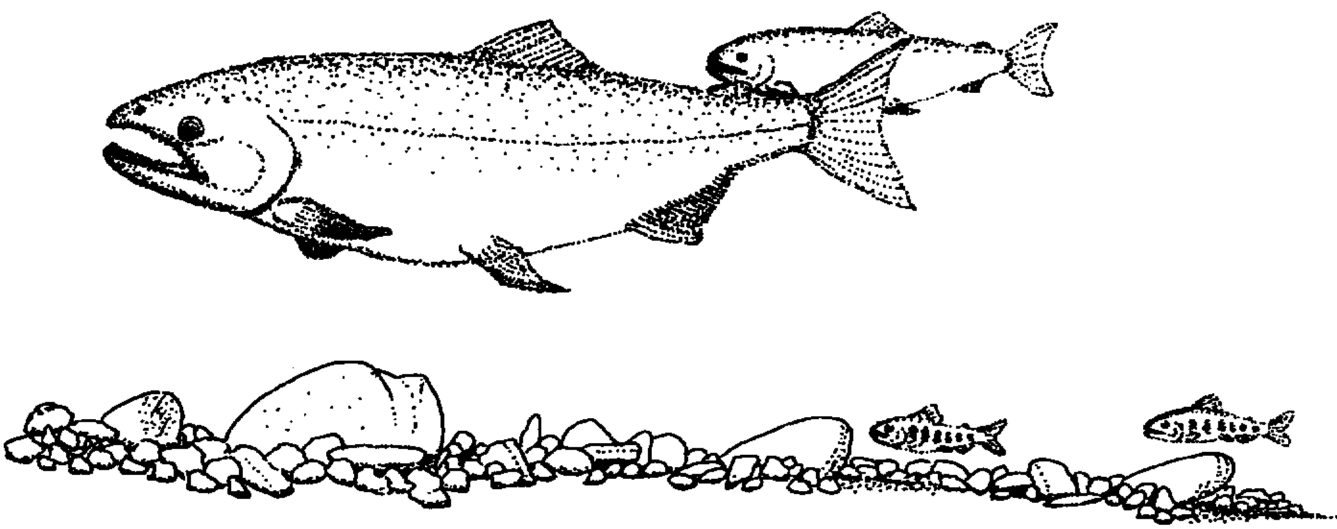
U.S. FISH AND WILDLIFE SERVICE

AN EVALUATION OF THE QUILCENE NATIONAL FISH HATCHERY SPRING CHINOOK RESTORATION PROGRAM



WESTERN WASHINGTON FISHERY RESOURCE OFFICE

OLYMPIA, WASHINGTON

APRIL 1992

An Evaluation of the Quilcene National Fish Hatchery Spring Chinook Salmon Restoration Program

Thomas R. Kane

U.S. Fish and Wildlife Service

Western Washington Fishery Resource Office

Olympia, Washington

April, 1992

Abstract

The Quilcene National Fish Hatchery spring chinook program began in 1978 as one of a number of approaches to restore severely depleted spring chinook stocks in Puget Sound. The program has been evaluated continuously since its inception. This report presents results through 1991 and includes broodyears 1981 through 1986. Hatchery production has contributed to sport and commercial fisheries in Washington and British Columbia. As concluded in earlier reports, the Quilcene program has suffered from a lack of source stock and is not yet returning to the hatchery at run maintenance levels. Tag recoveries from fisheries and hatchery returns to date average 0.29%. A 6-year cooperative evaluation program is in progress which will last through the 1993 brood year (1998 recovery year). The program addresses the influence of source stock and rearing location on total survival rates.

Table of Contents

Introduction

Quilcene National Fish Hatchery (NFH) is located in the Hood Canal region of western Washington, on the east side of the Olympic Peninsula. It is situated 4.5 kilometers (2.8 miles) from Quilcene Bay, at the confluence of the Big Quilcene River and Penny Creek. Since its authorization by Congress in 1909, the hatchery has raised a variety of fish species including: rainbow, brook, and cutthroat trout; fall chinook, sockeye, and pink salmon; steelhead; and its current production species - spring chinook, coho, and chum salmon. The Quilcene spring chinook program formally began in 1980, in accord with an interagency plan and agreement to preserve and enhance depressed spring chinook stocks in Puget Sound. Long range goals for Puget Sound spring chinook restoration include the use of a run established at Quilcene NFH as a source for restoration activities in Puget Sound rivers and for re-introductions of spring chinook into parts of their range where they no longer exist.

The first spring chinook stock used at Quilcene came from the Hood Canal State Fish Hatchery at Hoodsport, WA. This stock originated from a combination of races from the Green, White, Cowlitz, Umpqua, and Dungeness Rivers. Uncertain availability and uncertainty about run integrity from this stock led to an emphasis on other stocks starting with the 1981 broodyear. However, few local stocks have been abundant enough to contribute to the Quilcene program. The Service combined gametes from the Cowlitz (WA) and Nooksack rivers (WA) to augment the number of fish in the Quilcene program. From 1984 to 1988, smolt production came only from adults that returned to Quilcene.

The Hood Canal Production Evaluation Program (Point No Point Treaty Council, et al. 1989) was developed in part to answer questions of spring chinook stock suitability and rearing location effect. From the 1988 through 1993 broods, Quilcene NFH and Hood Canal State Fish Hatchery will raise both Quilcene and Soleduck (WA) stocks of spring chinook. This requires that approximately half the egg production at Quilcene be shipped to the Hood Canal Hatchery, that Soleduck stock eggs be supplied to both hatcheries, and that returning adults are spawned discretely according to stock of origin to maintain genetic integrity.

The production goal for Quilcene spring chinook under the Hood Canal Salmon Management Plan (Washington Department of Fisheries and Point No Point Treaty Council 1986) is 400,000 yearlings at 30 grams each and 200,000 subyearlings at 7 grams each. To maintain this goal, 500 adults must return annually. This goal has not yet been met.

Data Sources

Most of the life history and hatchery production data used in this report came from the Fisheries Resources Evaluation Database (FRED) maintained at the Western Washington Fisheries Resources Office, Olympia, Washington (US Fish and Wildlife Service 1991).

Coded wire tag recovery data came from the Pacific States Marine Fisheries Commission on-line database (Appendix A). Since Quilcene spring chinook recoveries are usually complete 5 years after spawning, tagging information reported through the 1986 broodyear is complete. Some recoveries reported by other agencies were not expanded to represent unsampled fish. This is allowable when either the total catch or sampling rate is unknown. For this report, I estimated these recoveries at a 20% sampling rate, the goal for coastwide sampling programs. No adjustments were made here for lost tags, lost heads, or sampled heads with no tag.

Release History

Quilcene National Fish Hatchery releases since 1983 (broodyear 1981) total over 1.6 million yearling spring chinook, representing 41 coded wire tag groups (Table 1). About half of all yearlings were coded wire tagged. Since 1987 (broodyear 1985), over 88 percent of the yearlings were tagged.

