Hatcheries, Harvest and Wild Fish: An Integrated Program at Warm Springs National Fish Hatchery, Oregon

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Abstract

Warm Springs National Fish Hatchery is operated by the U.S. Fish and Wildlife Service and is located on the Warm Springs River within the Warm Springs Indian Reservation of Oregon. The Warm Springs River is a major tributary of the Deschutes River in north central Oregon, which enters the Columbia River 205 miles from the Pacific Ocean. The purpose of the hatchery program is to cooperatively manage the hatchery with the Confederated Tribes of the Warm Springs Reservation of Oregon to provide harvest opportunities and protect wild fish populations. The management objectives established for the hatchery are: 1) produce fish for harvest, 2) maintain wild fish traits in the hatchery and stream environment, 3) minimize impact on wild fish to very low, acceptable levels, and 4) develop and implement a hatchery operations plan to achieve our harvest and conservation goals for Warm Springs River fish populations. The management of Warm Springs National Fish Hatchery demonstrates a sustainable program which integrates hatcheries, harvest and wild fish production.

Introduction

In this report, we present information on the Warm Springs National Fish Hatchery Program. We present information about the history of hatchery production along with providing comparisons of hatchery and wild life history traits and comparative performance measures. This paper describes a sustainable program that integrates hatcheries, harvest and wild fish production.

Information on the management of Deschutes River fish populations can be found in Oregon Department of Fish and Wildlife (1997). Spateholts and Olson (2001) presented information on the cultural significance and natural production of spring chinook salmon on the Warm Springs Indian Reservation. This paper describes an integrated program at Warm Springs National Fish Hatchery, which considers both harvest and wild fish production objectives.

The U.S. Fish and Wildlife Service (Service) operates Warm Springs National Fish Hatchery. The purpose or goal of the hatchery program is to cooperatively manage the hatchery with the Confederated Tribes of the Warm Springs Reservation of Oregon (Tribe) to provide harvest opportunities and protect/conserve wild fish populations (Olson et al. 1995; USFWS 1999). The Tribe and Oregon Department of Fish and Wildlife (ODFW) co-manage the Deschutes River fisheries.

As with most hatchery programs, a primary objective is to produce fish for harvest. We also wish to maintain wild fish traits in the hatchery and stream environment, and minimize impact on wild fish to very low, acceptable levels. To achieve our harvest objective and conserve Warm Springs River fish populations, we develop every five years, and implement annually, our Hatchery Operations Plan. This plan is policy guidance and is signed by representatives of both the Service and Tribe.

Production plans for the hatchery have changed over time. In the 1971 Master Plan, a substantial program was planned for stocking Reservation waters with trout. In 1977, with facility design changes and shifting Service and Tribal priorities, the trout program was reduced. And in 1981, the trout program was reduced further and hatchery production of summer steelhead (*Oncorhynchus mykiss*) was terminated because of disease and rearing problems. Hatchery production is now 100% spring chinook salmon (*Oncorhynchus tshawytscha*) with a production goal between 500,000 and 750,000 juvenile fish at 15 fish per pound.

Methods

Warm Springs National Fish Hatchery is located at River Mile 8 on the Warm Springs River, within the Warm Springs Indian Reservation, in north central Oregon (Figure 1). The Warm Springs River enters the Deschutes River at River Mile 84, which enters the Columbia River 205 miles from the Pacific Ocean, upstream of only two main-stem dams on the Columbia River, Bonneville and The Dalles dams.

The data was collected and analyzed through cooperative efforts by all three agencies, the Service, ODFW, and Tribe. A number of comparisons between hatchery and wild fish were examined. We reviewed juvenile and adult life history and production from the Warm Springs and Deschutes Rivers.

The run reconstruction data was developed using the mouth of the Deschutes River as our reference point. Adult recruitment was estimated by adding escapement plus harvest. Escapement was determined by enumerating adult fish returning to the Warm Springs River at the hatchery trap site by Service personnel. Harvest in the Deschutes River was estimated by ODFW and the Tribe as described in Lindsay et al. (1989).

Returning fish were sorted by species, examined for marks and sampled at the hatchery to determine age, length and sex composition. To determine age, coded-wire tags were recovered from hatchery fish (Johnson 1990) and scales were collected from 50 to 200 wild fish. Age was noted using the standard Gilbert and Rich (1927) format for pacific salmon. Length was measured to the nearest cm fork length. Hatchery fish were also sampled in the fishery and at the hatchery to recover coded-wire tags (Vreeland 1990).

The number of spawners was estimated by spawning ground surveys conducted by Tribal staff. Knowing how many fish were passed upstream of the hatchery and how many redds were deposited, we obtained an estimate of adult fish per redd production. By incorporating an estimate of the number of females upstream, we estimated pre-spawning mortality, where female mortality = 1-(# redds / # females). The total number of eggs taken and eggs per female were estimated by hatchery staff. The egg per female estimate for hatchery fish was also used to estimate egg deposition for wild fish, where each redd represented one female. Recruit per spawner ratios were used to estimate productivity of wild and hatchery fish.

Juvenile fish at the hatchery were externally marked prior to release to identify them as hatchery fish in the fishery and upon return to the hatchery. For external marks, we have applied a ventral fin clip and/or an adipose fin clip. For over 10 years now, hatchery production of spring chinook has been 100% adipose fin clipped and coded-wire tagged. This marking has also allowed us to conduct rearing and release group studies at the hatchery (Olson 1997).

Hatchery methods used standard Service techniques as described in Piper et al. (1982). Sampling was conducted at the hatchery for tag retention, mark quality, length and weight. We crowded fish to obtain our sample size of a minimum 100 fish per pond and between 300 to 500 fish per tag code. Juvenile fish were measured to the nearest mm fork length and/or total length. Fish were weighed using the "wet" method to determine number of fish per pound in each pond sampled. The number released from the hatchery into the Warm Springs River was quantified by subtracting the total pond mortality from the total number ponded at time of marking. Hatchery records were maintained by the Service's Columbia River information System or CRiS (Pastor 1992).

The Tribe estimated wild and hatchery juvenile production from the Warm Springs River by operating an out-migrant trap near the mouth of the Warm Springs River. Fish collected in the trap were also measured and weighed. For more detail see Lindsay et al. (1989) and Spateholts and Olson (2001).

Pearson's chi-square statistic (alpha @ 0.05) was used to compare age and length frequency distributions between hatchery and wild fish. Student's t-test and analysis of variance models (alpha @ 0.05) were used to test for differences in length at downstream migration, length at spawning, and differences in survival rates between hatchery and wild fish at various life stages, as appropriate. Additional details are provided in the subsequent results & discussion section. Statistical procedures are described in Zar (1974). SYSTAT, Microsoft PowerPoint and Excel, dBASE, and Lotus copyrighted software were used to analyze and present the data (reference to trade names does not imply endorsement by the U.S. Fish and Wildlife Service).

Results & Discussion

Spring Chinook Hatchery Broodstock - Production at the hatchery began in 1978. During the first 4 years of production (1978-81), 100% of the broodstock were wild origin. Initial guidelines were to not exceed one-third of the wild return or about 450 fish for hatchery broodstock, taken throughout the run.

During the first 10 years of operation, wild fish contributed a significant portion to the hatchery broodstock (Figure 2). We have recently developed a sliding scale for wild fish inclusion based on their projected return. For example, at wild runs < 800 no wild fish are retained for broodstock, and at wild runs >1,300 up to 10% of the broodstock can be wild brood (or about 60 wild fish for a hatchery broodstock of 600). Using this sliding scale method, we are considering increasing the number of wild fish in the hatchery broodstock during years of high wild fish abundance. For example when 1,800 or more wild fish are projected back to the Warm Springs River, up to 15% of the broodstock may be wild fish. Our goal, over a 10-year period of variable recruitment, is to have an average10% wild fish in our hatchery broodstock.

