Middle Fork also was cool. At approximately RM 3.5, average 7-day temperatures rarely exceed 10°C. However, the Clear Branch, tributary to the Middle Fork, just below Laurance Lake maintained temperatures of 10-12°C from early June through September, providing four months of suitable growth opportunity (Figure 10). Temperatures in the West Fork were within the optimal growth range for 2-3 months. The mainstem Hood River was above 11°C from early June through mid-September, and suitable for growth of juvenile steelhead (Figure 10).

Turbidity and Total Suspended Solids

The Hood River was heavily influenced by the Mount Hood glaciers (Figure 11). Typical streams lacking glacial influence were most turbid during months of major runoff, which usually occurs during fall and spring. The least turbid periods typically occurred during the summer. In glacially influenced systems, such as the Hood River, the opposite was true. Such streams were the most turbid during the summer months and least turbid in the winter because melting glaciers deposit fine ground-up sand and stone called “glacial flour” into the headwaters of the forks during summer. Within the Hood River Basin, the West Fork was least influence by glacial melting, while the East Fork and Middle forks were the most heavily influenced. Figure 12 presents turbidity estimates in the West Fork below Lake Branch, East Fork below Tilly Jane Creek and the mainstem. We were unable to locate sufficient data in the Middle Fork, and therefore depict the turbidity at mouth of Coe and Elliot Branches of the Middle Fork (Figure 11, and Figure 12). The headwaters of Coe and Elliot begin at the Coe and Elliot Glaciers, and were strongly influence by glacial melt-water.

Figure 11. Map of the Hood River indicating turbidity levels by stream reach.

Figure 12. Median turbidity estimates collected by grab samples in the mainstem (n=243), West Fork (n=32) and East Fork (n=33) and Coe Branch (n=47) and Eliot Branch (n=32) for the period 1960 to 2001 based on data collected by DEQ, EPA and PacifiCorp.

We reviewed literature and interviewed researchers familiar with the effects of suspended solids on salmonids. There were extensive documentation of influences by suspended sediments on salmonid distribution, physiology, feeding efficiency, and predator avoidance. Literature indicated that suspended solids have positive and negative effects on salmonids. Some of these effects include changes in rearing density (Ptolemy 1993; Sigler et al. 1994), distribution (Scrivener et al. 1994; Sigler et al. 1984; Gregory 1993; Bisson and Bilby 1982; Servizi and Martens 1992), growth rates (Sigler et al. 1984; Murray and Rosenau 1989; Newcombe and MacDonald 1991), foraging behavior and efficiency (Tippets and Moyle 1978; Gregory 1990; Ginetz and Larkin 1975; Gregory and Levings 1998; Murray and Rosenau 1989; Gregory and Northcote 1993), physiological stress (Redding et al. 1987, Sigler et al. 1984; Servizi and Martens 1987; Servizi and Martens 1992), predator avoidance (Gregory 1993; Gregory and Levings 1998) and primary production (Lloyd et al. 1987; Van Nieuwenhuyse, 1983; Van Nieuwenhuyse and LaPerriere 1986).

However, the literature also indicated that the concentrations where these effects take place were markedly higher than concentrations found in the Hood Basin, and that salmonids can adapt to certain levels of suspended solids given time. Ultimately, we determined that that native steelhead and spring Chinook stocks generally were not influenced by TSS concentrations experienced in the Hood Basin with respect to physiology. In much of the cited literature, harmful physiological effects only begin to occur at concentrations far higher than those found in the Hood. Hood TSS concentrations were generally below 50mg/L. Literature shows that avoidance in acclimated fish began at 100 NTU (275-600mg/L)(Bisson and Bilby 1982). Significant physiological effects in sockeye fry only began once concentrations reached 300mg/L, and smolts at concentrations as high as 14,000mg/L (Redding 1987; Servizi and Martens 1984). Foraging rates of juvenile Chinook were actually highest at concentrations similar to high concentrations in the Hood Basin (40-185mg/L)(Gregory and Levings 1998). Each of these studies inadequately evaluated the effects of long term exposures of salmonids to

TSS concentrations, but the evidence suggest that concentrations higher than those found in the Hood Basin were required for significant impairment of fish physiology.

Turbidity reduces macroinvertebrate production. Lloyd et al. (1987) found that turbidity of only 5 NTU could decrease primary production in shallow streams by 3-13%. An increase of 25 NTU decreased primary production by 13-50% in shallow streams. Primary production in streams greater than 0.5m would be reduced even further. Lloyd et al. (1987) cited studies from Great Britain that corroborate his results (Swale 1964; Westlake 1966; Lund 1969; Lack and Berrie 1976). These authors found that turbidity and light intensity, rather than nutrient concentrations were the factors most commonly limiting primary production in streams. In the Patuxent River, Maryland, Stross and Stottlemeyer (1965) found that increased turbidity decreased primary production per surface area.

Evidence suggests that macroinvertebrates are strongly influenced by TSS, and macroinvertebrates and fish production are directly related to primary production. Lloyd et al. (1987) found that densities and biomass of benthic invertebrates were significantly higher in unmined streams as opposed to mined streams. They also found that in heavily mined basins, most invertebrate taxa were rare or absent. Wagener and LaPerriere (1985) showed that reduced density and biomass of macroinvertebrates was most strongly statistically correlated to turbidity in mined streams.

Increases in sunlight penetration and invertebrate production have also been related to production of cutthroat. Murphy and Hall (1981) found that cutthroat trout abundance increased significantly ($P < 0.01$) in clear-cut compared to old-growth stream reaches in pair-wise comparisons within the same stream. The trout biomass (g/cm^2) in clear-cut areas increased an average 75.7% following logging of riparian areas. This increase appeared to result from higher primary production, followed by greater production of invertebrates on which the trout fed. Murphy and Hall (1981) found that chlorophyll accumulation was greater in clear-cut sites than in adjacent old-growth sites, and that densities of insects in riffles were greater in open reaches than in their paired shaded reaches.

In summary, decreases in primary production subsequently resulted in decreased macroinvertebrate (fish food) abundance and decreased macroinvertebrate production ended in limited fish growth and survival. The greater the turbidity, the less hospitable the environment for fish populations (Figure 11). These relationships were used in the next chapter to assign upstream limits of fish distribution and estimate carrying capacity. Appendix D provides a detailed review of the effects of turbidity on fish, and how these effects were quantified in estimating carrying capacity.

Sediment

Habitat surveys by ODFW during low flow show that the percent of sand and silt in riffles ranges from 41-46% in reaches of the lower East Fork Hood. During the same season, in the West Fork where spring Chinook spawn successfully, fines in riffles were much lower, ranging from 6-23% (Table 2).

Table 2. Length, gradient, active channel width and percent fines in riffles of reaches surveyed by ODFW in the East Fork Hood River and West Fork Hood River.

Subbasin	Reach	Reach Length (km)	% Fines in Riffles
East Fork	1	2.8	44
	2	1.5	41
	3	10.1	45
	4	1.9	46
Middle Fork	1	1.8	25
	2	4.3	24
West Fork	1	1.4	12
	2	1.4	11
	3	1.3	23
	4	1.9	18
	5	0.8	22
	6	2.0	22
	7	5.2	12
	8	2.8	12
	9	0.6	15
	10	1.4	6

It has been well documented that excessive fine sediments can reduce survival of salmonid eggs, rearing density of parr, and even survival of overwintering presmolts. Bjornn and Raiser (1991) present data showing that survival of Chinook and steelhead embryos begins declining as the percentage of fines (<6.35mm) in redds increase above 25%. The presence of fines impairs delivery of oxygen to the eggs. Condole (2000) found that fines <1mm diameter may suffocate eggs by impairing flow over the eggs, and should be less than 12-14% of particles in redds. Both Condole (2000) and Bjornn and Raiser (1991) found that emergence can be inhibited by high concentration of fines in redds.

Excess fines can reduce parr rearing potential as well. Newly emerged fry utilize interstitial spaces in the cobble substrate as cover from velocity. Density of juvenile steelhead and Chinook in summer and winter was reduced by more than half when enough sand was added to fully embed the large cobble substrate in an experimental stream (Bjornn et al. 1977). Thompson and Lee (2000) found that probability of moderate to high densities of steelhead parr in Idaho streams decreased as the percentage of the watershed with unconsolidated litho logy increased. They deduced that this type of litho logy was prone to sedimentation and reduced the survival of parr.

Cramer (2001) deduced from reviewed studies that fines in excess of 15% of the substrate in riffles had a negative effect on the potential rearing capacity of a given reach. Riffles in reaches of the West Fork Hood Basin consistently have less than 15% fines in the substrate (Figure 13). In the East Fork Hood River below Dog River, fines are exceedingly high at nearly 40%. Fines were also high at 25% of the substrate in riffles in the turbid Middle Fork. The high presence of fines in much of the Hood River was detrimental to the salmon and steelhead production potential of the basin.

Figure 13. Presence of fine sediment within riffles of important salmon and steelhead producing reaches of the Hood Basin. Data from ODFW habitat surveys. Refer to Table 3 for definition and delineation of each reach abbreviation.

Gradient

Gradient was an important habitat feature that played a role in determining fish distributions. Montgomery et al. (1999) showed that increased gradient was associated with increased scouring, and that increased scouring reduces the likelihood of successful spawning. He classified gradients of greater than 3% as steep, and less than 3% as low gradient. He found that spawning in steep gradient reaches would only be successful when spawning occurs after the period of peak flow. Since peak flow in the Hood Basin was primarily in the winter and early spring, steelhead are more likely to be successful than spring Chinook in steep reaches, because they spawn in the spring whereas spring Chinook spawn in the fall.

Don Chapman Consultants (1989) found that steelhead parr in the Wenatchee River, Washington, generally selected stations where adjacent velocities were 6-8 times their nose velocity. They also found that steelhead are typically concentrated in high gradient (>5%) reaches where they usually station themselves behind boulders.

The distribution of gradient throughout the Hood Basin provided insight into the distribution of spring Chinook and steelhead. Gradient in the Hood Basin was generally high at 3% or greater with a range of 1-7% (Figure 14). Spring Chinook production occurred almost entirely in the West Fork where gradient was only 1% in the most used reach. With the exception of the mainstem Hood River, and the East Fork from the confluence with the Middle Fork to the Dog River, gradient throughout the rest of the basin was high at 3% or greater.

(Figure 14). High gradient results in fast water habitat types dominated by boulder substrate. Steelhead have an affinity for pocket water associated with boulder habitat whereas spring Chinook have a lower preference for this type of habitat (Bjornn and Raiser 1991). Thus, steelhead make greater use of high gradient habitat than do spring Chinook.

Figure 14. Gradient by reach in areas surveyed by the ODFW within the Hood Basin. Data from ODFW habitat surveys. Refer to Table 3 for definitions of each reach abbreviation.

Table 3. Delineation of major salmon and steelhead producing reaches in the Hood Basin.

Reach	Downstream Extent	Upstream Extent
HR1	Mouth of Hood River	Powerdale Dam
HR2	Powerdale Dam	E. Fork/W. Fork confluence
Neal Cr.	Mouth of Neal Cr.	E. Fork Neal/W. Fork Neal confluence
MF1	Mouth of Middle Fork	USFS boundary
WF1	Mouth of West Fork	Mouth of Green Point Creek
WF2	Mouth of Green Point Creek	Mouth of Lake Branch
WF3	Mouth of Lake Branch	Mouth of Ladd Creek
WF4	Mouth of Ladd Creek	McGee Cree/Elk Creek confluence
Lake Branch	Mouth of Lake Branch	Lost Lake
EF1	Mouth of East Fork	Mouth of Middle Fork
EF2	Mouth of Middle Fork	Mouth of Dog River
EF3	Mouth of Dog River	Mouth of Tilly Jane Cr.
EF4	Mouth of Tilly Jane Cr.	Mouth of Clark Cr.
EF5	Mouth of Clark Cr.	Sahalie Falls

Stream Morphology

Gradient and channel morphology played an important role in determining the unit composition of a reach. Spring Chinook spawner densities were higher in reaches with high pool composition than in reaches with low pool composition (Hayman et al. 1996, Montgomery et al. 1999). Pools not only provide holding areas throughout the summer for spring Chinook, but they also create tailouts which were popular spawning locations (Lambert 2001). Juvenile rearing densities of both spring Chinook and steelhead parr were highest in pools of all main channel units (Johnson et al. 1993, Bumarnier et al. 1994; 1995, Mendel et al. 1993, Bjornn and Reiser 1991).

Within the Hood Basin, the West Fork had the highest pool composition and deepest pools among the forks (Figure 15). The average maximum depth of slow-water units in the West Fork was approximately 2.0m in three out of four reaches. In the East Fork and Middle Fork, depths were closer to 1.0m (Figure 16). The high presence of deep pools in the West Fork was well suited to summer holding of summer steelhead and spring Chinook adults. A lack of deep pools in the East and Middle forks may limit use by summer steelhead and spring Chinook.

The East Fork and Middle Fork were characterized by an abundance of rapid and riffle habitat. Though the East and Middle Fork were not as conducive for summer holding, winter steelhead were able to spawn successfully in these two forks, and the high rapid content in these reaches was well suited for steelhead rearing, because they have high boulder composition which creates the feeding stations favored by steelhead (Figure 15)(Don Chapman Consultants 1989, Fausch 1993, Johnson 1985).

Figure 15. Habitat composition of primary salmon and steelhead production reaches in the Hood Basin. Data from ODFW and USFS habitat surveys.

Figure 16. Average maximum depth of pools in important salmon and steelhead production reaches in the Hood River Basin. Data from ODFW and USFS habitat surveys.

Hydro Modifications

Powerdale Dam.

Powerdale Dam was completed in 1923 and was located 4.5 miles upstream from the mouth of the Hood River. This 206 feet long and 10 feet high dam creates an approximately 5 acre impoundment; the project was operated as a run-of-the-river facility. The dam diverts up to 500 cfs into a concrete-lined canal and a wood flume connected to 14,354 feet of pipeline downstream to a turbine with the capacity to product 6,000 kW (PacifiCorp, 2000). Diverted water was returned to the Hood River via the turbine at RM 1.5. Powerdale Dam (Figure 17) was owned and operated by PacifiCorp.

Powerdale Dam created three key impediments to fish survival: 1) it blocked adult anadromous fish migrating upstream, 2) it diverted smolts into a bypass channel and through a turbine, and 3) it removed water (~500 cfs) from 3 miles of river (Figure 18). Fish facilities made it possible to collect adults at the base of the dam and release them above the dam.

PacifiCorp and BPA have funded measures to reduce fish impacts. Adult fish were trapped in a pool-and-weir fish ladder and passed above the dam. PacifiCorp funded changes to the trapping facility in 1994 by improving attraction flows at the mouth of the ladder, and installing a new trash rack cleaner at the attraction flow pipe entrance.

The bypass channel excludes smolts by employing 5 vertical traveling belt fish screens. PacifiCorp estimated the efficiency of the fish screens between October 20th and November 3rd,

1995, by sampling a fyke net for 20 hours, the net caught 34 fish (CPUE = 0.28 fish per hour). Chinook salmon, coho salmon, cutthroat trout, and rainbow trout were present in the samples, and ranged in size from 95-246 mm with the majority less than 160mm. Sampling indicated that the screens were not fish proof and allowed entrainment of some juveniles. However, the proportion of juveniles entrained through the turbines (and their mortality) was unknown, because sampling took place during low migration period for a majority of the fish species and did not accurately represent annual fish loss. Conditions at the fish screen did not meet NOAA fisheries fish screen criteria (approach water velocity = 0.4 fps and the screen openings were greater than 1.75 mm).

Figure 17. Map of the Powerdale Dam, bypass channel and turbines (from PacifiCorp 2001).

Figure 18. Top photo: the Powerdale Dam and Fish trap to the left of the spill way. Bottom photo: Fish screens on 500 cfs diversion.

The three mile section downstream from Powerdale Dam and upstream from the turbines exhibits stage (stream elevation) changes from water withdrawal and resulting decreased flows. Currently there were no established guidelines to reduce fish stranding during stage changes in the Hood River and there was no estimate of the extent that any stranding occurs. However, in-stream flow restrictions were adhered to by dam operators (Table 4). Furthermore, Powerdale Dam was required to maintain fish facilities flows as part of the minimum flow requirement (e.g. fish bypass 20 cfs, fish ladder 15 cfs and fish attraction 70 cfs, totaling 105 cfs).

Table 4. Minimum flows below Powerdale Dam.

Period	Minimum Flow (cfs)
February 1 - April 30	270
May 1 - June 30	170
July 1 - July 31	130
August 1-November 30	100
December 1-January 31	170

The most recent Powerdale Dam FERC license expired in 2000. As part of the relicensing process FERC required PacifiCorp to make a number of fish friendly improvement to the dam. PacifiCorp determined that due to a combination of the required improvements, the expected life of the dam, and current economic conditions, the dam was not a good investment.

Powerdale Decommissioning

In June 2003, the Oregon State, CTWSOR and others agreed to a decommissioning plan for Powerdale Dam. The dam was expected to be removed by the end of 2010. PacifiCorp will completely remove the existing diversion dam including all gates, bridges, walls, spillways, fish ways, embankment sections, and intakes to the level of the original riverbed. The 604 ft long concrete power canal will be broken up and filled with available materials from the earth embankments, and will be graded to blend with the river bank. The 14,500 ft long flow line will be broken into sections and most sections will be removed completely. Wildlife access areas will be created beneath two sections of steel flow line that will not be removed. However, the powerhouse, a 86 ft by 51 ft concrete structure, will remain in place and protected as a historic site. PacifiCorp will also ensure the complete removal of the Powerdale Dam Fish Trapping Facility by February 29, 2012.

Before decommissioning the dam, PacifiCorp will not operate the dam from April 15 to June 30. Other interim operations include fish friendlier minimum stream flows, new ramping rates, and restricted sluicing of sediments. Once the dam is decommissioned, PacifiCorp will return their 500 cubic foot water right to the State of Oregon, which is expected to be reserved for fish and wildlife in-stream flows.

Clear Branch Dam

The Clear Branch of the Middle Fork was dammed one mile above the confluence with Coe Branch, creating Laurence Lake Reservoir. Middle Fork Irrigation District built the 109-foot high 1,460-foot long dam with a maximum discharge of 309 cfs to create a 3,550 acre-foot reservoir in 1968 for irrigation. This dam was located near the upper headwaters of the Middle Fork of the Hood River. This dam removed a limited amount of salmonid spawning and rearing habitat and may have an effect on fish survival downstream due to flow alterations.

Upper and Lower Green Point dams

The Hood River Irrigation District built two dams on Green Point Creek (Upper and Lower Green Point dams). The upper dam was completed in 1937 with a length of 920 ft and a height of 31 ft impounding 715 acre-feet. The lower dam was built in 1938 with a length of 558 ft and height of 36 ft, impounding 250 acre-feet. Both dams were in the upper headwaters of Green Point Creek and were believed to have minor impacts to anadromous fish.

Irrigation Water Withdrawals

Five irrigation districts operate in Hood River holding a total of 588 cfs in water rights (HRWG 2001). Figure 19 maps major irrigation canals and withdrawal points. Based on data obtained from the ODEQ website (www.deq.state.or.us 2003), there are three primary water withdrawal sites within anadromous fish migration and rearing corridors of the Hood River Forks and mainstem. At RM 5.9 of the East Fork, the East Fork Irrigation District operates an irrigation withdrawal and sand trap with a 157 cfs water right. On the West Fork, Dee Irrigation District withdraws water at RM 6.1 for irrigation with a 12.7 cfs water right. The Farmers Irrigation District withdraws water at RM 10 of the Hood River mainstem, holding a water right of up to 176 cfs. An additional 233 cfs of water rights was allocated to irrigation districts for water withdrawals from tributaries of the Forks and the mainstem Hood River. Municipalities also hold 40 cfs and industries hold approximately 60 cfs of water rights in Hood River tributaries.

Figure 19. Hood River Map showing major irrigation withdrawals.

The percentage of flow diverted was substantial throughout the year at Powerdale Dam, and high in the summer at East Fork Irrigation District (Figure 20). Diversions at Powerdale Dam reached 500 cfs (Figure 21) and removed 39-81% of average monthly discharge in the lower Hood River (Figure 20). This water was diverted at RM 4.5 and was returned at RM 1.5. Diversions at the Farmers Irrigation Diversion were less significant with diversions of 6-17% (47-82 cfs) of average monthly flows. In the East Fork, the East Fork Diversion withdrew a large portion of the river in the summer, constituting 50% to 62% of the flow in the East Fork during July through September. The Dee Diversion removed 6% (12 cfs) of the West Fork discharge in August, the month when withdrawals were most significant (Figure 20, Figure 21).

Figure 20. Proportion of river flow diverted by month at each of the main irrigation diversions in the Hood Basin and at Powerdale Dam.

Figure 21. Amount of flow diverted by month at each of the main irrigation diversions in the Hood Basin and at Powerdale Dam.

The affects of the cumulative withdrawals at these diversions was apparent when comparing flow conditions in the Hood in the period 1991-2000 to long-term flow conditions (1966-2000). During 1991-2000 from November through May stream flow was near or above the 1966-2000 average. However, in the spring and summer, flow during the same years was much lower than the long term average and in August dropped to 25% of the 34 year average (Figure 22). Either there has been a climatic shift to warmer wet winters and dryer summers or summer water withdrawals have increased dramatically. Limiting water in the summer during the height of the fish growing season could result in reduced stream carrying capacity.

Figure 22. Percent difference of 1991-2001 average daily stream flow to the 1966-2001 average daily stream flow at the mainstem Hood River, Tucker Bridge (RM 6.1, USGS Station 14120000).

Irrigation districts throughout the basin were actively increasing water use efficiency. Replacement of open ditch and canal segments with pressurized pipe eliminates seepage losses, soil erosion, and canal related landslides. Piping results in the need to withdraw less water leaving more water within natural channels for fish (Coccoli and Lambert 2000). The Farmers Irrigation District estimated that 20,000 acre-feet of water would be conserved for instream use upon completion of their water conservation plan (Coccoli and Lambert 2000). Reduced irrigation withdrawal not only restores flow to the stream, but also reduces turbidity from irrigation return flows. Although Neal Creek was not a naturally glacially turbid stream, irrigation diversions from the East Fork have brought glacial sediments to Neal Creek.

Water withdrawals reduce fish survival two ways by reducing available habitat and displacing fish out of the stream and into canals. The reduction of habitat occurs due to the volumetric reduction in stream volume thereby reducing living space. Unscreened or poorly screened withdrawal structures displace fish. Both of these impacts have survival consequence for salmon and steelhead in the Hood Basin. A detailed review of potential impacts to salmonids in the Hood River from water withdrawal is in Chapter 6.

CHAPTER 3: FISH DISTRIBUTION AND CARRYING CAPACITY

KEY FINDINGS IN CHAPTER 3

- Spring Chinook spawned almost exclusively in the West Fork Hood River. Glacial silt loads were sufficient to nullify the effectiveness of fall spawning in the East Fork and Middle forks.
- Summer steelhead appeared to be restricted to the mainstem Hood and West Fork Hood Rivers. Winter steelhead had a wider distribution (e.g. the Mainstem Hood River, Neal Creek, East Fork Hood River, and the Middle Fork Hood River).
- The Unit Characteristic Method (UCM) is presented as a model for estimating stream carrying capacity for salmonids based on measurements of habitat features. The UCM estimated the annual production potential in the basin was 15,692 spring Chinook smolts, 16,970 winter steelhead smolts, and 13,860 summer steelhead smolts.
- The UCM estimates of smolt capacity were comparable to maximum production observed in similar-sized basins elsewhere, and were substantially higher than observed smolt production in the Hood River Basin.
- The UCM estimates of capacity were only 24-37% of the previous capacities estimated from the Smolt Density Model (SDM). The SDM estimates had been the basis for setting natural production targets for the HRPP. Stream characteristics used in the SDM were derived largely from professional opinion.

Fish distribution combined with carrying capacity describes the possible natural production. This chapter outlines the distribution of anadromous fish in the Hood River by race and species, and then provides estimated carrying capacity of the basin. The methods and results for estimating carrying capacity are original analyses that

offer strong implications for the Hood River Production Program (HRPP) strategies and potential outcomes. These analyses relied predominantly on data that was not available at the time the Hood River Production Master Plan (O'Toole 1992) was developed, but has since been gathered by natural resource agencies or through the HRPP Monitoring and Evaluation portion of the program. Hence, the new salmon and steelhead carrying capacity estimates in combination with recent HRPP Monitoring and Evaluation data provided an opportunity to refine the understanding of natural fish production potential in the basin.

ANADROMOUS FISH DISTRIBUTION

Spring Chinook Distribution

The distribution of spring Chinook was downloaded from Streamnet and then modified based on professional opinion of ODFW and CTWSRO staff familiar with the Hood Basin. For one modification, Streamnet indicated that Chinook rearing extended 9 miles upstream and in numerous tributaries to the Lake Branch. ODFW and CTWSRO staff agree there was a natural migration barrier to adult spring Chinook at approximately RM 1.0 in the Lake Branch, so production was not assigned above that point. In addition, steelhead and spring Chinook production was eliminated from Pinnacle Creek, because the mouth of Pinnacle Creek lies above Laurence Dam on the Clear Branch, and thus was inaccessible.

Spring Chinook capacity was excluded in the East Fork Hood River and mainstem Middle Fork Hood River despite designations by Streamnet that spring Chinook exist in those reaches. We added distribution in Rogers Creek, and in the Clear Branch between Coe Branch and Laurence Lake. Observations by local state and tribal biologists indicated that use of the East Fork and mainstem Middle Fork by spring Chinook is either non-existent or very limited. The fact that spring Chinook do not use these subbasins raised the question of “Why not?” High influx of glacial sediments throughout the summer resulted in highly embedded substrate, and limited the potential for spring Chinook spawning, which occurred during the peak season of fine sediment deposition. Furthermore, the ability of adult spring Chinook to hold through the summer in these reaches appeared to be compromised by a lack deep pool habitat.

The deleterious effects of fine sediments in spawning substrate were widely recognized. The presence of fines in spawning gravels impairs stream flow that delivers oxygen to eggs, and may block emergence of fry (Lisle and Lewis 1992, Bjornn and Reiser 1991, Waters 1995). Embryo survival was not as much a function of the condition of the spawning gravels before or immediately after spawning, but during the several weeks or months during incubation (Lisle and Lewis 1992). The female spawner cleans fines from the substrate during redd construction, but sediment can subsequently infiltrate the interstices of the gravel reducing intra-gravel flow (Lisle and Lewis 1992). Lisle and Lewis (1992) found that sand (0.25-4 mm) were the predominant substrate that infiltrated spawning gravels in Jacoby Creek, California.

The East Fork Hood River and Middle Fork Hood River were glacially turbid systems with high throughput of sand and silt sediments. Newton Creek and Clark Creek originate from glaciers on Mt. Hood's north-eastern slopes and contribute large amounts of sediment to the East Fork. The Coe Branch and Eliot Branch carry sediment into the Middle Fork. Sediment concentrations were highest in the summer when fine sediments were transported as suspended solids. The coarser particles settle out onto the streambed and into the substrate. Through the summer the substrate becomes increasingly embedded as sediment influx continues and stream flow decreases. By late summer when spring Chinook spawning occurs in the East and Middle Forks the streambed had become highly embedded. Further, high rates of deposition were likely to continue through September after spawning, infiltrating redds and reducing egg survival.

It is likely that winter stream flow cleans the substrate of fines as flow correlates to increased mobilization of fine substrate. Major movement of fines was likely to occur in the spring when flows reach three to four times those experienced in the summer. As summer approaches, flows subside and the cycle begins again with the deposition of fine glacial sediments increasing as the summer progresses.

This cycle is not conducive to fall spawning, because spawning occurs just at the time when fine sediment composition in the substrate was at its greatest. Since peak flows do not occur until spring, there was a high potential for deposited eggs to suffocate during the fall. While the flow regime in the West Fork Hood River was similar to the East Fork and Middle Fork Hood River, fine sediment was much less prevalent in the West Fork. Although the East Fork and Middle Fork were not suited for fall spawners, they were capable of producing spring spawners (winter steelhead) because gravels have been cleaned by winter flows and fry were emerging before fine glacial silt was again produced during the summer.

In Chapter 2 and Chapter 5 of this report, data are presented on pool composition and pool depths of the Hood River. The West Fork Hood River had a greater proportion of pools than either the East or Middle Fork, and the pools in the West Fork were roughly two times deeper than those in the other forks. Adult spring Chinook arrive in the Hood River during early summer and hold throughout the summer before spawning in the fall. The availability of deep pool habitat was an essential component to prespawning survival, because they provide holding locations for the adults through the summer. The lack of deep pool habitat in the East and Middle Fork reduces the capacity of those forks to produce spring Chinook.

Despite the conclusion that the East Fork Hood River was not conducive to fall spawning, it may have been suitable for juvenile rearing and some tributaries could have been used for fall spawning. USFS (1996) observed Chinook and coho smolts in the East Fork Irrigation Ditch indicating that fall spawning has been successful in the East Fork subbasin, probably in tributaries. But, ODFW (Olsen Draft) screw trap data indicates that the East Fork produces very few, if any spring Chinook smolts.

Spring Chinook were assumed to successfully spawn and rear in the mainstem Hood River, West Fork Hood River, and secondarily in the Middle Fork Hood River. Rearing was distributed throughout the mainstem Hood River except for the lower mile, which was classified as only a migration corridor. Spring Chinook distribution in the West Fork Hood River includes the entire mainstem, approximately one mile of the Lake Branch, and lower sections of Red Hill Creek, Jones Creek, Elk Creek and McGee Creek. Rearing in the Middle Fork occurred in the Clear Branch just below Laurance Lake, as well as in Tony Creek, and Rogers Creek. (Figure 23).

STEELHEAD

Steelhead Distribution

Steelhead distribution covers a significant portion of the Hood River Basin (Figure 24 and Figure 25). Both summer and winter steelhead occupied the lower mainstem Hood River. Winter steelhead used Neal Creek and several other mainstem tributaries. Distribution in the East Fork Hood River extended to Sahalie Falls and included numerous tributaries below Sahalie Falls. In the Middle Fork Hood River distribution extended up to Laurance Dam on the Clear Branch as well as part way up the Coe Branch and in several tributaries below. In the West Fork Hood River, steelhead were found throughout the mainstem, and up through lower McGee Creek and lower Elk Creek as well as in numerous tributaries below. Important tributaries below Elk and McGee Creek included the Lake Branch and Green Point Creek.

Winter steelhead primarily inhabited the East and Middle Forks while summer steelhead inhabited the West Fork. Returning adult winter steelhead typically arrived to the Hood River during the winter with mature gonads and spawn within a couple months of arrival. In contrast, returning adult summer steelhead typically arrived in the summer with immature gonads and spawn roughly a year later. As a result, the adult winter steelheads spent a short period on the river prior to spawning, requiring the adults to spawn in river reaches with relatively easy access. The adult winter steelhead strategy also allows the fish to avoid inhospitable stream condition present during the summer and fall. Summer steelhead adults lived within the Hood River during all four seasons allowing them to exploit less accessible areas due to varying stream flows and ample time to explore. However, the drawback to this strategy was the summer steelhead adults had to endure inhospitable river conditions. In the Hood River inhospitable condition were present in the summer and fall due to glacially derived turbidity and bedload. In theory, summer steelhead were limited to the West Fork because it was the least glacially influenced fork, and has suitable holding areas; and since winter steelhead were in the Hood River during the winter and fall, they exploit the East and Middle Fork, partly because the summer steelhead were not present to compete for space.

Hood River Watershed Spring Chinook Rearing Distribution

Figure 23. Generally accepted distribution of spring Chinook rearing areas in the Hood Basin. Scale = 1:100,000.

Hood River Watershed Summer Steelhead Rearing Distribution

Figure 24. Generally accepted distribution of summer steelhead rearing in the Hood Basin.
Scale = 1:100,000.

Hood River Watershed Winter Steelhead Rearing Distribution

Figure 25. Generally accepted distribution of winter steelhead rearing in the Hood Basin. Scale = 1:100,000.

CARRYING CAPACITY

The goal of the HRPP was to establish self-sustaining runs of spring Chinook, summer steelhead, and winter steelhead with the assumption that the Hood River Basin provided adequate carrying capacity for rearing these species/races of anadromous salmonids. Supplementation with hatchery-reared fish was intended to build the density and distribution of target populations until they fully seeded suitable habitat in the basin. Additionally, the habitat improvement actions were intended to expand productivity (carrying capacity and/or survival) of natural habitat. Assumptions made about carrying capacity and survival were the basis for estimating the rate of supplementation needed to achieve program goals. The data for estimating carrying capacity and survival of naturally-produced Chinook and steelhead were sparse at the time of program inception, consequently the EIS acknowledged that carrying capacity was a critical uncertainty associated with the HRPP plan.

The Hood River Production Master Plan was developed using the assumption that the production potential of Hood River salmon and steelhead was estimated by the Smolt Density Model (SDM). The SDM was designed to employ the lowest common denominator of information broadly available on stream habitat throughout the Columbia Basin. SDM used a mixture of stream measurements to estimate surface area, and expert opinion to designate habitat quality. SDM was not fully accepted by fish managers and the carrying capacity estimates were viewed by some parties as too liberal, and or by others too conservative.

To help resolve the critical uncertainty about carrying capacity, we applied a new model for estimating carrying capacity, and we supplied its input from new detailed measurements of stream habitat features throughout the basin. The new method, known as the Unit Characteristic Method (UCM), relies on data from each channel unit to generate capacity estimates. The remainder of this chapter describes the UCM, compares UCM estimates to other basins and the observed data in the Hood River, and compares the estimates between UCM and SDM. UCM estimated carrying capacity estimates were lower than SDM estimates, and consequently present an opportunity for the Hood River Fish Managers to re-evaluate natural production expectations.

Since carrying capacity affects a number of topics within this report, UCM outputs were also applied in Chapter 6 to identify habitat limitation to fish, Chapter 7 to describe the effect of carrying capacity on the natural population and finally in Chapter 10 where the affect of carry capacity was incorporated into a life cycle model that considered possible future adult escapement and harvest.

Unit Characteristic Method (UCM) Overview

The UCM was recently developed by Cramer (2001) to estimate the steelhead and spring Chinook carrying capabilities in streams of the Pacific Northwest. We provide an overview of UCM here and refer the reader to Cramer (2001) for details. The model relies on specific measurements of habitat characteristics and well established relationships of the maximum fish densities to those characteristics. Key habitat characteristics that have been consistently related to rearing density of salmonids include the habitat unit type (e.g. pool, riffle, or glide), depth,

velocity, substrate, cover, and water chemistry. Cramer (2001) reviewed the most up-to-date findings from studies of salmon and trout ecology throughout western North America, and developed a model to estimate a stream's potential to produce steelhead trout, rainbow trout, spring Chinook, fall Chinook, and cutthroat trout, based on stream habitat. The UCM is suitable for application in the Hood Basin, because stream habitat in the basin has been extensively surveyed, and water quality data are available. UCM assumes that the quantity of summer rearing habitat controls the upper limit of parr production (Cramer 2001). Thus, the parr rearing capacity for steelhead and spring Chinook was determined for conditions at summer low flow.

Cramer (2001) found numerous studies demonstrating that rearing densities (fish/m²) of juvenile salmonids consistently differ between channel unit types (pool, riffle, glide, etc.), and that stratification of parr densities by channel unit type was a useful starting point for estimating habitat capacity to rear parr. For all species of anadromous salmonids, pools supported the highest fish densities and riffles supported the lowest (Table 5). Cramer (2001) also found evidence that use by steelhead and spring Chinook in large channels drops off sharply at distances over 40 ft from shore and in the calm mid section of pools longer than 4 channel widths (Cramer et al. 1998; Romey et al. 2001).

Table 5. Standard parr densities used in the UCM for each channel unit type.

Unit Type	Steelhead Capacity (#/100m ²)	Spring Chinook Capacity (#/100m ²)
Backwater	5.0	13.0
Beaver Pond	7.0	19.0
Cascade	3.0	2.4
Glide	8.0	7.0
Pool	17.0	24.0
Rapid	7.0	2.4
Riffle	3.0	2.4

Although there were consistent differences in juvenile densities between channel unit types, there was substantial evidence indicating that densities in each unit type were strongly influenced by depth and cover. Spring Chinook, steelhead and cutthroat parr avoid shallow areas <15cm deep, and their densities increase as unit depths increase up to at least 90cm. Steelhead and spring Chinook show strong preference to hold adjacent to much faster velocities, and their densities in boulder dominated riffles, where they held behind boulders, are several times greater than in riffles dominated by other substrate types. Parr density in pools for both species increased as woody debris cover increased from no wood to high wood complexity.

Spring Chinook

Fish densities and the effects of various habitat factors differ by species. The spring Chinook UCM focused on estimating the quantity and quality of habitat specifically preferred by spring Chinook parr. The method began with measurements at the habitat unit level (pools,

riffles, glides, etc.), the finest level at which resource agencies typically measure area, depth, substrate, and cover during aquatic habitat surveys. The model assigned average fish densities for each unit type, and then decrements or increments those fish densities according to the amount that habitat features or water chemistry deviate from base values (Figure 26).

For the purpose of this report, we provide a synopsis of findings by Cramer (2001), and then describe new information used to enhance the UCM functions for spring Chinook. The initial habitat factors described by Cramer (2001) for estimating spring Chinook capacity included only evidence of unique fish densities for each unit type, adjustable for effects of cover complexity and substrate. We supplemented those findings with additional factors that were evident in data obtained from the Coldwater River, British Columbia (data from D.B. Lister & Associates), and from the Grande Ronde River, Oregon (Keefe 1995, 1998; Jonasson 1996, 1997, 1999).

Data from all sources consistently showed that spring Chinook parr densities were highest in pools, followed by glides, and lowest in riffles. There was some inconsistency in the relative placement of rapids in these categories. Bjornn and Reiser (1991) found that rapids and cascades (referred to as “pocketwater”) supported higher densities than riffles, whereas reports from the Grande Ronde showed that densities in rapids were similar to those in riffles.

The data available from studies in the Coldwater River, British Columbia were most closely related to habitat delineations elsewhere, and therefore the data was used to derive initial standard densities of spring Chinook parr for use in UCM. Also, substantial evidence existed suggesting that the Coldwater River was fully seeded when juvenile densities were measured. However, because the data from the Coldwater River did not include any units classified as rapids, standard densities were set for rapids based on data from the Grande Ronde River. For a complete explanation of the standard parr densities and, relationships between spring Chinook, cover, and substrate, and their application to the UCM, see Appendix A.

A list of calculation steps for the spring Chinook UCM follows:

Channel Units

1. Surface area was determined for each pool, glide, riffle, rapid, cascade, beaver pond and backwater unit within each reach.
2. Surface area was deducted for calm, mid-sections of pools.
3. Surface area was discounted for any mid channel farther than 40 ft from shore in pools, riffles, and glides.
4. Raw parr capacity in each unit was calculated by multiplying the area for each unit by the average maximum parr density for that unit type.
5. Raw capacity was adjusted up or down in each unit according to whether depth was more or less than average.
6. Capacity for each unit was further adjusted up or down in each unit according to whether cover complexity was more or less than average. Cover in pools were derived from wood complexity and boulder abundance. Cover in glides and riffles were derived from boulders abundance.

Reaches

1. Reaches of homogenous flow, gradient and turbidity were separated.

2. Raw capacity for each reach was calculated by summing the adjusted capacities for all of its component units.
3. Capacity for each reach was discounted further, if embeddedness in riffles averages greater than 10%
4. Capacity for each reach was adjusted depending on how the alkalinity at low flow differs from the average alkalinity at low flow in the Coldwater River, B.C. where the standard densities were derived.
5. Capacity for each reach was decremented according to its low flow turbidity levels and average riffle depth.

Stream

1. Raw capacity for the stream was calculated by summing the adjusted capacities for all reaches.
2. Capacity for a stream was discounted, if cobbles (winter habitat) composed of less than 15% of substrate for all reaches combined.

Steelhead

The steelhead UCM calculated the capacity of a stream, or reaches in a basin, to produce age 1+ parr. The UCM for steelhead operates in the same manner as the UCM for spring Chinook, except that densities assigned to each habitat unit type were different, and the response to deviations in habitat features from average was specific to steelhead. As in the steelhead UCM, raw parr capacity was derived from the surface area of different unit types, and it was subsequently adjusted up or down based on cover, depth, and water chemistry (Figure 26). The steelhead UCM has previously been applied to the upper Deschutes Basin, and to Trout Creek, a tributary to the lower Deschutes River.

ESTIMATION OF STREAM CARRYING CAPACITY

Spring Chinook

Figure 26. Diagram of data input and calculation steps used in the UCM to estimate stream carrying capacity for spring Chinook parr.

A list of calculation steps for the steelhead UCM follows:

Channel Units

1. Surface area was determined for each pool, glide, riffle, rapid, cascade, beaver pond and backwater unit within each reach.
2. Surface area was deducted for calm, mid-section of pools.
3. Surface area was discounted for any mid channel farther than 40 ft from shore in pools, riffles, and glides.
4. Raw parr capacity in each unit was calculated by multiplying the area for each unit by the average maximum parr density for that unit type.
5. Raw capacity was adjusted up or down in each unit according to whether depth was more or less than average.
6. Capacity for each unit was further adjusted up or down in each unit according whether cover complexity was more or less than average. Cover in pools and glides were derived from woody debris. Cover in glides and riffles were derived from boulders abundance.

Reaches

1. Reaches of homogenous flow, gradient and turbidity were separated.
2. Raw capacity for each reach was calculated by summing the adjusted capacities for all of its component units.
3. Capacity for each reach was discounted if the percentage of area composed by riffles is less than 50%. This accounts for low availability of invertebrate drift, the principle food.
4. Capacity for each reach was discounted further, if embeddedness in riffles averaged greater than 10%
5. Capacity for each reach was adjusted depending on how the alkalinity at low flow differs from the average alkalinity at low flow in the coastal Oregon streams where the standard densities were derived.
6. Capacity for each reach is decremented according to its low flow turbidity levels and average riffle depth.

Stream

1. Raw capacity for the stream is calculated by summing the adjusted capacities for all reaches. Capacity for a stream was discounted, if cobbles (winter habitat) compose less than 15% of substrate for all reaches combined.

ESTIMATION OF STREAM CARRYING CAPACITY Steelhead

Figure 27. Diagram of the data input and calculation steps used in the UCM to estimate stream carrying capacity for steelhead parr.

Water Quality Effects

Relationships were developed for the influence of water quality on capacity for both steelhead and spring Chinook. These relationships accounted for differences in potential inherent productivity in the Hood River, compared to streams from which standard densities were derived. Other studies have indicated that alkalinity is a useful surrogate for nutrient concentrations in a stream, and that turbidity (or total suspended solids) is also related to primary production in a stream. Alkalinity and turbidity appeared to have a strong effect on the capacity of fish in the Hood River. Inclusion of water quality provides a means to adjust the capacity estimate with consideration of the river system as a whole rather than only relying on individual habitat units.

Ptolemy (1992) found that the relationship between salmonid density and alkalinity was strong and positive across a large number of streams in British Columbia, and we applied the relationship he found to the UCM. Alkalinity was a measure of the concentration of CaCO_3 in the water column, and was largely a function of the geochemical composition of parent material in a basin, plus runoff per area of watershed. Runoff per area of watershed was generally different in the Hood River than in streams from which standard fish densities were derived. Geology was also different, so we questioned whether nutrient loads (as indicated by alkalinity) might be different in the Hood River basin than in the streams used to develop the UCM. We used data from the Hood River Basin and methods described by Ackerman (2002) to account for the effects of differences between alkalinity concentrations in the Hood River Basin and the streams from which standard densities were derived.

We reviewed literature regarding the effects of turbidity (a measure of TSS) on stream productivity. The one relationship that was confidently affirmed, was increasing turbidity reduces light penetration, thereby reducing primary productivity and ultimately limiting invertebrate production, ending with reduced salmonid growth and survival. Studies in streams by Lloyd et al. (1987), Carlson et al. (1990), Murphy and Hall (1981), and Hawkins et al. (1983) each found evidence that as light penetration decreased, so did primary production and invertebrate production. Further, they found that salmonid production ultimately declined. Using findings by Lloyd et al. (1987) a relationship was described between turbidity, light penetration, stream depth, and salmonids production potential. A literature review and our analyses establishing the relationships between turbidity and salmonid capacity is detailed in Appendix D.

Comparison to other Pacific Northwest Basins

Hood River UCM spring Chinook and steelhead smolt capacity estimates were compared to observed production of smolts in other basins throughout the Pacific Northwest. Average steelhead smolt production estimates (1994-2001) from the mainstem Hood River trap were also compared to estimates from other basins. The purpose of this comparison was to demonstrate the range of production that may be expected from basins of size similar to the Hood and its subbasins, and how the UCM results and actual Hood River outmigrant estimates compared. Data were obtained from numerous reports and biologists who provided outmigrant trapping and abundance estimates. For each basin, the minimum, average and maximum annual outmigration

estimates from the duration of the projects were obtained. In some instances when an estimate was deemed unreliable by either a low confidence in the estimate (wide confidence interval), or the notation of an unreliable estimate by the author, the data were left out of the analysis. We also obtained the basin size from above the location where the outmigrant estimate was made.

In instances when both fall parr and spring smolt outmigration estimates were reported, fall outmigrant estimates were adjusted by a parr-to-smolt survival rate to estimate smolts produced from those early outmigrants and were added to the spring smolt estimate to obtain total smolt production above the trap.

We obtained sufficient data from five streams to estimate spring Chinook smolt production with UCM and to estimate basin size above the lower limit of parr production (Table 6). UCM capacity estimates compared favorably to maximum observed smolt production of other basins in the Pacific Northwest. The Middle Fork Hood, West Fork Hood and entire Hood Basin estimates all fell below the 95% confidence interval, for the regression of maximum smolt output on basin size (Figure 28). None of the other basins in the analysis were glacially influenced. Had the turbidity adjustment been exempted from this analysis, UCM estimates of carrying capacity would have been closer to maximum observed smolt emigration in other basins. Also, all the basins to which UCM estimates were compared in Figure 28 were from eastern Oregon and Washington. Average alkalinity in those basins was higher, and thus, the natural spring Chinook production was generally greater than in the Hood River. Data from Figure 28 suggests that habitat features in the Hood River basin may be less suited for spring Chinook production than typical spring Chinook streams in the Snake River Basin.

Estimates of actual steelhead smolt production and watershed area above the point of smolt estimation, was obtained for 39 locations (Table 7). Maximum production of natural steelhead smolts at the mainstem Hood River trap from 1994-2001 was slightly below what was expected for basins of similar size. UCM capacity estimates compared favorably to production of other basins in the Pacific Northwest. The UCM was slightly below the average of the other basins, but lied with in the 95% confidences interval (Figure 29). Furthermore, when the slope and intercept of the regression line for the Hood River UCM were compared to observed data from other basins by a conditional sum-of squares F-test, there was not a statistically significantly difference (slope was $F\text{-ratio}=0.02$, $P=0.884$; intercept was $F\text{-ratio}=0.27$, $p=0.601$; Figure 30).

Table 6. Spring Chinook UCM carrying capacity estimates in the Hood River compared to drainage area, years of estimates, and minimum, average, and maximum outmigration estimates from basins throughout the Pacific Northwest. See Appendix A for a list of sources of these data.

Basin	Subbasin	Est. Drainage	Years of Estimates	Minimum	Average	Maximum
		Area (mi ²) above trap				
Hood River	Mainstem (UCM)	352		?	15,785	?
Hood River	West Fork (UCM)	102		?	7,438	?
Hood River	Middle Fork (UCM)	45		?	568	?
Grande Ronde	Catherine Cr.	103	1995-2000	2774	8,538	14,075
Snake	Imnaha	850	1994	--	90,350	--
Grande Ronde	Lostine R.	98	1997-2000	2718	10,607	20,560
Grande Ronde	Upper Grande Ronde	196	1995-1996, 1998-2000	1151	11,853	28,761
Snake	Tucannon	438	1985-2001	90	28,416	58,200

Grande Ronde estimates expanded by the # of fall outmigrants multiplied by an overwinter survival rate.

Figure 28. Comparison of Hood Basin UCM spring Chinook smolt capacity estimates to maximum outmigration estimates from other basins in the Pacific Northwest.

Table 7. Steelhead UCM carrying capacity estimate in the Hood River compared to drainage area, years of estimates, and minimum, average, and maximum outmigration estimates for juvenile steelhead from basins throughout the Pacific Northwest. See Appendix A for a list of sources of these data.

Basin	Subbasin	Est. Drainage Area (mi ²) above trap	Years of Estimates	Outmigration Estimates		
				Minimum	Average	Maximum
Hood River	Mainstem (UCM)	452		?	30,830	?
Hood River	West Fork (UCM)	113		?	8,889	?
Hood River	Middle Fork (UCM)	102		?	9,410	?
Hood River	East Fork (UCM)	45		?	2,274	?
Hood River	Mainstem Trap	352	1994-2001	2,664	11,447	24,488
Alsea	Cascade Cr.	6	1998-2002	71	111	138
Clackamas	Fish Cr.	47	1989-2000	1,018	5,146	9,284
Clackamas	Big Bottom	139	1994 & 1998	2,982	3,113	3,243
Clackamas	Oak Grove Fk.	142	1998-1999	1,190	1,386	1,582
Clackamas	N. Fk. Clackamas	32	1998	2,024	2,024	2,024
Clackamas	N. Fk. Eagle Cr.	28	1999	3,750	3,750	3,750
Clackamas	Mainstem Above N. Fk. Dam	681	1994-1996	12,435	20,600	25,162
Coos	Fall Cr.		1999-2001	457	942	1,284
Coos	Bottom Cr.	18	1999	--	160	--
Coquille	N. Fk. Coquille	291	1998	--	4,348	--
Deschutes	Trout Cr.	550	1998-2002	12,170	33,390	76,417
Grande Ronde	Catherine Cr.	103	1997-2000	16,247	20,066	28,737
Grande Ronde	Lostine R.	98	1997-2000	3,470	8,426	15,544
Grande Ronde	Upper Grande Ronde	196	1997-2000	5,467	9,417	12,858
Kalama	Gobar Cr.		1978-1984	90	331	571
Kalama	Kalama R.	179	1978-1984	10,953	28,116	43,336
Kilchis	Little S. Fk. Kilchis	12	1998-2002	1,420	2,320	3,597
Lower Columbia	N. Fk. Scappoose		1999-2002	407	574	841
Lower Columbia	Germany Cr.	22.5	2001-2002	7,500	7,550	7,600
Lower Columbia	Mill Cr.	29.1	2001-2002	1,250	1,480	1,710
Lower Columbia	Abernathy Cr.	29	2001-2002	5,400	7,995	10,590
Nehalem	N. Fk. Nehalem	24	1998-2002	3,419	8,047	17,448
Nestucca	Little Nestucca	45	1998	--	7,957	--
Oregon Coast	Tenmile Cr.	23	1998-2002	6,030	11,745	19,883
Oregon Coast	Cummins Cr.	23	1998-2002	1,424	2,324	3,206
Oregon Coast	Euchre Cr.		1999-2002	2,951	5,348	7,537
Oregon Coast	Hunter Cr.		1996-2002	3,363	6,844	13,581
Oregon Coast	Hinkle Cr.		2002	--	597	--
Siletz	Mill Cr.	13	1998-2002	240	793	1,137
Snake	Imnaha	850	1994	--	107,826	--
Umpqua	Big Tom Folley Cr.	22	1998-2002	150	1,113	2,503
Umpqua	Brush Cr.	21	1998-2002	255	611	1,388
Umpqua	Elk Cr.	104	2002	--	1,477	--
Umpqua	Rock Cr.	98	2001	--	36,820	--
Umpqua	Cow Cr.	499	1999-2002	2,964	7,086	14,793
Umpqua	W. Fk. Smith R.	26	1998-2002	2,688	4,884	7,678
Umpqua	Smith R.	202	1998-2002	224	13,175	28,995
Wilson	Little N. Fk. Wilson	20	1998-2002	3,524	9,907	20,686
Yaquina	Mill Cr.	8	1999-2002	280	552	874

* Includes all juveniles. Report did not distinguish between life stages

Figure 29. Comparison of Hood Basin UCM steelhead smolt capacity estimates in comparison to maximum observed smolt production (estimates) from other basins in the Pacific Northwest.

Figure 30. Linear regressions of smolt production on watershed area for UCM capacity estimates in the Hood River, and maximum observed smolt production in other streams. Appendix A provides data sources for the comparative data.

Comparison UCM to Observed Parr Density

Observed steelhead parr density was compared to UCM predicted density by reach in the Hood River. ODFW estimated *O. mykiss* parr rearing densities in 60m long reach using a multiple-pass removal technique via electrofishing gear and block net during late summer 1994-1997 (Olsen et al 1996). *O. mykiss* greater than 85mm were assumed to be 1+ parr, and smaller fish were excluded from this comparison, because considered age-0 fish, and the UCM estimated capacity of age-1 steelhead. ODFW recorded the river mile of each electrofishing site. So, we used river mile to approximately align sample site and UCM reaches. The observed data did not estimated density by habitat type and therefore we compared observed fish density by reach which contained variable habitat types.

UCM steelhead density was lower than the observed density in 10 reaches, and higher than observed in 8 reaches (Table 8). The average and standard deviation of observed densities was 0.062 ± 0.045 fish/m² and the average UCM predicted density at capacity was 0.049 ± 0.015 fish/m². Although the mean appeared to differ, a Paired Student t Test indicated the observed and predicted densities overall did not differ (DF = 17, T Value=1.067, P Value=0.30). Given the annual variability of fish density due to a number of environmental and population factors, habitat type variability and the imprecise method of aligning sample sites with UCM reaches, this analysis failed to detect difference between observed and predicted density densities.

Table 8. Comparison of observed steelhead parr density to predicted density.

Reach	River Mile	Density (#/m ²)	
		Observed	Predicted
Bear Cr.	0.6	0.000	0.077
East Fork	20.2	0.001	0.053
Dog River	0.7	0.008	0.036
Middle Fork	4.5	0.022	0.026
Tony Cr.	1.0	0.033	0.070
East Fork	5.5	0.034	0.039
Neal Cr.	0.0	0.049	0.065
Neal Cr.	1.5	0.057	0.065
McGee Cr.	0.5	0.063	0.054
East Fork	0.5	0.067	0.036
Lake Branch	0.2	0.077	0.067
Neal Cr.	5.0	0.080	0.052
Evans Cr.	0.1	0.081	0.027
Lake Branch	7.0	0.081	0.040
Red Hill Cr.	0.1	0.082	0.045
Elk Cr.	0.5	0.087	0.037
Lake Branch	4.0	0.093	0.050
Green Point Cr.	1.0	0.194	0.042
Average		0.062	0.049
Standard Deviation		0.045	0.015

Comparison of UCM to Screw Trap Estimates

ODFW operated screw traps to estimate the number of steelhead smolts emigrating out of the Hood River. To compare the UCM estimate to the smolt emigration estimate, parr survival over the winter had to be considered, because many parr emigrated in the fall. We reviewed numerous literature sources regarding published estimates of steelhead parr to smolt survival rates, and found that over-winter survival rates were widely variable. Typical survivals range between 35-65% (Cramer and Beamesderfer 2001, Cramer et al. 1997, Beamesderfer et al. 2001, Kiefer and Lockhart 1999, Reeves et al. 1990, Tautz et al. 1992, Ward and Slaney 1993, Chilcote et al. 1984). Given the flashy conditions in the Hood River survival in the Hood River was assumed to be 35%. Thus, smolt capacity was predicted to be 35% of parr capacity. The steelhead capacity estimates were further reduced by 3% to account for assumed residualism in the Hood Basin.

During the period 1994-2001, the maximum number of emigrating steelheads smolts were 24,488 and UCM estimated a smolt capacity of 25,337. As a result, we believe steelhead were seeded to near carrying capacity one year out of the seven years smolt data was available years. However, estimated smolt production was below carrying capacity in many years and averaged less than half of capacity for 1994-2001 (see Chapter 7 for further details). Over-winter survival had a strong affect on this analysis. We tested the overwinter survival rate assumption in hindcast analysis of the life cycle model (chapter 11) and concluded that 35% was a reasonable estimate. However, 35% over winter survival can only be viewed as an approximation, because there have not been studies conducted to determine the overwinter survival in the Hood River. Likewise, annual summer low flow variability may have an effect on the number of outmigrants. Years with low flow may result in low smolt production and visa versa in higher flow years due to fluctuation in rearing space.

We believe UCM generated capacity estimates fall within an acceptable range of observed smolt emigrants. UCM provides an average maximum capacity estimate. Annual variability is expected. Thus, observed smolt data will vary annually. We are unable to speculated as to an expected annual variation. This analysis would take two to three decades of smolt production estimates to assure the stochastic nature of the system was captured. We did not compare UCM estimates to observed spring Chinook smolt estimates due to the unreliability of the estimates (see Chapter 7 for further details).

Comparison of UCM to SDM

The following section compares UCM estimates to those generated by the Smolt Density Model (SDM) at the onset of the Hood River Production Program. Differences between UCM and SDM will be explored.

The SDM estimated spring Chinook and steelhead carrying capacity for the Hood River Subbasin were constructed by a technical committee comprised of personnel from the ODFW, USFS, Soil Conservation Service (SCS), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and the CTWSRO (NWPPC 1990). The estimates were based on a subjective evaluation of habitat quality by reach along with several assumptions about

the spatial distribution of the populations. The accuracy of the SDM capacity estimates were unknown, and no other methods of estimating capacity were appropriate at the time, leaving uncertainty of the SDM accuracy.

SDM estimates of smolt capacity were retrieved from the Streamnet online database, and compared to parr capacity estimated with the UCM. Summer and winter steelhead were not differentiated in this analysis, because the SDM assigned equal capacity to both winter and summer steelhead in all reaches within the Hood Basin.

The UCM capacity estimates were markedly lower than those of the SDM for both spring Chinook and steelhead. The UCM spring Chinook estimate was 37% of that provided by SDM, and the steelhead estimate was 24% of that provided by SDM. Comparisons by Hood River forks indicated UCM consistently provided a lower estimate than SDM with the exceptions of spring Chinook estimates in the mainstem Hood River and Middle Fork Hood River (Figure 31 and Figure 32).

We explored possible reasons for differences between the model estimates. Both models incorporated the amount of suitable rearing area as a vital factor in the model. UCM used roughly 15% higher habitat surface area for spring Chinook and 5% higher surface area for steelhead as compared to the SDM model. The UCM predicted the maximum smolt densities for spring Chinook would be 1.6 to 3.5 smolts/100m² per stream reach, while the SDM predicted maximum smolt densities would reach 2 to 10 smolts/100m² in different stream reaches. The SDM applied a single habitat quality rating of poor, the lowest rating available, to all reaches. The UCM estimated densities by accounting for quantified levels of cover, depth, substrate, turbidity, and alkalinity, in addition to surface area of each unit type. The SDM did not discount potential densities for reaches with high turbidity, and this discount in particular accounted for much of the difference carrying capacity estimates between the two models.

UCM steelhead estimates were also lower than those of SDM. UCM steelhead smolt densities were estimated to range from 0.1 to a high of 3.4 smolts/100m². In contrast, the SDM assigned habitat ratings from poor to excellent, and densities from 3 to 10 smolts/100m².

Overall UCM Results

In summary, the UCM estimate appears to provide reasonable estimates of steelhead and spring Chinook in the Hood River Basin. UCM estimated carrying capacity to be one third or half of that estimated by the SDM. The UCM derived estimates should be used by the Fish Managers when reevaluating fishery expectations. The UCM generated results were incorporated into Chapter 6 Habitat Restoration, Chapter 7 Natural Production and Chapter 11 Future Expectations.

Figure 31. Comparison of Spring Chinook smolt capacities estimated by the UCM and SDM estimates for the mainstem and forks of the Hood River.

Figure 32. Comparison of Steelhead smolt capacities estimated by the UCM and SDM estimates for the mainstem and forks of the Hood River.

CHAPTER 4: IMPLEMENTED PROGRAM ACTIVITIES

KEY FINDINGS IN CHAPTER 4:

- Habitat improvement projects within the Hood Basin, have been completed by the CTWSRO, ODFW, USFS, local irrigation districts, ODEQ, and other agencies. .
- The Hood River supplementation program for spring Chinook, winter steelhead and summer steelhead, began in 1992, 1991, and 1997 respectively. Three hatcheries, two in the Deschutes Basin - Round Butte/Pelton Ladder and Oak Springs, and one in the Hood Basin - Parkdale Facilities, were used for these programs. All rearing was completed at the Deschutes Basin facilities. Collection of adults spawning and final acclimation of smolts at the time of release were planned for the Hood River Basin.
- The BPA funded monitoring and evaluation (M&E) began in 1991. Responsibility for M&E was split between ODFW and the CTWSRO. ODFW sampled adults at Powerdale trap, electrofished to determine juvenile densities, surveyed habitat, operated fish outmigrant screw traps at four locations, surveyed anglers, radio tracked adult returns and monitored stream flow. CTWSRO studied survival of spring Chinook reared in Pelton Ladder, radio tracked adult returns, surveyed spawning grounds, monitored water temperature, and monitored acclimation effectiveness.

This chapter is much like a methods section that reports what was done to implement the program. Results from those implemented actions are reported in later chapters. Program activities performed from 1988 to 2001 are presented, by category, in Table 9. Following the detailed listing in the table, we provide a narrative summary for each main category of action (except planning).

Table 9. HRPP activities for the period 1988 through 2001.

	Planning
1987	Northwest Power Planning Council's Fish and Wildlife Program Completed
1990	Hood River Subbasin Plan Completed
1991	Hood River Project separated from Northeast Oregon Hatchery Project
1992	Hood River Production and Pelton Ladder Project Master plans approved by the Northwest Power Planning Council, contingent on NEPA compliance
1992-1995	Baseline data collected was completed for an improved adult capture, holding, and transport facility adjacent to Powerdale Dam Pelton Ladder expansion baseline studies and a one-year experimental acclimation of spring Chinook and winter steelhead
1996	Hood River Project EIS
1999	Hood River Watershed Assessment completed
2000	Hood River Subbasin Summary completed
2001	Fisheries Management and Evaluation Plan and Hood River Harvest Plan

	Hatcheries and Acclimation Facilities
1995	Pelton Ladder rearing cells modifications complete
1996-2001	Began acclimating and practicing volitional release of spring Chinook in Blackberry Creek of the West Fork using temporary raceways.
1996	Began acclimating and practicing volitional release of winter steelhead in the East Fork using temporary raceways
1996-2001	Powerdale Dam adult trapping facility operational
1997-2001	East Fork Irrigation sand trap used to acclimate and volitionally release winter steelhead
1998-2001	Jones Cr. in the West Fork was added for acclimating and volitionally releasing spring Chinook and summer steelhead
1998-2001	Parkdale fish facility operational
1998-2001	Oak Springs Hatchery incubation and rearing ponds operational
2001	Parkdale expansion planning begins

2002	Parkdale fish facility purchases adjacent land and drills well.
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	Habitat
1996	Riparian Fencing with bank stabilization in Neal Creek (0.5 mi)
1997	Fish Screen East Fork Irrigation District Withdrawal
	Riparian Fencing and bank stabilization Neal Creek (1.5mi)
1998	Neal Creek canal diversion and screen preliminary feasibility evaluation
	Tony Creek Dee Mill Diversion modified to improve adult passage
1999	Middle Fork Evens Creek Diversion removed
	Riparian Fencing on Lenz Creek (0.5) mile
2000	Baldwin Creek Phoenix Pharms diversion and screen completed
	Riparian fencing and livestock enclosure on Baldwin Creek (0.7mi)
2001-2002	Screen Farmers Irrigation District mainstem withdrawal

	Hydromodifications
1998	Powerdale relicensing studies commence
2000	Draft relicensing document created
2002	PacifiCorp determines dam long term profitability outlook poor and moves to decommission Powerdale Dam.

	Monitoring and Evaluation
1988-2001	Adult life history and biological data at Powerdale Fish Trap
1988-2001	Monitor morphometric and meristic characteristics of wild, natural, and hatchery stocks of anadromous salmonids
1993	Develop a long term monitoring and evaluation plan for the Hood River and Pelton Ladder projects
1994-1996	Monitor spatial distribution of wild adult salmonids in the Hood river subbasin
1994-1997	Estimate natural production of juvenile and smolt rainbow-steelhead at selected sites in the Hood River subbasin
1994-1999	Monitor selected life history characteristics and escapements of wild and hatchery produced anadromous salmonids
1994-2001	Juvenile rearing density estimates in select reaches of the basin
1994-2001	Smolt quality, size at release and rearing unit studies associated with Round Butte/Pelton Ladder
1994-2001	Smolt outmigrant monitoring in forks and mainstem
1995	Oak Springs Hatchery evaluation studies
1995-1996	Radio telemetry study of adult spring Chinook salmon, fall Chinook salmon, and Summer steelhead in the lower Hood River
1995-1996	Habitat restoration and monitoring
1995-1996	Pelton ladder study design and coordination of ladder modifications
1995-1996, 1999-2000	Genetic studies of steelhead and cutthroat trout
1996-1999	Estimate harvest of jack and adult anadromous salmonids below Powerdale Dam
1996,	Hood River water temperature studies

1999-2000	
1996, 1999-2000	Oak Springs Hatchery coded-wire tagging and clipping evaluation
1996-2001	Acclimation and volitional release of hatchery smolts
1996-2001	Creel survey in mainstem Hood River from Powerdale to mouth
1997-1999	Monitor stream flows at selected sites in the Hood River subbasin
1997-2001	Spring Chinook salmon spawning ground survey in West Fork Hood River
1999-2000	Round Butte Hatchery coded-wire tagging and clipping evaluation
1999-2000	Pelton Ladder evaluation studies

	Fish Release
	<i>Spring Chinook</i>
1988- 1992	Carson spring Chinook ~150,000 smolts to West Fork
1993- 2000	Deschutes spring Chinook ~100,000-170,000 smolts to West Fork
2001	Deschutes/Hood spring Chinook ~85,000 smolts to West Fork ~40,000 smolt to Middle Fork

	<i>Winter Steelhead</i>
1988- 1992	Big Creek winter steelhead ~25,000 smolts to Middle and East Forks
1993- 2001	Hood winter steelhead ~40,000 smolts to East Fork
1999- 2001	Hood winter steelhead ~20,000-30,000 smolts to Middle Fork

	<i>Summer Steelhead</i>
1988- 1998	Skamania summer steelhead ~75,000 smolts to mainstem and West Fork
1999- 2001	Hood summer steelhead ~15,000-30,000 smolts into West Fork
1999- 2001	Skamania summer steelhead limited ~75,000 smolts below Powerdale only

HABITAT IMPROVEMENT ACTIVITIES

The BPA EIS (1996) outlined the need for habitat work, and suggested riparian fencing, riparian area rehabilitation (such as planting of trees and shrubs), and instream habitat improvements (i.e. log placement) in the Hood Basin. BPA further recommended that all habitat improvements meet the following criteria:

- BPA would consider funding a habitat improvement action if data generated by the Project monitoring and evaluation program indicated a need.
- The action must be sustainable (must be stable and require minimal or no upkeep).
- The action must facilitate the functioning of natural ecosystem processes.
- The action must reconnect the linkages between the aquatic, riparian, and upland environments.
- The action is critical to the success of the Project and clearly not the responsibility of other government and/or private agencies or entities.

The Hood River Habitat Improvement Project (BPA Project No. 9802100) was conducted by the CTWSRO. The CTWSRO have successfully received funding for numerous projects activities (Table 10). These activities focus primarily on three aspects: 1) planning/diagnosis, 2) riparian improvement, and 3) fish passage. Planning/diagnosis activities include the creation of a habitat and watershed action plan, aquatic inventories, and pesticide and water temperature monitoring. Riparian improvements consist of cattle exclusion fencing, and riparian enhancement with conifer, willow and dogwood plantings. Fish passage improvements focus on screening irrigation withdrawals and modifying withdrawal structures to increase access for fish migrating upstream past the withdrawal structure.

The US Forest Service (USFS) has also contributed to in-stream habitat enhancement by placing anchored woody debris such as logs in the stream at nine sites of the West Fork and tributaries. This action was taken to increase wood recruitment and create additional pool habitat. The USFS received funding for the project from BPA from 1984 to 1993 (BPA Project No. 8334100, 8338600, and 8401100).

Table 10. Habitat restoration and improvement projects in the Hood Basin in the last 10 years.

Project	Lead Agency	Action	Status	Purpose
Habitat and Watershed Action Plan	CTWS	Planning	Completed	Diagnostic
Aquatic Inventories Surveys	ODFW	Stream Surveys	Ongoing	Diagnostic
Pesticide monitoring	ODEQ/PSU	Chemistry Monitoring	Ongoing	Diagnostic
Temperature Monitoring	CTWS	Temperature Monitoring	Ongoing	Diagnostic
Photo points	CTWS	Temporal Monitoring	Ongoing	Diagnostic
Irrigation system and water use efficiency projects	Irrigation districts	Water Conservation	Ongoing	Flow restoration
Powerdale Dam hydroelectric project relicensing	Multiple agencies	Water Conservation	Ongoing	Flow restoration
Addition of gravel to Rogers Spring	CTWSR	Spawning Gravel Addition	Completed	Instream Improvement
West Fork Hood Instream Restoration	USFS	LWD/Boulder Placement	Ongoing	Instream Improvement
McGee Creek Instream Restoration	USFS	LWD/Boulder Placement	Completed	Instream Improvement
Lake Branch Instream Restoration	USFS	LWD/Boulder Placement	Completed	Instream Improvement
Clear Branch Instream Restoration	USFS	LWD/Boulder Placement	Completed	Instream Improvement
EFID Neal Creek Lateral project	CTWS	Water Conservation and Quality improvement	Ongoing	Passage Improvement
Tony Creek Dee Mill diversion adult passage	CTWS	Passage improvement	Completed	Passage Improvement
FID horizontal fish screen	CTWS	Entrainment Screen	Completed	Passage Improvement
MFID Evans Creek/glacier ditch passage	CTWS	Passage improvement/Water Conservation and Quality Improvement	Ongoing	Passage Improvement
Evans Creek culvert improvement	CTWS	Passage improvement	Ongoing	Passage Improvement
Baldwin Creek culverts improvement	CTWS	Passage improvement	Ongoing	Passage Improvement
Phoenix Pharms fish passage improvement	ODFW	Juvenile Screen improvement	Completed	Passage Improvement
Pinnacle Creek bridge fish passage improvement	USFS	Passage improvement	Completed	Passage Improvement
Neal Creek, Tony Creek and Clear Branch improvements	ODFW	LWD/Boulder Placement	Ongoing	Passage, Riparian/Instream Improvement
West Fork Hood Barrier Removal	ODFW	Removal of "moving barrier" at RM 3.0	Completed	
Neal Creek fence, riprap and riparian planting	CTWS	Cattle Exclosure	Completed	Riparian Improvement
Baldwin Creek riparian fencing	CTWS	Cattle Exclosure	Completed	Riparian Improvement
Lenz Creek fence and riparian planting	CTWS	Cattle Exclosure	Completed	Riparian Improvement
Tieman Creek riparian fencing	CTWS	Cattle Exclosure	Completed	Riparian Improvement
Shelly Creek riparian fencing	CTWS	Cattle Exclosure	Completed	Riparian Improvement
Wishart Creek riparian fencing	NRCS, DEQ, ODFW	Cattle Exclosure	Completed	Riparian Improvement
Nottingham Campground improvements	USFS	Riparian Degradation Prevention	Completed	Riparian Improvement
Rhoades Cr. riparian fencing	SWCD	Cattle Exclosure	Completed	Riparian Improvement
Baldwin, Graham, Tieman revegetation	DEQ	Riparian Planting	Completed	Riparian Improvement
Green Point Creek LWD placement and riparian planting	FID	LWD Placement/Riparian Planting	Completed	Riparian/Instream Improvement

HATCHERY ACTIVITIES

Three hatcheries were associated with this program: two in the Deschutes Basin - Round Butte/Pelton Ladder and Oak Springs (Figure 33), and one in the Hood River Basin - Parkdale Facilities (Figure 34). All rearing was completed at existing facilities in the Deschutes Basin, while only the collection of adults and then acclimation of smolts before release were planned to occur in the Hood River Basin. To accomplish this, all eggs were collected at the Parkdale Facility, and were transported to the Deschutes Basin to complete incubation and rearing. Chinook eggs were taken to the Pelton/Round Butte Facility, and steelhead eggs were taken to the Oak Springs Hatchery (Figure 35). Once rearing was completed in the Deschutes Basin hatcheries, fish were trucked in the spring back to the Hood River Basin, where they were held in acclimation facilities for a period and released (Figure 35). Chinook and summer steelhead were only released in the West Fork, so their numbers were split between the Jones Creek and Blackberry facilities. Winter steelhead were released in the Middle and East Forks, so those juveniles were acclimated at the Parkdale and East Fork Irrigation District facilities, (Figure 34). A summary of fish propagation activities is in Table 11. The BPA funded spring Chinook began in 1992, winter steelhead program began in 1991, summer steelhead began in 1997.

Broodstock Collection

Broodstock were collected from the Hood River at the Powerdale Adult fish trap as first priority, although Deschutes River returning adults were used when sufficient number of adults did not return to the Hood River.

Essentially all adult spring Chinook and steelhead in the basin return to areas above Powerdale Dam, and all must enter the trapping facility. The adult fish trap was installed in the uppermost pool of an existing fish ladder located on the east bank. A fyke net, installed just downstream, prevented fish from backing down the ladder after they entered the uppermost pool. In June 1992, the submerged fyke net was replaced with a finger weir because it was observed that spring Chinook would avoid swimming through the fyke net and would often try to jump over it (Olsen 2000). In late-1995, a new trapping facility was constructed at Powerdale Dam. The new trapping facility, which used the existing fish ladder on the east bank, was fully operational beginning in February, 1997. Fish were then directed from a holding area to a fish lock, then to a staging tank and from the staging tank to an anesthetic tank. After anesthetization, each fish was measured, scale sampled, and then moved to a sampling tank. A network of tubes were then used to transfer fish from the working area to either 1) an adult holding pen, 2) the Hood River above Powerdale Dam, or 3) a portable fish liberation tank. Each salmon was uniquely numbered with a Floy tag inserted below the base of the dorsal fin (Olsen 2000).

Figure 33. Map of Deschutes River with hatchery and fish trapping locations.

Figure 34. Map of the Hood River with acclimation / holding facilities, and fish traps locations.

Figure 35. Diagram of fish transfers between hatchery facilities in the Hood and Deschutes Basins as part of the HRPP.

Table 11. Summary of fish release targets for the Hood River Basin during 1988 through 2001. BPA funded projects are in normal font. Programs funded through ODFW are in italics.

Species	Number	Size	Stock	Stream	Sites/Type	Release Duration
<i>Spring Chinook</i>	<i>140,00</i>	<i>Smolt</i>	<i>Carson</i>	<i>West Fork</i>	<i>1 site , direct release</i>	<i>1998-1992</i>
Spring Chinook	125,000	Smolt	Deschutes	West Fork	1 site, direct release	1993-1995
Spring Chinook	95,000	Smolt	Deschutes	West Fork	2 site, acclimation	1996-2001
Spring Chinook	30,000	Smolts	Deschutes	Middle Fork	1 site, acclimation	1997-2001
<i>Summer Steelhead</i>	<i>75,000</i>	<i>Smolt</i>	<i>Skamania</i>	<i>West Fork, Mainstem</i>	<i>1 site, direct release</i>	<i>1988-1997</i>
<i>Summer Steelhead</i>	<i>75,000</i>	<i>Smolt</i>	<i>Skamania</i>	<i>Mainstem RM 4.5</i>	<i>1 site, direct release</i>	<i>1998-2001</i>
Summer Steelhead	40,000	Smolt	Hood River	West Fork	2 sites, acclimation	1998-2001
<i>Winter Steelhead</i>	<i>30,000</i>	<i>Smolt</i>	<i>Big Creek</i>	<i>Middle and East Fork</i>	<i>1 site, direct release</i>	<i>1988-1992</i>
Winter Steelhead	30,000	Smolt	Hood River	East Fork	1 site, direct Release	1993-1995
Winter Steelhead	30,000	Smolt	Hood River	East Fork	1 site, acclimation	1996-2001
Winter Steelhead	30,000	Smolt	Hood River	Middle Fork	1 site, acclimation	1999-2001

All captured fish were removed from a holding pond by conveyor, anesthetized in CO₂-saturated water and then interrogated for biometric data. Species, sex, maturation status, length, weight and other morphometric data were collected. Based on ODFW run predictions, timing of the year, fish origin and number of brood previously collected, brood collection decisions were made each day the trap was operated. An attempt was made to collect brood over the entire run. Each spring Chinook was marked with a uniquely numbered Floy Tag, and fish selected as brood stock were placed in a transport truck.

Brood stock were hauled to the Parkdale Hatchery using a 500 gallon fiberglass tank with an aeration system mounted on a one ton flatbed, capable of safely hauling 10 fish at a time. Transit time was approximately 30 minutes. Management guidelines prohibited passing progeny of non-indigenous stocks above Powerdale Dam; broodstock collection was not to exceed 25 percent of the run annually.

Parkdale Adult Holding and Egg Collection Facility

All broodstock for hatchery operations of either Chinook or steelhead were held and spawned at the Parkdale Facility, which began operation in 1998. Some of these broodstock were collected at Powerdale Dam and then transported to the facility, and some return voluntarily to the facility. BPA funded the creation in 1998 of Parkdale Adult Holding Pond and Egg Collection Facility (BPA Project No. 930190). This facility expanded an existing site adjacent to Middle Fork Irrigation District property, on Rogers Spring Creek near Parkdale, downstream from the District's Parkdale hydropower plant (Figure 34). BPA acquired about 10 acres of which about half was developed Figure 39. BPA project number 1988-053-07 funded facility construction, operation, and maintenance.

The facilities consisted of two adult holding ponds with approximate inside dimensions of 41x8x4 feet, two concrete juvenile acclimation ponds with inside dimensions of about 80x8x4 feet, associated piping from the powerhouse tailrace to the ponds and from the ponds back to the creek, and a small weir and trap in Rogers Spring Creek just below the outfall of the power plant.

When the adult holding and juvenile acclimation ponds were in full operation, they required about 5.3 cfs of water. The acclimation ponds were used from April through mid-May annually requiring 3.3 cfs of water daily. The adult holding ponds were used year-round and required a constant flow of about 2 cfs. The facility has also been used to acclimate and release smolts of up to 30,000 spring Chinook and 30,000 winter steelhead.

Newly arriving adults to the Parkdale Fish Hatchery were placed in a 8 by 40 ft camouflaged concrete holding ponds. Water depth can be adjusted for desired depths, but was normally held at four feet deep. Parkdale Hatchery has two different water supplies, spring-fed water at a constant 39-40°F, and Middle Fork water that varied from 33 to 55°F. Parkdale used both water supplies at different times of the year depending on the purpose (e.g. to lower water temperatures to hold adult brood and reduce disease potential, or elevate water temperatures to enhance adult maturation. Generally, water temperatures were set to reflect natural stream temperature in the West and Middle forks. Water could be adjusted for desired turn over rates, however, inflow was normally 400 gpm for each pond. During holding fish were given prophylactic oxytetracycline vaccination to control disease and minimize mortality. The upper end of each pond was fitted with slotted aluminum screen systems. Spray bars delivers approximately 50 gpm to each pond for fish security and sun shading. The adult ponds are painted camouflage and shade cloth was attached to the perimeter railing, covering the water surface.

The summer steelhead were collected throughout the year beginning in April, and were held for up to a 15 months based on when the fish were captured. Winter steelhead were collected and held from December through June.

At spawning, Chinook were crowded to one end of the pond, captured with dip nets, sorted according to spawning condition, euthanized, and handed to a person who took them to an enclosed, disinfected spawning area (Figure 36). Within the spawning building, each female were bled. All snouts were taken and examined for coded wire tags. Spawning took place in an

18 X 18 ft spawning building adjacent to the adult holding ponds. A floor drain diverted spawning refuse to the 8,000 gallon fish waste tank. Mating protocol was one male with one female. Fish were paired relative to the run time in which the fish were trapped. Fish run timing was tracked by uniquely numbered Floy tags placed in the fish at time of capture at Powerdale Fish Trap. The goal was to collect about 176,000 green eggs to meet the desired 125,000 smolts, allowing for roughly 29% mortality from green egg to smolt release stages.

Figure 36. Adults being sorted by maturation and placed on the deck surrounding the holding ponds for egg extraction and fertilization at Parkdale Hatchery during 2002.

Fertilized eggs were incubated in vertical stack incubators to the eyed stage in 42°C water from Roger Springs and transported to Round Butte Hatchery for final incubation and rearing by late September.

Round Butte/Pelton Ladder

In the preliminary phases of the Hood River Project, BPA funded the expansion of Round Butte Hatchery rearing facilities by modifying 300 feet of the Pelton Ladder to act as rearing vessels. (Figure 37). The Round Butte/Pelton complex expansion allowed for spring Chinook to be reared to smolt size and subsequently released into the Hood River. Portland General Electric (PGE) owns and operates the Pelton Hydro-electric Project located on the Deschutes River in Central Oregon (Figure 34). Pelton Ladder and Round Butte Hatchery were originally mitigation facilities meant to compensate for hydroelectric project impacts on anadromous fish in the Deschutes Basin.