Some released tag groups released are not representative of the current practice of releasing yearlings in early May. Four tag groups of sub-yearling spring chinook were released in 1982, 1983, and 1984 (Table 2). Two tag groups of yearling spring chinook heavily infected with bacterial kidney disease were released in March, 1984 when the hatchery water supply was interrupted by gravel blocking the intake structure.

Tag Recovery

Data from the coastwide tagging database show that Quilcene spring chinook are caught mainly in fisheries off Vancouver Island and in Puget Sound (Table 3). Most fishery captures are of age three (39% of all fishery captures) and age four fish (54% of all fishery captures). Three year olds are caught in net and seine fisheries (30%) and in the sport fishery (55%). Four year olds are caught in troll (46%) and sport fisheries (47%). Thirty-five percent of the catch was in Canadian waters and 65% in US waters, primarily Puget Sound and the Strait of Juan de Fuca. Inferences about timing and location of catches in the fishery should be made cautiously. Season closures and regulation changes can influence capture location and timing. The data in Table 3 are not weighted by survival rate and represent all tagged yearling groups. Capture from yearclasses with high survival may over-represent capture site and timing. Total survival to fisheries and the hatchery rack of yearling tag groups has ranged from less than 0.01% to 0.56% (Table 4, Figure 1). Higher survival rates were seen for broodyears 1981, 1983, and 1986. Average total survival for the five broodyears with complete tag recoveries is 0.29%. Recovery data for tag groups other than yearling spring chinook released in May are presented in Table 2.

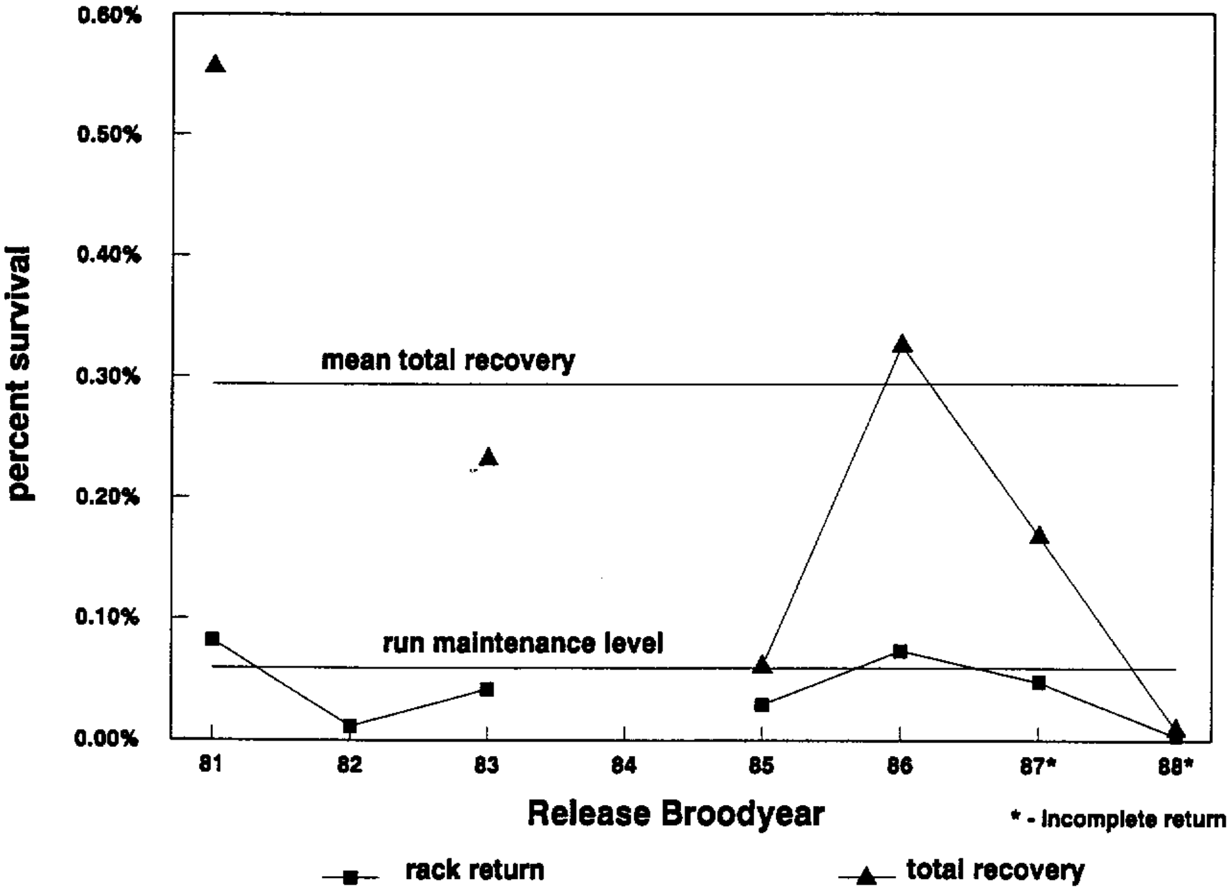


Figure 1. Total survival rate for Quilcene NFH spring chinook yearlings.

Hatchery Conditions

Standard Practices

Most adults enter the hatchery from mid-April through July. They are held through the summer until spawning season in a covered raceway receiving Big Quilcene River water. The adults are injected sub-cutaneously in the dorsal sinus with erythromycin phosphate at 11 mg/kg body weight during the summer holding period to control bacterial kidney disease infections. Fish returning after July 1 receive a single injection, fish returning before July 1 receive two injections. When injected, visual implant tags are also inserted into adipose eyelid tissue to identify individual fish. Adults are treated with a 1-hour, 200 ppm, formalin drip every 3 days throughout the summer to combat fungal infection. Adults are spawned from late August through September. Individual females are randomly paired with individual males to maximize genetic diversity. An individual male may be paired with more than one female in years when females outnumber males.

Primary incubation occurs in the hatchery building in individual colander incubator units fed with Penny Creek water. Water temperature ranges from 4°C to 12.5°C during incubation. The eggs are treated every 2 days with a 15-min, 167 ppm formalin drip for fungus prevention. At the eyed stage the eggs are shocked and picked with a mechanical egg picker. They are then transferred to Heath incubator trays. Hatch occurs in late October. First feeding begins in late November. The fish are fed BioDiet starter for one month, then converted to a diet of Oregon Moist Pellet.

The fish are moved to outside raceways in May. Fish are taken from the hatchery building, coded wire tagged, and then sent directly to the raceways from the tagging trailer at final rearing densities of about 18,000 fish per raceway. In the raceways, Big Quilcene River is the predominant water source. During late September and October and again from March through release, water from a saltwater well is added to the raceways to alleviate stress. This water is about 25‰ saline, and is usually less than 10% of the total flow. Throughout their hatchery life the fish are on single pass water flow, no serial reuse is involved.

