# QUILCENE SPRING CHINOOK: A CASE STUDY OF LIMITATIONS TO PUGET SOUND SPRING CHINOOK RESTORTATION

E. Eric Knudsen, Joseph M. Hiss, and David P. Zajac

U.S. Fish and Wildlife Service
Fisheries Assistance Office
2625 Parkmont Lane
Olympia, Washington 98502

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## INTRODUCTION

The U.S. Fish and Wildlife Service has been involved in western Washington spring chinook salmon restoration since 1978. We have cooperated with the Washington Department of Fisheries (WDF) and local tribes on the Nooksack, White, Dungeness, Queets, and Chehalis rivers on a variety of spring chinook projects. Our most concerted effort, however, has been to establish a spring chinook broodstock at Quilcene National Fish Hatchery on northern Hood Canal. As stated in the Hood Canal Salmon Management Plan, the spring chinook goal at Quilcene is production of smolts at a level providing enough adult returns to allow a surplus to hatchery broodstock requirements. This surplus would initially be stocked into the Skokomish River and other Hood Canal tributaries to rebuild natural stocks and provide recreational and commercial fishing opportunities. Although the program was initiated 10 years ago, and between 120,000 and 450,000 smolts of imported stocks were release annually during the first brood cycle, hatchery escapements have been 200 or less, far below the goal of 500 adults. We believe the low escapement is primarily due to low marine survival (Hiss et al. 1988).

We decided to further investigate potential causes for poor broodstock returns and possible management alternatives for dealing with, or compensating for, those low returns. To do this, we first outlined the causes and possible remedies for low survival and then we developed a simple spreadsheet model to help us evaluate the relative benefits of various courses of action. Since all other Puget Sound spring chinook stocks continue to remain depressed (Puget Sound Treaty Indian Tribes et al. 1987) and are not responding rapidly to restoration measures, we believe the concepts discussed and evaluated in this paper generally apply to all Puget Sound stocks.

## POOR BROODSTOCK RETURNS

Most spring chinook at Quilcene Hatchery have been released as yearlings in May. The three yearling tag groups known to have not suffered extreme disease problems or to have had any other obvious rearing problems exhibited an average total survival to the fishery and escapement of 0.38% (Table 1). This is somewhat below the median survival for other Puget Sound yearling spring chinook programs which ranged from 0.27 to 4.11% (Paul Seidel, WDF, personal communication). (Marine survival is here defined as the number of survivors from hatchery release to either the fishery or spawning escapement.)

Poor hatchery returns can be due to natural or fishing mortality or both. We reviewed causes of marine mortality, factors controlling mortality, and management practices which can effect mortality (Figure 1). Some marine mortality causes, such as weather and ocean conditions, are so far beyond human control, that there is no hope of managing them. Other factors may be more manageable, however. As can be seen in Figure 1, there may be management alternatives at least partially addressing disease, predation, pollution, and habitat losses. All spring chinook management can benefit from increased applied research addressing any of the causes, controlling factors, or management practices. For example, Fish and Wildlife Service studies are underway to determine the effects of, and treatment for, bacterial kidney disease, thought to be a possible cause for major reductions in available Quilcene spring chinook adults. Other ongoing research indicates adult spring chinook returning to the Quilcene River are being lost to harbor seals near the river mouth. Poaching is also listed in Figure 1 under predation because poaching losses are essentially counted as marine mortality.

Fishery interceptions also reduce adult returns to the hatchery (Figure 1). We examined contribution patterns of Quilcene spring chinook based on tag recoveries for the apparently healthy yearling tag groups (Table 2). On average, 50% of the total fishery interceptions were in Puget Sound sport catches, 39% in Canadian fisheries, and 11% were incidental catches in Puget Sound nets. Fishery management alternatives to allow more fish to escape to the hatchery are listed in Figure 1.

## MODEL-BASED PREDICTIONS

To investigate the relative efficacy of various management options, we designed a simple spreadsheet model for Quilcene Hatchery spring chinook. The model was designed to estimate catches, hatchery returns, and subsequent releases based on the average of the best available survival estimates from coded wire tagging (Table 1).

The generalized model can best be expressed as:

$$F_i = \sum_j (HS_{ij} * REL_j * FR_{ij})$$

where $F_i$ is the number of females returning in year i, $HS_{ij}$ is average survival to escapement in year i for j release years, $REL_j$ is release group size in year j, and $FR_{ij}$ is the female to male ratio in year i for release year j. FR was 0.44 for age four, 0.76 for age five, and 0.0 for other ages, as observed from all returns at Quilcene Hatchery.