Juvenile Production - Juvenile releases of spring chinook salmon from the hatchery have ranged from 200,000 to over 1 million fish (Figure 3). Release goals now range between 500,000 and 750,000, depending in part from adult returns available for broodstock and on-going rearing density studies. The number of juveniles released from the hatchery exceeded wild juvenile production from the Warm Springs River each year since 1978. Wild production of spring chinook salmon from the Warm Springs River has ranged from 30,000 to over 100,000 juvenile fish (Spateholts and Olson 2001).

Wild fish have shown a fall and spring out-migration pattern from the Warm Springs River with up to two-thirds exiting during the fall out-migration period (Lindsay et al. 1989; Spateholts and Olson 2001). Releases from the hatchery were typically split into fall and spring releases as well (Figure 3). The fall sub-yearling release from the hatchery has ranged from 10% to 50% of production. Since 1991, about 10 % of hatchery production was volitionally released in the fall as described in Olson (1997).

Examining their size at out-migration (mean (+/- SD) fork length), juvenile hatchery fish at release were larger than their wild counterparts, especially the fall out-migrants. For example, hatchery fish averaged 167mm (+/- 26mm) in fall of 1996 (n=448) and 149mm (+/- 26mm) in spring of 1997 (n=851), whereas wild fish averaged 98mm (+/- 11mm) in fall of 1996 (n=305) and 112mm (+/- 15mm) in spring of 1997 (n=64) as shown in Figure 4. For each out-migration period we used a two-sample t-test on length grouped by stock, assuming unequal variances. There was a significant difference in fork length between hatchery and wild fish for both the fall ($P<<0.001$, $t=-50.0$) and spring out-migration periods ($P<<0.001$, $t=-17.5$). A significant difference was also observed eight years prior for the fall of 1988 and spring of 1989 time periods (Olson et al. 1995).

Previous studies have shown that spring yearling fish, both wild and hatchery, migrate quickly downstream and can exit the Deschutes River within days (Cates 1992). The wild fall migrants typically over-winter in the Deschutes River (Lindsay et al. 1989). Hatchery fish released in the fall appear to exhibit both a fall and spring migration from the Deschutes River. There is evidence that smaller hatchery fish are over-wintering in the Deschutes River whereas some of the larger fish exit the Deschutes River that fall (USFWS 1999). To shed more light on the fate of fish released in the fall, the U.S. Geological Survey-Biological Resources Division, Columbia River Lab have initiated studies using radio telemetry techniques.

Average age at return - We updated Olson et al. (1995) with seven additional years of data to determine average (+/- SD) age composition of the Warm Springs stock at return to the Deschutes River, brood years 1978-95 (Figure 5). For both wild and hatchery stocks, most fish returned at age four (80% (+/-8%) for wild and 82% (+/-9%) for hatchery fish). However, the wild stock had more fish returning at age five (16% (+/-7%) for wild and 7% (+/-5%) for hatchery fish), whereas the hatchery stock returned more age three fish (5% (+/-1%) for wild and 11% (+/-7%) for hatchery fish). We pooled all brood years (n=18) and found a significant difference in age distribution between wild and hatchery fish ($P<<0.001$, Chi-square=1,816).

Length at spawning - Olson et al. (1995) previously reported a significant difference in length frequency distributions for age four and age five wild and hatchery fish. Age five fish were found to be significantly larger than age four fish; and wild fish were significantly larger than hatchery fish. Upon further investigation, Olson et al. (1995) used 1991-93 data where wild fish were sampled as they were passed upstream from May through early September while hatchery fish were sampled at time of spawning in late August and early September. All data from 1991-93 were pooled for both spring and fall periods. To further explore this issue, we eliminated the spring sample period and examined fork length of age four and age five hatchery and wild fish only at time of spawning. We pooled years 1990, 1992 and 1996, when approximately 10% of the broodstock were wild fish, and looked for differences in length. Sex and fork length were recorded from each fish spawned. We found that age five fish were larger than age four fish, males were bigger than females, and wild fish were bigger than hatchery fish (Figure 6). For each age we used a 2 x 2 Analysis of Variance model to look for significant differences between each stock and sex. For age four fish, there was a significant difference (P=0.009) in length between wild (n=129) and hatchery (n=1,293) fish but no significant difference (P=0.135) between sexes was found. For age five fish, the largest difference was between sexes (P=0.057) with no significant difference (P=0.433) found between wild (n=31) and hatchery (n=64) stocks. Furthermore there was no significant interaction of stock and sex on the length of age four (P=0.96) or age five (P=0.99) fish.

We also specifically looked for differences in lengths between hatchery and wild females. For each age we used a two-sample (pooled variance) t-test on length grouped by stock. For each age group, wild females were larger than hatchery females (Figure 6). We were able to detect a significant difference between hatchery (n=763) and wild (n=73) females at age four (P=0.02, t =-2.4). The difference between age five hatchery (n=37) and wild (n=17) females was not statistically significant (P=0.5, t =-0.6), in-part because of small sample size. The difference in means between hatchery and wild females in both age groups was 1.1 cm. The biological significance of 1.1 cm is not great but it may have an influence in the number of eggs produced per female. After examining 24 egg takes at Warm Springs NFH, egg production was positively correlated to the length of each mature female spawned (r = 0.655) and was a significant linear relationship, P < 0.001 (Columbia River information System, 10/16/01; see also Pastor and Sheldrake 1995). Based on this relationship, hatchery fish would produce fewer eggs per female than wild fish of the same age.

Differences in age and length at return may be affected by size at release from the hatchery. Our target has been to release fish at 15 fish per lb., however we have recently observed good survival of fish released at a smaller size at 22 fish per lb. We need to continue looking at size at release from the hatchery to not only maximize survival but also determine if we can achieve similar size at release, as well as achieve similar age and length composition at return for hatchery and wild fish.

Cumulative run timing - We examined 13 years (1987-1999) of return timing data collected at the hatchery. Wild and hatchery fish returned to the Warm Springs River from late April through September, spawning from late August through September. Most wild and hatchery fish returned to the Warm Springs River by late June. However, in the early part of the run, hatchery fish typically had a one to two week lag in their return when compared to wild fish (Figure 7). For example, by May 31 of each year, an average 64% (+/-15% SD) of the wild and 49% (+/-14% SD) of the hatchery fish had returned to the Warm Springs River. By June 30 of each year, an average 89% (+/-5% SD) of the wild and 85% (+/-5% SD) of the hatchery fish had returned. We pooled all brood years, separated by one-month intervals from May 31 through September 30 and found a significant difference in cumulative run timing between wild and hatchery fish (P<<0.001, Chi-square=396). Recognizing this difference, we have developed a broodstock collection strategy based on wild stock returns. Size at release may be affecting age at return, which may affect run timing as well. We will continue monitoring our management actions to see if a similar run timing between wild and hatchery fish can be achieved.

Survival - We have compared survival of hatchery and wild fish at different life stages and tested for significant difference using a paired sample t-test (Wilcoxon non-parametric analysis) for brood years 1978-96 (n=19). As expected, we observed an inverse relationship in egg-to-juvenile and juvenile-to-adult survival between hatchery and wild fish (Table 1). Hatchery fish had a consistent survival advantage from egg-to-juvenile (75% +/- 18% SD vs. 9% +/- 4% SD) and wild fish had a consistent survival advantage from juvenile-to-adult (2.8% +/- 2.7% SD vs. 0.3% +/- 0.3% SD). These differences between stocks were highly significant for both egg-to-juvenile ($P<<0.001$) and juvenile-to-adult survival ($P<< 0.001$).