In May of their second year the fish are released to the Big Quilcene River by removing the raceway screens and forcing the fish from the raceways. The release is usually done at night to reduce bird predation in the river and the estuary and about 2 hours before high tide to reduce stranding at the river mouth (Kenworthy et al. 1985). Spring chinook and coho yearlings are released within one day of each other to "swamp" any predators with prey and reduce the predation rate (Cardwell and Fresh 1979).

Rearing Densities

Raceway loading data were available from the FRED database for the 1986, 1987, 1988, and 1989 broodyears. Fish density as kilograms per cubic meter of available space varied between years (Figure 2), reflecting the different fish size between years (Table 1). The 1988 and 1989 broods had the highest densities seen. However, the density levels were still low relative to coho density. Spring chinook generally require much lighter densities than other salmonids (Joe Banks, US Fish and Wildlife Service, personal communication). One raceway of each stock of the 1988 brood held about half the normal number of fish to examine growth rates in low density rearing conditions. These fish did not show the anticipated increase in growth rate, but correlations between the low rearing density and tag recovery rates will be examined.

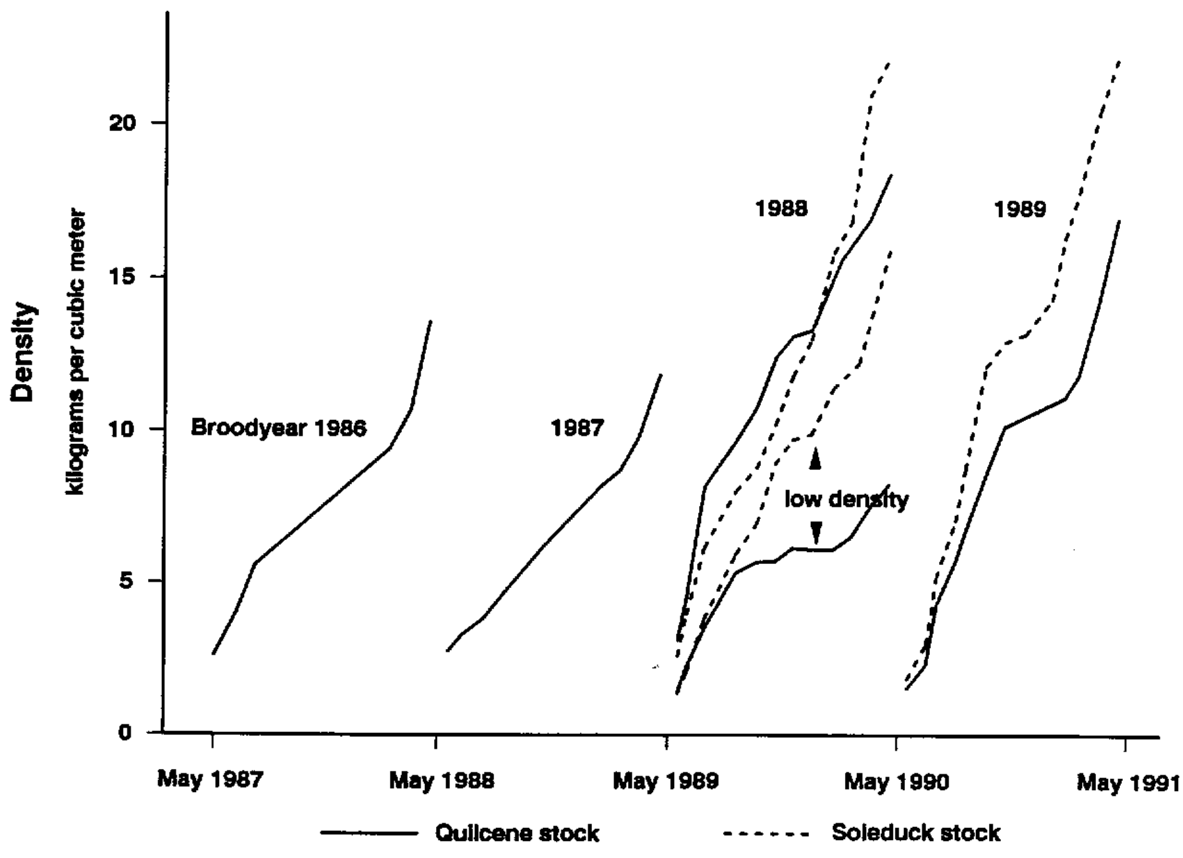


Figure 2. Raceway holding density, Quilcene NFH spring chinook.

Control of Bacterial Kidney Disease

Bacterial kidney disease (BKD), caused by *Renibacterium salmoninarum*, is a common stress-related problem in Pacific Northwest fish hatcheries using surface water supplies. Losses at the hatchery can be high and infected fish apparently do not survive well through smoltification. Before 1986 the hatchery staff attempted to control BKD by controlling fish size, which in turn would control the stress associated with a high rearing density. In 1986 (broodyear 1985), attempts to control hatchery mortality using antibiotics began. Fish received feed supplemented with oxytetracycline (Terramycin®) and erythromycin (Gallimycin®) during hatchery rearing. Antibiotics were fed to all broodyears from 1985 through 1989. Results to date show a survival benefit for the hatchery rearing phase, but no marine survival benefit is shown (Table 4). Differences in total survival for the 1985 brood are not significant by the non-parametric Wilcoxon's signed rank test ($T=4$) or the one-tailed t-test (treated mean = 0.063%, 95% confidence interval = 0.030% - 0.096%, control = 0.033%).

Similar antibiotic tests by the Oregon Department of Fish and Wildlife on five brood groups of spring chinook (Evenson and Ewing 1990) showed mixed results. Two broodyears showed higher survival for erythromycin-fed groups and three broodyears showed no difference. Evenson and Ewing theorized that the early treatments reduced the incidence of BKD to levels where antibiotic treatments in following years had no effect.

While antibiotic-treated fish from the 1985 Quilcene brood did not show an increased survival rate, they did live longer. Untreated control fish contributed to the fishery or returned to the hatchery rack at an average age of 3.12 years. Fish fed antibiotic averaged 3.71 years old ($SE=0.27$). The mean age at capture for treated fish differed significantly ($p \leq 0.05$) from the control mean age.

Residualism of Released Yearlings

During the first adult snorkel survey of 1991, divers observed many spring chinook yearlings still in the Big Quilcene River. This was on May 17, four days after the smolt release on May 13. During a foot survey on May 22, an estimated 21,000 fish (9% of the release) remained in the river. A sample of 57 tagged fish collected on May 24 revealed that 81% of the sample was Soleduck stock fish and 19% percent was Quilcene stock. Compared with the stock ratio at release (71% Soleduck:29% Quilcene) there was no significant difference by stock. Length and condition factor of the sampled fish were compared to raceway samples taken on May 10 (Table 5). The mean length of the post-release sample did not differ from the pre-release Soleduck stock, but was significantly greater than the pre-release Quilcene stock ($F_{2,230} = 39.9$, $p \leq 0.001$). The condition factors (K):

$$K = 10^5 * \frac{weight,\ g}{total\ length^3, mm}$$

of each group were significantly different from one another ($F_{2,230} = 55.9$, $p \leq 0.001$). The post-release fish had a higher mean condition factor than the pre-release fish.