Actual release values were used through 1989. Subsequent releases were estimated by:

$$REL_j = F_{i-2} * 2{,}750$$

where $F_{i-2}$ is the number of females which returned 2 years earlier. The value of 2,750 smolts produced per returning female was the greatest value observed at Quilcene Hatchery. At the outset, we varied this production rate widely and found the model to not be overly sensitive to it.

Total catches were estimated by:

$$TC_i = \sum_j (FS_{ij} * REL_j)$$

where $FS_{ij}$ is average survival to the fishery in year i for release year j.

Total hatchery returns were estimated by:

$$TR_i = HS_{ij} * REL_j.$$

We ran simulations and examined trends in hatchery returns and catches under a number of scenarios. In these scenarios we assumed 1) a constant relation between number of females and subsequent smolts, 2) survival rates are accurate and will remain constant, 3) any supplemental stocks will exhibit the same survival rates as the Quilcene stock, and 4) any fish not caught because of a reduction in fishing effort would survive to escape to the hatchery the same year.

**No action** - If no management changes are made and survival rates do not change, the Quilcene spring chinook may slowly decline between now and 2010 (Figure 2).

**Continual supplementation with an additional 150,00 smolts from an outside source** - This strategy would theoretically result in obtaining the hatchery escapement goal by 2004 (Figure 2). Catches would gradually increase to over 2,000 by 2010. Several supplementation values were tested in the model and 150,000 was found to be the smallest round number allowing attainment of the escapement goal before 2010. The major drawback to this alternative is that it depends on continual supplementation.

**Supplementation for one brood cycle with 500,000 additional smolts** - This alternative would initially reach the escapement goal by 1993 (Figure 2). However, if supplementation is not continued, the population begins to decline again at the same rate as with no action. Likewise, catches increase sharply but then decline.

**Reductions in fishing mortality of 10, 20, or 30%** - Reductions in fishing mortality of 10% results in only slow increase in the population; the escapement slowly increases but only reaches 299 by 2010. A 20% reduction, however, would potentially result in meeting the escapement goal by 2003 with catches reaching 1,285 by 2010 (Figure 2). If fishing effort were reduced 30%, the escapement goal would be reached by 1996 and the catches would exceed 2,000 by 2010 (Figure 2). This is a classic example of the Schaefer (1954) catch per effort model whereby a reduction in effort can result in increased catches.

**Decrease fishing mortality 10% and supplement with 150,000 smolts for one brood cycle** - This approach estimates that the escapement goal would be attained by 2003 and catches would exceed 1,300 annually by 2010 (Figure 2).

**Increase in marine survival of 50 or 100%** - These alternatives might be effected by various measures such as disease control, reduction in predation during downstream and upstream migration, control of poaching, etc. If it were possible to increase survival by 50%, the model predicts the escapement goal would be met by 2000 and catches would exceed 3,500 by 2010 (Figure 3). If survival could be increased 100%, the escapement goal would be met by 1992 and catches would approach 20,000 by 2010 (Figure 3). It is not unrealistic that survivals could be increased by 50 or 100% because these rates, and greater, have occurred in other Puget Sound spring chinook stocks (Paul Seidel, WDF, personal communication).

**Reduction of fishing mortality by 10% with simultaneous increase in survival 10%** - This alternative, which would be relatively easy to manage for, would possibly result in an escapement of 500 by 2009 and catches of 1,162 by 2010 (Figure 3).

**Fifty percent increase in survival with 150,000 supplemental smolts for one brood cycle** - Hatchery escapement would reach 500 by 1992 and catches would exceed 6,000 by 2010 (Figure 3).

## DISCUSSION

There are several alternatives which, according to the model, will help to build the Quilcene spring chinook broodstock. Each of the several scenarios with potential to increase broodstock utilizes, to some degree, one or more of the management alternatives listed in Table 2. It is clear that increasing marine survival would most expediently and dramatically increase returns to the hatchery and fishery. However, while some measures, such as reduction in poaching, may be relatively easy to implement, others, such as disease and predator control, will likely be more difficult. The Fish and Wildlife Service is actively pursuing solutions to these problems but answers will probably be relatively slow in coming. Results from marine survival research will be gradually applied as management practices to improve survival are developed.

It is also clear that reductions in fishing pressure and supplementation with outside stocks, or various combinations of reduced fishing, supplementation, and increased survival, can help in establishing a broodstock at Quilcene. As long as Hood Canal Salmon Management Plan cooperators remain committed to restoring spring chinook, management options, preferably the most effective ones, can and should be implemented whenever other resource considerations permit.