Mixed results were observed when comparing the adult recruit per spawner (R/S) ratio (Table 1). Wild fish had higher R/S ratios 13 out of 19 years while hatchery fish had higher R/S ratios 6 out of 19 years, however this difference was not significant ($P=0.243$). The average R/S ratio was similar for both stocks, with an average R/S ratio of 3.2 (+/- 1.9 SD) for wild and 2.8 (+/- 3.3 SD) for hatchery fish. A R/S ratio of one or greater indicates a population that is replacing itself over time and a population with a R/S ratio of about 3.0, as seen here for both wild and hatchery fish, has the potential to sustain a fishery, which leads into our next discussion, harvest in the Deschutes River.

Harvest - The primary fishing area for spring chinook salmon in the Deschutes River occurred at Sherars Falls (ODFW 1997). Both wild and hatchery fish have contributed to harvest (S. Pribyl, ODFW, personal communication). As shown in Figure 8, more wild than hatchery fish from the Warm Springs River were often harvested, until recently. Improved survival of Warm Springs hatchery fish and restrictive regulations on sport fisheries has led to increased harvest on hatchery fish, which is one of our objectives. For example, in return year 2000, almost 2,800 Warm Springs hatchery fish were harvested in tribal and sport fisheries, while only 339 wild fish were harvested (Gauvin and Olson 2001). A substantial number of wild fish were also caught (1,340) but were required to be released back to the river because of selective sport fishery regulations set by ODFW. Sport fishers were able to identify marked (adipose fin clipped) hatchery spring chinook. The objective of this ODFW regulation is to reduce sport fishing mortality on wild fish, catch & keep hatchery fish, and have more wild fish returning to the Warm Springs River to spawn.

Escapement goal - Based on analyses by Lindsay et al (1989), an escapement goal of 1,300 or more wild spring chinook salmon upstream of the hatchery has been established by the Tribe, ODFW and the Service. A wild spring chinook return projected to be less than 1,300 fish triggers more restrictive fishing regulations by ODFW and the Tribe. In early years of hatchery operation our intent was to supplement natural production; not all fish were marked; and up to 30% hatchery fish were passed upstream (Figure 9). Under our current operation plan guidelines, we manage for an exchange of 10% hatchery fish upstream for 10% wild fish incorporated into the hatchery broodstock. For example, in the 2000 return year over 2,600 wild and approximately 285 hatchery fish were passed upstream of the hatchery. We were also able to incorporate 55 wild fish with 452 hatchery fish for broodstock.

Pre-spawning mortality - From 1977 to 2000, the pre-spawn mortality of spring chinook salmon passed upstream of the hatchery to spawn naturally (both wild and hatchery fish) averaged 47% (+/- 12% SD). Spring chinook salmon kept for broodstock at the hatchery typically had less than 20% pre-spawn mortality, except for the first four years of hatchery operation (41% +/- 9%). Bacterial kidney disease was suspected as one of the primary causes of high pre-spawn mortality, especially in 1980 and 1981 for both the naturally spawning population (74% mortality) and hatchery broodstock (48% mortality). Because of this, erythromycin injections were administered since 1982 to all hatchery and wild adult spring chinook salmon either passed upstream or kept for broodstock. After using erythromycin, the pre-spawn mortality of fish passed upstream of the hatchery has averaged 46% (+/- 10%).

The amount of handling on fish as they returned to the hatchery may have contributed to fish health problems and pre-spawn mortality. Operation of a volitional passage system is being investigated to reduce handling and pre-spawn mortality of fish passed upstream of the hatchery, as discussed in the following section. Fish passed upstream by the volitional passage system will not be handled and subsequently not given erythromycin as well.

Passage system - A new passage system was installed at the hatchery in 1996. Our objectives were to reduce pre-spawning mortality of fish passed upstream to < 40% (< 3 fish per redd), curtail erythromycin injections on volitionally passed spring chinook, achieve 95% passage efficiency for wild spring chinook, and achieve 90% passage efficiency for hatchery spring chinook (95% tag retention X 95% tag detection). Implementing the 100% coded wire tagging program along with installation of the new passage system at the hatchery will allow us to reduce the handling of wild fish and will hopefully reduce pre-spawning mortality.

Service engineers designed the passage system to fit in existing catch ponds at the hatchery (Figure 10). The passage system includes a modified 15-foot long Denil steeppass fishway (Bell 1986), along with a coded-wire tag tube detector and gate manufactured by Smith-Root, Inc. (Figure 11). A video system is in place to monitor fish passing upstream of the hatchery, similar to that described by Hatch et al. (1994).

The hatchery staff conducted tests of the system during 1996-98 (Figure 12). During these tests, the fish entered the ladder and swam up the steeppass. The effectiveness of detecting and guiding coded-wire tagged hatchery fish to a holding pond was monitored. Non-tagged hatchery and wild fish were also monitored as they were guided to another catch pond and recorded by a video system as they continued their migration through the ladder then on upstream of the hatchery.

The passage system met our objective of 95% passage efficiency for wild fish, with fewer than 5% wild fish passed to the wrong catch pond (95.4% (+/- 0.7% SD) average passage efficiency). However, separating out hatchery fish was not as effective and a number of limitations became evident. Efficiency improved each year but on average 10.7% (6.8% SD) of the hatchery fish were passed to the incorrect catch pond because of poor tag retention. In addition, 11.3% (7.5% SD) of the coded-wire tagged hatchery fish were not detected and were also passed to the wrong catch pond. Our objective was to achieve 90% passage efficiency for hatchery fish but overall we averaged 77.8% (11.5% SD) for the three years tested.

The sheer number of hatchery and wild fish returning also effects operation of the passage system. When a large number of hatchery fish returned relative to wild fish, even if the passage system separated out 90% of the hatchery fish, more than 10% of the fish upstream would have been hatchery origin. For example in 1999, 2,770 hatchery and 493 wild fish returned to the Warm Springs River. Even with 90% passage efficiency, 277 hatchery fish would have been passed upstream. This would not meet our operation plan guidelines, so the passage system was not operable in 1999. Also during peak passage times, the system did not respond quickly enough to separate out each individual fish. The upstream channel needed improvement as well. Fish milled around in the upstream catch pond and swam back and forth past the viewing chamber. This appeared to not only impede passage but also required hatchery staff to spend a considerable amount of time monitoring videotapes.

With improvements in tag retention, detection and passage past the viewing chamber, volitional passage can potentially benefit wild fish passing the hatchery site, including Endangered Species Act (ESA) listed bull trout (*Salvelinus confluentus*). However, another ESA listed fish, summer steelhead, may continue to limit full implementation of the passage system, as described in the next section.

Summer steelhead - Adult summer steelhead enter the Deschutes River beginning in June. They over-winter in the Deschutes River until entering the Warm Springs River in February just prior to spawning. The peak of the spawning run at the hatchery is in mid-April and the run is complete by mid to late May (Cates 1992).

As stated earlier, steelhead hatchery production in the Warm Springs River was terminated in 1981; since 1986 all hatchery steelhead coming back to the Warm Springs River are strays. To eliminate hatchery steelhead strays from the upstream spawning population, all steelhead were sorted at the hatchery. To maintain the genetic characteristics of wild steelhead in the Warm Springs River, we sacrificed all steelhead with missing or deformed fins and passed only unmarked "wild" fish upstream.