As salmon near smoltification, condition factor drops. Chinook with higher condition factors at release also had a reduced tendency to migrate downstream. Some aspect of rearing practices or hatchery environment may have caused a physiological response in part of the hatchery population, causing a change in body form.

Adults

Return Timing

Entry timing to the river, based on snorkel survey graphs, differs little between years. Return timing to the hatchery rack differs between years (Table 6), probably due to differences in summer river temperature and flow. Based on 1984-1990 snorkel survey data (eliminating

1987, when limited surveying was done), regression of cumulative percent of adults entering the river on observation date ($\hat{Y}$) yields:

$$\hat{Y} = (-8.0506 * 10^{-7})X^3 + 0.000385X^2 - 0.05X + 2.00$$

$$r^2 = 0.90$$

$$Std.\ Err.\ of\ \hat{Y} = 0.120$$

where X is the Julian day of the year, Jan 1 = 1, Dec 31 = 365 (Figure 3).

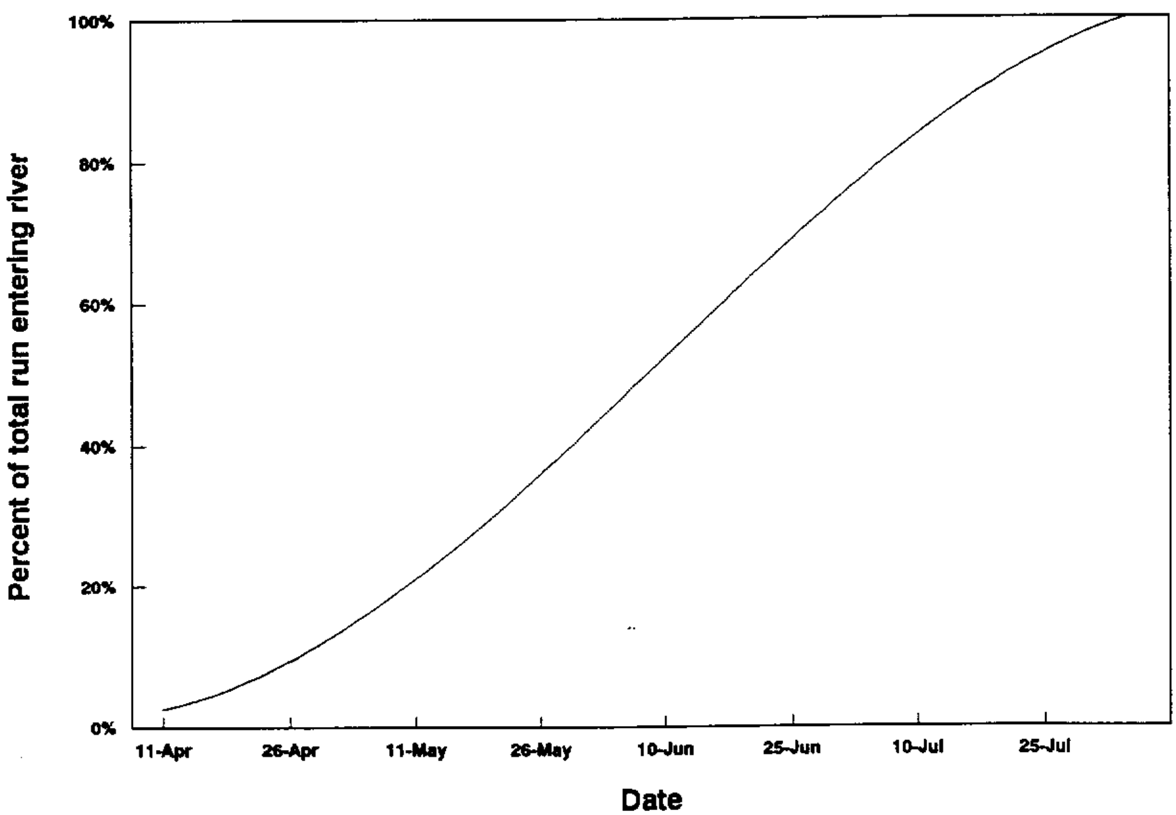


Figure 3. Spring chinook adult entry timing to Quilcene River, from snorkel surveys.

Holding Mortality

During the four month period when adults are held before spawning, mean mortality is 7.1% (Table 7). Seventy-six percent of this pre-spawning mortality is female. Beginning in 1986 adults were injected with erythromycin to reduce mortality from bacterial kidney disease and reduce the chance of vertical disease transmission to the eggs.

Age

Adult ages determined from scale samples taken at spawning or pre-spawning mortality show that just under half of the fish returning to the hatchery were four-year-olds, about one quarter were three-year-olds, and one quarter were five-year-olds (Table 8, Table 9). This differed from the ages of fish caught in the fisheries, where age composition was 39% three-year-old, 54% four-year-old, and 6% five-year-old (Table 3). Three-year-old fish are usually male and five-year-olds are usually female. Mean age for males returning to the hatchery rack from release broodyears 1982 to 1986 ranged from 3.31 to 4.04 years (Table 10). Mean age for females ranged from 4.24 to 4.91 years.

Spawning

For broodyears 1986-1991, spawning dates ranged from August 11 to October 3 (Table 11). The mean spawning date, weighted by the number of fish spawned per day was September 7. In 1986, the hatchery staff used five two-year-old jacks with the 45 adult males in spawning the 45 females.

Effective Population Size

Spawning of spring chinook at Quilcene is usually done by pairing individual fish. Considering the number of adults spawned since 1985 (Table 11), the calculated effective population size

(Simon et al. 1986) is 46. This is below any suggested minimum population size required to minimize the effects of inbreeding depression (Kapuscinski and Jacobson 1987). Tave (1986) recommends at least 424 parents for populations used in fishery management programs. The current calculated rate of inbreeding for the Quilcene population at an effective population size of 46 is 1.1%. While this is a relatively low rate of inbreeding, the combination of effective population size and inbreeding rate will lead to much higher rates of inbreeding after 75 years. Under the Hood Canal Production Evaluation Program, Soleduck and Quilcene stock adults that return to the hatcheries will be spawned and reared discretely, so neither stock will influence the genetics of the other.