The objective of the BPA funded program at Round Butte Hatchery and Pelton Ladder was to expand an already proven spring Chinook production program. BPA, in cooperation with CTWSRO, ODFW and PGE, funded construction of three new fish rearing cells in Pelton Ladder, as well as rehabilitation of existing facilities. The cells were completed in September 1995, allowing for an additional 220,000 spring Chinook salmon to be reared for release in the

Deschutes (95,000) and Hood Rivers (125,000) (BPA Project No. 8805303). Figure 37 is a schematic of Pelton ladder and Round Butte Hatchery.

Figure 37. Map of Round Butte and Pelton Ladder, Deschutes River.

Egg Incubation

Eggs were incubated at Round Butte Hatchery at temperatures near 42°F, and hatched during December and January. The incubation room is approximately 20 X 20 feet and contains 15 stacks of 16 Heath trays. The water source was from Round Butte Dam leakage. The water was well oxygenated and clear of contaminants. Water temperature was approximately 50°F, but beginning in 1996, the water was chilled to 41°F or warmed to 57.2°F, as needed to adjust egg maturation rates. Control of temperature was used to synchronize hatching. Spring Chinook eggs were treated for a week with a Formalin drip to combat soft shell disease. The egg incubation water can be treated with ultra violet light, but the ultra violet lights were seldom used. Fry were ponded when a majority of them have absorbed their eggs sac. The ponding of spring Chinook usually occurred during February when the Chinook were slightly over 1,200 fish per pound.

Juvenile Rearing at Round Butte Hatchery

There are 24-6 foot circular tanks for rearing fry, supplied with nearly constant 51.8°F gravity-flow seepage from Round Butte Dam. Dissolved oxygen content of the water was nearly 100%. Each pond has 1/16 inch mesh screens that allowed water to escape, but prevents fry from escaping. Water flow was about 15 gallons per minute into each tank. The tanks were located in a metal shed. Once the spring Chinook become about 400 fish per pound, they were transferred to one of 10 Burrows self cleaning raceways. Water for the raceways was also gravity flow seepage from Round Butte Dam. All the ponds were equipped with sprinklers to prevent sunburn of fish during the summer. All fish were fed by hand.

Average fish density at Round Butte Hatchery was about 1.4 pounds per cubic foot. Research studies by ODFW have shown that improved survival can be achieved by rearing fish at lower densities. Chinook were reared at much lower densities in the Pelton Ladder than at Round Butte Hatchery (Lewis 1996). Juvenile fry spring Chinook were reared at Round Butte Hatchery until they reach approximately 15 fish per pound. Fingerling spring Chinook were then transferred in November to the Pelton Ladder (personal communication, Jack Palmer, ODFW, December, 2002).

Juvenile Rearing at Pelton Ladder

In 1995, as part of the Hood River Production Program (HRPP), the Pelton Ladder was modified to rear Deschutes stock hatchery spring Chinook salmon for release into the Hood River. Two cells, originally fish ladder steps, were modified to replicate the existing rearing strategy used by the Deschutes mitigation program, and the modified facilities provided the capability to rear 187,000 additional spring Chinook to presmolts size. A third cell was designated for production of experimental study groups released into the Deschutes. Upon completion of the Pelton Ladder studies, the third cell will be used to rear Chinook for release into the Hood River (Lambert et al. 2001). Prior to release, all spring Chinook destined for the Hood River were marked with an adipose and left or right ventral, or left or right maxillary clip combination.

The Pelton Ladder was an adult fishway extending from below Pelton Regulating Dam to the Pelton Dam. The ladder was 10 feet wide, 6 feet deep, and 2.8 miles long. It was originally designed and constructed to allow passage of fish around the re-regulating dam to Lake Simtustus. The ladder was abandoned for fish passage after the facilities at Round Butte Dam failed to effectively pass juvenile salmonids downstream. Water was supplied by gravity flow from Lake Simtustus. Flow varies from 3,591 to 7,184 gpm. During the early 1980's, part of the Pelton Ladder was modified into 6 cells to rear juvenile spring Chinook as mitigation for the Pelton-Round Butte hydroelectric project. The cells were concrete, each with a volume of 24,100 cubic feet (Lewis 1996). Prior to 1994, approximately 270,000 spring Chinook smolts were reared in the ladder for release into Deschutes River.

Oak Springs Hatchery

Oak Springs Hatchery was located 7 miles north of Maupin, Oregon and adjacent to the Deschutes River (Figure 33). The facility has been operated by ODFW since the 1930s (circa) producing resident and anadromous fish. The Oak Springs Hatchery's water supply was from large springs producing 53°F-pathogen free water, which was ideal for growing steelhead and rainbow trout. As a result, the Fish Managers determined that Oak Springs Hatchery was the best alternative for rearing and incubating winter and summer steelhead for the Hood River. However, in order to produce additional fish, Oak Springs required the following equipment and modifications: four additional rearing ponds, new intake structure to collect additional spring water plumbed with 820 ft of 18 inch piping to supply the ponds with spring water and to carry effluent to treatment ponds, ten Canadian early rearing troughs, 4 Marisource incubation, isolation units in a new covered buildings, and a water chiller system. These modifications were funded by BPA and completed in time to begin releasing summer steelhead by 1998. A schematic of improvements is depicted in (Figure 38).

Figure 38. Schematic of Oak Springs Hatchery improvements (BPA 1996)

Acclimation Facilities

Juveniles released in the West Fork were transported to acclimation facilities at either Blackberry Creek or Jones Creek for release. Acclimation facilities were operated by the CTWSRO and funded by BPA through Project No. 198805303 and 199301900.

The original spring Chinook hatchery plan for the Hood River called for acclimation of half of the smolts prior to release in the subbasin. The other half would be released directly into the subbasin. The plan was designed to evaluate the benefits of acclimation. However, when the NPPC accepted the Hood River Production Program, they encouraged development of facilities to acclimate all smolts (NPPC 1992). The NPPC also recommended the use of temporary or portable facilities whenever possible to reduce costs and facilitate their removal, if monitoring and evaluation show them to be unnecessary. Consequently, all hatchery spring Chinook were acclimated and volitionally released since 1996 (Lambert et al. 1998). During 1993 and 1995, Deschutes spring Chinook were released directly into the West Fork (75,205 and 170,004 smolts respectively) prior to operational acclimation facilities.

Spring Chinook smolts were acclimated near primary spawning habitat with the intent that they imprint and return to good spawning habitat. Smolts were acclimated for a minimum of four to six days prior to volitional release to reduce stress and improve survival (Schreck et al. 1989; Whitesel et al. 1994). Acclimation of Chinook smolts began in 1996. The production goal for spring Chinook was 125,000 smolts.

Beginning in 1996, smolts were released in the West Fork Hood River from the Blackberry Creek acclimation site (RM 9), and beginning in 1998, at the Jones Creek acclimation site (RM 14). Portable raceways were used to acclimate and volitionally release hatchery spring Chinook smolts. The Parkdale Hatchery was completed during fall of 1998 on the Middle Fork of the Hood River (RM 4.0). A portion of the fish released at Blackberry Creek was acclimated at the Parkdale Fish Hatchery.

Blackberry Cr.

Acclimation facilities at Blackberry Creek were set up and taken down annually to avoid maintenance challenges during winter. Two ModuTank® portable raceways with dimension of 11.75ft x 49.25ft x 4.75ft and capacity of 19,500 gallons were installed during March (Figure 40). A screened head box and a 930 ft gravity flow pipeline diverts water from Blackberry Creek (RM 8.6) providing 351 gal/min for raceway one and 401 gal/min in raceway two with 38 ft of head (Olsen et al 1996). Approximately 125,000 spring Chinook smolts were released in two equal groups, 1996-1997. The two groups were acclimated for no less than 4 days and then were volitionally released. The first group was released roughly during the first week of April. Those fish who did not migrate were allowed to remain in the acclimation facility and a second group was placed in the trap, acclimated and then allowed to leave the tank. Non migration fish were considered residuals and released below Powerdale Dam. In 1998, Jones Creek acclimation facility was added sharing the 125,000 spring Chinook smolts released between the two facilities. Beginning in 1999, 30,000 summer steelhead have been acclimated and volitionally released from the Blackberry and Jones Creek facilities combined.

Figure 39. Schematic of Parkdale Springs Hatchery improvements (BPA 1996).

Figure 40. Picture of functioning raceways and schematic of water system for Blackberry Cr. acclimation site.

Jones Creek

Acclimation facilities were expanded in 1998 by adding a new site, Jones Cr (RM 14). A 10 diameter by 4.5 ft deep circular tank (2,344 gal.) was located next to the West Fork (Figure O). Operating procedures are similar to Blackberry Cr. However, Jones Cr. acclimates and releases only spring Chinook smolts.

Figure 41. Picture of the functioning circular tank and schematic of water system for Jones Cr. Acclimation Site.

Parkdale Adult Holding and Egg Collection Facility

Parkdale began acclimating and practicing volitional releases of winter steelhead in 1999. Between 20,000 and 30,000 winter steelhead smolt were acclimated 6 days and volitionally released in two groups (first and third weeks of April). All fish that did not volitionally out-migrate were trucked and released below Powerdale Dam. The preceding description of this hatchery provides hatchery schematics.

East Fork Irrigation District Sand Trap

Prior to 1996 all hatchery-origin winter steelhead were released directly into the East Fork. The first year of acclimation and volitional release employed portable raceways (11.75ft x 49.25ft x 4.75ft; 19,500 gal.) at RM 5.9 of the East Fork of the Hood River. Smolts were acclimated for a minimum of four days prior to release to reduce stress and improve survival (Olsen et al. 1996).

In 1997, the acclimation site was moved across and up the river to the East Fork Irrigation District Sand trap (RM 5.9). This facility was modified to accomplish the acclimation and volitional release needs, and to trap sand from the withdrawn stream water to reduce irrigation canals filling with sand (Figure 42). Approximately 60,000 winter steelhead were

released annually in two groups of equal size (~30,000 smolts). The first group was released during the first two weeks of April. Those that did not leave the tank were allowed to remain and the second group was released during the second week of April. All fish that did not outmigrate volitionally from the acclimation facility were subsequently released downstream from Powerdale Dam. Use of this facility was provided by the East Fork Irrigation District at no cost to BPA.

Figure 42. East Fork Hood River acclimation site and sand trap for the East Fork Irrigation district water withdrawal system (Lambert et al 1999).

MONITORING AND EVALUATION (M&E)

Monitoring Overview

BPA started funding Hood River activities in 1991. Responsibility for M&E was split between ODFW and the CTWSRO. The ODFW sampled adults at Powerdale trap, electrofished to determine juvenile densities, surveyed habitat, operated fish outmigrant screw traps at four locations, surveyed anglers, and monitored stream flow (BPA Project No. 8805304). The CTWSRO studied survival of spring Chinook reared in Pelton Ladder, radio tracked adult returns, surveyed spawning ground, monitored water temperature, and monitored acclimation effectiveness (BPA Project No. 8805303). Combined, these two M&E projects provide important data on adult run timing, spawning activities, juvenile migration, habitat conditions, juvenile density by reach, health and condition of hatchery releases, and biometric data for all ages of fish. Data collected through the M&E programs was used to: 1) choose and evaluate protocols for smolt releases, 2) developed race-specific guidelines for collecting hatchery summer and winter steelhead broodstock, 3) develop strict race specific guidelines for passing hatchery summer and winter steelhead above Powerdale Dam, and 4) evaluate performance of the Hood River Production Program (HRPP) (Olsen 2000). Information gathered under the M&E program was also used in the preparation of an Environmental Impact Statement (EIS; Bonneville Power Administration 1996a; Bonneville Power Administration 1996b), which was completed in 1997.

Program History

During the period 1991 to 2001, the Hood River M&E Program evolved from an adult return assessment to a comprehensive M&E program collecting data that described population status and life history strategies of Hood River fish. The accumulation of tasks over the years represents a lofty collection of annual duties. A chronological summary of developments in M&E activities follows.

- During 1991, ODFW funded the initiation of the M&E project focusing activities on the collection of stock-specific adult return data. The monitoring was intended to estimate adult population size, better understand life history characteristics from scale reading, and collect brood for the hatchery.
- In 1992, BPA began funding M&E activities and added the following activities: Design of Pelton Ladder for spring Chinook final rearing, evaluation of effects from Irrigation withdrawal systems on fish, and collection of genetics data for cutthroat, steelhead and rainbow to better understand possible hybridization.
- In 1994, the M&E activities were expanded to track life history attributes of the Hood River fish. Outmigrant traps were added to document timing and number of smolts migrating out of the Forks and Hood River; juvenile densities were estimated by electrofishing to assess seeding levels of habitat carrying capacity; and bull trout presence was examined by snorkel surveys.
- In 1994-96, Telemetry studies were funded by BPA to determine adult migration behavior.
- In 1996, the M&E program added a year round creel survey from the Hood River mouth to Powerdale Dam; began acclimating spring Chinook and winter steelhead prior to release; assessed hatchery fish residualism; implemented habitat improvement activities (cattle fencing, riparian planting and rip rapping of stream banks); and began assessing fish rearing in the Pelton Ladder.
- By 1998, M&E annual reports discontinued reporting juvenile density, stream habitat surveys and adult radio telemetry. We assume these activities were discontinued, but we found no summary that discussed finalization of these studies.
- The 1998-1999 Annual Report (Olsen et al 2000) and the 1998 annual report by Lambert et al (1999) were the latest complete M&E reports published by BPA. One additional published report written by Coccoli and Lambert (2000) reported on habitat activities.

In summary, data collected from 1991-2000 was reported in the following annual progress reports: Olsen et al. (1994), Olsen et al. (1995), Lambert et al. (1996), Olsen and French (1996), Olsen et al. (1996), Olsen and French (1999), Olsen (2000), Olsen et al. (2003), Lambert et al. (2001). These annual progress reports document information collected through the M&E program included the following studies:

1. Anadromous fish adult escapement and harvest
2. Powerdale trap, Pelton Ladder and Parkdale facility design and implementation
3. Spatial distribution of adult anadromous salmonids migrating in Hood River
4. Rearing densities of indigenous fish
5. Stream habitat characterizations
6. Irrigation water withdrawal system audits and improvements
7. Subbasin steelhead smolt production
8. Post-release survival of acclimated and direct released hatchery summer and winter steelhead smolts
9. Smolt to adult survival rates
10. Life history patterns,
11. Morphological and meristic characteristics of wild / hatchery resident and anadromous salmonids
12. Subbasin stream flow and water temperature
13. Hatchery coded-wire tagging and fin clip efficiency
14. Rainbow, steelhead and cutthroat genetic introgression studies

Brood Collection and Adult Monitoring at Powerdale Dam

The adult trapping facility constructed in December 1991 at Powerdale Dam (RM 4.5) was used both for broodstock collection and monitoring of adult fish returns. Essentially all adult spring Chinook and steelhead in the basin return to areas above Powerdale Dam, and all must enter the trapping facility. After anesthetization, each fish was measured, scale sampled, and then moved to a sampling tank. A network of tubes were then used to transfer fish from the working area to either 1) an adult holding pen, 2) the Hood River above Powerdale Dam, or 3) a portable fish liberation tank. Each salmon was uniquely numbered with a Floy tag inserted below the base of the dorsal fin (Olsen 2000). All captured fish were removed from a holding pond by conveyor, anesthetized in CO₂-saturated water and then interrogated for biometric data. Species, sex, maturation status, length, weight and other morphometric data were collected.

Hatchery fish arriving at Powerdale Dam in excess of broodstock needs were trucked back down to the mouth of the Hood River. As these “recycled” fish migrate upstream back toward the trap, they were vulnerable to harvest. The act of recycling provided greater harvest and additional catch opportunities for sport anglers. Prior to the 1992 run year, all wild and hatchery steelhead were passed above Powerdale Dam. In the 1993 run year, all Hood River stock hatchery winter steelhead were recycled to RM 0.2 of the Hood River. In the 1994 run year, limited numbers of hatchery winter steelhead were passed above the dam, and the remainder was recycled (Olsen and French 2000). Nonnative Skamania summer steelhead were passed above Powerdale Dam until August 8, 1997. Since then, no Skamania stock summer steelhead were allowed above the dam, and all were continually recycled to the mouth of the Hood River (Olsen and French 2000). Hatchery spring Chinook were rarely recycled, but rather were released above the dam.

Genetics Sampling

Since 1991, all natural-origin and hatchery-origin steelhead spawners passed upstream of the Powerdale Dam have been catalogued, measured and sampled for scales. Dr. Michael Blouin (2003) and his staff at Oregon State University successfully extracted microsatellite DNA from the scale samples, and genotyped between 97% and 99% of the steelhead collected for broodstock or passed over the dam each year. Therefore, distinctive genotype samples were taken for nearly every potential anadromous spawner from each run year since 1991.

Blouin analyzed a set of eight microsatellite loci with high heterozygosity, and found they provided statistical power to identify the specific parents of each fish. Furthermore, their ground truthing experiments with fish bred in the hatchery demonstrated they could accurately identify the true parents of each fish.

Blouin (2003) determined the reproductive success of steelhead trout spawning above the dam during four run years. Parentage analysis was accomplished by genotyping all of the adults passed upstream of the dam during each run year and genotyping all of their offspring returning to Powerdale Dam as adults in subsequent years (i.e., all natural-origin fish aged to the appropriate brood years). For each returning fish (putative offspring), they searched for genotypes of its mother and father passing Powerdale for the brood from which it was born (based on scale aging), plus or minus one year to allow for aging errors. From preliminary matching tests using a wider window, they found only a few percent of fish were miss-aged by one year, and none were miss-aged by two years. Blouin's complete report is in Appendix G.

Genetic Introgression

Resident and anadromous salmonids were sampled at selected sites in the Hood River and surrounding subbasins; and from hatchery fish from 1994 through 1996 (Lambert et al. 1999). Samples were collected to characterize and identify populations of rainbow-steelhead and cutthroat trout by allozyme electrophoresis and morphology to determine 1) the natural biodiversity of the Hood River Basin, including the subspecies present, the population and metapopulation structure, and the presence of any exceptionally unique populations; 2) if and where hybridization was occurring; and 3) the impacts of historic hatchery programs on the biodiversity of the subbasin, including contributions to hybrid zones (Lambert et al. 2001). Funding for the survey and analysis was provided by ODFW, USFS, and BPA. The analysis was contracted to staff at the University of Montana through the genetics program at ODFW, who were coordinating the effort.

Two progress reports have been completed by the Wild Trout and Salmon Genetics Laboratory staff at the University of Montana in the fiscal year 1999 and 2000, outlining genetic analysis methods and some early results. In Spruell et al. (December 1998), samples were collected from tributaries in the lower Columbia River Gorge and from selected locations within the Clackamas, Sandy, Hood/Mill, Deschutes, and John Day basins. All samples were collected under the supervision of ODFW personnel and shipped to the Wild Trout and Salmon Genetics Lab at the University of Montana. Samples consisted of either whole fish shipped on dry ice or caudal fin clips shipped in 95% ethanol. DNA was extracted from tissues

using the Pure Gene kit (Gentra). The concentration of all DNA samples was estimated through visualization on agarose gels stained with ethidium bromide. Species identification and detection of hybridization was performed utilizing Paired Interspersed Nuclear Element-PCR or PINE-PCR. This technique uses primers complementary to interspersed nuclear elements to amplify anonymous DNA fragments. Some of these fragments are found only in rainbow trout, and others are diagnostic for each cutthroat trout subspecies. These markers were used to identify these species and their hybrids.

Neraas et al. (October 2000) presents preliminary results of genetic variation of Hood River steelhead populations. The purpose of the study was to determine if hatchery released Skamania (Stock 24) steelhead and rainbow trout had introgressed with the native summer and winter run populations. For microsatellite amplification and analysis, 24 microsatellite loci were amplified and separated on a polyacrylamide gel. Fluorescently labeled PINE-PCR primers were used to identify the genetic makeup of individuals. GENEPOP was then used to calculate heterozygosity values, allele frequencies, F_{st} , and deviations from Hardy-Weinberg expectations. A Cavalli-Sforza and Edwards chord distance (CSE) was then used to estimate the genetic similarity among samples (Cavalli-Sforza et al. 1967).

Radio Tracking

A radio telemetry study was conducted by the ODFW 1994-96 to track and document spawning distribution of adult steelhead, coho and Chinook in the Hood River subbasin. An Advanced Telemetry Systems (ATS) radio transmitter was inserted orally into the fishes gut cavity. Each transmitter had a unique frequency so individual fish could be identified and tracked. A base station was setup in the East Fork Hood River (RM 0.8) to record tagged fish as they passed by. During most of the sampling period fish movement within the system was monitored every 2-3 days using a mobile receiver and antenna carried on foot.

Harvest Monitoring

Since 1996, ODFW monitored sport harvest of steelhead and Chinook in the Hood Basin by creel surveys (Olsen 2001). The creel survey was designed to evaluate the HRPP harvest and escapement objects for Hood River stocks. The year round creel survey covered the area from the mouth of Hood River to Powerdale Dam (RM 4.5). Sport harvest in the Hood River targeting summer and winter steelhead, spring and fall Chinook, and coho was restricted to below Powerdale Dam. Chinook harvest season was August 1 to December 31 and also was restricted to below Powerdale Dam. Anglers were allowed to harvest adipose clipped summer and winter steelhead, and both marked and unmarked spring and fall Chinook and coho. Trout fishing was allowed from May 24 to October 31 throughout the basin with the exception of the West Fork Hood River and its tributaries, the Clear Branch and Pinnacle. Trout fishing above Powerdale Dam was restricted to flies and artificial lures (ODFW 2003).

Limited tribal harvest was allowed basin-wide in both 2001 and 2002, but was again prohibited in 2003. Tribal harvest, when allowed, was monitored by the CTWSRO. Although tribal harvest was allowed basin-wide, the majority of effort takes place from just below Punchbowl Falls on the West Fork Hood River down to the confluence with the mainstem Hood River (RM 10; pers. comm. with Alexis Vaivoda, CRWSRO).

Spawner Surveys

The CTWS began conducting annual spring Chinook spawning ground surveys in the West Fork Hood River in 1997 and in Rogers Creek in 2000. The objective of these surveys were to obtain general information regarding:

1. spawning distribution and abundance
2. spawn timing
3. prespawning mortality and fish health
4. spawner origins and sex ratios

The West Fork Hood River was divided into nine index areas. From 1997 to 1999, all index areas were surveyed (except index area seven) every two weeks from the beginning of August to the end of October. In 2000, all index areas were surveyed during the weeks of September 5-12 and October 23-31. Index area seven was excluded from regular surveys due to high turbidity and was surveyed one time each year in late October when turbidity loads decreased. The low number of adult spring Chinook returns for 2000 did not warrant full-scale spawning surveys for that year. As a result, only two weeks of surveys were conducted in 2000 reflecting the peak and final spawning time periods.

Spawning ground surveys on Rogers Creek were conducted from the confluence of Rogers Creek and the Middle Fork Hood River to a weir at the Parkdale Fish Facility at RM 0.75. These surveys occurred on September 16, 2000 and November 4, 2000.

Surveys were conducted by a crew of two, working downstream on foot. Redds, carcasses, and live fish were counted and recorded along with the accompanying river mile. Redds were flagged with the date and surveyors initials which allowed distinction between old and new redds. Carcasses were examined for fin marks, sexed, measured and checked for Bacterial Kidney Disease and spawning success. Snouts were removed from carcasses with missing fins for the purposes of coded wire tag recovery. Scales were collected from non-Floy tagged carcasses and were archived for later use. Finally, the caudal peduncle was severed from carcasses to indicate a sampled fish.

Sampling of Rearing Juveniles (juvenile density)

Population estimates were made in selected reaches of stream located throughout the Hood River subbasin to estimate rearing abundance of anadromous and resident salmonids. Survey streams were selected based on two primary criteria: (1) the stream had habitat that was accessible to anadromous salmonids and (2) randomly selected reaches of stream were capable of being effectively sampled. The length of each reach sampled was approximately 60 meters. Both ends of a survey reach were block-netted (using 3 millimeter mesh seines) to prevent both immigration and emigration of fish from the sampling area. A three-pass removal method was used to estimate population numbers in virtually all the sampling reaches. Fish were collected using Smith-Root backpack electrofishers. Fish collected in each pass were held separately in live boxes. After the final pass, fish were anesthetized and counted by species. Rainbow-

steelhead and cutthroat trout were additionally sorted into one of two defined size groups (i.e. < 85 mm fork length and $\geq$ 85 mm fork length) and counts were made for each size group.

Volume and surface area was estimated for each stream reach sampled. Estimates were made by dividing the planar area of the stream reach by 11 equidistant parallel transects starting at the head of the sampling reach. With the exception of five stream reaches sampled in 1994, five depth measurements were taken along each transect at equal intervals. In 1994, four depth measurements were taken along each transect at equal intervals. The 11 equidistant parallel transects of common height (h) formed 10 trapezoids and, depending on the number of depth measurements taken (i.e., four or five), either fifty or sixty hexahedrons. Surface area for the entire sampling reach was estimated as the sum of the surface areas for the 10 trapezoids. Volume for the entire sampling reach was estimated as the sum of the volumes for each hexahedron.

Screw Trapping of Outmigrants (outmigrant estimates)

Beginning in 1994, downstream migrant anadromous salmonids were trapped at a rotary-screw traps located in the mainstem Hood River (RM 4.5); in the West (RM 4.0), Middle (RM 1.3), and East (RM 1.0) forks of the Hood River; and in Lake Branch (RM 0.1). Screw traps were deployed generally during the last week of March and fished until November. Due to seasonal variation in stream flow, traps were periodically repositioned in the stream channel to optimize trapping efficiency. Each rotary-screw trap funneled downstream migrants into a live box that was sampled daily. All fish were sorted by species, examined for fin clips, and counted. A random sample of migrants was collected for each species and sampled for scales, measured to the nearest millimeter (FL), and weighed to the nearest 0.1 gram. Scale samples are then sent to the ODFW research laboratory in Corvallis, Oregon, where ODFW staff determines freshwater age.

Downstream migrant salmonids sampled at the mainstem migrant trap were used to monitor migration timing from the Hood River subbasin. Estimates of migration timing were based on bi-weekly counts at the migrant trap. Rainbow-steelhead were used to indirectly estimate steelhead smolt migration timing, because no accurate methodology exists to visually identify rainbow trout from downstream migrant steelhead smolts.

Mark-Recapture Studies

Mark-recapture tests were used in conjunction with the rotary screw traps to estimate numbers of wild, natural, and hatchery produced anadromous salmonid smolts migrating past each downstream migrant trap.

Downstream migrants caught in the rotary screw traps were marked with a pan-jet needle less injector and transported upstream for subsequent release. This process permanently marks the fin with a unique color by infusing a small amount of the colored dye below the epidermal layer. The dye color was changed every two weeks to uniquely mark fish for defined time intervals during the sampling period. Additionally, a small piece of the caudal fin was removed from fish sampled at the mainstem migrant trap to distinguish fish marked at the mainstem trap

from those marked at all the other traps, and to provide additional means for identifying fish marked at the mainstem trap in cases where a color mark was not readily visible. Unique dye color and fin-mark combinations were assigned to each trap, so that the origin of recaptures at the mainstem migrant trap could be determined.

Habitat Assessment, Stream Flow and Water Temperature

The Hood River Fish Habitat Protection, Restoration, and Monitoring Plan identified over 17 anadromous streams that had not been surveyed within the Hood River subbasin. The ODFW completed stream habitat surveys in 1993 and 1994 on 63 miles of potential anadromous salmonid bearing streams located primarily on private land, with selected reaches of stream located in the Mount Hood National Forest (Olsen et al., 1995). In 2000, the CTWSRO surveyed Baldwin Creek, Graham Creek, and Tieman Creek and were expecting to continue to surveying additional streams in future years.

Habitat surveys were completed using the Aquatic Inventory Project: Methods for Stream Habitat Surveys prepared by the ODFW (2000). Stream habitat surveys were designed to provide quantitative information on habitat conditions, provide managers with a basic understanding of each stream, assist field biologists in developing objectives and recommendations for protecting existing habitat, and for developing and implementing habitat improvement projects.

Water temperatures were collected in the Hood River subbasin during the past ten years to develop a general database for the Hood River Production Program (HRPP). Baseline data was collected from the mainstem (RM 3.9), West Fork (RM 16), and East Fork (RM 15), and since 1990 and the Middle Fork (RM 19) since 1994. Three more sites, located at the mouth of Neal Creek (1998), the mouth of Lake Branch Creek (1998), and the mouth of Baldwin Creek (2000), were added as part of the Oregon Department of Environmental Quality (ODEQ) Total Maximum Daily Load (TMDL) plan to meet Clean Water Act requirements. Furthermore, water temperatures were collected since May 1995 from Rogers Creek, a tributary to the Middle Fork Hood River.

Ryan Tempmentor thermographs were used to collect water temperature data through July of 1998, at which time these units were replaced with Onset Hobo Stowaways. Water temperature data was recorded in Celsius at one hour intervals. All thermographs have been calibrated in accordance with the "Stream Temperature Protocol" developed for the Oregon Coastal Salmon Restoration Initiative (ODEQ, Draft Revised Version, May 1997) since May, 1998.

Water Withdrawal and Irrigation Audits

The CTWSRO staff reviewed and inventoried irrigation system withdrawals and canal systems to determine potential impacts to fish. Four main criteria were assessed:

- 1) Was the withdrawal equipped with a fish screen that met NMFS criteria?
- 2) Did the withdrawal structure allow adequate passage for upstream migrating fish?

- 3) Could the purveyor reduce water use? and
- 4) Did the water returned from the irrigation system reduce water quality of the receiving water?

The CTWSRO worked with irrigation districts to resolve problems exposed by the audits. The CTWSRO worked with the Hood River Watershed Council to identify and prioritize watershed improvement actions. Finally, The CTWSRO frequently partnered with water purveys by locating funds for irrigation system improvements, provided labor to make improvements and consulted with irrigation on fish issues related to the irrigation system improvements.

Acclimation and Release Studies

The Hood River Production Master Plan (1991) originally called for an acclimation project in which half of the spring Chinook smolts, half of the summer steelhead smolts and none of the winter steelhead smolts were acclimated (for a minimum of four days) prior to release into the Hood River subbasin. The remaining smolts were to be directly released into the subbasin. This approach was designed to evaluate the benefits associated with acclimation prior to implementing full acclimation for all species. HRPP tribal staff identified four key objectives for the acclimation project on the Hood River (Department of Natural Resources (CTWSRO) 1993):

1. Determine if acclimation significantly influences homing of spring Chinook salmon and summer and winter steelhead.
2. Determine if smolt outmigration was significantly higher for acclimated smolts than directly released smolts.
3. Determine if acclimated smolts had a higher smolt to adult survival rate than directly released smolts.
4. Determine if outmigration timing was similar between hatchery acclimated smolts and naturally produced smolts.

Since 1996, all hatchery produced spring Chinook and winter steelhead smolts were acclimated and volitionally released into the Hood River subbasin (Lambert et al., 1998). Beginning in 1999, all hatchery summer steelhead smolts were acclimated and volitionally released into the Hood River subbasin. Two concrete raceways were used for winter steelhead acclimation. One raceway was located on the East Fork Hood River and the other was located on the Middle Fork Hood River. In addition, two portable acclimation raceways on the West Fork Hood River and one concrete raceway on the Middle Fork Hood River were used for acclimating hatchery spring Chinook. Lastly, one portable acclimation raceway, located on the West Fork Hood River, was used for acclimating hatchery summer steelhead.

Pelton Ladder Studies

In the early 1980's, Pelton Ladder, an adult fishway extending from below Pelton Regulating Dam to the Pelton Dam (RM 100), was modified and used as a rearing site for some of the juvenile spring Chinook salmon produced at Round Butte Hatchery. Then, in 1995, as part of the HRPP, the ladder was modified to create three new cells for rearing Deschutes stock

hatchery spring Chinook salmon. The three new cells were modified to replicate the existing rearing strategy in each section. Fish reared in the new cells, L-4 and L-5, have been released into the Hood River since 1996. The other new cell, L-6, is used as an experimental study group for release into the Deschutes River. Upon completion of the Pelton Ladder studies, juvenile spring Chinook salmon reared in cell L-6 will be used for increasing production in the Hood River.

The objective of the Pelton Ladder Studies was to determine if modifying Pelton Ladder to rear more fish reduced the effectiveness of the existing production program. Furthermore, the studies were to evaluate the effect of smolt size at release on post-release survival and provide basic information about rearing conditions in the ladder. These studies used Coded Wire Tag (CWT) implemented fish reared at Round Butte and Pelton Ladder.

All spring Chinook smolts released into the Deschutes River were marked with an adipose fin clip, while those smolts released into the Hood River were marked with an adipose and left or right ventral, or left or right maxillary clip combination. All Deschutes and Hood River releases were differentially marked with a CWT (since brood year 1994).

Coded-wire tags from returning adults to the Deschutes River were recovered from snouts of fish collected at the Pelton Trap, Warm Springs National Fish Hatchery, and tribal and non-tribal fisheries at Sherars Falls. Return was calculated as the percentage of juveniles released with coded-wire tags that returned as adults. Comparisons of the modified Pelton Ladder cells were made against post-release survival rates of fish reared in the lower three cells of Pelton Ladder and hatchery ponds at RBH

SECTION 2. ACHIEVMENT OF PERFORMANCE TARGETS

CHAPTER 5: CONTRIBUTION FROM HATCHERY RELEASES

KEY FINDINGS IN CHAPTER 5:

- The assumed goal of the HRRP spring Chinook hatchery program to rely on Hood River returning adults for eggs could not be met; even if every Hood River returning adult allocated to the Parkdale Hatchery provided eggs.
- ODFW Pathology data indicated spring Chinook returning to the Hood River contained high incidences of Infectious Hematopoietic Necrosis (IHN). The prevalence of IHN may impede the collection of the eggs and in turn provide an impediment to the success of the HRPP.
- The spring Chinook brood stock was switched from Carson stock during 1988-1992, to Deschutes stock in 1993. The Deschutes stock release goal of 125,000 smolts into the Hood River Basin was met nearly every year.
- BKD was a chronic problem at Round Butte Hatchery and Pelton Ladder and limited program success for spring Chinook. High levels of BKD were believed to have caused mortality of presmolts in the Pelton Ladder during the 1995-96 and 1996-97 rearing periods.
- Mortality of juvenile spring Chinook increased from upstream to downstream in the Pelton Ladder rearing cells. The reason for the increased mortality of downstream cells may have to do with water quality or disease.
- Fish reared at Pelton Ladder appear to have much higher mortality than fish reared at the Round Butte Hatchery.
- The HRPP appeared to have achieved the goal of minimizing competition between outmigrating wild and hatchery spring Chinook parr. Hatchery fish left the Hood Basin shortly after release. However, hatchery fish were 5cm longer than wild fish upon capture at outmigrant traps, and their potential to displace wild juvenile should be reviewed.
- The proportion of hatchery spring Chinook mini-jacks and jacks was near 10-fold greater than among wild fish returning to Powerdale Dam. Mini-jacks composed an average of 46% of hatchery returns, compared to only 6.3% of wild returns during 1997-2001. Jacking and mini-jacking appears to be related to fast growth of fish reared in the hatchery setting.
- CWT data indicate Hood River hatchery spring Chinook strayed primarily to the

Deschutes River, at high rates. Spring Chinook rearing and acclimatization protocols should be revised to lower straying.

- Returns of spring Chinook have been far short of program goals to provide 1,080 adults for harvest of a total run size of 1,700. From 1996 to 2000, harvest below Powerdale ranged from 0 to 54 fish and run size was 2 to 560 age 4 adults. Tribal harvest of spring Chinook above Powerdale 1999-2001 did not exceed 100 fish per year.
- Deschutes spring Chinook released into the Hood River had smolt-to-adult survival rates that were only half of those released into the Deschutes River. High stray rates by the Hood River releases may explain the difference.
- CWT marked spring Chinook reared in the original cells at the Pelton Ladder appear to be recovered at higher rates than those raised in the new cells. Fish reared at Pelton Ladder had a lower CWT recovery rate than fish reared at the Round Butte Hatchery.
- There was little difference in return rates of spring Chinook released at small or medium size.
- The summer steelhead program recently (1999) shifted from releasing a non-indigenous-Skamania stock to releasing the progeny of wild summer steelhead collected in the Hood River. The indigenous program was not in operation for a sufficient period to test program success.
- The summer steelhead release goal of 40,000 smolts was met in 2000 and 2001. However, the implied NOAA Fisheries residual goal of 5 - 10% was not met as residuals ranged from 14-23%.
- Migration timing of smolts was similar between hatchery and wild summer steelhead. The HRPP appeared to meet the unstated goal of limiting competition between wild parr and hatchery smolts.
- Adult return timing of adult Skamania summer steelhead differed from that of the wild stock. A larger fraction of the Skamania stock entered the Hood River in May and June and than did wild fish.
- Columbia River harvest of Hood River summer steelhead ranged from 87 to 390 with an average of 207 fish. Hood River harvest ranged from 224 to 735 fish with an average of 412 fish. The Hood River harvest rate of hatchery summer steelhead varied from 19 to 35% during 1995-2001. The recycle program increased the number of hatchery fish harvested in the Hood River ranging from 30 to 44% for the years 1996-2001.
- An estimated 74% of summer steelhead recycled to the mouth of Hood River strayed, died, or spawned in the lower Hood River.. A large share of recycled winter steelhead below Powerdale were also unaccounted for. Potential straying of these fish is an uncertainty that should be resolved.

- Winter steelhead goals for brood collection and smolt releases have been met in most years.
- Residualism of winter steelhead stayed below the goal of less than 5% in three of five years monitored. Residual rates were 12% and 9% in the other two years.
- Emigration of hatchery steelhead smolts was rapid, so competition with wild fish appeared minimal.
- Our re-analysis of juvenile steelhead catches in screw traps confirmed that estimates made with annual efficiencies provided more accurate estimates than made with bi-weekly efficiencies.
- The actual adult returns from 1995 to 2000 of winter steelhead were from 529 to 1,899 fish, well below the goal of 5,000 fish.
- The average harvest of winter steelhead was only 28% of the goal 2,500 fish.
- Smolt-to-adult survival determined from fish marked with CWTs averaged 1.41%, and ranged from 0.29% to 2.89%. This is well below the goal of 4%.

In this chapter, we discuss the performance of hatchery fish for hatchery production. In chapter 6, we will discuss the contribution of hatchery fish to natural production. We present our findings one race at a time, beginning with spring Chinook.

SPRING CHINOOK

The Deschutes stock of spring Chinook was chosen for use in the HRPP due primarily to the geographic proximity of the Hood River and Deschutes basins, and also because spring Chinook were available for use at the Pelton/Round Butte Trap and the Warm Spring National Fish Hatchery (See **Figure 33**). Furthermore, fish from both collection facilities on the Deschutes system were intermittently mixed, and for management purposes were considered a single stock (Michael Paiya, USFWS, personal communication).

Adult spring Chinook entered the Deschutes River from early April to early June. Annually, more than half the adults were typically caught in the Pelton Trap by mid-June (Lindsay et al. 1989). Chinook broodstock were subsequently transported to Round Butte Hatchery, which has been in operation since 1972. Adults were held at the Round Butte facility from March through August, and spawned from August through October, with incubation lasting until March (Lambert et al 2001). In the Deschutes River, fry from natural spawning emerged during February and March. Deschutes River spring Chinook generally entered the ocean in the spring at age-1+ and return at age-3 through age-5.

Spring Chinook Broodstock Collection

The number of spring Chinook collected for brood at Powerdale are shown in Table 12. The brood collection goal was 110 adult spawners (55 males, and 55 females), and an adequate number of jacks to represent the percent of jacks in the wild run (approximately 5-10%). The HRPP annual release goal was 125,000 age-2 smolts. Spring Chinook were taken for broodstock and spawned at the Parkdale Facility from late August to early September. Initially, only fish returning to the Deschutes River were used to provide eggs for the Hood River Program.

Beginning in 1997, a satisfactory number of adults returned to the Hood River to provide eggs for the HRPP. Adults returning to the Hood River and allocated to the hatchery were a mix of hatchery and wild origin fish. During the period 1997-2001, roughly 75% of the females and 64% of the males held at Parkdale Hatchery were of hatchery origin. However, in most years an inadequate number of adults returned for the HRPP to rely solely on Hood River returning adults to meet production goals. As a result, eggs collected from adults returning to the Pelton Ladder, Deschutes River were used to backfill the HRPP production. We could not determine from

published HRPP reports what percentage of eggs were contributed each year from fish that returned to Hood River.

Table 12. Number of spring Chinook brood stock collected at Powerdale Adult Trap and held at Parkdale Fish Facility (Olsen Draft).

Run Year	Hatchery		Wild		Total
	Females	Males	Females	Males	
1997	51	30	18	11	110
1998	4	3	19	15	41
1999	7	7	-	-	14
2000	-	-	-	-	-
2001	53	13	1	3	70
Total	115	53	38	29	235

We assume it was an unstated goal of the program to rely on adults returning to Hood River for eggs. The program has not become self-sufficient, even if every Hood River returning adult were allocated to the Parkdale Hatchery. The exception was during 1997 when an adequate number of adults were held to meet production goals.

ODFW Pathology data indicated spring Chinook returning to the Hood River contained high incidences of Infectious Hematopoietic Necrosis (IHN). In 2001, 63 of the 83 adult spring Chinook sampled at the time of spawning at Powerdale Hatchery tested positive for IHN. In other words, 76% were diseased. However, in 1998 only 1 of the 13 fish sampled tested positive for IHN. IHN is believed to be both horizontally (from fish to fish) and vertically (from adult to egg) transferred and can cause catastrophic losses in the hatchery (Nash 2001, Flagg et al 2001). The Pacific Northwest Fish Health Protection Committee (PNFHPC) has established policies to minimize the prevalence of diseases such as IHN. The PNFHPC policy urges that fish with IHN not be released into the environment (Flagg et al. 2001). As a result, the eggs of IHN infected adults are generally destroyed.

The prevalence of IHN may impede the collection of the eggs and in turn provide an impediment to the success of the HRPP. If the average prevalence of IHN remains at 76% and IHN fish are excluded from the egg take, then approximately 460 returning adults will have to be held at Parkdale Hatchery to acquire sufficient number of uninfected eggs, to meet the release goal of 125,000 smolts. The successful reintroduction spring Chinook hinges on the adaptation of Deschutes spring Chinook to the Hood River system. Eggs collected from fish returning to the Hood River selects for phenotypes that have successfully adapted to the Hood River. Hence, high priority should be placed on collection of eggs from Hood River returning fish.

A reintroduction program does not have an indigenous stock to initiate the program with, and therefore must begin the reintroduction program with a stock that is not adapted to the unique environment of the Hood River. So, the first step to a reintroduction program should be to allow the donor stock to adapt to the Hood River. Successful adaptation can only occur

through natural selective forces. Further, the entire life cycle of the introduced fish should be subjected to natural selective forces, hence, returning hatchery and wild fish should be afforded the same opportunity to spawn in the wild. Only when the number of returning wild fish reach the level of a healthy population (with excess spawners) should wild eggs be taken into the hatchery.

The HRPP did not clearly document the reintroduction strategy. For example, how many spawners will be allocated to natural spawning before allocation to the hatchery is allowed? What is the appropriate proportion of eggs from returning hatchery fish to wild fish? Should the Deschutes stock be released only until the wild stock persists at identified goals or should continued releases be based on a time period rather than a performance mark? We explore these questions in the life cycle model and present the data in Chapter 10.

Spring Chinook Juvenile Production

Releases

From 1988 to 1992 Carson-spring Chinook were directly released by ODFW into the West Fork (Table 13). Carson Stock has been domesticated for 50 years and were originally derived from fish passing Bonneville Dam. Thus, the stock was a composite of unknown stocks from throughout the Columbia Basin, and was considered non-indigenous to the Hood River.

After the Hood River Master Plan (1991) was adopted by the NWPPC, BPA, ODFW and CTWSRO, the first release of Deschutes-spring Chinook began in 1993 (Table 14 and Table 15). Deschutes-spring Chinook were a supplemented population originally from the Deschutes River. On average, the release goal of 125,000 age-2 smolts was nearly met each year (except in 1994, when a chiller malfunctioned at Round Butte Hatchery killing spring Chinook destined for the Hood River). The size at release goal was originally set to produce two size classes (8 and 12 fish to the pound) for testing of performance between the size groups. Actual size at release varied from 6.3 to 14.2 fish per pound.

Table 13. Number of Carson stock spring Chinook released in the Hood River, 1988-1992.

Year	Number Released	Fish per Pound	Release Type	Release Location
1988	149,939	10.6	Direct	West Fork
1989	134,047	11.0	Direct	West Fork
1990	197,988	10.1	Direct	West Fork
1991	125,432	10.1	Direct	West Fork
1992	163,293	9.9	Direct	West Fork

Table 14. Number of Deschutes Stock spring Chinook released into the Hood River, 1993-2001.

Release Year	Number Released				Fish/lb	Release Type
	West F.	Middle F.	Mainstem	Total		
1993	75,205	-	-	75,205	9.5	Direct
1994	-	-	-	0	-	Direct
1995	170,004	-	-	170,004	13.4	Direct
1996	123,230	-	-	123,230	9.9	Acclimated
1997	100,719	-	-	100,719	8.2	Acclimated
1998	123,760	-	-	123,760	9.8	Acclimated
1999	71,648	30,164	19,356	121,348	7.1	Acclimated
2000	91,792	34,386	10,748	136,926	7.2	Acclimated
2001	82,878	38,385	3,416	124,679	10	Acclimated

Table 15. Acclimation of spring Chinook smolts at Hood River release sites began in 1996. Acclimation sites included Blackberry Creek (BC) and Jones Cr (JC) in the West Fork (WF), Parkdale Hatchery (PH) in the Middle Fork (MF), and at the Mouth of the Hood River (MHR), 1996-2000.

Year	Site Released	Group	Transfer Date	Fish/lb	Days Acclimated	Total Release
1996	BC-WF	Group 1	Apr 8-10	10.1	6 - 8	84,900
	BC-WF	Group 2	Apr 22-23	9.5	7 - 8	44,311
1997	BC-WF	Group 1	Apr 7-8	8	6 - 7	45,767
	BC-WF	Group 2	Apr 16-17	8.4	4 - 5	55,326
1998	BC-WF	Group 1	Apr 1-2	9.8	8 - 9	62,057
	BC-WF	Group 2	Apr 15-16	9.7	7 - 8	54,541
	JC-WF	Group 2	Apr 16	9.7	6	8,185
1999	BC-WF	Group 1	Mar 30-Apr 1	7.5	7 - 9	25,319
	BC-WF	Group 2	Apr 13	6.7	7	26,503
	JC-WF	Group 1	Mar 30-Apr 1	7.6	7 - 9	19,513
	JC-WF	Group 2	Apr 13	6.7	7	19,675
	PH-MF	Group 3	Mar. 29	6.4	14	30,409
	MHR	Residuals	May 5-6	8.3	0	19,536
2000	BC-WF	Group 1	Apr 4-5	7.6	6 - 6	33,282
	BC-WF	Group 2	Apr 18-19	6.4	5 - 6	31,052
	JC-WF	Group 1	Apr 4-5	8.3	6 - 6	19,865
	JC-WF	Group 2	Apr 18-19	6.3	5 - 6	18,566
	PH-MF	Group 3A	Apr 3	6.7	7	15,322
	PH-MF	Group 3B	Apr 20	5.7	5	15,164
	PH-MF	Group 4	Mar 20	14.9	PH Reared	4,160
	MHR	Residuals	May 8-5	7.3	0	10,748
2001	WF	Group 1	Apr 4	9.6	NA	20,451
	WF	Group 2	Apr 23	10.5	NA	24,554
	WF	Group 1	Apr 4	9.8	NA	20,002
	WF	Group 2	Apr 23	9.0	NA	17,871
	MF	Group 1	Apr 4	9.6	NA	31,319
	MF	Group 1	Apr 4	14.2	PH Reared	7,066
	MHR	Residuals	May 14	8.6	0	3,416

NA indicates not available at time of this report.

Spring Chinook Pathogens

Diseases limited success of the Round Butte/Pelton Ladder spring Chinook rearing program. Bacterial Kidney Disease (BKD) was a chronic problem at Round Butte Hatchery and Pelton Ladder. Large numbers of kokanee and bull trout in the water supply above the facilities, in Lake Billy Chinook, were known to be infected with the causative bacterium agent *Renibacterium salmoninarum*, and in turn were believed to be the horizontal vector for the disease.

Use of medicated feed with erythromycin has improved juvenile survival in the hatchery, but has not eliminated the problem. Since 1997, eggs from BKD negative females were selected for hatchery production to limit vertical migration of BKD. While the juvenile BKD infection rate was reduced, the infection has not been eliminated. Pathologists believe Chinook reared at Round Butte Hatchery and the Pelton Ladder will continue to have problematic levels of BKD from horizontal migration, which will continue to kill fish throughout their life cycle.

Tests for BKD use a system called ELISA. ELISA tests for the organism causing BKD. High levels of the organism probably indicate a disease process was occurring, but the level of causative agent does not necessarily mean the fish will die from BKD. At present, there is no way to evaluate the impact of the causative agent in a group of fish. The occurrence of BKD at Round Butte/Pelton Ladder was estimated by the ELISA test.

Although BKD is an endemic disease observed in a majority of populations at some background level, the prevalence in the Pelton Ladder complex appeared to be above adequate levels to meet adult return goals (Table 16). The spring Chinook smolts released in the years 1996, 1997, 2000 and 2002 expressed high levels of mortality while rearing in the Pelton Ladder, and may have experienced high mortality again when smolting and/or entering seawater.

Table 16. Number of fish infected with the causative agent of BKD as determined by ELISA tests, in cells 4 and 5 of the Pelton Ladder destined for Hood River, Round Butte Hatchery Program.

Release Year	Total Loss	Number		Percent Infected
		Infected	Tested	
1996	306	12	60	20%
1997	9,903	16	66	24%
1998	3,585	3	121	3%
1999	6,559	5	119	4%
2000	2,001	23	120	19%
2001	1,109	1	60	2%
2002	11,948	38	56	68%

Elliott et al. (1995) determined that BKD was related to seawater survival, and the greater the infective agent load, the lower the survival. Mesa et al. (1999) related the survival of BKD infected fish with the smolting process of spring Chinook by monitoring disease prevalence and osmoregulatory hormones along with other blood constituents (i.e. $\text{Na}^+\text{K}^+\text{ATPase}$, cortisol, glucose and lactate). The study suggested that the stress associated with converting from a freshwater osmoregulatory system to saltwater caused latent BKD to become active and completely express the disease. As a result, BKD may be acting as an undetected killer. Elliot suggested that a reduction in survival rate of up to 40% may be attributed to BKD. Unfortunately, the smolt-to-adult index also reflects other survival factors such as ocean conditions, dam passage and harvest. Therefore the impact of BKD on survival could not be established.

BKD may also limit survival while rearing in Pelton Ladder. A high level of BKD was believed to have caused presmolt loss in the Pelton Ladder during the 1995-96 and 1996-97 rearing periods (Ken Witty, personnel communication, SPCA). However, mortality did not appear to be directly related to prevalence of BKD in 1998 through 2000. Figure 43 compares the prevalence of BKD to Pelton Ladder Cell mortality as estimated by Lambert et al (2001). A clear pattern was not detected. Years with prevalent BKD detections also had low mortality; and the opposite was also true. BKD was believed to contribute to mortality while rearing in the Pelton Ladder, but a combination of other factors such as fish density, water temperature, feeding rates, and other diseases undoubtedly contributed to mortality. Furthermore, fungus contributed to the mortality in 1998-1999, confounding the relationship between BKD and mortality.

Figure 43. Mortality and percent BKD detection of fish released reared in Pelton Ladder Cells 4 and 5 and released into the Hood River.

Pelton Fish Ladder was modified to rear spring Chinook to smolt size due to space limitations at Round Butte Hatchery. Pelton Ladder (Figure 44) is an adult fish way extending from below Pelton Regulating Dam to the Pelton Dam (RM 100), which impounds Lake Simtustus. The ladder was 10 feet wide, 6 feet deep, and 2.8 miles long (Lambert et al. 2001). In the early 1980's, Pelton Ladder was used as a rearing site for juvenile spring Chinook produced at Round Butte Hatchery.

In 1995, as part of the HRPP, the ladder was modified to create three new rearing cells for Deschutes stock spring Chinook. The ladder cells labeled L1-L3 were the original program and cells L4-L6 were the new program. The new cells were designed to replicate the original rearing strategy used successfully in the other cells of the ladder. Both the original cells and the new cells were on separate water circuits. The water circuit was designed to minimize water use. As a result, Deschutes River water was pumped into cell L3, then by gravity the water was supplied to cell L2, then to cell L1 and finally back out into the river. Cells L6-L4 had a similar circuit, where the water flowed from cell L6 through L5, then L4 and finally back to the river. The modified Pelton Ladder provided additional rearing space sufficient to produce 187,000 spring Chinook smolts annually. Fish reared in the new cells, L-4 and L-5, have been released into the Hood River since 1996. Fish reared in the other cells were released into the Deschutes River.

Based on the data provide by Lambert et al (2001) mortality differed among cells. Fish mortality increased from upstream to downstream cells (Figure 45). Fish mortality in cells L3 and L6 were significantly lower ($p=0.0007$) than the corresponding down stream cells, based on percent mortality that was arcsine-square root transformed and compared using a one way ANOVA. The reason for the increased mortality of downstream cells may have to do with water quality or disease. Data was not readily available to explore reasons for the increased mortality.

Further, fish density in the cells did not appear to significantly contribute to mortality. Fish reared in the original program (cells L1-L3) were reared at a density of 80,000 fish per cell. Fish reared in the new program (cells L4-L5) were reared at a density of 47,500 fish per cell. Figure 46 compares the percent mortality in the original program to the new program. The percent mortality appeared to be higher in the original program when compared to the old program. However, the difference was not significant ($p=0.31$) when arcsine-square root transformed monthly percent mortality data (Dec-Apr 1997-1999), pooled by original and new program, was compared using a one way ANOVA.

Fish reared at Pelton Ladder appear to have much higher mortality than fish reared at the Round Butte Hatchery. Lambert et al (2001) compared mortality between the rearing ponds at Round Butte Hatchery and the rearing cells at Pelton Ladder. The density of fish in each pond was not provided and therefore we were unable to convert the number of mortalities to percent mortality for comparison to the ladder. But, the pond mortality was much lower, averaging 70 fish per pond as opposed to an average of roughly 500 to 6,000 fish per ladder cell (for fish reared during December to April 1997-1999). The Pelton Ladder mortality may be higher than the hatchery ponds due to rearing conditions such as water quality or fish density. Improvements to fish health in the ladder could result in higher smolt to adult survival and lower in-facility rearing mortality. The ultimate impact of fish health was not quantifiable based on the data

available, and should be viewed as a critical uncertainty, which has a high probability of limiting HRPP success.

Figure 44. Rearing strategy for Round Butte Hatchery and Pelton Ladder to accommodate production of spring Chinook salmon, release years 1999 and 2000 (from Lambert et al 2001).

Figure 45. Average mortality of spring Chinook reared in the Pelton ladder during 1997-1999.

Figure 46. Percent mortality spring Chinook reared in the original (L1-L3) and new (L4-L6) Pelton Ladder cells during December through April of fish released in 1998-2000.

Spring Chinook Juvenile Outmigration

A goal of the HRPP was to minimize the possibility of competition between hatchery and wild fish. A method commonly used in the Columbia Basin is to release smolts, which would immediately emigrate from the basin. The emigrating hatchery fish were believed to have limited competitive interactions with wild parr because of a limited period of spatial overlap. The HRPP appears to have achieved this goal. A majority of the hatchery fish migrated past the West Fork screw trap within two weeks of volitional release from the acclimation ponds (Olsen Draft). Hatchery fish appeared to have completely left the West Fork by June (Figure 47). Hatchery smolts migrated past the mainstem screw trap shortly after passing the West Fork screw trap, suggesting that the hatchery smolts moved to the lower Hood River and probably into the Columbia within a week or two after release (Figure 48). Hatchery smolts were not detected in screw traps throughout the remainder of the year, and scales from returning hatchery adults did not detect 3-year freshwater age. Thus, there appeared to be ample evidence that hatchery spring Chinook did not remain in the Hood River system an extra year before smolting.

There was a notable difference in length between hatchery and wild outmigrants caught in the mainstem screw trap (Figure 49). The average hatchery fish captured in the mainstem screw trap had a fork length of 153 mm, whereas wild fish had a mean fork length of 99 mm. Based on adult return and smolt outmigrant lengths, hatchery fish appeared to leave the Hood River about 5 cm longer. Numerous studies have established the relationship between smolt size and competitive advantage (Tipping 1997, McMichael et al 1999). Based on size, hatchery smolts have a competitive advantage over wild smolts that migrate at the same time (Figure 49). Release of smaller hatchery smolts may reduce competition with wild smolts. We found no observation to evaluate competition between hatchery and wild smolts, but we believe such an evaluation would be prudent. Appendix F reviews the precision of the outmigrant studies.

Figure 47. Average migration timing of juvenile hatchery and wild spring Chinook past the West Fork screw trap, 1994-2001 from analysis of ODFW Screw trap data (Olsen, July 2002). Catch data were corrected for days not sampled.

Figure 48. Average migration timing of juvenile hatchery and wild spring Chinook past the mainstem screw trap, 1994-2001 from analysis of ODFW Screw trap data (Olsen, July 2002). Catch data was corrected for days not sampled.

Figure 49. Length frequency histogram of juvenile wild and hatchery spring Chinook captured in the mainstem screw trap during April-May, 1995-2001 from analysis of ODFW Screw trap data (Olsen, July 2002).

Spring Chinook Adults

Returns to the Hood River

Adult fish returning the Hood River were primarily comprised of hatchery spring Chinook. Releases of Carson stock spring Chinook into the Hood River were discontinued in 1992. Thus, no returning Carson stock adults were observed after 1996. The number of hatchery fish returning to the Hood River steadily increased from 1999 through 2001 (Figure 50). However, Figure 50 is somewhat misleading because jacks and mini-jacks were included. The Deschutes hatchery stock exhibited years of extraordinarily high mini-jack (age 2) returns to the Hood River. In 1999 and 2000, 93% and 86% of the run consisted of hatchery mini-jacks (Figure 51). Although, in prior years (e.g. 1997), mini-jacks made up less than 4% of the annual hatchery run. Jack (age 3) returns of hatchery fish were also high, ranging up to 46% in 2001.

Wild fish, however, did not return in a similar proportion of mini-jacks or jacks during the same period (Figure 52). Mini-jacks and jacks accounted for nearly 10-fold greater proportion of hatchery fish than wild fish returning to Powerdale Dam (Figure 52 and Figure 53). Mini-jacks composed an average of 46% of hatchery returns, compared to only 6.3% of wild returns during 1997-2001.

Figure 50. Number of adult spring Chinook returning to Powerdale Fish Trap 1992-2001 including mini-jack and jacks. Data from Olsen (July 2002)

Figure 51. Number of Deschutes hatchery spring Chinook returning to Powerdale Dam as mini-jacks, jacks, and adults. Data from Olsen (July 2002).

Figure 52. Average percentage of Deschutes hatchery and wild spring Chinook returning to Powerdale Fish Trap that were mini-jacks (age 2), jacks (age 3) and adults (age 4 or greater), 1997 through 2001. Data from Olsen (Draft).

Figure 53. Number of age 4 or greater wild and Deschutes hatchery spring Chinook adults returning to Powerdale Dam, 1996-2001 data from Olsen (Draft).

Why were hatchery fish returning at ages 2 and 3 in higher proportions than the wild fish? Beginning in 1999, acclimation procedures were modified with regard to fish remaining in the acclimation facility after the volitional release period was completed. The remaining fish (those that did not volitionally exit) were considered by us to be “residuals” as defined by NMFS (1999). “Residual” fish are fish that do not migrate when released either because they are precocious males or fish not ready to smolt until next year. The HRPP released residual fish below the Powerdale Dam to reduce competition with wild parr and enhance the fishery. Prior to 1999, residual fish were forced out of the acclimation facility into the West Fork.

Table 17 indicates a dramatic increase of returning mini-jacks, the same year the release of residual fish at Powerdale Dam was implemented. The residual fish appeared to be larger than the average size of smolts released from the acclimation facilities. Shearer and Swanson (2000) have documented larger smolts tend to be precocious males, and consequently we believe the residuals were precocious males, not fish waiting another year before smolting. The high percentage of precocious males most likely had occurred from the beginning of the spring Chinook program, but was not detected because there were no stream reach population samples conducted from 1996 to 1999, that is, during years were the fish were forced into the West Fork.

Upon further review of Table 17 another notable point emerged. The number of mini-jacks and percent of residuals dropped dramatically in 2001. Coincidentally, the average size at release was the smallest since the program began. Shearer and Swanson (2000) showed that precocious males had higher lipid stores as compared to the hatchery population, and that feed with higher lipid levels resulted in a greater number of precocious fish. Releasing fish at 10 to the pound resulted in 2.7% residualism. Since residuals represent an unwanted result impeding HRPP success, measures should be taken to reduce precocity. Releasing smaller fish may result in reduced residualism. We were unable to compare the rate of mini-jack return at Pelton Fish Trap to Hood River releases because operators of that Pelton Trap rarely record mini jack returns.

Finally, the release of residuals below Powerdale should be avoided. The residual fish were released below the trap, in part to augment harvest. The creel surveys indicated anglers were not catching mini-jacks (Erik Olsen, personnel communication, ODFW). Since mini-jacks returned to the Powerdale Dam within four months of release, increasing the workload of fish trap operators, and since mini-jacks were viewed as undesirable fish, they were euthanized at the time of capture. This extra work would be avoided by euthanizing the residuals (those not volitionally exiting the acclimation pond) as part of the acclimation facility operation. Another alternative to the disposal of the “residuals” is to mark them (PIT tag, elasimer tag) and release them into the river below the acclimation facility, or below Powerdale. The recovery of these tagged fish upon return or as juveniles downstream would provide data on whether these are the fish returning as mini jacks or if it is the juveniles that volitionally migrate from the acclimation facility that return as mini jacks. It might provide data on whether these “residuals” leave the system.

Table 17. Number of residual spring Chinook released below Powerdale; the percent of releases residualized; size of residuals and total release groups; and the number of hatchery origin mini-jack returns to Powerdale Dam.

Year	Residuals Released		Size at Release (fish/lb)		Mini-Jack Returns
	Number	% of Total	Residuals	Total	
1996	0	?	?	9.9	0
1997	0	?	?	8.2	11
1998	0	?	?	9.8	14
1999	19,536	15.9%	8.3	7.1	182
2000	10,748	7.8%	7.3	7.2	918
2001	3,416	2.7%	8.6	10	32

Age composition as determined by scale analyses of adult fish returning to Powerdale indicated that hatchery fish returned at younger ages than wild fish (Olsen, 2001, Table 18). Both hatchery and wild fish returned predominantly after 2 years in salt water. However, hatchery fish had 47% of returns as 0-salt age and 26% as 1-salt age in contrast to only 5% and 2%, respectively for wild fish. The age-0 salt hatchery fish were mini-jacks previously discussed. The jack rate was also higher for the hatchery fish than the wild fish. This has been a commonly identified problem with hatcheries throughout the Columbia Basin. As with the mini-jack problem, jacking appears to be a result of highly nutritional feed and the associated fast growth of fish reared in the hatchery. Releasing smaller fish should reduce jacking rates as well as minijacking rates. In order for the hatcheries to produce smaller fish, the growth rate of the hatchery fish must be carefully managed by rearing juvenile fish in cooler water or reducing the level of feed. A combination of these and other techniques may be required to rear and release smaller fish annually.

Further, the HRPP may consider manipulating size at release towards smaller fish. Reducing the size of hatchery spring Chinook smolts would likely reduce residualism and jacking, but it may also reduce the survival of age-4 adults and therefore should be carefully monitored to determine success in terms of numbers released to number of age-4 or older adults returned.

Table 18. Average percent composition of hatchery and wild spring Chinook returning to Powerdale fish trap from 1997 through 2001. Data from Olson (2002).

Age	Wild			Hatchery		
	Fresh	Salt	Total	Fresh	Salt	Total
0		5%			47%	
1	23%	2%			26%	
2	77%	54%	6%	100%	48%	47%
3	<1%	35%	9%		<1%	26%
4		4%	57%			48%
5			27%			<1%
6			<1%

Hatchery fish also differed from wild fish in terms of adult run timing. On average, hatchery fish migrated past Powerdale Fish Trap earlier in the year than wild fish. The run began in late April, peaked in late May, and then sharply declined 2 weeks later. Migration ended during mid-September. The wild run did not begin until May, peaked during mid-June, showed a second weaker peak in September, and ended in mid-October (Figure 54).

Figure 54. Average run timing of adult spring Chinook past Powerdale Dam, 1994 through 2001. Data from Olsen (July 2002). Second peak of wild fish may include fall Chinook, but defined in the databases as spring Chinook.

On average, hatchery reared adults were shorter than wild adults for age 3 and age 4 fish. Figure 55 provides average fork length data of hatchery and wild females. Although not shown, males exhibited the same length pattern. At age 3 and 4, wild fish were significantly longer than hatchery fish (age 3, $n=72$, $p=0.01$, ANOVA; age 4, $n=1005$, $p<0.01$, ANOVA). Age 3 hatchery fish were about 6 cm shorter than wild fish and age 4 hatchery fish were 2 cm shorter than wild fish. By age 5 wild and hatchery origin fish were of similar length. Given that hatchery fish matured younger, had different run timing, and were on average smaller than wild fish, we inferred they probably had differing distributions in the ocean, or the wild fish had a competitive advantage.

Figure 55. Average fork length of Hood River wild and hatchery spring Chinook at ages three to five, 1994 through 2001. Data provided by Olsen (Draft).

Spring Chinook Hatchery Straying

Straying rates were estimated from recoveries of CWTs. All hatchery spring Chinook released into the Hood River since 1995 were marked with a coded wire tag (CWT). Recoveries of individual fish (either as catch or as spawners) from groups of CWT marked fish provide the data needed to examine the straying tendencies of hatchery fish. The number of CWT's recovered in each fishery or spawning area have been expanded by the recovering agency to account for the sampling fraction, and all recoveries (plus their expansions) are compiled in the Regional Mark Information System (RMIS; www.rmis.org/index.html) maintained by the Pacific States Marine Fisheries Commission (PSMFC). The PSMFC database was the primary source for CWT release/recovery data. All CWT marked fish intercepted in a river other than the Hood River, or in the Columbia River above the Dalles Dam, were considered strays. The detailed methods of this analysis are reported Appendix E.

The primary age-class of returning adults was age 4, consequently the vast majority of recovered CWT's came from age 4 fish.

Table 19 shows the estimated stray rates from all brood years in which CWT data was available. This limited data suggests straying of Hood River hatchery spring Chinook was occurring at a high rate, although the power of this analysis is limited due to the small number of recoveries. The NOAA Fisheries has established 5% as the upper limit for an acceptable stray rate of non-ESU hatchery fish that stray into a natural spawning population. The management guidelines increase to 30% if the hatchery fish are from within the ESU and derived from the local population. In some cases, depending on the program and broodstock used, the proportion

of hatchery fish in the natural spawning population can exceed 30%. And therefore, observed straying rates did not violate NOAA goals because a majority of the straying was within the ESU, but it certainly did not contribute to Hood River harvest and escapement goals. Straying reduces the number of adults available for Hood River harvest, hatchery broodstock and escapement. Thus, high stray rates limit HRPP success.

Table 19. Stray rates for age-4 hatchery Hood River spring Chinook estimated from expanded number of CWT recovered. Stray rate = Stray/(Hood River +Stray). Recovery of CWT's from brood year 1994 was corrected for stock mixing at Pelton Ladder prior to analysis. There were no releases of spring Chinook into the Hood River Basin in 1992.

Brood Year	Hood R	Stray	Total CWT's	% Stray
1993	29.45	7.03	36.48	19%
1994	12	7.07	19.07	37%
1995	79	26.6	105.6	25%
1996	14	1.01	15.01	6%
1997	552	3	555	5%
Average				18%

Spring Chinook releases in the West Fork were acclimated prior to release beginning in 1996 (1994 brood year). However, acclimation did not appear to reduce stray rates, as high levels of straying were expressed by both the 1994 and 1995 broods, even after acclimation. Brood year 1996 and 1997 exhibited low straying. However, the number of CWT's recovered were very low, thus limiting the power of this analysis. With that caveat, Figure 56 compares the stray rate of Deschutes stock spring Chinook released in the Deschutes River, and Carson and Deschutes stock spring Chinook released in the Hood River. Return data for recent releases of Deschutes spring Chinook into the Deschutes River were not available, and thus we had to infer that the low straying rate were maintained throughout the 1990's. On average, 20% of the Carson stock strayed from the Hood River (1986-1991). Furthermore, on average 18% of the Deschutes stock strayed from the Hood River (1993-1997). Conversely, when Deschutes stock spring Chinook were released into the Deschutes River, straying generally occurred at 2% or less.

One factor that may have influenced straying rate was timing of the rearing/acclimation events. Deschutes spring Chinook were reared in Deschutes River water until early April. After rearing the fish were transported to various acclimation sites on the Hood River. Acclimation occurred for 4-9 days before the fish were allowed to voluntarily migrate out of the acclimation ponds. Fish not exiting the acclimation ponds from the first release group could theoretically remain in the pond for up to a month, while fish from the second release group could theoretically remain in the pond for up to two weeks. Beckman et al (1999) conducted a smolt

timing study on Round Butte Hatchery reared spring Chinook from brood years 1988-1990. They detected that hormones associated with smolting plasma concentrations began to increase in February and peaked in March and April. It is likely that during this period of physiological transition, fish were establishing an olfactory imprint of the water they lived in. Hasler and Scholz (1983) clearly established the relationship between the smoltification process and the formation of an olfactory imprint memory of the fish's natal stream. As a result of operational timing, Deschutes River fish may have been moved to the Hood River and acclimated after they had already imprinted of the Deschutes River. In evidence of this notion, Figure 57 depicts the location at which strays were collected. Over 85% of the detected strays were in the Deschutes River, the river they were reared.

It appears that straying was limiting the success of the HRPP and should be addressed by the program. Straying could possibly be reduced if presmolts are acclimated earlier in the Hood River, prior to forming an olfactory memory of the water they were reared in. Based on plasma levels, smolting of spring Chinook in the Deschutes River begins in February. As a result, acclimation to the Hood River should begin in February.

Figure 56. Percent Straying as determined by CWT recovery from RIMS database.

Figure 57. Distribution of stray Hood River hatchery spring Chinook. Values represent the average relative distribution of strays from brood years 1994- 1997.

Spring Chinook Harvest

The HRPP does not state ocean or commercial harvest goals, nor does it provide Columbia River mainstem treaty fishery goals. The number of CWT's returned from the ocean fishery were insufficient to reliably estimate ocean harvest, and therefore we used Round Butte Hatchery fish released into the Deschutes to estimate ocean harvest rates. Ocean harvest was approximately 1.7% for age 4 fish (see Appendix E for further details). Data to estimate Columbia River harvest was also limited. We used the data presented in Appendix E to estimate Columbia River Harvest. Based on an annual average exploitation rate of 6%, the Hood River contributed from 0 to 65 fish to the Columbia River fishery during 1996-2001.

The harvest goal in the Hood River was 1,080 adults taken from a total run size of 1,700. From 1996 to 2000, marginal harvest has occurred, ranging from 0 to 54 fish (Table 20). Run size was also well below target level, ranging from 2 to 560 age 4 adults. Tribal harvest of spring Chinook above Powerdale from 1999-2001 did not exceed 100 fish per year (A. Vaivoda, CTWSRO, personal communication). The combined sport and tribal harvest did not exceed 150 age-4 adults.

Table 20. Spring Chinook sport harvest from the mouth of the Hood River to Powerdale Dam (PD) based on creel surveys conducted by Olsen (Draft).

Run Year	PD Returns		No. Harvested		Harvest Rate	
	Jack	Adult	Jack	Adult	Jack	Adult
1996	15	2	0	5	0.0000	0.7143
1997	1	280	0	15	0.0000	0.0508
1998	2	15	0	3	0.0000	0.1667
1999	5	88	0	0	0.0000	0.0000
2000	128	20	20	0	0.1351	0.0000
2001	496	560	31	23	0.0588	0.0395

Spring Chinook Survival

The 1991-2001 mean Smolt-to-Adult Return (SAR) was 0.15% for Deschutes Spring Chinook released into the Hood River. In contrast, the SAR of Deschutes stock released from Round Butte Hatchery/Pelton Ladder into the Deschutes River was significantly higher, at 0.35% (paired t-test, $df=5$, $p=0.009$). Deschutes fish released into the Hood River annually produced lower SARs than the same fish released into the Deschutes River (Figure 58). On average the Hood River SAR was half of the Deschutes SAR. The Deschutes releases should have a lower SAR than the Hood River releases, because the Deschutes fish must pass an additional dam (the Dalles Dam) on their way back to the Deschutes River. The releases were generally similar, with the only striking difference being the acclimation procedure and release site. Deschutes releases were released directly out of the Pelton Ladder into the Deschutes River, while Hood releases were transferred by truck to Hood River acclimation sites in April, acclimated for 4-9 days, and then allowed to volitionally emigrate. For this reason, we believe that a primary cause for the difference between SAR's maybe the high stray rates exhibited fish released in Hood River between fish released in the Hood and Deschutes rivers.

The HRPP did not identify a SAR goal for spring Chinook in the Hood River. The unstated goal was the number of fish released divided by the adult run goal. Thus, the unstated SAR goal was 1.36%. Based on brood years 1991-1997, the Hood River SAR of 0.15% was substantially lower than the goal. If Hood River fish continue to exhibit a SAR of 0.15%, then approximately 1.14 million fish would have to be released annually to meet the adult return goal of 1,700 adults. If the Hood releases approached the Deschutes SAR (0.38%) then approximately 450,000 smolts would have to be released to meet the goal of 1,700 returning adults. The SAR goal may be to optimistic. The 1997 brood year expressed the highest SARs of 0.81% in the Deschutes and 0.53% in the Hood River during the review period. Conditions may improve allowing for higher SAR rates, but if current conditions persist the HRPP will not meet adult return goals. Chapter 9 explores potential future outcomes with a life cycle model, and survival was one of the indices addressed.

Figure 58. Percent Smolt-to-Adult return of Deschutes stock spring Chinook released into the Hood River in comparison to fish released into the Deschutes River. The SAR included all jack and adult returns. Data provide by PGE and Olsen (Draft).

Pelton Ladder Evaluation

The Pelton Ladder Evaluation data provided an opportunity to compare smolt-to-adult survival between releases in the Deschutes and Hood rivers. Beginning in 1996 (brood year 1994), all fish released from the Pelton Ladder were CWT tagged, allowing for an accounting of each release group. Unfortunately, the original objective was not intended to compare Deschutes and Hood River release groups. Instead, the objective of the Pelton Ladder study according to Lambert et al (2001) was:

“The objective of experimental releases of spring Chinook salmon from Pelton Ladder and Round Butte Hatchery was to determine if modifying Pelton Ladder to rear more fish will reduce effectiveness of the existing production program. Further, the study will evaluate how size at time of release effects post-release survival and provide basic information about rearing conditions in the ladder”

The study design was based on a matched release strategy that compared recovery rates between release groups. Two matches were made: 1) release of fish from the old and new rearing cells into the Deschutes River and 2) release of small (12 fish/Lb) to medium (8 fish/Lb) sized smolts. Fortunately, there was a third unintended quasi-matched release made: releases into the Hood and Deschutes Rivers. We call it a quasi match because release basin was not

always the only variable altered. In some years, size at release was dissimilar, thus complicating the analysis.

At the time of this review, the data collected for the matched release study had not been analyzed. Because of its importance to describing Hood River performance, we conducted the analyses. Consult Figure 55 (appearing earlier in this chapter) to review Pelton Ladder schematic. Chapter 3, along with the subsection on Juvenile Production within this chapter, describes operational aspects of the ladder. Further, a detailed accounting of the study was provided in Lambert et al. (2001). In short, cells L1-L3 were the original cells and cells L4-L6 were the new cells constructed to accommodate the Hood River Program. Cell L6 (new program) was released into the Deschutes for comparison with cells L1-L3 (original program). The small (12 fish /Lb) release group was reared in Cell 6 in 1996 and Cell L3 in 1997 and 1998. All other cells reared medium (8 fish/Lb) sized fish. Fish reared in Cell L4 and L5 were released into the Hood River. All other fish were released into the Deschutes River.

Recoveries of CWT marked fish were reported to the Pacific States Marine Fisheries Commission (PSMFC), where they were incorporated into the Regional Mark Information System (RMIS) database. This database was a primary source for CWT recovery data used in this analysis. However, not all CWT data was available via the RMIS database. Two major sources of additional (unreported) CWT data were identified and incorporated into the analysis. One source was from the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). The Tribe provided CWT data to SP Cramer and Associates from spawning ground surveys conducted in the Hood River Basin since 1997. The other source of CWT data came from hatchery spring Chinook returning to Powerdale Dam on the Hood River (RM 4.5). Spring Chinook released into the Hood River were not solely for harvest purposes, but were also passed above Powerdale Dam to spawn naturally. When this occurred, the CWT's were generally not recovered from those fish (except when spawning surveys located carcasses). Therefore, each hatchery spring Chinook returning to Powerdale Dam was considered a unique CWT recovery. CWT's recovered from spawning ground surveys were subtracted from the numbers returning to Powerdale, to prevent double counting a fish.

Recovery rate of a tag group (used in these analyses as a surrogate for survival) was estimated as the total number of recoveries divided by the total number of smolts released in that tag group. Return rate (to home basin) was estimated using CWT recoveries in the home basin divided by the total number of smolts released in that tag group. Only recoveries of age 4+ fish were considered in these analyses because returns of jacks at ages 2+ and 3+ were not desired outcomes of the program. Recovery data from four brood years (1994-1997) were used in the analyses, thus providing a complete recovery data set for spring Chinook through age 4. A chi-squared analysis was used in each case to compare the proportion of CWT's recovered between sample groups.

To determine whether or not survival differed between Deschutes and Hood River fish, a number of factors had to be accounted for, leading to the formation of the following questions:

1. Did CWT recovery rate differ among rearing cells in Pelton Ladder ?
2. Did CWT recovery rate differ between fish released from the original cells and fish released from the new cells?

3. Did CWT recovery rate differ between fish released from the hatchery and fish released from Pelton Ladder?
4. Did CWT recovery rate differ between smolt release size classes?
5. Did return rate (to the Columbia River) differ between release basins?
6. Did return rate (to the release basin) differ between release basins?

Did CWT recovery rate differ among rearing cells in Pelton Ladder?

The CWT recovery rates from cells L1-L3 in the Pelton Ladder, were examined, regardless of smolt release size. The analysis was limited to the original program to eliminate the effect of release basin on the recovery rate. Recovery data from the four brood years (1994-1997) was pooled to strengthen the statistical analyses. There was no significant difference in CWT recovery rate between Pelton Ladder cells 1, 2, and 3 ($\chi^2 = 1.97$, $p = 0.3742$), with recovery rates of 0.0015 for L1 and L2 and 0.0017 for L3. Although not statistically significant, a slight advantage was detected for fish from cell L3, which coincidentally had lower mortality while rearing in the ladder (see juvenile production in this chapter for a detailed description of mortality within the cells). However, our assertion that cells receiving river water first, such as L6, had lower survival was not supported when cell L6 was compared to cells L1-L3 (pooled). L6 was significantly different from L1-L3 ($\chi^2 = 110.12$, $p < 0.001$). In this comparison, L6 (the first cell to receive river water) had a lower CWT recovery rate (0.0007) than cells L1-L3 (0.0015), which included cells receiving water from upstream cells. L6 not only represents an upstream cell, but also a new rearing cell that was released into the Deschutes River.

Did CWT recovery rate differ between fish released from the original cells and fish released from the new cells?

Cell L3 (the uppermost of the original cells) was compared to cell L6 (the uppermost of the newer cells) with all years pooled (brood years 1994-1997) to strengthen the analysis. There was a significant difference in CWT recovery rate between cell 3 and cell 6 ($\chi^2 = 103.08$, $p < 0.001$). Spring Chinook reared in cell 3 had a higher recovery rate (0.0017) than fish reared in cell 6 (0.0007). Based on this analysis, the recovery rate of fish reared in the original cells differed from those reared in the new cells. However, this analysis was somewhat weak and should not be viewed as conclusive evidence that the original and new cells produce fish with different survival rates. One factor which may have confounded the result was size at release, which differed among years and cells creating quasi matched releases. Additional studies should be conducted with controlled matched releases to limit bias.

Did CWT recovery rate differ between fish released from the hatchery and fish released from Pelton Ladder?

In a final analysis examining differences in CWT recovery rates between rearing locations, spring Chinook reared in ponds H-1 and H-2 (at Round Butte Hatchery) were compared to spring Chinook reared in cells L1-L6 (at Pelton Ladder). Recovery rates were significantly different for the two groups ($\chi^2 = 396.87$, $p < 0.001$), with Chinook reared in the

ponds having a recovery rate of 0.0029 and the Chinook reared in cells having a recovery rate of 0.0011. The hatchery environment appeared to result in greater recovery rates than did the Pelton ladder environment. The differences between hatchery and cell rearing environments should be explored further in an attempt to identify possible explanations for the lower return of Pelton Ladder fish. It is possible that disease may have contributed to these differences (see juvenile production above).

Did CWT recovery rate differ between smolt release size classes?