Starting in 1987 we observed a large increase in the estimated number of steelhead strays in the Warm Springs River (Figure 13). The percentage that were estimated as strays from 1987 to 2001 averaged 50.1% (+/- 11.8% SD), while the percentage of strays estimated from 1979 to 1986 averaged 11.8% (+/- 5.6% SD). If we were to pass all steelhead upstream, regardless of origin, a large proportion of the fish would have been strays since 1987. Because of these hatchery strays, the volitional passage system was not operated until the steelhead run was over in late May. In effect, we have maintained a wild fish refuge for steelhead upstream of the hatchery.

So where are these hatchery strays coming from? Each year we have observed a handful of steelhead strays with coded-wire tags. For example in 1998, 26 coded-wire tags were recovered. Based on simple mark release expansion we were able to account for the origin of 119 fish (Figure 14, from Olson and Pastor 1998). Note that 380 fish was the total stray count in 1998. Assuming the tagged-to-nontagged release expansion is accurate, 161 hatchery steelhead were recovered with an unknown origin. Almost all steelhead were marked to externally identify them as hatchery fish but not all were marked with representative coded-wire tags. We do not know the origin of all hatchery strays, but based on recoveries, the Snake River hatchery programs contributed a large portion of strays to the Warm Springs River, especially the Irrigon hatchery program which released steelhead into the Grande Ronde watershed of the Snake River.

The situation at Warm Springs is an indicator of a larger problem of hatchery steelhead straying into the Deschutes River. As estimated by ODFW, hatchery strays have accounted for over one-half of the estimated number upstream of Sherars Falls in recent years (Figure 15). For example, of the total 21,203 steelhead estimated past Sherars Falls in the 1999-2000 run year, 4,790 were wild, 2,628 were from Round Butte hatchery, and 13,785 were considered out of basin hatchery strays (S. Pribyl, ODFW, personal communication). The Draft NMFS Biological Opinion on hatcheries recognized this issue and has recommended some hatchery program changes in the Snake River to hopefully reduce the stray problem. Furthermore, all steelhead hatchery programs should have representative groups coded-wire tagged in order to assess straying. Fisherman should also be encouraged to keep all hatchery steelhead caught. The

Warm Springs program can continue to serve as an indicator for monitoring the effects of these management actions.

Conclusion

In this paper we have demonstrated that hatchery operations and production from Warm Springs National Fish Hatchery considered not only harvest, but wild fish production objectives as well. Future operations and research for evaluating this program include continuation of cooperatively collecting and sharing data between all three management agencies, the Tribe, ODFW and Service. For example, we will determine the annual run reconstruction of wild and hatchery spring chinook salmon, we will collect data for population monitoring of ESA listed summer steelhead and bull trout as well as monitor other fish passing the hatchery site, and we will continue with rearing and release studies at the hatchery to improve performance, including diet, growth, reduced rearing densities, and fish health evaluations. We will explore funding available to continue developing collaborative projects with our partners, including development of alternative rearing environments at the hatchery to simulate natural rearing behavior and growth, evaluating performance and ecological interactions of hatchery and wild fish, and evaluate & implement facilities to improve water quality at the hatchery. Using the information we have collected and analyzed to date, we have begun updating our operation plan for 2002-2006. We strive to cooperatively manage the hatchery in order to provide harvest opportunities and protect/conserve wild fish populations.

In *Fisheries* magazine, Pajak (2000) illustrated that institutions, society and the environment all need to be integrated to achieve a sustainable program. We are hopeful that our management of Warm Springs National Fish Hatchery demonstrates a sustainable program which integrates…hatcheries, harvest and wild fish production.

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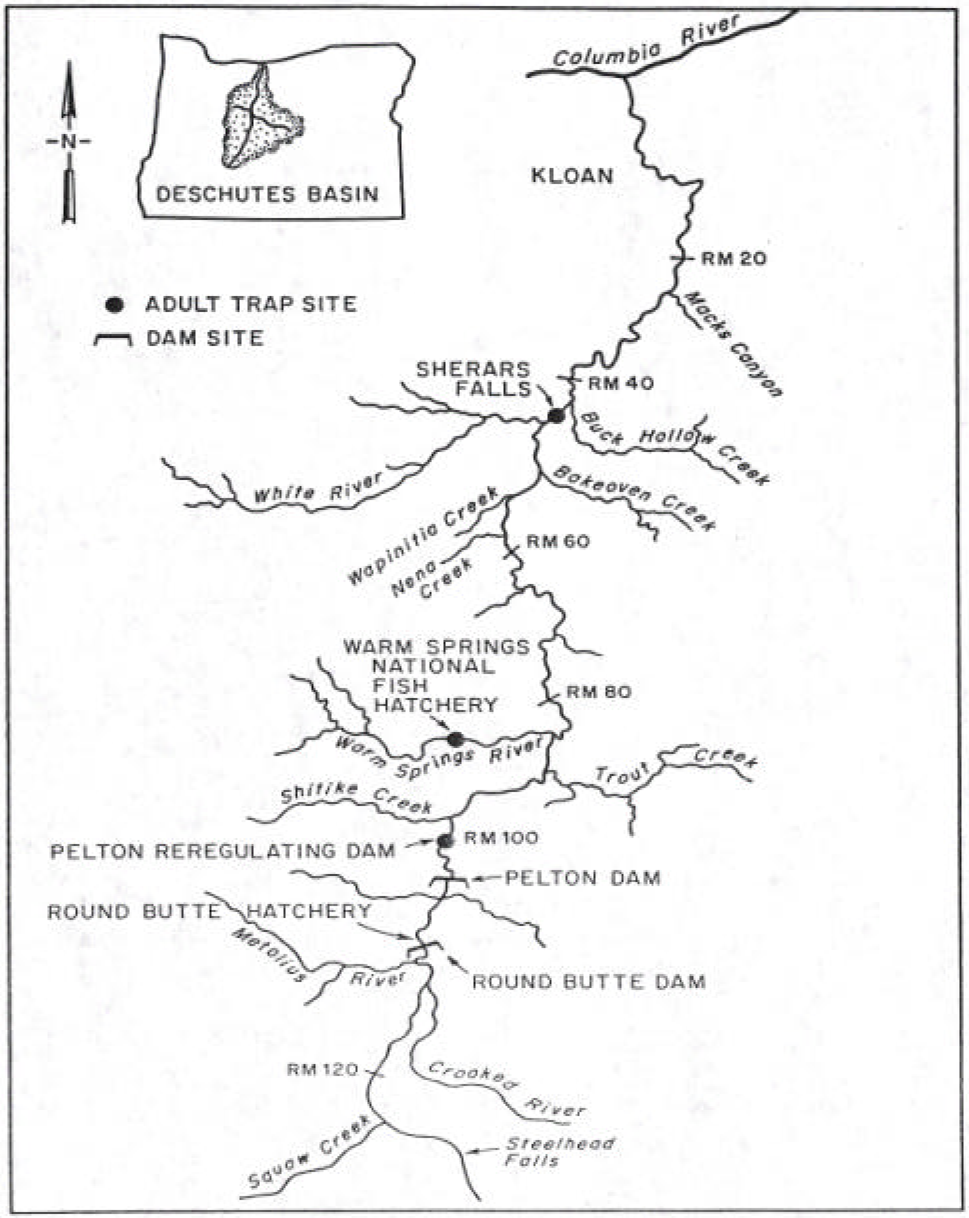


Figure 1. The lower 100 miles of the Deschutes River and location of Warm Springs National Fish Hatchery, Oregon (Lindsay et al. 1989).