While management by fishing regulation is politically unattractive, temporarily protecting rebuilding stocks will buy time while research on marine survival is advanced. Two current management schemes may already provide protection and may only need some refinement to more adequately protect weak spring chinook stocks while allowing healthy stocks to be harvested. First, Washington sport fishing regulations currently protect spring chinook with a maximum size limit in the Strait of Juan de Fuca. Tag recovery data indicates a majority of the sport catch occurs in Puget Sound and Hood Canal, rather than the Strait (Hiss et al. 1988). If the maximum size limit were extended to other Puget Sound areas, more females may escape to all Puget Sound spring chinook rivers. Second, as described by Walters (1987), quota regulation under the Pacific Salmon Treaty will tend to protect weak stocks if enhancement increases total abundance in mixed-stock areas and quotas are not increased. Key to the effectiveness of this strategy is the successful increase in abundance in the mixed-stock fishing areas.

A basic assumption of the models regarding supplementation was that imported stocks would exhibit survival rates similar to Quilcene spring chinook. It is not unreasonable to suspect that a properly chosen and managed introduced stock could have greater survival than the Quilcene stock. However, we will always be managing by crystal ball biology until some management-oriented research is conducted to determine whether the observed low marine survival at Quilcene is stock-based or a geographic problem. To investigate these questions, we propose that an outside stock be reared separately from Quilcene stock at Quilcene Hatchery simultaneously with

separate rearing of Quilcene stock and the outside stock at Hood Canal Hatchery. All smolts would be coded-wire-tagged to study relative survival and escapement of the four test groups and to enable separation of the stocks for separate spawning at return. This experimental design would allow conclusions regarding differences in survival between different stocks and between different rearing locations. It may result in the abandonment of one stock, or location, in favor of the other, or in abandonment of spring chinook restoration in Hood Canal altogether. Experimental results would generally shed light on management alternatives for all Puget Sound stocks. Importation of outside stocks for the experiment would also serve the basic function of supplementing the Quilcene stock while studies on improving marine survival are completed and their results implemented.

## CONCLUSIONS

1. The Quilcene spring chinook stock will probably gradually decline unless some new management options are exercised.

2. Supplementation with outside stocks alone may not reverse the decline unless survival of the imported stock is better than survival of Quilcene spring chinook.

3. Increasing marine survival or decreasing fishing pressure, or a combination of both, will result in increases in escapement and catches with increased survival being the more important of the two.

4. We recommend that supplementation of the Quilcene stock be conducted experimentally so survival can be compared between spring chinook of different stocks reared at different locations.

## LITERATURE CITED

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Table 1. Average fishery, hatchery, and total survival for Quilcene spring chinook salmon.

| | Percent survival | | |
|---|---|---|---|
| Age | Fishery | Hatchery | Total |
| 2 | 0.012 | 0.007 | 0.019 |
| 3 | 0.128 | 0.020 | 0.148 |
| 4 | 0.150 | 0.038 | 0.188 |
| 5 | 0.002 | 0.022 | 0.024 |
| Total | 0.292 | 0.087 | 0.379 |

SPRING CHINOOK MORTALITY

| ACTUAL CAUSES | CONTROLLING FACTORS | MANAGEMENT PRACTICES |
|---|---|---|
| NATURAL MORTALITY | | |
| Disease<br>Predation<br>Poaching<br>Pollution<br>Habitat losses<br>Environmental stresses | Genetics<br>Growth rate<br>Hatchery practices<br>Weather and ocean conditions<br>Poaching pressure | Better broodstock<br>Improved genetic fitness<br>Disease control<br>Improved hatchery practices<br>Release strategies<br>Increased law enforcement<br>Predator control |
| FISHING MORTALITY | | |
| British Columbia<br>Washington<br>sport<br>commercial | Fishing effort<br>Regulations | Gear regulations<br>Size regulations<br>Area closures<br>Season closures |

Figure 1. A review of causes, controlling factors, and management practices regarding spring chinook natural and fishing mortality.