Size classes of smolts reared at Pelton Ladder were defined as: small (12 fish/lb.), and medium (8 fish/lb.). However, hatchery operators were unable to exactly meet size specifications and therefore, for the purposes of this analysis, size was reclassified as: small (≥ 10 fish/lb) and medium (6-9 fish/lb). Recovery data from the four brood years (1994- 1997) was pooled to strengthen the statistical analysis. There was a significant difference in recovery rate between small and medium sized smolts ($\chi^2 = 22.63$, $p < 0.001$). Small smolts exhibited a recovery rate of 0.0018 while medium smolts exhibited a recovery rate of 0.0015. Although statistically significant, the relative difference was generally small, 0.0003. Figure 59 shows each within-year estimate of recovery rate as well as the across-year recovery rate for both small and medium sized smolts. Size at release is a germane topic of today's scientific community, receiving in-depth study by researchers (Shearer and Swanson 2000, and Berejikian 2000). It would be prudent for the HRPP M&E program to continue studies on the effects of smolt release size on survival.

Figure 59. CWT recovery rates of spring Chinook reared at Pelton ladder by smolt release size class.

Did return rate (to the Columbia River) differ between release basins?

CWT recovery rates (used here as a surrogate for return rates) from all cells in Pelton Ladder (cells L-1 – L-6), regardless of cell location, smolt release size and recovery site, were examined. All comparisons prior to this analysis only recognized recoveries of fish returning to the same basin in which it was released. For this analysis, all recoveries were recognized, regardless of where the fish was recovered. Data was pooled across brood years 1994- 1997. Cells 1, 2, 3, and 6 were released annually into the Deschutes Basin, while cells 4 and 5 were released into the Hood Basin. There was no significant difference in return rate between smolts released into the two respective basins ($\chi^2 = 0.39$, $p = 0.5327$). Return rate of releases into the Deschutes Basin was 0.0016, while the return rate of releases into the Hood basin was 0.0015. Some caution, however, should be applied to the interpretation of this finding. This is due to the fact that when examining these basin-specific return rates within years (as opposed to pooling across all years), Deschutes releases returned at significantly higher rates in 3 of the four years (all but 1997). In 1997 returns of Hood releases were significantly greater than returns of Deschutes releases, and it appears that this one year balanced out return rates between Hood and Deschutes releases when examined across all years. Figure 60 provides annual return rates of both Deschutes and Hood River releases.

Figure 60. Recovery rate of spring Chinook in the Columbia Basin released into the Hood and Deschutes Rivers based on CWT recovery rates.

Did return rate (to the release basin) differ between release basins?

Regardless of cell location or release size, return rates were estimated using (exclusively) CWT recoveries in the release basin (i.e. intended return basin) divided by the total number of smolts released in the tag group. It is important to note that in brood year 1994 there was a

mixing of two tag codes at Pelton Ladder. The result of the mixing was that approximately 9% of tag code 071130 was inadvertently released into the Hood River (91% correctly released into the Deschutes River). Similarly, approximately 6% of tag code 070938 was inadvertently released into the Deschutes River (94% correctly released into the Hood River). Therefore, when dividing CWT recoveries by the total number of smolts released in that tag group to estimate recovery rate, a deduction was made to the total release number of each of the tag codes to reflect the true number of smolts released into each respective basin.

We examined return rates from all cells in Pelton Ladder (L-1 – L-6) as well as the ponds (H-1 and H-2) in Round Butte Hatchery. Data was pooled across brood years 1994- 1997 to strengthen the analysis. The results showed a significant difference in return rate between Deschutes river releases and Hood River releases ($\chi^2 = 5.58$, $p = 0.0182$). The return rate for Deschutes releases was 0.0016 while the return rate for Hood releases was 0.0014. Although the difference between return rates was only 0.0002 (Figure 61), the same scenario exists in this analysis as was in the previous analysis. That is, when examining these basin-specific return rates within years (as opposed to pooling across all years), Deschutes releases returned at significantly higher rates in 3 of the four years (all but 1997). In 1997 returns of Hood releases were significantly greater than returns of Deschutes releases, and it appears that this one year again balanced out return rates between Hood and Deschutes releases when examined across all years. Straying appears to be the reason for the reduced return rate at age 4 of fish released in the Hood River in this analysis.

Figure 61. CWT return rates of spring Chinook reared at the Round Butte- Pelton Ladder complex by smolt release basin.

Spring Chinook Study Refinement

The matched release studies were originally designed to, 1) determine if the Deschutes program was affected by the inclusion of the new rearing cells for the Hood River, and 2) determine if small or medium size smolts performed better. Due to study design and implementation problems, such as fish intended for the Hood River escaping into the Deschutes and mixing study variables among release groups (i.e. size and program), our ability to detect differences between matched release groups was compromised. Further, stronger statistical methods to clarify differences could not be used, because of low recapture numbers, unbalanced release numbers, and lack of tag retention estimates.

If future CWT or matched release studies are conducted, we recommend that a 5-year CWT study plan be developed to address critical uncertainties. The plan should be reviewed annually and adjusted as needed to improve implementation. The plan should include the hypothesis being tested, the numbers marked, expected tagging and fin clip proficiency, anticipated returns, a power analysis to determine if the number of anticipated returns will result in a statistically powerful test, specified recovery protocols, expansion protocols and, most importantly, performance criteria and actions to be taken if criteria are not met.

SUMMER STEELHEAD

The steelhead program recently (1999) moved from releasing a non-indigenous-Skamania stock to releasing the progeny of wild summer steelhead collected in the Hood River. The indigenous program was not in operation for a sufficient period to allow for an in depth review that tested program success. Instead, this section documents progress up through 2001 to facilitate future reviews.

Summer Steelhead Broodstock Collection

The indigenous summer steelhead program began with the collection of broodstock at Powerdale Dam. Fish were then held and spawned at the Parkdale fish facility (Table 21). The program goal was to collect 160 adults to produce 150,000 smolts. The EIS agreed to an interim goal of releasing 40,000 smolts, and as result, the interim adult collection goal was 40 wild adults (20 female / 20 male). Only after four years of relying entirely on wild brood returning to the Hood River, could hatchery fish be used for brood. Further, no more than 25% of the wild run was to be exploited for use in the hatchery, based on ODFW wild fish policies. The 25% rule allowed for the collection of females up to the goal of 20, but forced the limitation of adult male collection. This situation caused the fish manager to chose between the 1:1 spawning rule and the 25% wild exploitation rule. The protection of the wild fish resulted in 1:2 spawning ratio that may have limited genetic diversity. The genetic studies conducted by Blouin (2003) will, in future years, determine if the fitness of hatchery summer steelhead has been compromised compared to wild fish. Initial results suggest the fitness of hatchery fish was similar to wild fish (Appendix G).

Table 21. Number of indigenous summer steelhead brood collected from Powerdale Dam Trap and held at Parkdale Fish Facility.

Run Year	Summer Steelhead					
	Hatchery		Wild		Total	
	Females	Males	Females	Males	Females	Males
1997	1	2	10	3	11	5
1998	-	3	21	10	21	13
1999	-	-	22	12	22	12
2000	-	-	16	11	16	11
2001	0	5	34	27	34	32
Total	45	24	82	39	127	63

Summer Steelhead Juvenile Production

During the first two weeks of April, summer and winter steelhead were graded into two size groups at Oak Springs Hatchery. The larger sized group was trucked to acclimation facilities and held there for a 4 to 6 day acclimation period. Once acclimated, the fish were allowed to volitionally swim out of the pond and into the river. During the last two weeks of April all remaining summer and winter steelhead at Oak Springs Hatchery were trucked to the acclimation facilities. After acclimation and volitional release, fish remaining in the acclimation ponds were trucked below Powerdale Dam and released. These fish were believed to be residuals that would not have smolted and migrated out of the Hood River during the year of release. Table 22 provides numbers of summer steelhead liberated in each Fork of the Hood River. Fish released in the West Fork were acclimated in the Blackberry Acclimation Ponds.

The release goal of 40,000 smolts was met in 2000 and 2001. However, residualism was high ranging from 14 -23% of release. The 1999 Artificial Propagation Biological Opinion argues hatchery fish residualism should be equal to or less than wild residualism (NMFS 1999). The BO indicated typical wild population residualism is between 5 -10%. Thus, an implied goal is to not exceed 5-10% residualism. NMFS defines a residual as a released fish, which fails to migrate. The NMFS definition of residual was applied to all fish which did not volitionally migrate out of the acclimation facility. We were unable to determine if the residual fish were precocious males or fish not ready to smolt the year of release (but would have next year given the opportunity). Based solely on the size of the residuals compared to the mean size at release, a large component of the residuals may have been fish requiring another year of growth prior to migrating. However, undoubtedly precocious males were also a component of the residuals.

Table 22. Indigenous Summer Steelhead releases into the Hood River, 1999-2001

Release Year	Release Group	Fish per Lb	Number Released	Release Area
1999	Acclimated - Group 1	5.5	15,616	West Fork Mouth
	Residuals	6.6	3,897	
	1999 Total		19,513	
2000	Acclimated - Group 1	6.2	15,620	West Fork
	Acclimated - Group 2	5.2	13,541	West Fork
	Residuals	6.2	4,738	Mouth
	2000 Total		33,899	
2001	Acclimated - Group 1	7.2	11,517	West Fork
	Acclimated - Group 2	6.8	11,575	West Fork
	Acclimated - Group 3	6.4	5,745	West Fork
	Residuals	8.1	8,828	Mouth
	2001 Total		37,665	

Stocking of non-indigenous Skamania summer steelhead was an ODFW funded program. These fish were produced exclusively for harvest. Prior to when BPA programs were operational, Skamania stock were released into the West Fork of the Hood River (Table 23). Once indigenous summer steelhead programs began releasing smolts, the Skamania releases were moved to below Powerdale Dam. This action maximized angler harvest opportunity while minimizing the chance of genetic introgression between the Skamania stock and the indigenous stock.

Table 23. Skamania Summer Steelhead released into the Hood River, 1992-2001

Year	Release Method	Fish per Pound	Number Released	Release Location
1992	Direct Release	5.2	60,900	West Fork
1993	Direct Release	6.3	70,928	West Fork
1994	Direct Release	4.9	90,042	West Fork
1995	Direct Release	5.1	76,330	West Fork
1996	Direct Release	5.5	68,378	West Fork
1997	Direct Release	5.2	60,993	West Fork
1998	Direct Release	5.5	64,910	RM 4.5
1999	Direct Release	6.1	62,218	RM 4.5
2000	Direct Release	6.1	49,278	RM 4.5
2001	Direct Release	6.3	60,338	RM 4.5

Summer Steelhead Pathology

No chronic or catastrophic diseases have impaired summer steelhead rearing at Oak Springs. Parkdale Fish facility did have difficulty with a “Cold Water Disease Like” bacteria infecting adult steelhead during holding. However, the use of antibiotic vaccinations appeared to have cured the disease (Jim Gidley, CTWSRO, Personal Communication). Regular use of antibiotics is expected to remedy this problem in the future.

Summer steelhead Juvenile Outmigration

Both indigenous hatchery and wild summer steelhead migrated out of the West Fork primarily during the spring months (FL >150 mm; Figure 62). The emigrants continued downstream in the mainstem below the Powerdale Dam and were believed to continue to the ocean during spring (Figure 63). Spring migration timing was similar between hatchery and wild fish. Based on hatchery emigration data, the HRPP appeared to meet the unstated goal of limiting competition between wild parr and hatchery smolts.

The hatchery fish were younger and larger than the wild fish. The wild outmigrant steelhead with a fork length greater than 150 mm were predominately 2 years olds (76%), followed by 3 year olds (16%) and 1 year olds (8%) (Olsen Draft). The mean fork length of hatchery (202 mm) and wild fish (145 mm) captured and measured at the mainstem screw trap were significantly different ($p=0.0001$; $n=1,396$; $f=1,238$; ANOVA) during the period from 1999 through 2001 (Figure 64). Larger hatchery smolts may result in negative impacts to wild smolts through competitive interactions. Such potential impacts were not assessed. Appendix F reviews the precision of the outmigrant studies.

Figure 62. Average percent of indigenous hatchery and wild summer steelhead and outmigration during 1998 through 2001 at the West Fork screw trap (Olsen July 2002)

Figure 63. Average percent of indigenous hatchery and wild summer steelhead and outmigration during 1998 through 2001 at the mainstem Hood River screw trap (Olsen July 2002)

Figure 64. Length frequency distribution of all hatchery (n= 1,264) and wild (n=2,546) juvenile migrants captured and measured at the mainstem screw trap (1999-2001).

Summer Steelhead Adult Returns

The indigenous summer steelhead hatchery program began releasing fish in 1999. Consequently, it was too early to determine if hatchery adults returning to the Hood River were representative of wild Hood River summer steelhead or not (Figure 65). At the time of this report, 7 adults had returned during run year 2000, and 395 adults in 2001.

However, the Skamania summer steelhead program has been in operation for many years, allowing a comparison of the run timing between these fish and the wild fish (Figure 66). As one might suspect, the non-indigenous Skamania stock exhibited different run timing than the wild stock. A larger fraction of the Skamania stock entered the Hood River in May and June and a smaller fraction entered in October and November from the wild fish. However, the size of returning wild and Skamania adults appeared to be similar (Figure 67). Additional years of adult return data will help determine if the indigenous program was able to replicate run timing more precisely than the Skamania stock, and maintain similar length frequency profiles to those of wild fish.

Figure 65. Number of adult hatchery and wild adult summer steelhead captured at Powerdale Dam for run years 1994-2001.

Figure 66. Average return timing of wild summer steelhead to Powerdale Dam (RM 4.5) compared to that for Skamania hatchery stock, 1994-2001 (Olsen July 2002).

Figure 67. Length frequency distribution comparing wild summer steelhead and Skamania Hatchery adults measured Powerdale Adult Trap.

Summer Steelhead Harvest

The HRPP does not identify ocean or Columbia River harvest goals, however, the Hood River basin was identified at 5,440 adults annually including both indigenous and Skamania stocks. An ocean harvest estimate was not available due to the insignificant levels of harvest. Hood River summer steelhead were not marked with CWT's, leaving no means to identify the Hood River fish from others harvested in the Columbia River. To overcome this obstacle, we estimated harvest rates from a surrogate stock. The average Columbia River harvest rate of hatchery summer steelhead was 14% from 1995 to 2000, based on the ODFW/WDFW Status Report: Columbia River Fish Runs and Fisheries, 1938 - 2000. We assumed the harvest rate on the Hood River fish was similar and applied the average harvest rate to the sum of Hood River harvest and Powerdale adult returns (Table 24). The resulting estimate of harvest in the Columbia River ranged from 109 to 390 fish with an average of 227 fish. Hood River harvest was determined by creel survey and ranged from 226 to 737 fish with an average of 474 fish (Olsen Draft). In-basin harvest accounted for roughly half of the total harvest in freshwater. Harvest of Hood River hatchery summer steelhead varied from 25% to 40% and averaged 34% during 1996-2001. Harvest regulations in the Hood River did not allow for retention of wild steelhead resulting in less than 1% harvest of returning wild summer steelhead in all years reported (1996-2001). However, harvest of naturally produced summer steelhead still occurs in the treaty fisheries in Bonneville Pool.

Harvest rate was higher in the Hood River due, in part, to recycling. Recycling was the process of transferring hatchery adults captured at Powerdale Dam back to the mouth of the Hood River and releasing them. The released fish were expected to migrate back upstream towards Powerdale Dam. These fish were exposed to anglers a second time, thereby increasing the number of fish harvested. The recycling program was successful in increasing the number of fish harvested by an average of 26%, with a range of 9% to 48% for the years 1996-2001 (Figure 68).

On the other hand, recycling also created unwanted side effects. For instance, individual fish were recycled up to 15 times, increasing the difficulty of processing fish in the adult trap (Table 25). Each fish recycled had a 40% chance of returning to the Powerdale Dam. Conversely, 60% of the fish recycled were either: harvested, died of natural causes, or strayed. On average, 22% of the recycles were harvested and 4% were removed from the recycle program (i.e. transferred to landlocked bodies of water or euthanized), leaving roughly 74% unaccounted for (Figure 69). The number of unaccounted fish ranged from 41 to 1,918 with an average of 605 summer steelhead annually from 1995-2001.

The fate of the unaccounted recycled fish represents a critical uncertainty requiring attention. Summer Steelhead were not coded wire tagged, and therefore the stray rate of these fish remains unknown. The unaccounted recycles may be contributing to straying. If we assume as a worst case that all the unaccounted fish did stray, then on average 56% of the adults returning strayed, ranging from 3% to 90% during 1996-2001. Based on the unaccounted fish, all but one year may have violated the NOAA Fisheries goal of 5% straying, if fish strayed to non-ESU rivers such as the Klickitat and Deschutes Rivers. Studies should be conducted to determine stray rate of recycled summer steelhead. Although the recycles were Skamania stock, we anticipate recycling of the indigenous stock will produce the same result.

Table 24. Hatchery summer steelhead (indigenous and Skamania stocks combined), annual Columbia and Hood River harvest with recycles, adult returns to Powerdale Dam and harvest rates, 1996-2000. Based on the ODFW/WDFW Status Report: Columbia River Fish Runs and Fisheries, 1938 – 2000 and Olsen (July 2002)

Year	Harvest		Adult Return Powerdale	Hood River Harvest Rate
	Columbia R.	Hood R.		
1996	321	727	1,296	0.3594
1997	142	335	564	0.3726
1998	139	352	524	0.4018
1999	109	226	460	0.3294
2000 ^a	259	486	1,158	0.2969
2001 ^{a,b}	390	719	2,131	0.2522
Average	227	474	953	0.3353

a = adult returns to Powerdale included indigenous hatchery fish that were not available for legal harvest due to a fin mark.

b= incomplete run year

Figure 68. Hatchery summer steelhead harvest in the Hood River with number harvested from recycles and from non-recycles (Olsen July 2002). The 2001 run year was incomplete at the time this report was written.

Table 25. Summer Steelhead Recycle Program indices for run years 1996-2001. The 2001 run year was incomplete at the time this report was written. Analysis was based on information presented in Olsen (Draft) and databases provided by Olsen (July 2002).

	1996	1997	1998	1999	2000	2001	Ave	StDev
Adult Return to Powerdale	1,296	564	524	460	1,158	2,131	1,021	647
Total Adults Harvested	727	335	352	226	486	719	474	210
No. in Recycled Program	52	144	549	473	1,173	2,106	750	773
Max. Recycle Circuits	1	3	9	11	15	15	9	6
No. of Uniquely Tagged Recycles Returned to PD	22	56	737	655	2,429	3,033	1,155	1,270
No. of Angler Opportunities^a	55	202	1,284	1,138	3,570	5,264	1,919	2,066
No. Recycles Harvested	11	69	107	106	166	182	107	63
% Recycles Harvested	21%	48%	19%	22%	14%	9%	22%	14%
% Recycles of Tot. Harvest	2%	21%	30%	47%	34%	25%	26%	15%
No. Recycles Unaccounted	41	75	428	360	808	1,918	605	701
% Recycles Unaccounted	79%	52%	78%	76%	69%	91%	74%	13%

a = total number of fish migrations to Powerdale Dam (a combination of recycles and single pass migrants).

Figure 69. Number of summer steelhead recycled with number harvested and number unaccounted (Olsen Draft). The 2001 run year was incomplete at the time this report was written.

Summer Steelhead Survival

An entire brood year of the indigenous stock raised in the hatchery had not yet returned at the time of this report, so indigenous stock survival could not be assessed.

WINTER STEELHEAD

The winter steelhead program was supplemented with non-indigenous stocks until 1993, when the first group of indigenous stock was released.

Winter Steelhead Brood Stock

The indigenous program began in 1992 by trapping winter steelhead at Powerdale Dam . The adults were then held and spawned in Neal Creek. Once the Parkdale Facility was operational, winter steelhead were held and spawned at the new facility. The goal was to collect 70 adults (1:1 sex ratio) for the production of 50,000 smolts. No more than 25% of the wild run was to be exploited for broodstock, based on ODFW wild fish policies. All broodstock for the first three years were to be from wild origin fish, after which hatchery origin fish could be used for broodstock. During the first three years, 98% of the broodstock were from wild origin fish. Since 1995, wild origin fish have composed from 51% to 99% of the broodstock (Table 26). The 25% wild exploitation rule was met with 24% or less wild fish taken for broodstock. The number of broodstock collected met the stated goal (of 70 adults) in all years except 1994, when insufficient numbers of brood were collected to meet production goals.

Table 26. Number of winter steelhead brood collected from Powerdale Dam Trap and held at Parkdale Fish Facility.

Run Year	Winter Steelhead					
	Wild		Hatchery		Total	
	Females	Males	Females	Males	Females	Males
1992	28	29	0	1	28	30
1993	44	34	1	0	45	34
1994	20	22	0	1	20	23
1995	35	30	8	16	43	46
1996	24	22	17	20	41	42
1997	22	17	24	17	46	34
1998	21	20	22	13	43	33
1999	27	20	27	19	54	40
2000	61	69	4	5	65	69
2001	39	35	0	1	39	36
Total	321	298	103	93	424	387

Winter Steelhead Juvenile Production

Winter Steelhead Releases

During the first two weeks of April, winter steelhead were graded into two size groups at Oak Springs Hatchery. The larger sized group was trucked to acclimation facilities and held there for a 4 to 6 day acclimation period. Once acclimated, the fish were allowed to volitionally exit the pond and enter the river. During the last two weeks of April the remaining winter steelhead at Oak Springs Hatchery (smaller sized group) were trucked to the acclimation facilities. After acclimation and volitional release, fish remaining in the acclimation ponds were trucked below Powerdale Dam and then released. These fish were believed to be residuals that would not have smolted and migrated out of the Hood River during the year of release. Table 27 shows the number of winter steelhead liberated in each fork of the Hood River. Fish released into the Middle Fork were acclimated in the Parkdale Facility, and fish released into the East Fork were acclimated in the East Fork Irrigation District Sand Trap.

The goal of releasing 50,000 smolts was generally met in 1993 and after 1995, ranging from 47,000 to 63,000 smolts released. During 1994 and 1995, however, release goals were not met, with 38,000 and 43,000 smolts released respectively (Table 27). In-hatchery egg to release survival data was not available for the early 1990's, therefore we were unable to identify the reason the 1994 release did not meet the goal. The low 1995 releases were due to insufficient number of broodstock collected in 1994.

Beginning in 1996, winter steelhead were acclimated prior to release. Any fish remaining in the acclimation ponds after two to four weeks were considered residuals (as defined by NMFS 1999). Residuals could have been either precocious males or small fish requiring an additional year of rearing before smolting. In the years 1997 through 2000, the HRPP winter

steelhead program produced less than 10% residuals based non-migrants in the acclimation ponds. In the years 1996 residual rate was 12%. For release years 1993-1995, there was no means to estimate residualism. According to NMFS (1999) hatchery residual should not exceed wild residualism rates which were reported to be between 5 and 10%.

The non-indigenous Big Creek stock of winter steelhead was directly released into the East and Middle Forks, totaling 20,434 smolts during spring of 1991. In 1992, Big Creek winter steelhead were hybridized with indigenous winter steelhead and 4,595 smolts were directly released in spring. No other non-indigenous winter steelhead were stocked into the Hood River since the BPA-authorized production program began releasing winter steelhead.

Table 27. Indigenous winter steelhead releases into the Hood River (Olsen July 2002).

Release Year	Release Method	Fish per Pound	Number Released	Release Location
1993	Direct Release	5.8	33,760	East Fork
	Direct Release	5.8	15,225	Middle Fork
	Total		48,985	
1994	Direct Release	5.1	38,034	East Fork
1995	Direct Release	5.4	42,860	East Fork
1996	Acclimated - Group 1	5.7	21,203	East Fork
	Acclimated - Group 2	5.0	23,706	East Fork
	Residuals	5.5	5,987	Mouth
	Total		50,896	
1997	Acclimated - Group 1	6.6	59,837	East Fork
1998	Acclimated - Group 1	5.2	29,510	East Fork
	Acclimated - Group 2	7.5	31,707	East Fork
	Residuals	9.0	918	East Fork
	Total		62,133	
1999	Acclimated - Group 1	5.6	12,430	East Fork
	Acclimated - Group 2	5.8	10,572	East Fork
	Acclimated - Group 1	5.6	9,857	Middle Fork
	Acclimated - Group 2	6.0	9,816	Middle Fork
	Residuals	6.9	4,106	Mouth
	Total		46,781	
2000	Acclimated - Group 1	7.3	13,852	East Fork
	Acclimated - Group 2	7.8	15,694	East Fork
	Acclimated - Group 1	7.3	15,279	Middle Fork
	Acclimated - Group 2	7.7	15,578	Middle Fork
	Residuals	10.7	2,779	Mouth
	Total		63,182	
2001	Acclimated - Group 1	5.3	13,265	East Fork
	Acclimated - Group 2	5.4	12,339	East Fork
	Acclimated - Group 1	5.6	14,535	Middle Fork
	Acclimated - Group 2	5.9	10,484	Middle Fork
	Residuals	9	256	RM 4.5
	Total		50,879	

Winter Steelhead Pathology

No chronic or catastrophic diseases have impaired the rearing of winter steelhead at Oak Springs. The Parkdale Fish facility did have difficulty with a “Cold Water Disease Like” bacteria infecting adult steelhead during holding. However, the use of antibiotic vaccinations appeared to have cured the disease (Jim Gidley, CTWSRO, Personal Communication). Regular use of antibiotics is expected to remedy this problem in the future.

Winter Steelhead Juvenile Outmigration

Hatchery outmigrants and wild outmigrants (FL > 150 mm, representing age 2 and age 3 fish) spring migration duration and run timing was comparable in the East and Middle Forks of the Hood River (Figure 70-Figure 74). All hatchery fish appeared to migrate out of both Forks by July, as did the larger wild fish. A goal of the HRPP was to minimize the possibility of competition between hatchery and wild parr by releasing hatchery fish when they are ready to migrate out of the Hood River. The screw trap data suggested the HRPP had met the goal.

Hatchery winter steelhead (mean FL=199 mm) were larger on average than wild fish (mean FL=152 mm) at age 1. If competition occurred between the wild and hatchery smolts, the hatchery smolts would have had the advantage based on size. Whether smolts aggressively compete was not known, and therefore competition as a factor limiting HRPP success could not be evaluated. Figure 73 describes the size of hatchery and wild fish by length frequency histogram.

The magnitude of the spring emigration differed between hatchery and wild smolts. From 1997 through 2000, Olsen (2001, Draft) estimated the number of wild outmigrants greater than 150 mm (smolts) (Figure 74). Numbers of emigrating wild smolts ranged from roughly 3,200 to 5,600. The number of hatchery smolts released into the Hood Rive ranged from 38,000 to 61,000 annually (Figure 75). The number of hatchery fish migrating out of the Hood River in spring was approximately 11 times the number of wild outmigrants during the same annual periods. Appendix F reviews the precision of the outmigrant studies.

Figure 70. Average percent of wild and hatchery winter steelhead migration out of the East Fork by size category, 1994-2001 (Olsen July 2002)

Figure 71. Average percent of wild and hatchery winter steelhead migration out of the Middle Fork by size category, 1998-2001 (Olsen July 2002)

Figure 72. Average percent of wild and hatchery winter steelhead migration out of the Mainstem by size category, 1998-2001 (Olsen July 2002)

Figure 73. Winter steelhead length frequency distribution of hatchery (n=4,087) and wild (n=4,952) fish captured and measured at the mainstem screw trap, 1997-2001 (Olsen July 2002).

Figure 74. Total number of wild winter steelhead smolts outmigrating past the East and Middle Fork screw traps 1997-2000 (Olsen July 2002).

Figure 75. Number of hatchery winter steelhead released into the Hood River, 1994-2001 (Olsen July 2002).

Winter Steelhead Adult Returns

The BPA-funded indigenous winter steelhead hatchery program began releasing fish into the East Fork in 1993 and into the Middle Fork in 1999. Hatchery-produced adults began returning a year after release (Figure 76). During the run years of 1996 through 1998, greater numbers of hatchery adults returned to the Powerdale Fish Trap than wild adults, but in run years 1999 and 2000 wild fish dominated adult returns. The adult run goal of 5,000 fish was for greater than actual returns of 529 to 1,899 fish from 1995 to 2000.

Run timing of hatchery and wild adult fish to Powerdale Dam was virtually identical in terms of timing and duration (Figure 77). Adult migration for both groups began in February, peaked between April and May, and swiftly declined in early June. However as with summer steelhead, the age composition and size of adults differed between wild and hatchery fish.

Table 28 summarizes age composition in terms of percent age by freshwater age, saltwater age and combined age. Ages were determined by scale analyses conducted by ODFW from fish captured at the Powerdale Fish Trap (Olsen 2001, Olsen July 2002, Olsen Draft,). Only 1.8% of the hatchery fish migrated to the ocean at age-2, suggesting that very few of the hatchery released fish overwinter in the Hood River and that hatchery fish smolt a year earlier than wild fish. The saltwater age composition was similar between hatchery and wild fish, with most adults spending 2 years at sea. The sex ratio for hatchery fish was close to even at 48% female and 52% males. Wild fish differed slightly with a 61% female and 39% male sex ratio.

Figure 76. Numbers of hatchery and wild winter steelhead adults returning to Powerdale Dam (Olsen Draft).

Figure 77. Average percent wild and hatchery winter steelhead adults migrating past Powerdale Dam 1994-2001.

Mean size of wild and hatchery fish differed. Wild fish (mean FL= 68.8 cm; n=1,104) were slightly larger than hatchery fish (mean FL= 67.9 cm; n=3,356; Figure 78). Size appeared to differ between wild and hatchery adults due to differences in age composition. Wild adults were on average older than hatchery fish and furthermore, older aged fish were on average larger than younger fish. Each year of life in the ocean averaged an additional 10cm of fork length.

Table 28. Average age composition of winter steelhead returning to the Hood River at Powerdale adult trap, 1994-2001.

Age	Wild			Hatchery		
	Freshwater	Saltwater	Total	Freshwater	Saltwater	Total
1	1.3%	5.7%	-	98.2%	2.2%	-
2	88.4%	79.8%	0.1%	1.8%	77.5%	2.1%
3	10.2%	14.3%	5.7%	-	20.1%	76.2%
4	0.1%	0.1%	72.2%	-	0.1%	21.4%
5	-	-	20.4%	-	-	0.3%
6	-	-	1.6%	-	-	-

Figure 78. Percent frequency of hatchery and wild adult fork lengths for adults sampled at Powerdale Fish Trap, brood year 1994 to 2001.

Harvest

Sport and commercial ocean harvest was limited, and as a result was not accounted for here. Columbia River harvest was also minimal. Although many Hood River winter steelhead were marked with a CWT, recoveries of these fish were too few to estimate a stock-specific harvest rate in the Columbia River. The modest winter salmonid fishery in the Columbia River was not sampled, therefore a surrogate stock could not be chosen from which to estimate Columbia River harvest. A U.S. v Oregon - Technical Advisory Committee report in which escapement goals were derived for Snake River steelhead (Curt Melcher, personal communication, ODFW) assumed the mainstem harvest of winter steelhead was 2%. We assumed the harvest rate for Hood River fish similar. Although we settled on 2% for analysis purposes, others suggest that exploitation rate may be as high as 50% (Olsen, ODFW, personal communication). None the less, Columbia River harvest of Winter Steelhead represents an unknown. In the Hood River, harvest rates were estimated from angler catch surveys and Powerdale Dam returns (Olsen Draft) (Table 29). The HRPP did not specify ocean or Columbia River harvest goals, but did specify an in-basin harvest goal of 2,510 fish. Sport harvest comprised 28% of the goal.

The harvest rate was higher in the Hood River due in part to recycling. Recycling, as discussed in the summer steelhead section, was the process of transferring hatchery adults captured at Powerdale Dam back to the mouth of the Hood River and releasing them. The

recycle process successfully increased the number of fish harvested by an average of 7%, with a range of 0% to 23% for the years 1996-2000 (Figure 68).

On the other hand, recycling also caused unwanted side effects. Individual fish were recycled up to 7 times, which increased the need for fish processing at the trap (Table 30). On Average, each fish recycled had a 52% chance of returning to the Powerdale Dam. Conversely, 48% of the fish recycled were either: harvested, died of natural causes or strayed. On average, 11% of the recycles were harvested leaving roughly 89% unaccounted for (Figure 69). The number of unaccounted fish ranged from 24 to 311 with an average of 141 winter steelhead from 1995-2000.

The fate of the unaccounted recycled fish represents an uncertainty, deserving attention. Winter Steelhead were coded wire tagged, but too few marked fish were recovered to estimate straying rate. The unaccounted recycles may be contributing to straying. If we assume as a worst case that all the unaccounted fish strayed, then an average of 31% of the adult returns would have strayed, ranging from 8% to 50% from 1996-2000. Based on the unaccounted fish, a majority of year may have violated the NOAA Fisheries goal of 5% straying, if fish strayed to non-ESU rivers such as the Klickitat and Deschutes Rivers. Studies should be conducted to determine stray rate of recycled winter steelhead.

Table 29. Annual estimates of harvest rate on hatchery winter steelhead including recycles in the Hood River (Olsen July 2002).

Run Year	Harvest		Hatchery PD Returns	Harvest Rate
	Columbia R.	Hood R		
1996	19	317	613	0.3409
1997	12	231	363	0.3889
1998	10	172	303	0.3621
1999	10	214	290	0.4246
2000	25	351	897	0.2813
Average	14	264	718	0.3888

Table 30. Hatchery Winter steelhead recycled in the Hood River (Olsen July 2002, and Draft).

	1996	1997	1998	1999	2000	Mean	ST Dev
Adult Return to Powerdale	613	363	303	290	897	454	252
Total Adults Harvested	317	231	172	214	351	264	118
No. in Recycled Program	311	167	83	26	293	161	69
Max. Recycle Circuits	6	4	3	4	7	5	7
No. Uniquely Tagged Recycles Returned to PD	40	33	39	35	47	37	272
No. of Angler Opportunities^a	464	309	142	56	776	311	2
No. Recycles Harvested	0	27	6	2	80	21	31
% Recycles Harvested	0%	16%	7%	8%	27%	11%	9%
% Recycles of Tot. Harvest	0%	12%	3%	1%	23%	0	0
No. Recycles Unaccounted	311	140	77	24	213	141	106
% Recycles Unaccounted	100%	84%	93%	92%	73%	89%	9%

a = total number of fish migrations to Powerdale Dam (a combination of recycles and single pass migrants).

Survival

Smolt-to-adult survival was determined based on returning fish to Powerdale Dam (detail on methods is presented in Appendix E). The average survival was 1.41% ranging from 0.29% to 2.89% (Figure 79). The HRPP program anticipated a 4% smolt to adult survival, which has not yet been achieved. Since program adult return and harvest goals were based, in part, on smolt to adult survival, steps should be taken to increase smolt-to-adult survival or the program goal should be readdressed.

Figure 79. Average brood year survival rates for hatchery Hood River winter steelhead.

CHAPTER 6: HABITAT RESTORATION

KEY FINDINGS IN CHAPTER 6:

- The HRPP habitat improvement focused on instream habitat renewal, riparian recovery, stream flow restoration, fish passage improvements, planning at the project and watershed level, and monitoring and evaluation of habitat activities.
- Analysis of habitat data with UCM modeling showed that a lack of pool habitat, low wood complexity, high fines, and high turbidity were key factors limiting freshwater capacity and survival for salmon and steelhead. Many instream improvements were aimed at alleviating one or several of these limitations.
- Estimation of restoration benefits were hindered by a lack of evaluation criteria and pre-/ post- project monitoring.
- Cattle exclusion and riparian habitat were projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively.
- If flows were increased an additional 10cfs at each of the major irrigation diversions (EFID, Dee, and FID) as well as return 250 cfs at Powerdale Dam for steelhead would increase parr capacity by 10,000-20,000 parr, and spring Chinook capacity would increase by 7,500-12,500 parr.
- Powerdale Dam diversion could impose the greatest point source mortality to outmigrating salmonids due to the large volume of water diverted and believed inefficiency of the diversions fish screen.
- Projects that involved restoring flow or screening of diversions appeared to have the greatest positive direct effects on spring Chinook and steelhead production.

INTRODUCTION

The HRPP began actions to improve habitat from the beginning of the program. Actions focused on six habitat improvement actions: instream habitat renewal, riparian recovery, stream flow restoration, fish passage improvements, planning at the project and watershed level, and finally monitoring and evaluation

of habitat activities. Table 31 lists the habitat actions conducted during the 1990's. This chapter will explore factors limiting fish production and relate limitations to direct and indirect benefits from habitat project activities.

Table 31. Habitat restoration and improvement projects in the Hood Basin during 1990-2001 years.

Project	Action
In-Stream Habitat Renewal	
Addition of gravel to Rogers Spring	Spawning Gravel Addition
West Fork Hood Instream Restoration	LWD/Boulder Placement
McGee Creek Instream Restoration	LWD/Boulder Placement
Lake Branch Instream Restoration	LWD/Boulder Placement
Clear Branch Instream Restoration	LWD/Boulder Placement
EFID Neal Creek Lateral project	Water Conservation and Quality improvement
Riparian Recovery	
Neal Creek fence, riprap and riparian planting	Cattle Exclosure
Baldwin Creek riparian fencing	Cattle Exclosure
Lenz Creek fence and riparian planting	Cattle Exclosure
Tieman Creek riparian fencing	Cattle Exclosure
Shelly Creek riparian fencing	Cattle Exclosure
Wishart Creek riparian fencing	Cattle Exclosure
Nottingham Campground improvements	Riparian Degradation Prevention
Rhoades Cr. riparian fencing	Cattle Exclosure
Baldwin, Graham, Tieman revegetation	Riparian Planting
Green Point Creek LWD placement and riparian planting	LWD Placement/Riparian Planting

Project	Action
Stream Flow Restoration	
Irrigation system and water use efficiency projects	Water Conservation
Powerdale Dam hydroelectric project relicensing	Water Conservation
Fish Passage Improvements	
Tony Creek Dee Mill diversion adult passage	Passage improvement
FID horizontal fish screen	Entrainment Screen
EFID Fish screen	Entrainment Screen
MFID Evans Creek/glacier ditch passage	Passage improvement/ Water Quantity & Quality Improvement
Evans Creek culvert improvement	Passage improvement
Baldwin Creek culverts improvement	Passage improvement
Phoenix Pharms fish passage improvement	Juvenile Screen improvement
Pinnacle Creek bridge fish passage improvement	Passage improvement
Neal Creek, Tony Creek and Clear Branch improvements	LWD/Boulder Placement
West Fork Hood Barrier Removal	Removal of "moving barrier" at RM 3.0
Watershed Planning	
Hood River watershed Assessment	Identify improvement projects
Hood River Subbasin Planning	Identify improvement projects
Monitoring and Evaluation	
Habitat and Watershed Action Plan	Planning
Aquatic Inventories Surveys	Stream Surveys
Pesticide monitoring	Chemistry Monitoring
Temperature Monitoring	Temperature Monitoring
Photo points	Temporal Monitoring

IN-STREAM HABITAT RENEWAL

Limiting Factors

We used stream survey data and the Unit Characteristic Model (UCM) to analyze limiting factors for salmon and steelhead production in the subbasin. The carrying capacities and limiting factors identified with the UCM was used to estimate benefits from several of the habitat restoration projects. The UCM was described in Chapter 2 and appendices A-D. Cramer (2001) argued the spring Chinook and steelhead carrying capacity of a river could be explained by estimating parr density at summer low flow through habitat characteristics. UCM not only predicted carrying capacity, but because the model relied on habitat data, it also identified habitat variables limiting parr abundance.

Spring Chinook

A key factor influencing the carrying capacity of a given stream reach was the percentage of pools. The raw capacity to produce parr in each reach (unadjusted for depth, cover,

embeddedness, or water chemistry) was highly correlated to the percentage of surface area composed by pools in the Hood Basin ($r = 0.99$, Figure 80). Pools were considered capable of supporting the highest density of Chinook parr (24.0 fish/100m²), followed by glides (7.0 fish/100m²), rapids (2.4 fish/100m²) and riffles (2.4 fish/100m²). Throughout the generally accepted Hood River distribution of spring Chinook, rearing areas, rapids were usually the dominant habitat type composing 15-79% of a reach (Table 32). Pools composed 8% to 39% of a reach, and riffles composed 4% to 51% of a reach (Table 32). The highest abundance of pools was in the lower West Fork (39%) and the Lake Branch (38%). The upper mainstem also had a relatively high pool density (24%). These reaches were considered to have the highest capacity to produce Chinook parr. However, when depth, cover, embeddedness or water quality, were included, the capacity was not as strongly correlated to percent pools ($r = 0.50$).

Figure 80. Relationship between raw capacity density and percent pools in reaches modeled for spring Chinook capacity in the Hood Basin.

Table 32. Proportions of unit composition by surface area of reaches used in the spring Chinook UCM.

Reach	Length		Surface Area (m²)	Casca de	Glid e	Unit Composition			
	(m)	(km)				Pool	Rapi d	Riffle	Othe r
Hood Mainstem									
Mouth to Powerdale	8,317	8.32	231,085	0.00	0.11	0.11	0.54	0.24	0.00
	14,11								
Powerdale to EFK/WFK	5	14.12	361,010	0.01	0.00	0.24	0.41	0.24	0.10
Middle Fork									
Clear Branch	998	0.99	7,033	--	0.03	0.22	0.55	0.21	0.00
Tony Cr.*	3,768	3.77	25,276	--	0.02	0.16	0.74	0.08	0.00
Rogers Cr.*	1,078	1.08	4,312	**	**	**	**	**	**
West Fork									
Mouth to Greenpoint Cr.	1,368	1.37	19,533	0.03	0.00	0.39	0.39	0.14	0.05
Greenpoint Cr. to Lake Branch	5,300	5.30	83,982	0.06	0.00	0.27	0.46	0.18	0.03
	13,57								
Lake Branch to Ladd Cr.	6	13.58	192,334	0.18	0.01	0.14	0.47	0.17	0.03
Ladd Cr. to Elk/McGee	1,592	1.59	16,859	0.08	0.12	0.23	0.15	0.39	0.03
	17,89								
Lake Branch	2	17.89	137,189	0.11	0.00	0.38	0.41	0.08	0.02
Red Hill Cr.*	1,268	1.27	6,185	--	0.02	0.15	0.36	0.46	0.01
Jones Cr.*	2,075	2.07	11,106	--	0.00	0.30	0.66	0.04	0.00
McGee Cr.*	5,530	5.53	45,680	--	0.01	0.12	0.79	0.08	0.00
Elk Cr.*	3,413	3.41	16,366	--	0.02	0.12	0.35	0.51	0.00

* Unit composition after adjustments to USFS data. Rapids incorporates both rapid and cascade type habitat in these reaches.

** No habitat survey data available.

Each reach was uniquely affected by subsequent adjustments to raw capacity. In general, the features of cover and water chemistry in each reach decreased the estimate of rearing capacity. The decrease resulted from low wood complexity, low alkalinity and high turbidity. Raw densities in most reaches increased from above average depth and boulder content.

Average wood scores throughout habitat surveyed were low. Wood complexity was rated on a scale of 1 to 5 with 1 being no wood present, and 5 being accumulations of small and large pieces of wood providing complex cover at all flow levels. Average ratings in pools of surveyed reaches were 1 to 1.4 (Table 33). The USFS did not gather data regarding wood complexity. Wood complexity in pools in USFS reaches was assumed to average 1.8, based on average wood scores reported by ODFW for reaches surveyed in or out of spring Chinook distribution. Wood complexity ratings below 2 received a decrement to capacity by the UCM, consequently, all spring Chinook reaches received a decrement for wood score ratings in both ODFW and USFS surveyed reaches (Figure 81).

Boulders were common in the Hood Basin with average substrate composition of 11-47%. Boulders provide cover for rearing Chinook parr, and high boulder content in pools, riffles and glides results in an increase in capacity assignment by the UCM. River reaches that had a

high percentage of boulder substrate received substantial capacity increases for boulder presence. These reaches included all of the mainstem Hood River, mainstem West Fork, McGee Creek, Lake Branch, Clear Branch, and Tony Creek.

Stream depth was often greater than the UCM standard, so it increased estimate of capacity. Depths in slow-water habitat types ranged from 0.6 to 2.6m and depths in fast-water habitats ranged from 0.3-0.7m (Table 33 and Table 34). Densities at capacity were estimated to be greatest in the West Fork Hood River, and this was partially attributable to the depth of mainstem habitat units in that fork.

Table 33. Habitat features in reaches surveyed by the ODFW and used to estimate spring Chinook parr capacity via the UCM. Depth was measured at its maximum in pools, but at its average in all other units. Slow-water units include pools and glides. Fast-water units include riffles, rapids and cascades.

Reaches Surveyed by the ODFW							
Reach	Average Width (m)	Average Depth (m)		Wood Score in Pools	% Fines in Riffles	% Boulders	% Cobble
		Slow-water	Fast-Water				
Hood Mainstem							
Mouth to Powerdale	32.1	1.1	0.6	1.0	25	34	26
Powerdale to EFK/WFK	25.6	1.8	0.7	1.0	30	27	23
West Fork							
Mouth to Greenpoint Cr.	14.3	2.4	0.6	1.1	12	31	25
Greenpoint Cr. to Lake Branch	16.0	2.0	0.6	1.0	16	29	26
Lake Branch to Ladd Cr.	14.0	2.0	0.5	1.0	13	35	29
Ladd Cr. to Elk/McGee	10.6	0.8	0.3	1.2	7	14	41
Lake Branch	9.4	2.6	0.5	1.0	13	29	22

Figure 81. Effects of adjustments to spring Chinook parr capacity for various habitat and water chemistry variables on the raw parr capacity of reaches in the Hood Basin.

Table 34. Habitat features in reaches surveyed by the USFS and used to estimate spring Chinook parr capacity via the UCM. Depth was measured as the maximum depth in all units. Slow water units include pools and glides. Fast-water units include riffles, rapids and cascades.

Reaches Surveyed by USFS								
	Average	Average Depth (m)		Substrate				
Reach	Width (m)	Slow-water	Fast-water	Dominant	Subdominant	%Sand	%Boulder	%Cobble
Middle Fork								
Clear Branch	6.6	0.9	0.5	--	--	2	20	44
Tony Cr.	6.3	0.8	0.6	--	--	8	11	35
Rogers Creek	--	--	--	--	--	--	--	--
West Fork								
Red Hill Cr.	4.6	0.7	0.5	--	--	5	12	28
Jones Cr.	5.6	0.8	0.5	--	--	2	47	45
McGee Cr.	8.4	1	0.7	--	--	7	20	27
Elk Cr.	4.6	0.6	0.4	Cobble	Boulder	--	--	--

Alkalinity was lower in every reach within spring Chinook distribution than baseline values within the UCM (33.6mg/l). Alkalinity served as a surrogate for primary and secondary productivity. Average values within reaches ranged from 13-27mg/l (Table 35).

Glacially induced turbidity was present in all three of the main forks of the Hood River. Any amount of turbidity above clear conditions reduced potential capacity by decreasing sunlight penetration and subsequent primary and secondary production. Averages of measured turbidity ranged from 5 NTU in the lower West Fork to 7-13 NTU in the mainstem Hood River. Qualitative ratings of turbidity levels throughout the rest of spring Chinook distribution were generally low or medium (Table 35). The mainstem Hood River was negatively affected by the high percentage of fines in riffles (Table 35). Fines in riffles in these reaches were 25-30%, and the UCM begins to assign a decrement to capacity when fines in riffles exceed 15%.

Figure 81 portrays the shift in carrying capacity due to in-stream habitat conditions and presents the affect habitat variables had on capacity. The UCM indicated spring Chinook production in the mainstem and West Fork was limited by a lack of wood, low productivity (alkalinity), and high turbidity. The Middle Fork was limited by a lack of pool habitat and low productivity.

Table 35. Alkalinity and turbidity values used in estimates of spring Chinook parr capacity via the UCM.

Reach	Alkalinity (mgCaCO ₃ /l)	Turbidity NTU
Hood Mainstem		
Mouth to Powerdale	27	7
Powerdale to East Fork/West Fork confluence	25	13
Middle Fork		
Clear Branch	22*	L
Tony Creek	22*	L
Rogers Creek	22*	L
West Fork		
Mouth to Green Point Creek	20	5
Green Point Creek to Lake Branch	19*	M
Lake Branch to Ladd Creek	15*	M
Ladd Creek to Elk/McGee confluence	13	L
Lake Branch	17*	L
Red Hill Creek	16*	L
Jones Creek	16*	L
McGee Creek	13*	L
Elk Creek	13*	L

* Assumed alkalinity value

Winter and Summer Steelhead

Winter and summer steelhead rearing capacities were based on identical habitat requirements. The only difference between the two races was distribution, with winter steelhead in the East and Middle Forks, summer steelhead in the West Fork, and both races in the mainstem. Similar to the model for spring Chinook, the UCM assigned the highest capacity to pools, so the capacity increased with the percentage of pools ($r = 0.91$) (Figure 82). When other habitat variables (i.e. cover, depth, substrate, water quality) were included in the UCM estimate, the relationship between percent pools and capacity weakened ($r = 0.53$). This reflects that cover, depth, substrate and water quality influenced final estimates of steelhead capacity.

Rapids were the dominant habitat type comprising 53% of the individual reaches, throughout known steelhead rearing distribution. Pools and riffles were evenly represented comprising an average 17% and 19% in modeled reaches (Table 36). The West Fork and mainstem contained more pools than did the East or Middle Forks.

Throughout the basin, cover from wood was low. Wood complexity ratings assigned by the ODFW ranged from 1 to 1.5 in the major producing streams (Table 37), and the highest value observed in all streams was 1.7 in the Dog River. Boulders were an important source of cover and typically made up 10-30% of the riffle substrate in the main reaches of the Hood Basin (Table 37). Boulders did not significantly impact the cover adjustment because they only applied to riffles, which composed a moderately low percentage of the habitat in the Hood Basin. Boulders are typically the dominant substrate in rapids.

Figure 82. Relationship between percent pools and predicted densities at raw *O. mykiss* parr capacity in the Hood Basin.

Table 36. Unit composition of reaches estimated to be major steelhead rearing areas.

Reach	Length (m)	Length (km)	Surface Area	Cascade	Unit Composition				
					Glide	Pool	Rapid	Riffle	Other
Hood Mainstem									
Mouth to Powerdale	8,317	8.32	231,085	0.00	0.08	0.23	0.44	0.22	0.02
Powerdale to EFK/WFK	14,115	14.12	361,010	0.01	0.00	0.24	0.41	0.24	0.10
Neal Cr.	11,844	11.84	56,525	0.30	0.00	0.10	0.39	0.17	0.03
East Fork	34,276								
Mouth to Middle Fk.	3,487	3.49	64,973	0.02	0.00	0.11	0.60	0.25	0.01
Middle Fk. to Dog River	19,775	19.77	227,922	0.01	0.00	0.06	0.63	0.28	0.03
Dog River to Tilly Jane Cr.	2,448	2.45	22,860	0.04	0.00	0.02	0.84	0.10	0.01
Tilly Jane Cr. to Clark Cr.*	15,996	16.00	176,112	--	0.03	0.04	0.67	0.26	0.01
Clark Cr. to Sahalie Falls	5,643	5.64	35,256	--	0.00	0.18	0.69	0.04	0.09
Middle Fork	47,350								
Mouth to Coe Branch ^a	7,684	7.68	67,508	0.04	0.00	0.08	0.74	0.12	0.03
Mouth to Coe Branch ^b	6,999	7.00	56,309	--	0.01	0.09	0.75	0.11	0.04
West Fork	14,683								
Mouth to Greenpoint Cr.	1,368	1.37	19,533	0.03	0.00	0.39	0.39	0.14	0.05
Greenpoint Cr. to Lake Branch	5,300	5.30	83,982	0.06	0.00	0.27	0.46	0.18	0.03
Lake Branch to Ladd Cr.	13,576	13.58	192,334	0.18	0.01	0.14	0.47	0.17	0.03
Ladd Cr. To Elk/McGee	1,592	1.59	16,859	0.08	0.12	0.23	0.15	0.39	0.03
Lake Branch	17,892	17.89	137,189	0.05	0.02	0.21	0.43	0.20	0.09

a = Portion surveyed by ODFW

b = Portion surveyed by USFS

Table 37. Habitat features in reaches estimated to be major *O. mykiss* rearing areas. Depth was measured as maximum in pools and average in all other units. Slow water units include pools and glides. Fast-water units include riffles, rapids and cascades. Only dominant producing reaches are displayed here.

Reach	Average Width (m)	Average Depth (m)*		Wood Score			
		Slow-water	Fast-Water	in Pools & Glides	% Fines in Riffles	% Boulder in Riffles	% Cobble
Hood Mainstem							
Mouth to Powerdale	27.8	1.3	0.5	1.1	16	23	26
Powerdale to EFK/WFK	25.6	1.8	0.7	1.0	30	26	23
Neal Cr.	4.8	0.7	0.4	1.2	8	14	38
East Fork							
Mouth to Middle Fk.	18.6	1.2	0.7	1.5	38	10	29
Middle Fk. to Dog River	11.5	0.9	0.5	1.2	38	9	26
Dog River to Tilly Jane Cr.	9.3	1.1	0.6	1.0	44	16	24
Tilly Jane Cr. to Clark Cr.***	10.9	0.9	0.6	--	--	--	--
Clark Cr. To Sahalie Falls***	5.7	0.6	0.4	--	--	--	--
Middle Fork**							
Mouth to Coe Branch	8.8	1.0	0.5	1.4	25	19	27
West Fork							
Mouth to Greenpoint Cr.	14.3	2.4	0.6	1.1	12	36	25
Greenpoint Cr. to Lake Branch	15.8	2.0	0.6	1.0	16	26	26
Lake Branch to Ladd Cr.	14.1	2.0	0.5	1.0	13	30	29
Ladd Cr. To Elk/McGee	10.6	0.8	0.3	1.2	7	12	41
Greenpoint Cr.	8.2	1.0	0.4	1.1	21	25	23
Lake Branch	7.7	1.3	0.3	1.4	23	18	25

*incorporates max depth in pools

** incorporates only ODFW surveyed portion

*** surveyed by the USFS; no substrate data; max depth multiplied by 0.8 to estimate average depth

Turbidity was the parameter that most negatively affected carrying capacity. The effect was most pronounced in the Middle Fork where turbidity was rated as high, but the effect was also substantial in the East Fork and mainstem. Turbidity affects were least in the West Fork where turbidity ratings were typically medium (Table 38). The capacity in the mainstem Hood River, East Fork and Middle Fork were also negatively affected due to abundant fines in riffles. Fines in riffles were high throughout the basin, but were exceptionally high in the East Fork where they ranged from 38-44% of the substrate in reaches below Tilly Jane Creek (Table 38)

Alkalinity was low in a majority of the Hood River resulting in capacity decrements. The exception included streams such as Neal Creek in the northeast portion of the basin where alkalinity generally ranged from 30-45 mg CaCO₃/l (Table 38)

In summary UCM determined, carrying capacity of steelhead in the East Fork was limited by pool habitat, fines, alkalinity and turbidity. Capacity in the West Fork was limited due to pool habitat, cover, alkalinity and turbidity. Capacity in the mainstem was limited by pool habitat, cover, % riffles, fines and turbidity (Figure 83).

Predicted densities of steelhead parr were highest in the West Fork, followed by the East Fork, and were lowest in the Middle Fork. Of the three forks, the West Fork has the lowest gradient, the fewest fines in riffles, the most pools, the deepest pools, and the least turbidity. The Middle Fork and East Fork were higher in turbidity, low in pools, had a high percent of fines and moderate to high gradient. By simply reviewing these differences in habitat, one would presume that the West Fork was the most suitable for juvenile rearing while the Middle and East Fork lagged behind.

In-Stream Renewal Activities

Instream improvements focused on the addition of large woody debris and boulders to the West Fork Hood River, Lake Branch, Clear Branch, and Robinhood and McGee Creeks, among other areas (Coccoli and Lambert 2000, Brunfelt 1992). Gravel was added to Rogers Spring to increase the amount of suitable spawning substrate for salmon and steelhead (A. Vaivoda, CTWS, personal comm.). Riparian vegetation was planted and instream wood was placed in Green Point Creek during 2000 (Coccoli 2002).

Results of instream habitat restoration varied. Addition of instream structures and large wood were often designed to increase pool habitat, cover, storage of spawning gravels and overall habitat complexity. The success of restoration activities often depends on the long-term durability and persistence of the added structures. In some restoration efforts, structures may not be anchored well, and are displaced within the first year of placement from high flow events (Frisell and Nawa 1992).

Table 38. Alkalinity and turbidity values used in modeling major steelhead producing reaches in the Hood Basin.

Reach	Alkalinity (mgCaCO ₃ /l)	Turbidity NTU
Hood Mainstem		
Mouth to Powerdale	27	7
Powerdale to East Fork/West Fork confluence	25	13
Neal Cr.	45	8
East Fork		
Mouth to Middle Fork	23*	M
Middle Fork to Dog River	23	8
Dog River to Tilly Jane Creek	20	M
Tilly Jane Creek to Clark Creek	17	M
Clark Creek to Sahalie Falls	43	M
Middle Fork		
Mouth to Coe Branch	22*	H
West Fork		
Mouth to Green Point Creek	20	5
Green Point Creek to Lake Branch	19*	M
Lake Branch to Ladd Creek	15*	M
Ladd Creek to Elk/McGee confluence	13	L
Lake Branch	17*	L

* Assumed value

Figure 83. Affects of adjustments on capacity density for various habitat and water chemistry variables on the raw parr capacity of reaches in the Hood Basin modeled for *O. mykiss*

Limited monitoring of instream habitat restoration occurred in the Hood Basin, and much of the monitoring was short term. However, results indicated that the effects of restoration have been generally positive. In RM 1.2-2.1 of McGee Creek, pool habitat increased 6% pre-project to 35% post project during the year following USFS improvements (Bergamini and Lindland 1992). In this section, the percentage of pool habitat within a reach was correlated to estimated parr rearing capacity for steelhead and spring Chinook (Figure 80 & Figure 82). In the same stream, density of large woody debris (LWD) increased from 4.2 to 17.4 pieces/100m. UCM modeling indicated that wood cover was low throughout the Hood Basin. Documentation of low wood complexity in stream surveys used in the UCM resulted in reduced rearing capacity for spring Chinook and steelhead. Thus, increasing the frequency of large wood was expected to result in greater rearing capacities. These results indicated that at least in the short-term, rearing capacity in McGee Creek (RM 1.2-2.1) was increased by restoration efforts. In RM 2.1-2.8 of McGee Creek, monitoring methods did not allow a direct comparison of pre and post project conditions. However, results of surveys indicated that restoration activities increased available pool habitat area within the study site (Bergamini and Lindland 1992). A USFS stream survey report of McGee Creek in 1997 noted the continued existence of stream improvement structures above RM 1.0 indicating that improvements were continuing to function six years after restoration.

Although effects of restoration on the Lake Branch (RM 5.0-7.0) were confounded by using different pre and post-survey protocols, there appeared to be no change in habitat composition within the study area two years after restoration efforts. Large woody debris density was as high as 18.2 pieces/100m post-project, but no comment was made on pre-project conditions (Bergamini and Lindland 1992).

Riparian Restoration

Efforts to restore riparian vegetation were intended to improve water quality and instream habitat. CTWSRO, with the assistance of landowners and other agencies fenced, rip-rapped, and planted riparian vegetation along reaches of several streams in the Hood Basin (A. Vaivoda, CTWSRO, personal comm.). Many efforts occurred in the lower basin, where livestock grazing has prompted the need for such actions. Riparian habitat restoration took place in the following streams: Neal Creek, Baldwin Creek, Tieman Creek, Rhoades Creek, Shelley Creek and Lenz Creek.

SPCA and CTWSRO personnel inspected seven grazing exclosures installed and maintained by the CTWSRO in the Hood Basin. Nine exclosures were installed from 1996 to 2001 (Table 39), and inspection of seven of these exclosures was conducted on March 27, 2003. Two exclosures, Baldwin Creek #1 and #2, were not inspected because access was not secured from the landowners. The seven remaining exclosures were walked and photographed throughout their length, and two exclosures (Neal Creek #2 and Shelly Creek) were chosen for synoptic channel measurements. The objectives of these inspections were to: (1) observe the locations, settings, and physical conditions of the exclosures and stream channels, and (2) record channel measurements. Information gathered during the inspections provided a rudimentary baseline from which to compare the CTWSRO exclosures to more intensively studied exclosures in the region. Furthermore, channel measurements and photographic documentation provided

the potential for monitoring and quantifying changes in the channel and riparian areas over time. Results of these inspections were meant to inform whether and to what degree exclosures in the Hood River watershed were likely to result in restorative geomorphic adjustment of the stream channel and improved water quality.

Because streams respond variably to grazing exclosures, to extrapolate changes observed at reference sites to grazing exclosures in the Hood River watershed was difficult. However, similarities in gradient and channel dimensions between channels studied by McDowell and Mowry (2003) and those observed in the Hood River watershed were used to make general predictions about whether and to what degree exclosures in the Hood River watershed would respond to grazing exclosures. Data gathered during inspection of grazing exclosures in the Hood River watershed indicated that at least one exclosure site surveyed by McDowell and Mowry (2003) (Chesnimnus Creek in the Wallowa Whitman National Forest) was similar in gradient and channel dimensions to exclosure sites in Lenz, Shelley, and Baldwin Creeks of the Hood River watershed. The stream reach within the grazing exclosure of Chesnimnus Creek was considerably narrower, and had greater percent area in pools and lower bankfull width-to-depth ratios than grazed reference reaches approximately 14 years after exclosure installation. Evidence in the form of field measurements indicated that exclosure sites in Shelley, Lenz, and Baldwin Creeks would be expected to behave similarly over time.

Neal and Tieman Creeks were separated from other streams with exclosures for the purposes of comparative analysis. Neal Creek had a much larger drainage area and carried several times more flow than other exclosed streams in the Hood River watershed, and was locally incised. Tieman Creek has a higher gradient and had experienced far less clearing of woody vegetation than any of the other than the other streams.

McDowell and Mowry (2003) cited inadequate bank vegetation, sediment supply, and stream competence, channel incision, placement of bank hardening structures within the exclosure, and the effects of grazing history as factors that may limit the geomorphic impacts of grazing exclosures. Mowry (2003) reported that one of the most important geomorphic processes affecting exclosure performance was deposition of fine-grained sediment during over bank flows. Neal Creek adjacent to the #1 and #3 exclosures was incised and disconnected from its floodplain; other streams in the watershed with exclosures were lower order channels that appeared to have more connection with their floodplains and riparian areas. As a result of channel incision, geomorphic adjustments in Neal Creek, particularly in those reaches adjacent to exclosures #1 and #3, may be limited because of lack of interaction between the channel and newly established riparian vegetation. Geomorphic adjustments may also be limited by the construction of bank-hardening and bank-heightening structures within the exclosures, and was likely to limit channel adjustment within the exclosure.

Table 39. Characteristics of grazing exclosures installed in the Hood River Basin since 1996.

Exclosure Name	Date Completed*	Approximate stream length fenced* (m)	Active Channel* (m)		Wetted Channel* (m)		Estimated stream gradient**	Vegetation within exclosure*
			Width	Depth	Width	Depth		
Neal Creek 1	Sep-96	402	5.80	0.40	5.20	0.45	0.017	Mix of alders, large conifers and grasses. Seedling Pines
Neal Creek 2	Nov-98	298	6.70	0.40	4.60	0.42	0.017	Mix of alders and grasses. After fencing project, conifers planted
Neal Creek 3	Oct-98	545	6.30	0.40	4.90	0.43	0.17	Mix of alders, large pines, and grasses. Bundles of willow planted and staked hardwoods. After fencing project, pines and firs planted in enclosure
Lenz Creek	Nov-99	247	4.50	0.40	2.30	0.50	0.015	Mix of hardwoods, brush, grasses, and some large conifers. After fencing project, conifers planted in enclosure
Shelly Creek	Sep-02	396	5.00	3.00	0.30	0.20	0.022	Young to mature hardwoods, brush (blackberries), and grazed grasses
Baldwin Creek 1	Jul-00	653	3.50	0.40	3.40	0.27	0.013	Young hardwoods and grasses. After fencing project, cedars, firs and pines were planted in enclosure
Baldwin Creek 2	Nov-01	247	2.80	0.37	2.10	0.30	0.013	Mix of alders, willows, and grasses.
Baldwin Creek 3	Oct-02	101	2.80	0.37	2.10	0.30	0.015	Mature hardwood, brush, and grasses
Tieman Creek	Nov-00	457	1.60	0.20	1.40	0.15	0.04	Mixture of small and large hardwoods with firs.

* = reported by CTWSRO

** = measured from USGS topographic map

Geomorphic adjustment of the channel within the Tieman Creek enclosure was likely to be most influenced by site history. Because it experienced far less clearing of woody vegetation, this stream was not as affected as other grazed streams in the area; therefore the enclosure would not likely be as significant of a factor influencing stream geomorphology as would the similarity in existing and pre-existing riparian conditions.

Cattle exclusion and riparian habitat protection fencing were projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively. This estimate is biased on the assumption that parr capacity would increase 300% in the treated reaches, similar to the findings of Gunderson (1968) for cattle exclusion and fencing of riparian zone. These projected increases in steelhead rearing density resulted from approximately two miles of protective fencing. Although an additional 1.5 miles of fencing was installed along four more streams in the Hood Basin as part of HRPP activities, none occurred along juvenile spring Chinook rearing habitat. Fencing was also installed along reaches that generally lack anadromous salmonid rearing habitat. However, these activities likely provided additional downstream benefits to water quality and habitat suitability for resident fish and native lower trophic level fauna in the individual streams where the projects occurred. Furthermore, reduced erosion and sediment loading rates and improved thermal and physical water quality conditions in areas “treated” with protective fencing would also have benefited higher-order streams and the downstream mainstem Hood River. Thus, treatment effects of exclusion and protection fencing likely provided ecological benefits throughout the Hood Basin, although these were not measured.

It was difficult to quantify precisely what role these enclosures play in affecting channel geomorphology and improving instream salmonid habitat, but it was clear that improvements in water quality resulting from these grazing enclosures *per se* were sufficient to warrant their maintenance and monitoring. In addressing future opportunities to install additional grazing enclosures in the Hood Basin, managers should site enclosures in channels with a relatively low degree of incision, and should avoid or minimize adverse effects of the factors that limit enclosure effectiveness identified by McDowell and Mowry (2003). Furthermore, to increase direct benefits to the HRPP program, efforts should be focused on reaches expected to rear steelhead and spring Chinook. Future projects should include more data on morphological, riparian, thermal, and cover changes associated with exclusion efforts if more accurate conclusions are desired regarding benefits to production potential.

Complete documentation of the field assessment by SPCA and CTWSRO staff of cattle enclosures in Hood Basin can be found in Appendix F

Stream Flow

Estimates were made of the number of additional parr capacity that could be accommodated in the Hood Basin if flows are increased. Estimates were made using UCM estimates of parr capacity density as they related to August flow in reaches below each diversion. We assumed that the relationship between increased percent of flow restored and increased percent of capacity was positively linear and 1:1. Thus, restoring 10% of August flow in a reach below the East Fork Irrigation Diversion will result in a 10% increase in capacity. This

assumption was based on the presumption that increased flow produces increased depth and surface area that together would increase rearing capacity. This was a crude method designed to illustrate the potential benefits of increasing water availability below diversions. Estimates of increased capacity should be viewed with caution. Specifically, estimates of increased production potential from restored flow below Powerdale Dam seem unrealistically high. More accurate estimates of increased capacity could be made if the relationship between flow conserved below diversions and increased depth and surface area in downstream reaches was determined.

Steelhead – Independent 15-cfs reductions in irrigation water withdrawals at Farmers’ and East Fork Irrigation Districts and 10-cfs at Dee Irrigation Diversion were estimated to jointly provide enough rearing habitat for 4,352 additional steelhead in all three streams combined (Table 40; Figure 84). Lesser reductions into irrigation water diversions were projected to provide rearing habitat for fewer additional steelhead parr (Table 40; Figure 84).

Conservation of every 50cfs of water at Powerdale Dam could increase capacity within the depleted reach below the dam by an estimated 3,107 parr. Restoring 250 cfs below Powerdale would increase steelhead capacity by 15,533 parr base on a one to one relationship of flow and increased habitat which appears to result in a liberal estimate (Figure 85).

Furthermore, implementation of the Central Canal upgrade/Neal Creek inverted siphon project was estimated to improve turbidity conditions in Neal Creek increasing capacity by 478 parr (12%) (Table 40).

Table 40. Projected increases in steelhead and spring Chinook rearing numbers from various water conservation practices in the Hood River Basin.

HRPP Water Conservation Activity	Additional Steelhead Rearing Capacity (# Parr)	Additional Spring Chinook Rearing Capacity (# Parr)
Central Canal Upgrade/Neal Cr. Inverted Siphon	479	A
5 cfs flow restoration at EFID	714	A
10 cfs flow restoration at EFID	1,428	A
15 cfs flow restoration at EFID	2,143	A
5 cfs flow restoration at Dee	542	505
10 cfs flow restoration at Dee	1,085	1,009
5 cfs flow restoration at FID	375	314
10 cfs flow restoration at FID	749	627
15 cfs flow restoration at FID	1,124	941
50 cfs flow restoration at Powerdale bypass reach	3,107	1,564
100 cfs flow restoration at Powerdale bypass reach	6,213	3,217
150 cfs flow restoration at Powerdale bypass reach	9,320	4,691
200 cfs flow restoration at Powerdale bypass reach	12,426	6,254
250 cfs flow restoration at Powerdale bypass reach	15,533	7,818

a = No spring Chinook in these streams

Spring Chinook – In addition to increased number of rearing steelhead parr in the Hood River Basin with water conservation activities, evaluation of these activities also generated projections of increasing numbers of rearing spring Chinook parr. Simulated irrigation diversion reductions of 10 cfs in the Dee and 15 cfs in the FID systems projected an added habitat capacity of 1,950 Chinook parr in these two systems combined (Table 40). As with steelhead, a positive relation existed between the magnitude of water diversion reductions and the additional rearing capacity for spring Chinook in the Hood River Basins (Figure 84).

Conservation of every 50cfs of water at Powerdale Dam could increase capacity within the depleted reach below the dam by an estimated 1,564 parr. Restoring 250 cfs below Powerdale would increase spring Chinook capacity by 7,818 parr (Figure 85).

Figure 84. Estimated increased parr production potential from reduction of water withdrawals at irrigation diversions.

Figure 85. Estimated increased parr production potential from reduction of water withdrawals at Powerdale Dam.

Powerdale Dam was scheduled for decommissioning by 2010 with 500 cfs of water rights returning to the state of Oregon. The water rights were allocated for fish and wildlife benefits by increasing stream flow. The increased flow will increase production of steelhead and spring Chinook. Caution should be used using the data presented in Figure 4 for setting expected benefits from the increased stream flow. Our analysis of expected benefits appears to be optimistic and should be viewed only as a means to compare maximal magnitudes of benefit from actions instead of an actual estimate of production. The bottom line is the additional 500 cfs in the stream will benefit fish and wildlife greatly, and benefits will depend to some extent on the degree that juvenile steelhead and spring Chinook use reaches with restored flow.

Fish Passage

A major restoration action, in 1996 was conducted by the East Fork Irrigation District (EFID). EFID installed a fish screen at its diversion on the East Fork Hood River (RM 8; Coccoli and Lambert 2000). This diversion was operated without a screen for decades despite the high proportion of flow diverted by the diversion. The addition of this screen marked an important step in recovering natural steelhead populations in the Hood River Basin. Despite the importance of screens such as this one, many of the irrigation diversions in the Hood River Basin remain unscreened, or were in poor working condition. Several projects proposed by Coccoli (2002) to improve anadromous population in the Hood River Basin were targeted at installing or improving irrigation diversions.

The benefits of adding screens at major diversion were evaluated by estimating the number of mortalities that were prevented with screens of various efficiencies. This analysis involved an assumption regarding the number of juveniles that would be entrained into the diversion if it were unscreened. We assumed that entrainment would be proportional to the percent of stream flow that was diverted. The proportion diverted was multiplied by the estimated number of outmigrants passing the diversion. Separate estimates were made on a monthly basis and summed across the spring outmigration season. Various estimates of the amount of entrainment prevented were calculated for screens of varying efficiencies. The method of estimating entrainment can be described with the following equation:

$$\# \text{ Entrained} = \sum \% \text{ Diverted}_i * \# \text{ of Outmigrants}_i$$

Where: % Diverted = Percent of flow that is diverted.

of Outmigrants = Number of juveniles passing the diversion estimated via
bi-weekly trap efficiencies.

i = Month

At the Dee Irrigation Diversion, flow estimates in the West Fork at the diversion were back-calculated from the flow gauge near the mouth of the West Fork by the flow contributed by Green Point Creek.

Estimates of entrainment at Powerdale Dam indicted that up to 85,000 hatchery and wild juvenile spring Chinook and steelhead would be entrained if there were no screen at the diversion. Screens of progressive efficiencies in increments of 20% decreased the number of entrained juveniles by 17,000. The number of juveniles entrained in each group (origin, life stage, or species) were relative to their abundance passing the diversions. Losses were highest among hatchery spring Chinook smolts with significant losses also occurring among hatchery and wild steelhead smolts (Figure 86).

Figure 86. Estimated entrainment of various groups of juvenile salmonids at Powerdale Dam under various diversion screen efficiencies.

Entrainment losses at the East Fork Irrigation Diversion were comprised solely of wild steelhead juveniles. Under a no screening scenario, an estimated 7,200 wild steelhead were entrained each year. Increased screen efficiencies of 20% decreased entrainment by 1,400 steelhead at each level of efficiency (Figure 87). Losses of steelhead smolts were estimated to be 288 fish under a no screening scenario. Losses were greatest in the fry age class (<100mm) at 4,700 fish.

Figure 87. Estimated entrainment of various groups of juvenile salmonids at East Fork Irrigation Diversion under various diversion screen efficiencies.

Losses from entrainment at the Dee Irrigation Diversion were relatively minor. An estimated 86 juveniles were lost annually from the irrigation diversion. These losses were comprised by hatchery and wild summer steelhead and wild spring Chinook smolts (Figure 88).

Figure 88. Estimated entrainment of various groups of juvenile salmonids at Dee Irrigation Diversion under various diversion screen efficiencies.

Diversions at the Farmers Irrigation Diversion were estimated to entrain approximately 13,000 juveniles under no screen conditions. Additions of screens with increments of 20% efficiency decreased the entrainment by 2,600 juveniles for each increment. Hatchery spring Chinook and steelhead smolts comprised the largest portion of the entrained population, but a significant portion was made up by wild steelhead smolts as well (Figure 89).

Figure 89. Estimated entrainment of various groups of juvenile salmonids at Farmers Irrigation Diversion under various diversion screen efficiencies.

Each form of habitat restoration carried out as part of the HRPP had positive effects on spring Chinook and steelhead habitat, and most likely benefited non-target populations. Quantification of benefits was somewhat hindered by a lack of pre and post-project monitoring for some projects, and a lack of understanding of how changes in habitat affect production potential and survival at different spatial and temporal scales. Of the various improvements, the projects that involved restoring flow or screening of diversions had the most positive effects on spring Chinook and steelhead production. Those projects influenced the primary migratory and rearing reaches within the basin, and thus impacted the most individuals. Future restoration activities should take into account the likely benefit from the proposed action and weigh the benefit against benefits from other proposed projects in order to prioritize project implementation.

Future restoration efforts should consider the findings of the UCM and analysis of habitat data that identified what features were limiting capacity in the basin. Consideration should also be given to the theorized natural state of the basin. Turbidity levels were naturally high, and given the high throughput of sediment, it was likely that fines have always been somewhat high in riffle substrate. Also, high gradient and the flashy nature of the system likely prevent the

accumulation of significant wood cover throughout the main forks and mainstem. Consideration of these factors will increase the likelihood of HRPP habitat improvement success. Our review indicated habitat improvement actions that increased stream flow and screened withdrawals provided the greatest benefit to fish. These activities should be considered a higher priority than in-stream habitat improvements and riparian management. .

CHAPTER 7: ENHANCEMENT OF NATURAL PRODUCTION

KEY FINDINGS IN CHAPTER 7:

- Unmarked adult spring Chinook generally arrived at Powerdale Dam from mid-April to early October with a peak in June and the second in September.
- On average, returns of naturally-produced spring Chinook were 4% mini-jacks, 3% jacks, and 93% adults age 4 and older.
- Spawning ground surveys indicated that spring Chinook spawning peaked about mid-September. A majority of the spawning effort occurred in the lower portion of the West Fork.
- Thermograph data and spawn timing indicated that spring Chinook fry should have begun emerging in mid March. Catches of juvenile spring Chinook in the West Fork screw trap indicated that most juveniles emigrated as fry (FL<50mm) in the spring or as presmolts in the fall.
- The absence of a presmolt emigration in the fall pass the mainstem trap indicated that many presmolts leaving the West Fork remained in the upper mainstem through winter, and then emigrated as smolts in the spring.
- Captures of wild spring Chinook outmigrants in screw traps from 1994 to 2001 suggested that wild spring Chinook predominantly migrated out of the Hood River in the fall.
- Wild spring Chinook smolt production in the Hood River Basin was at it highest 11,745 smolts in 1994 and ranged from 873 to 1,723 during the period 1995 to 1999.
- UCM modeling estimated the Hood River capacity at 44,835 spring Chinook parr, which would produce 15,692 smolts. Smolt production measured by the screw traps indicated the basin was producing less than 10% of the estimated capacity.
- The number of wild adult spring Chinook returning to Powerdale Dam on the Hood River ranged from 24 to 97 annually, with a total wild and hatchery return ranging from 53 to 647 adults.
- Based on the life cycle model described in chapter 10, we estimated that roughly 125 adult spring Chinook were needed to fully seed the Hood River to capacity. In only two of the years from 1996- 2001, was that number of adults reached above Powerdale Dam.
- Recruits per spawner (R/S) estimates for spring Chinook were low due to poor egg to smolt survival in the Hood River Basin. Hood River egg to smolt survival averaged 0.55%, where as the Warm Spring River egg to smolt survival averaged 8.71%.

- Prespawn mortality of spring Chinook has not been measured in the Hood River and is therefore a critical uncertainty.
- The survival of hatchery fish was dramatically different from wild fish. The average survival rate of hatchery spring Chinook for brood years 1993- 1997 was 0.2%, compared to a survival rate of 5% for wild fish during the same period.
- Wild spring Chinook mortality occurred primarily during the egg to smolt stage, while hatchery spring Chinook mortality occurred primarily during the smolt to adult stage. Straying and precocity contributed to low returns as adults of hatchery fish.
- Since 1994, the number of returning hatchery spring Chinook was increasing, while the number of wild fish was decreasing. Thus, the current program was not meeting the goal of supplementation. The lack of adaptation in the supplemental stock appeared to be a primary problem of the HRPP program and should be resolved.
- Adult summer steelhead began arriving at Powerdale Dam in mid-March, migration typically peaked in early July, and declined sharply during August. Passage peaked a second time during November.
- Summer steelhead returned to the Hood River at between 2 – 6 years of age. The predominant age of returning wild adults was age four. Returning adults spent from 1 –3 years in the ocean, with the average length of time spent in the ocean being 2 years.
- Females composed an average 68% of summer steelhead returning to the Powerdale fish trap from 1994 to 2001. Fecundity averaged 4,100 to 4,400 eggs per female from 1997 through 2000.
- Outmigration of summer steelhead smolts past the West Fork and mainstem screw traps peaked from mid-April to mid-June. Spring outmigration was primarily smolts with a fork length greater than 150 mm.
- Wild fish composed less than 10% of summer steelhead smolts migrating out of the Hood River from 1999 through 2001. Hatchery releases ranged from roughly 15,000 to 30,000 smolts, while the number of wild smolts migrating past the screw trap ranged from 550 to 2,000.
- Comparison of observed parr rearing densities for summer steelhead in tributaries to the West Fork Hood River during 1994-1997 to predicted densities at full capacity indicated that seeding there was near capacity.
- Summer steelhead recruits per spawner (R/S) averaged 0.18, and ranged from 0.38 to 0.09 for hatchery and wild adults passed above Powerdale Dam to spawn. The low R/S estimate indicated the natural spawning population was not replacing itself.
- Winter steelhead spawned primarily in the mainstem Middle Fork and East Fork of the

Hood River (Coccoli 2000), while summer steelhead spawned in the West Fork Hood River.