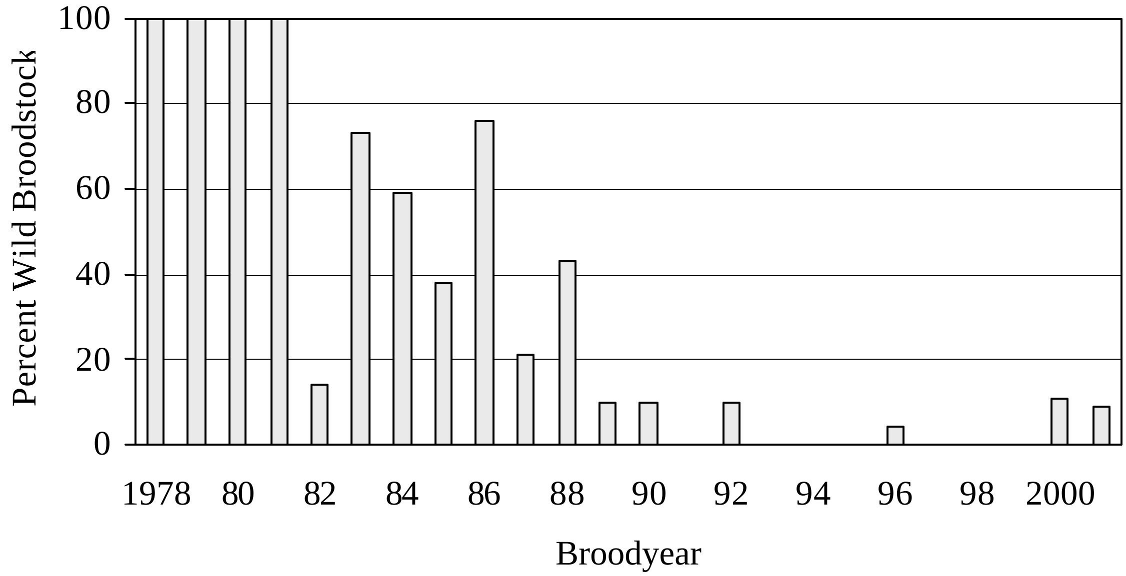


Figure 2. Percentage of wild spring chinook salmon used for broodstock at Warm Springs National Fish Hatchery, 1978-2001.

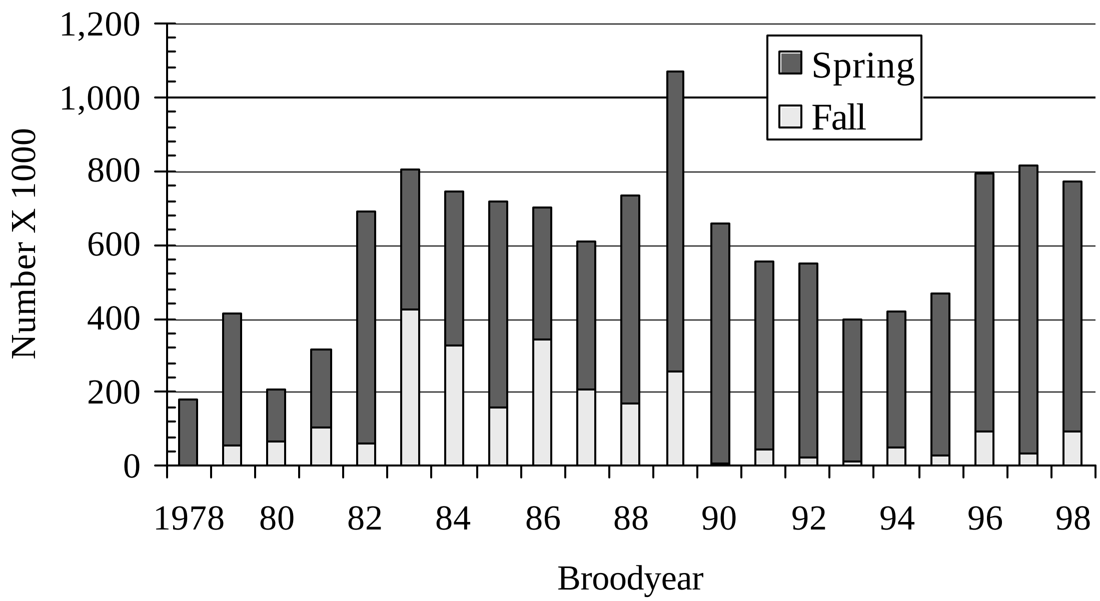


Figure 3. Releases of juvenile spring chinook salmon from Warm Springs National Fish Hatchery during fall and spring periods, broodyears 1978-98.

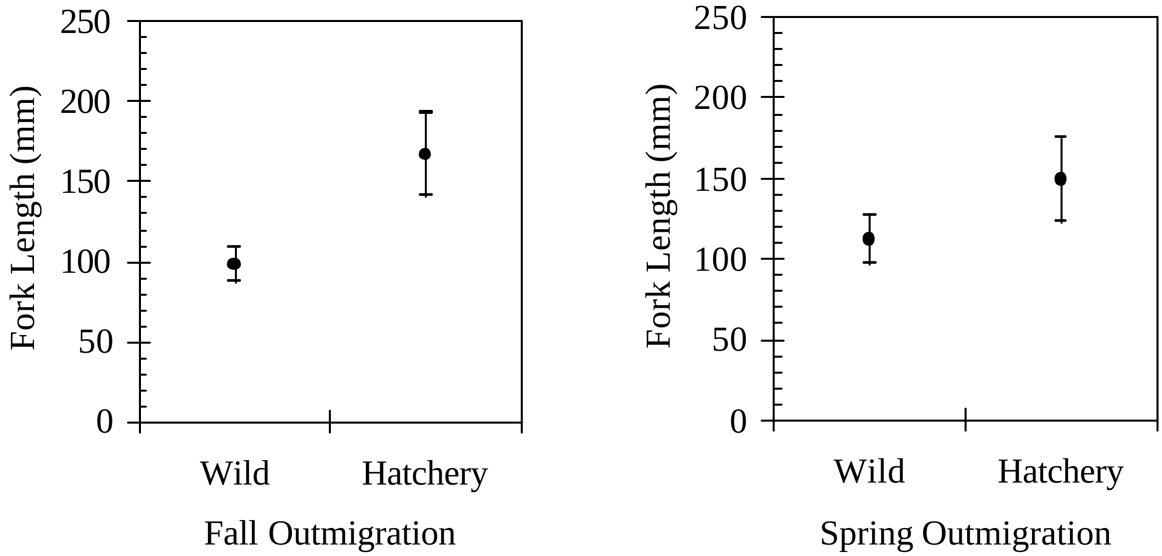


Figure 4. Fork length comparisons (mean and SD) between wild and hatchery juvenile spring chinook salmon during the fall 1996 and spring 1997 out-migration periods from the Warm Springs River.