Discussion

Recent production at Quilcene has averaged about 3,450 smolts per female spawned. At this production rate, a 0.058% rack return is necessary to maintain the current run size of about 120 fish, which is below the program goal of 500 returning adults. Return to the rack has averaged 0.047% (Table 9). Only the returns from broodyears 1981 and 1986 have exceeded the run maintenance level. Hiss, et al. (1988) based projections of catch and escapement for Quilcene spring chinook on the highest three years of yearling survival data (0.38% total survival). Releases of all groups of spring chinook in this report average 0.29% total survival to date. The outlook for the program is not optimistic if past trends continue.

In relation to other spring chinook programs in Puget Sound, results for the Quilcene program are poor. Mean total tag recovery rates (one value per brood year, only brood years through 1986) for other yearling release programs in Puget Sound have been: Hupp Springs (Minter Creek, Kitsap County), 1.98%; Nooksack, 0.55%; Skagit, 0.57%; and Skookum Creek (South Fork Nooksack), 2.19% (Table 12). The combined mean recovery for these programs is 1.32%. One obvious difference between these programs and Quilcene's is the fish size at release. Quilcene fish are generally smaller. Release timing is similar between the groups. Releases from Quilcene in recent years have been of larger fish (Table 1). Expectations are that increased returns will result from the larger release size.

Some sport fishing regulations are meant to address the Quilcene program. The current closure of Quilcene and Dabob Bays from April 16 through August 15 assures that fish returning to the Quilcene River can pass through these local waters. The springtime 30 inch (762 mm) maximum length limit in the Strait of Juan de Fuca and the San Juan Islands may be effective in protecting five-year-old fish from sport harvest. Since there is no sampling conducted to determine the origin of released sport caught fish, we cannot be certain of the success of the 30-inch limit. Few five-year-old fish are reported in the catch, so it may be that they are not taken by either the sport or commercial fisheries. These five-year-old fish are predominantly female. They produce more eggs and resultant smolts than four-year-old females. These fish are important to successful restoration, given the poor rack return rates.

Early marine survival is the most important aspect determining total survival in unimpounded river systems. Quilcene spring chinook usually do not survive well enough to be strongly represented in fisheries that target three-year-old fish. Once a yearclass displays poor survival to these fisheries, they are also poorly represented in fisheries on four-year-olds and at the hatchery rack. Conversely, yearclasses that are strongly represented in early fisheries return strongly in subsequent years.

Early Marine Survival Factors

The causes of early ocean mortality are still speculative. Potential sources include predation by fish, birds, or marine mammals; disease; osmoregulatory incapacity; outmigration orientation; lack of forage; genetic maladaption; or a synergistic combination of factors. It should be noted that the coho salmon released at the same time as the spring chinook have a relatively high marine survival rate. Since both are subjected to the same environmental and predation factors, there must be a species-related difference in their response to those factors.

Predation

In most years, smolt size is not a critical factor in survival. In years when the regular prey (mostly herring) of predators is not abundant, predators may switch to alternative sources (Holtby et al. 1990). Then, smaller salmon are more vulnerable to predation. Recent unpublished Canadian studies suggest that hake and dogfish are major predators on salmonids. Published literature does not support the idea that hake are major predators on salmon, but sampling may not have occurred during salmon outmigrations.

Schooling behavior is important in reducing predation. Larger school size reduces the probability of individual capture. Recent releases of spring chinook at Quilcene have coincided with releases of coho from Quilcene to "swamp" predators with potential prey and reduce predation.

Marine mammal populations increased coastwide since passage of the Marine Mammal Protection Act in 1972. Published literature reports only minor predation upon young salmon by marine mammals. As mentioned above, sampling may not have occurred during salmon outmigrations. Knudsen et al. (1990) observed harbor seals feeding at the mouth of the Big Quilcene River coincidental to spring chinook and coho smolt releases from Quilcene NFH. Actual consumption of salmon smolts could not be verified and they beleived that predation by gulls and herons was probably of a higher magnitude than seal predation.

Disease and Osmoregulation

Gills, kidneys, and skin are the major organs controlling ion flux in migrating salmonids. Bacterial kidney disease infections can severely compromise osmoregulation in fish. The damage caused by bacterial lesions in the kidney interferes with ion exchange. Spring chinook infected with bacterial kidney disease have shown limited ability to survive even the stress of migration in fresh water (Rondorf et al. 1988).

Smaller fish have a higher surface area to body volume ratio than larger fish. With more skin and gill surface area relative to their internal body volume, the higher hypo-osmotic differential on a small fish can make the transition to the ocean environment more difficult. The smaller size at release for Quilcene spring chinook relative to other Puget Sound spring chinook hatchery programs could help explain the lower marine survival rates.

Migration

On release from Quilcene NFH, fish follow the river to Quilcene Bay. The geography of Dabob and Quilcene Bays forces the fish to move about 11 miles south before they can enter Hood Canal. The currents in Hood Canal then provide some orientation for the migrating fish to enter Puget Sound and the Strait of Juan de Fuca. The tidal magnitude and inflow to Hood Canal allow for an exchange of only 2.3% of the total volume with each tidal cycle. Annual freshwater inflow to the Canal is only 16% of the total volume of the Canal. If spring chinook have an innate tendency to migrate toward the northwest, they could become trapped in Dabob Bay before finding Hood Canal. The low inflow and geographic character of Dabob Bay could slow migration out of Hood Canal and subject fish to increased near-shore predation.

Forage

It may be that spring chinook require some food items that are not available in the near marine environment when they are released. If so, they could suffer from a reduced growth rate which would subject them to increased predation pressure.

Genetics

The transplanted stocks used at Quilcene came from locations remote to Hood Canal and would produce fish with expected lower survival (Reisenbichler 1988). Crossing geographically separate stocks should also be of limited success. Hybrid populations resulting from even hundreds of such matings rarely contain individuals with the original parental genotypes (Hindar et al. 1991). Although the original genes persist in the hybrid population, the successful combinations of genes expressed in the parent population become mixed. The progeny survive poorly in either of the original environments.

From a genetics standpoint, the future of the spring chinook program at Quilcene is bleak. Since the Hood Canal Production Evaluation Program was begun, genetic studies have shown that Soleduck stock has a genetic profile of coastal stocks - not Puget Sound stocks. Even if the Soleduck stock were successful at Quilcene, genetic stock identification and harvest management concerns may restrict its use.

Recommendations

As the Service is in the middle of the long-term, cooperative Hood Canal Production Evaluation Program involving Quilcene spring chinook, little can be done in the way of substantial program changes until 1995. The evaluation program will help determine if the problems encountered at Quilcene are caused by the stock, the rearing location, or the fish size at release. If the stock is determined to be a limiting factor, then a new source stock must be located. The lack of sufficient source stock has been a problem for the Quilcene program since its inception. Restoration programs coastwide have the common problem of too small gene pools to implement restoration. If the rearing location is the limiting factor, then a solution requires re-programming of hatchery production to accomplish spring chinook restoration goals. If fish size is the limiting factor, then hatchery production methods will need to be changed to produce larger fish. Once the Hood Canal Production Evaluation Program is completed, the Service and its cooperators should re-examine Puget Sound spring chinook restoration and the role of Quilcene National Fish Hatchery in that restoration. New understandings of genetics, wild stocks, harvest management, and inter-basin transfers will change some of the underlying assumptions used to develop the original restoration strategies in the late 1970s.