- Screw trap sampling suggested winter steelhead primarily migrated out of the East Fork in the fall instead of the spring. Emigrants moved into the upper mainstem and roughly 9% of the fall emigrants moved into the lower 4 miles of the Hood River or the Columbia River. The contribution of fall migrants to adult returns was unknown and should be resolved
- Steelhead smolts migrated from the Middle Fork and upper mainstem primarily in the spring.
- Comparisons of observed rainbow/steelhead densities to predicted densities at full capacity in Neal Creek indicate it was probably seeded near capacity, and that the East Fork and Middle Fork Basins were producing below capacity.
- Estimates of winter steelhead smolt capacity in the East and Middle forks were usually greater than estimates of wild steelhead passing screw traps suggesting that the East Fork may be below full seeding.
- Adult returns of wild winter steelhead to Powerdale Dam ranged from 194 to 1,002, during 1993 through 2000.
- The mean egg-to-smolt survival was 1.8% and the mean smolt to adult survival was 6.4%. The HRPP undocumented goal of 4% smolt-to-adult survival was exceeded.
- The adult recruits per wild winter steelhead spawner averaged 1.98 and ranged from 0.87 to 3.71. The supplementation program appeared to be meeting the goal of stabilizing and increasing the population.
- The hatchery program appeared to benefit the wild population by increasing population size. The average smolt to adult survival for hatchery fish was far lower (1.45%) than for wild fish (6.4%). However, the mortality associated with both initial release and harvest appeared to account for a majority of the difference. This hatchery program met or exceeded program goals.
- DNA analysis of adult steelhead passing Powerdale Dam since 1991 revealed that Skamania Summer steelhead which spawned naturally produced only 50% and 23% as many recruits per spawner from the 1995 and 1996 broods as did wild fish spawning naturally. Similarly, the natural spawners of the Big Creek stock produced only 35% as many recruits per spawner as wild winter steelhead spawners. In contrast, hatchery winter steelhead from the native stock produced similar numbers of recruits per spawner to wild spawners.

SPRING CHINOOK

Information was generally lacking on the indigenous stock of spring Chinook in the Hood River Basin, which was extirpated by approximately 1965

(Cramer 1991). The only historical records of spring Chinook abundance were obtained from trapping at

Powerdale Dam during May and July from 1962 to 1971. The largest annual number trapped during this period was 28, collected in 1964 (Cramer 1991). No description of indigenous Hood River spring Chinook life history traits was completed prior to their extirpation. Therefore, we were limited to drawing comparisons between re-introduced spring Chinook in the Hood River (1994 through 2001) and the Deschutes donor stock.

Spring Chinook Life History Traits

The ODFW began releasing a mix of marked and unmarked Carson stock spring Chinook into the Hood River from 1986 to 1992. As a consequence, the returning fish designated as wild may have been unmarked hatchery fish or wild progeny of the Carson stock. Moreover, the Columbia Basin contains numerous spring Chinook hatchery programs, many of which released unmarked fish during the collection of the data provided in this report. As a result, the apparent wild fish may have been unmarked hatchery fish straying into the Hood River. We assumed, however, that a majority of the unmarked fish represented wild progeny of fish that had spawned naturally in the Hood River.

Spring Chinook Adult Migration

Unmarked adult spring Chinook generally arrived at Powerdale Dam from mid-April to early October (Figure 90). The migration exhibited two distinct peaks, the first occurring in June and the second in September. 1995 was the last year unmarked Carson stock spring Chinook returned in substantial number to the Hood River Basin.

Figure 90. Average percent adult spring Chinook migrate to Powerdale Adult fish trap (RM 4.5) of wild fish, 1994-2001 (Olsen July 2002)

Age composition of returning adults was determined by scale analyses conducted by ODFW. The majority of spawners were age-4 (57%) or age-5 (27%) (Table 41). Most of these fish had smolted at age 1+ (age 2 in Table 18), but the 23% that smolted in their first year (Table 41) is unusually high for spring Chinook. On average, 4% were mini-jacks, 3% were jacks, and 93% were adults age 3 and older. Mini-jacks accounted for 0 to 13% and jacks comprised 0 to 6% of total annual runs. Spring Chinook in the Deschutes River generally entered the ocean in the spring at age-1+ and return at age-3 through age-5.

Table 41. Age composition by freshwater, saltwater, and total age for wild spring Chinook returning to the Hood River from 1994 through 2001 (Olsen Draft).

Age	Freshwater	Saltwater	Total
0	-	5%	-
1	23%	2%	-
2	77%	54%	6%
3	<1%	35%	9%
4	-	4%	57%
5	-	-	27%
6	-	-	<1%

Spawning ground surveys indicated that peak spawning occurred, on average, approximately mid-September (Lambert et al. 1999). A majority of the spawning effort occurred in the lower portion of the West Fork, although, some spawning occurred throughout the entire fork. Spawning was not surveyed in the mainstem. However, radio telemetry studies indicated that few if any fish spawned in the mainstem (Lambert et al. 1996). The East Fork and Middle Forks did not support Chinook spawning, as indicated by the absence of juvenile Chinook catches in screw traps in those forks (Olsen Draft).

Spring Chinook Egg Incubation and Fry Emergence

Emergence timing was not studied in the Hood River, but thermograph data and spawn timing indicated that spring Chinook fry should have emerged beginning in mid March (Figure 91). Studies by Piper et al. (1982) indicated that Chinook eggs require about 450 daily temperature units (DTU's) to achieve eyed stage, 750 DTU's to hatch, and 1,600 DTU's to emerge. Emigrating fry were detected in West Fork screw traps from March through mid-June. In contrast, fry emergence from natural spawning in the Warm Springs River was slightly earlier, beginning in February. The difference in emergence times between the Hood River and Warm Spring River appeared to be driven by water temperature. The Warm Spring River was slightly cooler in the summer, resulting in peak spawning two weeks earlier than in the Hood River (Figure 92). Furthermore, the Warm Springs River was slightly warmer during the winter months after hatching. Theoretically, the Warm Spring population could have emerged an entire month before the Hood River population.

Water temperature during incubation did not appear to be a factor directly affecting egg survival. Spring Chinook eggs are susceptible to mortality when the water temperature is below 5°C and above 15°C (Piper et al 1982). Spring Chinook eggs in the Hood River Basin were not subjected to temperatures outside of these tolerance limits. Egg to smolt survival may be affected, however, by the later emergence in the Hood River. In the Hood River, February was generally the period of highest peak flows caused from rain-on-snow events (Figure 93). These peak flows may have scoured pre-emergent fish out of the gravel, thus reducing survival. If emergence occurred at the beginning of February, as was suggested for the Warm Springs River, fry may have experienced greater survival.

During development of the Hood River Production Program, consideration was given to genetic and life history traits for the re-introduction of spring Chinook. The Deschutes hatchery stock at Round Butte Hatchery was selected as the Hood River re-introduction stock because the stock was available and in close proximity to the Hood River. This Deschutes hatchery stock may not spawn early enough in the season to avoid the deleterious effects of winter freshets as suggested above. The Deschutes stock did not demonstrate special survival traits under extreme natural environmental conditions during the embryo and fry stages resulting in high productivity.

Figure 91. Estimate of spring Chinook egg development based on mean West Fork water temperature (temperature data provided by Alexis Vaivoda, CTWSRO).

Figure 92. 7-day average temperature profiles for both the West Fork Hood River (Hood River Basin) and the Warm Springs River (Deschutes River Basin). Daily values for the West Fork Hood River are average daily values from 1994-2001. Daily values for the Warm Springs River are average daily values from 1999-2002.

Figure 93. Daily minimum, maximum and mean stream flow at Tucker Bride averaged over the period 1991 to 2000.

Spring Chinook Juvenile Outmigration

Catches of juvenile spring Chinook in the West Fork screw trap, expanded for days not sampled, indicated that most juveniles emigrated as fry (FL < 50 mm) in the spring or as pre-smolts in the fall (Figure 92, Olsen July 2002). Mean length of emigrants in the fall were similar to those of yearling migrants the following spring (Figure 95). Trapping generally did not start until the last week of March, and it appeared that fry were migrating prior to trap installation (Figure 35).

An emigration of yearling smolts in the spring was far more apparent downstream in the mainstem screw trap (Figure 94). The majority of spring migrants were longer than 70 mm (age 1+ and 2+)(Figure 97). The main difference between trap locations was that many more yearlings were captured at the mainstem trap, while catches of fry were similar between the two locations (West Fork, n=180 and mainstem n~ 250). Emigration of fish >70 mm during the fall was also similar between the West Fork and mainstem traps. However, few fish were sampled for age determination, resulting in a limited understanding of actual age at emigration.

Figure 94. Average number of spring Chinook captured in screw traps from 1995 through 2001 in the West Fork Hood River (RM 1). Catches were expanded to include unsampled days for each two-week period, but were not expanded for capture efficiency.

Figure 95. Average fork length of emigrating wild spring Chinook captured in the West Fork Hood River screw trap from 1995 through 2001. Age was determined by scale analyses.

Trap catches indicated that most juveniles left the West Fork during their first summer, either as fry or as fall pre-smolts. The much larger catch of age 1+ smolts in the spring at the mainstem trap indicated that many fish leaving the West Fork, remained in the mainstem through winter, and then emigrated as smolts in the spring. Furthermore, it appears that a large percentage of juveniles emigrating from the West Fork did not stop in the mainstem, rather they continued to the lower four miles of the mainstem or into the Columbia River.

In their 1993 Annual Report Olsen and French (1994) identified an unusual growth pattern on spring Chinook scales showing accelerated freshwater growth for a short period before entering salt water. This was odd because the accelerated growth implied the fish migrated into the mainstem Hood River and/or Columbia River during the fall, a life history pattern not believed to be expressed in lower Columbia River spring Chinook. This unique life history pattern could be the result of misidentified fall Chinook and strays, or due to unusual behavior of the Carson Stock. Olsen et al (1995) in the 1994 Annual Report detected the unusual life history pattern and suggested the possibility the Carson stock could be maladapted for the Hood River and therefore outmigrated in the fall. Subsequent annual reports make no further mention of this unique life history pattern previously observed. Nor do the reports address potential reasons for the observed pattern, or explore possible risks and benefits from the aberrant life history.

Captures of wild spring Chinook outmigrants in screw traps from 1994 to 2001 by Olsen (personnel communication, ODFW) suggested that wild spring Chinook predominantly migrated out of the Hood River in the fall. Are fish moving to the ocean in the fall or to the Hood Mainstem and Columbia River to rear until next spring? Further, do fish migrating in the fall benefit, in terms of survival, over fish migrating in the spring?

Brannon et al. (2002), Healy (1991) and others have reported a fall outmigrant life history pattern in some spring Chinook populations. Data for the Hood River was not sufficient to confirm the fate of the fall migrants, but ODFW biologists report that many of these fish have the same silvery appearance as spring smolts. The program should determine whether fall outmigration was indeed a viable life history pattern, or whether this behavior indicates poor adaptation to the Hood River. PIT tagging of these fish would reveal much about their eventual migration timing past Bonneville Dam and their survival to return as adults.

Figure 96. Average number of spring Chinook captured in screw traps from 1995 through 2001 in the mainstem Hood River (RM 4.5), with expansion for average number of days sampled per biweekly sample period. Size categories are based on fork length.

Figure 97. Average fork length of wild spring Chinook captured in the mainstem Hood River screw trap from 1995 through 2001. Age was determined by scale analyses.

Wild smolt production has been limited in the Hood River Basin, ranging from 873 to 1,723 during the period 1995 to 1999 (Olsen July 2002; Table 42). The one exceptional year of production was 1994, when an estimated 11,745 smolts emigrated through the mainstem. Coincidentally, 1994 marked the first year of screw trap operation in the mainstem Hood River. Olsen (1998) indicated that mortality of marked fish was believed to be high, which artificially increased the smolt estimate. In fact, Olsen (pers. com. ODFW) believed the smolt migrant estimates for spring Chinook were suspect due to the limited recaptures, and had not formally reported the estimates. We provide the estimates here recognizing the limitations of the data. Future outmigrant studies should be designed to estimate spring Chinook smolt numbers through the mainstem, and be able to compare these estimates to wild smolt outmigrant goals.

A goal of the HRPP reintroduction program was to create a self-sustaining population of wild spring Chinook. A reliable estimate of smolt outmigrants was required to measure progress towards the goal, but was not provided by the M&E program. However, even though the estimates were weak they did indicate that spring Chinook production was far below capacity. The UCM estimated the Hood River capacity at 44,835 parr, resulting in 15,692 smolts (based on 35% survival from parr to smolt). Smolt production measured by the screw traps indicated the basin was producing at less than 10% of the estimated capacity. The reintroduction program will not be successful without reestablishing a locally adapted wild population.

Based on the life cycle model described in Chapter 9, we estimated that roughly 125 adults were needed to fully seed the Hood River to capacity. The number of spring Chinook adults (age 3, 4 and 5) passed above the Powerdale Dam ranged from 57 to 989 adults (Figure 98) during the period from 1996- 2001. In only three of the years did the number of adults passed above the dam exceed the number of spawners needed to fully seed to capacity. Consequently, smolt production fell far short of capacity.

Table 42. Number of wild spring Chinook smolts (fork length greater than 70mm) emigrating past the mainstem screw trap.

Emigration Year	Smolts	Marked	Recovered	Catch	Trap Efficiency
1994	11,745	522	15	585	0.0498
1995	1,723	53	1	65	0.0377
1996	135	5	1	27	0.2000
1997	1,079	83	3	143	0.1325
1998	1,799	159	12	181	0.1006
1999	837	72	10	93	0.1111
2000	-	7	0	10	0.0000
2001	-	1	0	2	0.0000

Figure 98. Number of spring Chinook adults passed above Powerdale Dam to spawn in the wild, 1996 to 2001 based on data provide by Olsen during document review.

The reason for the low production was not detected owing to the fact that historic data on spring Chinook in the Hood River was limited. However the limited data available did suggest that the Hood River probably never produced substantial numbers of spring Chinook. Possible reasons for low production may be low over-winter survival, or that fish migrate out of the river in the fall due to an undetected habitat deficiency. Factors limiting smolt production was a critical uncertainty requiring HRPP attention. Measures should be taken to obtain better outmigrant estimates and identify reasons for the limited number of smolts.

Spring Chinook Adult Returns

The number of wild adults returning to Powerdale Dam on the Hood River ranged from 24 to 97 annually, with a total wild and hatchery return ranging from 53 to 647 adults (Figure 99). The HRPP adult return goal was 1,700 fish (Coccoli 2000). A sub-goal was an in-basin spawning escapement of 400 adults and a brood stock goal of 110. These goals did not differentiate between wild and hatchery fish. So, if we assume the brood stock and in-basin escapement was intended for wild fish, then 550 returning adults was needed to achieve the goal (Figure 98). Adult return data indicated the HRPP achieve less than 20% of the goal. (Olsen Draft). Furthermore, the goal was still not met based on a combined number of wild and hatchery passed above Powerdale Dam. The combined numbers ranged from 54 to 403 fish (Figure 98).

Figure 99. Number of wild and hatchery spring Chinook returning at age 3 and 4 to Powerdale Dam, 1996 through 2001 based on data provide by Olsen during document review.

The HRPP did not explicitly state a recruit per spawner (R/S) goal. The unstated goal must have been greater than replacement (2 R/S or greater) to rebuild the wild population. R/S estimates for wild Hood River spring Chinook were less than 1 R/S, indicating that the wild and hatchery fish allowed to spawn naturally above Powerdale Dam were not replacing themselves (Figure 100). In contrast, the Warm Spring River population was above 3 R/S in most years during the same period. Hood River and Warm Springs populations were both presumed to be from Deschutes Stock. Therefore, the data suggested that the Hood River population was not performing as well as the Warm Springs population, and in the right environment the Deschutes stock was capable of producing 6 R/S or perhaps greater.

Why was the Deschutes stock performing better in the Warm Spring River than in the Hood River? Olson and Spateholts (2001) reported juvenile to adult survival rates, which included fall and spring migrants. In the Hood River, the only migrant estimates were for spring migrants. In order to compare these data, we had to consider the effect of the Warm Springs fall migrant survival on the overall survival estimate. Fall migrants were believed to overwinter in the lower Columbia, and therefore experienced mortality associated with overwintering. Spring migrants were believed to go directly to the ocean and not experience a second winter in the lower Columbia. These differences had to be accounted for in order to compare Hood River and Warm Springs populations on an equal footing. Doug Olson (personal communication, USFWS) indicated approximately 30% of the Warm Spring migrants were from the fall. We have

established overwinter mortality was approximately 35% (see Chapter 10 for further details).

Figure 100. Hood River and Warm Springs spring Chinook recruits per spawner. Hood River data from Olsen (Draft) and Warm Springs data from Olson and Spateholts (2001).

Figure 101 presents the revised smolt to adult survival of the Warm Springs and Hood River populations, comparing only spring migrant survival. The smolt to adult survival rates appeared to be similar between the two populations. The Warm Springs survival was on average 5% lower than the Hood River. That was to be expected, because the Warm Springs population had to pass an additional Columbia mainstem dam (The Dalles Dam). The difference in R/S estimates between the populations did not appear to be due to survival during the smolt to adult period. Instead, R/S appeared to differ due to egg to smolt survival. As with the smolt to adult comparison, the Warm Springs data was adjusted to remove the affect of including fall migrants in the survival estimate. Figure 102 displays the egg to smolt survival differences. Hood River egg to smolt survival averaged 0.55%, where as the Warm Spring River egg to smolt survival averaged 8.71%; approximately a 15 fold difference in survival rates.

The weak smolt outmigrant estimate may have factored into the low egg to smolt survival estimate. Both smolt to adult and egg to smolt survival estimates utilized the smolt outmigrant estimate. There was not a meaningful method to test the accuracy of the wild estimate, other than assuming low reliability due to the limited number of recaptures. However, after comparing the smolt to adult survival estimate between basins, we concluded the Hood River estimate was reasonable due to the similarity to the Warm Springs estimate. Therefore, we were convinced the primary reason for the low R/S estimate was low egg to smolt survival.

Figure 101. Smolt-to-adult survival of wild Hood River and Warm Springs spring Chinook. Hood River data from Olsen (Draft) and Warm Springs data from Olson and Spateholts (2001).

Figure 102. Egg to juvenile survival of the wild Hood River and Warm Spring Chinook populations.

A number of factors may have contributed to the low egg to smolt survival in the Hood River. The estimated number of eggs released was based on an assumption that 90% of the spring Chinook released above the Powerdale Dam survived to deposit eggs in redds. However, prespawn mortality has not been measured in the Hood River and was therefore a critical uncertainty. Far fewer fish may have survived to spawning than was assumed.

Another possible reason for low egg to smolt survival in the Hood River was hatchery fish likely experienced disproportionately lower survival in the river than did the wild fish. Hatchery fish were released into the headwaters of the West Fork and were then expected to find appropriate spawning areas when they returned as adults. In contrast, we believe wild fish imprint to precise spawning areas when they emerge from the gravel. These spawning areas become proven production sites, as evidenced by the survival of the now returning wild fish. The hatchery fish spawn where they can find appropriate conditions without proven survival from a prior generation. Consequently, hatchery fish that spawned in poor habitat resulted in reduced egg to smolt survival.

Finally, emergence (regardless of hatchery or wild origin) in March rather than in February may have reduced egg to smolt survival due to flood events. However, when average daily flow for February was regressed against egg to smolt survival, the relationship was not significant ($p=0.73$, $r^2=0.22$). Similar results were obtained when annual flow, and a number of other combinations by month and mean daily flow, were regressed against egg to smolt survival. In most analyses there appeared to be a positive relationship between flow and egg survival. The greater the flow the greater the survival. Ultimately, data collected by the M&E program was not sufficient to identify the factors limiting egg to smolt survival in the Hood River. Since egg to smolt appears to be the life stage limiting the wild population, further investigation is warranted.

Hatchery Contribution to Wild Fish

The survival of hatchery fish was dramatically different from wild fish (Figure 103). The average survival rate of hatchery fish for brood years 1993- 1997 was 0.2%, compared to a survival rate of 5% for wild fish during the same period (the brood year 1994 survival of wild fish was inexplicably high, and was thus excluded; Table 43). Wild fish mortality occurred primarily during the egg to smolt stage, while hatchery fish mortality occurred primarily during the smolt to adult stage, because life in the hatchery allows unfit fish to survive until release into the wild. Even though hatchery fish were not expected to perform at the same level as wild fish, the hatchery return rates of 0.2% were far below the undocumented HRPP goal of 1% or greater. The straying and precocity issues discussed in Chapter 5 were most likely the main cause for the low smolt to adult survival beyond initial release mortality. Strays and precocial fish were not included in the survival estimates because they did not contribute to hatchery or harvest objectives.

Since 1994 the number of returning hatchery fish was increasing, while the number of wild fish was decreasing (Figure 104). The HRPP was attempting to reintroduce and then supplement subsequent wild fish. RASP (1992) defined supplementation as:

Supplementation is the use of artificial propagation in an attempt to maintain or increase natural production, while maintaining the long-term fitness of the target population and keeping the ecological and genetic impacts on non-target populations within specified biological limits.

Since the wild fish were decreasing, the current program was not meeting the goal of supplementation. This point presents a dilemma. To increase wild fish numbers through supplementation, the hatchery program should use brood stock from the best adapted group, which were the wild spawners. However, the number of wild spawners was not sufficient to supply the hatchery brood, and further removal of wild fish from the river reduced the number of wild spawners. As a result, non-Hood River adapted spring Chinook (from the Deschutes River) were used to backfill the brood stock deficiency. Thus, hatchery offspring from parents with little to no adaptation to the Hood River were released into the river and expected to supplement the wild population. The lack of adaptation appears to be a primary problem of the HRPP program. Chapter 10 explores a means to surmount this difficult problem with use of the life cycle model.

Figure 103. Smolt-to-adult survival of hatchery and wild spring Chinook in the Hood River.

Table 43. Adult Returns (age 3 and 4) and survival indices of wild (naturally produced) and hatchery spring Chinook in the Hood River .

Offspring Brood Year	1993	1994	1995	1996	1997	Average	Stdev
Wild							
Males Past PD (a)	19	18	21	9	37	21	10
Females Past PD (a)	28	33	16	16	48	28	13
Females Spawning (b)	21	25	12	12	36	21	10
Total eggs (c)	63,000	74,250	36,000	36,000	108,000	63,450	30,036
Egg-Smolt Survival	0.0024	0.0002	0.0026	0.0170	0.0065	0.0057	0.0067
Egg to Adult Survival	0.0001	0.0001	0.0001	0.0007	0.0002	0.0003	0.0003
Smolt-Adult Survival (g)	0.0567	0.3131	0.0433	0.0475	0.0417	0.0473	0.1190
Smolt-Adult Return	0.0505	0.2815	0.0380	0.0434	0.0382	0.0425	0.1070
Recruits/Spawner	0.20	0.08	0.13	1.00	0.27	0.34	0.3786
Hatchery							
Males Past PD (a)	103	157	102	22	23	81	58
Females Past PD (a)	290	297	171	31	9	160	137
Females Spawning (b)	218	223	128	23	7	120	103
Total eggs (c)	652,500	668,250	384,750	69,750	20,250	359,100	308,568
# Smolt Outmigrants (d)	1,723	135	1,079	1,799	837	1,114	685
Wild PD Returns (e)	87	38	41	78	32	55	25
Hatch Smolt Release (f)	170,004	123,230	100,719	123,760	121,348	127,812	25,463
Hatch PD Returns (f)	298	13	92	23	688	223	284
Smolt-Adult Return	0.0018	0.0001	0.0009	0.0002	0.0057	0.0017	0.0023
Smolt-Adult Survival (h)	0.0025	0.0003	0.0014	0.0003	0.0080	0.0025	0.0032

(a) Data from ODFW PD return database adult returned in the previous year.

(b) Prespawn mort estimates assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.)

(c) Eggs/fem for StS & StW assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.) Eggs/fem for ChS, personal comm with Jack Palmer (RB Hatchery mgr.)

(d) Wild smolt outmigrants from ODFW Smolt database (Olsen July 2002)

(e) Data from ODFW PD return database (Olsen July 2002)

(f) Data ODFW (Tables 31, 53 and 73, Olsen Draft 2000-2001 Annual Rpt.)

(g) Estimated from expanded wild PD returns (e) (expanded via species specific survival model) and wild outmigrants (d)

(h) Estimated from expanded hatchery PD returns (g) (expanded via species specific survival model) and hatchery releases (f)

Figure 104. Hatchery and wild spring Chinook returning to Powerdale Dam.

SUMMER STEELHEAD

Summer Steelhead Life History Traits

Summer Steelhead Adult Migration

Adults began arriving at Powerdale Dam (RM 4.5) in mid-March, migration typically peaked in early July, and declined sharply during August. Passage peaked a second time during November (Figure 105). Pre-spawning adults remained in the river from the time of their arrival (March-November) until spawning the following spring (May-June).

Figure 105. Average migration timing of wild summer steelhead adults to Powerdale Dam (RM 4.5), 1994-2001 (Olsen July 2002)

Fish returned to the Hood River at 2 to 6 years of age with most at age 4 (Table 44). Returning adults spent from 1 –3 years in the ocean, with the average length of time spent in the ocean being 2 years (Olsen July 2002, Olsen Draft). Approximately 6% of the returning adults were repeat spawners. The average percent of females returning to the Powerdale fish trap from 1994 to 2001 was 68%, with an average fecundity of 4,100 to 4,400 eggs per female (ages 2 through 5 respectively) from 1997 through 2000 (Olsen Draft).

Table 44. Average age composition for wild summer steelhead trapped at Powerdale Dam from 1994 through 2001, based on scale samples (n=1,088). Data from Olsen (July 2002).

Age	Percent Composition		
	Freshwater	Saltwater	Total
1	1.3%	11.2%	0.0%
2	76.0%	76.7%	0.2%
3	22.6%	12.0%	9.9%
4	0.1%	0.0%	59.0%
5	0.0%	0.0%	29.1%
6	0.0%	0.0%	1.7%

Summer Steelhead Egg Incubation and Fry Emergence

Egg incubation studies have not been conducted in the Hood River, thus, stock-specific egg incubation timing data were not available. However, based on Hood River water temperatures, fry should swim-up during June through August. Screw trap data collected at the mouth of the West Fork indicated small numbers of fry present from June through August (Figure 106).

Summer Steelhead Juvenile Outmigration

The typical outmigration of steelhead smolts past the West Fork and mainstem screw traps peaked from mid-April to mid-June (Figure 107). The spring outmigration was primarily composed of fish with a fork length greater than 150 mm (age 1-3).

Scale analysis of wild summer steelhead outmigrants suggested that smolts ranged in age from 1- 3 years old with the majority of summer steelhead smolts having spent 2 years in freshwater (Olsen 2000 & 2003). Smolts (fork length greater than 150 mm) began migrating from the basin from late March through July, with peak migration during early May. Fish less than 150 mm were believed to be presmolts (ages 1-2), which would rear downstream until becoming smolts the following spring. Beginning in August, ODFW switches the size classes recorded from greater or less than 150 mm to greater or less than 100 mm. A steelhead/rainbow fork length greater than 100 mm roughly corresponded to fish age 1 or 2, and fish less than 100 mm were considered young-of-year. Figure 108 provides mean fork length by age and biweekly sample periods of fish captured by the West Fork screw trap from 1994 through 2001.

Figure 106. Average migration timing of wild steelhead/rainbow captured in West Fork screw trap, 1994-2001. Fish were distinguished as less than or greater than 150 mm from March through July, and were distinguished as less than or greater than 100 mm from August through November (Olsen July 2002).

Figure 107. Average migration timing of wild steelhead/rainbow captured in the Mainstem screw trap, 1994 through 2001 (Olsen July 2002). Capture data is expanded for days not sampled.

Figure 108. Mean fork length of wild steelhead/rainbow captured in the West Fork screw trap from 1994 through 2001. Age designations use July 1 as the birthday for increasing age by 1 year.

In the West Fork Hood River, up to 13% of the wild outmigrants had a fork length less than 150 mm. However, less than 1% of fish passing the mainstem trap were less than 150mm. This suggested that age 0 and age 1 fish moved out of the West Fork, and reared in the mainstem above Powerdale. The distance between the mainstem trap at Powerdale and the West Fork is approximately 10 miles. Therefore, the upper mainstem Hood River may provide important rearing habitat for the wild summer steelhead population.

Summer steelhead smolts migrating out of the Hood River during 1999 through 2001 were dominantly hatchery smolts. Hatchery releases ranged from roughly 15,000 to 30,000 smolts, while the (Figure 109). Number of wild smolts (greater than 150 mm) migrating past the mainstem screw trap ranged from 550 to 2,000. Thus, the number of hatchery smolts migrating out of the Hood River was about 15 times the number of wild smolts during the same spring period.

Figure 109. Total number of wild summer steelhead smolts (fish greater than 150mm) migrating past the West Fork trap during spring and summer, and number of hatchery summer steelhead smolts released into the Hood River (Olsen 200 and Draft).

Summer Steelhead Comparison to Electrofishing Densities

We compared observed rearing densities of parr estimated from ODFW to the densities at full capacity predicted by UCM. During late summer from 1994- 1997, ODFW estimated steelhead parr rearing densities via electroshocking at various locations within the Hood River Basin. Each sample location was a 60m reach where density estimates were made via multiple-pass removal electrofishing with block nets. The upstream end of each reach was generally at

the bottom end of a riffle, and the downstream end of each reach was generally at the upstream end of a riffle. Densities were calculated by dividing the total abundance estimate by the reach surface area and stream volume (Olsen et al. 1996).

For comparison purposes, only steelhead greater than 85 mm were used in the calculation of observed density. This was because, 1) 85mm was the length criteria set by ODFW to distinguish between age-0 and older fish, and 2) the UCM estimated capacity of age 1+ *O. mykiss*. ODFW river mile estimates from each sample site were used to align sample and UCM reaches. It was impossible to determine the exact location of the sample site, therefore electrofishing density was compared to UCM reaches (a much larger reach than 60 m). If a location was electrofished in multiple years, the observed densities between years were averaged for comparison to the estimated capacity density.

As reported in Chapter 3, observed densities in the West Fork Hood River during 1994-1997 appear to be near capacity. Observed densities of steelhead parr in six of seven tributaries reaches in the West Fork drainage were mid-way between the standard densities at capacity for pools and riffles (Figure 110). The percentage that pools or riffles composed of the sample reaches were not recorded, so we can only conclude generally that West Fork tributaries were seeded near capacity.

Figure 110. Comparison of observed *O. mykiss* densities in West Fork tributaries to standard densities used in the UCM.

Summer Steelhead Adult Returns

The recruits per spawner (R/S) averaged 0.18, and ranged from 0.38 to 0.09 for hatchery and wild fish passed above Powerdale Dam to spawn. The R/S estimate was calculated based on the assumption of a 90% prespawn survival rate (Olsen Draft). The low R/S estimate indicated the natural spawning population was not replacing itself. Egg to smolt survival was also very low, ranging from 0.03% to 0.33% with an average of 0.18% (Table 45). The 1993-1995 brood years were mainly wild spawning Skamania stock. However, the 1996 and 1997 brood was predominantly wild origin spawners and the survival quadrupled. The smolt to adult survival was on average 5.25%, indicating good survival after leaving the Hood River. As with the spring Chinook, the wild summer steelhead R/S estimate appeared to be low due to poor survival from the time they are released above Powerdale Dam to the smolt stage. Some reason for this may be inaccurate prespawn mortality estimates, poor egg survival due to flooding, and/or other factors limiting parr survival. Skamania hatchery fish were not include in this analysis because they are not considered a BPA program.

Summer Steelhead Hatchery Contribution to Wild Fish.

The Skamania stock was no longer used to supplement the wild fish after 1998. The wild endemic stock began returning in 2001 and was allowed to pass the Powerdale Dam to spawn naturally in the river (Figure 111 and Figure 112). A full brood year of returns from the native stock used in the hatchery had not been completed by the time of this report, so supplementation benefits from this new program could not be determined.

Table 45. Survival indices for wild origin naturally spawning summer steelhead in the Hood River from data provided in Olsen (July 2002, Draft).

Brood Year	1993	1994	1995	1996	1997	Average	Stdev
<u>Wild</u>							
Males Past PD(a)	130	85	67	43	56	76	34
Females Past PD(a)	350	145	133	81	113	164	107
Females Spawning(b)	315	131	120	73	102	148	96
Total eggs (c)	1,102,500	456,750	418,950	255,150	355,950	517,860	335,616
Egg-Smolt Survival (d)	0.0003	0.0010	0.0016	0.0030	0.0033	0.0018	0.0013
Egg to Adult Survival	0.0000	0.0000	0.0000	0.0002	0.0001	0.0001	0.0001
Smolt-Adult Survival (e)	0.0684	0.0498	0.0317	0.0712	0.0448	0.0532	0.0166
Smolt-Adult Return	0.0618	0.0450	0.0286	0.0643	0.0404	0.0480	0.0150
Recruits/Spawner	0.038	0.098	0.091	0.387	0.278	0.179	0.140

(a) Data from ODFW PD return database adult returned in the previous year.

(b) Prespawn mort estimates assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.)

(c) Eggs/fem for StS & StW assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.) Eggs/fem for ChS, personal comm with Jack Palmer (RB Hatchery mgr.)

(d) Wild smolt outmigrants from ODFW Smolt database (Olsen July 2002)

(e) Estimated from expanded wild PD returns (e) (expanded via species specific survival model) and wild outmigrants (d)

Figure 111. Number of summer steelhead adults returning to Powerdale Dam (Olsen July 2002 and comment provide by Olsen during draft review). Run year 2001 is based on an incomplete return.

Figure 112. Number of adult summer steelhead passed above Powerdale Dam (Olsen July 2002). Run year 2001 is based on an incomplete return.

Summer Steelhead Genetic Fitness of Hatchery x Wild Crosses

Recent advances in DNA analysis of salmonids made it possible to determine the individual parents of each naturally-produced steelhead passed above Powerdale Dam after 1995. Blouin (2003) was able to determine DNA types from scale samples that had been collected from every steelhead at Powerdale Dam since 1991, and age 4 offspring from DNA-typed steelhead began returning in 1995. Blouin's full report and analyses are presented in Appendix H. Blouin's data made it possible to determine the number of recruits from each spawner, and to compare fitness for natural production of wild and hatchery spawners in the wild. We summarize some key findings from his analysis here.

Blouin (2003) determined the number of adult recruits that could be assigned to each spawner, and then calculated the average recruits per spawner produced by each brood stock for either summer or winter steelhead. These calculations showed that Skamania Summer steelhead, which spawned naturally produced only 50% and 23% as many recruits per spawner as did wild fish spawning naturally (Figure 113). Similarly, the natural spawners of the Big Creek stock produced only 35% as many recruits per spawner as wild spawners. In contrast, hatchery winter steelhead from the native stock produced similar numbers of recruits per spawner to wild spawners (Figure 113). These data provide strong confirmation of prevailing theory that use of indigenous stocks will produce greater fitness for natural production than will introduced stocks.

Figure 113. Observed relative fitness for producing natural recruits from each brood having a full compliment of DNA-typed returns to Powerdale Dam. Values presented are weighted averages across sexes for the sex-specific values reported by Blouin (2003). Relative fitness is recruits per spawner for the stock of interest, divided by recruits per spawner for the wild stock.

The genetics data also revealed that from 20% to over 80% of spawners in a given brood failed to contribute any offspring to the next generation. Blouin (2003) reported this data separately for each sex of the parents, and we calculated a weighted average for those proportions across sexes for each brook. We found a curvilinear relationship between the

percentage of fish failing to recruit offspring and the recruits per spawner for that brood (Figure 114). That is, as recruits per spawner (survival) increased, an increasing percentage of spawners succeed in producing recruits to the next generation. The curve suggests that there are also 20-30% of the fish that do not contribute offspring, even when recruitment rate is high. It is likely that this base level of 20-30% non-contributors represents the typical range of prespawning mortality from all sources. It also suggests that prespawning mortality could not have been higher than 20-30%. We used this data as the basis to assume 25% prespawning mortality in our modeling work in Chapter 10.

Figure 114. Percentage of steelhead passing Powerdale Dam from the 1993-1996 broods for which no subsequent offspring returned to Powerdale Dam in the next generation. Data from DNA parentage analysis reported by Blouin (2003). Data includes summer and winter steelhead, and wild and hatchery fish that spawned naturally.

It was possible to unambiguously assign a mother-father pair to fewer than 40% of the unmarked adults returning to Powerdale Dam (1992 or later broods), a single parent to around 50% of them, and no parents to around 10-20%, depending on run year (Figure 115). When only one or no parent could be assigned, this indicated that the unidentified parent had not crossed Powerdale Dam, and therefore the recruit was either a stray or had one or both parents from resident fish above Powerdale Dam. Parentage analysis of marked steelhead taken for broodstock was able to distinguish parents for 96% of the hatchery fish, which indicates that stray rate of hatchery fish into the basin was about 4%. For those unmarked fish from which only one parent could be assigned, the identified parent was the mother approximately four times more often than it was the father. Blouin concluded that this was evidence of non-anadromous males parenting a significant number of anadromous offspring. We agree, and those males may have been either residual steelhead or resident rainbow.

Parentage Assignment Rate

Figure 115. Proportions of steelhead returning to Powerdale Dam for which parents could be identified among adults passed above the dam in previous years. From Blouin (2003). All steelhead passing Powerdale Dam in the parent generation had been sampled for DNA type.

WINTER STEELHEAD

Winter Steelhead Life History Traits

Winter Steelhead Adult Migration

Returning adult winter steelhead reached the Powerdale Dam fish trap beginning in February. The run rapidly increased throughout March, peaked during late April, then rapidly declined in May (Figure 116). ODFW developed and began employing a multifaceted protocol in 1996 to distinguish summer and winter steelhead at the Powerdale Trap. The protocol used a number of morphological measures to identify race (e.g. fin and maxillary mark combinations, external coloration degree of scale tightness and scale erosion, state of sexual maturity relative to the time of year, external parasite load, color of gill filaments and general appearance; Olsen 2000).

Winter steelhead spawned primarily in the mainstem, Middle Fork and East Fork of the Hood River (Coccoli 2000), while summer steelhead spawned in the West Fork Hood River. Spawning grounds had only been surveyed occasionally, so this separation of natal areas for the two runs was not confirmed until the mid 1990's. Radio telemetry studies of adult steelhead conducted by ODFW indicated that roughly 95% of the fish assigned to the summer run at the Powerdale Adult Trap spawned in the West Fork, while a similar percentage assigned to the winter run spawned in either the East or Middle Forks (personal communication, Erik Olsen, ODFW).

Figure 116. Average migration timing of wild and hatchery winter steelhead adults past Powerdale Dam, 1994 to 2001 (Olsen July 2002).

Approximately 61% of the wild fish returning to the Hood River during 1994-2001 were female. Average fecundity from 1992 through 2000 ranged from 3,700-4,700 eggs per female, for age 2 through age 5 fish respectively (Olsen Draft).

Winter Steelhead Egg Incubation and Fry Emergence

As with summer steelhead, stock-specific egg incubation studies had not been conducted in the Hood River. Therefore, empirical data on egg incubation timing for Hood River winter steelhead was not available. However based on water temperatures, fry should swim-up during June through August. Screw trap data collected at the mouth of the East and Middle Forks indicated that fry emigrated from June through August (Figure 117 and Figure 118).

Winter Steelhead Juvenile Outmigration

Historical data collected from outmigrant traps in the East Fork and Neal Creek during 1963 indicated that smolt outmigration peaked during April in Neal Creek and during June in the East Fork. Migration time probably reflected differences in temperature and flow regimes between these two tributaries (Cramer 1991). Recent screw trap data suggested steelhead/rainbow with a fork length greater than 150 mm (roughly equating age 2-3 migrates) and less than 150 mm (roughly age 1) moved out of the East and Middle Forks in the spring (mid-April through mid-June). In the Middle Fork, outmigration for the less than 150 mm size class peaked in July, much later than in the East Fork, which exhibited a weaker peak in April, but continued through July. Beginning in August, the size classes shifted to greater or less than 100 mm to distinguish between young-of-year and age-1 or greater migrants (Figure 119). East Fork fish exhibited a strong outmigration during fall of greater and less than 100 mm. The Middle Fork fall migration was not as pronounced as the East Fork, however the fall migration was worth noting. The Middle Fork outmigration pattern appeared very similar to that in the West Fork (Figure 118 and Figure 108).

In the East Fork 73% of the annual migration of steelhead juveniles occurred during fall, of which 54% were <100 mm. The Middle Fork wild fall migration was not as strong. Approximately 37% of the annual migration was fish with a fork length less than 100mm (age 0), and a small fraction of fish with a fork length greater than 100 (age1 or age 2) were observed. Mick Jennings (CTWSRO, personal communication) believes the fall migration may be in response to irrigation withdrawals at RM6 by the East Fork Irrigation district. If managers want to better understand the reasons for the fall migration, the effect of irrigation withdrawal warrants review.

Emigration past the mainstem trap differed between the forks and upper mainstem. As with spring Chinook, the mainstem trap indicated the greatest percent of emigration occurred in the spring with fewer fish emigrating in the Fall (Figure 120). A majority of the wild juveniles appeared to leave the East Fork in the fall and reside in the upper mainstem until the following spring. Approximately, 9% of the entire winter steelhead emigrated past the mainstem trap and out of the Hood River were accounted for by the Fall emigration. Fall emigrants may represent fish moving out of the East Fork due to an unknown habitat deficiency forcing the fish to move into the upper mainstem to overwinter and some fish may continue emigrating past the mainstem trap, because the upper mainstem had filled to capacity. The contribution of fall migrants to adult returns was unknown and represents a critical uncertainty. If fish emigrating out of the Hood River in the fall do not contribute to adult returns, then fall emigration represent a dead ended life history strategy. Further if the fall emigration past the mainstem trap occurred due to limited capacity in the upper mainstem then the UCM carry capacity estimates may be an overestimate, because UCM assumed carrying capacity in the East Fork, not only the mainstem. If fish managers want to further refine the UCM estimate and better understand the contributions of fall migrants to adult returns, studies should be conducted to address these uncertainties.

Figure 117. Number of wild steelhead/rainbow believed to be primarily winter steelhead captured at a screw trap in the Middle Fork from 1995 through 2001 (Olsen July 2002). Capture data is expanded by days of effort sampled.

Figure 118. Number of wild steelhead/rainbow believed to be primarily winter steelhead captured at a screw trap in the East Fork from 1994 through 2000 (Olsen July 2002). Capture data is expanded by days of effort sampled.

Figure 119. Mean length of steelhead/rainbow captured in the East Fork screw trap from 1995 through 2000 (Olsen July 2002).

Figure 120. Average migration timing of wild steelhead/rainbow captured in the Mainstem screw trap, 1994 through 2001 (Olsen July 2002). Capture data was expanded for days not sampled.

Olsen (draft, review comments) provided an estimate of winter steelhead spring emigrants at the mainstem screw trap. The number of winter steelhead smolting in the spring is represented in Figure 121 along with the number of hatchery smolt estimated at the mainstem trap. The number of wild winter smolts ranged from 3,383 to 20,912 and the number of hatchery fish released ranged from 11,089 to 52,412. The number of wild smolts accounted for 11% to 29% of the total emigrating steelhead smolts.

Figure 121. Comparison of wild and hatchery steelhead smolts regardless of race emigrating past the mainstem trap, 1994-2001 (Olsen Draft and review comments)

Winter Steelhead Comparison to UCM

ODFW estimated winter steelhead parr rearing densities via electrofishing at various locations in the Hood Basin in 1994-1997. Comparisons of these observed densities to predicted capacity densities and standard parr densities used in the model indicated that Neal Creek was probably seeded near capacity, and that the East Fork and Middle Fork Basins were producing below capacity.

Predicted capacity densities were higher than observed densities in 8 of 11 reaches. Observed densities in the East Fork Hood Basin and Middle Fork Hood Basin were similar to standard riffle densities and lower than standard pool densities (Figure 122). In Neal Creek, observed densities were higher than standard riffle densities and lower than standard pool densities. These results suggested that the East and Middle Fork were under-seeded while Neal Creek was closer to capacity.

East Fork, Middle Fork, & Neal Cr.

Figure 122. Comparison of observed *O. mykiss* densities to standard densities used in the UCM for electrofished reaches in the East Fork and Neal Creek.

Winter Steelhead Comparison to Screw Trap Estimates

Screw trap estimates of total outmigrants were compared to UCM winter steelhead smolt capacity estimates for the East and Middle Forks. Since the traps were not located at the mouth of each subbasin, capacity estimates in this comparison were adjusted to reflect production only from above the trap.

Winter steelhead smolt capacity estimates in the East and Middle forks were usually greater than wild steelhead downstream migrant estimates from screw trapping activities. The Middle Fork Hood was the only subbasin that ever exceeded capacity, and in four instances the upper 95% CI estimate exceeded that capacity (Figure 123).

Results of this comparison suggests that the East Fork was below full seeding. However, outmigration of winter steelhead parr in the fall from above the traps in the East and Middle forks may have influenced the smolt outmigration estimate. This is because smolts that appeared at the mainstem trap in the spring, but not at the forks, may have reared through the parr stage above the traps in the forks. Thus, production could be coming from the East or Middle Forks,

but because they move past those traps in the fall they do not count as part of the smolt outmigrant estimate in those respective forks.

In either event, while basins can rarely be expected to maintain full seeding consistently, it appears that the Hood Basin was to some extent under-seeded with winter steelhead at the time when UCM capacity estimates were compared to parr rearing densities and natural smolt outmigration estimates.

Figure 123. Comparison of UCM smolt capacity estimates (shown by the dotted line) to juvenile *O. mykiss* downstream migrant estimates from the East and Middle Forks. Bars denote 95% confidence intervals of migrant estimates.

Winter Steelhead Adult Returns

Adult returns of wild winter steelhead to Powerdale Dam ranged from 194 to 1,002, during 1993 through 2000 (Figure 124). The recruits per wild spawner (R/S) averaged 1.98 and ranged from 0.87 to 3.71. The supplementation program appeared to be meeting the goal of stabilizing and increasing the population. The wild origin natural spawners made up 59% of the population (Figure 125), which may be the reason for the stronger R/S estimate than either spring Chinook or summer steelhead exhibited. The mean egg to smolt survival was 1.8% and the mean smolt to adult survival was 6.4%. The HRPP undocumented smolt to adult survival goal of 4% was exceeded.

Figure 124. Number of winter steelhead returning to Powerdale Dam, 1993-2000 run years (Olsen July 2002). Run year begins in September of the year listed and ends the following July.

Figure 125. Number of winter steelhead Passed above Powerdale Dam, 1993-2000 run years (Olsen July 2002). Run year begins in September of the year listed and ends the following July.

Table 46. Winter Steelhead Survival indices, data provided by Olsen (July 2002, Draft)

Brood Year	1993	1994	1995	1996	1997	Average	Stdev
Wild							
Males Past PD (a)	119	80	72	79	89	88	18
Females Past PD (a)	214	204	79	129	142	154	56
Females Spawning (b)	203	194	75	123	135	146	53
Total eggs (c)	711,550	678,300	262,675	428,925	472,150	510,720	185,823
Egg-Smolt Survival	0.0066	0.0064	0.0276	0.0336	0.0125	0.0174	0.0125
Egg to Adult Survival	0.0004	0.0003	0.0011	0.0019	0.0010	0.0009	0.0006
Smolt-Adult Survival	0.0689	0.0532	0.0452	0.0622	0.0880	0.0635	0.0164
Smolt-Adult Return	0.0622	0.0480	0.0408	0.0562	0.0794	0.0573	0.0148
Recruits/Spawner	0.97	0.82	2.15	3.71	2.25	1.98	1.17
Hatchery							
Males Past PD (a)	5	3	3	93	95	40	49
Females Past PD (a)	8	2	1	67	150	46	65
Females Spawning (b)	8	2	1	64	143	43	61
Total eggs (c)	26,600	6,650	3,325	222,775	498,750	151,620	214,593
# Smolt Outmigrants (d)	4,870	4,416	7,347	21,895	12,161	10,138	7,256
Wild PD Returns (e)	303	212	300	1,230	966	602	464
Hatch Smolt Release (f)	38,034	42,860	44,909	59,837	62,135	49,555	10,760
Hatch PD Returns (e)	362	665	393	217	382	404	162
Smolt-Adult Survival	0.0159	0.0259	0.0146	0.0061	0.0103	0.0145	0.0074
Smolt-Adult Return	0.0095	0.0155	0.0088	0.0036	0.0061	0.0087	0.0045

(a) Data from ODFW PD return database adult returned in the previous years.

(b) Prespawn mort estimates assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.)

(c) Eggs/fem for StS & StW assumed by ODFW (Table 6, Olsen draft 2000-2001 Annual Rpt.)

(d) Wild smolt outmigrants from ODFW Smolt database (Olsen July 2002)

(e) Data from ODFW PD return database (Olsen July 2002)

(f) Data ODFW (Tables 31, 53 and 73, Olsen Draft 2000-2001 Annual Rpt.)

(g) Estimated from expanded wild PD returns (e) (expanded via species specific survival model) and wild outmigrants (d)

(h) Estimated from expanded hatchery PD returns (g) (expanded via species specific survival model) and hatchery releases (f)

Winter Steelhead Hatchery Contribution to Wild Fish

Since 1993, the indigenous hatchery program was releasing fish into the Hood River. This program appears to have benefited the wild population by increasing population size (Figure 126). The average smolt to adult survival for hatchery fish was far lower (1.45%) than for wild fish (6.4%). However, the mortality associated with both initial release and harvest appeared to account for a majority of the difference. Although Olsen (ODFW, Personal Communication – draft review comment) suggested that out of basin factors may also describe smolt to adult survival. This hatchery program met or exceeded program goals.

Figure 126. Winter steelhead adult return to Powerdale Dam (Olsen July 2002).

Genetic Fitness of Hatchery x Wild Crosses

Blouin (2003) analyzed DNA of steelhead returning to Powerdale Dam for estimating the number of adult recruits that could be assigned to each spawner. As described in the previous summer steelhead section, Blouin calculated the average recruits per spawner produced by each brood stock for either summer or winter steelhead. These calculations showed that natural spawners of the Big Creek stock produced only 35% as many recruits per spawner as wild spawners. In contrast, hatchery winter steelhead from the native stock produced similar numbers of recruits per spawner to wild spawners (see Figure 113). These data provide strong confirmation of prevailing theory that use of indigenous stocks in hatcheries will produce greater fitness for natural production than will introduced stocks. Blouin's report is included as Appendix H.

CHAPTER 8: EFFECTS OF HRPP ON NON-TARGET POPULATIONS

KEY FINDINGS IN CHAPTER 8:

- A primary objective of the HRPP was to minimize program affects on non-target populations. Non-target populations include species other than spring Chinook or steelhead within the Hood Basin, or any species outside of the Hood Basin.
- Stray rates of Deschutes stock spring Chinook released into the Hood River from the 1993-1997 brood years ranged from 0% -37% and averaged 18%. This compares to an average stray rate of 2% for Deschutes stock spring Chinook released into the Deschutes River from the 1980-1997 brood years.
- Given the low numbers of Deschutes stock Hood River returns from the pre-1997 broods (13-302 adults), the straying of hatchery spring Chinook into other basins was unlikely to have had insignificant genetic influence on other populations. The effects were particularly muted since most of the fish that strayed (86%) strayed into the Deschutes River.
- Data from CWT recoveries and observations by local biologists suggested that straying of hatchery summer and winter steelhead from the Hood River was low, however, a potentially large source of stray hatchery steelhead came from the sport fishery recycle program. The fate of unaccounted recycles was not known representing a critical uncertainty and should be resolved.
- The affect of competition on non-target populations within the Hood River was difficult to assess from available data. Monitoring of juvenile production has focused on trapping outmigrants, so there was inadequate information to detect changes in resident populations. The efficacy of an expanded M&E program to asses these effects should be deliberated.
- Genetics studies indicated that breeding with either resident rainbow or residual steelhead contributed up to half of all steelhead adults returning to Powerdale Dam.
- Cutthroat trout were present in the Hood Basin, but most populations were located upstream of anadromous populations (BPA 1996). Captures of cutthroat at screw traps within the basin were limited in number and insufficient to determine trends in abundance or condition.
- Bull trout were also present in the basin, but competition with anadromous hatchery fish was unlikely. This was because bull trout were found primarily in the upper Middle Fork, upstream of the steelhead production areas (BPA 1996).
- Predation caused by the HRPP fish on non-target species or populations was unknown

This data gap should be assessed.

- Additional predation could exist from precocial hatchery steelhead, however, it could not be assessed because the number of residual steelhead was unknown.
- Steelhead released into the Hood River were only diagnosed with diseases common to the region and therefore were not believed to transmit exotic diseases. Steelhead were diagnosed with Infectious Hematopoietic necrosis virus (IHN) and a “cold water” like disease. The incidence of illness was low and was not considered a reservoir of disease.
- Spring Chinook were found to be infected with IHN, bacterial kidney disease (BKD), fungus and Ceratomyxosis. Two out of eight years, the HRPP spring Chinook program has released fish with high BKD levels, which could have served as a reservoir of disease transmittable to wild fish.
- Very little harvest occurs on either natural fall Chinook or coho in the lower Hood River, so increased harvest on HRPP fish did not adversely affect these species. However, bull trout was a highly catchable species, and incidental hooking mortality likely occurred.

A primary objective of the HRPP was to minimize program affects on non-target populations. Non-target populations include species other than spring Chinook or steelhead within the Hood Basin, or any species outside of the Hood Basin. Native non-target populations within the Hood Basin include bull trout, cutthroat trout, rainbow trout, mountain whitefish, suckers, sculpin, and longnose dace. The Hood River Fisheries Project Environmental Impact Statement (EIS) (1996) and Genetic Risk Assessment (Cramer 1991) identified the potential impacts that proposed program actions may have on non-target populations. Potential affects included:

- 1) genetic risk associated with hatchery fish from the HRPP straying into other basins to spawn,
- 2) competition with Hood River non-target populations as the HRPP pushes the Hood Basin towards carrying capacity of spring Chinook and steelhead,
- 3) predation of hatchery fish on smaller non-target fish prior to and during outmigration,

- 4) disease propagation in the hatchery and disease transmission to non-target populations,
- 5) increased harvest on non-target populations in the Hood River resulting from increased effort on HRPP fish.

In this section, we present possible affects of the HRPP on non-target populations with respect to the concerns listed above.

POTENTIAL IMPACTS

Genetic Risk of Strays

Stray rates of spring Chinook and winter steelhead released into the Hood River were estimated from recoveries of CWT-marked fish. Although recoveries of CWT-marked spring Chinook and winter steelhead were relatively few, they provide an important insight into the general distribution and proportion of straying HRPP fish. Stray rates of Deschutes stock spring Chinook released into the Hood River from the 1993-1997 brood years ranged from 0% -37% and averaged 18% (Table 47). This compares to an average stray rate of 2% for Deschutes stock spring Chinook released into the Deschutes River from the 1980-1997 brood years (Table 48). These numbers indicated that stray rates of HRPP spring Chinook were high over the last 5 broods. However, the 1997 brood provided by far the greatest return of all broods (870 adults) and also had the lowest stray rate (0.5%) of the 5 year span. Quinn and Fresh (1984) found that straying of Cowlitz Hatchery spring Chinook was negatively correlated to the number of fish returning. Given the low numbers of Deschutes stock Hood River returns from the pre-1997 broods (13-302 adults), the straying of hatchery spring Chinook into other basins was unlikely to have had significant genetic influence on other populations. The effects were particularly muted since most of the fish that strayed (86%) strayed into the Deschutes River. This is because the spring Chinook released in the Hood River were Deschutes stock. In addition, if the stray rate of the 1997 brood (which returned more fish) was maintained in subsequent broods, then the genetic effect of Hood River strays on other populations would have been negligible.

Table 47. Stray rates for age 4 hatchery Hood River spring Chinook estimated from expanded CWT recoveries. Stray rate = Stray/(Powerdale + RiverSport + Stray). Recovery of CWT's from brood year 1994 was corrected for stock mixing at Pelton Ladder prior to analysis.

Brood Year	Hood R	Stray	Total CWT's	% Stray
1993	29.45	7.03	36.48	19%
1994	12	7.07	19.07	37%
1995	79	26.6	105.6	25%
1996	14	1.01	15.01	7%
1997	552	3	555	5%
Avg (93-97)				17%

Table 48. Stray rates for age 4 hatchery (Round Butte) Deschutes River spring Chinook estimated from expanded CWT recoveries. Stray rate = $\text{Stray}/(\text{Pelton} + \text{RiverSport} + \text{Stray})$. Recovery of CWT's from brood year 1994 was corrected for stock mixing at Pelton Ladder prior to analysis.

Brood Year	CWT Recovery Classification			Total	Stray Rate
	Pelton	River Sport	Stray		
1980	207.0		4.8	211.8	2.2%
1981	953.0	678.7	30.4	1,662.2	1.8%
1982	1,034.0	62.4	24.6	1,121.0	2.2%
1983	756.0	262.5	81.4	1,099.9	7.4%
1984	486.0	389.5	16.9	892.4	1.9%
1985	805.0	303.2	62.5	1,170.7	5.3%
1986	893.0	306.6	11.3	1,210.9	0.9%
1987	659.0	393.7	18.2	1,070.9	1.7%
1988	718.0	361.8	8.1	1,087.9	0.8%
1989	534.0	224.6	8.4	767.0	1.0%
1990	229.0			229.0	0.0%
1991	615.0		8.6	623.6	1.4%
1992	627.0	148.0	4.0	779.0	0.5%
1993	181.8			181.8	0.0%
1994	239.0			239.0	0.0%
1995	886.7			886.7	0.0%
1996	346.4	79.0		425.4	0.0%
1997	5.0			5.0	0.0%

Limited CWTs recoveries, combined with observations by local biologists indicated that straying of hatchery summer and winter steelhead from the Hood River was low. However, a potentially large source of stray hatchery steelhead came from the sport fishery recycle program. Excess hatchery steelhead that were not passed above Powerdale Dam to spawn were recycled to the lower Hood River to supplement the sport fishery. A certain proportion of these fish were harvested, and the rest either returned to Powerdale to be recycled again, or strayed, or died. Some of the recycled fish that returned to Powerdale Dam three or more times were sacrificed, but other fish were recycled up to 15 times (Olsen and French 2003).

Harvest rates of recycled steelhead were typically low, and in the past few years averaged approximately 5% for both summer and winter steelhead. Approximately 35% of the recycled fish that were not harvested returned to Powerdale and were recycled again. This leaves a large proportion of recycled steelhead that either strayed or died. Analysis of data on the fate of recycles showed that 4,474 steelhead have fallen into the category of stray/die over the last 6 years, and that the number grew larger with greater number of returns (Figure 127).

Figure 127. Number of recycled summer and winter steelhead that stray or die by spawn year.

The fate of the non-harvested fish was unknown. Although, studies of fall Chinook passage in the Snake River system provided insight as to the potential fate of recycled fish. Mendel et al. (1992;1993) radio tagged hatchery adult fall Chinook at Ice Harbor Dam in 1991 and 1992. A portion of these fish were passed above the dam, released and monitored. The remaining fish were transported several kilometers downstream of the dam and monitored. Of fish that were recycled below Ice Harbor Dam, 33-36% returned to Ice Harbor Dam and passed upstream, similar to the percentage of recycled steelhead in the Hood River that return to Powerdale Dam. Another 31-32% returned to the Ice Harbor Dam, but did not pass the dam and migrated back downstream towards the Columbia River. The remaining 31-36% proceeded immediately downstream to the Columbia River following release and never returned to Ice Harbor Dam. A large number of these fish were subsequently detected in the Yakima Basin while others were found in the Hanford Reach, Umatilla River, and John Day River. While it was difficult to distinguish between the affect of the radio-tagging on the migration patterns, Mendel (1993) suggested that evidence from the study indicated little difference in migration patterns between tagged and untagged fish.

The rate of tagged fall Chinook returning to Ice Harbor Dam and passing the dam were similar to observed rates of recycled steelhead returning to Powerdale Dam. An average of 54% of summer steelhead and 36% of winter steelhead that were not harvested returned to Powerdale Dam after each recycle. It could be assumed that the mortality rate of fish recycled was low, as in the fall Chinook study. Evenson and Cramer (1984) found that mortality of recycled spring Chinook in the Rogue River in 1981 to 1983 varied from 24.4 to 59.5%. The estimates from these studies suggested that a mortality rate of recycled fish may range from 3%- 60%, and that 30% was a reasonable approximation of actual mortality rates. By applying this strayed/died rate

since 1996 to the estimated number of recycled steelhead from the Hood River, we estimated that the recycle program has produced approximately 3,100 strays.

Stray Hood River recycled steelhead were recovered at multiple locations in the Lower Columbia Basin including: the White Salmon, Klickitat, Deschutes, Wind, and Clackamas rivers as well as Rock Creek, Eagle Creek, and at Bonneville Dam. A majority of the recoveries were in the White Salmon River whose mouth was directly across the Columbia River from the Hood River. Therefore, the potential impact of these strays on other populations was unclear, but would likely be the greatest in the White Salmon River. If these fish successfully spawn, then the genetic effects may be significant. If most of the fish were straying, but not spawning, or were straying to numerous locations with only a few surviving to spawn, then the effects were likely negligible. More data was needed to accurately assess the influence of recycled steelhead strays on non-target populations. These data could include the proportion of recycles that actually stray as opposed to those that die, and more information on where the strays relocate to.

Increased Competition

The affect of competition on non-target populations within the Hood River was difficult to assess from available data. The EIS (1996) noted that the HRPP could modify the abundance and distribution of rainbow trout, but that evaluation of the direct competition would be difficult, because juvenile steelhead and rainbow trout cannot be distinguished in the field. The affects were complicated by the presence of an ODFW hatchery rainbow trout fishery, which last stocked rainbow trout in 1996 (ODFW Fish Propagation, Portland as cited in Cramer et al. 1997). Isolating the affect of the HRPP steelhead induced competition from competition resulting from the hatchery rainbow trout not possible, but the discontinuation of that program has alleviated those difficulties.

Monitoring of juvenile production has focused on trapping outmigrants, so there was inadequate information to detect changes in resident populations. Genetics studies described in another section of this report indicated that breeding with either resident rainbow or residual steelhead contribute up to half of all steelhead adults returning to Powerdale Dam (Figure 128). Blouin (2003) found, "The surprisingly large number of missing parents, and the fact that most missing parents are fathers, suggests that precocious parr or resident trout are obtaining matings that produce anadromous offspring. Alternate explanations for offspring that lack both parents include a large number of unclipped hatchery fish or wild strays entering the system." However, elsewhere in the report Blouin (2003) found that fin-clipped strays were projected to account for only 4% of the run returning to the Hood River.

Figure 128. Fraction of steelhead offspring returning to Powerdale Dam that had one parent, both parents, or neither parent accounted for. Graph obtained from Blouin (2003).

Cutthroat trout were present in the Hood Basin, but most populations were located upstream of anadromous populations (BPA 1996). Captures of cutthroat at screw traps within the basin were limited in number and insufficient to determine trends in abundance or condition. The total number of cutthroat trout trapped among all five traps in the basin has ranged from 6-43 since 1994 (Table 49).

Table 49. Counts of cutthroat trout at downstream migrant traps located in the mainstem Hood Basin, 1994-2001.

Year	Mainstem	W. Fk.	M. Fk.	E. Fk.	Lake Branch	Total
1994	2	1	--	14	--	17
1995	6	0	1	6	--	13
1996	14	1	4	6	--	25
1997	14	0	1	3	0	18
1998	18	0	5	20	0	43
1999	14	0	3	13	0	30
2000	13	0	6	11	0	30
2001	3	0	2	0	1	6

Bull trout were also present in the basin, but competition with anadromous hatchery fish was unlikely. This was because bull trout were found primarily in the upper Middle Fork, upstream of the steelhead production areas (BPA 1996). Limited numbers of bull trout were detected at Powerdale Dam. But, it was believed that the adfluvial fish were migrating in the Hood River to spawn from other Columbia River subbasins (USFS 1996). Adult bull trout counts at Powerdale Dam ranged from 2-28 since 1992. Significant bull trout interaction and rearing throughout anadromous fish distribution were likely limited by thermal regimes in those reaches. The Genetic Risk Assessment (Cramer 1991) hypothesized that bull trout might benefit from the expanded forage base of juvenile salmon and steelhead to prey on, but monitoring data were not sufficient to detect such interactions.

Little data were available regarding the status of fall Chinook and coho populations in the Hood River. Recent adult returns to Powerdale Dam of both species were consistent with returns in the early 1990's, indicating that no significant decline in the populations above Powerdale Dam has occurred. Fall Chinook were generally considered to be strays from other Columbia basin hatcheries, and no monitoring of fall Chinook spawning in the lower Hood River was conducted. Most adult coho passing Powerdale Dam were out of basin strays. These numbers jumped from a range of 7-80 fish from 1992 to 2000, to 996 fish in 2001. The cause of this sudden increase may be due to strays from new hatchery programs in the mid Columbia and Snake River basins. If these fish successfully reproduce in the Hood Basin, then they may constitute an opportunity for reestablishment of naturally producing coho, whose interactions with HRPP fish should be monitored. Beginning in 2001, hatchery coho were recycled and wild fish/unmarked hatchery fish were passed above Powerdale Dam.

Increased Predation

Predation caused by the HRPP fish on non-target species or populations was unknown. Monitoring has not included stomach content analysis of HRPP fish. Spring releases of hatchery fish minimized residency time in the Hood River, thereby reducing the likelihood of predation. The largest source of predation would likely come from residualized steelhead. Data regarding the degree of residualism of Hood River hatchery steelhead was virtually non-existent. Genetics data suggested that offspring from residualized steelhead may constitute a large portion of adults returning to the Hood River (Blouin 2003).

Implementation of acclimated/volitional release of hatchery steelhead reduced the potential for residualism in the Hood Basin. Prior to implementation of acclimation, only 26% - 37% of hatchery winter steelhead released in the Basin were detected at screw traps. Since acclimation began, 72-90% of releases were detected moving past outmigrant traps (Lambert et al. 2001). Similar benefits of acclimation and volitional releases were observed with summer steelhead (Lambert et al. 2001). These data indicated that either hatchery fish were experiencing less initial release mortality, less fish residualized, or more likely a combination of the two. Data on abundance and behavior of residual hatchery fish were needed before predation on non-target populations could be dismissed as an insignificant issue.

Additional predation could exist from precocial hatchery spring Chinook. Returns to Powerdale indicated that precocial rates of hatchery spring Chinook were higher than desired. The proportion of precocial spring Chinook returning to Powerdale Dam since the 1991 brood year has averaged 12%, with a high of 36% (Figure 129). In comparison, precocial rates of returning wild spring Chinook averaged 5% since the 1987 brood. It was unknown whether these fish were rearing in the lower Hood River, or the Columbia River, but the potential exists for them to be preying on juvenile salmon and trout in the lower Hood River. Efforts to evaluate the extent of precocial spring Chinook predation in the lower Hood River were unnecessary, if actions are taken to minimize the spring Chinook precocial rate.

Figure 129. Proportion of spring Chinook hatchery returns to Powerdale Dam that are precocials (Age 2).

Disease Propagation

Hatcheries involved in the HRPP, as well as all anadromous salmonids hatcheries in the Columbia Basin, were operating under policies and procedures developed by IHOT. These policies and procedures guided hatchery operations used in all phases of hatchery production. The policies were developed to ensure that hatchery operations were consistent with the regional goal of rebuilding natural spawning runs.

Fish disease at the hatchery was managed by regular visits from fish health specialists, regular broodstock inspection, and hatchery sanitation procedures. Isolation of small family groups of steelhead in the HRPP ensures that pathogens did not spread from one group of eggs to another.

A risk associated with the introduction of hatchery fish into a river is disease transmission. The transmission of an exotic organism creates the greatest concern. Steelhead released into the Hood River were only diagnosed with diseases common to the region and therefore were not believed to transmit exotic diseases. Steelhead were diagnosed with

Infectious Hematopoietic necrosis virus (IHN) and a “cold water” like disease. The incidence of illness was low and was not considered a reservoir of disease.

Conversely, spring Chinook were found to be infected with IHN, bacterial kidney disease (BKD), fungus and Ceratomyxosis. Two out of eight years, the HRPP spring Chinook program has released fish with high BKD levels, which could have served as a reservoir of disease transmittable to wild fish. The epidemiological affects of releasing infected hatchery fish on wild populations were not understood by pathologists, and therefore the true impact to non-target populations remains a mystery. The Pacific Northwest Fish Health Protection Committee (PNFHPC) recommended the destruction of infected hatchery fish (rather than releasing them) as a means to manage against possible pathogen transmission. The HRPP should not only establish acceptable disease levels for fish released into the Hood River, but also develop disposal protocols for fish that exceed the allowable level. The PNFHPC recommends releases be 100% pathogen free. However, this standard may not be achievable under current spring Chinook rearing conditions at the Pelton Ladder.

Increased Incidental Catch

Very little harvest occurs on either natural fall Chinook or coho in the lower Hood River, so increased harvest on HRPP fish did not adversely affect these species. Furthermore, run timing of these species was such that maximum passage through the lower river and past Powerdale Dam coincided with the least amount of harvest effort in the lower river (Figure 130).

Harvest of bull trout in the Hood Basin was illegal. However, bull trout was a highly catchable species, and incidental hooking mortality likely occurred. While few adfluvial bull trout pass Powerdale Dam each year (2-28 fish), their timing overlaps with the peak of angler effort in the lower Hood River (Figure 130). Increased runs of HRPP fish that attract additional angling effort may be increasing incidental catch of bull trout in the lower Hood River. In the Rapid River, Idaho, an estimated 12.3% of steelhead anglers incidentally caught adult bull trout. This incidental catch resulted in an estimated 17.5% exploitation rate (Elle 1994). While these rates would not be experienced in the Hood River, because the bull trout populations in the Rapid River were much healthier, these data did indicate that significant incidental catch of bull trout could occur within a steelhead fishery. Typically during the course of a Hood River creel survey season, biologists recorded one or two illegally kept bull trout that were probably misidentified by the angler (Erik Olsen, ODFW, pers. comm.). This provides evidence of incidental catch of bull trout, and given that only 2-28 fish pass Powerdale Dam per year, one kept fish could be a significant loss. As the HRPP proceeds and larger numbers of steelhead return to the Hood River, angler effort will likely expand, increasing the potential for incidental take of bull trout. More data describing incidental catch of bull trout in the lower Hood River was warranted.

Figure 130. Angler effort in the lower Hood River, and Powerdale Dam passage timing of bull trout, fall Chinook, and coho. Effort is based on average angler hours per month 1998-2001. Passage timing is based on 1992-2001 returns.

SECTION III. – PROGRAM COURSE AND ADAPTATION

CHAPTER 9: PROGRAM EXPENSES AND BENEFITS

KEY FINDINGS IN CHAPTER 9:

- The HRPP expended approximately \$28 million in pursuit of reintroducing spring Chinook and supplementing summer and winter steelhead for species conservation and harvest augmentation.
- The greatest program cost was associated with capital improvements. These expenditures accounted for approximately 44% of the total program cost by modifying Pelton Ladder and Oaks Springs Hatchery, altering the Powerdale Dam Fish Trap, and creating Parkdale Fish Facility.
- Hatchery operations contributed greatly to the production of adult spring Chinook and winter steelhead stocks. Of the known spring Chinook and winter steelhead production throughout the Hood River Basin, 83% and 58% respectively, were of hatchery origin.
- Another benefit of the HRPP was additional harvest opportunities. There would not have been harvest of spring Chinook or winter steelhead without the hatchery program due to limited numbers of wild fish and strict conservation measures.
- Screening of the previously unscreened irrigation withdrawals has benefited both steelhead and spring Chinook.
- Cattle exclusion and riparian habitat protection fencing was projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively.

COSTS

The costs associated with the Hood River Production Program (HRPP) described in Table 50 were provided by BPA for project activities from 1991-2001 (Tom Morse, personal communication, BPA). The HRPP expended approximately \$28 million in pursuit of reintroducing spring Chinook and supplementing summer and winter steelhead for species conservation and harvest augmentation. Costs of a project were organized into categories based on the major activities of that project. The individual project costs were not split into categories (i.e. planning, monitoring and evaluation, operations and maintenance, and capital improvements) and therefore reflect rough estimates (Figure 131).

The greatest program cost was associated with capital improvements. These expenditures accounted for approximately 44% of the total program cost by modifying Pelton Ladder and Oaks Springs Hatchery, altering the Powerdale Dam Fish Trap, and creating Parkdale Fish Facility. The second greatest cost was associated with monitoring and evaluation activities. These expenditures, which accounted for approximately 38% of the total program cost, included such activities as genetic studies, adult and juvenile fish sampling in the Hood River, and hatchery fish assessments. Operation and maintenance costs were third in line, accounting for 16% of total program costs. Operation and maintenance costs were associated primarily with hatchery activities. Finally, planning was the lowest identified cost, making up approximately 2% of total program costs. However, costs associated with planning were most likely underestimated because planning occurred in virtually all HRPP projects/activities.

Table 50. Costs associated with HRPP activities from 1991 through 2001 (T. Morse , BPA, Personnel Communication).

Project Number	Project Name	Duration	Amount
Monitoring and Evaluation		1991-2002	
1988-053-03	HRPP-CTWSR: M&E		\$3,182,142
1988-053-04	HRPP-ODFW:M&E		\$2,836,184
1988-053-14	HR Program Review		\$251,215
1998-053-12	HR Genetics		\$168,342
1988-053-03	HR Genetics		\$250,000
1998-053-04	HR Genetics		\$250,000
Subtotal			\$6,937,883
Planning & Coordination			
1988-053-03	Powerdale/Oak Springs		\$25,000
1988-053-03	Parkdale		\$25,000
1988-053-03	Program Coordination		\$800,000
1998-053-04	Powerdale/Program		\$800,000
1988-053-05	NEOR Out-plant Master Plan		\$590,575
Subtotal			\$2,240,575
Operation and Management			
1988-053-04	Powerdale O&M		\$200,000
1988-053-03	HRPP O&M-PGE		\$916,734
1988-053-07	HR Parkdale O&M	1998-2002	\$1,856,392
1988-053-08	Powerdale/Oak Sp. O&M	1997-2002	\$1,526,777
1995-007-00	HRPP PGE: O&M		\$106,292
1998-021-00	HR Fish Habitat		\$1,893,611
Subtotal			\$6,499,806
Capital Improvements			
1989-029-00	HRP Pelton Ladder/Hatchery Const.		\$572,660
1993-019-00	Design/Construct Powerdale Facility		\$3,967,854
Misc. Task Orders	Parkdale and other Capital		\$7,884,029
Subtotal			\$12,424,543
Total			\$28,102,807

Figure 131. HRPP costs by percent and category for the period 1991-2001.

BENEFITS

Hatchery

The Pelton Ladder was modified to rear an additional 125,000 spring Chinook smolts, while Oak springs was modified to rear an additional 30,000 winter steelhead smolts and 40,000 summer steelhead smolts, annually (Table 51). Beginning in 1996, the construction and use of temporary acclimation facilities allowed for the volitional release of fish and increased the percentage of released smolts migrating out of the basin. In 1998, the Parkdale Facility was fully operational. Activities at the Parkdale Facility increased the survival of collected adults and allowed for efficient egg extraction.

Hatchery operations contributed greatly to the production of adult spring Chinook and winter steelhead stocks. During the period from 1997 – 2000, an additional 147 spring Chinook adults (on average) either returned to the Hood River or were harvested (Figure 132). During the same period an additional 724 adult winter steelhead (on average) returned to the Hood River or were harvested (Figure 132). Clearly the hatchery provided a valuable contribution to the adult return. Of the known spring Chinook and winter steelhead production throughout the Hood River Basin, 83% and 58% respectively, were of hatchery origin.

Table 51. Total number of smolts released by the HRRP (Olsen July 2002).

Release Year	Spring Chinook	Summer Steelhead	Winter Steelhead
1993	75,205	-	48,985
1994	0	-	38,034
1995	170,004	-	42,860
1996	123,230	-	50,896
1997	100,719	-	59,837
1998	123,760	-	62,133
1999	121,348	19,513	46,781
2000	136,926	33,899	63,182
2001	124,679	37,665	50,879
Total	975,871	91,077	463,587

Figure 132. Total production of spring Chinook and winter steelhead adults (returns + harvest), 1997-2000 (Olsen July 2002).

Harvest

Another benefit of the HRPP was additional harvest opportunities. Although total spring Chinook harvest numbers (including ocean and Lower Columbia) were low, averaging 53 adults from 1997- 2001, there was an encouraging increase in numbers harvested up to 118 fish in 2001 (Figure 133). Wild spring Chinook comprised approximately half of all spring Chinook harvested, until 2001, when virtually all of the harvest was hatchery fish.

Total winter steelhead harvest ranged from 185 to 386 adults, with an average of 277 adults harvested annually from 1996 -2000 (Figure 133). The vast majority of harvest during this time was on hatchery fish. Conservation measures to protect wild winter steelhead resulted in regulations banning the harvest of wild fish. Ultimately, there would not have been harvest of spring Chinook or winter steelhead without the hatchery program due to limited numbers of wild fish and strict conservation measures. Summer steelhead were not discussed here because the BPA program was too young to account for harvest from this program.

Figure 133. Total harvest of spring Chinook and winter steelhead (Olsen July 2002).

Habitat

Irrigation and Hydroelectric Withdrawals

Screening of the previously unscreened irrigation withdrawals benefited both steelhead and spring Chinook. Assuming that all unscreened irrigation withdrawals were effecting a 100% mortality rate, and that subsequent screen improvements resulted in a 0% mortality rate, then the habitat activities regarding the withdrawals have saved an average of 70,400 migrants a year (Table 52). Although this scenario assumes the most pessimistic impact prior to HRPP involvement and the most optimistic survival after, screening activates none the less represent a substantial benefit to fish survival in the Hood River Basin.

Table 52. Estimated number of fish saved from irrigation withdrawal screen replacement

	Wild Steelhead				Chinook	Hatchery Smolts		Total
	Fork Length (mm)				> 70	Summer	Spring	
	>100	>150	<100	<150		Steelhead	Chinook	
Farmer	13	1,310	0	7	90	1,255	5,693	8,368
Power	118	8,832	0	47	692	8,452	36,637	54,777
EFID	1,809	288	4,727	3,44	0	0	0	7,169
Dee	1	13	0	10	26	36	0	86
Total	1,942	1,0442	4,727	408	807	9,744	42,330	70,400

Fencing

Cattle exclusion and riparian habitat protection fencing was projected to increase steelhead parr rearing capacity by 233 and 34 fish in Neal and Baldwin creeks respectively. These increased parr density estimates were based on empirical juvenile density increases of nearly 30% resulting from similar cattle exclusion and fenced riparian zone protection (Gunderson 1968). This projected increase in steelhead rearing density is a result from adding approximately two miles of new exclusion and protection fencing to these creeks. Although an additional 1.5 miles of fencing was installed along four streams in the Hood River Basin as part of the HRPP habitat improvement activities, no improvements occurred along known juvenile spring Chinook rearing habitat. Additionally, the fencing was installed along reaches that generally lack anadromous salmonid rearing habitat. However, these activities did provide additional downstream benefits to water quality and habitat suitability for resident fish and native lower trophic level fauna. Furthermore, reduced erosion and sediment loading rates and improved thermal and physical water quality conditions in areas “treated” with exclusion and protection fencing, also benefited higher-order streams and the downstream mainstem Hood River. Thus, treatment effects of exclusion and protection fencing provide ecological benefits throughout the Hood River Basin, some of which were not directly evaluated or accounted for by the HRPP.

CHAPTER 10: FORECASTS OF FUTURE PERFORMANCE

KEY FINDINGS IN CHAPTER 10:

- The affects of HRPP activities and environmental variation on adult returns and harvest was evaluated using a life-cycle model with carrying capacity estimates from the Unit Characteristic Method. Models were developed separately for spring Chinook, summer steelhead and winter steelhead.
- Physical factors and fish populations parameters used in the Life Cycle model were based primarily on data collected in the Hood River Basin.
- The model begins with the number of adults spawning naturally. The number of parr that these spawners produce in the next generation was predicted according to a modified form of the Ricker stock-recruitment function.
- The life-cycle model was run as a baseline scenario using estimated parameters. The baseline scenario generates long-term equilibrium (average values) of harvest, returns to Powerdale Dam, strays, and recycles. Subsequent scenarios were run that altered 1 or 2 parameters from the baseline scenario to examine the potential changes in equilibrium values.
- Assumptions in the Life Cycle Model were tested by using the hindcast method of comparing predicted to observed escapements of natural and hatchery fish to Powerdale Dam. The hindcast method involved using actual spawner escapement from the early 1990's, and applying year specific values of certain model parameters where data was available to populate the life cycle model.
- The baseline simulation of the Hood River spring Chinook population estimated equilibrium Powerdale Dam returns of 170 natural and 215 hatchery jacks and adults. In addition, it estimated returns of 23 natural and 52 hatchery precocials.
- Total harvest of spring Chinook was estimated at 258 fish made up primarily of 145 above Powerdale Dam in the tribal fishery, and 58 in the lower Hood River sport fishery.
- Alteration of stream capacity, freshwater survival, or smolt-Age 2 survival without altering other variables resulted in a 1:1 change in natural returns to Powerdale Dam, and harvest of natural fish.
- Combining effects of changes in capacity and freshwater and marine survival indicated that total harvest and returns to Powerdale indicate a high of 250% and a low of 45% to baseline conditions.