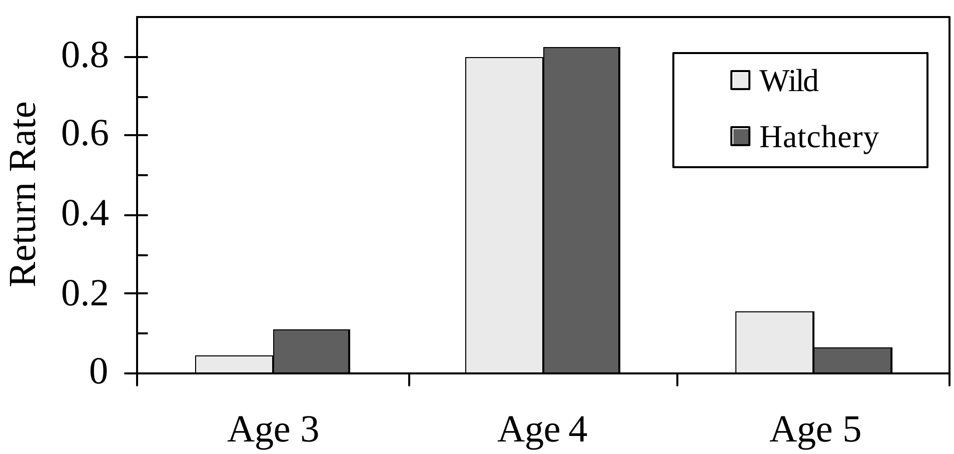


Figure 5. Comparison of age-class strength for wild and hatchery spring chinook salmon returning to the Deschutes River, brood years 1978-95.

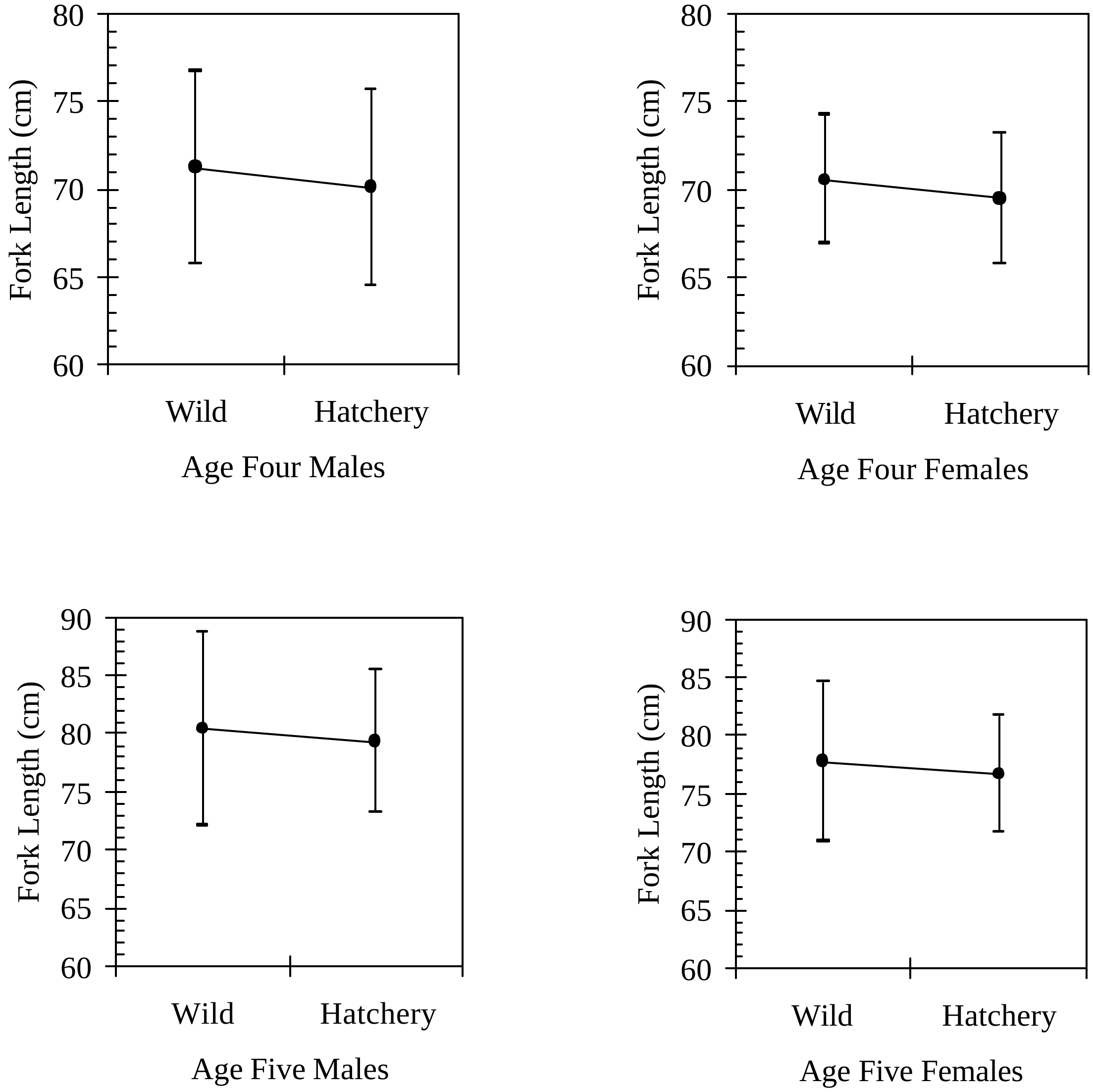


Figure 6. Fork length comparisons (mean and SD) between wild and hatchery adult spring chinook salmon in the Warm Springs River, sampled at spawning in 1990, 1992 and 1996.

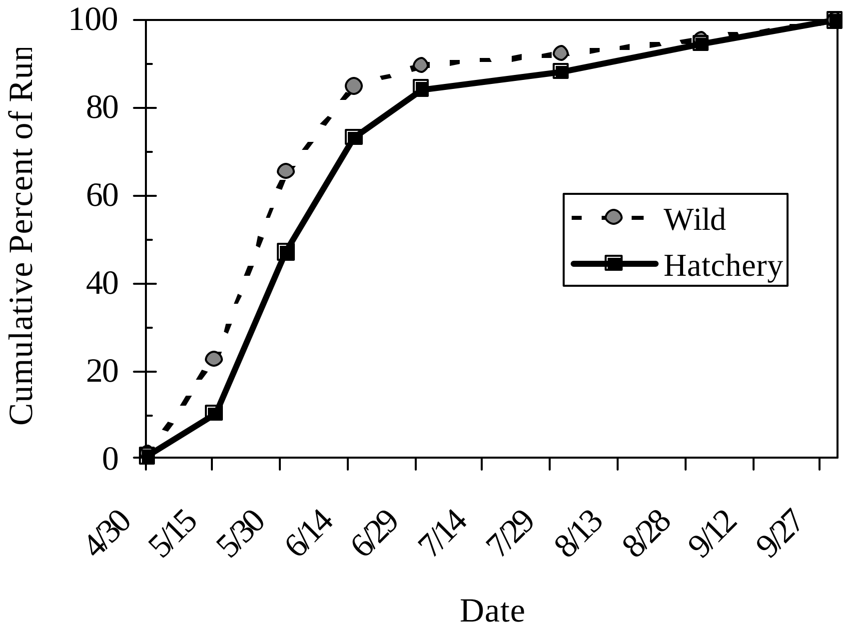


Figure 7. Cumulative run timing (%) of wild and hatchery spring chinook salmon returning to the Warm Springs River, 1987-1999.