In the short term the following recommendations are given for the Quilcene program:

Culture techniques

- Reduce pre-spawning mortality. Even though the mortality is less than ten percent, the percentage of females that do not survive to spawning is of concern. Success requires as many breeding females as possible to build a suitable run.
- Continue to address the impacts of bacterial kidney disease. Minimize stress and loading factors during all phases of production.
- Target production to fish over 40 grams (11.3 fish per pound) raised at density levels below 12 kg/m^3 (0.75 $pounds/ft^3$).

Evaluation

- Continue the Hood Canal Production Evaluation Program through broodyear 1993. This will affect production through 1995, and tag recovery will be complete in 1998.
- Continue coded wire tagging of all production fish to evaluate restoration progress.
- Initiate efforts to identify physiological or hatchery environmental limits to survival.

- Monitor condition factor during the last months at the hatchery.
- Monitor migration timing out of the Quilcene River.
- Begin efforts to determine the short-term marine fate of smolts.

    Identify and enumerate predators.

    Document smolt travel routes, timings, and related environmental conditions in Quilcene Bay, Dabob Bay, and Hood Canal.

Genetics

The reality of spring chinook stock status in Puget Sound will probably continue to prevent us from using a pure local stock of spring chinook for run development. In this case:

- Continue to spawn all returning adults individually to maximize genetic input.
- Investigate fractional spawning as a means of increasing the effective population size.

Successful results achieved in other Puget Sound drainages may make donor stock available. If this should happen:

- Maintain any donor stock as a discrete, pure stock throughout rearing and spawning.
- Use a gene pool from at least 200 pairs to found any donor contribution.

To augment the number of eggs available for building a run:

- Consider keeping part of either Quilcene stock or a pure donor stock as a captive broodstock to augment future egg supplies.

Bibliography

Cardwell, R.D., and K.L. Fresh. 1979. Predation upon juvenile salmon - Draft#8. Washington Department of Fisheries Mimeo.

Evenson, M.D., and R.D. Ewing. 1990. Annual progress report, fish culture project, Oregon. Project number AFS-78-1. Cole Rivers Fish Hatchery Evaluation. Oregon Department of Fish and Wildlife, Portland, Oregon.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural populations. Canadian Journal of Fisheries and Aquatic Sciences. 48:945-957.

Hiss, J.M., D.P. Zajac, and E.E. Knudsen. 1988. The spring chinook program at Quilcene National Fish Hatchery, 1981-1987, and projections of catch and escapement to the year 2010. US Fish and Wildlife Service, Fisheries Assistance Office, Olympia, WA.

Holtby, L.B., B.C. Andersen, and R.K. Kadowski. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 47:2181-2194.

Kapuscinski, A.R., and L.D. Jacobson. 1987. Genetic guidelines for fisheries management. University of Minnesota, Minnesota Sea Grant publication M/P 5.

Kenworthy, B., J.H. Meyer, and R.S. Boomer. 1985. Quilcene National Fish Hatchery outmigrant evaluation study. US Fish and Wildlife Service, Fisheries Assistance Office, Olympia, WA.

Knudsen, E.E., J. Calambokidis, and A. Erickson. 1990. Predation of salmonid smolts by harbor seals in Quilcene Bay, Washington. US Fish and Wildlife Service, Fisheries Assistance Office, Olympia, WA.

Pacific States Marine Fisheries Commission. 1992. Coastwide tagging database, on-line system. Portland, Oregon.

Point No Point Treaty Council, United States Fish and Wildlife Service, and Washington Department of Fisheries. Hood Canal Production Evaluation Program. Memorandum of Understanding. August 15, 1989.

Reisenbichler, R.R. 1988. Relation between distance transferred from natal stream and recovery rate for hatchery coho salmon. North American Journal of Fisheries Management. 8:172-174.

Rondorf, D.W., J.W. Beeman, M.E. Free, and D.E. Liljegren. 1988. Correlation of biological characteristics of smolts with survival and travel time. DOE-BPA-US Fish and Wildlife Service DOE/BP-35245-1, Project No. 87-406, Annual Report FY 1987.

Simon, R.C., J.D. McIntyre, and A.R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 43:2434-2442.

Tave, D. 1986. Genetics for fish hatchery managers. AVI Publishing, Westport, CT.

US Fish and Wildlife Service. 1991. Fisheries Resources Evaluation Database. Western Washington Fisheries Resources Office, US Fish and Wildlife Service, Olympia, Washington.

Washington Department of Fisheries and the Point No Point Treaty Council. 1986. Hood Canal Salmon Management Plan. US District Court, US v. Washington #9213, sub-proceeding 83-8.

Table 1. Quilcene NFH spring chinook yearling tag groups released.

Release date	Brood year	Tagcode	Fish size (g)	Fish released		
				Tagged	Adipose only	Unmarked
5/ 9/83	81	051033	38.1	28,442	2,010	124,599
5/14/85	83	051452	44.5	26,974	2,378	25,937
5/15/85	83	051453	26.4	25,737	3,543	372,450
5/14/86	84	-	18.7	0	0	27,695
5/ 8/87	85	050832	19.7	25,442	2,640	787
5/ 8/87	85	051462	19.7	27,606	2,014	830
5/ 8/87	85	051748	19.7	21,811	3,580	712
5/ 8/87	85	051749	19.7	20,694	3,680	683
5/ 8/87	85	051750	19.7	18,637	5,504	677
5/ 8/87	85	051831	19.7	22,951	2,924	725
5/ 8/87	85	051832	19.7	22,388	3,736	733
5/ 8/87	85	051833	19.7	22,862	3,236	732
5/10/88	86	051911R3	22.5	127,819	5,187	3,140
5/10/89	87	051959R3	26.4	47,434	1,879	6,259
5/10/89	87	051961R3	26.4	37,667	1,962	5,030
5/10/89	87	051962R3	26.4	17,545	817	2,331
5/ 7/90	88	052121R3	30.9	21,318	888	6,360
5/ 7/90	88	052122R3	30.9	20,628	1,317	6,285
5/ 7/90	88	052125R3	30.9	18,613	1,861	5,864
5/ 7/90	88	052126R3	30.9	19,227	2,437	6,205
5/ 7/90	88	052150R3	30.9	8,965	806	2,799
5/ 7/90	88	052128R3	41.7	19,932	564	0
5/ 7/90	88	052131R3	41.6	20,038	835	0
5/ 7/90	88	052132R3	41.7	18,887	1,099	0
5/ 7/90	88	052135R3	41.7	14,433	680	0
5/ 7/90	88	052152R3	41.7	10,415	844	0
5/13/91	89	052405	45.4	9,214	104	328
5/13/91	89	052406	45.4	8,413	95	300
5/13/91	89	052407	45.4	9,414	347	344
5/13/91	89	052408	45.4	8,906	329	325
5/13/91	89	052409	45.4	8,576	420	317
5/13/91	89	052410	45.4	9,020	442	333
5/13/91	89	052411	45.4	9,301	269	337
5/13/91	89	052357	56.7	17,512	764	0
5/13/91	89	052358	56.7	17,245	1,358	0
5/13/91	89	052359	56.7	18,669	292	0
5/13/91	89	052360	56.7	18,292	181	0
5/13/91	89	052361	56.7	17,840	193	0
5/13/91	89	052362	56.7	17,457	153	0
5/13/91	89	052363	56.7	18,269	278	0
5/13/91	89	052448	56.7	18,241	0	0
5/13/91	89	052449	56.7	15,150	51	0