- Incorporating different supplementation levels into the model influenced harvest and returns of hatchery fish, but not natural fish. Increased supplementation did not reduce the natural population, because the allocation scheme mandated that of all fish passed above Powerdale Dam, anything in excess of the spawner capacity was harvested in the model.
- Changes in harvest below Powerdale Dam affected returns to Powerdale Dam and harvest above Powerdale Dam, but did not affect the number of available spawners because spawner above Powerdale had higher priority than harvest above Powerdale.
- Increased hatchery stray rates had a negative effect on hatchery returns to Powerdale and harvest of hatchery fish but had no effect on natural fish.
- Increased hatchery precocial rates caused a decrease in jack and adult in-basin harvest and returns to Powerdale Dam.
- The baseline simulation of the Hood River summer steelhead population estimated equilibrium Powerdale Dam returns of 238 natural and 470 hatchery jacks and adults.
- Total baseline harvest of summer steelhead was estimated at 506 fish made up primarily of in-river harvest of hatchery fish.
- The baseline simulation of the Hood River winter steelhead population estimated equilibrium Powerdale Dam returns of 241 natural and 475 hatchery jacks and adults.
- Total baseline harvest of summer steelhead was estimated at 307 fish made up primarily of in-river harvest of hatchery fish.
- Combining effects of changes in capacity and freshwater and marine survival showed that total harvest and returns to Powerdale of steelhead was as high as 250% or as low as 45% of baseline conditions.
- Incorporating different steelhead supplementation levels into the model influenced both hatchery and natural fish. Hatchery returns were positively correlated at a 1:1 ratio with supplementation. Wild fish were negatively affected by increased supplementation.
- Changes in steelhead harvest below Powerdale Dam affected hatchery returns to Powerdale Dam and the number of fish recycled, but did not affect the number of available spawners.
- Increased steelhead residualism reduced both harvest and the number of wild and hatchery fish returning to Powerdale Dam. Increased residualism had a more pronounced effect on wild fish than on hatchery fish.

LIFE CYCLE MODELING

The relative affects of the Hood River Production Program (HRPP) actions and environmental variation on adult returns and harvest was evaluated using a life-cycle model with carrying capacity estimates from the Unit Characteristic Method (UCM; See Chapter 2 for further information). Models were developed separately for spring Chinook, summer steelhead and winter

steelhead. Physical factors and fish populations parameters used in the Life Cycle model were based primarily on data collected in the Hood River Basin including: fish distribution, life stage survival, harvest, ocean survival rates, maturity rates, age at smolting, sex composition, and recycle rates.

A simplified picture of the Chinook and steelhead modeled life stages is depicted in Figure 134. The diagram was simplified to emphasize the flow of information resulting in an oversimplification of the part age structure played in the model. Parr were able carry through 1, 2, or 3 years in freshwater. Immature fish in the ocean were able to stay there up to 4 years. Returning adults in any given year was composed of multiple ages that originated from different broods.

The carrying capacity that results in density-dependent growth and survival of anadromous salmonids and was determined by habitat features in the UCM. Density-dependent mortality means that the rate of mortality increased as density increased. This increase in mortality may result from competition, attraction of predators, disease, etc. In chapter 2 of this report we describe how we derived carrying capacity for Chinook and steelhead directly from measurements of stream habitat (for details refer to chapter 2 of this report describing the Unit Characteristic Method).

OVERVIEW OF MODEL STRUCTURE

The model begins with the number of adults spawning naturally. The number of parr that these spawners produce in the next generation was predicted according to a modified form of the Ricker stock-recruitment function. The modified Ricker function mimics a standard Ricker function until it reached recruitment capacity, at which point the modified Ricker function plateaus, whereas the standard Ricker function would have declined (Figure 135).

Figure 135. Recruitment functions of a hypothetical population examined for use in the Hood River spring Chinook and summer and winter steelhead life-cycle models.

The Beverton-Holt recruitment function increased at a gradually diminishing rate until it reached maximum recruitment at an infinite spawner level (Figure 135). This function allowed high spawner numbers without exceeding recruitment capacity. However, to fit the Beverton-Holt curve to Hood River data, we needed to elevate parr recruitment capacity as estimated by the Beverton-Holt function above that estimated by the UCM. Under supplementation scenarios that resulted in increased spawner escapement. This resulted in parr production higher than could be supported by the habitat causing the Beverton-Holt recruitment function to be a poor fit for the Hood River models.

Once the recruitment of parr was predicted, parr were assigned an overwinter survival rate to estimate the number of smolts outmigrating the next spring. For steelhead, most age 1+ parr outmigrate as 2 year old smolts, but for the remaining fish that did not outmigrate until age 3, an extra year of overwinter mortality was assigned. Natural smolts were combined with hatchery smolts to estimate the total number of smolts outmigrating from the Hood River by outmigration year.

Hatchery smolts were released in the spring and were immediately assigned a post-release mortality. Also, the hatchery smolts were decremented by an assumed residualism factor.

The remaining fish were smolts that outmigrated to the ocean with the natural smolts. The hatchery residuals remained in the Hood River to rear until maturity. The hatchery residuals reduce the numbers of natural parr produced by the following brood year when natural parr production was near capacity by out-competing the natural parr for rearing space.

Once the hatchery and natural smolts reach the ocean they were assigned a smolt-to-age 2 survival rate for Chinook, and smolt-to-1 salt survival rate for steelhead (steelhead outmigrate as smolts of two different year classes, so their salt age was used in the model). Once smolts were converted to adult recruits, they were divided into groups that matured after 1, 2 or 3 years in the ocean. Harvest in the ocean was assumed to be negligible for both species.

A portion of the maturing fish reentering the Columbia River were harvested. Un-harvested adults were assigned mortality for passing Bonneville Dam, and an additional proportion strayed and did not enter the Hood River. Fish that survived the mainstem harvest, upstream passage, and do not stray were considered available for harvest in the Hood River Basin.

Once in the Hood River, fish were exposed to sport harvest. Fish that escaped harvest arrived at Powerdale Dam where they were either taken for brood, passed above the dam, or recycled downstream for harvest based on the allocation schemes presented in Table 53. Adults passed upstream to spawn were subjected to prespawning mortality, and the life-cycle began for the next generation.

Among steelhead that were recycled in the sport fishery, a given portion were harvested, an additional proportion returns to Powerdale Dam, and the rest were assumed to stray or die. Recycles that returned to Powerdale Dam were recycled again and their fate was determined at the same rate as in the previous recycles. Multiple recycles were made until the available number of recycled fish was exhausted. Derivation of the mathematical functions for each step in the life-cycle model described in Appendix F and a summary of parameters values are presented in Table 54.

Table 53. Allocation guidelines applied in the life cycle model to salmon and steelhead that arrive at Powerdale Dam.

Allocation Scheme	Summer Steelhead	Winter Steelhead	Spring Chinook
Number above Powerdale	Allow all wild fish above Powerdale except for hatchery allocation. Based on wild adult run size prediction, allow only up to 50% (by policy but, 40% in practice) of the run to be composed of hatchery fish.	Allow all wild fish above Powerdale except for hatchery allocation. Based on wild adult run size prediction, allow only up to 50% (by policy but, 40% in practice) of the run to be composed of hatchery fish.	Allow all wild and hatchery fish above Powerdale except for hatchery allocation.
Hatchery Allocation	40 adults are required to produce 40,000 smolts. Wild fish will make up 100% of the brood not to exceed 25% of wild run. 50% of the brood will be female and brood will be taken over the entire run period as established by previous years M&E work.	70 adults are required to produce 50,000 smolts not to exceed 25% of wild run. 50% of the brood will be female and brood will be taken over the entire run period as established by previous years M&E work.	110 adults are required to produce 125,000 smolts. Hatchery fish will make up 100% of the brood. 50% of the brood will be female and brood will be taken over the entire run period as established by previous years M&E work.
Future Hatchery Allocation	160 adults are required to produce 150,000 smolts.	90 adults are required to produce 85,000 smolts.	220 adults are required to produce 250,000 smolts.
Harvest	Hatchery only. No harvest above Powerdale.	Hatchery only. No harvest above Powerdale.	Hatchery only. Above Powerdale tribal harvest, no recreational harvest.
Priority at Powerdale Trap	1) Wild Fish above Powerdale 2) Wild Fish to Hatchery for Brood. 3) Hatchery Fish to Harvest Below Trap 4) Hatchery Fish above Powerdale	1) Wild Fish above Powerdale 2) Wild Fish to Hatchery for Brood. 3) Hatchery Fish to Harvest Below Trap 4) Hatchery Fish above Powerdale	1) Wild Fish above Powerdale 2) Hatchery Fish above Powerdale 3) Hatchery Fish to Harvest above Trap 4) Hatchery Fish to Hatchery for Brood

Table 54. Parameter values used in the life-cycle models.

	SpChk	StS	StW
Parr Carrying Capacity	44,835	40,827	49,986
Smolt Supplementation	125,000	40,000	50,000
% Residualism (STH only)	--	5%	5%
# Parr from capacity per residual (STH only)	--	5	5
% Parr that Smolt at Age 2 (STH only)	--	70%	78%
Parr-To-Smolt Survival	35%	35%	35%
Post Release Survival	20%	80%	80%
Smolt-To-Age 2*	3.6%	5.1%	3.9%
Ricker α			
CHS (Smolt – Age 4); STH (Smolt – 2 Salt)	10	2.7	2.2
Ricker β (From Parr Capacity)	0.0156	0.00326	0.00281
Maturity And Harvest Rates	Table 56	Table 57	Table 58
Ocean Survival rate	Table 56	Table 57	Table 58
Adult Mortality At Bonneville Dam	5%	5%	5%
Straying Of Hatchery Fish	23%	5%	5%
Prespawning Mortality Rate	25%	10%	5%
Sex Ratio	Table 56	Table 57	Table 58
Hood River Harvest Rate of Recycles	--	6.3%	5.8%
% Recycles not Harvested that return to PD	--	54%	36%
Max. Brood Take	110	40	70
Spawners Needed to Fully Seed Stream	64	306	356

* Smolt to 1-Salt survival for steelhead

DERIVATION OF PARAMETER VALUES

Density-Dependent Effects on Survival

Density-dependent effects on survival for salmonids were generally described analytically with either the Beverton-Holt or the Ricker stock recruitment functions. We used a modified form of the Ricker function in our analytical framework (see Figure 135).

The Ricker stock-recruitment function describes the mathematical relationship between the abundance of spawners in the parent generation and the abundance of their offspring that were recruited to the next generation. This mathematical function was designed to reflect the

density-dependent mortality that occurred between the time that the parents spawned and the time their offspring reach the defined level of recruitment. The Ricker stock-recruitment equation is:

$$R = \alpha P e^{(-\beta P)} \quad (1)$$

where,

R = Recruits

P = Parents

α = parameter defining maximum value of R/P

β = parameter defining maximum value of R

The above equation can be converted to a linear form by taking the logarithm of both sides and rearranging the equation to:

$$\ln(R/P) = \ln(\alpha) - \beta P \quad (2)$$

The parameters of the function are usually estimated from equation (2) by least squares regression of $\ln(R/P)$ on P. Alternatively, the equation can be expressed as:

$$R = P e^{a(1-P/P_r)} \quad (3)$$

where,

$a = \ln(\alpha)$

P_r = Number of parents at the level of replacement (the level where $R = P$)

We introduced this additional form of the function, because some workers who have estimated the parameters of the Ricker function, have reported their parameter values in this form. Additionally, this form was useful for estimating the value of β for each stream, based on the estimated parr capacity of that stream. Parr capacity was converted to the maximum achievable number of recruits, R_m , by multiplying parr by the expected parr-to-adult survival rate, if we assume that parr-to-adult survival rate was not influenced by density dependence. It was likely that parr-to-adult survival decreases as parr abundance increases, due to smaller size of parr and smolts, but we minimized the bias in translating the response variable from adults to parr by using an average, rather than maximum estimate of parr-to-adult survival for the translation. The following is how β was estimated.

Ricker (1975) demonstrated that the maximum number of recruits, R_m , was given by:

$$R_m = (e^{a-1})(P_r)/a \quad (4)$$

If we apply an independent estimate of α derived for adult recruits, then we can substitute $a = \ln(\alpha)$ into equation (4) and we can substitute the estimated parr carrying capacity (converted to adult recruits) for R_m in equation (4), so that we can solve for P_r . Once we have solved for P_r , it can be shown that,

$$\beta = a/P_r$$

so we can solve for β that will then be expressed in terms of parr.

The values of α and β reflected the units of measure applied to P and R. In this case, α was in units of parr per spawner and β was in units of 1/spawners. If R was expressed in terms of parr, α would be substantially greater than if α was expressed in terms of adults in the ocean. Since the value of α was equal to the value of R/P without density dependence, any density independent change in R/P was reflected by a proportional change in α . It was important to understand this principle, because comparison of α values reported from studies of various stocks could be confused if the values used for either parents or recruits in the different studies represented a slightly different life stage. For example, the value of α would be smaller if parents was taken as the spawning escapement before prespawning mortality, than if parents was the number of fish surviving to successfully spawning. Rarely do studies estimate the Ricker parameters in precisely the same measures of Parents and Recruits; so, before α parameters was compared, the data was adjusted to life stages that were equivalent between studies.

We estimated the β value of the Ricker curve from the carrying capacity of the basin for parr. This was based on the assumption that production of salmonids that rear in freshwater more than one year was limited by rearing habitat, such that, the maximum size of the population was limited by the capacity of the river to produce parr. In order to make use of the parr carrying capacity value for estimating β , we defined parr to be the Recruits. Thus, our estimate of parr capacity became the value of R_m in equation (4), introduced previously.

Carrying Capacity

We derived basin carrying capacity for parr with the Unit Characteristic Method (for details refer to sections describing the Unit Characteristic Method).

Parr-to-Smolt Survival

Spring Chinook

We reviewed numerous literature sources regarding published accounts of spring Chinook parr to smolt survival rates and conducted a pit tag analysis of Snake River spring Chinook to estimate overwinter survival for spring Chinook parr. We found that overwinter survival of parr that smolt the following spring averages 35%. Published overwinter survival rates vary considerably, and many estimates were confounded by the lack of accounting for parr that emigrated from study areas in the fall or winter. This factor tends to result in an underestimate of parr to smolt survival. A synopsis of the information that led us to estimate parr-to-smolt survival at 35% follows.

Petrosky (1990) used PIT tag data in the upper Salmon River to estimated 26% overwinter (parr-to-smolt) survival for parr that remained in the study area over winter. He also found that 67% of the parr migrated out of the study area and past the Sawtooth Hatchery weir in the fall. Petrosky (1990) used PIT tags in Crooked River (tributary of the South Fork Clearwater) to estimate that overwinter survival was 31%. Only 16% of parr left Crooked River in the fall. Fast et al. (1991) found overwinter survival for juvenile stream-type Chinook of 22%

to 49% annually during five winters for Naches winter migrants to Prosser in the Yakima River. Survival of migrants branded at Rosa Dam in the winter was 44.9% in 1989-90. Lindsay et al. (1989) estimated 52% overwinter survival in the mainstem Deschutes River based on CWT's of wild fish emigrating from the Warm Springs River in fall and spring, 1978 brood. However, Lindsay et al. qualify this estimate, because fall migrants that overwintered in the Deschutes River were bigger in spring than those in the Warm Springs River, and their 52% estimate assumed equal survival from smolt to adult of both groups. Lindsay et al. (1989) estimated that overwinter survival was 20% for fish remaining in the Warm Springs River throughout the winter. Lindsay et al. (1986) estimated that overwinter survival of stream-type Chinook parr averaged 30% in the John Day River during a 3 year study.

Monzyk et al. (2000) pit-tagged spring Chinook parr at several life stages including early migrants, a winter group, and late migrants in the mainstem upper Grande Ronde, and in Catherine Creek and Lostine River (tributaries to the Grande Ronde). Early migrants were classified as fish moving past the trapping locations in July-December. The winter group consisted of fish captured above the traps by seine or dip-nets in December to February. Late migrants were classified as fish moving past trapping locations in February through June. By comparing tag detection rates at McNary Dam of the winter tagged group to the late migrant group they found overwinter survival rates in the upper Grande Ronde were 29% for the 1998 brood year. Estimates from previous years ranged from 20-33%. Overwinter survival rates for the 1998 brood year in juveniles overwintering in Catherine Creek was estimated at 37%. Estimates from previous years were highly variable ranging from 19-65% (brood years 93-97). The 1998 overwinter survival estimate for the Lostine River was 50% as compared to estimates of 44-53% in previous years. It should be noted that all of these reported survivals were likely somewhat higher than actual parr to smolt survival, because comparisons were made between groups tagged in the winter to those tagged in the spring. These survival rates did not account for mortality incurred between late summer and the winter tagging season. However, Monzyk et al. (2000) also present evidence indicating that juveniles that migrated early had higher overwinter survival rates than juveniles who remained in the upper basin to overwinter.

We used detections of PIT-tagged yearling Chinook emigrating from the Snake River during 1995 and 1996 to obtain parr to smolt survival rates from various Snake River subbasins. We found parr-to-smolt survivals for various subbasins ranged from 26.2% to 92.4% in 1995 and from 51.1% to 84.4% in 1996. The wide range of survivals estimated by this analysis in these two years illustrates how variable survival can be.

Summer & Winter Steelhead

We estimated that survival through each winter for steelhead parr (age 1+ and age 2+) in the Hood River was 35%. Therefore, we multiplied by 35% to convert parr to age 2 smolts, and multiplied by 35% twice to convert parr to age 3 smolts. Steelhead parr to smolt survival rates were gathered by review published literature. Wild steelhead studies in Idaho estimated that parr to smolt survival averages 50% (Cramer et al. 1997). Tautz et al. (1992) calculated overwinter survival of 48.8% for steelhead parr by using data from the Keogh river system. Steelhead pre-smolt survival over winter in Fish Creek in the Clackamas Basin, Oregon, averaged 60% during 1985-88 ranging from 40% to 92% (Reeves et al. 1990).

Beamesderfer et al. (2001) reported 35% overwinter survival rates for Clackamas River steelhead based on comparisons of recovery rates of pit tag groups released in the spring as compared to those released in the summer/fall. They admitted that this number may be an underestimate of survival, if significant numbers of tagged fish left the system before spring. Overwinter survival in the North Fork Reservoir in the Clackamas Basin was 78% when data was evaluated in years with no spill (Beamesderfer et al. 2001). This estimate likely represents a maximum over-winter survival that would normally occur in a stream because it is based on a comparison of December to March/April release groups and was estimated in the reservoir where overwinter survival is higher than in the stream network.

In the Kalama basin, 35.9% of parr emigrating from Gobar Creek in the spring were estimated to have emigrated as smolts in the Kalama River the following year (Chilcote et al. 1984). This survival may be somewhat low because the fish were tagged leaving Gobar Creek in the spring, and incorporates mortality in the spring to summer period not taken into account in other studies we've cited. Ward and Slaney (1993) found on the Keogh River that in two years, the steelhead age-1 parr to age-2 smolt survival was 61.5 and 64.6% for the 1976 and 1978 broods.

Estimates of age 2+ and older steelhead parr-to-smolt survival for migratory years 1988-1995 in the upper Salmon River averaged 26.3%, and for migratory years 1989-1995 in Crooked River averaged 37.6%. However, age 2+ and older steelhead trout parr-to-smolt survival has declined dramatically in the upper Salmon River, from an average of 51.4% for migratory years 1988 and 1999 to an average of 17.9% for migratory years 1990-1995 because of the invasion of whirling disease (Kiefer and Lockhart 1999).

Considering the wide range of survivals reported, we believe 50% to be a realistic estimate of steelhead parr to smolt survival in most basins, but survivals of 35-65% were likely common. Given that the Hood River was such a flashy, dynamic, and often inhospitable environment in the winter and spring, we believed that parr to smolt survival in the Hood was on the low end of the scale of values observed elsewhere. Therefore, we used 35% as the parr-smolt survival rate for steelhead in the Hood River Basin.

Post Release Survival

Spring Chinook

Post release survival of hatchery spring Chinook released into the Hood River was estimated using data from the Warm Springs River. The same stock of spring Chinook was released in both the Warm Springs and the Hood Rivers. Between the 1978 and 1996 brood years, juvenile-to-adult survival ranged over 30-fold between broods, and survival of wild fish was always substantially higher than hatchery fish (Table 55). Across these 19 brood years (1978-1996), survival of hatchery fish averaged only 14% of that for wild fish. We assumed the survival of hatchery smolts in the Hood Basin was 20% of the release size, or 20% of that of natural fish. We presumed that since the natural spring Chinook in the Hood Basin was not the native stock, their genetic fitness was not optimal, and the difference in survivals between hatchery and natural fish was less than in the Warm Springs River.

Table 55. Juvenile-to-adult survival of hatchery and wild spring Chinook emigrating from the Warm Springs River (Deschutes River Basin), 1978-1996 broods. Data from Olson (2002)

Brood Year	Juvenile to Adult Survival (%)		Survival Ratio
	Wild	Hatchery	Hatchery/Wild
1978	1.52	0.84	0.55
1979	4.11	0.09	0.02
1980	3.3	0.42	0.13
1981	4.12	0.56	0.14
1982	2.82	0.03	0.01
1983	2.25	0.13	0.06
1984	2.41	0.12	0.05
1985	3.01	0.54	0.18
1986	3.19	0.28	0.09
1987	1.46	0.13	0.09
1988	1.78	0.18	0.10
1989	0.69	0.02	0.03
1990	0.44	0.005	0.01
1991	0.37	0.02	0.05
1992	2.57	0.16	0.06
1993	2.68	0.29	0.11
1994	0.46	0.15	0.33
1995	12.95	0.43	0.03
1996	2.27	1.27	0.56
Average			0.14

Summer & Winter Steelhead

We assumed that hatchery summer and winter steelhead smolts survive to the ocean was 80% of the rate of wild fish. This was similar to the value applied by Cramer and Beamesderfer (2001) to summer steelhead in the Deschutes River based on the following rationale. Return rates of steelhead to the Columbia River mouth from hatchery smolts released in the Deschutes River averaged 5.6% for the 1975-1996 brood years. At an assumed 10% mortality to smolts passing each of the two Columbia River dams downstream of the Deschutes River, the corresponding smolt survival without dams would be 6.9%. This survival rate for hatchery smolts was approximately 70% of the 10% pre-dam survival rate that Cramer and Beamesderfer (2001) deduced for naturally-produced steelhead smolts. We assumed the relationship between natural and hatchery steelhead smolts in the Hood Basin would be similar.

Hatchery Residuals

An uncertain number of released hatchery steelhead residualized and did not contribute to the adult steelhead fishery or spawning population. Little data were available to estimate this proportion. However, Blouin (2003) found that up to 30% of parents of F1 generation steelhead returning to the Hood Basin had not in previous years passed Powerdale Dam. This indicated

that a potentially substantial amount of steelhead returns to the Hood Basin were strays, or a large amount of steelhead production was being derived from resident rainbow trout or residual hatchery steelhead. Steelhead straying in the Hood Basin was thought to be low, and the degree of residualism versus anadromous production from resident rainbow was unknown, so we conservatively assumed that 5% of the released hatchery steelhead residualized.

Number of Parr from Capacity per Residual

Residual hatchery steelhead occupied freshwater year round, and competed with naturally produced parr for rearing space. At high natural parr production, density dependent competition with the hatchery residuals existed. We assumed that since the hatchery residuals were larger than the natural parr, they out competed the natural parr. The number of parr that were out competed by natural fish was derived by estimating the differences in estimated territory size of natural parr and hatchery residuals. Territory sizes was estimated based on fish length using the equation presented by Grant and Kramer (1990). They found that territory size was strongly positively related to fork length ($r^2 = 0.87$), and could be described as:

$$\log_{10} \text{Territory Area (m}^2\text{)} = 2.61 * \log_{10} \text{length (cm)} - 2.83.$$

Length data of natural parr was obtained from electrofishing studies in the Hood River published in Olsen et al. (2003). The average length of steelhead parr was 9cm. We assumed that the average length of hatchery residuals was 20 cm. This value was similar to lengths of age 3 smolt outmigrants from the Hood River reported by Olsen et al. (2003).

Using the equation of Grant and Kramer (1990), we estimated that the territory size of hatchery residuals was 10 times that of natural parr, and thus each residual could consume the habitat required to support 10 parr. However, substantial outmigration of parr past the mainstem Hood River screw traps documented by Olsen et al. (2003) indicates that parr undergoing pressures of density dependence and competition may move out of the Hood River to rear through the capacity bottleneck in the Columbia River. Given this life history strategy, and that some fish that otherwise would have been out competed by hatchery residuals may survive to smolt age by rearing in the Columbia River, and the territory size ratio estimated via Grant and Kramer (1990), we assumed that each hatchery residual would eliminate the capacity to produce 5 parr.

Smolt-to-Adult Survival

Spring Chinook

We calculated the smolt-to-age 2 survival of natural spring Chinook based on an iterative comparison of smolt-to-adult survival to that observed for hatchery spring Chinook returning to the Hood River. We first used data by Olsen et al. (2003) and determined that average return rate of age 2-5 adults combined during 1993-1997 averaged 0.21% of smolts released. We then ran the simulation model with both hatchery and natural spring Chinook with all parameters as specified in this report, except the smolt-to-age 2 survival. Both hatchery and natural fish shared the same smolt-to-age 2 survival rate in the model, and then hatchery fish were also assigned the

reduced survival factor relative to natural fish. We varied the smolt-to-age 2 survival in the model until simulated hatchery returns to Powerdale for ages 2-5 combined equilibrated at 0.21% of smolts released. The smolt-to-age 2 of 3.6% gave the appropriate results and was assigned to both hatchery and wild fish for simulations.

Summer & Winter Steelhead

As described for spring Chinook, we calculated the smolt-to-one salt survival of natural steelhead based on an iterative comparison of smolt-to-adult survival to that observed for hatchery steelhead returning to the Hood River. We first determined that the average return rate of age 2-5 adults combined during 1990-1998 hatchery brood years for summer steelhead, and 1992-1998 hatchery brood years for winter steelhead. The average observed return rates were 1.18% (0.67-1.97%) and 0.95 (0.19-2.05%) respectively. The smolt to 1-salt survival that gave the appropriate results was 5.07% for summer steelhead, and 3.92% for winter steelhead.

Value of Ricker α Parameter

Spring Chinook

Data was not available from which to directly estimate the α parameter of a Ricker stock-recruitment function for spring Chinook in the Hood River Basin, so we estimated α using data from Deschutes River spring Chinook in the Warm Springs River. The α parameter was estimated by regressing $\ln(\text{recruits/spawner})$ on spawners, and its value represents the maximum recruits per spawner reached at low population size. The α parameter for spring Chinook in the Warm Springs River was estimated at 8.5 for the 1975 to 1987 broods (Olsen 1993). This estimate did not account for Columbia River harvest which we assumed averaged 15% for the period of interest. By accounting for this harvest, the estimate of α would be 10 recruits/spawner. Since Deschutes stock spring Chinook were used in the Hood River, we believed that 10 recruits per spawner would reasonably reflect what would be expressed in the Hood River.

We corroborated this estimate by comparison to results of studies with wild spring Chinook in the Columbia Basin. Cramer and Neeley (1993) compiled results from several studies, and converted them to values for equivalent life stages. They found slight differences between the studies cited in measures used for Parents and Recruits, and they adjusted them, as necessary, to Parent values equivalent to successful spawners, and Recruit values equivalent to adults that would be caught in the ocean or return to the mouth of the Columbia River. The net result of these adjustments was that values of α were estimated to be 9.9 for both the Columbia River (Chapman et al. 1982) and the John Day (Lindsay et al. 1985), but 16.3 for the Deschutes River (Lindsay et al. 1989). We concluded from this comparison that an α value of 10 was reasonable for stream-type Chinook in the Hood River spring Chinook.

Summer and Winter Steelhead

Chilcote (1998) summarized recent stock-recruitment data for 26 steelhead populations in the Columbia River and Oregon coast. The maximum recruit per spawner value for Chilcote's

Ricker curve fits averaged 4.5 and ranged from 2.1 to 8.2 for summer steelhead. We chose to exclude data from basins in northeastern Oregon because their alpha values were consistently higher than the Deschutes and coastal basins, and the Hood River stock likely performs similar to these basins. Blouin (2003) estimated that summer steelhead recruits per spawner were between 1.01 and 1.48 in the 1995-96 and 1996-97 run years. These were similar to values from the Deschutes and the Coast ranging from 2.1-3.4 and averaged 2.7 than to the higher estimates in the northeastern Oregon Basins. Chilcote's values for winter steelhead averaged 2.2 and ranged from 1.0 to 3.7. Chilcote's (1998) productivity estimates applied primarily to 2-salt fish, and did not expand estimates of recruitment to account for passage losses of juveniles and adults at dams. Given that we used the Ricker curve in our model to estimate recruitment to 1-salt age, before mortality from dam passage was subtracted, the equivalent α value in our model was back-calculated to approximate smolt to 1 salt recruit.

Value of Ricker β Parameter

We derived the β value of the Ricker curve for Hood River spring Chinook and steelhead from the carrying capacities for parr estimated with the Unit Characteristic Method (for details refer to the section of this report describing the Unit Characteristic Method). The derivation of the Ricker β parameter from parr capacity was described previously in this report.

Spawner Capacity

Spawner capacity was the estimated minimum number of spawners needed to fully seed the parr capacity of the basin. Estimates according to equations presented by Ricker (1975) as $1/\beta$ were used. Spawner capacity was calculated as 64 for spring Chinook, 306 for summer steelhead, and 356 for winter steelhead.

Smolt Age

Steelhead smolt at various ages. In general, most smolting takes place at age 2 or age 3. It was important in the life-cycle model to incorporate the breakdown between these two ages, because age 3 smolts were subjected to an additional year of potential freshwater mortality not experienced by age 2 smolts.

The proportion of both summer and winter natural steelhead smolting at age 2 and age 3 was estimated via cohort analysis by brood year. Hood River steelhead smolt age was estimated via scale analysis of adults returning to Powerdale, and was obtained from Olsen (draft 2002). For summer steelhead of the 1989-1993 broods, 70% of returning adults smolted at age 2, and 30% smolted at age 3. For winter steelhead of the 1988-1993 broods, 78% smolted at age 2, and 22% smolted at age 3.

Maturity Rates

Maturity rates for hatchery and wild spring Chinook (ages 2-6), hatchery and wild summer steelhead (1-5 salts), and hatchery and wild winter steelhead (1-5 salts) were estimated

via cohort analysis using returns to the Powerdale Dam (Table 56, Table 57, Table 58). The cohort analysis model is described in Appendix F.

Table 56. Values used in the spring Chinook model for the percentage of the population at each age that matured, was female, was harvested, and survived over winter in the ocean.

Total Age	Ocean Survival	Maturity Rates		Ocean	Harvest Rate		% Females	
		Natural	Hatchery		Columbia	Hood	Natural	Hatchery
2	60%	4.8%	8.6%	0.3%	5.9%	4.0%	0.0%	0.0%
3	70%	8.8%	8.0%	0.2%	5.9%	20.4%	28.5%	16.8%
4	80%	72.0%	86.6%	1.7%	5.9%	11.4%	56.9%	72.8%
5	90%	99.2%	100.0%	1.3%	5.9%	11.4%	72.9%	58.5%
6	90%	100.0%	100.0%	1.3%	5.9%	11.4%	100.0%	0.0%

Table 57. Values used in the summer steelhead model for the percentage of the population at each age that matured, was female, was harvested, and survived over winter in the ocean.

Age	Ocean Surv.	Maturity Rate		Ocean	Harvest Rates				% Females	
		Natrl.	Hatch.		Columbia		Hood R.		Natrl.	Hatch.
1 Salt	60%	5.0%	1.5%	0.5%	7.4%	15.0%	0.0%	27.0%	64.0%	54.0%
2 Salt	70%	78.6%	68.7%	0.5%	7.4%	15.0%	0.0%	27.0%	73.0%	68.0%
3 Salt	80%	93.7%	96.2%	0.5%	7.4%	15.0%	0.0%	27.0%	48.0%	39.0%
4 Salt	90%	98.4%	99.9%	0.5%	7.4%	15.0%	0.0%	27.0%	100.0%	60.0%
5 Salt	90%	100.0%	100.0%	0.5%	7.4%	15.0%	0.0%	27.0%	100.0%	100.0%

Table 58. Values used in the winter steelhead model for the percentage of the population at each age that matured, was female, was harvested, and survived over winter in the ocean.

Age	Ocean Surv.	Maturity Rate		Ocean	Harvest Rates				% Females	
		Natrl.	Hatch.		Columbia		Hood R.		Natrl.	Hatch.
1 Salt	60%	2.8%	2.0%	0.5%	2.0%	2.0%	0.0%	33.0%	16.0%	6.0%
2 Salt	70%	69.4%	63.6%	0.5%	2.0%	2.0%	0.0%	33.0%	62.0%	45.0%
3 Salt	80%	97.6%	94.8%	0.5%	2.0%	2.0%	0.0%	33.0%	68.0%	67.0%
4 Salt	90%	100.0%	97.6%	0.5%	2.0%	2.0%	0.0%	33.0%	50.0%	29.0%
5 Salt	90%	100.0%	100.0%	0.5%	2.0%	2.0%	0.0%	33.0%	0.0%	0.0%

Harvest Rates

Spring Chinook

Harvest rates on spring Chinook from the mouth to Powerdale Dam on the Hood River were estimated from annual returns to Powerdale Dam and sport catch (released fish not counted as catch). These rates were presented in Table 56. The average jack harvest rate from run years 1996-2001 were used for age 3 spring Chinook. The average harvest rate on adults from run years 1996-2001 was used for age 4+ spring Chinook. An assumed harvest rate of 4% was used for age 2 spring Chinook.

Harvest rates on spring Chinook from the mouth through Zone 6 on the Columbia River were estimated from data presented in PFMC (2001). Both sport and tribal catch data for Columbia River spring Chinook bound for areas above Bonneville Dam was used to estimate harvest rate. Harvest rates from run years 1995–2000 ranged from 5.2%- 7.2%, with an average of 5.9%. This average harvest rate on spring Chinook in the Columbia River was applied to age 2-6 spring Chinook.

Harvest rates on spring Chinook in the ocean was minimal and were estimated by cohort analysis of CWT marked Round Butte Hatchery spring Chinook released into the Deschutes Basin. Harvest of upriver spring Chinook in the ocean declined dramatically since the early 1990's, and was at extremely low levels for the period of this review. Cohort analysis showed a harvest rate of 0% age 2 fish, 0.24% for age 3 fish, 2.63% for Age 4 fish, and 0% for age 5 and 6 fish. These were the values of age specific harvest rate assumed in the model.

Summer & Winter Steelhead

Both summer and winter steelhead. Only hatchery steelhead were legally harvested below Powerdale Dam in the Hood River. Harvest rates for hatchery steelhead are given in Table 57 and Table 58, and were derived using the average of harvest estimates reported by Olsen et al. (2003) for 1996-2001.

Each year, a significant number of hatchery steelhead returning to Powerdale Dam were recycled to near the mouth of the Hood River to supplement the sport harvest fishery. We estimated the percent of the recycled steelhead that was harvested, each time they were recycled. Data from the 1998-2001 return years showed that 6% of each recycle of summer steelhead were harvested, and data from the 95-96 to 00-01 runs indicated that 6% of recycled winter steelhead were harvested. With summer steelhead, we excluded high estimates (20-34%) of recycle harvest from the 1996 and 1997 run because they didn't correlate with recent harvest rates which ranged from 3-9%.

Columbia River harvest rates of summer steelhead returning to the Hood River were assumed to be the same as harvest rates reported by PFMC (2002) for steelhead stocks passing above Bonneville Dam. Harvest rates include tribal and non-tribal harvest. Columbia River harvest of winter steelhead was minimal and was assumed to be 2.0%. Ocean harvest rates of both summer and winter steelhead were assumed to be negligible at 0.5%.

Percent Recycled Returning to Powerdale Dam

We determined the percent of steelhead recycled to the sport fishery in the lower Hood River that return to Powerdale Dam, minus the number of fish harvested. This was calculated based on recycle return rates and recycle harvest rates presented by Olsen et al. (2003). This proportion was used to estimate the number of recycles returning to Powerdale Dam under various exploitation rates on recycled fish. For summer steelhead, 54%, and for winter steelhead 36% of recycled fish not harvested return to Powerdale Dam to be recycled again. All non-harvested fish were assumed to have strayed or died.

Adult Mortality At Bonneville Dam

We used a mortality rate of 5% per dam for adults migrating upstream. Chapman et al. (1991) reviewed estimates of inter-dam loss and concluded 95% survival per dam was the most reasonable estimate. NMFS (1992) estimated that survival of stream-type Chinook past all eight dams into the Snake River Basin was 66%, which is equivalent to 95%/dam. This rate was applied to spring Chinook and summer and winter steelhead.

Stray Rates of Hatchery Fish

Spring Chinook

Stray rates for hatchery spring Chinook were estimated from recoveries of CWT-marked fish released into the Hood River Basin. Using the "fishery" code and "recovery site" code in the RMIS database, all recoveries were labeled as either Ocean, Net, River Sport, Powerdale, or Stray. By examining the proportion of fish classified as Strays in relation to those classified as River Sport and Powerdale, an estimate of the stray rate was obtained. Recoveries classified as either Ocean or Net were omitted from the stray rate analysis owing to the fact that it was impossible to determine whether or not these fish had indeed strayed. For spring Chinook, the primary age-class of returning adults was age 4, consequently the vast majority of recovered CWT's come from age 4 fish. The stray rate parameter used in the model was estimated as the average stray rate from brood years in which there were greater than 10 expanded CWT recoveries (i.e. brood years 1986, 1988, 1990, 1993, and 1995). The stray rate parameter used for Hood River hatchery spring Chinook was 46%.

Summer & Winter Steelhead

For both summer and winter Hood River hatchery steelhead, straying is considered to occur at a very small rate. An analysis of CWT data for Hood River hatchery winter steelhead support this assumption (only winter steelhead receive CWT's in the Hood River). For years in which CWT recovery data exist, Hood River hatchery winter steelhead stray at a rate less than 1%. Thus, the stray rate parameter used for both summer and winter steelhead was 5%.

Prespawning Mortality Rate

Spring Chinook

We used a prespawning mortality rate of 25% after fish had passed all dams and escaped all fisheries. Estimates of this mortality were variable. Petrosky (1991) estimated prespawning mortality at 10%. Prespawning mortality was likely to vary from stream to stream and year to year. Anderson and McConnaha (1992) concluded that 20% was the most representative value. Hood River spawning ground survey indicated less than half of the fish passed above Powerdale Dam created detectable redds (Lambert et al 2001). As a result, we presumed the prespawn mortality was greater the 20% but, most likely less than 50% because spawning ground surveys were not comprehensive. Thus, we chose 25% because it was an intermediate value within the range of observations.

Summer Steelhead

Some summer steelhead died of natural causes during the extended period of freshwater holding before adult spawning. Olsen et al. (1991) reported a 9.2% average prespawning mortality rate of 1973-1989 brood years of hatchery steelhead held at Round Butte Hatchery after collection at the Pelton Ladder Trap. The NPPC (1989) used a value of 10% prespawning mortality in their System Planning Model for steelhead. Cramer and Beamesderfer (1991) assumed a 10% prespawning mortality rate for modeling summer steelhead in the Deschutes Basin. This is the value we assumed for Hood River.

Winter Steelhead

We assumed that prespawning mortality of winter steelhead in the Hood Basin was 5%, half of that of summer steelhead. Winter steelhead do not hold in freshwater for the extended period that summer steelhead do, and the holding period of winter steelhead does not encompass the summer when temperatures in the Hood may be high and flows low causing stress and potentially mortality.

Sex Ratio

Spring Chinook

Sex ratios for both natural and hatchery spring Chinook (Table 56) were estimated, by brood year, from annual returns to Powerdale Dam. The average sex ratio from brood years 1991- 1996 was used in the life cycle model for spring Chinook ages 2-6.

Summer Steelhead

Sex ratios for both natural and hatchery summer steelhead were estimated, by return year, from annual returns to Powerdale Dam (Olsen et al. draft 2002). The average sex ratio from return years 1991-1992 to 2000-2001 was used in the life cycle model for summer 1-salt to 4-salt steelhead. Hatchery fish estimates were based on Skamania stock returns.

Winter Steelhead

Sex ratios for both natural and hatchery summer steelhead were estimated, by return year, from annual returns to Powerdale Dam (Olsen et al. draft 2002). The average sex ratio from return years 1992-1993 to 2000-2001 was used in the life cycle model for 1-salt to 5-salt wild winter steelhead. Hatchery fish estimates were based on Hood River stock returns from return years 1993-1994 to 2000-2001.

Ocean Survival Rate

We used standard assumptions applied by the Pacific Salmon Commission for natural mortality rates in the ocean. This was mortality that occurs each year in addition to harvest, and was assumed to occur principally during winter. Ocean Survival Rates for spring Chinook salmon, summer steelhead, and winter steelhead used in the life cycle models were displayed in Table 56, Table 57, Table 58. These were the over-winter survival rates assumed by the Pacific Salmon Commission (PSC 2001) for Chinook salmon. We assumed these values to be similar for steelhead.

Supplementation Levels and Brood Take

Supplementation levels and brood take were set at the most recent hatchery goals. The supplementation goals are 125,000 spring Chinook smolts, 40,000 summer steelhead smolts, and 50,000 winter steelhead smolts. Brood take requirements were 110 spring Chinook, 40 summer steelhead, and 70 winter steelhead.

LIFE-CYCLE MODEL METHODS – EFFECTS OF CHANGING MANAGEMENT AND ENVIRONMENTAL CONDITIONS

The life-cycle model was run as a baseline scenario using the parameters described in the preceding methods section. The baseline scenario generates long-term equilibrium (average values) of harvest by location (ocean, Columbia River, Hood River below Powerdale Dam, and Hood River above Powerdale Dam), returns to Powerdale Dam, strays, and recycles. Subsequent scenarios were run that altered 1 or 2 parameters from the baseline scenario to examine the potential change in equilibrium values. Adjustments to the baseline scenario were chosen to test impacts on equilibrium values arising from changing freshwater and marine conditions, varying hatchery releases, changes in stray rates, precocial rates, residualism, and changing harvest effort in the Hood River below Powerdale Dam

Altered Conditions

Effects of changing freshwater and marine conditions on equilibrium values estimated by the life-cycle model were evaluated. Four scenarios were created to test the normal realm of variation in environmental variability. Those scenarios included a good freshwater/good marine survival condition, poor freshwater/good marine, good freshwater/poor marine, and poor freshwater/poor marine. Good freshwater survival was simulated through a 25% increase in

freshwater survival and 25% increase in stream capacity. Poor freshwater survival incorporated a decrease in survival and capacity of the same degree. Good and poor marine survival were considered to be double and half the baseline smolt-to-age 2 survivals.

Independent effects of changes in marine survival and freshwater survival were also tested independently by altering marine survival between 25% and 400% of baseline conditions, and freshwater survival and capacity by 50-150% of baseline conditions.

The effects of hatchery releases were tested for each species by running simulations with hatchery release levels above and below current release goals. The number of fish released was tested for each species (Table 59).

Table 59. Supplementation rates simulated in the life-cycle models.

Spring Chinook	Summer Steelhead	Winter Steelhead
0	0	0
75,000	40,000	10,000
125,000	80,000	30,000
250,000	150,000	85,000

Harvest in the Hood River below Powerdale Dam was altered by +/- 20% of current harvest rates for spring Chinook and +/-25% for steelhead.

For spring Chinook, stray rates were tested at 5%, 20%, and 40% of the returning population. Spring Chinook precocial rates were simulated at 5%, 20%, and 40% of natural recruits alive at age 2.

Steelhead simulations were conducted that test the effects of 10% and 18% residualism rates. Both of these values were above the current assumed residualism rate of 5%.

EXAMINING MODEL ASSUMPTIONS

Assumptions in the Life Cycle Model were tested by using the hindcast method of comparing predicted to observed escapements of natural and hatchery fish to Powerdale Dam. The hindcast method involved using actual spawner escapement from the early 1990's, and applying year specific values of certain model parameters where data was available to populate the life cycle model. Spawner escapement estimates were provided for the first full life-cycle to begin the model. The model then estimates returns to Powerdale Dam of natural and hatchery fish for the next x number of years. Those predicted returns were compared to observed returns reported by Olsen et al. (2003). The hindcast differed from the standard life-cycle model in that brood and return year specific estimates of multiple variables were applied uniquely to the appropriate year in the model, and was only run for the number of years that actual observations were available. The standard life-cycle model applied an average value for each parameter from multiple years of observation to the model, and then ran the population until it reached an

equilibrium x number of years in the future. The standard model operates on average conditions over a number of years, while the hindcast model operates on specific conditions for each year.

This method was useful because it provided the ability to check the accuracy of the model by predicting hatchery and wild returns. In doing so, it provided insight on accuracy of parameter values that were not adjusted during the hindcast, and assumed relationships inherent in the model.

Hindcast Methods

Spring Chinook

We began the spring Chinook hindcast by populating the model with the estimated number of natural spawners from the 1993-1996 return years. The natural spawners were estimated by using the number of fish passed above Powerdale (Olsen et al. 2003) and multiplying them by a 75% prespawn survival rate. Smolt-to-adult return rates of hatchery spring Chinook from the 1993-1997 hatchery broods were used to estimate smolt-age 2 survivals as described in the Derivation of Parameters section, and were applied to their respective model years. Hatchery supplementation was based on actual releases from the 1993-1999 broods. Maturity rates were calculated as described in the Derivation of Parameters section, and applied to the 93-97 broods. Harvest rates for the lower Hood River from 1996-2001 run years were derived from Olsen et al. (2003) and applied to the appropriate year. The remaining parameters were run as in the standard life-cycle model as reported in Table 54 and Table 56.

Summer Steelhead

The model was started by populating it with the estimated number of natural spawners for 1993-1997. Natural spawners were estimated by multiplying the number of summer steelhead passed above Powerdale Dam by a 90% prespawn survival factor. The proportion of available juveniles smolting at age 2 was used for the 1993 and 1994 natural broods, the only years where complete estimates were available. Smolt to 1-salt survival for the 1994-1997 hatchery broods was derived from hatchery to adult return rates (Olsen et al. draft 2003), and applied to the 1994-1997 hatchery broods and the 1993-1996 natural broods. The survival rates for natural fish were offset by one year because hatchery steelhead rear one less year than natural steelhead before outmigration. The 1997 hatchery smolt to adult return rate was an approximation based on observed returns of 1 and 2 salt fish and expected return of 3 salt fish. The expected return of 3 salt fish was based on age composition of returns of previous run years. Actual smolt releases from the 1994-2000 hatchery broods were used in the supplementation program in the model. Maturity rates for natural fish were used for the 1993-1998 broods, and the 1994-1998 broods of hatchery fish. Actual harvest rates were used for the 1995-2000 return years. All of the data used to estimate the above parameters was from Olsen et al. (2003), and methods were described in the Derivation of Parameters section. All variables not specifically mentioned here were left the same as in the standard life cycle model as reported in Table 54 and Table 57.

Winter Steelhead

The model was started by populating it with the number of natural spawners in 1992-1995. Natural spawners were estimated by multiplying the number of fish passed above Powerdale Dam by a 95% prespawn survival factor. The proportion of available juveniles smolting at age 2 was used for the 1992-1994 natural broods, the only years with complete estimates were available. Smolt to 1-salt survival for the 1992-1998 hatchery broods was derived from hatchery to adult return rates (Olsen et al. 2003), and applied to the 1993-1998 hatchery broods and the 1992-1997 natural broods. The survival rates for natural steelhead were offset by one year because hatchery steelhead reared one less year than natural steelhead before outmigration. The 1998 hatchery smolt to adult return rate was an approximation based on observed returns of 1 and 2 salt fish and expected return of 3 salt fish. The expected return of 3 salt fish was based on age composition of returns of previous run years. Actual smolt releases from the 1992-2000 hatchery broods were used in the supplementation program in the model. Maturity rates for natural fish were used for the 1992-1998 broods, and the 1993-1998 broods of hatchery fish. Actual harvest rates were used for the 1995-96 to 2000-2001 return years. All of the data used to estimate the above parameters was from Olsen et al. (2003), and methods are described in the Derivation of Parameters section. All variables not specifically mentioned here were left the same as in the standard life cycle model as reported in Table 56 and Table 57.

Examining Model Assumptions – Results

Spring Chinook

The hindcast of the spring Chinook model produced return year estimates for 1997-2001 that were compared to observed returns. Returns of natural fish predicted by the model were similar to observed values in 1997-1999. In 2000 and 2001, the model overestimated the number of natural returns by 250% and 1,284% respectively. The model accurately tracked trends in observed returns in all years except 2001 (Figure 136).

Figure 136. Actual returns of natural spring Chinook to Powerdale Dam as compared to those estimated by the spring Chinook hindcast with the life-cycle model (1997-2001).

Predicted returns of hatchery spring Chinook to Powerdale Dam were essentially equal to observed returns in 1997-2000 with the deviation between predicted and observed never exceeding 25%. In 2001, the model underestimated actual returns by 39%, but still accurately reflected an upward trend in returns (Figure 137).

Figure 137. Actual returns of hatchery spring Chinook to Powerdale Dam as compared to those estimated by the spring Chinook hindcast with the life-cycle model (1997-2001).

Summer Steelhead

The hindcast of the summer steelhead model produced returns in four years that could be compared to actual returns (1998-2001). The model predicted natural returns to Powerdale Dam with reasonable accuracy. Predicted values were within 15% of the observed in 3 years, and in 2000, were within 40%. In the years with the most deviation, the model over-predicted actual returns. Trends in actual returns were accurately predicted in all 4 years (Figure 138).

Figure 138. Actual returns of natural summer steelhead to Powerdale Dam as compared to those estimated by the summer steelhead hindcast with the life-cycle model (1998-2001).

The comparison between predicted and observed hatchery returns to Powerdale Dam predicted returns within 25% of observed returns, and the trend (increasing or decreasing) was accurately predicted all years. The model consistently under-estimated actual returns to a small degree (Figure 139).

Figure 139. Actual returns of hatchery summer steelhead to Powerdale Dam as compared to those estimated by the summer steelhead hindcast with the life-cycle model (1998-2001).

Winter Steelhead

The winter steelhead hindcast model predicted returns to Powerdale for the 1995-96 to 2000-01 return years that could be compared to observed returns. The model accurately predicted actual returns in 1996 and 1998. In 1997 the model over-estimated actual returns by 35%. In 1999-2001 the model underestimated actual returns by 52-80%. 1999 was the only year that the model did not correctly reflect the positive /negative trend in returns, though the slope of the trend was never accurately predicted (Figure 140).

The winter steelhead hindcast model accurately predicted observed returns to Powerdale in 5 of 6 years. In all years but 1997, the model estimated returns within 9%, and in 1997 underestimated by only 23%. Despite variable trends in returns, the model accurately predicted the positive/negative trend each year (Figure 141).

Figure 140. Actual returns of natural winter steelhead to Powerdale Dam as compared to those estimated by the winter steelhead hindcast with the life-cycle model (1996-2001).

Figure 141. Actual returns of hatchery winter steelhead to Powerdale Dam as compared to those estimated by the winter steelhead hindcast with the life-cycle model (1996-2001).

Examining Model Assumptions – Discussion

Results of the hindcasting exercise indicated that all three models accurately depicted short term future hatchery fish abundance and trends. The results also indicated that while the summer steelhead model accurately reflected returns of natural fish, the spring Chinook and winter steelhead models did not. However, the model did estimate natural returns of spring Chinook and winter steelhead that, with one exception (2001 spring Chinook over-estimate), were within the range of observed values of returns, indicating a reasonable estimate of carrying capacity for the basin for each species.

Results of the hindcast exercise suggested that hatchery returns estimates were fairly accurate. Deviations between model results and actual returns of hatchery fish over time resulted primarily from changes between past and future ocean conditions. The model operated on average ocean conditions observed in the last 5-10 years, but past conditions were not necessarily indicative of future conditions. Annual estimates of natural returns will likely deviate in large degrees from actual returns. However, if ocean conditions remain similar to the past several years, and freshwater survival rates in the long term average near the estimated rates used in the model, then equilibrium spawner returns predicted by the model was reasonably accurate.

The results raised several points about assumptions made within the life-cycle model. First of all, the accurate estimate of the hatchery returns was indicated the actual values of smolt supplementation, smolt to adult return rates, maturity rates, and sex ratios were reliable. However, other critical values that were not adjusted, including the annual marine survival rates, ocean and Columbia River harvest rates, and dam mortality were less reliable. Annual marine survival rates appeared to have had a significant impacts on the number of returns to Powerdale Dam. But at the end, even with the affect of marine survival, the model was able to produce suitable estimates.

Natural returns were more difficult to predict than hatchery fish because of two primary unknowns: 1) variability in freshwater survival, and 2) imperfect natural smolt-adult survival estimates. In the life-cycle model, observed smolt to adult return rates of hatchery fish were applied to natural fish because of lacking data. Results of the models supported the use of the surrogate survival estimates. In most cases, the model accurately predicted positive and negative trends to the observed, indicating that annual variations in survival was predicted (major exception was 2001 spring Chinook return). The only survival factor adjusted in the hindcast exercise was the marine survival derived from hatchery fish. Since this was the only adjusted survival factor, it caused the positive/negative trend predicted by the model. Since the model correctly tracked trends in natural abundance, natural and hatchery fish were experiencing similar marine conditions.

While the predicted trends of natural fish returns was primarily influenced by the variable marine survivals, in reality, the natural fish were also experiencing variable freshwater survival. The difference between the actual and modeled returns indicated that freshwater survival variability played an important role from year to year. The only freshwater survival factor

incorporated into the life-cycle model was the parr to smolt survival rate, which was assumed to be constant.

Freshwater survival rates were highly variable and were completely independent of marine survival. Estimates of spring Chinook freshwater and marine survival in the Warm Springs River from the 1978-1996 broods illustrate this concept. In an 18 year span, egg to smolt survival varied between 2 and 18%, a nearly 10-fold variation (Figure 142).

Figure 142. Freshwater and marine survival rates estimated for spring Chinook in the Warm Springs River for brood years 1978-1996. Data from Olsen and Spateholts 2002.

This variability in freshwater survival was the primary reason that the spring Chinook and winter steelhead models under or overestimated returns. However, while this variability was important to capture in the hindcast exercise, it was not considered a strong influence on life-cycle model when used for forecasting. When forecasting, the model was allowed to run for 30 years (i.e. enough generations to reach equilibrium). The freshwater survival rate (parr-smolt survival) incorporated in the model was meant to reflect average conditions, and it was recognized that annual variations around this mean could be large. However, the model runs over sufficient time (30 years) that the central limit theorem was allowed to work improving the accuracy of the model over time as illustrated in Figure 143. The life-cycle model should be viewed as predicted average long-term annual returns (equilibrium returns) rather than specific annual returns. In hindcast exercise, the model was only able to run for 4-6 years, and high variability around the mean freshwater survival produced inaccurate return predictions. Given a long enough time frame, we believe the hindcast would have been able to accurately predict average annual returns of natural fish.

The accuracy of the summer steelhead model in predicting actual returns was most likely attributed to relatively consistent freshwater survival between years, an appropriate alpha value assigned to the population, appropriate survival rates throughout the life-cycle, and a realistic carrying capacity estimate.

Figure 143. Illustration of variable annual escapement plotted with the cumulative average escapement among years. The life cycle model is designed to estimate the average returns recognizing variability in annual returns.

LIFE-CYCLE MODEL RESULTS - EFFECTS OF CHANGING MANAGEMENT AND ENVIRONMENTAL CONDITIONS

Spring Chinook

The baseline simulation of the Hood River spring Chinook population estimated equilibrium Powerdale Dam returns of 170 natural and 215 hatchery jacks and adults. In addition, it estimated returns of 23 natural and 52 hatchery precocials (Figure 144). Total harvest of spring Chinook was estimated at 258 fish made up primarily of 145 above Powerdale Dam in the tribal fishery, and 58 in the lower Hood River sport fishery (Figure 145).

Figure 144. Equilibrium returns to Powerdale Dam of natural and hatchery spring Chinook as estimated by the baseline run of the life-cycle model.

Figure 145. Equilibrium harvest of Hood River natural and hatchery spring Chinook as estimated by the baseline run of the life-cycle model.

Altered Conditions

Environmental Conditions

Alteration of stream capacity, freshwater survival, or smolt-Age 2 survival without altering other variables resulted in a 1:1 change in natural returns to Powerdale Dam, and harvest of natural fish. A fifty percent decrease, resulted in 50% fewer natural fish returning and harvested, and 50 percent increase resulted in 50% more natural fish returning and harvested. Changes in freshwater variables did not affect hatchery fish.

Combining effects of changes in capacity and freshwater and marine survival indicated that total harvest and returns to Powerdale could be as high as 250% or as low as 45% of

baseline conditions. The largest variation occurs among natural fish because they were exposed to both freshwater and marine variation whereas the freshwater variations were bypassed by hatchery fish. Natural fish harvest and returns experienced variations ranging from 25-300% of baseline conditions (Figure 146).

Under good freshwater and marine conditions and current harvest rates, out of basin harvest reached 135 adults annually, harvest below Powerdale Dam reached 144 adults annually, and harvest in the fishery above Powerdale Dam could have been as high as 463 fish. Under poor freshwater and marine conditions, out of basin harvest was 23, below Powerdale harvest was 23, and above Powerdale harvest was 29 adults. Returns to Powerdale Dam ranged from 155 to 963 fish under the long-term worst and best conditions (Table 60).

The simulated alterations to freshwater and marine environment encompass a 3 fold variation in freshwater survival, and 4 fold variation in marine survival. Larger annual variations were possible, but these simulations reached equilibrium values taking into account annual variations spread over the long term. Data from the Warm Springs River from the 1978-1996 broods of spring Chinook indicated that the environmental variations reflected a realistic range of long term changes in freshwater and marine survival (see Figure 142).

Figure 146. Effects of variable environmental conditions on returns to Powerdale Dam and harvest below Powerdale Dam to hatchery and natural fish.

Table 60. Effects of variable freshwater and marine conditions on returns to Powerdale Dam, out of basin harvest, harvest below Powerdale Dam, and harvest above Powerdale Dam of natural and hatchery fish. Bold and italics denote the baseline condition.

	Escapement to Powerdale			Harvest					
				Out of Basin		Below PD		Above PD	
	Nat.	Hatch.	Total	Nat.	Hatch.	Nat.	Hatch.	Nat.	Hatch.
Parr Capacity									
22,417	85	215	300	10	35	13	32	40	64
33,626	128	215	343	16	35	19	32	60	64
44,835	170	215	385	21	35	25	32	81	64
56,043	213	215	428	26	35	32	32	101	64
67,252	255	215	471	31	35	38	32	121	64
Smolt-Age 2 Survival.									
0.90%	43	54	96	5	9	6	8	12	0
1.80%	85	108	193	10	17	13	16	33	10
3.60%	170	215	385	21	35	25	32	81	64
7.20%	341	430	771	42	70	51	64	161	211
14.40%	681	860	1542	83	139	102	128	323	504
Variable Conditions									
Good FW/Poor Marine	133	108	241	16	17	20	16	52	10
Good FW/Good Marine	533	430	963	65	70	80	64	252	211
Poor FW/Good Marine	192	430	622	23	70	29	64	91	211
Poor FW/Poor Marine	48	108	155	6	17	7	16	19	10

Supplementation Levels

Incorporating different supplementation levels into the model influenced harvest and returns of hatchery fish, but not natural fish. Harvest of hatchery fish increased and decreased at a 1:1 ratio with increased and decreased supplementation (Figure 147, Table 61). When supplementation was eliminated, the natural population was able to maintain itself. The ability of the population to sustain itself was dependent on the marine and freshwater survival conditions and the productivity of the population (Ricker α). The model indicated that given environmental conditions similar to those of the past decade, and assuming appropriate alpha value were used, wild spring Chinook population were able to maintain full capacity in the Hood River.

Increased supplementation did not reduce the natural population, because the allocation scheme mandated that of all fish passed above Powerdale Dam, anything in excess of the spawner capacity was harvested. When numbers above Powerdale Dam were sufficient, only natural fish were allowed to spawn and all hatchery fish were harvested.

Figure 147. Effects of various release levels on escapement to Powerdale Dam and harvest below Powerdale dam.

Table 61. Effects of various supplementation levels on escapement to Powerdale Dam, Out of basin harvest and in-basin harvest of hatchery spring Chinook as estimated by the life-cycle model. Bold and italics indicate baseline scenario.

Supplementation Level	Escapement to Powerdale Powerdale	Harvest		
		Out of Basin	Below PD	Above PD
0	0	0	0	0
75,000	129	15	19	38
<i>125,000</i>	<i>215</i>	<i>25</i>	<i>32</i>	<i>64</i>
250,000	430	50	64	128

Hood River Harvest Rate

Changes in harvest below Powerdale Dam affected returns to Powerdale Dam and harvest above Powerdale Dam (Figure 148, Table 62), but did not affect the number of available spawners. The affect of increasing or decreasing harvest was more accentuated in the harvest above Powerdale Dam than in the returns to Powerdale Dam when viewed as a relative change from baseline conditions.

Figure 148. Effects of lower Hood River harvest rates on returns to Powerdale Dam and in-basin harvest on adult fish.

Table 62. Effects of lower Hood River harvest rates on returns to Powerdale Dam and in-basin harvest on adult fish as estimated by the life cycle model. Bold and italics indicates baseline scenario.

Lower Hood Harvest Rate	Escapement to Powerdale Powerdale	Harvest	
		Below PD	Above PD
5%	412	29	164
9%	396	46	152
<i>11%</i>	<i>385</i>	<i>58</i>	<i>145</i>
14%	375	69	137
20%	349	97	119

Stray Rate

Increased hatchery stray rates had a negative effect on hatchery returns to Powerdale and harvest of hatchery fish (Figure 149, Table 63), but had no effect on natural fish. The effect was most pronounced on harvest of hatchery fish above Powerdale because that harvest was modeled to target hatchery fish more so than the lower Hood River harvest.

Figure 149. Effects of stray rates on hatchery returns to Powerdale, harvest in the Hood River, and number of straying fish. Baseline stray rate is 23%.

Table 63. Effects of stray rates on hatchery escapement to Powerdale Dam, out of basin, and in basin harvest as estimated by the life-cycle model. Bold and italics indicate baseline scenario.

Stray Rate	Escapement to Powerdale		<u>Harvest</u>	
	Powerdale	Out of Basin	Below PD	Above PD
5%	262	35	65	135
20%	223	35	59	103
23%	215	35	57	96
40%	171	35	50	65

Precocial Rate

Increased hatchery precocial rates caused a decrease in jack and adult in-basin harvest and returns to Powerdale Dam. As with stray rate, the effect was most pronounced with harvest above Powerdale because that fishery was modeled to target hatchery fish more so than the lower river harvest.

Figure 150. Effects of precocial rate on hatchery returns and in-basin harvest.

Table 64. Effects of precocial rate on hatchery returns and in-basin harvest as estimated by the life-cycle model. Bold and italics denotes baseline conditions.

Precocial Rate	Escapement to Powerdale	Harvest	
		Below PD	Above PD
5%	224	32	70
9%	215	32	64
20%	188	31	49
40%	141	30	26

Steelhead

The baseline simulation of the Hood River summer steelhead population estimated equilibrium Powerdale Dam returns of 238 natural and 470 hatchery jacks and adults (Figure 151). Total harvest of summer steelhead was estimated at 506 fish made up primarily of in-river harvest of hatchery fish (Figure 152).

Figure 151. Equilibrium returns to Powerdale Dam of natural and hatchery summer steelhead as estimated by the baseline run of the life-cycle model.

Figure 152. Equilibrium harvest of Hood River natural and hatchery summer steelhead as estimated by the baseline run of the life-cycle model.

The baseline simulation of the Hood River winter steelhead population estimated equilibrium Powerdale Dam returns of 241 natural and 475 hatchery adults (Figure 153). Total harvest of winter steelhead was estimated at 307 fish made up primarily of in-river harvest of hatchery fish (Figure 154). Based on review comments from Olsen (ODFW, personnel Communication) the natural fish equilibrium point appears to be below the last 10 year average of 548 adults during years of varying habitat conditions (i.e. drought and good ocean survival). Based on this prospective we agree the winter steelhead model appears to be under estimating natural winter steelhead adult return equilibrium. The model was not adjusted base on this comment due to a limitation of resources. However, we suspect parr survival was the main reason for the underestimate.

Figure 153. Equilibrium returns to Powerdale Dam of natural and hatchery winter steelhead as estimated by the baseline run of the life-cycle model.

Figure 154. Equilibrium harvest of Hood River natural and hatchery winter steelhead as estimated by the baseline run of the life-cycle model.

Altered Conditions

Environmental Conditions

Altering smolt-1 Salt survival without altering other variables resulted in a 1:1 change in natural returns to Powerdale Dam, and harvest of natural fish. Fifty percent decrease resulted in 50% fewer wild fish returning and harvested, and 50 percent increase resulted in 50% more wild fish returning and harvested.

Changes to parr capacity or freshwater survival caused increases or declines in wild returns proportionally greater than the increase or reduction in survival or capacity (Figure 155). Reducing capacity to 50% of baseline conditions caused wild returns to drop to 37% of baseline conditions. An increase of 50% in capacity resulted in an increase in returns of 62%. Changes in returns and harvest after altering freshwater survival were similar to those of altering capacity. Changes relative to baseline were the same for summer and winter steelhead.

Combining effects of changes in capacity and freshwater and marine survival showed that total harvest and returns to Powerdale was as high as 250% or as low as 45% of baseline conditions. The largest variation occurs among wild fish because they are exposed to both freshwater and marine variation whereas the freshwater variations were bypassed by hatchery fish. Wild fish harvest and returns varied from 25-340% of baseline conditions (Figure 156).

Under good freshwater and marine conditions, and current harvest rates, out of basin harvest of summer steelhead consistently was as high as 278 fish, harvest below Powerdale Dam would reach 623 consistently (including recycles). Under poor freshwater and marine conditions, harvest would consistently be 70 out of basin and 181 in basin. Returns to Powerdale Dam ranged from 295 to 1,745 fish under the long-term worst and best conditions (Table 65).

For winter steelhead, good freshwater and marine conditions provided 58 fish for out of basin harvest and 524 fish for lower basin harvest (including recycles). Under poor freshwater and marine conditions, harvest would consistently be 14 out of basin and 136 in basin. Returns to Powerdale ranged from 298 to 1,759 winter steelhead under the long-term worst and best conditions (Table 66).

Figure 155. Effects of altering parr capacity or freshwater survival on wild summer and winter steelhead returns to Powerdale and harvest as estimated by the life-cycle model.

Figure 156. Effects of variable environmental conditions on returns to Powerdale Dam, harvest of non-recycles, and number recycled.

Table 65. Effects of variable freshwater and marine conditions on summer steelhead returns to Powerdale Dam and harvest of hatchery fish. Bold and italics denote the baseline condition.

	<u>Escapement to Powerdale</u>			<u>Hatchery Harvest</u>		
	<u>Nat.</u>	<u>Hatch.</u>	<u>Total</u>	<u>Out of Basin</u>	<u>Below PD</u> <u>Non-Rec.</u>	<u>Recycles</u>
Parr Capacity						
20,413	90	470	560	139	174	192
30,620	164	470	634	139	174	181
40,827	238	470	708	139	174	169
51,033	312	470	782	139	174	157
61,240	386	470	856	139	174	144
Smolt-1 Salt Surv.						
1.27%	60	118	177	35	44	43
2.54%	119	235	355	70	87	86
5.07%	238	470	708	139	174	169
10.14%	475	940	1,416	278	348	332
20.28%	951	1,880	2,831	557	695	657
Variable Conditions						
Good FW/Poor Marine	202	235	437	70	87	73
Good FW/Good Marine	805	940	1,745	278	348	275
Poor FW/Good Marine	238	940	1,178	278	348	373
Poor FW/Poor Marine	60	235	295	70	87	94

Table 66. Effects of variable freshwater and marine conditions on winter steelhead returns to Powerdale Dam and harvest of hatchery fish. Bold and italics denote the baseline condition.

	Escapement to Powerdale			Hatchery Harvest		
				Out of Basin	Below PD	
	Nat.	Hatch.	Total		Non-Rec.	Recycles
Parr Capacity						
24,993	90	475	565	29	234	39
37,489	166	475	641	29	234	37
49,986	241	475	716	29	234	35
62,483	317	475	791	29	234	32
74,979	392	475	867	29	234	30
Smolt-1 Salt Surv.						
0.98%	60	119	179	7	58	9
1.96%	121	237	358	14	117	17
3.92%	241	475	716	29	234	35
7.84%	482	949	1,432	58	468	68
15.68%	965	1,899	2,864	116	935	133
Variable Conditions						
Good FW/Poor Marine	202	237	440	14	117	15
Good FW/Good Marine	809	949	1,759	58	468	56
Poor FW/Good Marine	243	949	1,193	58	468	76
Poor FW/Poor Marine	61	237	298	14	117	19

The highest harvests occurred when freshwater conditions were poor and marine conditions were good. Poor freshwater conditions resulted in less natural fish passed above the dam, causing more of the hatchery fish to be recycled rather than passed above the dam. This was because hatchery steelhead was only passed above Powerdale Dam up to 25% of the wild run. Since wild fish were not harvested within the Hood Basin, reductions in wild returns did not reduce harvest.

Supplementation Levels

Incorporating different supplementation levels into the model influenced both hatchery and natural fish. Hatchery returns were positively correlated at a 1:1 ratio with supplementation. Wild fish were negatively affected by increased supplementation. The mechanism for this was increased numbers of residuals under higher supplementation strategies. The residuals out competed wild parr for rearing territory, thereby decreasing the number of potential wild recruits. Accordingly, under increased supplementation programs, the number of fish being recycled grew proportionally faster than the number of supplemented smolt (Figure 157, Figure 158, Table 67).

Figure 157. Effects of various release levels of summer steelhead on escapement to Powerdale Dam of wild and hatchery fish, and number of fish recycled.

Figure 158. Effects of various release levels of winter steelhead on escapement to Powerdale Dam of wild and hatchery fish, and number of fish recycled.

Table 67. Effects of various supplementation levels on escapement to Powerdale Dam, Out of basin harvest and in-basin harvest of hatchery summer and winter steelhead as estimated by the life-cycle model. Bold and italics indicate baseline scenario.

Supplementation Level	Escapement to PD		In-Basin Hatchery Harvest	
	Wild	Hatchery	Non-Recycles	Recycles
Summer Steelhead				
0	292	0	0	0
40,000	238	470	174	169
80,000	180	940	348	384
150,000	78	1763	472	754
Winter Steelhead				
0	293	0	0	0
10,000	289	95	47	1
30,000	265	285	140	17
50,000	241	475	234	35
85,000	199	807	398	65

Hood River Harvest Rate

Changes in harvest below Powerdale Dam affected hatchery returns to Powerdale Dam and the number of fish recycled (Figure 159, Table 68), but did not affect the number of available spawners. Increases in harvest rates reduced the number of fish reaching Powerdale and thus decreased the number of fish that had to be recycled. The relative effects of increases and decreases in harvest rates were the same for summer and winter steelhead.

Figure 159. Effects of lower Hood River harvest rates on summer and winter steelhead hatchery returns and the number of fish recycled.

Table 68. Effects of lower Hood River harvest rates on returns to Powerdale Dam and the number of fish recycled as estimated by the life cycle model. Bold and italics indicates baseline scenario.

Hood R. Harvest Rate	Hatchery Escapement to Powerdale	# Fish Recycled
Summer Steelhead		
20%	515	880
27%	470	789
34%	425	698
Winter Steelhead		
25%	531	529
33%	475	603
40%	425	689

Residualism

Increased residualism reduced the number of wild and hatchery fish returning to Powerdale Dam and harvest. Increased residualism had a pronounced effect on wild fish than hatchery fish because every one hatchery residual reduces the capacity of the freshwater habitat to produce several parr. The number of fish recycled and number of recycles harvested is reduced because of the reductions in wild production (Figure 160, Table 69).

Figure 160. Effects of residualism on summer and winter steelhead escapement, harvest of non-recycles, and number recycled. Bars represent returns to Powerdale and harvest of non-recycles (effect of residuals was the same for both).

Table 69. Escapement to Powerdale and harvest of hatchery summer and winter steelhead at different hatchery residualism rates as predicted by the life-cycle model.

Residual Rate	Escapement to Powerdale			Hatchery Harvest			
				Out of Basin	Below PD		Total
	Nat.	Hatch.	Total		Non-Rec.	Recycles	
Summer Sthd.							
5%	238	470	708	139	174	169	482
10%	180	445	625	132	165	168	464
18%	87	406	493	120	150	165	435
Winter Sthd.							
5%	241	475	716	38	234	35	307
10%	181	450	631	34	222	34	290
18%	84	410	494	28	202	33	263

CHAPTER 11: RECOMMENDATIONS

KEY FINDINGS IN CHAPTER 11:

- Review and adjust program goals and objectives based on new information gathered over the last 10 years. Create short and long term goals and associated performance standards, crafted in a manner that allows the M & E program to measure progress.
- Develop, implement and evaluated means to reduce the release of residual hatchery fish.
- Test the efficacy of reducing precocity rates of spring Chinook by releasing smaller hatchery fish, while considering trade offs such as smolt survival.
- The utility of acclimating spring Chinook smolts in the Hood River earlier and for a longer period should be evaluated and tested.
- Hatchery brood should come from Hood River returns over Deschutes River returns.
- Methods to reduce Spring Chinook disease (i.e. BKD) at Pelton Ladder should be explored and implemented.
- The effect of the removal of Powerdale Dam on the goals, objectives and protocols of the HRPP should be estimated, assessed and evaluated in terms of potential program changes.
- Place the highest priority on irrigation withdrawal screening and withdrawal structural improvements. The next highest priority should focus on stream flow restoration activities.
- Conduct fencing projects only in core anadromous fish rearing habitat that has poor riparian vegetation and appropriate geologic conditions.
- Prior to conducting habitat improvement projects estimate impacts of degraded condition and the benefit of the project in terms of fish, and conduct M&E activities to measure realized benefits.
- Determine stray rates of recycled fish and adjust harvest management strategies to meet stray rate goals.
- Determine the contribution of fall outmigrants to adult returns.
- Refocus screw trap efforts to attain spring Chinook migration estimates for spring and fall migrants. Furthermore, attempt to increase precision of screw traps by improving trap catch performance and analyze data in biweekly to monthly time-steps for all migrating size classes.
- If Coded Wire Tagging (CWT) Programs continue, create a five year mark and recovery plan, which is updated annually. ”
- Studies measuring the affect of habitat factors limiting egg to smolt survival should be conducted. Studies such as bed-load movement and sediment transport may explain the low egg to smolt survival and lead the HRPP to implement novel strategies for increasing wild fish survival.
- Annually review HRPP successes and failures, reprioritize M&E activities, and report finding in summary reports focusing on monitored performance indicators, which are tied to goals.

PLANNING

- Review and adjust program goals and objectives based on new information gathered over the last 10 years. Create short and long term goals and associated performance standards, crafted in a manner that allows the M & E program to measure progress.

FISH PRODUCTION

- Fish remaining in acclimation facilities after volitional release should be euthanized or released into closed basin lakes, rather than released below Powerdale Dam to minimize the number of precocious males (mini-jacks).
- Test the feasibility of reducing precocity rates of spring Chinook by releasing smaller hatchery fish, ranging between 15 and 20 fish per pound, while considering trade offs such as smolt survival.
- Begin acclimation of spring Chinook smolts in the Hood River by March 1st and increase acclimation time to a minimum of 30 days. This will allow smolts to acquire an adequate olfactory imprint of the Hood River, and reduce straying into the Deschutes River.
- Hatchery brood should come from Hood River returns over Deschutes River returns.
- Spring Chinook disease (i.e. BKD) at Pelton Ladder should be reduced to meet an established goal. If goal is not achieved, rearing at other facilities may be warranted.
- Releases of Skamania stock below Powerdale Dam should be discontinued, if adult fish control structures associated with Powerdale Dam are removed to minimize impacts on indigenous summer steelhead stocks.
- Adjust adult return and harvest goals based on number of fish released.

HARVEST

- Explore new strategies to increase harvest by methods other than recycling to reduce the possibility of straying until acceptable stray rates are detected and accomplished. Furthermore, decommissioning Powerdale Dam will likely leave recycling an incompatible strategy with conservation goals requiring the use of alternative methods.

HABITAT PROGRAM

- Place the highest priority on irrigation withdrawal screening and withdrawal structural improvements. The next highest priority should focus on stream flow restoration activities.
- Conduct fencing projects only in core anadromous fish rearing habitat that has poor riparian vegetation and appropriate geologic conditions.

- Prior to conducting habitat improvement projects estimate impacts of degraded condition and the benefit of the project in terms of fish, and conduct M&E activities to measure realized benefits.

MONITORING AND EVALUATION PROGRAM

- Determine stray rates of recycled fish and adjust compare to stray rate goal.
- Determine the residualism rates for all species and compare to residualism goal.
- Determine the contribution of fall outmigrants to adult returns.
- Refocus screw trap efforts to attain spring Chinook migration estimates for spring and fall migrants. Furthermore, attempt to increase precision of screw traps by improving trap catch performance and analyze data in biweekly to monthly time-steps for all migrating size classes.
- Monitor the disease load (i.e. BKD) of Pelton Ladder rearing spring Chinook and compare to health goals.
- If Coded Wire Tagging (CWT) Programs continue, create a five year mark and recovery plan, which is updated annually. Use the CWTs to test fish performance to examine questions such as “What is the different return rate between Pelton Ladder and Parkdale Hatchery reared spring Chinook that were released in to the Hood River?”
- Studies measuring the affect of habitat factors limiting egg to smolt survival should be conducted. Studies such as bed-load movement and sediment transport may explain the low egg to smolt survival and lead the HRPP to implement novel strategies for increasing wild fish survival.
- Annually review HRPP successes and failures, reprioritize M&E activities, and report finding in summary reports focusing on monitored performance indicators which are tied to goals.

EXPLANATION

Planning

Both the M&E program and this review described the HRPP progress towards goals, documented proven hypotheses and identified uncertainties. The HRPP would benefit from using this information to revise the 10 year old program goals and objectives. The HRPP program goals were generally lacking the specifics required to adequately measure intermediate progress toward long-term goals. The long term goal for the year 2016 provided the HRPP vision, but was less affective at identifying year-to-year or generation-to-generation standards by which to measure performance.

Appropriately scoped goals, objectives and performance standards serve both a long and short-term function. Short and intermediate term goals, and measurable performance standards that are evaluated by the M&E program, facilitate adaptive management and program success. We strongly believe adaptive management is the most viable program implementation strategy available and believe the HRPP should employee this management technique. The HRPP will benefit from continually questioning program performance and evaluating means to achieve the desired end result. This may entail adjusting goals, objectives, strategies or performance indicators. The acceptance of a goal should not be preserved simply because it was created years

ago or to maintain the status quo. Achievement of goals can only occur by adjusting the program to surmount obstacles and by continually questioning the appropriateness of each goal and strategy. Methodical documentation of program adjustments (including justification for each) would provide a formal means of documenting shifts in program activities due to new understanding. The M&E program should be the vehicle to facilitate adaptive management and maintain adequate records.

The planning of the HRPP required the creation of goals, objectives, etc. which grew from the collective understanding of the fisheries professionals. Hypotheses formulation, whether recognized or not, was a key component of creating the goals and strategies of the HRPP. However, the HRPP has not documented the hypotheses used to set goals. As a result, we pieced together the hypotheses based on concepts presented in the Hood River Master Plan (O'Toole 1991). Many of the inexplicitly stated hypotheses proved to be true, but a few were either false or unresolved (Table 70). Based on the data and new understanding after 10 years of program implementation, we created a suite of new or modified hypotheses (Table). These hypotheses should be reviewed for their relevance and reflected upon as the Fish Managers refine the 10 year old goals and strategies. Once the goal, objectives and performance standards are refined, the M&E program should amend the studies to better address unresolved hypotheses viewed vital to program success and implement measurements to directly address performance indicators.

Table 70. HRPP hypotheses extracted from the Hood River Master Plan (O'Toole 1991).

Resolution	Hypotheses
True	The Hood River is a dynamic glacier driven system that provides poor habitat conditions (i.e. high sediment load and high gradient) for juvenile salmonids resulting in below average egg to smolt survivals.
True	Egg-to-smolt survival is the limiting factor controlling population size of summer/winter steelhead and spring Chinook below management expectations.
Unresolved	A hatchery program will increase the egg-to-smolt survival resulting in harvestable numbers and maintain a healthy wild population.
True	Hood River programs will rebuild naturally self-sustaining spring Chinook and summer/winter steelhead populations.
Unresolved	The hatchery program is of sufficient size to meet both harvest goals and fully seed the Hood River with wild fish.
False	Capacity to sustain natural production is accurately estimated from the NWPPC smolt density model.
Unresolved	Hatchery smolts releases have no significant impacts on wild juveniles.
True	Acclimated releases result in greater survival as opposed to direct releases.
Unresolved	Hatchery smolt releases have little effect on wild smolts, because these fish do not compete for food or space.
True	The hatchery program will not significantly affect the genetic fitness of the wild population as long as 10% of the brood comes from wild fish, and breeding protocols are followed. The protocol includes taking of eggs throughout the run, mating randomly, maintaining male-to-female ratio appropriate for breeding population size (1:1), and using all ages of returning fish for breeding.
Unresolved	The Deschutes River Spring Chinook Stock at Round Butte released into the Hood River will adapt and result in a wild self sustaining population in the West Fork Hood River.
Unresolved	Rearing steelhead and spring Chinook in a Deschutes River Hatchery and on water different from Hood River will not affect performance of hatchery fish.
True	Indigenous stocks of summer and winter steelhead reared in the hatchery will perform better than out-of-basin stocks reared in the hatchery.

Table 71. New and modified hypotheses based on 10 year of HRPP data gathering and implementation.