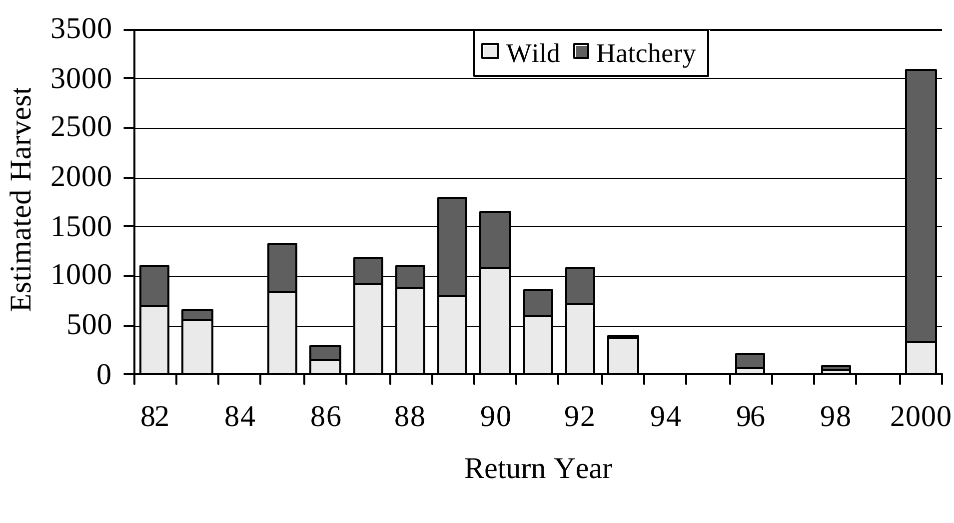


Figure 8. Estimated harvest of Warm Springs stock spring chinook salmon in the Deschutes River, 1982-2000. Data derived from S. Pribyl, ODFW, personal communications.

Table 1. Comparison of survival at different life stages for wild and hatchery spring chinook salmon from the Warm Springs River, 1978-1996 broodyears.

	Wild Stock			Hatchery Stock		
Brood Year	Egg to Juvenile (%)	Juvenile to Adult (%)	Recruit per Spawner	Egg to Juvenile (%)	Juvenile to Adult (%)	Recruit per Spawner
1978	6.38	1.52	1.59	25.89	0.84	2.65
1979	5.42	4.11	3.59	60.53	0.09	0.89
1980	11.58	3.30	6.46	53.99	0.42	2.76
1981	10.75	4.12	6.67	57.20	0.56	3.49
1982	8.73	2.82	4.16	71.71	0.03	0.30
1983	10.72	2.25	3.70	86.73	0.13	1.71
1984	8.74	2.41	3.33	70.46	0.12	1.38
1985	7.31	3.01	3.49	55.33	0.54	4.53
1986	8.27	3.19	3.57	87.14	0.28	3.20
1987	7.47	1.46	1.47	84.10	0.13	1.20
1988	9.88	1.78	2.65	86.94	0.18	1.79
1989	7.59	0.69	0.82	92.93	0.02	0.21
1990	7.29	0.44	0.52	68.94	0.005	0.04
1991	5.40	0.37	0.28	81.54	0.02	0.22
1992	13.66	2.57	4.11	88.95	0.16	1.58
1993	8.76	2.68	3.55	98.46	0.29	4.10
1994	13.79	0.46	0.99	85.71	0.15	1.94
1995	2.24	12.95	4.54	83.51	0.43	7.30
1996	18.48	2.27	6.09	93.45	1.27	14.35
Mean	9.08	2.76	3.24	75.45	0.30	2.82
SD	3.63	2.72	1.94	18.22	0.32	3.32

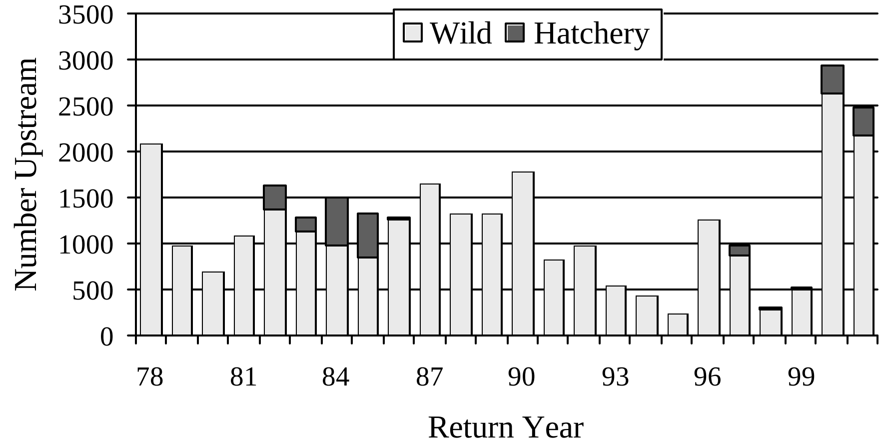


Figure 9. Number of wild (unmarked) and hatchery spring chinook salmon passed upstream of Warm Springs National Fish Hatchery, 1978-2001. A small percentage (< 5%) of unmarked fish each year may in fact be hatchery fish.

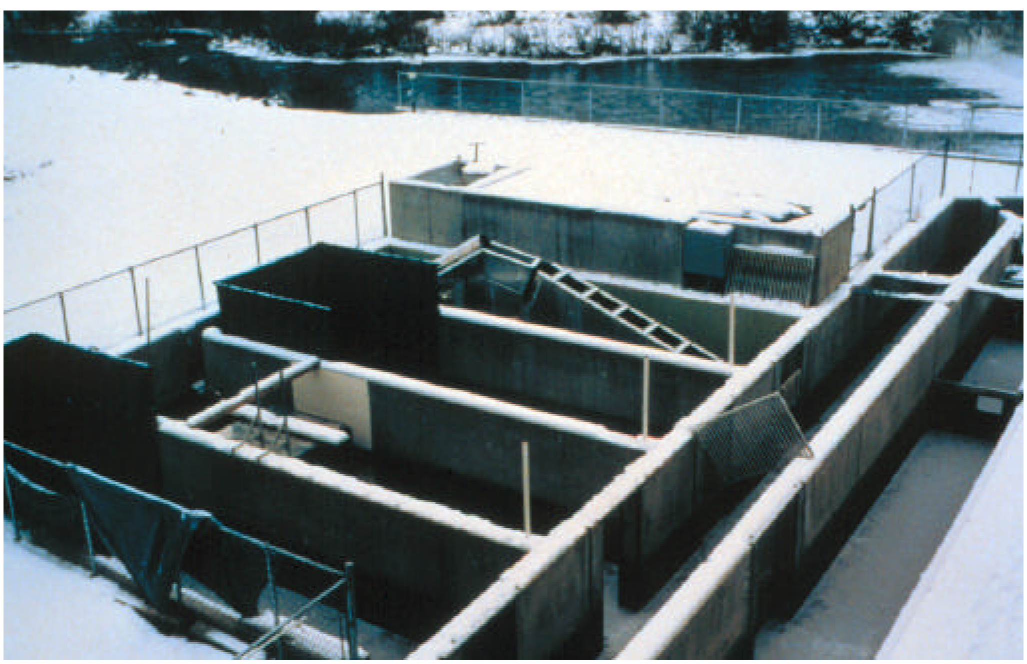
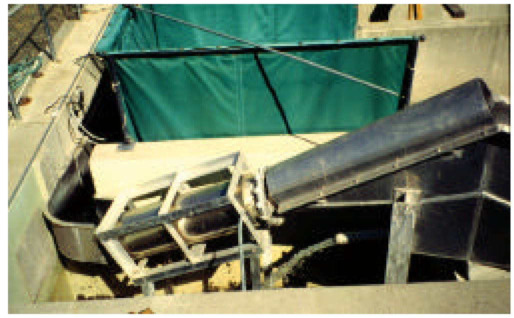


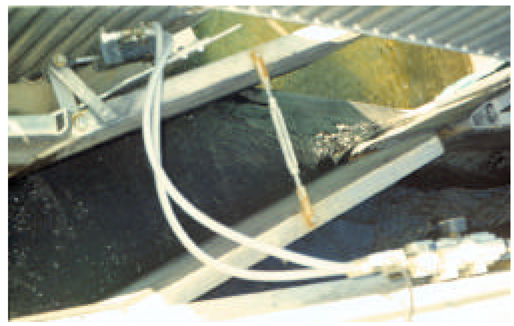
Figure 10. Volitional passage system installed in existing catch ponds at Warm Springs National Fish Hatchery, Oregon.