Table 2. Quilcene NFH atypical release spring chinook tag groups, release and recovery data.

Release date	Brood year	Tagcode	Stock	Fish size (g)	Fish released: Tagged	Fish released: Adipose only	Fish released: Unmarked	Tags recovered	Expanded recovery	Total recovery
sub-yearlings										
10/22/82	81	051017	Cowlitz x NF Nooksack	26.2	27,286	2,898	122,061	0	0	0.00%
6/ 3/83	82	051419	Cowlitz x SF Nooksack	4.9	46,505	5,225	198	19	40	0.09%
6/ 4/84	83	051426	Cowlitz x SF Nooksack	6.8	47,023	4,537	0	7	18	0.04%
6/ 4/84	83	051454	Cowlitz x NF Nooksack	6.8	47,880	4,909	97,603	12	29	0.06%
yearlings, early release										
3/20/84	82	051347	Cowlitz x NF Nooksack	47.3	18,972	4,450	86,342	0	0	0.00%
3/20/84	82	051348	Cowlitz x SF Nooksack	36.3	24,820	1,697	191,316	3	14	0.06%

Table 3. Catch of Quilcene NFH spring chinook in fisheries, yearling tag groups.

		Caught at age 3		Caught at age 4		Caught at age 5	
	Fishery	Peak month	Percent of catch	Peak month	Percent of catch	Peak month	Percent of catch
Canada	Ocean sport	August	11%	June	7%	June	9%
	Ocean troll	August	2%	July	28%	July	34%
	Mixed net and seine	August	17%	July and Sept	3%	-	-
Washington	Sport	Sept and Dec	44%	Mar and May	40%	May	34%
	Treaty troll	December	9%	January	17%	March	19%
	Ocean troll - non-treaty	-	-	June	1%	May	4%
	Mixed net and seine	Aug - Sept	13%	Aug - Sept	1%	-	-
California	Ocean troll	July	4%	-	-	-	-
Alaska	Ocean gillnet	-	-	June	1%	-	-
		N = 303 fish		N = 420 fish		N = 47 fish	

Table 4. Quilcene NFH spring chinook yearling releases tag recovery - data to 3/12/92.

Tagcode	Brood year	Stock	Treatment	Tags recovered	Expanded recovery	Total recovery
			complete recovery data			
051033	81	Cowlitz x SF Nooksack	-	69	158	0.56%
051452	83	Cowlitz x NF Nooksack	-	36	85	0.32%
051453	83	Cowlitz x SF Nooksack	-	17	36	0.14%
050832	85	Quilcene	control	3	8	0.03%
051462	85	Quilcene	erythromycin-fed	7	11	0.04%
051831	85	Quilcene	erythromycin-fed	1	1	0.00%
051832	85	Quilcene	erythromycin-fed	5	23	0.10%
051833	85	Quilcene	erythromycin-fed	6	11	0.05%
051748	85	Quilcene	erythromycin-fed	2	8	0.04%
051749	85	Quilcene	erythromycin-fed	9	15	0.07%
051750	85	Quilcene	erythromycin-fed	11	25	0.13%
051911R3	86	Quilcene	mixed, antibiotic-fed and unfed	165	415	0.33%
			incomplete recovery data			
051959R3	87	Quilcene	erythromycin-fed	30	55	0.12%
051961R3	87	Quilcene	terramycin-fed	33	78	0.21%
051962R3	87	Quilcene	control	13	38	0.22%
052121R3	88	Quilcene	erythromycin-fed	1	1	0.01%
052122R3	88	Quilcene	erythromycin-fed	1	3	0.02%
052125R3	88	Quilcene	erythromycin-fed	1	2	0.01%
052126R3	88	Quilcene	erythromycin-fed	3	5	0.03%
052150R3	88	Quilcene	erythromycin-fed, low rearing density	2	2	0.02%
052128R3	88	Soleduck	erythromycin-fed	0	0	-
052131R3	88	Soleduck	erythromycin-fed	0	0	-
052132R3	88	Soleduck	erythromycin-fed	0	0	-
052135R3	88	Soleduck	erythromycin-fed	0	0	-
052152R3	88	Soleduck	erythromycin-fed, low density rearing	0	0	-

Table 5. Quilcene NFH spring chinook, 1989 broodyear, length and condition factors.

	Mean length, mm (std error)	K factor (std error)
Post-release sample	178.9 (2.42) [a*]	1.044 (0.011) [x]
Soleduck stock, pre-release	179.9 (2.30) [a]	0.934 (0.011) [y]
Quilcene stock, pre-release	153.2 (2.57) [b]	0.897 (0.007) [z]

[*] Values followed by different superscripts are different from each other at $p \leq 0.001$.

Table 6. Spring chinook adult entry into Quilcene NFH.

Return year	Mean hatchery entry date
1987	July 2[a*]
1988	July 2[a]
1989	July 22[b]
1990	Aug 20[c]

[*] Dates followed by different superscripts are different from each other at $p \leq 0.01$.

Table 7. Quilcene NFH spring chinook, adult holding mortality.

	Pre-spawning mortality		
Return year	Number	Percent mortality	Percent female
1986	12	5.9%	50%
1987	5	4.6%	80%
1988	18	14.2%	94%
1989	4	3.1%	100%
1990	3	5.2%	100%
1991	3	9.4%	33%
mean		7.1%	76%

Table 8. Quilcene NFH spring chinook, returns to hatchery rack and river - by return year.

Return year	Age at return 2	3	4	5	6	Unknown	Total for year
1985	0	5	133	15	0	0	153
1986	7	113	16	68	0	0	204
1987	0	8	84	16	1	0	109
1988	0	14	40	73	0	0	127
1989	0	55	42	26	0	4	127
1990	5	34	32	5	0	1	77
1991	2	0	21	11	0	0	34
mean	1%	28%	44%	26%			119

Table 9. Quilcene NFH spring chinook, returns to hatchery rack and river - by release broodyear.