Resolution	Hypotheses
True	The Hood River is a dynamic glacier driven system that provides poor habitat conditions (i.e. high sediment load and high gradient) for juvenile salmonids resulting in below average egg-to-smolt survivals. Further, egg-to-smolt survival is the limiting factor controlling population size of summer/winter steelhead and spring Chinook.
True	A hatchery program will increase the egg-to-smolt survival resulting in harvestable numbers and maintain a healthy wild population.
Unresolved	Hood River programs will rebuild naturally self-sustaining spring Chinook and summer/winter steelhead populations.
False	The hatchery program is of sufficient size to meet both harvest goals and fully seed the Hood River with wild fish (based on UCM).
False	Capacity to sustain natural production is accurately estimated from the NWPPC smolt density model.
Unresolved	Hatchery smolt releases have insignificant impacts on wild parr.
Unresolved	Acclimated releases result in greater survival as opposed to direct releases.
Unresolved	Hatchery smolt releases do have an effect on wild smolts; hatchery and wild migrants do compete for dynamic and finite food or space.
True	The hatchery program will not significantly affect the genetic fitness of the wild population as long as a majority of the brood comes from wild fish, eggs will be used throughout the broodstock run, mating will be random, with males to female ratio appropriate for breeding population size (1:1), and all ages of returning wild fish will be used for egg take and fertilization.
Unresolved	The Deschutes River Spring Chinook Stock at Round Butte released into the Hood River will adapt and result in a wild self sustaining population in the West Fork.
True	Rearing steelhead and spring Chinook in a Deschutes River Hatchery and on water different from Hood River will affect performance of hatchery fish.
True	Indigenous stocks of summer and winter steelhead reared in the hatchery will perform better than out-of-basin stocks reared in the hatchery.
	<i>Spring Chinook</i>
True	Capacity to sustain natural production of spring Chinook is substantially less than estimated from the NWPPC smolt density model.
Unresolved	Hatchery spring Chinook experience high straying rates because they are moved from Pelton Ladder to the West Fork acclimation after the smolting/imprinting peak (April) and held in the acclimation facility for too short a period (6 days) for the fish to gain an imprint of the upper West Fork.
Unresolved	Hatchery spring Chinook experience high mini-jacking rates because they are grown at accelerated rates in the Pelton Ladder, stimulating precocity in males.

Resolution	Hypotheses
Unresolved	Spring Chinook migrate out of the West Fork and into the mainstem Hood River due to limiting environmental conditions in the West Fork.
Unresolved	Presmolt outmigrants contribute significantly to adult returns.
Unresolved	Successful adaptation of hatchery Deschutes spring Chinook stock will only occur by using wild adults returning to the Hood River.
Unresolved	Spring Chinook reared in the Pelton Ladder become infected with BKD from fish upstream, resulting in poor smolt-to-adult survival.
Unresolved	Spring Chinook do not enter 17% of the area that had been assumed to provide suitable habitat. These areas were at the upstream end of the assumed distribution, and may be limited by cold temperatures, or low flow for adult access or holding. Juveniles do not exploit the habitat in the areas upstream of spawning.
Unresolved	Low water temperatures limit opportunity for growth of juvenile Chinook, and this translates into low survival.
	<i>Winter and Summer Steelhead</i>
Unresolved	Recycling of non-indigenous adults through the lower Hood River below Powerdale Dam likely results in straying to other rivers.
True	Numerous recycle trips are necessary for anglers to harvest a majority of the returning hatchery adults.
Unresolved	Hatchery smolts contribute an unacceptable number (>5%) of residuals/precocious males. Residuals limit smolt production by occupying habitat and preying on young.

Fish Production

Reduce Residuals

Based on evidence collected by the HRPP M&E program, hatchery fish which did not volitionally migrate out of the acclimation facilities into the Hood River (called residuals) were likely precocious males based on our analysis of data contained in ODFW databases (Olsen July 2002). Further, a large percentage of spring Chinook released below the Powerdale Dam returned to Powerdale Dam as mini-jacks the same year of release. The mini-jacks did not substantially contribute to the creel and was a nuisance for adult trap operators. Precocious hatchery spring Chinook and steelhead compete for food and space with wild fish and were not considered a beneficial product of the hatchery program. Consequentially, we recommend either euthanizing the residuals or planting them in closed lake basins to support trout type fisheries.

Reduce Precocity of Spring Chinook

Residuals represented an unwanted by-product of the hatchery, and therefore, efforts to reduce residuals will benefit the HRPP. Since a large majority of the residuals were precocious males, we recommend measures be taken to reduce precocity. Shearer and Swanson (2000) established that the higher the lipid level of the fish, the greater the likelihood of precocity. Further, high growth rates were linked to high lipid levels. Therefore, slowing growth rates by

using a lower lipid containing food may reduce lipid levels and precocity of smolts. Measures should be taken to reduce growth, targeting 15-20 fish per pound at release. However, this measure should be viewed as experimental. A dominate belief in the Columbia River Basin was spring Chinook smolts result in lower survival than big smolts. Tests conducted in the Deschutes River indicated the opposite. Smaller smolts had a slight survival advantage over larger smolts. However, this study had limited power and should be viewed as an initial finding warranting further study (see chapter 5 for further details). Thus, releases of differentially marked hatchery fish with size at release being the only known difference would test residualism rates and smolt to adult survival differences. A decision to shift the entire program to smaller release size should be based on pre-study performance standards for residualism and smolt to adult survival in comparison to study results.

Reduce Straying of Spring Chinook

The HRPP spring Chinook program experienced high straying rates. The majority of strays returned to the Deschutes River (natal stream), suggesting little to no genetic consequences for other populations. However, the reduced number of returning adults to the Hood River was viewed as an unacceptable outcome of the hatchery and acclimation practices. Hatchery spring Chinook were moved from the Deschutes River to the Hood River in April. Physiological studies of smolts in the Deschutes R. indicated smolting began as early as February (Beckman et al. 1999). The creation of an olfactory imprint memory of the natal stream occurs during smoltification (Hasler and Scholz). The olfactory imprint is the mechanism used by returning adults to find their natal stream. As a result, a number of the fish released into the Hood River had imprinted to the Deschutes and therefore returned to the Deschutes. To resolve this problem, presmolts must be moved to Hood River water prior to imprinting (March 1st). Further, holding the fish for a minimum of 30 days will allow for the fish to regain strength after being transferred and provide a long enough period to imprint to the acclimation area.

Minimize Straying from Recycling

Skamania Stock summer steelhead were recycled up to 15 times and winter steelhead up to 7 times during the 1990s. During each recycle, roughly 56% of the fish either strayed or died. This suggested the level of straying was unacceptable based on NOAA Fisheries 5% straying goal. Since the actual level of stray versus mortality was unknown, the HRPP should conduct studies to establish the actual stray rate. Until stray rate are know the number of recycle circuits should be limited, and new techniques should be employed to increase harvest rates (i.e. increase bag limit, advertise fishery, involve fishing clubs, conduct angler clinics, etc.).

Spring Chinook Hatchery Brood Collection

Brood for the hatchery were collected primarily in the Deschutes River and their progeny were released into the Hood River. Less than half of the brood was of fish returning to the Hood River. Wild adults returns to the Hood River represented fish that survived the Hood River. Returning fish are the few that because of luck or because of their phenotypic superiority survived. They survived the Hood River environment and returned. We assume survivors were

the best adapted to the Hood River and contain the appropriate genetic information to give rise to progeny with superior survivability in the Hood River. Ideally, the HRPP would use wild fish as brood. Unfortunately, insufficient numbers of wild fish return to sustain a wild population and provide for the Hatchery needs. This presents a conundrum.

If the HRPP uses wild fish exclusively, they would mine the last of the adapted fish causing the collapse of the wild fish spawning in the wild. No more highly adapted fish would exist in the wild, but would exist in the hatchery. The selective pressures in the wild only allowed for the survival of the adapted fish. In the wild, selective pressures causing the adaptation is continually applied generation after generation improving on the wild population's survivability (fitness) in the Hood River. Once the wild fish are brought into the hatchery the selective pressures changes. Many fish unfit in the wild survive in the hatchery and if the unfit fish survive to reproduce, the wild genotypic character will be altered. If we assume wild fish have the greatest fitness, then the hatchery program should do all it can to exploit the wild fish without jeopardizing their existence. The HRPP should determine the percent or number of wild fish available for the hatchery program and further the HRPP may consider crossing wild fish with wild fish to limit the influence of hatchery fish on the wild genetic character.

Until the wild population builds to a level capable of sustaining the hatchery program, returning hatchery fish to the Hood River should be the second group used in the hatchery. All measures possible should be taken to maximize returning hatchery fish survival, such as not allowing harvest, decreasing precocity and reducing strays. Hatchery fish returning to Powerdale should be allocated to the hatchery as brood over escapement into the Hood River to spawn. Although hatchery fish were not subjected to the natural selective pressures as juveniles, they did survival those pressures from smolt through adulthood. So, these fish were at least partially adapted to survive in the ocean and possible in the Hood River.

Adults returning to the Deschutes River should be avoided and only used in the wild and hatchery Hood River returns were unable to support the hatchery program.

Disease Effects

Spring Chinook survival in the Pelton Ladder rearing vessel was below optimum due to disease problems. Pelton Ladder rears spring Chinook on river water containing BKD, among other pathogens. Survival within the hatchery system and as smolts was believed to impact program success (see chapter 4). We recommend measures be taken to further reduce disease, which may include upgrading filtering systems in the hatchery, using prophylactic antibiotics or vaccinations, changing water sources and/or changing rearing facilities. The fish managers should set a disease performance standard, and if after attempts to curtail disease at the Pelton Ladder were not able to meet the standard, a change in water source at Pelton Ladder or alternative rearing facilities should be explored.

Align Harvest goals

Based on current hatchery releases and environmental conditions, the Life Cycle model indicated current program goals were unattainable on an annual basis. There may be years with

very good freshwater and ocean conditions allowing for unusually high survival, but on average the goals appeared to be unattainable. HRPP proponents would benefit from readdressing goals based on the data presented in this and other reports.

Harvest

Recycling and Harvest Augmentation

Recycling may not be an option in the future due to the removal of Powerdale Dam. As a result, other methods should be explored to increase harvest rates. At each recycle, roughly 44% of the recycled fish were harvested. The Fish Managers could implement measures to increase harvest rate such as liberalizing bag limits, advertising success of the fishery and allowing more effective gear types. If harvest does not increase with abundant returns, then the number released may need to be reduced.

Habitat Program

Habitat Renewal Priorities

The habitat program appeared to provide the greatest benefits through irrigation withdrawal screening and stream flow restoration (Chapter 6). As a result, greatest program emphasis should be placed in these areas. Riparian fencing, although a recommended strategy by the Hood River TMDL to decrease water temperature, were completed at a small enough scale (1.5 miles) and conducted in areas with limited anadromous fish use to limit realized benefits. Large scale riparian restoration will take considerable effort and should not be conducted at the expense of addressing water withdrawals.

Monitoring and Evaluation

The M&E Program collected many vital data sets in order to provide an indication of program success and remove uncertainty. Corner stones of the Hood River M&E program were the adult return data to Powerdale Fish trap, smolt outmigration estimates, and creel surveys. From this information, the M&E program was able to evaluate the success of each hatchery release group, provide a means to differentiate between adult summer and winter steelhead, estimate numbers of steelhead smolts leaving the Hood River, identify spatial temporal distribution of juvenile and adult salmonids, assess habitat and irrigation withdrawal in terms of fish impacts, and determine age structures and life history strategies of wild and hatchery fish. The M&E program has recognized the need for and implemented studies which address the many uncertainties associated with the HRPP. Still, there were many uncertainties the M&E program had not resolved.

Fate of Recycled Fish

The ODFW began the M&E program in 1991 by trapping adult salmonids at the Powerdale Ladder and passing them over the dam. From 1991 to 2001 the adult trap was periodically modified to improve performance and serve the needs of the M&E program.

Operators of the Powerdale trap appear to have taken all possible measures to insure the safety of the trapped adults while collecting biometric data (i.e. length, weight, and scales). Trapping and sorting of adults allowed for controlled allocation of adults to (1) natural spawning in the upper river basin, (2) hatchery broodstock, (3) or recycling through the lower river for harvest enhancement. Collection of adults in the Powerdale ladder were effective and the cornerstone of the M&E program.

Although the trapping data provided strong estimates of adult returns, it did not alone provide sufficient data from which to determine the fate of recycled fish. Recycling studies indicated that from 25 to 50% of the fish recycled fish could not be accounted for. Straying and death were possible outcomes of the recycling process. Owing to the fact that a majority of the recycled steelhead were from non-indigenous stock (out-of-basin Skamania stock) and in the vicinity of ESA listed steelhead stocks, the straying issue ought to be addressed. A study should be conducted to determine the fraction of adult recycled steelhead that stray to other rivers or perish prior to spawning. This could be accomplished with telemetry studies if recycling is continued. The HRPP should adopt a straying standard, and if the M&E program finds the recycle program exceeds the goal/standard, the recycle program would require modification.

Residuals

The acclimation program began in 1996 with winter steelhead and spring Chinook and has grown to include summer steelhead. The program now releases all fish after a period of acclimation. Studies focused on survival and size of fish in the acclimation facility. Thus, no studies were conducted to validate the assumption that survival of direct releases were less than acclimated releases. Instead, the some members of the M&E program relied on the inference that since direct releases have stopped and acclimated releases have begun, the survival of released smolts has dramatically increased (Lambert 2001). Other members of the HRPP do not believe acclimation has increase survival. We believe that acclimation was likely to increase survival, but benefits of the practice cannot be estimated under present sampling regimes.

A deficiency of the M&E program was residualism studies. The M&E program attempted to determine the percent of hatchery released steelhead and spring Chinook that residualized by snorkeling and electrofishing. In the West Fork, snorkeling discovered no residual spring Chinook, but did find 1 to 5 residual steelhead in four out of five pools surveyed (Lambert et al 1998). The East and Middle Forks were not sampled due to low visibility. More recent annual reports indicated that electrofishing and snorkeling were ineffective for estimating residualism in spring, and insufficient staffing levels precluded fall surveys (Lambert et al. 1999).

In addition, from 1994 -1996, ODFW staff electrofished in 60 m block-netted segments of stream to estimate juvenile fish density (Olsen 1995, 1996). Fish density was reported separately for two length categories; those with a fork length greater than 85 mm and those with a fork length less than 85mm. No estimates were given for residuals and the level of residualism was left unresolved. Genetics studies on steelhead in the Hood River indicated that roughly 50% of the spawning population was unaccounted for and may be the result of residualized males (Blouin 2000).

Residualism should be viewed as a critical uncertainty requiring M&E program attention. One of the purposes behind releasing hatchery smolts was to limit competitive interactions with wild fish. If hatchery smolts were residualizing then hatchery induced competition and predation may be limiting wild fish survival. Life cycle modeling indicated that even modest numbers of residuals can dramatically impact wild parr (see chapter 9 for details). Theoretically, residual steelhead (because of their larger size than parr), inhabit the area of 5 or more wild parr. A possible suite of sampling approaches to estimate residuals are: hook and line, electrofishing, and snorkel surveys during the summer and fall.

Fall Emigrants

Spring Chinook and winter steelhead both expressed noteworthy emigration during the fall. The reason for the emigration and the contribution of the fall emigrants to adult returns was unknown. These unknowns created many questions. Do the Forks of the Hood River contain undesirable habitat conditions, forcing fish to emigrate early? Was the Hood River at capacity and the fall emigrants represent fish in excess of capacity? How does the survival of fall and spring emigrants compare? The freshets associated with rain-on-snow events in the winter may reduce survival, thus fish emigrating in the fall may have greater survival. Identifying the possible benefits of the fall migration may prompt changes to the current program. For example, fall hatchery plants of spring Chinook may increase the rate at which the Deschutes Stock adaptation to the Hood River. Marking fall emigrants, estimating migration numbers, and tracking survival of fall migrants in comparison to spring migrants (through tagging studies) may result in greater knowledge.

Screw Trap Studies

Fisheries Managers rely on egg-to-smolt and smolt-to-adult survival estimates in order to identify survival bottlenecks, and to determine the annual performance of fish populations. Each index relies upon an accurate estimate of smolt outmigrants. In the Hood River, screw traps were employed to estimate the number of outmigrants. So, if the accuracy and precision of the screw trap data is in question, the Fish Managers are presented with a critical uncertainty: are the egg-to-smolt and smolt-to-adult survival estimates reliable? To alleviate this critical uncertainty, we suggest the M&E program address marked fish survival, sampling intensity, sampling location, and sampling stratification. Further, it is especially important if efforts to establish spring Chinook are to continue, that sampling be upgraded to enable estimation of natural production of outmigrants (see chapter 5).

Marked Fish Survival

The act of marking fish induced handling stress that may have reduced survival of marked fish. If mark survival is less than 100% the outmigrant number will be overestimated. Each year, stream conditions (stream flow) and fish health (disease) were apt to vary, resulting in different post-release survival rates. If survival does vary between years, then this variation would increase estimation errors in the number of outmigrants. There appeared to be notable post-release mortality of marked spring Chinook and possibly steelhead. Survival studies should

be conducted to remove this critical uncertainty. The M&E program could employ two methods to estimate survival. Thedinga et al. (1994) periodically held a random sample of 25 marked fish per species in an aerated tub or flow through box, and after 1-2 days, accounted for percent survived. Another approach is to release paired treatment groups of hatchery fish above the trap and compare their recovery rates. One group would be released in the usual manner while the second group (released at the same time) would have been held in a recovery pen for a day or more before release. The difference in recovery rate would represent post-release survival of test fish released immediately after marking. Multiple replications of this experiment with varying fish sizes, time of year and stream flows should provide a reliable estimate of survival.

Sampling Intensity

The trap efficiency varies among years, and fewer fish are captured in years of low trap efficiency. Carson et al. (1998) details a means to estimate the number of marked fish required to meet mark recovery rates and relative error levels. We recommend this approach be used to guide marking goals.

In order to increase the number of test fish, sampling efficiency or intensity must be increased. We recommend that both the sampling efficiency and the number of marked test fish be increased by deploying multiple traps at or near the same sampling location. Further, traps could be fished during periods of high water and during high fish passage by checking the trap multiple times through the day and night when the situation warrants. Reducing the hours the trap is out of operation will increase the recovery rates of marked and unmarked fish.

Sample Location

Highest priority for screw trapping should be given to the mainstem Hood River, followed by the West Fork. The mainstem screw trap was used to determine the number of outmigrants leaving the river. This estimate in turn was used for egg-to-smolt and smolt-to-adult survival indices. The West Fork screw trap could be used to estimate production of summer steelhead and spring Chinook, which almost exclusively used this fork. The ability of the West Fork to support spring Chinook, and the genetic fit of the donor stock remain key areas of uncertainty.

Data from traps in the forks have provided valuable insight into how the fish partition habitat use in the basin for different life stages. These traps revealed that juvenile winter steelhead and spring Chinook commonly emigrate from the forks in the fall, which raises a critical uncertainty. Is fall emigration adaptive or does it reflect a habitat limitation in the basin? What proportion of the fall migrants produce returning adults and how does that number compare to spring migrants? If sufficient funds, staff, and the intent to address the accuracy issue were present, then the continued screw trap sampling in the forks would benefit the program.

We believe that application of PIT tags to fish captured in the forks and at the mainstem trap would answer critical questions about the fate and survival rates of different life histories in the basin. PIT tags could be detected as juveniles pass Bonneville Dam, and again as adults

return to Powerdale Dam. Juveniles Pit tagged in the forks may also provide informative detections at the mainstem trap if efficiency is increased.

Outmigrant Stratification

Estimation of outmigrant abundance presently relies on a “settle for” approach of applying one trap efficiency estimate representing the entire year. Trap efficiency is clearly not constant through the sampling season. However, our analysis indicated the present sampling method will support a single annual estimate of efficiency better than biweekly estimates. If recovery and/or survival conditions were addressed on a monthly or biweekly interval, those intervals should provide better estimates of abundance. Stream flow, fish size, and behavior all affect trap efficiency (Carlson et al 1998). Stream flow, fish size, and behavior differ weekly to monthly. Thus, in order for an outmigrant estimate to be as accurate as possible, the estimate must be calculated from stratified time intervals to bracket like conditions for trapping efficiency.

Spring Chinook Disease

Spring Chinook reared at Pelton Ladder were infected with BKD, Fungus, and Ceratomyxosis at high enough levels to reduce survival in the rearing vessel and most likely reduce subsequent smolt survival (see Chapter 5). The affect of disease should be accounted for in this program by assessing the annual level of disease and relating it to survival. Further, goals regarding acceptable disease levels should be created. If the Pelton Ladder is unable to meet the disease goals, rearing at other facilities may be warranted.

Coded Wire Tag Studies

We recommend that a 5-year CWT study plan be developed to address critical uncertainties for the steelhead and Chinook program in the Hood River. The plan should be reviewed annually and adjusted as needed to improve implementation. The plan should include: the uncertainty being addressed, the numbers marked, expected tagging and fin clip proficiency, anticipated returns, a power analysis to determine if the number of anticipated returns will result in a statistically powerful test, specification of recovery protocols, expansion protocols, and most importantly, performance criteria and actions to be taken if criteria are not met.

Habitat affects on Survival

The HRPP M&E program confirmed the hypothesis that egg to smolt survival was limiting wild populations. A possible reason for the low survival was bed-load movement and sediment transport. In the UCM, we used turbidity as a quasi surrogate for bed-load and sediment transport. The UCM showed that carrying capacity of parr was substantially influenced by turbidity. However, the UCM and turbidity only addressed parr survival, not egg survival, and therefore bed-load and sediment movement still represent critical uncertainties. A better understanding of these factors may prompt the HRPP to alter habitat improvement strategies, by employing strategies that reduce the effect of these habitat factors. Strategies may also include the installation of sediment settling basins or creating spawning channels.

Program Prioritization and Reporting

The Hood River M&E Program began with a limited scope, but over the years additional critical uncertainties were identified, resulting in added annual duties. In an era of do more with less, it appears as if the program underestimated the required budget and staff necessary to collect the data, analyze data, report findings, and apply M&E finding to fish management decisions. For instance, the 1993 and 1994 Annual Reports were an example of thoughtfully synthesized data which identified possible interpretations and provided numerous recommendations. In contrast, the 2000 Annual Reports focused on presenting the collected data in tables with little to no synthesis and provided a single recommendation.

In the Columbia Basin, a large number of M&E programs have fallen into the trap of “more is better”. In an attempt to become comprehensive, they have become overwhelmed and less effective then when the M&E programs were smaller and focused. This is a general criticism of M&E programs, not only of the Hood River Program. The ISRP made this case during the subbasin summary process in their many project review documents (www.cbfwa.org). The Columbia Basin has been struggling with the question of “what constitutes a good M&E program?” with little resolve. Those programs which focus on a few critical uncertainties are criticized for having too narrow a focus, while those programs which focus on multiple uncertainties are criticized for their lack of focus and inability to provide data on a real time basis. We do not have a complete answer to this conundrum, but we identify it as an important issue. The HRPP would benefit by focusing M&E actions on key performance criteria and prioritized uncertainties.

Annually, the M&E program and Fish Managers have not clearly documented: unresolved critical uncertainties, updated performance indicators, needs to revise study designs, or evaluation of data accuracy for performance measurement. Ideally, the M&E program would take these factors into consideration while prioritizing study objectives, budgeting, and staffing each year during scope of work renewal with BPA. Rather, the M&E program appears to change to meet the new need without adequately resolving the previously identified uncertainty. Since the previously identified uncertainty was not resolved, the previous studies persist, resulting in a larger more cumbersome annual program.

The purpose of an M&E program is to track progress and resolve uncertainties, thereby promoting adaptive management of the HRPP Programs (i.e. hatchery, harvest and Habitat programs). Although volumes of data were collected and reported, the use of the M&E program for adaptive management purposes was not clearly documented. Perhaps the M&E program addressed critical uncertainties germane to the Fish Manager’s needs and provided that information through informal communications. However, the M&E Annual Reports did not describe this activity, and therefore the use of M&E program data for adaptive management lacked a systematic formality.

The HRPP members and related participants would benefit from thorough annual reports by the M&E program. Further documentation of decisions in response to M&E findings would provide a feed back loop in which the M&E program may evaluate its own performance. For

example, if recommendations were disregarded by managers due to a lack of compelling information, the M&E program could respond with a study design to address the critical uncertainty, review the design with the Fish Managers, and then prioritize activity based on staffing, budgetary and logistical concerns. At present, the multiple annual reports provided an impression of limited coordination among M&E proponents and leave the reader confused as to the reason for a number of the M&E study facets.

An example of abbreviated reporting lacking interpretation was the CWT activities for winter steelhead and spring Chinook. The 1995 and 1996 annual reports authored by Lambert et al. (1998, 1999) reported winter steelhead coded wire tag retention rates and fin clip efficiencies. This data was important for expanding the number of recovered marked fish by correcting for the number of hatchery fish not retaining the tag. Regrettably, neither ODFW, nor CTSWRO Annual M&E reports described the number of CWT fish recaptured, nor did they provided a thorough explanation as to the reason the fish were tagged.

Another example of missing information was from habitat surveys. The 1994 Annual Report documented surveying 7.5 miles of stream, but provided no habitat characterization or an indication of when the data would be presented. Researchers and manager should address these inconsistencies to assure coherent reporting, which provides clearly articulated reasons for studies, study design, methods, results, conclusion, and if appropriate, an explanation of how the study fell short of expectations and recommendations. Further, the reader would gain clarity if the M&E reports included comprehensive lists of past and present activities, with time period of that activity, and identification if the entity completing the activity. Radio Telemetry studies were mentioned in the 1994 annual report, and maps were provided detailing fish movement. However telemetry methods, study design, and purpose were not provided. We were left with uncertainty to its application to the M&E program or what questions were addressed by the tagging study.

M&E reports may better serve their audience by focusing data presentation in key summary tables and figures, and by providing complete data sets through digital means for those who need supplementary information. Each year the M&E program should provide an executive summary styled report which describes the reason for the M&E program (i.e. goals, measurable objects, and critical uncertainties), outlines all M&E activities, identifies findings and provides recommendations based on the findings.

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APPENDIX A. METHODS AND DETAILED SUMMARY RESULTS OF UCM CAPACITY ESTIMATES

MODEL DATA AND METHODS

Compatibility of ODFW and USFS Stream Surveys

In Chapter 2 of this report, the UCM is introduced as the tool through which parr capacity estimates of the Hood Basin were made. A general overview of the model structure is given, results are briefly presented, and the implications of those results are discussed. In this appendix, the methods used in applying the UCM to the Hood Basin are more thoroughly discussed. Sources of data are covered as well as assumptions and adjustments regarding those data. Also in this appendix, the capacity estimates of the Hood Basin are presented and examined. Comparisons between basins are made, and investigations are made as to why the UCM generated the results it did. The factors that most influenced the capacity estimates are evaluated, and compared to habitat data from the basin.

The most recent habitat survey data in the Hood River Basin were obtained from the ODFW and USFS. Surveys by the ODFW were conducted between 1993 and 2000, and those by the USFS surveys took place between 1989 and 2001. Surveys by the two agencies were performed according to their respective protocols. The protocols for each agency changed somewhat between years, but the types of data collected were similar between years. Each agency collected data regarding unit types, their dimensions, substrate composition, wood cover, gradient, and riparian vegetation. Surveys by ODFW were primarily conducted in the lower basin, and those by USFS were conducted in the upper basin within Mount Hood National Forest (Figure A1). If a reach was surveyed in multiple years, data were used from the most recent survey.

Figure A1. Distribution of stream surveys conducted by ODFW and USFS in the Hood River Basin (1989-2001).

The form of data collected by ODFW provided a better fit to UCM than data collected by the USFS. For example, the UCM requires specific data on substrate composition by unit type expressed in terms of percent substrate type. The ODFW collects substrate data in this manner. The USFS substrate data was recorded in two ways. Substrate was either reported as results from Wolman Pebble Counts by reach, or sometimes as dominant/subdominant substrate class by unit type or reach.

The lack of congruity between input variables for the UCM and some of the data collected by the USFS required assumptions to transform some USFS data into forms specified by the UCM. Specifically, USFS data on depth, substrate, unit composition, and woody debris were adjusted. Each of those transformations is explained in the following paragraphs.

The transformations regarding channel unit composition involved subdividing USFS classifications of riffle and pool habitat types. The UCM recognizes several habitat types that may be viewed as sub components of riffles and pools. However, USFS typed all fast-water unit types as riffles. Thus, rapids and cascades, which support different fish densities than riffles, were all grouped in one classification by USFS. Similarly, USFS combined both pools and glides into the classification of pools. Using data from reaches surveyed by ODFW, the percentage that rapids and cascades composed of all fast-water units combined was regressed on channel width and gradient. The resulting relationship was used to predict the percentage of fast-water units in USFS surveys that was comprised by rapids or cascades. Similarly, the percentage that pools composed of pools and glides in ODFW surveys was regressed on gradient and channel width. This relationship was then used to predict the percentage that pools and glides composed of the pool classification in USFS surveys. These transformations were made in all reaches surveyed by USFS. The unit composition of each reach in both the spring Chinook and steelhead UCM before and after our transformations is presented in Table A1 and Table A2.

Table A1. Unadjusted and adjusted unit composition of reaches surveyed by the USFS and expected to support spring Chinook .

Reach	Original Composition		Adjusted Composition			
	Pool	Riffle	Glide	Pool	Rapid/Cascade	Riffle
Elk Cr.	0.14	0.86	0.02	0.12	0.35	0.51
Jones Cr.	0.30	0.70	0.00	0.30	0.66	0.04
McGee Cr.	0.13	0.87	0.01	0.12	0.79	0.08
Red Hill Cr.	0.17	0.82	0.02	0.15	0.36	0.46
Tony Cr.	0.18	0.82	0.02	0.16	0.74	0.08

Table A2. Unadjusted and adjusted unit composition of reaches surveyed by USFS and expected to support steelhead.

Reach	Original Composition		Glide	Adjusted Composition		
	Pool	Riffle		Pool	Rapid/Cascade	Riffle
Bear Cr.	0.27	0.73	0.00	0.27	0.68	0.05
Cat Cr.	0.02	0.98	0.00	0.02	0.08	0.90
Clark	0.00	0.93	0.00	0.00	0.69	0.24
Clear Branch	0.24	0.76	0.03	0.21	0.55	0.21
Coe Branch	0.05	0.79	0.01	0.04	0.67	0.22
Cold Springs Cr.	0.18	0.80	0.00	0.18	0.72	0.08
Culvert Cr.	0.71	0.22	0.08	0.63	0.22	0.07
Divers Cr.	0.15	0.85	0.00	0.15	0.76	0.09
Dog River	0.11	0.84	0.00	0.11	0.79	0.05
EFK: Tilly Jane to Clark	0.07	0.93	0.03	0.04	0.68	0.26
EFK: Clark to Sahalie F.	0.18	0.74	0.00	0.18	0.73	0.09
Elk	0.12	0.82	0.03	0.09	0.34	0.48
Engineers Cr.	0.48	0.52	0.05	0.43	0.39	0.13
Hellroaring Cr.	0.61	0.39	0.00	0.61	0.37	0.02
Indian Cr.	0.21	0.79	0.00	0.21	0.75	0.05
Jones Cr.	0.27	0.73	0.00	0.27	0.69	0.04
McGee	0.12	0.84	0.01	0.11	0.78	0.06
Meadows Cr.	0.36	0.54	0.04	0.32	0.27	0.37
Middle Fork	0.10	0.86	0.01	0.09	0.75	0.11
Newton	0.01	0.99	0.00	0.01	0.78	0.21
No Name Cr.	0.15	0.85	0.00	0.15	0.80	0.05
Pocket	0.19	0.81	0.00	0.19	0.76	0.05
Pollalie Cr.	0.02	0.97	0.00	0.02	0.91	0.06
Red Hill Cr.	0.16	0.79	0.02	0.14	0.36	0.43
Tony Cr.	0.21	0.75	0.01	0.20	0.66	0.09
West Fork Neal Cr.	0.12	0.88	0.01	0.11	0.79	0.09

For a comprehensive explanation of adjustments to and assumptions regarding the USFS data, and a comparison of capacity estimation results between data from the two agencies, see Appendix B.

Alkalinity

Alkalinity data from three sources was summarized for reaches used in the UCM. Alkalinity data were primarily obtained from the Oregon Department of Environmental Quality (DEQ) online data site and the U.S. Environmental Protection Agency (EPA) EPASTORET online data site (DEQ 2002 and EPA 2002). We obtained 12 samples from Pacific Corp to supplement our dataset. Samples were taken at numerous locations throughout the basin periodically between 1965 and 2001. Data from these sources were presented as mgCaCO₃/l.

Only alkalinity data collected between July 1 and October 31 was used to characterize the stream, because alkalinity is sensitive to flow, with decreasing concentrations at increased flows.

Averaged results of replicate samples, i.e. samples taken at the same location at the same time were derived. These average results produced a single data value for that sampling event. These criteria and methods provided 168 alkalinity values in 52 sampling locations. Most of the locations where sampling was conducted were in reaches where we estimated spring Chinook and steelhead parr capacity. Data were summarized by averaging values of data taken within each UCM model reach. A summary of the average alkalinity values for each reach, and other descriptive statistics is given in Table A3.

Table A3. Average summer alkalinity values of reaches in the Hood Basin. Data obtained from the Oregon DEQ, EPA and Pacific Corp.

Alkalinity (mg/l) by UCM Reach				
Basin	Stream	Average	St. Dev	# of Observations
Hood Mainstem	Mouth to Powerdale	27	4	42
	Powerdale to EFK/WFK	25	5	59
	Whiskey Cr.	42	5	3
	Neal Cr.	45	7	17
	WF Neal	28	5	4
East Fork	Middle Fork to Dog River	23	5	12
	Dog River to Tilly Jane Cr.	20	6	2
	Tilly Jane Cr. to Clark Cr.	17	8	5
	Clark Cr. to Sahalie Falls	43	13	4
	Baldwin Cr.	41	4	3
	Griswell	37	0	1
	Cold Springs	18	2	2
West Fork	Mouth to Green Point Cr.	20	4	13
	Ladd Cr. to Elk/McGee	13	1	2

In addition to the 168 values described previously, additional data were sought in reaches where no summer data existed. In Griswell Creek, a sample with a result of 28mg/l was taken on June 3, 1998. The temporal trend in alkalinity values in the mainstem Hood River revealed that average values in June were 75% of the average values seen in July through October. The value of 28mg/l in Griswell Creek was expanded by this factor to get a summer alkalinity estimate of 37mg/l in Griswell Creek. This was the only data this method was used on.

We estimated rearing capacity of spring Chinook and steelhead in 13 and 41 reaches respectively. Alkalinity data were available in only 4 and 12 reaches respectively. In the remaining reaches it was assumed that alkalinity would be similar in reaches of similar geology and precipitation patterns.

In the mainstem East Fork Hood River, data were available for all but the lowest reach, from the mouth to the Middle Fork Hood River. It was assumed that alkalinity in this reach was the same as the reach just above it. Likewise, it was assumed that alkalinity in Meadow Creek was similar to that in the uppermost reach of the East Fork Hood River which Meadow Creek flows into. In the West Fork Hood River, data were available for the lowest reach (mouth to Green Point Creek) and the uppermost reach (Ladd Creek to the Elk Creek/McGee Creek).

confluence). Data values in these two reaches were 20mg/l and 13mg/l. It was assumed that alkalinity steadily increased from 13mg/l to 20mg/l moving downstream from Ladd Creek.

In the East Fork Hood River subbasin, Baldwin Creek had an alkalinity of 41mg/l. Graham Creek is a tributary to Baldwin Creek, so we assumed its alkalinity was 41mg/l. It was assumed values in Evans Creek were the same as Griswell Creek because they enter the East Fork Hood River in similar locations and are adjacent sub-watersheds. It was also assumed alkalinity in Dog River was similar to values seen in West Fork Neal Creek because they originate on the same ridge. All of the small tributaries to the East Fork Hood River entering from the west that had no data, were assumed equal in alkalinity to the mainstem East Fork Hood River reach that they entered.

No alkalinity data were available in the Middle Fork Hood River subbasin. We assumed that alkalinity throughout the Middle Fork Hood River subbasin would be 22mg/l based on values seen in the lower reaches of the mainstem East Fork Hood River (23mg/l) and mainstem West Fork Hood River (20mg/l).

McGee Creek and Elk Creek combine to form the uppermost reach of the West Fork Hood River. Alkalinity in the uppermost reach of the West Fork Hood River was 13mg/l, so it was assumed that concentrations in McGee and Elk Creek would be the same. Values in Jones Creek and Red Hill Creek were assumed to be the same as the estimate of the reach of the West Fork River that they entered. No data were available for the Lake Branch or its tributaries. Alkalinity data were obtained from DEQ for Eagle Creek, a tributary to the Columbia River. The headwaters of Eagle Creek originate on the opposite side of the ridge as the headwaters of the Lake Branch less than 5 miles away. It was assumed alkalinity in the Lake Branch and its tributaries was the same as that in Eagle Creek (17mg/l). This is similar to values seen throughout the West Fork Hood subbasin.

Turbidity or Total Suspended Solids

Turbidity and total suspended solids (TSS) data from two sources was summarized for reaches used in the UCM. Both turbidity and TSS data were primarily obtained from the Oregon Department of Environmental Quality (DEQ) online data site. Six samples from PacifiCorp were obtained to supplement our dataset. Samples were taken at numerous locations throughout the basin periodically between 1977 and 2001. For modeling purposes, only data taken between July 1 and September 31 were used because this is when the capacity limitation period is, and turbidity is consistently at its highest.

The UCM is designed to use turbidity data in its adjustment to capacity. In locations where turbidity data were not available, but TSS concentrations were, we used the measure of total suspended solids as a surrogate. Turbidity is caused by suspended solids. Lloyd et al. (1987) reports a linear relationship between turbidity and suspended solids in Alaskan systems. He notes that relationships between turbidity and suspended sediment concentrations are only useful for the specific drainages where they were developed because the relationship is affected by the size and shape of the particles causing the turbidity.

The relationship between turbidity and TSS in the Hood Basin was described by using data from the DEQ at sampling events where samples of both turbidity and TSS were taken at the same time and location. We limited the data set to values under 50mg/l TSS because most of the values observed in the Hood Basin were below that standard. The relationship between the two parameters was, as in the Alaskan systems, strong and positive ($r^2 = 0.74$, $n = 338$)(Figure A2). The regression equation from the relationship was used to estimate turbidity where turbidity data were lacking but TSS data were available. Of 128 turbidity values used in the UCM, 83 were derived from TSS measurements.

Figure A2. Relationship between TSS and turbidity in the Hood Basin. Data obtained from the Oregon DEQ. Data incorporate all data from the Hood Basin below 50mg/l TSS

The resulting turbidity estimates were summarized by finding the median value reported in each reach of the UCM model. Where there were less than five measurements available qualitative turbidity rankings of high, medium and low turbidity were assigned. High turbidity was defined as 20NTU or greater, medium was 2-20NTU, and low was under 2NTU. These rankings were based on the effects of turbidity and riffle depth on capacity at these different turbidity levels and the range of values recorded in the Hood Basin (see Table A4). Qualitative rankings were based on professional judgment from personal observations and pictures of reaches in question. Reaches where data were available were used to calibrate the qualitative rankings. Summer median turbidity values and other descriptive statistics by reach are presented in (Table A4).

Table A4. Summer turbidity values of reaches in the Hood Basin. Data obtained from Oregon DEQ and Pacific Corp. Q1 and Q3 are the first and third quartiles.

Subbasin	Reach	Summer data only (NTU mg/L)					Count
		Min	Q1	Med	Q3	Max	
Hood Mainstem	Mouth to PD	2	4	7	13	78	40
	PD to EFK/WFK	2	8	17	24	57	52
	Neal Cr.	4	6	8	13	18	5
	Lenz Cr.	--	--	6	--	--	1
East Fork	Mid.Fk. to Dog R.	5	6	8	13	22	8
	Dog R. to Tilly Jane Cr.	--	--	17	--	--	1
	Tilly Jane Cr. to Clark Cr.	5	--	7	--	64	3
	Clark Cr. to Sahalie Falls	1	--	14	--	27	2
	Baldwin Cr.	--	--	8	--	--	1
	Cold Springs Cr.	1	--	1	--	1	3
	Mitchell Cr.	--	--	1	--	--	1
Middle Fork	Coe Branch	9	27	56	84	273	13
	Clear Branch	1	1	2	9	13	14
	Eliot Branch	54	76	85	175	505	11
West Fork	Mouth to Greenpoint Cr.	3	4	5	7	10	10
	Ladd Cr. to Elk/McGee Cr.	1	--	1	--	1	3

Habitat in Unsurveyed Areas

Habitat data were not available in all reaches of steelhead rearing distribution. Data were not available for Lenz, Griswell, Whiskey and a portion of Evans Creeks. Stream area in these reaches accounted for only 0.7% of the modeled area for the entire basin. Capacity was estimated in these reaches by using capacity per area, prior to alkalinity and turbidity adjustments, from nearby streams where data existed. Area was estimated using the length of steelhead distribution, and average summer low flow width estimated by local ODFW biologists. The resulting capacity was subsequently adjusted for capacity and turbidity estimates in the respective reaches. Capacity in these reaches accounted for only 0.7% of the estimated capacity of the basin.

Data for the spring Chinook UCM were lacking in Rogers Creek. Distribution in Rogers Creek was assumed to cover the lower 0.75 miles of the creek. Average summer low flow width was estimated at 4.0m, and the capacity density was assumed to be equal to the highest UCM estimated density in the Middle Fork which was the Clear Branch just below Laurance Lake. Rogers Creek capacity accounted for 1% of the capacity for the Hood Basin.

CAPACITY ESTIMATION RESULTS AND DISCUSSION

Spring Chinook

The estimated parr capacity of spring Chinook in the Hood Basin was 44,835 parr (Table A5). Capacity was similar between the West Fork subbasin (21,250) and the mainstem Hood River (21,961). Capacity densities (parr/100m²) per reach ranged from 4.7 to 9.9. Mean capacity densities were similar in the West Fork subbasin 5.4 parr/100m² and the Hood River mainstem (5.3 parr/100m²), and higher (8.6 parr/100m²) in the Middle Fork subbasin (Table A5Table).

Table A5. Spring Chinook parr capacities and capacity densities by reach in the Hood Basin as estimated by the UCM.

	Surface Area (m ²)	UCM Parr Capacity	UCM Parr Density (#/100m ²)
Hood River Mainstem			
Mouth to Powerdale	50,650	3,210	6.3
Powerdale to EFK/WKF	361,010	18,751	5.2
Mainstem Subtotal	411,659	21,961	5.3
Middle Fork			
Clear Branch	7,033	695	9.9
Tony Cr.	7,632	503	6.6
Rogers Cr.	4,312	426	9.9
Middle Fork Subtotal	18,977	1,624	8.6
West Fork			
Mouth to Green Point	19,533	1,413	7.2
Green Point to Lake Branch	83,982	4,886	5.8
Lake Branch to Ladd	192,334	9,052	4.7
Ladd to Elk/McGee	16,859	1,290	7.7
Lake Branch	17,294	1,103	6.4
Red Hill	6,260	449	7.2
Jones	4,388	267	6.1
McGee	38,865	1,861	4.8
Elk	16,730	929	5.6
West Fork Subtotal	396,245	21,250	5.4
Hood River Total	826,881	44,835	5.4

Factors Influencing Capacity

The summary of habitat and water chemistry variables by reach reveal some important differences between the reaches and their capacities. The “raw capacity” is the capacity estimate after only the surface areas of each unit have been accounted for. It does not incorporate depth, cover, embeddedness, or water chemistry. The model assigns the highest capacity of unit types to pools, and thus the greater the percentage of pools, the greater the raw capacity density is. Percent pools was highly correlated to estimated raw capacity density in the Hood Basin ($r =$

0.99)(Figure A3). The West Fork from its mouth to Green Point Creek and the Lake Branch had the highest percent pools as well as the highest raw capacity density estimates.

However, raw capacity does not reflect the effects of differences in stream depth or cover between reaches. After these factors and the effects of substrate and water quality were included in the estimate of capacity, the relationship between percent pools and capacity was not as strong ($r = 0.50$). This reflects the importance and influence of available cover, depth, substrate and water quality on the stream's capacity to produce spring Chinook.

Figure A3. Relationship between raw capacity density and percent pools in reaches modeled for spring Chinook capacity in the Hood Basin.

Raw capacity is also influenced by the proportions of rapids, riffles, cascades and glides comprising the reach. Throughout the distribution of spring Chinook rearing, rapids were generally the dominant habitat type comprising 15-79% of the area for individual reaches (Table A6). Pools composed 8% to 39% per reach, and riffles composed 4% to 51% of area per reach.

Table A6. Proportions of unit composition by surface area of reaches used in the spring Chinook UCM.

Reach	Length		Surface		Unit Composition				
	Length (m)	(km)	Area (m ²)	Cascade	Glide	Pool	Rapid	Riffle	Other
Hood Mainstem									
Mouth to Powerdale	8,317	8.32	231,085	0.00	0.11	0.11	0.54	0.24	0.00
Powerdale to EFK/WFK	14,115	14.12	361,010	0.01	0.00	0.24	0.41	0.24	0.10
Middle Fork									
Clear Branch	998	0.99	7,033	--	0.03	0.22	0.55	0.21	0.00
Tony Cr.*	3,768	3.77	25,276	--	0.02	0.16	0.74	0.08	0.00
Rogers Cr.*	1,078	1.08	4,312	**	**	**	**	**	**
West Fork									
Mouth to Greenpoint Cr.	1,368	1.37	19,533	0.03	0.00	0.39	0.39	0.14	0.05
Greenpoint Cr. to Lake Branch	5,300	5.30	83,982	0.06	0.00	0.27	0.46	0.18	0.03
Lake Branch to Ladd Cr.	13,576	13.58	192,334	0.18	0.01	0.14	0.47	0.17	0.03
Ladd Cr. to Elk/McGee	1,592	1.59	16,859	0.08	0.12	0.23	0.15	0.39	0.03
Lake Branch	17,892	17.89	137,189	0.11	0.00	0.38	0.41	0.08	0.02
Red Hill Cr.*	1,268	1.27	6,185	--	0.02	0.15	0.36	0.46	0.01
Jones Cr.*	2,075	2.07	11,106	--	0.00	0.30	0.66	0.04	0.00
McGee Cr.*	5,530	5.53	45,680	--	0.01	0.12	0.79	0.08	0.00
Elk Cr.*	3,413	3.41	16,366	--	0.02	0.12	0.35	0.51	0.00

* Unit composition after adjustments to USFS data. Rapids incorporates both rapid and cascade type habitat in these reaches.

** No habitat survey data available.

Each reach was affected by the subsequent adjustments to raw capacity uniquely. In general, the features of cover and water chemistry in each reach decreased the estimate of rearing capacity (Figure A4). This decrease resulted from decreases due to low wood complexity, alkalinity below that of reference streams, and turbidity higher than reference streams. Most reaches were assigned increases in density from sufficient depths and high boulder content (Figure A4).

Average wood scores throughout habitat surveyed by ODFW were low. Wood complexity is rated on a scale of 1 to 5 with 1 being no wood present, and 5 being accumulations of small and large pieces of wood providing complex cover at all flow levels. Average ratings in ODFW surveyed reaches were 1 to 1.4 in pools (Table A7). The USFS did not gather data regarding wood complexity. Wood complexity in pools in USFS reaches was assumed to average 1.8. This assumption was based on average wood scores seen among all reaches surveyed by ODFW whether they were within spring Chinook distribution or not. It was assumed wood complexity in reaches surveyed by USFS would be similar to the maximum observed wood complexity in reaches surveyed by the ODFW. Ratings below 2 receive a decrement to capacity by the UCM, consequently, all spring Chinook reaches received a decrement for their wood score ratings (Table A7).

Figure A4. Effects of adjustments on capacity density for various habitat and water chemistry variables on the raw parr capacity of reaches in the Hood Basin modeled for spring Chinook.

Table A7. Habitat features in reaches surveyed by the ODFW and used to estimate spring Chinook parr capacity via the UCM. Depth was measured as max in pools and average in all other units. Slow-water units include pools and glides. Fast-water units include riffles, rapids and cascades.

Reaches Surveyed by the ODFW							
Reach	Average	Average Depth (m)		Wood Score	% Fines		
	Width (m)	Slow-water	Fast-Water	in Pools	in Riffles	%Boulders	% Cobble
Hood Mainstem							
Mouth to Powerdale	32.1	1.1	0.6	1.0	25	34	26
Powerdale to EFK/WFK	25.6	1.8	0.7	1.0	30	27	23
West Fork							
Mouth to Greenpoint Cr.	14.3	2.4	0.6	1.1	12	31	25
Greenpoint Cr. to Lake Branch	16.0	2.0	0.6	1.0	16	29	26
Lake Branch to Ladd Cr.	14.0	2.0	0.5	1.0	13	35	29
Ladd Cr. to Elk/McGee	10.6	0.8	0.3	1.2	7	14	41
Lake Branch	9.4	2.6	0.5	1.0	13	29	22

Depths within the Hood Basin were sufficient to warrant increased capacity assignments by the UCM. Depths in slow-water habitat types ranged from 0.6 to 2.6m and depths in fast-water habitats ranged from 0.3-0.7m (Table A7 and Table A8). Capacity densities were greatest in the mainstem West Fork Hood River, and this is partially attributable to the fact that it had the deepest habitat units.

Table A8. Habitat features in reaches surveyed by the USFS and used to estimate spring Chinook parr capacity via the UCM. Depth was measured as max depth in all units. Slow water units include pools and glides. Fastwater units include riffles, rapids and cascades.

Reaches Surveyed by USFS								
	Average	Average Depth (m)		Substrate				
Reach	Width (m)	Slow-water	Fast-water	Dominant	Subdominant	%Sand	%Boulder	%Cobble
Middle Fork								
Clear Branch	6.6	0.9	0.5	--	--	2	20	44
Tony Cr.	6.3	0.8	0.6	--	--	8	11	35
Rogers Creek	--	--	--	--	--	--	--	--
West Fork								
Red Hill Cr.	4.6	0.7	0.5	--	--	5	12	28
Jones Cr.	5.6	0.8	0.5	--	--	2	47	45
McGee Cr.	8.4	1	0.7	--	--	7	20	27
Elk Cr.	4.6	0.6	0.4	Cobble	Boulder	--	--	--

The mainstem Hood River was negatively affected by the high percentage of fines in riffles (Figure A4). Fines in these reaches were 25-30%, and the UCM begins to assign a decrement to capacity when fines in riffles exceeds 15%.

Boulders are common in the Hood Basin with average substrate composition of 11-47%. Boulders provide cover for rearing Chinook parr, and high boulder content in pools, riffles and glides results in an increase in capacity assignment by the UCM. Reaches that had a high percentage of boulders (except for those in rapids) received substantial capacity increases for boulder presence. These reaches included all of the mainstem Hood River, mainstem West Fork, McGee Creek, Lake Branch, and Clear Branch, and Tony Creek.

Alkalinity was lower in every reach within spring Chinook distribution than baseline values within the UCM. The baseline alkalinity value for the spring Chinook model is 33.6mg/l. Average values of measurements within reaches ranged from 13-27mg/l. Estimates of alkalinity within reaches with no data ranged from 13-22mg/l (Table A9).

Glacially induced turbidity is present in all three of the main forks of the Hood River Basin. Any amount of turbidity above clear conditions reduces potential capacity by decreasing sunlight penetration and subsequent primary and secondary production. Averages of measured turbidity ranged from 5NTU in the lower West Fork to 7-13NTU in the mainstem Hood River. Qualitative ratings of turbidity levels throughout the rest of spring Chinook distribution were generally low or medium (Table A9).

Table A9. Alkalinity and turbidity values used to estimate spring Chinook parr capacity via the UCM.

Reach	Alkalinity (mgCaCO ₃ /l)	Turbidity NTU
Hood Mainstem		
Mouth to Powerdale	27	7
Powerdale to East Fork/West Fork confluence	25	13
Middle Fork		
Clear Branch	22*	L
Tony Creek	22*	L
Rogers Creek	22*	L
West Fork		
Mouth to Green Point Creek	20	5
Green Point Creek to Lake Branch	19*	M
Lake Branch to Ladd Creek	15*	M
Ladd Creek to Elk/McGee confluence	13	L
Lake Branch	17*	L
Red Hill Creek	16*	L
Jones Creek	16*	L
McGee Creek	13*	L
Elk Creek	13*	L

* Assumed alkalinity value

Potential Spring Chinook Smolt Production

The spring Chinook smolt capacity of the Hood Basin was estimated by adjusting the parr capacity estimates of the UCM by a 35% parr-to-smolt survival. Numerous literature sources with published estimates of spring Chinook parr-to-smolt survival rates showed that over-winter survival rates are variable, but typically are near 35% (Fast et al. 1991, Kiefer and Lockhart 1999, Lindsay et al. 1989, Monzyk et al. 2000, Petrosky 1990). The estimated spring Chinook smolt capacity for the entire Hood Basin is 15,692. The estimated capacities in the Middle Fork, West Fork, and mainstem are 568, 7,437 and 7,686 respectively.

Estimation of Steelhead Parr Capacity

The parr capacity of *O. mykiss* in the Hood Basin was estimated to be 90,814 parr (Table A10). Capacities were similar in the mainstem, East Fork Hood River and West Fork Hood River with capacities ranging from 26,183 to 30,217. Capacity densities (parr/100m²) per reach ranged from 0.4 to 9.8. Of the main subbasins, the West Fork had the highest mean capacity density (4.8 fish/100 m²)(Table A9).

Table A10. *O. mykiss* parr capacities and capacity densities by reach in the Hood Basin as estimated by the UCM.

Hood Mainstem	Surface Area (m²)	Steelhead Parr Capacity	Density #/100m²
Mouth to Powerdale	231,085	12,184	5.3
Powerdale to EFK/WFK	361,010	14,036	3.9
Whiskey	805	50	6.2
Neal Cr.	56,525	3,123	5.5
Lenz Cr.	6,438	401	6.2
WFK Neal Cr.	18,208	423	2.3
Hood Subtotal	668,153	30,217	4.5
East Fork			
Mouth to Middle Fk.	64,973	2,356	3.6
Middle Fk. To Dog River	227,922	7,925	3.5
Dog River to Tilly Jane Cr.	22,860	714	3.1
Tilly Jane to Clark Cr.	176,112	8,624	4.9
Clark Cr. To Sahalie Falls	35,256	1,864	5.3
Baldwin Cr.	12,247	346	2.8
Graham Cr.	3,346	31	0.9
Evans Cr.	9,451	205	2.2
Griswell Cr.	2,226	48	2.2
Cat Cr.	192	1	0.4
Dog River	9,333	447	4.8
Polallie Cr.	6,808	350	5.1
Cold Springs Cr.	15,769	1,022	6.5
Culvert Cr.	1,163	47	4.0
Engineers Cr.	293	19	6.6
Hellroaring Cr.	346	22	6.4
Newton Cr.	27,672	475	1.7
Clark Cr.	20,324	450	2.2

Hood Mainstem	Surface Area (m²)	Steelhead Parr Capacity	Density #/100m²
Pocket Cr.	2,441	135	5.5
Meadows Cr.	11,218	1,101	9.8
East Fork Subtotal	642,158	26,183	4.1
Middle Fork			
Mouth to Coe Branch	123,817	3,108	2.5
Tony Cr.	25,276	1,834	7.3
Bear Cr.	10,523	812	7.7
Coe Branch	24,775	488	2.0
Clear Branch	7,033	455	6.5
Middle Fork Subtotal	197,072	6,697	3.4
West Fork			
Mouth to Greenpoint Cr.	19,533	1,443	7.4
Greenpoint to Lake Branch	83,982	4,097	4.9
Lake Branch to Ladd	192,334	8,233	4.3
Ladd to Elk/McGee	16,859	687	4.1
Greenpoint Cr.	42,022	2,086	5.0
Lake Branch	137,189	6,643	4.8
Divers Cr.	4,903	322	6.6
No Name Cr.	1,145	66	5.8
Indian Cr.	1,324	82	6.2
Red Hill Cr.	6,185	282	4.6
Jones Cr.	11,106	743	6.7
McGee Cr.	45,680	2,445	5.4
Elk Cr.	16,366	587	3.6
West Fork Subtotal	577,305	27,717	4.8
Hood River Total	2,084,687	90,814	4.4

Factors Influencing Capacity

The summary of habitat and water chemistry variables by reach reveals some important differences between reaches and their capacities. Similar to the model for spring Chinook, the model assigns the highest capacity to pools, and thus the greater the percentage of pools within a reach, the greater the capacity density is. Raw *O. mykiss* parr capacities in the Hood Basin were positively correlated to percent pools ($r = 0.91$) (Figure A5). Similar to the spring Chinook UCM, after all other model factors were included (cover, depth, substrate, water quality) the relationship between percent pools and capacity was not as strong ($r = 0.53$). This reflects the importance and influence of available cover, depth, substrate and water quality on the final *O. mykiss* capacity estimate.

Figure A5. Relationship between percent pools and predicted raw *O. mykiss* parr capacity densities in the Hood Basin.

Throughout the distribution of *O. mykiss* rearing, rapids are the dominant habitat type comprising an average of 53% of the individual reaches. Pools and riffles were evenly represented comprising an average 17% and 19% in modeled reaches.

Roughly 75% of the estimated production in the basin was expected to come from the mainstem Hood, mainstems of the three major forks, or the Lake Branch. Consequently, our examination of the effects of different modeling parameters on estimated capacities focuses on those reaches.

Turbidity was the parameter that most negatively affected estimates of capacity. The effect was most pronounced in the Middle Fork Hood River where turbidity was rated as high, but the effect was also substantial in much of the East Fork Hood River and mainstem Hood River, and to a lesser extent the West Fork Hood River where turbidity ratings were typically medium (Figure A6, Table A11). The high presence of fines in riffles in the mainstem Hood River, East Fork and Middle Fork also had negative effects on capacity (Figure A6). Fines in riffles were high throughout the basin, but were exceptionally high in the East Fork where they ranged from 38-44% of the substrate in reaches below Tilly Jane Creek (Table A12).

Figure A6.

Effects of adjustments on capacity density for various habitat and water chemistry variables on the raw parr capacity of reaches in the Hood Basin modeled for *O. mykiss*

Table A11. Alkalinity and Turbidity values used in modeling major *O.mykiss* producing reaches in the Hood Basin.

Reach	Alkalinity (mgCaCO ₃ /l)	Turbidity NTU
Hood Mainstem		
Mouth to Powerdale	27	7
Powerdale to East Fork/West Fork confluence	25	13
Neal Cr.	45	8
East Fork		
Mouth to Middle Fork	23*	M
Middle Fork to Dog River	23	8
Dog River to Tilly Jane Creek	20	M
Tilly Jane Creek to Clark Creek	17	M
Clark Creek to Sahalie Falls	43	M
Middle Fork		
Mouth to Coe Branch	22*	H
West Fork		
Mouth to Green Point Creek	20	5
Green Point Creek to Lake Branch	19*	M
Lake Branch to Ladd Creek	15*	M
Ladd Creek to Elk/McGee confluence	13	L
Lake Branch	17*	L

* Assumed value

Table A12. Habitat features in reaches estimated to be major *O. mykiss* rearing areas. Depth was measured as max in pools and average in all other units. Slow water units include pools and glides. Fastwater units include riffles, rapids and cascades. Only dominant producing reaches are displayed here.

		Average Depth (m)*		Wood Score			
Reach	Average Width (m)	Slow-water	Fast-Water	in Pools & Glides	% Fines in Riffles	% Boulder in Riffles	% Cobble
Hood Mainstem							
Mouth to Powerdale	27.8	1.3	0.5	1.1	16	23	26
Powerdale to EFK/WFK	25.6	1.8	0.7	1.0	30	26	23
Neal Cr.	4.8	0.7	0.4	1.2	8	14	38
East Fork							
Mouth to Middle Fk.	18.6	1.2	0.7	1.5	38	10	29
Middle Fk. to Dog River	11.5	0.9	0.5	1.2	38	9	26
Dog River to Tilly Jane Cr.	9.3	1.1	0.6	1.0	44	16	24
Tilly Jane Cr. to Clark Cr.***	10.9	0.9	0.6	--	--	--	--
Clark Cr. To Sahalie Falls***	5.7	0.6	0.4	--	--	--	--
Middle Fork**							
Mouth to Coe Branch	8.8	1.0	0.5	1.4	25	19	27
West Fork							
Mouth to Greenpoint Cr.	14.3	2.4	0.6	1.1	12	36	25
Greenpoint Cr. to Lake Branch	15.8	2.0	0.6	1.0	16	26	26
Lake Branch to Ladd Cr.	14.1	2.0	0.5	1.0	13	30	29
Ladd Cr. To Elk/McGee	10.6	0.8	0.3	1.2	7	12	41
Greenpoint Cr.	8.2	1.0	0.4	1.1	21	25	23
Lake Branch	7.7	1.3	0.3	1.4	23	18	25

*incorporates max depth in pools

** incorporates only ODFW surveyed portion

*** surveyed by the USFS; no substrate data; max depth multiplied by 0.8 to estimate average depth

In general, alkalinity in the Hood Basin was lower than that of the streams the UCM standard densities were derived from, so most reaches received a decrement to capacity for alkalinity. The exception included streams such as Neal Creek in the northeast portion of the basin where alkalinity was 45 mgCaCO₃/l (Table A11).

Cover from wood in pools and glides throughout the basin was low. Wood complexity ratings assigned by the ODFW ranged from 1 to 1.5 in the major producing streams (Table), and the highest value observed in all streams was 1.7 in the Dog River. Boulders were an important source of cover and typically made up 10-30% of the riffle substrate in the main reaches of the Hood River Basin (Table A12). Boulders did not significantly impact the cover adjustment because they only apply to riffles which composed a moderately low percentage of the habitat in the Hood River Basin (Table A13). However, standard densities in rapids are higher than those in riffles because of their high boulder content, so the cover provided by boulders in rapids is reflected in the raw capacity density estimates.

Table A13. Unit composition of reaches estimated to be major *O. mykiss* rearing areas. Unit composition in USFS reaches was adjusted as described in Appendix B.

					Unit Composition				
Reach	Length (m)	Length (km)	Surface Area	Cascade	Glide	Pool	Rapid	Riffle	Other
Hood Mainstem									
Mouth to Powerdale	8,317	8.32	231,085	0.00	0.08	0.23	0.44	0.22	0.02
Powerdale to EFK/WFK	14,115	14.12	361,010	0.01	0.00	0.24	0.41	0.24	0.10
Neal Cr.	11,844	11.84	56,525	0.30	0.00	0.10	0.39	0.17	0.03
East Fork	34,276								
Mouth to Middle Fk.	3,487	3.49	64,973	0.02	0.00	0.11	0.60	0.25	0.01
Middle Fk. to Dog River	19,775	19.77	227,922	0.01	0.00	0.06	0.63	0.28	0.03
Dog River to Tilly Jane Cr.	2,448	2.45	22,860	0.04	0.00	0.02	0.84	0.10	0.01
Tilly Jane Cr. to Clark Cr.*	15,996	16.00	176,112	--	0.03	0.04	0.67	0.26	0.01
Clark Cr. to Sahalie Falls	5,643	5.64	35,256	--	0.00	0.18	0.69	0.04	0.09
Middle Fork	47,350								
Mouth to Coe Branch ^a	7,684	7.68	67,508	0.04	0.00	0.08	0.74	0.12	0.03
Mouth to Coe Branch ^{b*}	6,999	7.00	56,309	--	0.01	0.09	0.75	0.11	0.04
West Fork	14,683								
Mouth to Greenpoint Cr.	1,368	1.37	19,533	0.03	0.00	0.39	0.39	0.14	0.05
Greenpoint Cr. to Lake Branch	5,300	5.30	83,982	0.06	0.00	0.27	0.46	0.18	0.03
Lake Branch to Ladd Cr.	13,576	13.58	192,334	0.18	0.01	0.14	0.47	0.17	0.03
Ladd Cr. To Elk/McGee	1,592	1.59	16,859	0.08	0.12	0.23	0.15	0.39	0.03
Lake Branch	17,892	17.89	137,189	0.05	0.02	0.21	0.43	0.20	0.09

a = Portion surveyed by ODFW

b = Portion surveyed by USFS

Parr-to-Smolt Survival

Because fish densities at capacity are estimated from observations of parr densities in fully seeded streams, we must use an estimate of parr-to-smolt survival to convert the parr numbers into smolt numbers. The literature regarding published estimates of steelhead parr to smolt survival rates show that over-winter survival rates are widely variable. Typical survivals range between 35-65% (Cramer and Beamesderfer 2001, Cramer et al. 1997, Beamesderfer et al. 2001, Kiefer and Lockhart 1999, Reeves et al. 1990, Tautz et al. 1992, Ward and Slaney 1993, Chilcote et al. 1984). Given the flashy conditions in the Hood River we assumed survival in the Hood River was 35%. Thus, smolt capacity was predicted to be 35% of parr capacity. The *O. mykiss* capacity estimate was further reduced by 3% to account for residualism in the Hood Basin.

Winter and summer steelhead smolt capacities were derived by examining the distribution pattern of the two runs. Where distribution overlapped, 50% of capacity was assigned to each run. Winter steelhead smolt production potential in the Hood Basin was estimated to be 16,970, and summer steelhead smolt production potential was estimated at 13,860 for a total steelhead production estimate of recalculate 30,830 smolts. The number of estimated smolts generated from parr rearing in the main forks would be 8,889 from the East Fork Hood River, 9,410 from the West Fork Hood River, and 2,273 from the Middle Fork Hood River.

Discussion of Capacity Estimates

Comparison of steelhead capacity estimates between forks favorably reflect what is known about rearing habitat preferences of juvenile steelhead. Average densities by fork are highest in the West Fork, followed by the East Fork, and are lowest in the Middle Fork. Of the three forks, the West Fork has the lowest gradient, the fewest fines in riffles, the most pools, the deepest pools, and the least turbidity. The Middle Fork and East Fork are high in turbidity, low in pools, have a high percent of fines and moderate to high gradient. By simply reviewing these differences in habitat, one would presume that the West Fork is the most suitable to juvenile rearing while the Middle and East Fork would lag behind. This confirms that the UCM is portraying differences in habitat quality between the forks, and these differences are based on actual data.

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APPENDIX B. ADJUSTMENTS AND ASSUMPTIONS REGARDING HABITAT DATA USED IN THE UCM

INTRODUCTION

In Appendix A, the data used in the UCM are described, and the methods through which those data were used are detailed. Some data used in the model needed to be reconciled in order to use them in the UCM. This appendix details those reconciliations, and provides analysis regarding their possible effects on model outcomes.

A habitat-based model developed by Cramer (2001) was used to estimate the steelhead and spring Chinook production capabilities of the Hood Basin. Cramer (2001) reviewed the most up-to-date findings from studies of salmon and trout ecology throughout western North America, and developed a model that uses measurements of stream habitat to estimate a stream's potential to produce steelhead trout, rainbow trout, spring Chinook, fall Chinook, and cutthroat trout. The model relies on measurements of the stream area composed by different channel unit types, and then assigns a fish density to each of those types. The model, hereafter referred to as the Unit Characteristic Method (UCM), developed by Cramer (2001) further adjusts the densities to account for variations in depth, substrate, and cover of each habitat unit, and for variations in water quality between stream reaches.

The UCM is designed to incorporate data regarding unit types, their surface areas, wood complexity, substrate composition, and water chemistry. The model analyzes and summarizes these data in a specified manner.

The UCM incorporates data that has been summarized in specific formats depending on the parameter. For instance, adjustments to capacity based on wood cover require that the stream survey have rated wood complexity within each unit on a scale of 1 to 5 with 1 being least amount of wood, and 5 being the most amount of wood. This method is used by the Oregon Department of Fish and Wildlife (ODFW), but not all habitat survey protocols are alike, and many protocols do not measure wood cover in this manner.

In this appendix, we will document the differences in the form of habitat measurements from various survey protocols used in the Hood Basin, particularly as they differ from the data format required by the UCM. We will describe how we reconciled those differences, and finally we will evaluate the effects of those reconciliations on capacity estimates.

All data reconciling was performed on data provided by the United States Forest Service (USFS). The remaining data provided by the ODFW used measurements suited to the UCM. USFS data comprised only 8% of the data used in modeling spring Chinook parr capacity, and only 25% of the data used in modeling steelhead parr capacity.

There were five factors for which USFS data differed from the requirements of the UCM. First, the UCM requires that wood cover be expressed as a rating of 1 to 5, but the USFS reports pieces of large woody debris (LWD) of various size classes. Secondly, the UCM requires that substrate be presented as a percentage of substrate by size class for each unit. The USFS

presented data rating substrate classes as dominant and subdominant. In some cases these data were presented for each unit, and sometimes one rating for an entire reach. In some reaches, substrate data was presented as Wolman pebble counts. Finally, the UCM requires maximum depths for all pools, and average depths for other unit types. The USFS presented data as maximum depth for all unit types.

The fourth and fifth factors were unit-type designations. The UCM recognizes several habitat types including pools, glides, riffles, rapids and cascades. The only unit types in the USFS protocol recognized by the UCM are riffles and pools. These two unit types represent all fast-water and slow-water habitat types in a stream. Other units recognized by the USFS include side channels, tributaries, dry channels, culverts and special case units (chutes, falls, dams, marshlands and braided channels), but these are not used by the UCM. Riffles as surveyed by the USFS were subdivided into riffles, rapids and cascades, and pools were subdivided into pools and glides. These adjustments provided more realistic estimates of parr capacity.

DATA ADJUSTMENTS

Wood Complexity

Cramer (2001) found that the best study demonstrating the influence of woody debris cover on parr densities was in a study by ODFW of coastal Oregon streams. In this study, Johnson et al. (1993) correlated increased steelhead densities with increased wood complexity. Johnson scored wood complexity from 1 to 5, with 1 being little to no wood present, and 5 being large amounts of stable complex wood present. Cramer (2001) used the findings of Johnson et al. (1993) as the basis for the adjustment to steelhead densities from wood cover in the UCM. In Appendix C of this report, we correlate spring Chinook densities to wood cover as well, and use the same 1-5 rating of wood complexity as the basis of the model adjustment.

In the Hood Basin, we used USFS habitat data collected between 1989 and 2001. Throughout this period, the USFS stream survey protocol changed somewhat between years and streams, but the general approach to quantifying wood was the same. The USFS protocol recognizes certain size classes of wood based on length and diameter of pieces of wood. Pieces that met a specified minimum criterion were counted, and others were not counted.

Numerous attempts were made to establish correlations between the 1 to 5 rating of wood complexity, and the density of pieces of large woody debris (LWD). The ODFW stream survey protocol not only assigns a wood class rating of 1 to 5 for each unit, but also requires that surveyors count the number of pieces of LWD of multiple size classes. However, we found no relationships between the wood complexity rating and counts of LWD.

When LWD/m was regressed on wood complexity with data from 9,103 pools and glides it was found that these two measures of wood are not correlated ($r=0.17$). In this analysis data was used from ODFW stream surveys from the north coast of Oregon to maximize sample size and variation in wood complexities observed and numbers of pieces of wood counted. Further, the USFS protocol designation of the size classes of LWD varied between years and between basins, and often differed from size classes observed by the ODFW. Even if a relationship

between LWD and wood complexity from ODFW data had been found, it would have been difficult to reliably apply the relationship to USFS data.

Because there was no quantitative relationship between wood complexity and pieces of LWD, we assigned a standard value for wood complexity, based on findings in the areas surveyed by the ODFW.

Among all the reaches surveyed by the ODFW the average wood complexity among pools and glides within a reach ranged from 1 to 1.67. Many of the reaches surveyed by the ODFW in the lower basin where wood cover would be expected to be lower than in the upper basin because of the differences in riparian vegetation and land use. However, ODFW also surveyed the Lake Branch, Green Point Creek, Dog River, and the upper West Fork Hood River which would be expected to have similar amounts of wood to reaches surveyed by the USFS, and still the highest average wood complexity rating was 1.67. The USFS surveyed reaches primarily in the upper basin, and we assumed that wood cover in those reaches would on average be greater than the reaches surveyed by the ODFW. A wood score rating of 1.7 was assigned to reaches surveyed by the USFS in the steelhead UCM. This value is similar to the highest value observed in ODFW surveyed reaches. Similarly, average wood complexities in pools in ODFW reaches ranged from 1 to 1.77, so wood complexity ratings of 1.8 in was assigned to USFS reaches in the spring Chinook UCM. Many of the USFS stream survey reports state that wood abundance is low. Our ratings of 1.7 for the steelhead model and 1.8 for the spring Chinook model reflect a moderately low amount of wood cover.

Substrate

The UCM uses substrate data for several purposes. First of all, it calculates the percentage of silt and sand in riffles by compiling data from all riffle units within a reach. Secondly, it uses the percent of boulders making up habitat unit substrate as an indication of cover availability. Adjustments are made on a unit by unit basis depending on the percentage of substrate in that unit comprised of boulders. Boulder adjustments are made in riffles in the steelhead model, and in riffles, glides and pools in the spring Chinook model. Finally, the UCM compiles data from each unit to calculate the percentage of cobbles available to provide winter cover over the whole stream.

In the data provided by the USFS, substrate data was gathered and presented in several manners. Wolman pebble counts were the primary method of describing stream substrate. Wolman pebble counts were done in riffles, so they reflect substrate conditions in riffles within a reach. Wolman pebble counts consist of a random selection of 100 particles from the streambed. The diameter of each particle is measured, and tallied in its respective size class (Wolman 1954). Size classes can be aggregated based on diameter into substrate types including sand and fines (<2mm), gravel, cobble, boulders and bedrock. We calculated the total percent of substrate comprised of each of these substrate types, and applied these substrate compositions to the UCM. The Wolman pebble counts were not done in every riffle, but at least one count was done in every reach. It was assumed that results of the pebble counts represented substrate composition of all units within a reach. There are aware of two problems with this assumption: 1) Wolman pebble counts are biased against fine sediments, and 2) substrate composition would not likely be

similar between riffles and pools. The USFS acknowledges the bias against fine sediments, and in their protocol take measures to reduce this bias (USFS 1999). Substrate composition in pools would likely have finer substrate particles than in riffles because of less velocity in these units. We have no way to compensate for this, but it should be noted that riffles comprised 70% or more of the habitat in 23 of 27 reaches in the Hood Basin. This means that the Wolman Pebble counts typically represented 70% or more of the habitat surveyed. Furthermore, the UCM only uses percent fines data from riffles when adjusting capacity for embededness.

In some stream surveys, the USFS classified substrate based on a dominant/subdominant classification. This required that we develop a method to estimate the percent of substrate comprised by size classes noted as dominant, those noted as subdominant, and those not noted as either.

We used USFS data from 51 reaches in the Hood Basin where they recorded Wolman pebble counts, and developed frequency distributions of the percent of substrate of the dominant size class, and the percent of substrate of the subdominant size class from the pebble counts. From each pebble count we examined the percent composition of each of the substrate size classes (boulder, cobble, gravel, sand) was examined. The size class that composed the greatest amount of the substrate was called dominant, and the next greatest was called subdominant. Frequency distributions using the percent composition of the dominant size classes and the subdominant size classes were developed. Whenever a size class was called subdominant, it comprised 25% or more of the substrate in 80% of surveys. When a size class was called dominant, it comprised 30% or more of the substrate in all instances, and 40% or more in 79% of surveys (Figure B1).

Figure B1. Frequency histograms of the percentage of substrate within the size class that was scored as either dominant or subdominant. Data derived from Wolman pebble counts done by the USFS in the Hood River basin.

When a substrate size class was noted as dominant it was assumed it made up 40% of the substrate. When a size class was subdominant, it comprised 25% of the substrate and when dominant/subdominant classifications were made for each unit, the above assumptions were applied to each unit separately. Otherwise, the above assumption was applied to all of the units within that reach.

In the UCM, the percent cobble cover adjustment only applies when the percent of cobbles within an entire stream is less than 15%. When a particular substrate class is classified as either subdominant or dominant, it typically comprises at least 25% of the substrate. We parsed out reaches from the same data set as the previous analysis where cobble was not listed as either dominant or subdominant. Only 11 reaches of 51 satisfied these criteria. The data showed that under these criteria, the percent of cobble in the substrate ranged from 0-18%, with a distribution skewed to the right and a median of 5%. It was assumed that when cobbles were neither dominant nor subdominant they only comprised 5% of the substrate.

Depth

Steelhead and spring Chinook parr densities per surface area of a unit increase as depth increases (Cramer 2001). The UCM depth adjustment is designed to apply to maximum depth in pools and average depth in all other units. The data provided by the USFS presented maximum depth in both pools and riffles. A scaling factor was developed that we multiplied maximum riffle depth by to estimate average depth.

Both the ODFW and the USFS surveyed the Lake Branch, data from these surveys were compared to determine how depth measurements were related to each other. Both surveys covered the entire length of the Lake Branch up to Lost Lake. Lake Branch flows were approximately 35cfs during the ODFW survey in August/September of 1994 and 60cfs during the USFS survey in July, 1995.

The average depth measured by ODFW in glides, riffles, rapids and cascades, was compared to the average maximum depth measured by USFS in riffles. Pools were excluded from the analysis because the UCM uses maximum depths in pools and thus there was no adjustment to make. The average depth from ODFW surveys was 0.34m (95%CI +/- 0.2m). The average maximum depth from USFS surveys was 0.53m (95%CI +/- 0.03m). This means that average depths observed by the ODFW were 64% of the maximum depths observed by the USFS. However, flows were also less at the time of the ODFW survey.

This ratio was improved by incorporating differences in flow between the two surveys, and it was found that average depths in non-pool units would have been approximately 0.44m. As a result, we assumed that averaged depths are roughly 80% of measured maximum depths in units surveyed by the USFS.

Subdividing Riffles

The UCM recognizes several habitat types and applies unique standard densities to each of these unit types. The standard densities between unit types are different, and reflect differences between typical velocities and substrates of these different unit types.

The UCM recognizes three unit types (riffles, rapids and cascades) that can be classified as “fast-water” unit types, but the USFS protocol classifies all three unit types as riffles. According to the ODFW protocol, riffles are fast, turbulent, shallow flows over submerged or partially submerged gravel, cobble and small boulder substrates (Moore et al. 1997). Gradients in riffles are typically 0.5-2% depending on channel width. Rapids are swift, turbulent flows that include chutes, hydraulic jumps, and swirling around boulders. Gradients in rapids are typically 2-4% and greater than in riffles (Moore et al. 1997). The ODFW protocol defines cascades as fast, turbulent flows with hydraulic jumps, eddies and chutes. Much of the substrate may be exposed boulders, and gradients are typically high at 3.5-10% (Moore et al. 1997). The USFS definition of riffles encompasses the definitions of all these unit types; “Riffles are an inclusive term for low gradient riffles, moderate gradient rapids, and high gradient cascades,” (USFS 1999). In surveys of the Lake Branch by the ODFW and USFS in consecutive years, the cumulative percent surface area of riffles, rapids and cascades combined in the ODFW survey was 68%, and the percent surface area of riffles surveyed by the USFS was 65%.

Because the three fast-water unit types sustain different densities of steelhead parr, it was appropriate to subdivide riffles as surveyed by the USFS into components including riffles, rapids and cascades. Steelhead densities in rapids are 2.3 times higher than those in riffles. Of reaches surveyed by the ODFW in the Hood Basin, rapids comprised up to 91% of the surface area of each reach and averaged 53%. Had the differentiation between rapids and riffles not been made in the ODFW reaches, steelhead rearing potential in those reaches would have been greatly underestimated because riffles are assigned a density less than half of that in rapids.

A relationship between gradient, wetted channel width and the percentage of fast-water habitat comprised by riffles, rapids and cascades was found by using ODFW survey data from 921 reaches in the Hood, Nehalem and Umpqua basins. Surveys from these basins provided data from a breadth of streams of different widths and gradients. In the process of the analysis, it was necessary to pool data from rapids and cascades to develop a reliable relationship. The USFS did not present active channel width data for all reaches so average wetted widths were used.

For each reach in the data set, total surface area of riffles, rapids and cascades combined was determined. Next, the percentage each of the three components made of that total was calculated. Then the data set was stratified by groups of wetted widths and gradient. Increasing gradient caused an increase in percent rapids and cascades, and decrease in riffles among fastwater habitat types (Figure B2). The relationship changed depending on average widths. For a given gradient, a greater proportion of rapids and cascades was found in reaches greater than 6m wide than in reaches less than 6m wide (Figure B2).

Figure B2. Effects of gradient on percent rapids and cascades of fastwater habitat in two different wetted width strata. Numbers above boxes represent sample size.

Measurements by the USFS of the amount of riffle habitat surveyed, gradient, and average width and the results seen in Figure B2 to determine the proportion of their riffles that should be rapids and cascades. Average wetted width and gradient reported by the USFS for each reach were used to determine from Figure B2 what percentage should be assigned to rapids and cascades. We determined the total surface area of riffles in the USFS reach, and multiplied it by the median proportions from Figure B2 to estimate the amount of surface area comprised by rapids and cascades, and the amount of surface area comprised by riffles.

Subdividing Pools

Pools as surveyed by the USFS were subdivided into pools and glides for the same reason that riffles surveyed by the USFS were subdivided. The UCM recognizes two primary “slow-water” habitat types, including pools and glides. There are several sub-types of pools, but generally a pool is defined as having a slope of 0%, and usually formed by scouring action or an impoundment (Moore et al. 1997). Glides are uniform in depth and flow with no surface turbulence, and are low gradient (0-1% slope). They may have small scour areas, but are usually distinguished from pools by their homogeneity and lack of structure. They are generally deeper than riffles and have few obstructions and low habitat complexity (Moore et al. 1997). The USFS defines a pool as “A portion of the stream which usually has reduced surface turbulence and has an average depth greater than in riffles when viewed during low flow conditions...” This definition leads to the inference that glides are more likely to be classified as a pool by the USFS than a riffle because of the lack of surface turbulence, low slope, and depth greater than riffles.