Denil Steeppass Fishway



Coded-Wire Tag Tube Detector

Video Camera Housing



Tag Detector Gate

Figure 11. Photographs of components of the volitional passage system installed in existing catch ponds at Warm Springs NFH.

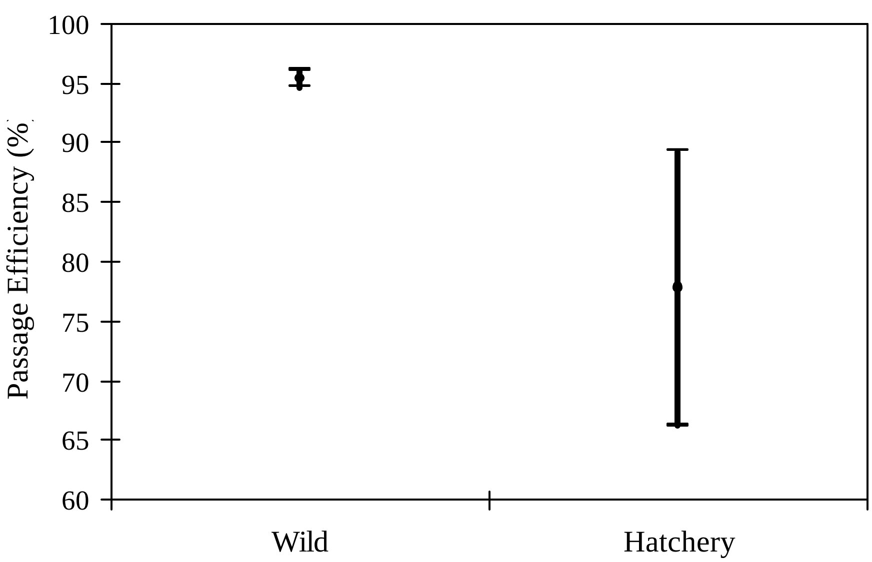


Figure 12. Percentage of wild (n=855) and hatchery (n=823) spring chinook salmon diverted to the correct pond during tests of the volitional passage system, 1996-98 (mean and SD).

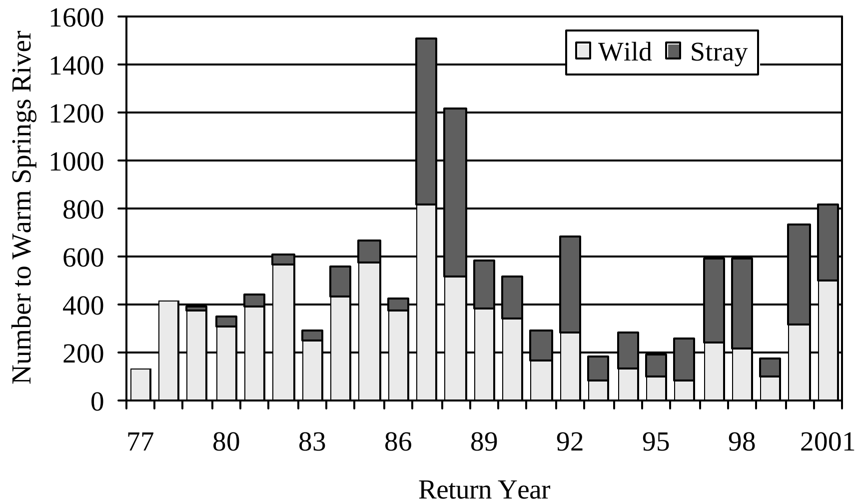


Figure 13. Total number of wild (unmarked) and stray hatchery summer steelhead returning to the Warm Springs River, 1977-2001.

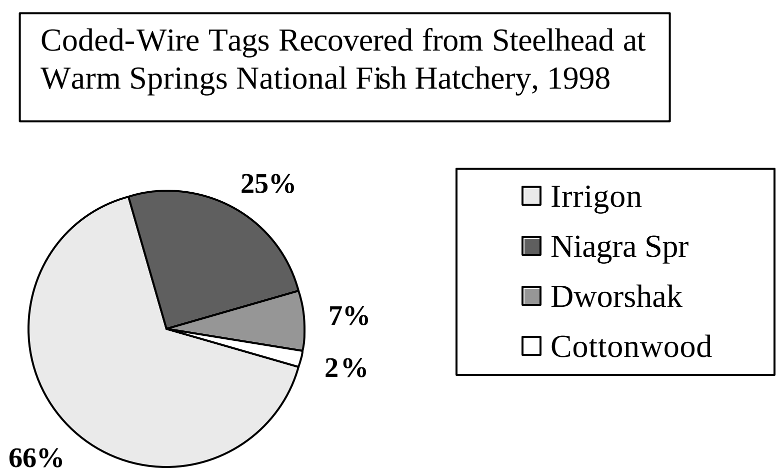


Figure 14. Hatchery origin of coded-wire tagged summer steelhead (n=26) recovered at Warm Springs National Fish Hatchery in 1998. The percent distribution represents an expanded estimate (n=119) of non-tagged and tagged release groups from the hatchery of origin (Olson and Pastor 1998). All adult recoveries in 1998 originated from Snake River juvenile release sites.

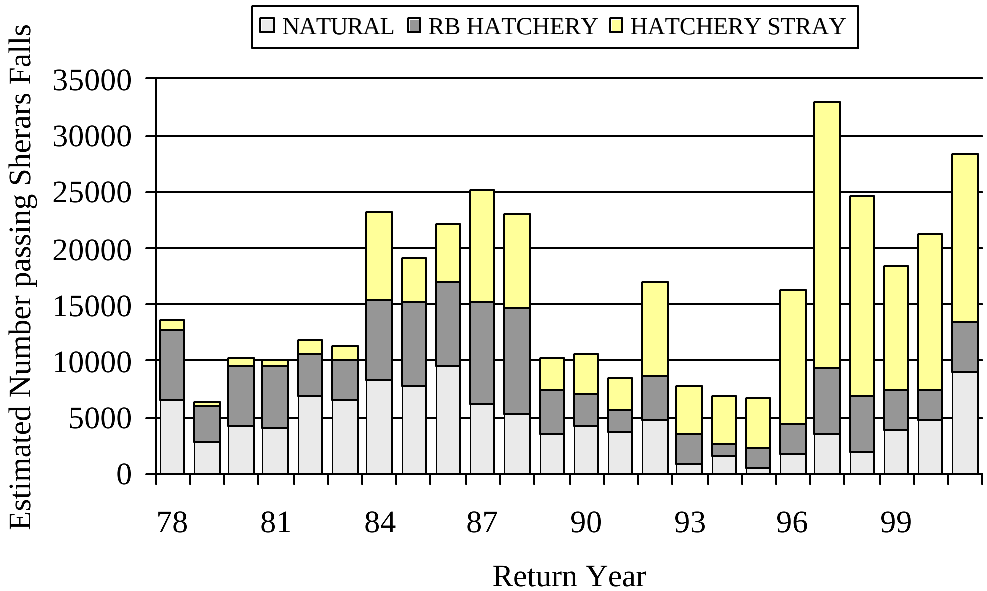


Figure 15. Estimated number of summer steelhead that migrated past Sherars Falls, Deschutes River, Oregon by run year 1977-78 to 2000-01 (S. Pribyl, ODFW, personal communication).