Brood year	Age at return 2	3	4	5	6	Total for yearclass	Percent return to rack
1981	26	20	133	68	1	248	0.081%
1982	0	5	16	16	0	37	0.010%
1983	0	113	84	73	0	270	0.041%
1984	7	8	40	26	0	81	-
1985	0	14	42	5	0	61	0.028%
1986	0	55	32	11	-	98	0.072%
1987	0	34	21	-	-	57	0.047%
1988	5	0	-	-	-	-	-
mean	3%	26%	47%	24%		122	0.047%

Table 10. Quilcene NFH spring chinook mean age and length of adults returning to hatchery rack.

Release brood year	Males: Mean age, years	Males: Mean fork length, mm	Females: Mean age, years	Females: Mean fork length, mm
1982	4.04	703	4.91	855
1983	3.36	550	4.68	805
1984	3.51	575	4.55	795
1985	3.65	671	4.24	766
1986	3.39	551	4.46	739

Table 11. Quilcene NFH spring chinook, numbers spawned and date spawned.

Brood year	Number spawned: Males	Number spawned: Females		Spawning date: Weighted mean	Spawning date: Range
1985	48	58		-	-
1986	50	45		Sept. 13	Aug. 25 - Oct. 2
1987	36	37		Sept. 7	Aug. 20 - Sept. 29
1988	36	56		Sept. 3	Aug. 11 - Sept. 27
1989	32	32		Sept. 13	Aug. 29 - Oct. 3
1990	10	10		Sept. 3	Aug. 17 - Sept. 12
1991	14	10		Sept. 1	Aug. 23 - Sept. 10
			mean	Sept. 7	

Table 12. Other Washington State spring chinook programs tag recovery, data to 3/12/92.

Tag code	Brood year	Hatchery	Size at release (g)	Tags recovered	Expanded recovery	Total recovery	Mean recovery
			yearling releases				
634161	86	Cowlitz	75.6	960	2173	1.53%	
632047	79	Hupp Springs	90.7	44	171	0.35%	
632136	80	Hupp Springs	50.4	107	244	1.25%	
632604	81	Hupp Springs	90.7	19	31	0.08%	
632853	82	Hupp Springs	64.8	302	707	3.86%	
633050	83	Hupp Springs	64.8	243	563	3.31%	1.98%
633049	83	Hupp Springs	64.8	252	549	2.80%	
632508	84	Hupp Springs	90.7	117	207	0.62%	
633060	84	Hupp Springs	90.7	10	14	0.18%	
633131	85	Hupp Springs	56.7	981	1574	6.49%	
633648	85	Hupp Springs	56.7	409	721	3.38%	
633246	86	Hupp Springs	73.2	62	151	0.52%	
634145	86	Hupp Springs	73.2	155	428	0.90%	
632411	81	Kendall Creek	47.3	195	478	0.89%	
632546	82	Kendall Creek	60.5	15	37	0.34%	0.55%
633453	84	Kendall Creek	70.9	317	643	1.22%	
633452	84	Kendall Creek	70.9	344	677	1.30%	
633248	86	Kendall Creek	56.7	4	12	0.04%	
633336	86	Kendall Creek	56.7	2	15	0.05%	
633247	86	Kendall Creek	56.7	2	7	0.02%	
632606	81	Skagit	28.4	70	136	1.43%	
632607	82	Skagit	34.9	102	279	0.48%	
632608	83	Skagit	28.4	25	65	0.18%	0.57%
633354	84	Skagit	34.9	27	57	0.43%	
633353	84	Skagit	34.9	36	72	0.54%	
633314	86	Skagit	40.1	87	307	0.38%	
050838	80	Skookum Creek	50.4	72	238	0.92%	
050946	81	Skookum Creek	64.9	292	757	2.98%	2.19%
050634	81	Skookum Creek	64.9	185	605	2.66%	
633322	86	Soleduck	141.8	314	1061	1.59%	
			subyearling releases				
633905	86	Hupp Springs	8.3	27	48	0.33%	
633904	86	Hupp Springs	8.3	26	44	0.30%	
633123	85	Skagit	6.5	84	130	0.22%	
050837	80	Skookum Creek	7.1	110	344	0.74%	
051418	82	Skookum Creek	15.1	118	370	1.82%	

Appendix A. Status of the coastwide database tag recovery data sets used for this report, Pacific Salmon Commission (PSC) format (Pacific States Marine Fisheries Commission 1992).

24 FEB 1992 CWT RECOVERY DATA SETS AVAILABLE IN PSC RECOVERY FILES

	RECOVERY AGENCY											
YEAR	CDFG	ODFW	WDF	WDW	IDFG	CDFO	ADFG	FWS	NMFS (AK)	NIFC	QDNR	METL
77	NR	V	V		NR	V	NR		NR	V	V	
78	V	V	V		NR	V	NR		NR	V		
79	V	V	V		NR	V	NR	V		V	V	
80	V	V	V		NR	V	V	V	NR	V	V	
81	V	V	V	I	NR	V	V	V	NR	V	V	
82	V	V	V	I	NR	V	V	V	NR	V	V	I
83	V	V	V	I	NR	V	V	V	NR	V	V	I
84	V	V	V	I	NR	V	V	V	NR	V	V	I
85	V	V	V	I	NR	V	V	V	NR	V	V	I
86	V	V	V	I	NR	V	V	V	NR	V	V	I
87	V	V	V	I	NR	V	V	V	S	V	V	I
88	V	V	V	I	NR	V	V	V	NR	V	V	I
89	V	V	V	I	NR	V	V	I	NR	V	V	I
90	V	V	V	NR	NR	V	V	V	NR	V	S	I
91	I	I	I	I	NR	I	I	NR	NR	NR	NR	I

I Incomplete data set (but available data is validated and online)

V Fully (Finalized) Validated and online data set

S Submitted but not yet validated data set

NR NOT REPORTED AT THIS TIME IN PSC FORMAT

INCOMPLETE DATA SETS

1) WDW's recoveries in the main stem Columbia River have been reported through ODFW. However, recoveries in Columbia River basin tributaries and Puget Sound are unreported.

2) Metlakatla (METL) has reported recoveries for its fisheries through ADFG. However, hatchery returns are unreported at this time.

ADFG - Alaska Department of Fish and Game
CDFG - California Department of Fish and Game
CDFO - Canada Department of Fisheries and Oceans
FWS - US Fish and Wildlife Service
IDFG - Idaho Department of Fish and Game
METL - Metlakatla Indian Community, Alaska
NIFC - Northwest Indian Fisheries Commission
NMFS - National Marine Fisheries Service
ODFW - Oregon Department of Fish and Wildlife
QDNR - Quinault Department of Natural Resources
WDF - Washington Department of Fisheries
WDW - Washington Department of Wildlife