Because pools and glides sustain different densities of spring Chinook and steelhead parr, it was appropriate to subdivide pools as surveyed by the USFS into components including pools and glides. Spring Chinook densities in pools are 3.5 times greater than in glides, and steelhead densities in pools are 2 times higher than those in glides.

ODFW data were used from 557 reaches in the Hood, Nehalem and North Umpqua basins to establish relationships between pool and glide surface areas. For each reach in the data set, the combined surface area of pools and glides and the percentage that each type made of that total was determined. There was a significant difference between the median percent pools in reaches with low (0-3%), medium (3.1-6%), and high (6.1+%) gradient (Kruskal Wallis test: $P < 0.01$). As gradient increased, the percent pools of slow-water habitats increased (Figure B3). Stream width did not have an effect on the relationship, even when five different width strata were used (Figure B4).

Figure B3. Relationship between gradient and percent pools of pool and glide habitat. Based on ODFW habitat survey data from the Hood, Nehalem, and N. Umpqua basins. Differences in medians are significant ($P < 0.01$). Numbers above boxes represent sample size.

Figure B4. Relationship between wetted width and percent pools of slow-water habitat. Used only reaches with gradient less than or equal to 3%. Based on ODFW habitat survey data for the Hood, Nehalem, and North Umpqua basins. Differences in medians are not significant ($P = 0.07$). Numbers above boxes represent sample size.

Using findings from the above analysis, pools surveyed by the USFS were subdivided into pools and glides. Average gradients of each reach as reported by the USFS were used to determine from Figure B3 what percentage of their pools class should be assigned to either pools or glides.

VALIDATION OF DATA ADJUSTMENTS AND ASSUMPTIONS

Stream surveys by the ODFW and USFS in the Lake Branch were compared to validate the adjustments and assumptions described in this appendix. In August/September, 1994 the ODFW surveyed the Lake Branch from its mouth to Lost Lake. The USFS surveyed the same stretch in July of 1995. USFS staff know of no major disturbances or changes in the Lake Branch in the winter of 1994/1995 (Katie Cerres, USFS Mt. Hood National Forest, pers. comm.). The effects of adjustments and assumptions described in the previous section were evaluated by comparing estimated steelhead parr capacity densities in the Lake Branch using the USFS data unadjusted, the USFS data adjusted, and ODFW data. We applied the adjustments regarding use of USFS substrate data to the USFS unadjusted data set so that we had substrate data to run the model with. Conversion of USFS measurements into forms similar to those of the ODFW substantially decreased estimated parr densities, and made capacity estimates more similar between the ODFW and USFS data.

Differences between the USFS estimated capacities and the ODFW estimated capacities were reduced by 50% through the adjustments and assumptions made with the USFS data (Figure B5). Because flows were greater during the USFS habitat survey, the USFS surveyed more surface area of stream. This was accounted for in this analysis by comparing capacity densities between the two model runs based on the Lake Branch surface area surveyed by each respective agency. Both the unadjusted and adjusted USFS capacity densities were higher than those estimated with the ODFW data.

Figure B5. Capacity density estimates using unadjusted and adjusted USFS data compared to ODFW data for the Lake Branch.

Adjustments and assumptions to the USFS data resulted in a significant decrease in capacity density estimate differences between models using the USFS data and the ODFW data. Differences still exist between the capacity density estimates using the two data sets, but this should be expected. First of all, no two habitat surveys will yield exactly the same results. These differences may be exaggerated when different protocols are used in the two surveys. Secondly, in each of the assumptions and adjustments made to the USFS data, there is a degree of variability and uncertainty that should be recognized. This variability will ensure that the adjustments and assumptions are rarely 100% accurate, but the results of this analysis indicate that modifications have resulted in more realistic capacity estimates when using the USFS data.

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APPENDIX C. DEVELOPMENT OF THE SPRING CHINOOK PARR CAPACITY MODEL

INTRODUCTION

Cramer (2001) reviewed the most recent findings from studies of salmon and trout ecology throughout western North America, and developed a model for using measurements of stream habitat to estimate a stream's potential to produce spring Chinook as well as other salmonid species. The model, referred to as the Unit Characteristic Method (UCM), relies on measurements of the stream area composed by different channel unit types, and then assigns a standard fish density to each of those types. The UCM further adjusts the densities to account for variations in depth, substrate, and cover of each habitat unit, and for variations in water quality between stream reaches.

Cramer (2001) described habitat features found to strongly influence the production of salmonids, and used empirical evidence to quantify the relationship between fish production and habitat features. Cramer (2001) extensively reviewed literature that described the habitat preferences of Chinook at each life stage, and further described evidence of quantitative relationships between habitat features and fish use at each life stage. The life stages that he examined included spawning, fry rearing, parr rearing, and presmolt overwintering. Evidence showed that production of spring Chinook smolts is most frequently limited by parr rearing capacity, because they rear a full year in freshwater before migrating to sea, and show density dependent growth during the parr stage. Accordingly, the spring Chinook UCM focuses on estimating capacity for rearing spring Chinook parr. However, the model also takes into account the potential for a capacity bottleneck in the winter by evaluating the presence of cobbles in the substrate as overwinter refuge.

Cramer (2001) presented evidence regarding rearing densities of spring Chinook parr by habitat type. He also showed evidence that parr capacities were reduced in calm mid sections of large pools and in the middle of large channels. He developed quantitative relationships between percent fines in riffles, and percent cobbles and their effects on densities.

The spring Chinook UCM had, prior to this project, not been used. There was a need to further develop the model for application to the Hood Basin. Specifically, we needed to establish standard densities for each unit type, and seek data regarding the effects of cover and depth on Chinook densities.

In this report, we review data obtained since the publication of Cramer (2001) that we used to further develop the spring Chinook UCM. We synthesize the findings of Cramer (2001) with findings from the Grande Ronde River, Oregon and the Coldwater River, British Columbia that provide evidence for standard parr densities as well as relationships between parr density, depth, and cover.

STANDARD PARR DENSITIES

Five studies that made extensive and repeated observations of Chinook parr densities, and reported those densities according to habitat unit type were reviewed. These studies included investigations by Bjornn and Reiser (1991) for 22 streams in Idaho, by Don Chapman Consultants (1989) for the Wenatchee River, by Washington Department of Fish and Wildlife researchers for 8 years of study on the Tucannon River (Bumgarner et al. 1994 and Mendel et al. 1993), by D.B. Lister & Associates for 3 years on the Coldwater River, B.C., and by the Oregon Department of Fish and Wildlife for five years in the Grande Ronde Basin on Catherine Creek and the Lostine River (Keefe et al. 1995; 1998 and Jonasson et al. 1996; 1997; 1999).

Some habitat types were reported somewhat differently in the five studies, so it is necessary to describe how these different types can be compared. Don Chapman Consultants (1989) and D.B. Lister & Associates combined all fast-water habitats into riffles. Bjornn and Reiser (1991) sub-divide fast-water units into pocketwater and riffles, and Bumgarner et al. (1994) and Mendel et al. (1993) divide out boulder units and riffles. Keefe et al. (1995; 1998) and Jonasson et al. (1996; 1997; 1999) sub-divided fast-water units into riffles, riffles with pockets, and rapids. The designations of boulders, pocketwater, and riffles with pockets represent the same habitat type, which is a moderate-gradient riffle with boulders as the dominant substrate type. For comparison, we classified boulder units and pocketwater as pocket riffles. Rapids are similar to riffles with pockets except they have a higher gradient (Moore et al. 1997), and thus were treated separately. Studies from the Grande Ronde subdivided pools into straight scour, lateral scour, plunge, isolated and dammed. In this analysis we pooled data from these pool sub-types.

In the Wenatchee River, Don Chapman Consultants (1989) estimated Chinook parr densities by habitat type each month during June through October, 1987. Chinook densities decreased steadily throughout their survey, and by September densities were only 7% of those in June (Table C1). Because densities stabilized by August, we limited our examination of data to data collected in August and September. It is at this time period when rearing capacity of spring Chinook parr is typically limiting (Cramer 2001).

Table C1. Mean and relative densities of Chinook parr, by habitat type, during June-September, 1987 in the Wenatchee River, km 21-42. Data from Don Chapman Consultants (1989; p. 219).

Unit Type	Density (#/100m ²)				Mean Relative Density
	June	July	August	September	
Pool	63.1	15.5	3.7	4.8	100%
Run	35.1	13.0	2.8	1.9	64%
Riffle	7.8	0.4	0.4	0.2	8%
Glide	87.3	22.7	3.4	5.7	121%

Chinook parr density estimates by unit type can vary from year to year and location to location depending on sample method and time of year of the surveys (Don Chapman Consultants 1989; Bumgarner et al. 1994, 1995; Mendel et al. 1993). Densities are also subject to spawner escapements and freshwater environmental variables. Densities in the studies we reviewed varied moderately. Average pool densities ranged from 4.3 fish/100m² to 35 fish/100m². Densities in glides were less variable ranging from 4.6 to 14 fish/100m². Runs were highly variable with reports of 2.4-30.9 fish/100m². Riffles and rapids were less variable, with all reported average densities of 10 fish/100m² or less (Figure C1).

Figure C1.

Top: Densities by unit type in each of the studies examined. Bottom: Densities in each unit type relative to densities in pools in each of the studies examined. Wenatchee only includes data from August and September.

Relative differences in densities between unit types varied less between studies than actual densities. We found that when densities in other units were scaled against pools, there were similarities between studies. Among runs and glides, which are similar habitat types, densities were between 56-60% in 5 of 7 instances (Figure C1). Riffles were reported in all studies, and their densities relative to pools ranged from 7-29%. Pocket riffles had higher densities at 15-43% of those in pools, and rapids had the lowest relative densities at 6-14% of densities in pools (Figure C1).

These data indicate that Chinook parr densities are inversely related to velocity. Bjornn and Reiser (1991) found that in Idaho streams, by late summer Chinook parr were found primarily in velocities at the low end of those that were available. Densities were consistently highest in pools which have the lowest velocities of the unit types, intermediate in glides and runs which have velocities greater than pools but less than riffles, and lowest in riffles and rapids which are the highest velocity unit types.

Densities in pocket riffles were greater than those in riffles or rapids. Pocket riffles are created when a riffle has a high proportion of boulders that create small pockets of calmpwater. Chinook parr have been shown to use these pockets as velocity refuge and feeding stations (Hillman et al. 1987). Velocity shear zones created by boulders are optimum feeding stations for Chinook parr. The USFWS (1989) showed that juvenile Chinook densities were greatest near velocity shear zones where the fish could easily move back and forth between velocities of 0.06m/s and 0.3-0.6 m/s. Generally, more boulders in riffles will create more shear zones, more feeding stations, and will support more spring Chinook. Rapids have high boulder content, similar to pocket riffles, but rapids generally have higher gradient and higher velocities. Velocities in rapids are typically so high that the benefits of the cover provided by boulders are often outweighed by the extreme velocities. If velocities are too great, salmonids will not be present (Bjornn and Reiser 1991).

The studies reviewed support the premise that densities differ by habitat type, and comparisons of relative densities show that the differences between different habitat types are consistent between basins. These findings support the use of standard densities in the spring Chinook UCM because different densities in different unit types reflect preferences of Chinook parr for various velocities. However, varied densities between basins make establishing standard densities difficult.

We determined that median densities from the Coldwater River were best suited for use in the UCM (Figure C2). Of all the studies reviewed, densities in the Coldwater River best represented densities in fully seeded habitat during the late summer when the parr capacity bottleneck occurs. Density estimates in the Coldwater River were made using blocknets, and multiple pass electrofishing and likely provided the most realistic density estimates of methods used in the studies examined. Densities from the other studies were useful for examining relative densities between unit types, but we could not determine if streams in those studies were operating at capacity. Evidence suggested that the Coldwater River was fully seeded and likely operating at capacity.

Figure C2. Median Chinook parr densities by habitat unit type in the Coldwater Drainage, B.C. Densities based on data from D.B. Lister & Associates.

We examined data from the Coldwater River in a several manners to evaluate the seeding status of the system. First of all, we compared spawner abundance in the river among survey years to estimated juvenile abundances in the survey areas. Secondly, we compared recent spawner run sizes to run sizes in the Coldwater River over a 26 year span. Finally, we examined what average spawner escapement would be expected in a British Columbia river similar in size to the Coldwater River. The results of each of these comparisons indicated that the Coldwater system was at or near capacity during the years that juvenile densities were estimated.

Stability in juvenile abundances under vastly different spawner population sizes is an indication that a system is at rearing capacity. Estimated parr abundances varied little between years studied ranging from 2,503-2,941 (Table C2). Escapement of adults to the Coldwater Basin showed much greater variation during the same years, with escapement estimates of 550-2,100 during the 1985-1987 brood years (Table C2). Spawner run sizes varied by 380% during the study period compared to a variation of 17% in juvenile abundances.

Table C2. Escapement and estimated parr abundances in the Coldwater River, B.C. from 1985-1988.

Brood Year	Escapement ^a	Est. Parr Abundance ^b
1985	1,500	--
1986	2,100	2,941
1987	550	2,681
1988	--	2,503

a. Source: G. Kosakoski, Dept. of Fisheries and Oceans, Kamloops

b. Abundance estimated in sampling sites.

Healey (1982) reported a minimum spawning escapement in the Coldwater River of 200 spawners, a maximum of 1500 and an average of 587 over a 26 year span, through the report didn't specify what years the estimates covered. In 1985 and 1986 spawning escapements were equal to and higher than the maximum reported by Healey (1982), and the 1987 escapement was similar to the 26 year average. This indicates that the river was fully seeded for the 1985 and 1986 broods by spawners.

Healey (1991) presented data relating average spawning populations between 1952 and 1976 and average river discharge for British Columbia populations of Chinook. The data are for individual spawning populations within each river system. We added the three years of Coldwater data to this plot to compare spawner abundance during the study period to what is typical in British Columbia systems of similar size. We obtained Coldwater River discharge data from a gauge within the study area and then used the spawning population within or above the study area. Stewart (1986) estimated that 55% of the Coldwater River run in 1985 spawned in or above the study area. The data in all three years indicates that the Coldwater was at the higher end of spawning population size of what would be expected in watersheds of it's size (Figure C3).

Figure C3.

Relationship between average spawning population size and average river discharge for British Columbia populations of Chinook salmon. These data are for individual spawning populations within each river system. Coldwater River data appears as squares. Figure modified from Healey 1991.

Median densities from the Coldwater River provided data for the most common habitat types except rapids and cascades. The only study we found that presented data for rapids were the studies in the Grande Ronde Basin. In the Grande Ronde, densities in rapids were 10% and 18% of densities in pools and glides respectively. These relative densities in the Coldwater River would convert to 2.5 and 2.3 fish/100m² in rapids and cascades. Accordingly, we will assume density of spring Chinook parr in rapids is 2.4 fish/100m².

INFLUENCE OF HABITAT FEATURES ON CAPACITY

There is variation in physical features between units of a habitat type, but data to evaluate how such variation might influence fish densities is limited. Findings from several sources regarding the effects of channel size, depth and cover on spring Chinook rearing densities were synthesized. Cramer (2001) reviewed several sources and found that Chinook densities decrease after pools reach a certain maximum size, or channel widths exceed 24m. The only data that provided quantitative relationships between Chinook parr densities and cover and depth was data from D.B. Lister and Associates in the Coldwater River, B.C.

Limits of Pool Size

Bjornn and Reiser (1991) found densities in pools decline in pools that are extra large for their channel size. They show that Chinook parr densities in pools of several Idaho streams increases linearly up to a pool volume of about 200m³, after which there is little change in number of Chinook. Such a relationship is consistent with the data on micro-habitat preferences that show Chinook prefer velocity shear zones found along the edges of pools and glides. Bjornn and Reiser (1991) reported that Chinook were concentrated near the head of pools where the supply of invertebrate drift (food) was greatest, and that few Chinook were found in the downstream portion of large pools.

Cramer (2001) obtained further data from habitat surveys of the lower Sandy River, Oregon, that showed the relative size at which pools become so large that the mid-section becomes calm (without a distinct current trail) during summer low flow. The calm middle section of such pools would be of low desirability to Chinook or steelhead, because the shear zones sought by these species are not present. In the survey of the Sandy River, Cramer et al. (1998) measured dimensions for head, mid, and tail section of pools that qualified as having a calm mid section without a distinct velocity thalweg. The data show from a sample of 47 qualifying pools that calm mid-sections form when pool lengths are greater than four times their width. Based on these data, and those of Bjornn and Reiser (1991) Cramer (2001) assumed for calculation of rearing capacity that pool length beyond 4 channel widths should be excluded from usable area for Chinook.

Fines in Riffles

It has been well established that excessive amounts of fine sediment can reduce survival of salmonid eggs, rearing density of parr, and even survival of overwintering presmolts. Excess fine sediment can also reduce rearing density for salmonid parr. Newly emerged fry can occupy

the voids of substrate made up of 2-5 cm diameter gravel, but presmolts need cobble (>7.5 cm) and boulder-sized rock to provide interstitial spaces they can occupy. Density of juvenile steelhead and Chinook in summer and winter was reduced by more than half when enough sand was added to fully embed the large cobble substrate in an experimental stream (Figure C4)(Bjornn et al. 1977). Thompson and Lee (2000) found that probability of moderate to high densities of steelhead parr in Idaho streams decreased as the percentage of watershed with unconsolidated lithology increased ($P < 0.05$). They deduced that this type of lithology was prone to sedimentation that could reduce survival of parr. Because the capacity bottleneck for spring Chinook occurs at the parr stage, Cramer (2001) concluded that the effects on parr should be used to adjust capacity for spring Chinook.

Figure C4. Densities of Chinook salmon and steelhead juveniles remaining after 5 days during winter and summer tests in laboratory stream channels with varying amounts of embeddedness by fines < 6mm. From Bjornn et al. (1977).

Cover

The importance of cover to rearing salmonids has been widely documented. Cover provides fish with protection from predators and allows use of stream areas that they might otherwise not use. Cover can come in several forms (overhead, frontal, lateral) and can be provided by substrate, submerged debris and objects at or above the surface. Johnson (1985)

found that parr densities of steelhead in boulder dominated riffles averaged about 5 times greater than in riffles with other substrate types as dominant. The boulders provided refuge from high velocities while providing a holding station to capture drifting invertebrates. Ward and Slaney (1993) showed that steelhead parr densities increased as more boulders were added to study sites in the Keogh River. The number of Chinook in pools increased with increasing amounts of cover (Steward and Bjornn unpublished data, cited in Bjornn and Reiser 1991). Wesche (1974) correlated increased cutthroat standing crop with increased cover and surface area. Brusven et al. (1986) showed that juvenile Chinook rearing in a test stream during July and August showed strong preference for covered rather than uncovered experimental sections of stream. Raleigh et al. (1986) concluded from available studies of Chinook parr that, "Juvenile Chinook use water depth (deep, low velocity pools and bank eddies), surface turbulence, instream structures, and substrate (primarily 10-40 cm in diameter) as cover, with substrate being the major source of escape and winter cover (Hartman 1965; Everest 1969)."

Boulders

Boulders increase rearing capacity by increasing cover within a stream (Bjornn and Reiser 1991). Relationships between Chinook rearing densities and boulder cover with data from the Coldwater River, B.C. was quantified. Chinook density was positively related to boulder cover in pools, riffles and glides (Figure C5). Different classes of boulder frequency for different unit types were used, because the range of boulder presence differs between unit types (Table C3). In pools, densities were significantly greater in pools with more than 2% boulder cover, than in pools with less than 2% boulder cover (Figure C5). In glides, density was lowest in units with no boulder cover, moderate in units with 1-6% boulder cover, and highest in units with greater than 6% boulder cover. In riffles, densities were significantly higher in units with greater than 11% as compared to those with less than 11% (Table C3).

Table C3. Range of boulder composition seen in the Coldwater Basin by unit type.

	Pools	Glides	Riffles
Range in % Boulders	0-58%	0-63%	0-91%

Figure C5.

Chinook densities by boulder cover strata in the Coldwater River, B.C. Geometric means of densities are significantly different between strata within a unit type (Kruskal-Wallis $p < 0.05$). Points represent the median. Bars indicate the first and third quartile. Number above or below bar represent sample size. Data obtained from D.B. Lister & Associates, Inc.

This finding is substantiated by other studies. Studies from the Grande Ronde, Idaho, and the Tucannon cited earlier show that densities in riffles with boulders (pocketwater) support Chinook densities equal to or greater than densities in riffles not dominated by boulders (see Figure C1)(Keefe et al. 1995, 1998; Jonasson et al. 1996, 1997, 1999; Bjornn and Reiser 1991; Bumgarner et al. 1994, 1995; Mendel et al. 1993).

Non-Boulder Cover

Densities in pools are positively related to non-rock cover (Figure C6). We found that when non-rock cover was less than 2% of the unit surface area in the Coldwater River that densities were lower than when above 2%. Non-rock cover in the Coldwater River was provided by wood, overhanging vegetation, and undercut banks. There was no indication from the Coldwater data that densities in pools continued to increase when non-rock cover was above 2%. There was also no indication that non-rock cover was correlated to density in riffles or glides.

Figure C6.

Chinook densities by non-rock cover strata in the Coldwater River, B.C. Geometric means of densities are significantly different between strata (Kruskal-Wallis $p < 0.05$). Points represent the median. Bars indicate the first and third quartile. Number above bars represent sample size. Data obtained from D.B. Lister & Associates, Inc.

Associations of juvenile salmonids with large wood has been widely reported (Everest 1969, Raleigh et al. 1986, Bjornn and Reiser 1991). Hillman et al. (1987) suggested that overhead cover, including wood, undercut banks, and surface turbulence; can be an important summer habitat component for juvenile Chinook, particularly in small streams. In the Bumping River, Washington, Chinook parr densities were found to increase with increasing wood cover. In wood class ratings of 1 to 5 with 1 being little to no wood, and 5 being complex wood cover, average densities in units with wood cover of 5 were approximately 6 times greater than units with wood cover ratings of 1 (Kalin and Ackerman 2002a, Kalin and Ackerman 2002b).

Depth

Chinook parr densities were positively correlated to average depth in riffles and glides, and maximum depth in pools at shallow depths in the Coldwater River. Depth was strongly related to density in riffles, where we identified five depth strata with significantly different densities (Figure C7). In glides, differences in densities in units with average depths greater than 30cm and less than 30cm. In pools, there was no correlation between density and depth when maximum depth was greater than 55cm (Figure C8). However, between 24cm (the most shallow observation) and 55cm, depth was positively correlated to density ($r = 0.90$). The relationship was described by the equation:

$$\text{Density} = 0.83 * \text{max depth (cm)} - 20$$

Figure C7.

Chinook densities by depth strata in the Coldwater River, B.C. Geometric means of densities are significantly different between strata within unit types (Kruskal-Wallis $p < 0.05$). Points represent the median. Bars indicate the first and third quartile. Number above bars represent sample size. Data obtained from D.B. Lister & Associates, Inc

Figure C8. Relationship between maximum pool depth and spring Chinook parr density based on data from the Coldwater River, B.C. Points represent observed densities at depth between 24 and 55cm. Analysis of data from pools >55cm deep showed no significant increase in densities. Data from D.B. Lister & Associates

These findings are corroborated by others who have seen increased densities with increased depth. Densities by surface area will increase with increasing depth as long as the volume:surface area ratio increases and fish continue to distribute at increasing depths. Everest and Chapman (1972) suggest that as fish grow larger, they prefer deeper water, and that this movement is related to both food and cover. They found that juvenile Chinook densities were highest in the 30-45cm range, and that they were found in all depths observed up to 1.65m deep. Conner et al. (1995) showed that depth suitability of juvenile Chinook increased as depth increased from 10-50 cm and plateaued at 50cm in the White River, Washington. Habitat suitability curves presented by Raleigh et al. (1986) showed that suitability increased for juvenile Chinook from 0 to 30cm, and reached a plateau from 30-60cm. Beyond these depths, suitability may decrease because Chinook prefer not to station themselves much beyond these depths, but densities by surface area vary little.

APPLICATION OF FINDINGS TO SPRING CHINOOK UCM

We synthesized findings by Cramer (2001) with findings from data reviewed since the publication of Cramer (2001) to further develop the spring Chinook UCM. We have previously described the rationale behind the standard densities designated for use in the UCM, and relationships between those densities and habitat features. Here the standard densities to be used in the spring Chinook UCM, and the nature of the adjustments that will be applied to these densities are presented.

The standard densities reflect the typical spring Chinook pattern of higher densities in lower velocity units. Densities are the highest in pool habitats, and lowest in rapids and riffles (Table C4). We assumed that densities in cascades are similar to rapids since no data regarding cascades were available.

Table C4. Spring Chinook standard densities used in the spring Chinook UCM, and densities relative to pools.

Unit Type	Parr Density (fish/100m ²)	Relative Density
Pool	24	100%
Log Jam Pool	19	79%
Backwater	13	54%
Glide	7	29%
Rapid	2.4	10%
Cascade	2.4	10%
Riffle	2	8%

Adjustments to standard densities are based on the relationships between Chinook parr densities and habitat features discussed earlier. The magnitude of adjustments, and levels at which they apply were derived from data from the Coldwater River, B.C. Relationships were developed by comparing the geometric mean of Chinook densities in strata of each variable. The number of strata were maximized while maximizing sample size and testing for significant differences between mean densities in those strata ($p < 0.05$). We pooled strata that were not significantly different until all strata had significantly different geometric means. Adjustment factors were determined using the following equation:

$$\text{Adjustment Factor} = \text{Geo Mean}_S / \text{Geo. Mean}_T$$

Where: Geo. Mean_S = Geometric mean of units within the strata

Geo. Mean_T = Geometric mean of all units within that unit type

And:

$$\begin{aligned} \text{Geo. Mean}_T \text{ Pools} &= 24 \text{ Chinook}/100\text{m}^2 \\ \text{Geo. Mean}_T \text{ Glides} &= 7 \text{ Chinook}/100\text{m}^2 \\ \text{Geo. Mean}_T \text{ Riffles} &= 2 \text{ Chinook}/100\text{m}^2 \end{aligned}$$

Adjustments are multiplied by the capacity to obtain the adjusted capacity. The adjustment proportions and the level at which each adjustment applies for all the habitat variables analyzed can be seen in Table C5.

Table C5. Adjustment factors and levels at which the factors apply in the spring Chinook UCM.

	% Boulder Cover Adjustments						
	Pools		Glides			Riffles	
	<2%	≥ 2%	0%	1-6%	≥ 6%	<11%	≤11%
Geo. Mean Density	11	29.5	4	6	11	2	4
Adjustment factor	0.46	1.23	0.57	0.86	1.57	1.00	2.00
	% Non Boulder Cover						
	<u>Pools</u>						
	<2%	≥ 2%					
Geo. Mean Density	11	27					
Adjustment Factor	0.46	1.13					
	Avg. Depth (cm)						
	Glides		Riffles				
	<30	≥30	<10	10-15	15-24	24-35	≤35
Geo. Mean Density	4	14	0	1	2	7	15
Adjustment Factor	0.57	2.00	0.00	0.50	1.00	3.50	7.50

Non-boulder cover in the Coldwater River was provided by wood, overhanging vegetation, and undercut banks. We assumed, that most of this cover came from wood, and that average conditions in the Coldwater were equivalent to an ODFW wood score rating of 2.

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APPENDIX D. SUSPECTED EFFECTS OF SUSPENDED SOLID ON SALMONID REARING CAPACITIES IN THE HOOD RIVER BASIN

BACKGROUND

The Hood River system is influenced by glacial suspended solids. Several glaciers on Mt Hood supply the main Hood River forks with suspended glacial sediments primarily via Clark Creek, Newton Creek, Coe Branch, Eliot Branch and Ladd Creek. In general, suspended sediment levels are greater in the East and Middle Forks than in the West Fork. Concentrations are higher in the summer and spring during melt off than in fall and winter.

We extensively reviewed literature and interviewed researchers familiar with the effects of suspended solids on salmonids. The purpose of the research was to quantitatively estimate the effects of suspended solids on the potential steelhead and spring Chinook rearing capacities of the Hood River basin via the Unit Characteristic Method (UCM). There is extensive documentation of influences by suspended sediments on salmonid distribution, physiology, feeding efficiency, and predator avoidance. However, the literature also indicated that the concentrations where these effects take place are markedly higher than concentrations found in the Hood Basin, and that salmonids can adapt to certain levels of suspended solids given time. Ultimately, we found that the only likely limitation imposed on capacity by suspended solids in the Hood Basin was through reductions in primary production due to reduced levels of light penetrating the water column. We found that decreases in primary production subsequently resulted in decreases in invertebrate abundance and finally salmonid abundance.

Sampling of total suspended solids (TSS) has been conducted in the Hood Basin by the Oregon Department of Environmental Quality since the 1960's. Sampling has occurred through several projects and consists primarily of grab samples taken at various locations throughout the basin, although many locations have been sampled numerous times. A majority of the sample sites have been at lower elevations. Median summer suspended solid concentrations in the mainstem Hood and East Fork typically range from 10-40mg/L. In the Middle Fork, the Coe Branch is highly influenced with a median summer value of 110mg/L. The Eliot Branch is moderately influenced at 43mg/L. The West Fork is less concentrated with median summer values less than 10mg/L.

RELATIONSHIP BETWEEN TOTAL SUSPENDED SOLIDS AND TURBIDITY

A common measure of TSS is turbidity measured in NTU's. Turbidity is a measure of light penetration in the water, and is generally a good indicator of TSS. However, the relationship between TSS and turbidity is related to particle size and shape (Sorenson et al. 1977), and may vary between basins depending on the physical nature of the suspended particles. Servizi and Martens (1992) found the relationship between TSS and NTU with Fraser River sediments could be explained by the equation:

$$NTU=113 (TSSg/L)^{0.916} \quad r^2 = 0.90$$

Lloyd et al. utilized data from throughout Alaska to develop a relationship between TSS and NTU that was described by the equation:

$$\text{NTU} = 0.44 (\text{TSS mg/L})^{0.858} \quad r^2 = 0.83$$

Using data from the Hood River system where samples were concurrently taken of TSS concentrations and turbidity it was found that the relationship could be described as:

$$\text{NTU} = 0.49\text{TSS} + 1.11 \quad r^2 = 0.74$$

REPORTED EFFECTS OF SUSPENDED SEDIMENTS ON SALMONIDS

When modeling steelhead and spring Chinook parr capacity of the Hood River basin, it was necessary to take into account the effects of TSS. Substantial literature has indicated that suspended solids have positive and negative effects on salmonids. Some of these effects include changes in rearing density (Ptolemy 1993; Sigler et al. 1994), distribution (Scrivener et al. 1994; Sigler et al. 1984; Gregory 1993; Bisson and Bilby 1982; Servizi and Martens 1992), growth rates (Sigler et al. 1984; Murray and Rosenau 1989; Newcombe and MacDonald 1991), foraging behavior and efficiency (Tippets and Moyle 1978; Gregory 1990; Ginetz and Larkin 1975; Gregory and Levings 1998; Murray and Rosenau 1989; Gregory and Northcote 1993), physiological stress (Redding et al. 1987, Sigler et al. 1984; Servizi and Martens 1987; Servizi and Martens 1992), predator avoidance (Gregory 1993; Gregory and Levings 1998) and primary production (Lloyd et al. 1987; Van Nieuwenhuysse, 1983; Van Nieuwenhuysse and LaPerriere 1986).

Ptolemy (1993) found that total suspended solids were significantly ($p < 0.05$) negatively correlated to fish abundance in fluvial habitats of British Columbia. We examined the data used by Ptolemy and found that while the relationship was significant, it was weak. In a multiple regression based on data from 1,671 reaches where reliable salmonid density, average salmonid weight, and water chemistry data was available a multiple regression using average weight and alkalinity explained 84.6% of the variation in density. While suspended solids were significantly correlated, adding suspended solids data only increased the r^2 value to 85.6%. In addition, Ptolemy (1993) states that there was considerable variation in density in strongly glacial systems. Ptolemy (1993) found that comparisons of the Squamish River (56mg/L) with no steelhead or char found in the mainstem, and the Bulkley River (47mg/L) with low but biologically significant production highlight the need for further research on the effects of TSS on salmonid densities. Further, Ptolemy's model incorporating the suspended solids function was not validated with data outside British Columbia, and is based on data for all salmonid species and all life stages. Evidence exists suggesting that not all species or life stages react to TSS in the same manner (Sigler et al. 1984; Murphy et al. 1989; Servizi and Martens 1987).

Several authors have documented changes in distribution in the water column and in a basin resulting from TSS. Scrivener et al. (1994) cited high levels of TSS as a potential reason for the utilization of non-natal streams by migratory juvenile Chinook in the Fraser river system. They found that juvenile Chinook moving downstream would enter Hawks Creek, a non-natal

tributary, for on average nine days before returning to the mainstem Fraser. TSS concentrations in the Fraser averaged 20-60mg/L in the summer as compared to 5-30mg/L in Hawks Cr. Servizi and Martens (1992) found that coho subjected to increased levels of TSS in a laboratory experiment would move to the water surface where TSS concentrations were lower. Sigler et al. (1984) reported that juvenile steelhead and coho emigrated from rearing areas with TSS concentrations of 120-274mg/L. Gregory and Levings (1998) found that in clear water, predation was greater near the substrate than elsewhere in the water column. No spatial differences were seen in turbid water indicating that predators and prey were spread more uniformly in the water column. Bisson and Bilby found that juvenile coho exhibited significant avoidance of turbid conditions in laboratory conditions when turbidity levels were high (>70 NTU), but not below these levels. They found no preference for clear or turbid water when turbidity was below 70 NTU. In contrast, Noggle (1978) found that juvenile coho preferred slightly turbid water over clear water.

Kissner (1983) found that juvenile Chinook grew faster in clear tributaries than in the mainstem of the glacially turbid (JTU>400) Taku river. Sigler et al. (1984) found in laboratory conditions that steelhead and coho exposed to turbid conditions (120-275mg/L) had significantly lower growth rates than those in clear conditions.

Salmonids are predominately visual feeders (Gregory and Northcote 1993), and several studies have shown that increases in suspended solid concentrations can decrease foraging efficiency and modify foraging behavior. Gregory (1990) showed that foraging rates of juvenile Chinook decreased in the mainstem Fraser when TSS concentrations exceeded 200NTU (approximately 1,800mg/L). Gregory and Levings (1998) showed that salmonid predators were more impaired by increased turbidity than non-salmonid predators that relied less on vision for predation in the Fraser River system.

Gregory and Levings (1998) were also able to show that juvenile Chinook foraging rates were higher at 40-185mg/L concentrations than in clear conditions. The authors attributed this to turbidity acting as cover which reduced the inhibition of the juveniles to expose themselves to predators rather than forage. However, at the extremely high levels of TSS, visibility became so poor as to outweigh the advantages of the increased cover.

Physiological stress in salmonids has been documented by several authors. Redding et al. (1987) found that TSS concentrations of 2,000-3,000mg/L caused increased levels of plasma cortisol among salmonids. Plasma cortisol levels began to rise significantly when TSS levels reached 300-600mg/L after 2 days of exposure. Servizi and Martens (1984) found that TSS of 3,148mg/L resulted in lodging of fine particles in gills of underyearling sockeye. Sockeye smolts suffered slight impairment from hypoosmoregulatory capacity when exposed to TSS concentrations of 14,407mg/L for 96 hours. In adult sockeye, plasma glucose levels rose 39% when TSS reached 500mg/L (Servizi and Martens 1984). Servizi and Martens (1992) found that coughing rates of coho increased eightfold over control conditions when TSS reached 240mg/L. No increase in cough frequency was observed at 20mg/L. They also found that blood glucose levels were positively related to TSS concentrations.

Several papers have shown that juvenile survival may be enhanced by certain levels of turbidity due to decreased encounters with predators. Gregory and Levings (1998) found that during seaward migration, sockeye salmon in the Fraser River system were less likely to encounter and be consumed by fish piscivores in turbid waters than in clear waters. They found that predators in the Harrison river (a clear tributary to the Fraser) consumed more fish/predator than those in the mainstem Fraser. Gregory (1993) found that responses of juvenile Chinook in lab conditions to imitation predators was less exaggerated in turbid conditions than in clear conditions, and that normal behavior resumed faster in turbid conditions. Ginetz and Larkin (1975) found increasing turbidity decreased predation rates of rainbow trout on sockeye fry.

FACTORS CONFOUNDING TSS AND EFFECTS ON SALMONIDS

Despite all of the literature regarding the effects of TSS on salmonids, there is still a great lack of clarity on the quantitative relationships between TSS concentrations and its effect on salmonids including their rearing densities. This lack of clarity is largely a result of numerous factors working together. There is evidence that TSS effects are not only expressed through concentrations, but through duration of exposure and physical properties of the particles. The problem is further complicated by different impacts on different species, different life stages and potentially different stocks.

Newcombe and MacDonald (1991) developed a “Stress Index” model to predict the effects of TSS concentrations on fishes. They found that concentration alone was a relatively poor indicator of TSS effects ($r^2 = 0.14$). When duration of exposure was accounted for, the regression was strengthened ($r^2 = 0.64$). While the accuracy of the model has been highly debated and refuted, researchers have generally agreed that duration of exposure is an important factor to consider (Gregory et al. 1993). Many lab experiments evaluating the effects TSS have attempted to account for duration of exposure (Redding et al. 1987; Servizi and Martens 1992; Servizi and Martens 1987).

Servizi and Martens (1987) found that smaller sized particles are more damaging to juvenile salmonids than larger particles. Coarse and medium coarse sediments were not observed on gill lamellae of underyearling sockeye at lethal or sublethal concentrations, whereas fine sediments were found on lamellae at both lethal and sublethal concentrations during laboratory experiments. Servizi and Marten (1992) theorized that equal concentrations of TSS resulted in higher turbidities with smaller particle sizes. They proposed that smaller particle sizes increased the refractive nature of the particles resulting in higher turbidities. This confounds many between basin and between study comparisons of NTU because similar NTU's may correspond to different TSS concentrations.

Murphy et al. 1989 showed that different species react differently to TSS. They found in the glacially turbid Taku River, Alaska, that both sockeye and coho had significantly lower densities in highly turbid water (JTU>400) than in less turbid water. Chinook densities were not significantly different between highly and less turbid water. Their results were complicated by the finding that velocity was found to be more important to habitat selection than turbidity, and that the most turbid waters were also the fastest and least preferred by sockeye and coho.

Several reports have shown that effects of TSS on salmonids vary with life stage. Sigler et al. (1984) found that smaller steelhead fry were less likely to remain in turbid waters than larger steelhead fry. Servizi and Martens (1987) showed that sockeye smolts were less susceptible to negative effects from turbidity than sockeye fry at given concentrations. Juvenile salmonids prefer certain low turbidities because of the cover advantage provided, and piscivorous adult salmonids had decreasing foraging efficiency with increased suspended solids (Gregory and Levings 1998).

Finally, some evidence has suggested that salmonids have the ability to acclimate to certain levels of suspended solids. Bisson and Bilby (1982) showed that coho acclimated to background levels (3 weeks of holding) of clear water showed avoidance of turbid water at 70 NTU. Coho acclimated to slightly turbid water (2-15 NTU) did not show avoidance of turbidity until levels reached 100 NTU. This suggests that salmonids have an ability to adapt to background levels of turbidity, even in the short term. One can speculate that stocks native to naturally turbid environments have developed acclimated populations, and at low to moderately-low concentrations will experience negligible physiological and feeding impacts.

EFFECTS OF TURBIDITY ON STREAM PRODUCTION

The complicated nature of the previously described research makes quantifying effects of TSS levels on rearing capacities of steelhead and spring Chinook in the Hood Basin difficult. We reason that native steelhead and spring Chinook stocks generally are not influenced by normal TSS concentrations with respect to physiology in the Hood Basin. First of all, in much of the literature cited above, harmful physiological effects only begin to occur at concentrations far higher than those found in the Hood. Hood TSS concentrations are generally below 50mg/L. Literature shows that avoidance in acclimated fish begins at 100 NTU (275-600mg/L)(Bisson and Bilby 1982). Significant physiological effects in sockeye fry only began once concentrations reached 300mg/L, and smolts at concentrations as high as 14,000mg/L (Redding 1987; Servizi and Martens 1984). Foraging rates of juvenile Chinook were actually highest at concentrations similar to high concentrations in the Hood Basin (40-185mg/L)(Gregory and Levings 1998). Each of these studies inadequately evaluated the effects of long term exposures of salmonids to TSS concentrations, but the evidence suggest that concentrations higher than those found in the Hood Basin are required for significant impairment of populations.

Evidence presented by Bisson and Bilby (1982) suggests that salmonids are able to adapt and acclimate to mildly turbid conditions. It is possible that the Hood River stocks are genetically adapted to surviving and growing at similar rates and abundances as other stocks despite mildly turbid conditions. Significant mainstem rearing of salmonids occurs in the mainstems of the glacial Taku River and Fraser Rivers in Alaska and British Columbia (Murphy et al. 1989, Northcote and Larkin 1989). We concluded that no adjustments be made to Hood River rearing capacities of juvenile steelhead and Chinook in the UCM model based on physiological impairments. However, there should be an adjustment that accounts for reduction in primary production and subsequent food availability resulting from decreased light penetration from suspended solids.

Van Nieuwenhuyse (1983) examined the relationship between light penetration and turbidity in the Birch Creek and Chatanika drainages in the interior of Alaska. He found that mining induced turbidity was highly correlated to light extinction ($r^2 = 0.99$). Using this relationship he was able to estimate the amount of light reaching certain depths at given turbidity levels. He summarized his findings by stating that the amount of light reaching a depth of 0.1m ranges between 75 and 79% of the light available at the surface when turbidities ranged between 0.5 and 10 NTU's. At turbidities of 25-50 NTU's, 60-69% of the light reached 0.1m, and at 500-1,000 NTU's, only 0.3-5% reached 0.1m.

Van Nieuwenhuyse and LaPerriere (1986) found that gross primary production was highly correlated to light penetration ($r^2 = 0.67$) in streams less than 0.5m deep. Lloyd et al. (1987) synthesized the finding of Van Nieuwenhuyse (1983) and Van Nieuwenhuyse and LaPerriere (1986) by developing an equation that predicts the effect of various turbidity levels on light available at depth and ultimately of primary production. The equation is:

$$P = 10^{2 - [1 + 0.024(T)Z] / (10^{2-Z})}$$

Where:

P = proportion of primary production in streams of turbidity T to primary production in clear water at depth Z;

T = turbidity (NTU);

Z = depth (m).

Using this equation Lloyd et al. (1987) found that turbidities of only 5 NTU's can decrease primary production in shallow streams by 3-13%. An increase of 25 NTU's may decrease primary production by 13-50% in shallow streams (Figure D1). Primary production in streams greater than 0.5m would be reduced even further (Lloyd et al. 1987). Lloyd et al. (1987) cite studies from Great Britain that corroborate the results of this equation (Swale 1964; Westlake 1966; Lund 1969; Lack and Berrie 1976). These authors found that turbidity and light intensity, rather than nutrient concentrations were the factors most commonly limiting primary production in streams. In the Patuxent River, Maryland, Stross and Stottlemeyer (1965) found that increased turbidity decreased primary production per surface area.

Figure D1. Effects of turbidity on stream production. Derived from equation presented above by Lloyd et al. 1987 relating decreases in primary production to increases in turbidity.

Evidence suggests that invertebrates are strongly influenced by TSS, and invertebrates and fish production are directly related to primary production. Lloyd et al. (1987) found that densities and biomass of benthic invertebrates were significantly higher in unmined streams as opposed to mined streams. They also found that in heavily mined basins, most invertebrate taxa were rare or absent. Wagener and LaPerriere (1985) found that reduced density and biomass of macroinvertebrates was most strongly statistically correlated to turbidity in mined streams.

Carlson et al. (1990) was able to correlate increased macroinvertebrate densities with increased solar radiation resulting from decreased canopy density. Newbold et al. (1980) found that total macroinvertebrate numbers increased by 2.5 fold in northern California streams within 1-5 years of timber harvesting. Murphy and Hall (1981) found that macroinvertebrate numbers increased two-fold within 5-10 years after logging. These studies coupled with those in mined streams in Alaska indicated that as solar penetration (and primary productivity) decrease, macroinvertebrates decrease, and as solar penetration increases, so do macroinvertebrates.

Increases in sunlight penetration and invertebrate production have also been related to production of cutthroat growth. Murphy and Hall (1981) found that cutthroat trout abundance increased significantly ($P < 0.01$) in clear-cut compared to old-growth stream reaches in pair-wise comparisons within the same stream. The average increase in trout biomass (g/cm^2) in clear cut areas was 75.7%. This increase appeared to result from higher primary production, followed by greater production of invertebrates on which the trout fed. Murphy and Hall (1981) found that chlorophyll accumulation was greater in clear-cut sites than in adjacent old-growth sites, and that densities of insects in riffles were greater in open reaches than in their paired shaded reaches.

Hawkins et al. (1983) compared densities of invertebrates and vertebrates in stream reaches with complete removal of the stream side canopy to that in unaltered reaches (67-94% shading) of similar morphology. Hawkins et al. (1983) found the absence of shading consistently resulted in a significant increase in invertebrates ($P = 0.025$) and salmonids ($P = 0.023$). The synthesis of the above cited studies is that turbidity is inversely related to primary production, which has been shown to be positively related to invertebrate abundance, and subsequently salmonid abundance.

APPLICATION TO THE HOOD RIVER BASIN

Using the relationship presented by Lloyd et al. (1987) (Figure D1) relating turbidity to primary production, we estimated a reduction in capacity based on turbidity levels. The average depth of riffles in each reach, and turbidity for each reach was determined. We use average riffle depth because riffles are the primary location in the stream where drift invertebrates on which salmonids feed are generated (Hawkins et al. 1983). In each reach, we rounded the average riffle depth down to the nearest depth curve from Figure D1. For example, if a reach has an average depth of 0.48m, we used the 0.3m depth curve. This was done because with an average depth of 0.48m, half the riffle will be deeper, and half shallower than the average. We assume that a majority of the invertebrate production will come from the portion of the riffle that is shallower because there is less current and more sunlight penetration. This assumption can be supported by the observation that significant rearing of juvenile salmonids occurs in margins of highly turbid rivers in Alaska (Murphy et al. 1989). Since the equation was developed for small streams, we assumed that effects in larger streams was equivalent to effects realized at 0.5m in depth (the deepest value for which the equation calculates). In reaches where no turbidity data was available, we used qualitative rankings of high, medium and low and associated each of those rankings with a given reduction in capacity. Where we had data, we used the median turbidity values from the samples taken between July 1 and September 30. Where there was no turbidity data, but was TSS data, we will use equation 3 presented above to estimate turbidity.

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APPENDIX E. ANALYSIS AND SURVIVAL RATE ESTIMATION FOR MARKED RELEASE GROUPS INTO THE HOOD & DESCHUTES RIVER BASINS

INTRODUCTION

An effective method by which to accurately estimate survival rates of marked release groups is through construction of a Cohort Analysis Model. Cohort Analysis uses recovery data of fish marked with a coded wire tag (CWT) to estimate, by age and sex, ocean and freshwater harvest rates, survival rates, maturity rates, and stray rates. In the Hood River Basin, both spring Chinook and winter steelhead are marked with CWT's, while in the Deschutes River Basin only spring Chinook are marked with CWT's. Recoveries of individual fish (either as catch or as spawners) from groups of CWT marked fish provide the data needed to complete a cohort analysis for each group.

Cohort analysis requires that the number of CWT fish which end up in each of four possible categories be estimated: 1) those captured in ocean fisheries, 2) those captured in river fisheries, 3) those that escaped to a hatchery or fish trap, and 4) those that spawned naturally. Excellent sampling programs are in place to recover CWT's from fish harvested in ocean fisheries, Columbia River gillnet fisheries, sport fisheries in the Columbia, and fish returning to the hatchery. The number of CWT's recovered in each fishery or spawning area have been expanded by the recovering agency to account for the sampling fraction, and all recoveries (plus their expansions) are compiled in the Regional Mark Information System (RMIS; www.rmis.org/index.html) maintained by the Pacific States Marine Fisheries Commission (PSMFC). The PSMFC database is the primary source for CWT recoveries.

The cohort analysis procedure is an expanded accounting system of the number of fish from each release group that were either caught or escaped to spawn in a hatchery. Additionally, estimates of the number of fish that died between each of these events are incorporated into the accounting. The procedure begins with the oldest age group and works back through time to reconstruct the population (or cohort) at successively younger ages. Calculations are based on the relationship:

$$\text{Recruit}(I) = \text{Remain}(I+1) + [\text{Spawn}(I) + \text{Stray}(I) + \text{Rcatch}(I)] + \text{Ocatch}(I)$$

Where,

Remain(I)	is the number of fish remaining alive in the ocean after fish maturing at age (I) left to spawn
Spawn(I)	is the number of fish at age (I) returning to the hatchery
Stray(I)	is the number of fish at age (I) that spawn in the river or other hatcheries
Rcatch(I)	is the number of fish at age (I) caught in river fisheries
Ocatch(I)	is the number of fish at age (I) caught in ocean fisheries
Recruit(I)	is the number of fish alive at age (I) before harvest begins

These general components of the cohort accounting are diagrammed in Figure E1. Both salmon and steelhead occasionally survive to age 6, so the analysis begins at age 6 by assuming that no fish would remain alive after age 6.

Figure E1. Diagram of general life-history categories accounted for in the cohort

analysis of spring Chinook. In the actual analyses, the life span is extended to 6 years, with separate accounting for males and females.

In building the model, we assumed that ocean harvest starts each spring after any spring Chinook maturing that year have left the ocean to enter freshwater. All natural mortality is assumed to occur in the winter between seasons of ocean fishing. Once the number of recruits at the oldest age is calculated, we assign a natural mortality rate to calculate the number of fish remaining at the next younger age. For the current model we assumed the following natural mortality rates:

$$\text{Survive}(2) = .6$$

$$\text{Survive}(3) = .7$$

$$\text{Survive}(4) = .8$$

$$\text{Survive}(5) = .9$$

These are the over-winter survival rates assumed by the Pacific Salmon Commission (PSC 2001) for Chinook salmon. For modeling purposes, these rates are also assumed for steelhead. After we extend the procedure backwards in time to age 2, we have all of the information necessary to calculate, by age class, survival rate to age 2, maturity rates, river harvest rates and ocean harvest rates.

It was initially thought that this type of Cohort Analysis would be used to estimate the above parameters for all species released into both the Hood River and Deschutes River Basins. However, after constructing and completing the cohort analysis for each species/race in each basin, it became evident that recoveries of CWT marked fish (Appendix A) released into the Hood River Basin were too few to be useful in the cohort analysis model. Recovery of CWT's, even if few in number, can provide important insights to population dynamics and trends in survival. However, when being used in a model (such as cohort analysis), having a large number of recoveries is necessary. Extremely low CWT recovery numbers, while not precluding the cohort model from functioning, strongly affect the confidence and/or accuracy of a given estimate. Therefore, for modeling purposes, if a CWT group showed less than 200 fish surviving to age 2 (after being modeled via cohort analysis), it would be omitted from the final model. These limits are based on the findings of Hankin (1990), which states that sampling rates of such small populations yielded unreliable results.

For the two species (spring Chinook and winter steelhead) receiving CWT's in the Hood River Basin, the vast majority of tag codes showed far fewer than 200 fish surviving to age 2. Specifically, for Hood River spring Chinook, only two CWT groups had more than 200 fish surviving to age 2 (Table E1). For Hood River winter steelhead, none of the CWT groups showed more than 200 fish surviving to age 2 (Table E2). With so few CWT recoveries, confidence in the estimated parameters is very low. As a result, the estimates of harvest rate, survival rate, maturity rate, and stray rate (estimated by cohort analysis) were not used in any further analyses for fish released into the Hood River Basin.

Table E1. Numbers of fish surviving to age 2 (Recruit 2) from the cohort analysis model for Hood River spring Chinook.

Brood Year	Tag Code	Recruit 2
1986	074257	378
1987	074258	75
1988	075223	220
1989	075530	33
1990	075659	46
1991	073335	28
1993	070549	51
1994	071130	18
1995	091747	55
1995	091806	29
1996	092226	3
1997	092555	36
1997	092556	26
1997	092557	5

Table E2. Numbers of fish surviving to age 2 (Recruit 2) from the cohort analysis model for Hood River winter steelhead.

Brood Year	Tag Code	Recruit 2
1993	070536	35
1993	070537	53
1993	070538	30
1993	070539	50
1994	070863	89
1994	070916	78
1994	070917	50
1994	070918	65
1995	071131	31
1995	071132	14

IN THE DESCHUTES RIVER BASIN, LOW CWT RECOVERY NUMBERS WERE NOT A PROBLEM.

Recoveries of CWT marked spring Chinook released into the Deschutes River Basin (Appendix A) were sufficient in number for use in a cohort analysis. A cohort analysis was run on CWT recoveries of Round Butte Hatchery spring Chinook released into the Deschutes Basin. For each recovered tag group (with many tag groups released in a year), an estimate of maturity rate, stray rate, river harvest rate, and survival rate was obtained. Brood year specific estimates of these rates were then obtained by taking the average of the individual estimates from all tag codes in a given brood year.

Survival rate (to age 2 in the ocean) was estimated for each recovered tag group. Brood year specific estimates of survival rate are displayed in Table E3. Survival rates ranged from 0.30% in brood year 1993 to 4.1% in brood year 1986. Maturity rates were also estimated for each recovered tag group. A brood year specific estimate of maturity rate for ages 2-4 spring Chinook is displayed in Table E4. An average of maturity rate, by sex and age class, from brood year 1980- 1996 is displayed in Figure E2.

Stray rates for age 4 Round Butte Hatchery spring Chinook released into the Deschutes Basin were estimated from brood year 1980- 1996 (Table E5). Stray rates ranged from 0% to 13%, and are reported for age 4 fish; as the vast majority of recovered CWT's are from the 4 year old age class. Fresh water (i.e. Columbia and Deschutes Rivers combined) harvest rates for jack (age 3) and adult (age 4) Round Butte Hatchery spring Chinook released into the Deschutes Basin were estimated from brood year 1980- 1996 (Table E6). Harvest rates ranged from 0% to 49% for jacks, and from 0% to 44% for adults. Most of the larger harvest rates were from the earlier brood years (i.e. 1980- 1989). Since the 1990 brood year, however, ocean harvest on both jack and adult spring Chinook has declined sharply.

Table E3. Average brood year specific estimates of survival rates to age 2 in the ocean. Estimates obtained via cohort analysis of Round Butte Hatchery spring Chinook released into the Deschutes Basin. CWT recovery data were incomplete for brood year 1997.

Brood Year	Survival Rate
1980	0.0296
1981	0.0410
1982	0.0313
1983	0.0186
1984	0.0300
1985	0.0393
1986	0.0468
1987	0.0374
1988	0.0395
1989	0.0214
1990	0.0084
1991	0.0109
1992	0.0145
1993	0.0030
1994	0.0031
1995	0.0099
1996	0.0099

Table E4. Average (age-specific, sex-specific, and overall) estimates of maturity rates from brood years 1980- 1996. Estimates obtained via cohort analysis of Round Butte hatchery spring Chinook released into the Deschutes Basin. CWT recovery data were incomplete for brood year 1997.

Brood Yr	Mat 2F	Mat 2M	Mat 2	Mat 3F	Mat 3M	Mat 3	Mat 4F	Mat 4M	Mat 4
1980	0.047	0.001	0.012	0.104	0.527	0.204	0.965	0.926	0.960
1981	0.002	0.000	0.001	0.011	0.272	0.120	0.947	0.944	0.946
1982	0.014	0.000	0.008	0.031	0.497	0.276	0.933	0.931	0.932
1983	0.009	0.000	0.005	0.043	0.589	0.282	0.944	0.906	0.935
1984	0.045	0.001	0.017	0.033	0.535	0.201	0.915	0.894	0.911
1985	0.021	0.001	0.008	0.053	0.320	0.150	0.966	0.966	0.966
1986	0.022	0.001	0.010	0.011	0.517	0.231	0.916	0.921	0.917
1987	0.041	0.000	0.015	0.010	0.259	0.095	0.842	0.867	0.849
1988	0.018	0.001	0.009	0.012	0.316	0.155	0.865	0.865	0.865
1989	0.004	0.000	0.001	0.008	0.182	0.064	0.943	0.948	0.945
1990	0.008	0.000	0.003	0.027	0.407	0.209	0.982	0.918	0.961
1991	0.006	0.000	0.002	0.004	0.163	0.061	0.991	0.987	0.990
1992	0.001	0.000	0.001	0.012	0.335	0.150	0.918	0.889	0.910
1993	0.033	0.001	0.013	0.022	0.298	0.120	0.992	0.992	0.992
1994	0.000	0.000	0.000	0.021	0.169	0.078	1.000	0.991	0.997
1995	0.000	0.000	0.000	0.003	0.132	0.044	0.985	0.988	0.986
1996	0.000	0.000	0.000	0.005	0.270	0.108	0.994	0.994	0.994
Avg	0.016	0.000	0.006	0.024	0.341	0.150	0.947	0.937	0.944

Figure E2. Average maturity rate, by sex and age class, from brood year 1980- 1996 of Round Butte hatchery spring Chinook released into the Deschutes Basin.

Table E5. Average estimates of stray rates from brood years 1980- 1996. Estimates obtained via cohort analysis of Round Butte hatchery spring Chinook released into the Deschutes Basin. CWT recovery data were incomplete for brood year 1997.

Brood Year	Stray Rt (Age 4)
1980	0.0367
1981	0.0293
1982	0.0243
1983	0.1373
1984	0.0453
1985	0.1052
1986	0.0254
1987	0.0303
1988	0.0161
1989	0.0196
1990	0.0000
1991	0.0152
1992	0.0102
1993	0.0000
1994	0.0000
1995	0.0000
1996	0.0000
Avg	0.0291

Table E6. Average estimates of fresh water harvest rate (i.e. Columbia R. & Deschutes R. combined) from brood years 1980- 1996. Estimates obtained via cohort analysis of Round Butte hatchery spring Chinook released into the Deschutes Basin. CWT recovery data were incomplete for brood year 1997.

Brood Year	Jack (Age 3)	Adult (Age 4)
1980	0.4894	0.0223
1981	0.0000	0.4117
1982	0.4841	0.0938
1983	0.1265	0.2474
1984	0.4032	0.4446
1985	0.3298	0.2639
1986	0.3290	0.2502
1987	0.2849	0.3569
1988	0.4234	0.3681
1989	0.4084	0.2931
1990	0.2848	0.0000
1991	0.0000	0.0572
1992	0.0000	0.1918
1993	0.3665	0.0000
1994	0.0000	0.0000
1995	0.0000	0.0159
1996	0.0000	0.1959

As stated previously, even though each model functions correctly, the resulting estimates are only as good as the data input. With such small CWT recovery numbers for releases into the Hood River Basin, confidence in the resulting estimates is quite low. The inability to use the estimated parameters from the Hood River spring Chinook and steelhead cohort models required that new methods of estimating survival rate, harvest rate, maturity rate and stray rate be devised (for releases into each basin). Therefore, new methods were developed which used returns to Powerdale Dam, returns to Pelton Ladder, and CWT recoveries to estimate survival rate, maturity rate, stray rate and harvest rate of marked release groups from each basin.

METHODS

In general, a new model was developed to estimate smolt to adult survival for all marked fish (fin clip and/or CWT) of each species/run released into a given basin that returns to freshwater. For nearly every fish returning to the Powerdale Dam (river mile 4.5 in the mainstem Hood River) an external examination is conducted and scale sample is taken. These procedures provide an identification of the type of fin clip/tag code present as well as the origin (hatchery or wild) and age of the fish. Together, these data allow for determination of brood year and release group for each hatchery fish returning to the Hood River. Once brood year and release group are identified for returning hatchery fish, smolt release data provides the final variable from which to estimate survival rates. Similarly, all fish returning to Pelton Trap (Deschutes River) are counted and identified as either hatchery or wild and as either jack or adult.

An important characteristic of this model is that the estimated survival rate is not based solely on returns to a hatchery or trap, but rather takes into account, and adjusts for, harvest and straying. By accounting for both harvest and straying we obtain a more accurate estimate of overall smolt to adult survival (i.e. survival to freshwater return) than by simply estimating survival from those fish returning to the basin.

From Figure E3, which shows the accounting procedure used by the model to estimate survival rate for spring Chinook released into the Hood River, we can see that returns to Powerdale Dam can be expanded to account for both harvest and straying (derivation of species-specific harvest rates and stray rates used in the model are discussed in following sections). First, raw Powerdale returns are expanded by a harvest rate to obtain the total number of hatchery fish entering the Hood River Basin. Second, the total number of hatchery fish entering the basin is then expanded by a stray rate to obtain an estimate of the total number of hatchery fish returning to freshwater. Finally, a survival rate is estimated by dividing the total number of hatchery fish returning to freshwater by the total number of smolts released. This procedure is done for all uniquely identifiable release groups. A brood year specific estimate of survival is then obtained by taking the average survival from each individual release group within that brood year. All analyses for spring Chinook carry through brood year 1997 and all analyses for both summer and winter steelhead carry through brood year 1998, as these were the last years in which brood year specific estimates of escapement are complete.

Using identical methodology, brood year estimates of survival rate were also estimated for Deschutes River hatchery spring Chinook. For Deschutes River spring Chinook, survival rates were estimated from returns to the Pelton Trap (Round Butte Hatchery). Spring Chinook returning to Pelton Trap were then expanded by brood year specific estimates of harvest rate and stray rate.

Figure E3. Accounting procedure used by the model to estimate smolt to adult survival for all marked fish of each species/run released into the Hood River Basin that returns to freshwater.

RESULTS

Figure E4 shows the results of modeling brood year survival rates for Hood River spring Chinook. It is important to note that the modeling procedure for spring Chinook omits returning mini-jacks (age 2) from the analytical equations. That is, returning mini-jacks are essentially treated as a mortality since they are a highly undesirable product of a hatchery program. From brood year 1991 to brood year 1996, survival rates ranged from 0.0002 to 0.0027. However, in brood year 1997 a significant increase in survival rate (to 0.0111) was seen. This was most likely the result of a shift in ocean productivity from low to high, as returns of salmonids statewide showed marked increases.

Figure E4. Average brood year survival rates for Hood River hatchery spring Chinook. There were no releases of spring Chinook into the Hood River Basin in brood year 1992.

Figure E5 shows the results of modeling brood year survival rates for Deschutes River hatchery spring Chinook. From brood year 1990 to brood year 1996, survival rates ranged from 0.0011 to 0.0050. However, in brood year 1997 a significant increase in survival rate (to 0.0135) was seen. As discussed previously in regard to survival of Hood River spring Chinook, this was most likely the result of a shift in ocean productivity from low to high, as returns of salmonids statewide showed marked increases.

Figure E5. Estimated brood year survival rates for Deschutes River hatchery spring Chinook.

Spring Chinook reared at the Round Butte Hatchery are released into both the Deschutes River and the Hood River Basin. Fish scheduled for release into either location are reared side by side in separate cells under identical conditions. Theoretically, any difference in survival would be attributable to conditions in the release basin, as both stocks would encounter similar physical and environmental conditions once outside of the release basin. Figure E6 shows brood year estimates of survival rate for Round Butte Hatchery spring Chinook from both the Hood River and Deschutes River basins.

Figure E6. Estimated brood year survival rates for both Deschutes River and Hood River hatchery spring Chinook. There were no releases of spring Chinook in brood year 1992 into the Hood River.

Round Butte Hatchery spring Chinook appear to be experiencing higher survival rates when released into the Deschutes River than when released into the Hood River. As mentioned previously, given the similar rearing conditions in the hatchery and assuming similar physical/environmental conditions outside of the release basin (i.e. ocean distribution/conditions), it can be assumed that the difference in survival is directly attributable to either the behavior of the fish in the Hood River, or the Hood River itself. Some caution, however, must be taken if interpreting the results in this way. This is because fish returning to the Pelton Trap, even though identified as either hatchery or wild, are not identified by release basin. That is to say some of the hatchery spring Chinook returning to the Pelton Trap may be hatchery strays from other basins, and not products of Deschutes releases. As such, including those fish with total Pelton Trap returns will inflate the numbers of surviving fish and thus increase the estimated survival rate. The degree to which hatchery spring Chinook stray into the Deschutes Basin is unknown.

For Hood River hatchery summer and winter steelhead, Figures E7 and E8 show the estimated survival rates by brood year. Survival rates for both summer and winter steelhead are significantly higher than for spring Chinook.

Figure E7. Average brood year survival rates for hatchery Hood River summer steelhead.

Figure E8. Average brood year survival rates for hatchery Hood River winter steelhead.

DERIVATION OF MODEL EXPANSION PARAMETERS: HARVEST RATE

Hood River

For Hood River spring Chinook, both sport and commercial harvest in the ocean is limited, due primarily to the difference between annual run timing and the fishing season.

Furthermore, harvest in the Hood River itself (down stream of Powerdale Dam) is also quite limited (personal communication with Erik Olsen, ODFW). Thus, there was no expansion of spring Chinook returning to Powerdale for either ocean harvest or in-river harvest. There is, however, significant harvest of Hood River spring Chinook in the Columbia River downstream of Hood River. With so few CWT recoveries it was not possible to accurately estimate a harvest rate on Hood River spring Chinook specifically. Therefore, a surrogate stock was chosen, which included Hood River spring Chinook, from which to estimate a Columbia River harvest rate. Hood River spring Chinook returning to Powerdale Dam were then expanded by annual estimates of harvest rate in the Columbia River (Table E7).

Table E7. Annual estimates of harvest rate on spring Chinook in the Columbia River. Data specific to Columbia River spring Chinook bound for areas above Bonneville Dam. Data from Pam's: Review of 2001 Ocean Salmon Fisheries, February 2002. Numbers represent thousands of fish. Bolded values are averages from 1995 - 2000.

Run Year	In River Run Size	Lower Col. R.		Mainstem Col. R.		Total Harvest	Harvest Rate
		Comm.	Sport	Comm. Treaty	Treaty Cerem.		
1986	120.6	1.3	1.3	0.4	7.1	10.1	0.0837
1987	100.2	1.2	0.4	0.3	6.4	8.3	0.0828
1988	97.2	5.3	1.4	0.2	6.8	13.7	0.1409
1989	83.4	1.6	0.5	0.1	6.6	8.8	0.1055
1990	99.5	2.2	3.1		6.9	12.2	0.1226
1991	59.9	1	1.5		3.9	6.4	0.1068
1992	90	0.4	1.2		5.7	7.3	0.0811
1993	111.8	0.5	0.4		7.3	8.2	0.0733
1994	21.1	0.5	0.4		1.1	2	0.0948
1995	10.2				0.6	0.6	0.0588
1996	51.5				2.8	2.8	0.0544
1997	114.1				8.3	8.3	0.0727
1998	38.4				2.2	2.2	0.0573
1999	38.7				2	2	0.0517
2000	178.6	0.1	0.1		11.2	11.4	0.0638
2001							0.0598
2002							0.0598

For Hood River summer steelhead, both sport and commercial harvest in the ocean is extremely limited. Thus, there was no expansion of summer steelhead returning to the Powerdale Dam for ocean harvest. There is, however, significant harvest of Hood River summer steelhead in the both the Hood River and the Columbia River. For the Hood River, harvest rates were estimated from angler catch data and Powerdale Dam returns (unpublished data, ODFW) (Table E8). With no Hood River summer steelhead receiving CWT's from which to estimate a stock-specific harvest rate in the Columbia River, a surrogate stock was chosen, which included Hood River summer steelhead, from which an estimate of harvest could be obtained (Table E9). Hood

River summer steelhead returning to Powerdale Dam were then expanded by annual estimates of harvest rate for both the Hood River and the Columbia River.

Table E8. Annual estimates of harvest rate on hatchery summer steelhead in the Hood River.

Run Year	Hatchery Harvest	Hatchery PD Returns	Harvest Rate
1995-1996	38	511	0.0692
1996-1997	727	1296	0.3594
1997-1998	335	564	0.3726
1998-1999	352	524	0.4018
1999-2000	226	460	0.3294
2000-2001	486	1151	0.2969
Avg			0.3049

Table E9. Annual estimates of harvest rate on hatchery summer steelhead in the Columbia River. Data specific to Columbia River Group A summer steelhead bound for areas above Bonneville Dam. Data from ODFW/WDFW Status Report: Columbia River Fish Runs and Fisheries, 1938 - 2000. Bonneville counts include a 2% expansion for lower river sport and commercial catch of wild fish and a 10% expansion for lower river sport and commercial catch of hatchery fish. Harvest rate calculation assumes that only one-half of the zone 6 catch are fish bound for the Deschutes River Basin or below. Numbers represent thousands of fish. Bolded values are averages from 1995 - 2000.

Run Year	Bonneville Dam Counts			Zone 6 Comm Catch			Harvest Rate	
	Wild	Hatchery	Total	Wild	Hatchery	Total	Wild	Hatchery
1985	53.0	255.1	281.5	10.8	42.4	53.2	0.1220	0.1831
1986	57.8	256.6	287.5	7.8	36.0	43.8	0.0875	0.1702
1987	108.9	146.2	238.3	16.8	31.1	47.9	0.0972	0.2063
1988	65.6	121.0	173.2	11.0	27.8	38.8	0.1038	0.2149
1989	58.7	150.7	193.1	9.2	24.8	34.0	0.0984	0.1823
1990	27.7	98.3	115.6	4.3	15.0	19.3	0.0977	0.1763
1991	61.5	193.1	234.1	8.8	25.1	33.9	0.0915	0.1650
1992	45.2	219.1	241.5	7.2	30.8	38.0	0.0996	0.1703
1993	29.3	120.0	136.7	4.4	16.0	20.4	0.0951	0.1667
1994	21.6	110.9	121.0	2.2	10.0	12.2	0.0708	0.1451
1995	26.5	171.1	180.0	2.7	16.0	18.7	0.0709	0.1468
1996	26.2	165.2	174.4	2.3	11.8	14.1	0.0639	0.1357
1997	31.5	197.0	208.2	3.2	17.6	20.8	0.0707	0.1447
1998	35.5	111.0	134.7	3.1	7.1	10.2	0.0636	0.1320
1999	57.8	133.2	176.5	4.3	10.4	14.7	0.0572	0.1390
2000	64.9	170.1	216.7	2.3	7.7	10.0	0.0377	0.1226
2001							0.0607	0.1368
2002							0.0607	0.1368

For Hood River winter steelhead, both sport and commercial harvest in the ocean is extremely limited. Thus, there was no expansion of winter steelhead returning to the Powerdale Dam for ocean harvest. There is, however, significant harvest of Hood River winter steelhead in the Hood River (down stream of Powerdale Dam) and slight harvest in the Columbia River. For the Hood River, harvest rates were estimated from angler catch data and Powerdale Dam returns (unpublished data, ODFW) (Table E10).

Table E10. Annual estimates of harvest rate on hatchery winter steelhead in the Hood River.

Run Year	Hatchery Harvest	Hatchery PD Returns	Harvest Rate
1995-1996	298	259	0.5350
1996-1997	317	613	0.3409
1997-1998	231	363	0.3889
1998-1999	172	303	0.3621
1999-2000	214	290	0.4246
2000-2001	351	897	0.2813
Avg			0.3888

Although many Hood River winter steelhead have been receiving CWT's, recoveries of these fish were again too few to estimate a stock-specific harvest rate in the Columbia River. The modest salmonid fisheries in the Columbia River are not sampled during the winter months, therefore a surrogate stock could not be chosen from which to estimate Columbia River harvest. Thus, based on the U.S. v Oregon Technical Advisory Committee report concerning development of escapement goals for Snake River steelhead (personal communication with Curt Melcher, ODFW), a 2% harvest rate was assumed for Hood River winter steelhead in the Columbia River. Winter steelhead returning to Powerdale Dam were then expanded by annual estimates of harvest rate for both the Hood River and the Columbia River.

DESCHUTES RIVER

For Deschutes River spring Chinook, both sport and commercial harvest in the ocean is limited, due primarily to the difference between annual run timing and the fishing season. Thus, there was no expansion of spring Chinook returning to Pelton Trap for ocean harvest. There is, however, significant harvest of Deschutes River spring Chinook in both the Columbia River downstream of Hood River and in the Hood River itself. As in the Hood River, a surrogate stock was chosen, which includes Deschutes River spring Chinook, from which to estimate a Columbia River harvest rate. Deschutes River spring Chinook returning to Pelton Trap were then expanded by annual estimates of harvest rate in the Columbia River (Table E9).

Harvest of hatchery spring Chinook in the Deschutes River itself is also significant. Brood year specific, in-river harvest rates on hatchery fish were estimated from hatchery returns (to both Warm Springs NFH and Round Butte Hatchery) and total catch (from both sport and tribal fisheries). Deschutes River spring Chinook returning to Pelton Trap were then expanded by annual estimates of harvest rate in the Deschutes River (Table E11).

Table E11. Annual estimates of harvest rate on hatchery spring Chinook in the Deschutes River.

Brood Year	Deschutes R Harv Rt	
	Adults	Jacks
1988	0.409	0.528
1989	0.314	0.376
1990	0.000	0.509
1991	0.043	0.000
1992	0.249	0.000
1993	0.000	0.276
1994	0.060	0.000
1995	0.003	0.000
1996	0.295	0.011
1997	0.243	0.508

DERIVATION OF MODEL EXPANSION PARAMETERS: STRAY RATE

Hood River

Stray rates were estimated from recoveries of CWT-marked fish released into the Hood River Basin. Although recoveries of CWT-marked spring Chinook and winter steelhead are relatively few, they nonetheless provide an important insight into the general distribution of returning Hood River hatchery salmon and steelhead. Using the "fishery" code and "recovery site" code in the RMIS database, all recoveries of each species/run are labeled as either Ocean, Columbia River, Hood River, or Stray. All recoveries in the ocean are labeled as Ocean. All commercial and non-commercial recoveries from the Columbia River (estuary, buoy 10, Youngs Bay, and zones 1 - 6) are labeled as Columbia River. All recoveries from the Hood River, including the sport fishery and returns to Powerdale Dam are labeled as Hood River, and all recoveries from tributaries other than the release tributary (i.e. Hood River) are labeled as Stray. Because hatchery spring Chinook returning to the Hood River Basin are not sacrificed (and CWT's recovered) at a hatchery, but rather are passed above Powerdale Dam to spawn naturally, recovery of these CWT's are rare (only a few are recovered in spawning ground surveys). However, because each CWT marked fish is also fin clipped, it is possible to identify those fish as they pass Powerdale Dam. Although never recovered, these CWT marked fish represent surviving spring Chinook returning to the Hood River Basin and are considered a "recovery" for analysis purposes. By examining the proportion of fish classified as Stray in relation to those classified as Hood River, an estimate of the stray rate can be obtained. Recoveries classified as either Ocean or Columbia River are omitted from the stray rate analysis due to the fact that it is impossible to determine whether or not these fish would stray.

For Spring Chinook, the primary age-class of returning adults is age 4, consequently the vast majority of recovered CWT's come from age 4 fish. Table E12 shows the estimated stray rates from all brood years in which CWT data was available. From these data it is clear that straying of Hood River hatchery spring Chinook is occurring at a significant rate. For modeling survival rates, incorporating an expansion factor for straying would provide a more accurate estimate of overall smolt to adult survival. The expansion factor used in the model was

estimated as the average stray rate from brood years 1993- 1997 (Figure E9). The stray rate expansion factor used for both adult (age 4+) and jack (age 3) spring Chinook returning to Powerdale Dam was 17.76%.

Table E12. Stray rates for age 4 hatchery Hood River spring Chinook estimated from expanded CWT recoveries. Stray rate = Stray/(Hood River +Stray). Recovery of CWT's from brood year 1994 was corrected for stock mixing at Pelton Ladder prior to analysis. There were no releases of spring Chinook into the Hood River Basin in 1992.

Brood Year	Hood R	Stray	Total CWT's	% Stray
1986	16	4.03	20.03	0.2012
1987	5	2	7	0.2857
1988	98	27.49	125.49	0.2191
1989	80	0	80	0.0000
1990	55	8.4	63.4	0.1325
1991	22	3.01	25.01	0.1204
1992				
1993	29.45	7.03	36.48	0.1927
1994	12	7.07	19.07	0.3707
1995	79	26.6	105.6	0.2519
1996	14	1.01	15.01	0.0673
1997	552	3	555	0.0054
Avg (93-97)				0.1776

Figure E9. Stray rates for age 4 Hood River hatchery spring Chinook.

It is important to note that in brood year 1994 there was a mixing of CWT-marked spring Chinook in Pelton Ladder (tag codes 070938 and 071130). When seals broke around rotary screens used to prevent movement among holding cells, fish scheduled for release into the Deschutes River mixed with fish scheduled for release into the Hood River. The result was that a small percentage of CWT-marked Deschutes fish were released into the Hood River and a small percentage of CWT-marked Hood River fish were released into the Deschutes. Prior to estimating stray rates, a correction was made to the RMIS CWT database to account for this mixing.

For tag code 070938, the RMIS CWT database shows that all of the smolts (95,000) were released into the Deschutes River. In reality, due to the mixing of stocks, only 85,000 smolts were actually released into the Deschutes and the remainder (10,000) were actually released into the Hood. Thus, 10.5% of the total release group went into the Hood River. A correction was then made within the RMIS database to the “release location” variable, which changed the release location from Deschutes River to Hood River in 10.5% of the recoveries for this particular tag code.

Similarly, for tag code 071130, the RMIS database shows that all of the smolts (120,653) were released into the Hood River. In reality, due to the mixing of stocks, only 113,371 smolts were actually released into the Hood and the remainder (7,282) were actually released into the Deschutes. Thus, 6% of the total release group went into the Deschutes River. A correction was then made within the RMIS database to the “release location” variable, which changed the release location from Hood River to Deschutes River in 6% of the recoveries for this particular tag code.

Once the database was corrected to account for the mixing of the two CWT groups, stray rates were estimated as described above. It is important to note that the methodology used to correct for the stock mixing assumes equal survival rates between those smolts released into the Hood River and those released into the Deschutes River.

For both winter and summer Hood River hatchery steelhead, straying is considered to occur at a very small rate (personal communication with Erik Olsen, ODFW). Analysis of CWT data for Hood River hatchery winter steelhead support this assumption. Table E13 shows that, for years in which CWT recovery data exist, Hood River hatchery winter steelhead stray at a rate less than 1%. Thus, there was no expansion of either summer or winter steelhead returning to the Powerdale Dam for straying.

Table E13. Stray rates for adult hatchery Hood River winter steelhead estimated from expanded CWT recoveries. Stray rate = Stray/(Powerdale+RiverSport+Stray).

Brood Year	CWT Recovery Classification			Total	Stray Rate
	Powerdale	River Sport	Stray		
1993	7	75		82	0.0000
1994	65	79	1	145	0.0069
1995	43	19		62	0.0000

Deschutes River

Using identical methodology as for Hood River spring Chinook, brood year estimates of stray rate were also estimated for age 4 Deschutes River hatchery (Round Butte) spring Chinook. For Deschutes River spring Chinook, stray rates were extremely low (Table E8, Figure E10). A 2% straying rate was assumed as an expansion factor for Deschutes River spring Chinook.

Table E8. Stray rates for age 4 hatchery (Round Butte) Hood River spring Chinook estimated from expanded CWT recoveries. Stray rate = Stray/(Pelton+RiverSport+Stray). Recovery of CWT's from brood year 1994 was corrected for stock mixing at Pelton Ladder prior to analysis

Brood Year	CWT Recovery Classification			Total	Stray Rate
	Pelton	River Sport	Stray		
1980	207.0		4.8	211.8	0.0226
1981	953.0	678.7	30.4	1662.2	0.0183
1982	1034.0	62.4	24.6	1121.0	0.0220
1983	756.0	262.5	81.4	1099.9	0.0740
1984	486.0	389.5	16.9	892.4	0.0189
1985	805.0	303.2	62.5	1170.7	0.0534
1986	893.0	306.6	11.3	1210.9	0.0093
1987	659.0	393.7	18.2	1070.9	0.0170
1988	718.0	361.8	8.1	1087.9	0.0075
1989	534.0	224.6	8.4	767.0	0.0109
1990	229.0			229.0	0.0000
1991	615.0		8.6	623.6	0.0138
1992	627.0	148.0	4.0	779.0	0.0051
1993	181.8			181.8	0.0000
1994	239.0			239.0	0.0000
1995	886.7			886.7	0.0000
1996	346.4	79.0		425.4	0.0000
1997	5.0			5.0	0.0000

Figure E10. Estimated stray rates for returning Age 4 Round Butte Hatchery spring Chinook released into the Deschutes River. No stray CWT's were recovered in 1990 and from 1993-1997.

As stated previously, Round Butte Hatchery spring Chinook are released into both the Hood River and the Deschutes River. Examining years in which recovery of CWT marked Hood River spring Chinook were sufficient, we can see that straying rates for those fish released into the Deschutes River are much lower than for those fish released into the Hood River (Figure E11).

Figure 11. Estimated stray rates for Round Butte Hatchery spring Chinook released into both the Hood River and the Deschutes River.

ADDITIONAL ANALYSES

The analysis of survival rates for Hood River spring Chinook revealed some other important findings. Figure E12 shows both the number of Hood River spring Chinook returning to Hood River (from Powerdale Dam returns) and the number of Hood River spring Chinook returning to freshwater (from the model). A clear discrepancy can be seen between the two numbers, as far fewer Hood River spring Chinook actually return to the Hood River, than survive to return to freshwater. CWT recovery data suggest that these fish do not suffer mortality in the Columbia River, but rather stray to other basins. Together these data suggest that the Hood River Basin is experiencing a significant loss of biomass of hatchery spring Chinook. That is, Hood River hatchery spring Chinook appear to be surviving at a much greater rate than they are returning to the Hood River Basin, and that this may be due to significant straying of both adults and jacks.

Figure E12. Numbers of returning adult and jack spring Chinook to both freshwater and the Hood River Basin.

Another important finding from the analysis of survival rates is that the proportion of returning hatchery spring Chinook comprised of mini-jacks (age 2 fish) has increased dramatically in recent brood years (Figure E13). From brood year 1991 to brood year 1994, the mean percentage of mini-jacks from all spring Chinook returning to the Hood River Basin was 4.41%. From brood year 1995 to brood year 1997 that percentage increased sharply to a mean of 22.35%. A theory regarding the presence of mini-jacks from a hatchery brood is that the reared smolts are being released at a size in excess of what is optimal to reduce or eliminate the occurrence of mini-jacks. An examination of smolt release data showed that from brood year 1991 to brood year 1994 the average size at release was 11.05 fish/lb and that from brood year

1995 to brood year 1997 the average size at release was 8.31 fish/lb (Figure E13). This increase in average release size, while not statistically significant ($p=0.13$ from a t-test comparing means), may suggest that as the average release size of smolts increases, so does the tendency for those smolts to remain in freshwater and return to the basin as mini-jacks.

Figure E13. Average size of smolts released into the Hood River Basin and the corresponding proportion of mini-jacks in that brood.

In other analyses, raw CWT release/recovery data and/or Powerdale Dam return data were used to estimate the survival rates of specific release groups (i.e. # of returns/recoveries divided by # released = survival rate). These estimated survival rates were then used to compare hatchery practices such as release time and release location. Analyses such as these were limited in number, however, due to the fact that the CWT and fin-clip marking methodology was not originally designed for such analyses. That is, in most brood years individually marked groups were split into two or more release groups and subsequently released at various times and locations, thus prohibiting analysis of these hatchery practices. A comprehensive CWT marking strategy could provide the opportunity to evaluate the success of various hatchery practices, such as: size at release, release location, rearing diet, rearing pond, etc.

For Hood River hatchery spring Chinook, a comparison of survival rates between release times showed that for each brood year in which a comparison was possible, the early release group exhibited a higher survival rate than did the late release group. Figure E14 shows the estimated survival of spring Chinook for each release group in each brood year.

Figure E14. Comparison of survival rates for spring Chinook released at two separate times. Numbers above each bar show the release date and the number of smolts released (in thousands).

Similarly, for Hood River hatchery winter steelhead, a comparison of survival rates between release times showed that for the one brood year in which a comparison was possible (1995), the early release group exhibited a higher survival rate than did the late release group. Figure E15 shows the estimated survival for each release group in the 1995 brood year. No such comparison was possible for Hood River hatchery summer steelhead.

Figure E15. Comparison of survival rates for winter steelhead released at two separate times. Numbers inside each bar show the release date and the number of smolts released (in thousands).

For Hood River hatchery spring Chinook, a comparison of survival rate between release locations was possible only in brood year 1997. In this brood year survival appears to be greater for smolts released into the Middle Fork and lower for smolts released into the West Fork. Figure E16 shows the estimated survival rates for each release location in brood year 1997. No such comparison was possible for either Hood River hatchery summer or winter steelhead.

Figure E16. Comparison of survival rates for spring Chinook released at two separate locations. Numbers inside each bar show the release date(s) and the number of smolts released (in thousands).

EXTENDED ANALYSIS OF STRAYING IN HOOD RIVER HATCHERY SPRING CHINOOK

The analysis of straying was taken further in an attempt to discover the actual distribution of stray Hood River hatchery spring Chinook. By examining the recovery location of those fish classified as stray, it was possible to see which basins were consistently attracting the strays from the Hood River. Figure E17 shows the average relative distribution of stray Hood River hatchery spring Chinook from brood years 1994- 1997. These data clearly show that Hood River hatchery spring Chinook display an affinity to home to the Deschutes River.

Figure E17. Distribution of stray Hood River hatchery spring Chinook. Values represent the average relative distribution of strays from brood years 1994- 1997.

Beginning in brood year 1991, Deschutes broodstock spring Chinook were being reared in the Round Butte Hatchery on the Deschutes River for subsequent release into the Hood River. In 1991 a limited number of smolts (28,760) were released into the Hood River and 1992 no smolts were released. It was not until brood year 1993 that a significant number (170,004) of Deschutes broodstock spring Chinook were released into the Hood River. It was at this time that straying of Hood River spring Chinook into the Deschutes increased dramatically (Figure E18). From these data it is apparent that straying of Hood River spring Chinook into the Deschutes has increased from brood year 1993 to present. Intuitively, this is what one might expect to see given the fact that the spring Chinook being released into the Hood River Basin are not only of wild Deschutes River spring Chinook origin, but are also reared to smolt stage in Deschutes River water. Recent efforts to acclimate reared smolts in Hood River water prior to volitional release may alleviate some of the straying.

Figure E18. Straying of hood River hatchery spring Chinook to the Deschutes River Basin.

TEMPERATURE REGIMES IN MAJOR SPAWNING TRIBUTARIES

Temperature has a pervasive influence on spring Chinook salmon, and temperature can influence all aspects of their life. Following is a lists of the more important physiological and ecological processes directly affected by temperature (Spence et al. 1996).

- I. Decomposition rate of organic materials;
- II. Metabolism of aquatic organisms;
- III. Food requirements, appetite, and digestion rates;
- IV. Growth rates;
- V. Developmental rates of embryos and alevins;
- VI. Timing of life-history events including adult migration, spawning, fry emergence, and smoltification;
- VII. Competitor and predator-prey interactions;
- VIII. Disease-host and parasite-host relationships; and
- IX. Development rate and life history of their food.

Slight modification of the temperature regime, natural or man-caused, can alter the processes listed above.

The West Fork Hood River, where most spring Chinook spawn in the Hood River subbasin, has harsh environmental conditions at the time when eggs are developing. Water temperature vary from 0°C to the low teens and anchor ice forms on gravel which then breaks loose causing movement of gravel, rock and shore-line vegetation. Rains may wash silt into the stream, and the silt fills gravel inter-spaces resulting in reduced water flow over the eggs.

During development of the Hood River Production Program, consideration was given to genetic and life history traits for the re-introduction of spring Chinook. The Deschutes hatchery stock at Round Butte Hatchery was selected because that stock was available and near the Hood River. The Deschutes hatchery spring Chinook stock presently shows no special survival traits under extreme natural environmental condition during the embryo and fry emergence period.

Temperature, as pointed out above, is one of the primary parameters affecting spawning timing, embryos and sac fry development. To demonstrate the influence of temperature, we compare natural temperature regimes for principal spawning habitat in the Warm Springs River, one of the primary spring Chinook spawning habitat in the Deschutes subbasin, and the West Fork Hood River (Figure E19).

Figure E19. 7-day average temperature profiles for both the West Fork Hood River (Hood River Basin) and the Warm Springs River (Deschutes River Basin). Daily values for the West Fork Hood River are average daily values from 1994-2001. Daily values for the Warm Springs River are average daily values from 1999-2002.

Figure E19 shows the 7-day average temperature profile for both the West Fork Hood River (from 1994-2001) and the Warm Springs River (from 1999-2002). Temperature data for the West Fork Hood River was obtained from a single Hobo temperature recorder located at river mile 8 at the 1600-foot elevation level. This location within the West Fork Hood River is ideally situated just upstream from reaches with the greatest density of observed redds (Lambert et. al. 2001). Similarly, temperature data for the Warm Springs River was obtained from a single Hobo temperature recorder located at the 2500-foot elevation level. This location within the Warm Springs River is ideally situated in the reach with the greatest density of observed redds (personal communication with Bob Spateholts, CTWSRO).

Within the spawning reaches of the two basins, both the West Fork Hood River and the Warm Springs River appear to have, on average, a similar annual temperature profile. The Warm Springs River appears to run warmer in the spring, summer, and winter months (March- July). However, during the late-summer and fall months (August- November) the West Fork Hood River runs slightly warmer. Also, the Warm Springs River appears to begin cooling approximately one month prior to cooling in the West Fork Hood River. This early cooling is most likely explained by the difference in elevation between the temperature recorders in each basin. Once cooling begins, however, the West Fork Hood River cools more rapidly than does the Warm Springs River. Glacial influence in the West Fork Hood River may explain the cooler spring/summer temperatures as well as the more rapid cooling during the fall/winter.

Besides having an influence on spawn timing, water temperature in the spawning reach and around the redd itself can effect egg development, time to hatching, and time to fry emergence (Piper et al. 1982). Several methods have been devised for determining the incubation period for salmon eggs. One method utilizes daily temperature units (DTU's). One DTU equals 1 degree F above freezing (32°F) for a 24-hour period. Piper et al. (1982) reported that, on average, Chinook salmon eggs require 450 DTU's to develop into eyed embryos, 750 DTU's to hatch, and 1,600 DTU's to emerge from the gravel as free feeding fry. Temperature units required for a given species of fish are not fixed and can vary depending on the date of fertilization and subsequent water temperatures, oxygen level, and flow. However, DTU's can be used as a guide to estimate the hatching date of a group of eggs at a specific temperature.

Figure E20 above displays the average cumulative DTU's effecting eggs in both the West Fork Hood River and the Warm Springs River from September through March. For the West Fork Hood River, accumulation of DTU's was initiated on September 10. For the Warm Springs River, accumulation of DTU's was initiated on September 1. These dates were selected because it is the approximate peak spawning period in each basin. As noted above, the West Fork Hood River and the Warm Springs River have, on average, a similar temperature profile. Based on cumulative DTU's, the difference in timing of egg development between the two systems appears to be relatively small for eggs reaching both the eyed stage and the hatching stage. However, there appears to be a larger difference in time to emergence between the two systems, with emergence taking place in the Warm Springs River approximately 2 weeks earlier than in the West Fork Hood River. The date of emergence and the associated date of spawning maybe critical to survival. While a wide range in timing of emergence maybe critical to the species survival mechanism, endemic species demonstrate a more narrow window for spawn timing. We also suspect that survival of fry varies greatly year-to-year, and the natural extended period of fry emergence is an adaptation for survival in a variable environment.

Figure E20. Cumulative Daily Temperature Units (DTU's) from primary spawning reaches within both the West Fork Hood River and the Warm Springs River. Markers represent key DTU levels for the development of Chinook eggs (Piper et al. 1982).

SPAWN TIMING

The major spring Chinook spawning tributary in the Hood River Basin is the West Fork Hood River. Spawn timing in the West Fork Hood River was estimated from annual ground-level spawning surveys conducted by the Confederated Tribes of the Warm Springs Indian Reservation. During these surveys, counts of visible redds were made during August through October from 1997- 2002. Results of these surveys show that spawning in the West Fork Hood River begins about mid August and lasts through October. Most spawning appears to take place in the month of September, with peak spawning around the middle of September (Figure E21).

For the Deschutes River Basin, the major spring Chinook spawning tributary is the Warm Springs River. A similar time series of spawning ground survey data does not exist for the Warm Springs River. Rather, surveys are conducted on 35.3 km of stream once a year during the peak of spawning. Spawning in the Warm Springs River begins approximately the last week in August, peaks by the second week in September, and is usually completed by the end of September (Witty 1999, Olsen et. al. 1995). From figure CC it can be seen that the peak spawning time of wild spring Chinook in both the Warm Springs River and the West Fork Hood River is very similar, that is early September in the Deschutes River and mid September in the Hood River.

Figure E21. Average timing of all wild spring Chinook redd observations in the West Fork Hood River during ground-level spawning surveys conducted from mid August through October, 1997-2002, by the Confederated Tribes of the Warm Springs Indian Reservation. The circled dates represent the average peak spawn period of wild spring Chinook in the Warm Springs River.

TEMPERATURE INDUCED EGG MORTALITY

Average daily temperatures in the West Fork, Middle Fork, and East Fork of the Hood River were examined to determine if temperature could be a source of mortality for spring Chinook eggs. Published studies on the thermal tolerances of salmon eggs show that mortality of freshly spawned Chinook eggs begins when temperatures drop to 4°C. However, tolerance to cold temperatures appears to increase substantially by the time the eggs reach the eyeing stage (Beacham and Murray 1990). Therefore, spawning of Chinook must occur sufficiently early to enable egg development to a stage that can tolerate water temperatures below 4-5°C. This is a key factor that limits how late in the fall spring Chinook in the Hood River Basin can spawn and be successful. On the other hand, fish must spawn sufficiently late in the year so that water temperatures have dropped below the upper tolerance limits of freshly spawned eggs (approximately 14°C; Beacham and Murray 1990). Generally, spawning time for local stocks of spring Chinook coincides with the earliest week for which there is low chance of sustained temperatures above 12°C (pers. comm. with Steve Cramer, SP Cramer & Ass.).

Average daily temperatures in each of the three forks were examined from September 10 (estimated peak spawning) through the eyed egg stage (400 DTU's) to determine the frequency of temperatures at which Chinook eggs suffer mortality ($<5^{\circ}\text{C}$ and $>14^{\circ}\text{C}$). Results showed that in none of the forks did daily average temperatures fall below or rise above the thermal tolerance limits for Chinook eggs through the eyed stage. Therefore, in no fork is low-end or high-end thermal tolerance a source of mortality on spring Chinook eggs. Figure E22 displays the frequency of temperatures encountered in each fork of the Hood River from September 10 (estimated peak spawning) through fry emergence (1600 DTU's). Although the frequency of low-end temperatures in each fork is significant, these temperatures are not encountered until after the eggs have eyed up, and the thermal tolerance of the organism has increased.

Figure E22. Frequency of average daily temperatures in the West, Middle, and East Forks of the Hood River.

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Appendix Table A. Expanded CWT recoveries by assigned cohort. Raw data from the Regional Mark Information System (RMIS; www.rmis.org/index.html) maintained by the Pacific States Marine Fisheries Commission (PSMFC). Brood year 1997 data for Deschutes Spring Chinook is incomplete.

Basin	Species	Run	Brood Year	Tag Code	Expanded CWT Recoveries by Assigned Cohort					
					Hatch/Trap	Col R Net	Ocean	River Sport	Stray	Total
Hood	Chinook	Spring	1986	074257		103.42	16.48	4	14.69	138.59
Hood	Chinook	Spring	1987	074258		21.81	5.46		2	29.27
Hood	Chinook	Spring	1988	075223		44.84		6	27.49	78.33
Hood	Chinook	Spring	1989	075530		12.81		1		13.81
Hood	Chinook	Spring	1990	075659		3.35	4.63	0	8.4	16.38
Hood	Chinook	Spring	1991	073335		3.35		1	6.36	10.71
Hood	Chinook	Spring	1993	070549	13			2	3.03	18.03
Hood	Chinook	Spring	1994	070938					5.05	5.05
Hood	Chinook	Spring	1994	071130		1.66		1	4.22	6.88
Hood	Chinook	Spring	1995	091747	6.06				13.47	19.53
Hood	Chinook	Spring	1995	091806	5.05				5.04	10.09
Hood	Chinook	Spring	1996	092226	1.01					1.01
Hood	Chinook	Spring	1997	092555	1.01				16.02	17.03
Hood	Chinook	Spring	1997	092556					13.05	13.05
Hood	Chinook	Spring	1997	092557					3	3
Hood	Steelhead	Winter	1993	070536		3.26		15		18.26
Hood	Steelhead	Winter	1993	070537	4	5.16		15		24.16
Hood	Steelhead	Winter	1993	070538				16		16
Hood	Steelhead	Winter	1993	070539	3	1.63		21		25.63
Hood	Steelhead	Winter	1994	070863	13	1.14		32		46.14
Hood	Steelhead	Winter	1994	070916	18	1.14		21		40.14
Hood	Steelhead	Winter	1994	070917	7	5.7		14		26.7
Hood	Steelhead	Winter	1994	070918	12	1.14	9	12	1	35.14
Hood	Steelhead	Winter	1995	071131	1	5.35		11		17.35
Hood	Steelhead	Winter	1995	071132	1	2		7		10
Deschutes	Chinook	Spring	1975	090406	28.56				1	29.56
Deschutes	Chinook	Spring	1975	090407	7.02					7.02
Deschutes	Chinook	Spring	1976	091601	2.34		21.36			23.7
Deschutes	Chinook	Spring	1976	091603			27.12			27.12
Deschutes	Chinook	Spring	1976	091604	2.34					2.34

Basin	Species	Run	Brood Year	Tag Code	Expanded CWT Recoveries by Assigned Cohort					
					Hatch/Trap	Col R Net	Ocean	River Sport	Stray	Total
Deschutes	Chinook	Spring	1977	071611	2.22					2.22
Deschutes	Chinook	Spring	1977	071612	1.11		2.45	1		4.56
Deschutes	Chinook	Spring	1977	071615	1.11			1		2.11
Deschutes	Chinook	Spring	1977	071653	72.48			6		78.48
Deschutes	Chinook	Spring	1977	071654	107.88	4.95	6.94	6		125.77
Deschutes	Chinook	Spring	1977	071655	110.46	3.14		16	2.1	131.7
Deschutes	Chinook	Spring	1978	071824	6.14		2.27			8.41
Deschutes	Chinook	Spring	1978	071949	79.11	3.3		15.6		98.01
Deschutes	Chinook	Spring	1978	071950	197.21	4.99	19.67	35		256.87
Deschutes	Chinook	Spring	1978	071951	85.18	2.5		16.7	3.34	107.72
Deschutes	Chinook	Spring	1979	072153	6.16			1.5		7.66
Deschutes	Chinook	Spring	1979	072309	214.17	13.45	14.62	105.5	17.64	365.38
Deschutes	Chinook	Spring	1979	072310	80.01	9.38		60.6		149.99
Deschutes	Chinook	Spring	1979	072311	365.12	8.13	37.68	133	2.94	546.87
Deschutes	Chinook	Spring	1980	072347	11.09		3.05			14.14
Deschutes	Chinook	Spring	1980	072348	229.39	18.45		50.19	4.78	302.81
Deschutes	Chinook	Spring	1980	072349	6.01					6.01
Deschutes	Chinook	Spring	1980	072350	14.05			16.1		30.15
Deschutes	Chinook	Spring	1981	072520	11		5.3			16.3
Deschutes	Chinook	Spring	1981	072714	128	13.11		71.8	3.36	216.27
Deschutes	Chinook	Spring	1981	072715	144	13.03	11.1	89.75		257.88
Deschutes	Chinook	Spring	1981	072716	648	123.65	14.89	344.77	18.72	1150.03
Deschutes	Chinook	Spring	1981	072717	359	46.16	6.53	172.32	11.7	595.71
Deschutes	Chinook	Spring	1982	072836	19		7			26
Deschutes	Chinook	Spring	1982	072837	9			14.36		23.36
Deschutes	Chinook	Spring	1982	072839	72	3.36		22.95		98.31
Deschutes	Chinook	Spring	1982	072840	38			17.95		55.95
Deschutes	Chinook	Spring	1982	072841	657	53.24	26.3	222.42	20.1	979.06
Deschutes	Chinook	Spring	1982	072842	536	42.66	43.24	131.37	6.72	759.99
Deschutes	Chinook	Spring	1982	072843	34		1.05	9.38		44.43
Deschutes	Chinook	Spring	1983	073128	320	17.73	8.64	87.18	18.84	452.39
Deschutes	Chinook	Spring	1983	073129	252	39.53	17.52	79.09	32.81	420.95
Deschutes	Chinook	Spring	1983	073130	369	47.67	9.11	131.9	33.22	590.9
Deschutes	Chinook	Spring	1983	073131	144	27.48	8.64	39.8	7.21	227.13
Deschutes	Chinook	Spring	1983	073132	179	32.53	12.39	30.09	6.63	260.64

Basin	Species	Run	Brood Year	Tag Code	Expanded CWT Recoveries by Assigned Cohort					
					Hatch/Trap	Col R Net	Ocean	River Sport	Stray	Total
Deschutes	Chinook	Spring	1984	073320	352	84.4		295.9	10.04	742.34
Deschutes	Chinook	Spring	1984	073321	403	76.29	26.7	263.7	22.46	792.15
Deschutes	Chinook	Spring	1985	073928	429	45.22	14.45	200	35.8	724.47
Deschutes	Chinook	Spring	1985	073929	599	81.33	35.98	243.7	34.81	994.82
Deschutes	Chinook	Spring	1986	074461	465	24.3	20.97	226.85	11.31	748.43
Deschutes	Chinook	Spring	1986	074462	837	81.17	76.91	341.45	7.51	1344.04
Deschutes	Chinook	Spring	1987	074622	214	12.93	5.46	148.4	18.24	399.03
Deschutes	Chinook	Spring	1987	074623	191	17.7	3.25	113		324.95
Deschutes	Chinook	Spring	1987	074624	190	27.71	11.71	71.4		300.82
Deschutes	Chinook	Spring	1987	074625	161	28.62	3.61	71.2		264.43
Deschutes	Chinook	Spring	1987	074626	126	21.8	56.03	91.6		295.43
Deschutes	Chinook	Spring	1988	075058	289.1	51.1	21.84	131.1	6.76	499.9
Deschutes	Chinook	Spring	1988	075059	208	48.77	10.92	102.2		369.89
Deschutes	Chinook	Spring	1988	075060	223.1	36.59	10.92	130.4	5.92	406.93
Deschutes	Chinook	Spring	1988	075061	106.2	21.65		94.9		222.75
Deschutes	Chinook	Spring	1988	075062	148.3	29.4	32.84	80.5	2.21	293.25
Deschutes	Chinook	Spring	1989	075361	152	17.49	5.29	103.4		278.18
Deschutes	Chinook	Spring	1989	075362	153	23.32	4.63	44.6	4.66	230.21
Deschutes	Chinook	Spring	1989	075363	127	12.32	4.13	43.3	4.72	191.47
Deschutes	Chinook	Spring	1989	075401	106	11.52	5.29	48.5		171.31
Deschutes	Chinook	Spring	1989	075402	67	12.85		20.6		100.45
Deschutes	Chinook	Spring	1990	075645	54			2.5	15.84	72.34
Deschutes	Chinook	Spring	1990	075646	62	2	4.63	8.9		77.53
Deschutes	Chinook	Spring	1990	075647	44			2.2		46.2
Deschutes	Chinook	Spring	1990	075648	49			4.5		53.5
Deschutes	Chinook	Spring	1990	075649	63	2		4.7		69.7
Deschutes	Chinook	Spring	1991	075008	156	12.7		1	8.63	178.33
Deschutes	Chinook	Spring	1991	075938	53	1				54
Deschutes	Chinook	Spring	1991	075939	48	5				53
Deschutes	Chinook	Spring	1991	075940	56	3			1.01	60.01
Deschutes	Chinook	Spring	1991	075947	113	10.35				123.35
Deschutes	Chinook	Spring	1991	075948	122	8.35				130.35
Deschutes	Chinook	Spring	1991	075949	130	6.35				136.35
Deschutes	Chinook	Spring	1992	070227	236.06	16.63	1.62	44	2	300.31
Deschutes	Chinook	Spring	1992	070228	327.1	5		58	1	391.1

Basin	Species	Run	Brood Year	Tag Code	Expanded CWT Recoveries by Assigned Cohort					
					Hatch/Trap	Col R Net	Ocean	River Sport	Stray	Total
Deschutes	Chinook	Spring	1992	070229	327.05	15.01		46	2	390.06
Deschutes	Chinook	Spring	1992	070230	2					2
Deschutes	Chinook	Spring	1993	070526	71.23			6		77.23
Deschutes	Chinook	Spring	1993	070527	50.22			1		51.22
Deschutes	Chinook	Spring	1993	070528	66.27		1.87	9		77.14
Deschutes	Chinook	Spring	1993	070529	23.06			2		25.06
Deschutes	Chinook	Spring	1994	070933	59.52					59.52
Deschutes	Chinook	Spring	1994	070934	80.74					80.74
Deschutes	Chinook	Spring	1994	070935	68.61					68.61
Deschutes	Chinook	Spring	1994	070936	9.08					9.08
Deschutes	Chinook	Spring	1994	070937	6.05					6.05
Deschutes	Chinook	Spring	1994	070938	45.09					45.09
Deschutes	Chinook	Spring	1994	071130	1.01					1.01
Deschutes	Chinook	Spring	1995	091741	215.81	1.04				216.85
Deschutes	Chinook	Spring	1995	091742	118.15	4.16				122.31
Deschutes	Chinook	Spring	1995	091743	67.65	1.33		1		69.98
Deschutes	Chinook	Spring	1995	091744	70.7	3.71				74.41
Deschutes	Chinook	Spring	1995	091745	120.19	1.04		1		122.23
Deschutes	Chinook	Spring	1995	091746	351.47	6.85	2.87			361.19
Deschutes	Chinook	Spring	1996	092220	101	5.12	3.03	15		124.15
Deschutes	Chinook	Spring	1996	092221	53.53	2.06		10		65.59
Deschutes	Chinook	Spring	1996	092222	32.32	2		7		41.32
Deschutes	Chinook	Spring	1996	092223	68.67	8.36		15		92.03
Deschutes	Chinook	Spring	1996	092224	136.33	11.36		28		175.69
Deschutes	Chinook	Spring	1996	092225	26.26			1		27.26
Deschutes	Chinook	Spring	1997	092551	44.41	2		30		76.41
Deschutes	Chinook	Spring	1997	092552	30.29	2	5.02	23		60.31
Deschutes	Chinook	Spring	1997	092553	45.45	4.12		29		78.57
Deschutes	Chinook	Spring	1997	092554	39.38	1.06		24		64.44

APPENDIX F. OUTMIGRANT DATA REVIEW

A thorough review of the outmigrant studies was conducted in order to explore the accuracy and precision of the study. The review centered on the winter steelhead program due to the duration and quality of the data collected. The screw trap was a complex sampling scheme that provided important fish behavior and survival data. A review of the screw trap data is interjected here to improve the readers understanding of the juvenile fish data.

Outmigrants were sampled with screw traps placed in the East Fork (RM 1.0), West Fork (RM 4.0) and Mainstem (RM 4.5) beginning in 1994 and in the Middle Fork beginning in 1995. The screw traps were operated from April through October. Captured fish were marked with PanJet Injector, which delivered a colored dye into the epidermal layer of the fish's fin. The fin and dye color were changed every two weeks. Marked fish were released above the screw trap to estimate trap efficiency. In spite of changes in dye color every two weeks, captives of these fish were pooled to estimate an average trap efficiency for the entire year. Pooling of data was chosen because the number of recaptures was low. Thus, catches in the traps are expanded to estimates of total outmigration using a single estimate of trap efficiency each year (Olsen et al. 1995). Steelhead/rainbow smolts were identified based on a fork length greater than 150mm during April through July and a fork length greater than 100mm from August through October. Spring Chinook smolts were identified by fork length greater than 70mm (Olsen et al. 1995).

Our initial review of the screw trap program led us to hypothesize that the outmigrant estimates were inaccurate, because trap efficiency was estimated as a single value for the year. Trap efficiency (percentage of marked fish recovered) is assumed to describe the percent of the natural population captured by the trap. Changes in stream flow or turbidity generally alter trap efficiency. At high flows, trap efficiency is generally reduced as the cross-sectional area of the stream sampled is reduced. Efficiency can also drop at low flows when velocity into the trap becomes so slow that fish swim back out the throat of the trap. Recoveries of biweekly test groups (of marked fish) showed indications that efficiency varied weekly, although sample sizes were small (Figure F1).

Figure F1. The average number of marked summer and winter steelhead released to test trap efficiency in comparison to the average percent recovered at the mainstem screw trap, 1993-2001 (Olsen July 2002).

Outmigrant estimates derived from annual and biweekly efficiencies were compared to the actual number of hatchery fish released. Results showed that use of biweekly trap efficiencies did not improve the annual estimate of outmigrant abundance. Estimates were judged to be accurate if the estimated number of hatchery smolts passing the trap was similar to the number released. Figure F2 compares outmigrant estimates derived from either annual or biweekly trap efficiencies to the number of winter steelhead smolts released. During 1998-2001, the annual estimate of efficiency resulted in outmigrant estimates that represented 86% of smolts released, while the estimates derived from biweekly efficiencies averaged 100% of fish released. Although the 100% value may sound like a better match at face value, it would only be true if there were no mortality or residualism of smolts between their release sites and Powerdale Dam. However, smolts do experience post release mortality and residualism, and we later show that an 80% post-release survival provides a better fit to the data than does a 100% survival. Therefore, the 86% average survival to the mainstem trap (based on annual efficiency) appeared to be more accurate than the 100% average survival to the mainstem trap (based on biweekly efficiency). Furthermore, the estimates using annual efficiency were less variable between years. The standard deviation of the 1994-2001 annual estimates was 52% as apposed to a standard deviation of 90% for the sum of biweekly estimates.

Biweekly outmigrant estimates were then compared to biweekly average flow measured at Tucker Bridge by the USGS (Figure F3). The regression analysis indicated there was a relationship, but it was weak ($r^2 = 0.258$). A similar analysis was conducted using summer

steelhead hatchery smolts and stream flow, and it produced a similar result. The weak correlation of trap efficiency to stream flow indicated that other factors, such as small sample size or variable turbidity, may have played a larger role in causing variation in the outmigrant estimates. Small sample size was clearly a problem when trap efficiencies dropped below about 2%. At those low efficiencies, few marked fish were available to test efficiency (less than 20) and tests often resulted in zero recaptures (Figure F4).

Figure F2. Percent difference between number of hatchery winter steelhead smolts released as compared to the estimated number of smolts migrating past the mainstem trap for annual and biweekly derived trap efficiencies.

Figure F3. Mainstem trap efficiency of hatchery winter steelhead smolts 1994-2001 regressed against biweekly average stream flow at Tucker Bridge (USGS Station 14120000).

Figure F4. Relationship of the percentage of marked hatchery steelhead smolts recovered in the trap to the number of marked fish released. Marked fish to test efficiency were obtained from captures in the trap, so the result was generally low numbers marked when efficiency was low.

Even though the annual estimate of trap efficiency appeared to be more accurate than the biweekly estimate, we further examined reliability of annual estimates. Because the limited number of recaptured fish left us room for questioning the strength of the outmigrant estimates. To test the accuracy of the screw trap data, the number of hatchery winter steelhead released was compared to the outmigrant estimate at the mainstem trap (Figure F5 and Table F1). From 1994-1997, the numbers of hatchery winter steelhead smolts were overestimated, ranging from 120% to 177% of actual releases. The estimates from 1998 to 2001 were underestimated, ranging from 57% to 91% of actual releases. Post-release mortality should result in fewer fish reaching the trap than were released.

Figure F5. Estimated number of winter steelhead hatchery smolts migrating past the Mainstem Screw Trap compared to the number of hatchery smolts released in the East Fork (Olsen July 2002).

Table F1. Steelhead screw trap data used to investigate the accuracy and precision of annual smolt estimates (Olsen July 2002).

Summer Steelhead							
Year	Capture	Mark	Recapture	Percent of Marked Recaptured	Estimate Number of Hatchery Smolts	Actual Number of Hatch Smolts Released	Estimate as % of Release
1994	1,369	1,110	41	3.7%	37,063	90,042	41%
1995	1,450	1,100	19	1.7%	83,947	76,330	110%
1996	2,077	1,083	42	3.9%	53,557	68,378	78%
1997	1,592	788	24	3.0%	52,271	60,993	86%
1998	5	4					
1999	735	660	38	5.8%	12,766	15,616	82%
2000	1,333	1,012	55	5.4%	24,527	29,161	84%
2001	296	243	7	2.9%	10,275	28,837	36%
Winter Steelhead							
1994	437	430	15	3.5%	12,527	38,034	33%
1995	497	459	3	0.7%	76,041	42,860	177%
1996	2,428	1,155	52	4.5%	53,930	44,909	120%
1997	2,634	1,157	29	2.5%	105,088	59,837	176%
1998	2,060	1,769	71	4.0%	51,326	61,217	84%
1999	1,762	1,371	62	4.5%	38,963	42,675	91%
2000	2,693	1,358	72	5.3%	50,793	60,403	84%
2001	683	551	13	2.4%	28,949	50,623	57%

The magnitude by which the passage estimate deviated from the total number released (estimate minus release, expressed as a positive value) showed a tendency to be less as the estimated trap efficiency increased. That is, the estimates of fish passage tended to be more similar to actual releases when the capture efficiency was higher (Figure F6). We would expect this relationship to be true based on sampling theory (deviation increases with smaller sample size). This relationship was then used to examine whether including an assumed residualism rate (or mortality) would increase the fit of the regression. Results showed that the fit of the regression improved (higher r^2) when post-release mortality was assumed to be 80% (Figure F6).

Figure F6. Deviation of smolt passage estimate from the actual number released for summer and winter steelhead smolts. Passage estimated for hatchery fish at the mainstem screw trap using annual trap efficiency. Percent of marks recovered is for test fish used to estimate trap efficiency (Olsen July 2002).

Based on the r^2 value, the assumption that 80% of fish released migrate past the mainstem trap appeared to be more accurate than assuming all fish (100%) migrate past the trap. The analysis shown in Figure 7 indicated that precision of the smolt outmigrant estimate was dependant on the recovery rate ($r^2 = 0.54$), with low recovery rates (1-3%) resulting in highly variable estimates. Recovery rates of approximately 4.5% or greater significantly improved the precision of the smolt estimates to within $\pm 4,500$ smolts (approximately 13% of the number released).

Further analyses were conducted to determine whether there was a difference in trap efficiency between hatchery and wild smolts. No significant difference was found. Figure F7 depicts the trap efficiency by fish origin and size class. Trap efficiencies for each two week period were arcsine-square root transformed and compared using a one-way ANOVA. Results showed a significant difference ($P = 0.0011$) in trap efficiency between size classes. The difference among size classes was then tested with the Fisher's PLSD test, which showed significant differences between fish greater than 150 mm and less than 100mm ($P = 0.0043$), between fish greater than 100 mm and fish greater than 150 mm ($P = 0.0028$), and between fish greater than 150 mm and fish less than 150mm ($P = 0.0141$). There was no significant difference between fish greater than 150mm and hatchery smolts ($P = 0.2106$).

Figure F7. Trap efficiency estimate, by size class (mm of fork length) of summer and winter steelhead for all traps (West Fork, Middle, and East Forks and Mainstem) and years (1994-2001). Error bars represent one standard deviation. Greater or less than 150 mm size classes were used from March through July, and fish reported in these size classes were assumed to be wild. All hatchery steelhead were recorded in the hatchery smolt class (Olsen July 2002).

The similarity of trap efficiency between wild and hatchery spring migrants indicated that precision of abundance estimates for wild smolts greater than 150mm would parallel that for hatchery fish. The trap efficiency of wild smolts ($> 150\text{mm}$) at the mainstem trap fell below 4.5% in 1994, 1995 and 2001, so precision of the estimate was low in those years. In 1996-2000, the mainstem trap efficiency was above 4.5%, suggesting adequate precision of the estimate in these years. Figure F8 indicates that outmigration estimates were probably within 15% of the actual number.

Trap efficiencies were estimated assuming that 100% of the test fish survived to the trap, and that vulnerability of test fish to the trap was the same as that for all other steelhead. Erik Olsen (2003, personal communication) indicated that he believed the over estimates in 1994-1997 were due to poor survival of hatchery fish. This may be true, since the trap efficiency at the mainstem appears to be higher for wild fish than for hatchery fish in corresponding years (Figure F8 and Table F2). The survival of marked fish may have had a notable influence on estimates of trap efficiency. ODFW has not reported studies examining the post-release survival of marked and released fish. Olsen chose to use trap efficiencies estimated from wild fish and not hatchery fish in 1994-97, because the survival of hatchery fish and spring Chinook appeared to be low. Furthermore, Olsen et al (1996) observed weak and moribund hatchery fish in the trap. If there was a significant mortality of marked fish before they reached the trap, then the number of outmigrants would have been overestimated.

Figure F8. Annual trap efficiency at the mainstem screw trap for wild steelhead greater than 150 mm.

The effect of post-release mortality of marked fish on the estimates of smolt passage is portrayed in the following example. In the first scenario, post release survival is 100%, and 5 of 100 marked fish released were recaptured. The resulting trap efficiency would have been 5%. Therefore, if 100 unmarked fish were captured in the trap, then the estimated number of total outmigrants would have been 2000 fish (Table F2). In contrast, the second scenario assumes 60% of the marked and released fish survived, resulting in 3 fish recaptured. The resulting trap efficiency would have been 3%. Therefore, if 100 unmarked fish were captured, the estimated number of total outmigrants would have been 3,333 fish. The 60% survival translates into an estimated number of smolts that is 1.67 times higher than actual. Post release survival of test fish most likely had an effect on the 1994-1997 estimates, but its effect on more recent estimates is less likely. Screw trap operators have changed marking and release protocols in recent years to improve survival, including measures such as dissolved oxygen in the holding tanks (Erik Olsen, personal communication, ODFW).

Table F2. Example of affect marked fish survival has on outmigrant estimates.

	100% Survival	60% Survival
Marked-Released	100	100
Recaptured	5	3
Trap Efficiency	0.05	0.03
Unmarked	100	100
Estimated Outmigrants	2,000	3,333

Up to this point, spring Chinook have not been included in the screw trap discussion. Spring Chinook smolt estimates have not been reported by HRPP participants, because they were believed to be unreliable. We used raw screw trap data provided by Olsen (July 2002) to estimate the number of hatchery Chinook outmigrants (Table F3). The average difference between the estimated number of outmigrants and actual smolts released was 138%, with a standard deviation of 97%. The 1998 estimate was not included in the average, because no fish were marked. Three out of 5 years of data resulted in overestimates, ranging from 129% to 282% of actual releases. The remaining two years (1997 and 2001) were underestimates (71% and 33% respectively). Erik Olsen (personal communication, ODFW) indicated that trapped hatchery spring Chinook smolts appeared to be weak and probably experienced high mortality after being subjected to handling stress associated with mark and release activities. This circumstance would cause an over-estimate as previously shown. The calculations summarized here confirm that emigration of Chinook smolts could not be estimated reliably with the available sample data.

Table F3. Comparison of the number of hatchery Spring Chinook smolts released to the estimated passage at the mainstem screw trap, 1996 - 2001.

Year	1996	1997	1998	1999	2000	2001	Mean
No. Captured	10,635	3,020	11,374	11,148	8,185	2,422	7,797
No. Marked	363	166	0	1,963	142	2,784	903
No. Recaptured	17	7	0	140	3	171	56
Percent Recaptured	4.68%	4.22%	-	7.13%	2.11%	6.14%	4.86%
Estimated No. Hatchery Smolts	227,089	71,617	-	156,311	387,423	39,432	176,374
Actual No. Hatchery Smolts	129,211	101,093	124,783	121,419	137,411	121,263	122,530
Difference (Est. -Act.)	97,878	-29,476	-	34,892	250,012	-81,831	54,295
Percent Difference	176%	71%	-	129%	282%	33%	138%

APPENDIX G. CATTLE EXCLOSURE REVIEW

Introduction

We reviewed seven grazing exclosures installed and maintained by the Confederated Tribes of the Warm Springs Reservation (CTWSR) in the Hood River watershed. Nine exclosures were installed from 1996-2001 (Table G1), and inspection of seven of these exclosures was conducted on March 27, 2003. Chuck Gehling of the CTWSR facilitated the inspections. Two exclosures, Baldwin Creek #1 and #2, were not inspected because access was not secured from the landowners. The seven remaining exclosures were walked and photographed throughout their extent, and two exclosures (Neal Creek #2 and Shelly Creek) were chosen for synoptic channel measurements. The objectives of the inspections were: (1) to observe the locations, settings, and physical conditions of the exclosures and stream channels, and (2) to record channel measurements. Information gathered during the inspections provides a rudimentary baseline from which to compare the CTWSR exclosures to more intensively studied exclosures in the region. In addition, channel measurements and photographic information provide the potential for monitoring and quantifying changes in the channel and riparian areas over time. Results of the inspections are meant to inform whether and to what degree exclosures in the Hood River watershed are likely to result in restorative geomorphic adjustment of the stream channel and improved water quality.

Neal Creek Exclosures

Neal Creek is tributary to Hood River at river mile 5.5. It is approximately 7.5 meters wide and one meter deep at bankfull discharge in the observed reach. Three grazing exclosures, numbered chronologically by the date they were installed, were inspected on Neal Creek. Neal Creek #1 (upstream) and #3 (downstream) are adjacent to one another, but separated by Fir Mountain Road; Neal Creek #2 is downstream of #3, and separated from them by a railroad grade that spans Neal Creek.

Neal #1 and #3 were walked and visually inspected. Neal Creek #2 was walked and photographed, and two cross-sectional profiles were surveyed. One section was located immediately upstream of the exclosure and the other was immediately adjacent to it. These sections were located with a GPS unit and surveyed using a Jacob's staff, hand level, and stadia rod. Locations of the cross-sections were monumented by affixing a small aluminum tab to well-established trees. These trees mark the end members of the cross-sections. Zero elevation is marked by the level of the ground immediately adjacent to the tree with the monument tag.

All exclosures on Neal Creek were in satisfactory condition, and the abundance and health of riparian vegetation within the exclosures were generally greater than outside of exclosure. Factors that could limit the performance of the exclosures were: (1) Neal Creek adjacent to exclosures #1 and #3 is incised, thereby limiting direct interaction with riparian vegetation, (2) there is a rip-rap revetment at the upstream end of exclosures #1 and #2 that prevents bank erosion and limits channel adjustment within these exclosures, and (3) there was a fallen tree on the fence near the mid-point of exclosure #1 that if not removed may compromise

the enclosure of cattle from the adjacent riparian area. Photographs of the three Neal Creek enclosures can be seen in Figures G1-G3.

Shelley Creek Enclosure

Shelley Creek is a small perennial stream that flows into Neal Creek approximately 0.5 miles north of the intersection of Fir Mountain Road and Route 35. Cross-section P was located with a GPS unit and surveyed near the terminus of the enclosure with a Jacob's staff, hand level, and stadia rod. Zero elevation is marked by the level of the ground adjacent to the tree monumented with an aluminum tab stamped "P". Results are considered accurate to approximately +/- 0.1 vertical feet. A photograph of the Shelley Creek enclosure can be seen in Figure G4.

This enclosure was found to be in satisfactory condition on the day of inspection. It is worthwhile to note that the Shelley Creek with the enclosure is not the same as the Shelley Creek noted on the Hood River 7.5 Minute Digital Raster Graphic (DRG; digital topographic sheet). It is possible that these streams were confused during the naming of the enclosure or that the labeling on topographic sheet does not correspond to naming convention adopted by local residents.

Lenz Creek Enclosure

Lenz Creek is an intermittent stream that flows into Neal Creek immediately upstream of the Neal #2 enclosure. This enclosure prevents the stream channel near the Lenz Creek-Neal Creek confluence. Lenz Creek is lined with young vegetation and is geomorphically active, showing evidence of active bank erosion within the enclosure. This enclosure was found to be in satisfactory condition; no channel measurements were recorded. A photograph of this enclosure can be seen in Figure 5.

Baldwin Creek Enclosures

Baldwin Creek is a perennial stream that flows into the East Fork of the Hood River at river mile 2. There are three enclosures on Baldwin Creek. These enclosures are numbered in the order they were installed. Only Baldwin Creek #3 was inspected. Baldwin Creek #1 was not inspected because access could not be secured from the land owner; however, the enclosure was photographed from the road adjacent to the property and its general conditions were viewed with binoculars from a distance of approximately 100 meters. Baldwin Creek #2 protects an area of vegetated riparian wetlands; it was viewed from the adjacent road, but not inspected due to time limitations.

Baldwin Creek #1 is the longest grazing enclosure in the Hood River watershed. It lines approximately 650 meters of Baldwin Creek. Sheep were observed grazing within the enclosure on the day of the visit. The area grazed by the sheep appeared to be relatively bare in comparison to adjacent areas within and outside of the enclosure, suggesting that it is a chronic condition. Other portions of the Baldwin Creek #1 enclosure appear to be located exceedingly close to the edge of the stream bank, which may undercut the enclosure if not relocated. It is

estimated that as much as 30-40% of the enclosure is not in a properly functioning condition, and that another 10-20% may be subject to failure if streambank continues to erode in the upstream portion of the site.

The Baldwin Creek #2 and #3 enclosures appeared to be in satisfactory shape. Baldwin Creek #3 protects a thin riparian buffer of hardwood trees and shrubby plants. A “push-up” levee at the upstream end of the enclosure was installed to prevent the channel from eroding into the enclosed pasture. Standing water connected to Baldwin Creek was observed within this pasture, indicating that pollution outside of the enclosure could be mobilized into Baldwin Creek; however, no livestock were in the pasture during the day of the visit. A photograph of Baldwin Creek #3 can be seen in Figure 6.

Tieman Creek Enclosure

Tieman Creek is an intermittent stream that flows into to the East Fork Hood River. The enclosure on Tieman Creek protects a small area of mature mixed forest adjacent to the stream channel. In many places within the enclosure the channel is densely covered by shrubby vegetation and large fallen trees. The riparian area within the enclosure appears to have suffered less clearing and disturbance than any of the other enclosure sites.

The enclosure in Tieman Creek was found to be in satisfactory condition. The lower portion of the enclosure, however, may be vulnerable to catastrophic flooding. Chuck Gehling noted during the site visit that floodwater breached the East Fork Irrigation District (EFID) Canal, perched immediately above Tieman Creek at the enclosure site, and flowed directly into Tieman Creek during the regional flood of 1996. On the day of the inspection, the channel that was eroded as a result of this event remained intact and now serves as a hillslope water conduit. Future events similar to the flood of 1996 could damage the enclosure and delete protected riparian vegetation within the enclosure. Further investigation of the hazard posed to Tieman Creek by the location of the EFID canal is needed before corrective action can be recommended. A photograph of the Tieman Creek enclosure can be seen in Figure 7.

Synthesis and Evaluation

Widespread portions of intermountain streams in the western U.S. are adversely affected by cattle grazing. Direct impacts of cattle grazing include browsing, removal, and alteration of riparian vegetation (Kauffman, 1983), trampling of streambanks (Trimble, 1995), and increased nutrient loading (Moyer et al., 1998). Indirect effects include increased sediment flux to stream channels (Trimble, 1993). A comprehensive review of the impacts of cattle grazing on stream channels and riparian areas is offered by Kauffman and Krueger, 1984. The installation of grazing enclosures, which eliminate livestock grazing in the riparian zone, is a common technique for the restoration of stream channels adversely affected by cattle grazing, and recent studies have focused specifically on the geomorphic response of stream channels to the elimination of cattle grazing (McGilligan and McDowell, 1997; McDowell and Mowry, 2003; Mowry, 2003).

Although variability in the responses of streams to grazing exclosures makes it difficult to extrapolate changes observed at reference sites to grazing exclosures in the Hood River watershed, similarities in gradient and channel dimensions between channels studied by McDowell and Mowry (2003) and those observed in the Hood River watershed can be used to make general predictions about whether and to what degree exclosures in the Hood River watershed will respond to grazing exclosures. Data gathered during inspection of grazing exclosures in the Hood River watershed indicates that at least one exclosure site surveyed by McDowell and Mowry (2003) (Chesnimnus Creek in the Wallowa Whitman National Forest) is similar in gradient and channel dimensions to exclosure sites in Lenz, Shelley, and Baldwin Creeks of the Hood River watershed. The stream reach within the grazing exclosure of Chesnimnus Creek was significantly narrower, and had greater percent area in pools and lower bankfull width-to-depth ratios than grazed reference reaches approximately 14 years after exclosure installation. Evidence in the form of field measurements indicate that exclosure sites in Shelley, Lenz, and Baldwin Creeks would be expected to behave similarly over time.

Neal and Tieman Creeks are separated from other streams with exclosures for the purposes of comparative analysis. Neal Creek has a much larger drainage area and carries several times more flow than other exclosed streams in the Hood River watershed, and is locally incised. Tieman Creek has a higher gradient and has experience far less clearing of woody vegetation than any of the other than the other streams.

McDowell and Mowry (2003) cite inadequate bank vegetation, sediment supply, and stream competence; channel incision; placement of bank hardening structures within the exclosure; and the effects of grazing history as factors that may limit the geomorphic impacts of grazing exclosures. Mowry (2003) identified that one of the most important geomorphic processes affecting exclosure performance was deposition of fine-grained sediment during over bank flows. Neal Creek adjacent to the #1 and #3 exclosures is incised and disconnected from its floodplain; other streams in the watershed with exclosures are lower order channels that appear to have more connection with their floodplains and riparian areas. As a result of channel incision, geomorphic adjustments in Neal Creek, particularly in those reaches adjacent to exclosures #1 and #3, may be limited because of lack of interaction between the channel and newly established riparian vegetation. Geomorphic adjustments may also be limited by the construction of bank-hardening and bank-heightening structures within the exclosures is likely to limit channel adjustment within the exclosure.

Geomorphic adjustment of the channel within the Tieman Creek exclosure is likely to be most influenced by site history. Because it experienced far less clearing of woody vegetation, the stream was not as affected as other grazed streams in the area; therefore the exclosure would not likely be as significant of a factor influencing stream geomorphology as would the similarity in existing and pre-existing riparian conditions.

Despite these potential limitations on the geomorphic effectiveness of exclosures, it is likely that all exclosed stream channels would have experienced immediate improvements in water quality when livestock were excluded from direct contact with the stream channel and riparian area. Factors that may limit the effectiveness of grazing exclosures to sustain improvements in stream-water quality livestock grazing within the exclosure (Baldwin #1),

unchannelized flow connected to the stream outside of the enclosure (Baldwin #3), and excessive encroachment of the enclosure on stream banks (Baldwin #1 and #3).

It is difficult to quantify precisely what role these enclosures play in affecting channel geomorphology and improving instream salmonid habitat, but it is clear that improvements in water quality resulting from these grazing enclosures *per se* are sufficient to warrant their maintenance and monitoring. In addressing future opportunities to install additional grazing enclosures in the Hood River watershed, managers should seek to site enclosures in channels with a relatively low degree of incision and to avoid or minimize the adverse effects of the factors that limit enclosure effectiveness identified by McDowell and Mowry (2003).

Table G1. Names and descriptions of grazing exclosures installed in the Hood River Basin since 1996 by the CTWSRO.

Exclosure Name	Date Completed*	Approximate stream length fenced* (m)	Active Channel* (m)		Wetted Channel* (m)		Estimated stream gradient**	Vegetation within exclosure*
			Width	Depth	Width	Depth		
Neal Creek 1	Sep-96	402	5.80	0.40	5.20	0.45	0.017	Mix of alders, large conifers and grasses. Seedling Pines
Neal Creek 2	Nov-98	298	6.70	0.40	4.60	0.42	0.017	Mix of alders and grasses. After fencing project, conifers planted
Neal Creek 3	Oct-98	545	6.30	0.40	4.90	0.43	0.17	Mix of alders, large pines, and grasses. Bundles of willow planted and staked hardwoods. After fencing project, pines and firs planted in exclosure
Lenz Creek	Nov-99	247	4.50	0.40	2.30	0.50	0.015	Mix of hardwoods, brush, grasses, and some large conifers. After fencing project, conifers planted in exclosure
Shelly Creek	Sep-02	396	5.00	3.00	0.30	0.20	0.022	Young to mature hardwoods, brush (blackberries), and grazed grasses
Baldwin Creek 1	Jul-00	653	3.50	0.40	3.40	0.27	0.013	Young hardwoods and grasses. After fencing project, cedars, firs and pines were planted in exclosure
Baldwin Creek 2	Nov-01	247	2.80	0.37	2.10	0.30	0.013	Mix of alders, willows, and grasses.
Baldwin Creek 3	Oct-02	101	2.80	0.37	2.10	0.30	0.015	Mature hardwood, brush, and grasses
Tieman Creek	Nov-00	457	1.60	0.20	1.40	0.15	0.04	Mixture of small and large hardwoods with firs.

* = reported by CTWSR

** = measured from USGS topographic map

Figure G1. Neal Creek enclosure number 1 looking upstream. Note young conifers within the enclosure and downed wood within the active channel.

Figure G2. Neal Creek enclosure number 2 looking upstream. Note the difference in vegetation inside and outside the enclosure.

Figure G3. Neal Creek enclosure number 3.

Figure G4. Riparian area within the Shelley Creek enclosure looking upstream.

Figure G5. Lenz Creek enclosure looking downstream.

Figure G6. Baldwin Creek enclosure number 3. Note the presence of wood and undercut banks.

Figure G7. Tieman Creek enclosure near the mid-point of the enclosure. Stream flow is left to right. Note the difference in vegetation inside and outside of the enclosure.

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APPENDIX H. RELATIVE REPRODUCTIVE SUCCESS OF HATCHERY AND WILD STEELHEAD IN THE HOOD RIVER

Final report on work conducted under

BPA Intergovernmental Contract 9245, Project # 1988-053-12

and

ODFW Interagency agreement No. 001-2007s

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OVERVIEW

Motivation for the project

There is a considerable interest in using hatcheries to speed the recovery of wild populations. The Bonneville Power Administration (BPA), under the authority of the Northwest Power Planning Act, is currently funding several hatchery programs in the Columbia Basin as off-site mitigation for impacts to salmon and steelhead caused by the Columbia River federal hydropower system. One such project is located on the Hood River, an Oregon tributary of the Columbia. These hatchery programs cost the region millions of dollars. However, whether such programs actually improve the status of wild fish remains untested. The goal of this project was to evaluate the effectiveness of the Hood River hatchery program as required by the Northwest Power Planning Council Fish and Wildlife Program, by the Oregon Plan for Coastal Salmonids, by NMFS ESA Section 4(d) rulings, and by the Oregon Department of Fish and Wildlife (ODFW) Wild Fish Management Policy (OAR 635-07-525 through 529) and the ODFW Hatchery Fish Gene Resource Management Policy (OAR 635-07-540 through 541).

This work was funded by the Bonneville Power Administration through BPA Intergovernmental Contract 9245 (Project # 1988-053-12), and through ODFW Interagency agreement No. 001-2007s.

Brief summary of project and results

The Hood River supports two populations of steelhead, a summer run and a winter run. They spawn only above the Powerdale Dam, which is a complete barrier to all salmonids. Since 1991 every adult passed above the dam has been measured, cataloged and sampled for scales. Therefore, we have a DNA sample from every adult steelhead that went over the dam to potentially spawn in the Hood River from 1991 to the present. Similar numbers of hatchery and wild fish have been passed above the dam during the last decade. During the 1990's "old" domesticated hatchery stocks of each run (multiple generations in the hatchery, out-of-basin origin; hereafter H_{old}) were phased out, and conservation hatchery programs were started for the purpose of supplementing the two wild populations (hereafter "new" hatchery stocks, H_{new}). These samples gave us the

unprecedented ability to estimate, via microsatellite-based pedigree analysis, the relative total reproductive success (adult-to-adult production) of hatchery (H_{old} or H_{new}) and wild (W) fish for two populations, over multiple brood years. Our analyses of samples from fish that bred in the early to mid 1990's show that fish of "old" hatchery stocks have much lower total fitness than wild fish (17% to 54% of wild fitness), but that "new" stocks have fitness that is similar to that of wild fish (ranging from 85% to 108% of wild fitness, depending on parental gender and run year). Therefore, our results show that the decision to phase out the old, out-of-basin stocks and replace them with new, conservation hatchery stocks was well founded. We also conclude that the H_{new} fish are leaving behind substantial numbers of wild-born offspring. The similar fitnesses of H_{new} and W fish suggests that wild-born offspring of H_{new} fish are unlikely to have negative genetic effects on the population when they in turn spawn in the wild. We will test this hypothesis once enough F2 offspring have returned. Another interesting result is that we were unable to match a large fraction of the unclipped, returning fish with parents from their brood year. Furthermore, we were missing more fathers than mothers. Because we sampled almost every possible anadromous parent, these results suggest that non-anadromous trout or precocious parr may be obtaining a substantial number of matings. Substantial reproduction by precocious parr could be one unintended consequence of the hatchery program.

Personnel and project Coordination:

The genetics pedigree work was carried out at Oregon State University by Drs. M. Blouin and W. Ardren (formerly a postdoc in Dr. Blouin's laboratory, now at the USFWS Abernathy Fish Genetics lab). This project was coordinated with the Hood River steelhead hatchery and research project, funded by Bonneville Power Administration and administered and implemented by the Oregon Department of Fish and Wildlife (Rod French and Erik Olsen, supervisor and database manager). The project was also coordinated with Dr. Thomas E. Morse, Bonneville Power Administration (BPA), Fish and Wildlife Division, and with Kathryn Kostow, ODFW.

INTRODUCTION

Using hatcheries to enhance wild populations

Hatchery supplementation is the use of captive propagation to increase the size of an endangered wild population (also known as supportive breeding or as a conservation hatchery program; Ryman et al., 1995). The concept is to take part of a small wild population into captivity, protect their offspring through the high-mortality early life stages, and then allow them to spawn naturally when they return as adults. The return of their offspring should increase the size of the wild population. Whether such supplementation programs actually work (increase the size of wild populations) is not clear (Waples 1999). While we may observe that a wild population's size increases or decreases after hatchery adults were allowed to spawn in the same stream, we have not been able to determine which fish among the spawners actually produced returning adults. It is possible that the hatchery fish are making little contribution to the next generation, or even worse, are dragging down the fitness of the wild population for genetic or ecological reasons (Waples 1991; 1999; Fleming and Petersson, 2001; Lynch and O'Hely, 2001). On the other hand, the hatchery fish may indeed be leaving behind offspring that return to breed successfully and contribute to the next generation. Until now we have had no way of determining which of these scenarios is true.

Background on the Hood River basin and stocks

The Hood River supports wild runs of winter and summer steelhead. Breeding areas for winter and summer fish are segregated, with summer fish breeding in the West Fork of the Hood River and winter fish breeding in the remaining tributaries (Fig. H1). The Powerdale Dam at mile 4.0 on the river is a complete barrier to migrating salmon. Facilities include an adult trap and sorter built by BPA. The trap is used for all broodstock collection, for monitoring hatchery and wild adults, and for controlling entry of hatchery fish into natural production areas (a photo of the dam and of the inside of the fish handling facility can be seen at http://oregonstate.edu/~blouinm/Hood%20RiverProject_files/slide0001.htm). This facility provides the unique opportunity to handle the entire population of returning adults every year. Since 1991 every adult passed over the dam has been catalogued, measured

and sampled for scales. Traps for sampling juveniles have been in place in the mainstem and at the outlets of all the main tributaries since the mid 1990s. The dam is scheduled to be removed in 2010, although the actual date has not yet been determined. The dam is being kept in place until that time in order to facilitate several ongoing research projects in the basin, including this one.

Winter run

Winter run hatchery stock 13 (a domesticated, out-of-basin, multi-generation hatchery stock from Big Creek) was previously stocked in the basin but was phased out in 1991. It was replaced by conservation hatchery stock 50, which uses wild Hood River broodstock each generation and was implemented for the purposes of supplementing the wild winter population. The first generation of stock 50 adults began returning in appreciable numbers in 1995 (Fig. H2). Since then the number of H_{new} fish passed above the dam has been limited to no more than the number of wild fish passed (Table H1). This protocol created an ideal opportunity to evaluate the relative reproductive success of each type of fish spawning in the wild.

Summer run

Summer run hatchery stock 24 (a domesticated, out-of-basin, multigeneration hatchery stock from Skamania) was phased out in 1998 and replaced by summer conservation hatchery stock 50 in 1998. The protocols for this summer-run supplementation program are the same as for the winter run program. Skamania stock 24 are still planted below the dam to provide a sports fishery, but none are allowed above the dam.

Here we use the abbreviation H_{old} to refer to “old” hatchery stocks 24 and 13, and H_{new} to refer to the “new” conservation hatchery winter stock 50 and summer stock 50. Run years begin in the fall and breeding occurs in the spring and summer of the following year. Thus, for example, parents of run year 1991-1992 produce offspring whose brood year (date of birth) is 1992. For simplicity’s sake we will, for example, refer to 91 as the parental run year and offspring birth year.

Figure H1. Study site. Powerdale dam is a complete barrier to salmonids at mile 4.0. Summer steelhead breed in the West Fork, while winter steelhead breed in the Middle Fork, East Fork, and Neal Creek. Juvenile traps are located just above the dam and at the base of each of the main branches within the system.

Table H1. Summary of numbers of wild (unclipped) and hatchery (clipped) fish passed above Powerdale Dam. These counts do not include fish taken for broodstock, which we also genotyped. Run year refers to the fall season (e.g. the 91-92 run year fish began arriving fall of 1991 and continued arriving into 1992). In 1992 the H_{old} stock 13 program was phased out for winter run, and the winter run conservation hatchery program was begun. Those H_{new} winter stock 50 fish began returning to spawn in the wild in 94-95. The old summer stock 24 program was phased out and the new summer run conservation hatchery program was begun in 1998. Those H_{new} summer fish began returning in 01-02. Highlighted cells have been genotyped. The rest will be typed as part of the work proposed here. The key parental years for which we have preliminary comparisons of hatchery and wild parental fitness are highlighted in bold. For example, to compare the fitness of the 212 W and 161 H_{new} winter fish that went upstream in the 95-96 run year, we matched them against all *unclipped* winter fish that returned in 1998 to 2001 and whose scale ages indicated they were born in 1996 (i.e. from the 95-96 run year parents; see also Fig. 2) (We did not genotype the H fish from 98-01 for current analyses because they can't be the offspring of fish that bred in wild).

WINTER RUN

run year	wild fish passed	hatchery fish passed: H_{old} stock 13	hatchery fish passed: H_{new} stock 50
91-92	632	273	
92-	350	5	
93-	304	2	
94-	160	0	6
95-	212	0	161
96-	242	0	249
97-	184	0	162
98-	258	0	186
99-	875	0	222
00-	883	0	657
01-	954	0	682

SUMMER RUN

run year	wild fish passed	hatchery fish passed: H_{old} stock 24	hatchery fish passed: H_{new} stock 50
92-93	489	1722	
93-	243	1105	
94-	218	1635	
95-	132	520	
96-	182	1312	
97-	65	447	
98-	100	4	
99-	148	0	
00-	179	0	
01-	415	0	127
02- (03 to date)	540	0	492

Figure H2. Example of when offspring of each winter run parental breeding year are expected to return. Circles represent run years (e.g. 92-93 means the fish that returned in fall of 1992 through winter of 1993, and spawned in 1993. For simplicity, we will say spawning took place and their offspring were born in 92). Lines and numbers represent the percentage of babies born in a given breeding year that will return in each of the subsequent years. For example, 6% of the offspring born in the wild in 96 are expected to return to Powerdale Dam as unmarked adults in year 98, 61% are expected to return in year 99, and so on (the timing of return of hatchery fish is different from that of wild fish). Solid lines represent hatchery fish, dotted lines represent fish born in the wild. These numbers are based on age distributions of wild adults returning to Powerdale dam. Descendents of the first generation of winter run conservation hatchery stock 50 fish are illustrated as an example. Those hatchery fish spawned in nature mostly in years 95 and 96. Their F1 offspring are almost all returned by 01, and > 90% of F2's born in 99 and 00 are back by 05. The study proposed here involves genotyping samples collected through the 08-09 run year in order to insure a large sample of F2's from several F1 breeding years.

Specific questions asked

Adult offspring returning to the dam in the late 1990's and early 2000's were matched back their parents that were sampled in previous years (Fig. H2, Table H1; dates of birth from scale aging). From these data we asked the following questions.

(1) What is the mean and year-to-year variance in relative reproductive success (adult to adult production) of conservation hatchery-origin (H_{new}) and wild-origin (W) fish that spawned naturally in the Hood River?

The relative rate of adult-to-adult production by H_{new} and W fish is the key unknown parameter needed for predicting the demographic effects of hatchery supplementation on wild populations. Here we measured the parameter ($H_{new}:W$ fitness) for each of three years of winter fish (run years 95, 96, and 97; Table H1).

(2) Are “new” hatchery stocks closer in fitness to wild fish than “old” hatchery stocks?

Theory and substantial circumstantial evidence suggest that “old” hatchery stocks will have substantially lower total fitness than “new” hatchery stocks in the wild (Lynch and O’Hely, 2001; Fleming and Petersson, 2001). However, there has never been a direct test of this hypothesis, nor are there any empirical data on how much better the “new” stocks should perform. Here we compared the $H_{new}:W$ relative fitnesses with that of $H_{old}:W$. For winter run we have one run year of H_{old} vs. W (91), and for summer run we have data on two years (95 and 96) (Table H1).

Methods*(1) Sampling:*

All handling of fish, phenotypic data collection, and sampling of scales and fin snips was done at the Powerdale Dam by ODFW staff. All fish approaching the dam were shunted into a trap and lifted into a building built specifically for the purpose of handling these fish. After being measured and sampled, each fish was either recycled downstream (e.g. extra hatchery fish), taken as broodstock or put above the dam to continue on to the spawning grounds. Sampling and database management protocols have been in place

since project inception. Thus, we have an extensive database on the size, run timing, age and freshwater residency (from scales), gender, fin clip and disposition (i.e. taken for broodstock, recycled, etc...) of every fish for which we also have pedigree data. We successfully genotyped between 97% and 99% of the steelhead collected for broodstock or passed over the dam each year. Therefore, we have an almost complete sample of all potential anadromous spawners from each run year.

(2) Molecular Methods:

We used a standard chelex protocol to extract DNA from fin snips or scales. Note that we obtain high quality DNA template from the scale samples, even those from the early 1990's. All extractions are done in 96-well plates.

From an initial set of 27 microsatellite loci that are known to work well in steelhead, we chose a set of eight loci based on the criteria that they amplify well, can be scored unambiguously in two sets of four multiplexed loci, and lack high-frequency null alleles. These eight loci provide a total power to reject a false parent-offspring pair via simple exclusion of > 0.9999 . Furthermore, our ground truthing experiments (see below) demonstrate a very low empirical rate of false parentage inclusion, and high power to exclude all but the true parents.

Template plates are pooled into 384-well plates for PCR, and those are pooled into four-locus, 384-well plates for multiplex scoring on an ABI 3100 16-channel capillary electrophoresis system. We use a Hydra-96 liquid handling robot (Robins Scientific) for all pipetting procedures involving plates (i.e. for all procedures following the initial handling of the scale or fin snip). Adding this device to our lab has cut sample handling errors down to virtually zero.

Table H2. Example of diversity at the eight loci we use (from a sample of 2,487 winter run fish; summer fish have similar levels of diversity).

Locus	Number of Alleles	Expected Heterozygosity
Omy1001	28	0.91
Omy1011	27	0.90
Omy77	20	0.89
One108	33	0.92
One2	67	0.94
Rt191	35	0.93
Ssa407	30	0.90
Str2	44	0.95

(3) *Data analysis:*

Estimation of individual fitnesses

The eight-locus genotypes are merged with ODFW's database in Microsoft Access. For each returning fish (putative offspring) we search for it's mother and father in the year in which it was born (based on scale aging), plus or minus one year to allow for aging errors. From preliminary matching tests using a wider window we found only a few percent of fish are mis-aged by one year, and none are mis-aged by two years. For parent-offspring matching we use standard likelihood-based parentage analysis with an empirically-determined genotyping error rate (Marshall et al., 1998). Note that the presence of trout or precocious parr in the system is not be a problem, even if they obtain matings with anadromous parents. Our main question is to compare the average fitness of anadromous H and W parents, where fitness is defined as production of returning anadromous adults. Only offspring that assign to parents are relevant to the main question, and we have large sample sizes of those.

Parameters vs. parameter estimates

For each run year we are interested in making inference about the fitness of the anadromous hatchery and wild fish that went above the dam. Because we sample all the

fish at the dam each year, the fitness values we obtain for each type of parent (H or W) in a given run year are the parameters for that year, not estimates of the parameter. In other words, the parents that return each run year *are* the population of inference, not a sample from some larger population of hatchery and wild fish to which we wish to make inference for that year (the fitness of an individual fish may be measured with error owing to mis-assignment of offspring, but that is an issue of precision of measurement). On the other hand, the fitness estimates obtained for a given year can be considered to be a sample from some larger universe of run years. Because the ultimate goal here is to estimate H:W relative fitness for use in modeling conservation hatchery programs in general, the key values of interest are the mean and variance of H:W fitness among run years. So our main focus here is in measuring H:W fitness in as many run years as possible. In this report we provide data on H_{new} vs. W for three run years.

(4) Ground truthing:

All fish taken for broodstock are also genotyped. Therefore, as a form of ground truthing we ran fin-clipped returning adults from four brood years through the parentage analyses. For these analyses the fish taken for broodstock were included in the pool of wild potential parents. Ninety-six percent of the clipped returning fish were unambiguously matched back to a single mother-father pair in their expected brood year, and in every case our hatchery records show that that male-female pair was indeed crossed in the hatchery. The remaining unassigned, clipped offspring mismatch all potential parents at multiple loci and so are probably stray hatchery fish from out of the basin. Clipped and unclipped fish were treated identically during all stages of data collection. Therefore, we should have the same power to find the parents of unclipped returnees if their parents are in the parent pool.

Results

(1). Fraction of putative offspring that were assigned

We were able to unambiguously assign a mother-father pair to fewer than 40% of the putative offspring, a single parent to around 50% of them, and no parents to around 10-20%, depending on run year (Figure H3). From our ground-truthing experiments we

know that the unassigned offspring are not the result of experimental error. Because we sampled essentially all anadromous parents, these results suggest that missing parents may be non-anadromous, resident trout or precocious parr. Offspring for which neither parent could be found might also be wild strays or unclipped hatchery fish. Note, however, that for purposes of comparing the relative reproductive success of anadromous hatchery and wild fish, only those offspring that match to anadromous parents are relevant to this study. Resident parents are a separate issue that we will address in the future.

I think it would be well that you remind everyone of the definition of fitness (the number or proportion of the young of different parents that return as adults) in this section.

(2). *Analyses for individual fish of each sex:*

Winter run: H_{old} vs. W and H_{new} vs. W

The 91 year gives a comparison of H_{old} vs. W, and the 95, 96 and 97 years give comparisons of H_{new} vs. W. In 91 the H_{old} had 35% the fitness of wild fish (Fig. 4; Table 3). In 95 the H_{new} had 85% the fitness of wild fish, in 96 they had 85-90%, and in 97 they had 90-108% the fitness of wild fish (Table H3). These results are consistent with the opinion that “new” hatchery stocks perform much better than “old” hatchery stocks. They also show that the relative performance of H_{new} fish might vary substantially from year to year.

Summer run H_{old} vs. W

We matched summer-run offspring back to their putative parents that spawned in the 95 and 96 run years. Both years involve comparisons of H_{old} vs. W. The relative fitness of H_{old} vs. W was 45-54% in 95 and only 17-30% in 96 (Table H3). These results again suggest that H_{old} have low fitness, and also show how variable the relative fitness of hatchery fish may be from year to year. In this case it is interesting that the relative performance of the H_{old} fish was lowest in the 96 run year when almost twice as many summer fish were on the spawning grounds.

Figure H3. Fraction of offspring that were assigned to one parent, both parents or neither parent, by parental run year. For example, 33% of offspring born in 1992 (1991 run year) were matched to a single mother-father pair, 41% matched to a mother only, 11% to a father only, and 14% to neither parent. The offspring that match no parents could be unclipped hatchery fish or out-of-basin strays. The fact that some fish are missing single parents suggest that resident fish of some sort are breeding with anadromous fish.

Parentage Assignment Rate

Figure H4. Example of distributions of number of offspring per male or female breeder (1991 run year). Distributions for other years have similar shapes, although the right skew and variance increases with the mean (Table 3). Notice that most adults produced zero returning offspring. See Table 3 for summary data by parental gender and year.

Table H3. Analysis of average number of offspring produced per potential spawner of each type in each run year. n = number of adults collected at the dam (potential spawners) and genotyped. "Avg. # offspring per adult" = average fitness (number of offspring matched back) per potential spawner. "H/W relative fitness" is the average # of offspring per hatchery adult divided by the avg. # per wild adult. Discrepancies between the total number of fish in this table and in Table 1 in some years result because (1) for this analysis we excluded hatchery fish that had been recycled once or twice before being put above the dam (because that may have affected their fitness), and (2) we excluded a few parents for whom we did not have complete genotypes.

WINTER RUN

Run Year	H _{old} (stock 13)			Wild			
	n	Avg. # offspring per adult (variance)		n	Avg. # offspring per adult (variance)		H/W relative fitness
1991-92							
males	165	0.24 (0.28)		247	0.68 (1.10)		0.35
females	99	0.23 (0.36)		379	0.68 (1.02)		0.34
Run Year	H _{new} (stock 50)			Wild			
1995-96							
males	90	3.66 (19.6)		78	4.31 (25.05)		0.85
females	65	4.39 (16.4)		132	5.05 (25.23)		0.87
Run Year	H _{new} (stock 50)			Wild			
1996-97							
males	95	2.28 (6.01)		93	2.54 (8.03)		0.90
females	153	2.08 (3.71)		148	2.47 (7.04)		0.85

WINTER RUN continued

1997-98							
males	53	2.08 (3.19)		64	2.30 (5.26)		0.90
females	107	2.71 (6.89)		109	2.50 (6.05)		1.08

SUMMER RUN

Run Year	H _{old} (stock 24)			Wild			
1995-96							
males	211	0.72 (1.07)		44	1.34 (3.44)		0.54
females	297	0.45 (0.67)		86	1.01 (3.75)		0.45
Run Year	H _{old} (stock 24)			Wild			
1996-97							
males	474	0.45 (0.69)		61	1.48 (4.45)		0.30
females	766	0.20 (0.32)		121	1.18 (3.70)		0.17

(3) *Analyses of parental pairs (performance of HxH, HxW and WxW crosses):*

We could estimate the proportions of each type of observed cross expected if H and W fish mate randomly, and then compare those proportions to the observed proportions of parental pairs we detected of each type. But because we cannot count pairs that left no surviving offspring, there is no way to disentangle non-random mating from differences in parental fecundity or offspring survival (you would need to observe matings to do that). If we restrict our analysis to pairs that left *at least one surviving offspring*, then we can calculate the relative fitness of each type of cross for that truncated dataset. Any difference here is necessarily owing to offspring survival or parental fecundity because we have restricted the inference to those fish that, by definition, mated. This analysis probably underestimates the fitness differences among the three types of pairs because we have no zero-offspring class. Nevertheless, even for this restricted dataset our results show that $H_{old} \times H_{old}$ crosses always did worse than $H_{old} \times W$, which in turn were worse than $W \times W$ crosses (see Table 4 WINTER RUN 91 and SUMMER RUN 95-96). This result indicates that breeding by H_{old} fish in the wild may indeed be dragging down the fitness of wild fish. In contrast, $H_{new} \times H_{new}$ and $H_{new} \times W$ crosses did much better, sometimes equaling or exceeding $W \times W$ fitness, although the differences are quite variable from year to year (see Table H4, WINTER RUN 95-97). Of more importance, however, these results show that all three types of crosses occur in the wild and produce substantial numbers of surviving F1 offspring.

Table H4. Analysis of average number of offspring per type of parental pair (HxH, HxW or WxW) for pairs *that left at least one offspring*. n = number of that type of pair unambiguously identified as leaving at least one offspring. The two reciprocal H x W crosses were pooled to increase the sample sizes.

WINTER RUN

Type of cross	1991 Avg. # (n)	Fitness of the cross relative to W x W	Type of cross	1995 Avg. # (n)	Fitness of the cross relative to W x W	1996 Avg. # (n)	Fitness of the cross relative to W x W	1997 Avg. # (n)	Fitness of the cross relative to W x W
W x W	1.33 (87)	1.00	W x W	2.53 (72)	1.00	1.54 (57)	1.00	1.24 (34)	1.00
W x H _{old}	1.09 (11)	0.82	W x H _{new}	2.05 (78)	0.81	1.58 (90)	1.03	1.50 (47)	1.21
H _{old} x H _{old}	NA (0)	NA	H _{new} x H _{new}	1.29 (21)	0.51	1.42 (38)	0.92	1.56 (25)	1.26

SUMMER RUN

	Type of cross		1995 Avg. # (n)	Fitness of the cross relative to W x W		1996 Avg. # (n)	Fitness of the cross relative to W x W
	W x W		1.75 (4)	1.00		1.46 (13)	1.00
	W x H _{old}		1.29 (17)	0.74		1.24 (50)	0.85
	H _{old} x H _{old}		1.0 (10)	0.57		1.05 (63)	0.72

CONCLUSIONS

1. Fish from old hatchery stock consistently have very low fitness (usually less than 50% that of wild fish) when breeding in the wild. The fact that $H_{old} \times W$ crosses consistently produce fewer offspring than $W \times W$ crosses (Table H4) suggests that having H_{old} breeders in a system might lower the fitness of the wild population. Whether the surviving wild-born offspring of such crosses re-establish “wild” levels of fitness after one full generation of selection in nature remains to be tested.

2. Fish from new, conservation hatchery stock have fitness that is about equal to that of wild fish (less than wild in two years, greater than in the third year). The same pattern is apparent from examination of the relative fitness of pairs that left at least one offspring. The similar fitnesses of H_{new} and W fish when examined for single parents of each sex, and the similarity of $H_{new} \times W$ and $W \times W$ pairs, suggests that having H_{new} fish in the system is probably not dragging down the fitness of the wild population for genetic reasons (as might have been expected under some models; Lynch and O’Hely, 2001). Thus, the conservation hatchery program appears to have added a demographic boost to the population without having obvious negative genetic consequences - at least in regards the effects of domestication selection and mutation accumulation that should occur in the hatchery. We have not yet conducted a formal analysis of the effect of the hatchery program on the effective size of the wild population (e.g. Ryman et al., 1995), but the high levels of microsatellite diversity we observe in both runs suggest that reduced effective size is not a problem.

3. The surprisingly large number of missing parents, and the fact that most missing parents are fathers (Fig. H3), suggests that precocious parr or resident trout are obtaining substantial numbers of matings that produce anadromous offspring. Alternate explanations for offspring that lack both parents include a large number of unclipped hatchery fish or wild strays entering the system.

Future Work

We hope to continue genotyping fish through the rest of this decade. Additional questions we anticipate addressing include:

(1) Do F1 progeny (born in the wild) of $H_{new} \times W$, $H_{new} \times H_{new}$ and $W \times W$ winter run parents differ in their production of F2 progeny?

We know from our current analyses that all three types of matings occur on the spawning ground, and that all three types of mating produce offspring that return to spawn as adults. F2 offspring of those winter F1s that spawned in the late 1990s are now returning (see Fig. H2). If we continue sampling through the end of the decade we will have a large number of returned F2s from multiple brood years with which to test the relative fitness of different types of F1s (Fig. H2). Given the apparently high fitness of H_{new} hatchery fish, our expectation is that the three types of wild-born F2's will have similar fitnesses.

(2) Selection to maintain the difference between summer and winter runs:

What is the rate of hybridization between the runs? What are the phenotypes (run time, size, freshwater residency) and actual fitnesses of any hybrids?

(3) Selection on measurable phenotypic traits:

We can use standard selection gradient analysis (Lande and Arnold, 1983) to analyze fitness as a function of body size, run time, age and freshwater residency (known from scales), after controlling for hatchery/wild genetic background.

(4) Quantitative genetic parameter estimation:

From our pedigrees we can estimate the heritabilities of, and genetic correlations among any measurable phenotypic traits. We can also estimate the average breeding value for each trait in individuals of $H \times H$ and $W \times W$ genetic background, in order to test whether genetic changes in the hatchery, and subsequent mating with wild fish, could be changing phenotypic distributions in the wild population (Ford, 2001).

(5) Parental contributions of resident, non-anadromous fish

We sample all potential breeding adults passed over the dam, and we know from our ground truthing experiments the expected rate of mismatching owing to experimental error. Therefore, unassigned offspring are either wild strays from out of the basin, or were parented by resident fish (non-anadromous *O. mykiss*, or precocious parr). We will use likelihood methods (Rannala and Mountain, 1997) to attempt to determine the most likely source of missing parents of offspring that only match to a single known parent, and whether fish lacking both parents are most likely to be Hood River wild, Hood River hatchery (unclipped) or immigrants from adjacent steelhead populations. Because we sample all anadromous parents, the Hood River is an ideal system in which to ask questions about the rate of parentage from resident fish and about the sources of those fish.

(6) Effective size estimation

From the pedigrees we can obtain direct estimates of the effective size (N_e) of each population over time. These data will be used to estimate the impact of hatchery programs on the effective size of the wild population and to provide basic parameter estimates such as the variance in family sizes (number of returning adults) for hatchery broodstock, for H fish in the wild, and for W fish in the wild. These are important parameters that are unknown for most populations and can be very useful for estimating N_e and the effects of supplementation in other steelhead populations (e.g. *sensu* Ryman et al., 1995). We can also use our system to evaluate the accuracy of indirect methods for estimating effective size (e.g. Waples, 2002; Anderson et al., 2000). If the indirect methods give very different values from the pedigree-based estimates, then we can ask what assumptions of the indirect methods cause the difference. Note that because of our ability to sample all potential anadromous parents, we can take into account the contributions of non-anadromous, resident fish in our calculations.

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