Table 2. Survival and relative contribution of three yearling spring chinook coded wire tagged groups released from Quilcene Hatchery.

| Brood year | Tag code | Tags released | Rack recoveries | Expanded recoveries[a] | | | | Total survival |
|---|---|---|---|---|---|---|---|---|
| | | | | Washington | | British Columbia | Total | |
| | | | | Sport | Commercial | | | |
| 1981 | 051033 | 28,442 | 37 | 52 | 17 | 64 | 170 | 0.60 |
| 1983 | 051452 | 26,974 | 12 | 41 | 10 | 25 | 88 | 0.33 |
| 1983 | 051453 | 25,737 | 9 | 25 | 0 | 3 | 37 | 0.14 |

[a] Calculated as (tags observed)/(mark sampling rate). This does not include untagged recoveries.

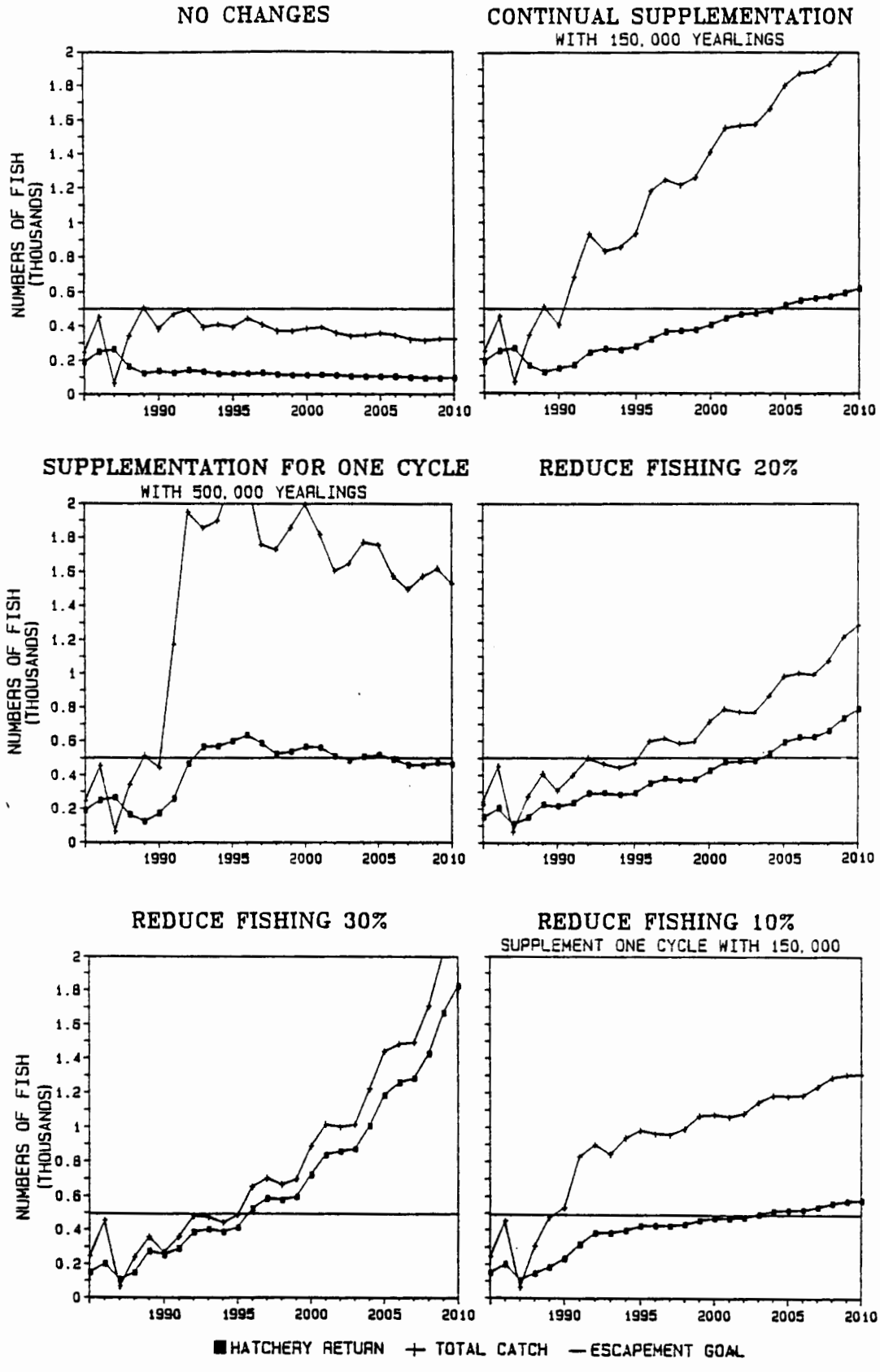


Figure 2. Projected hatchery returns and total catches of Quilcene spring chinook under various supplementation, fishery management, and survival enhancement scenarios.

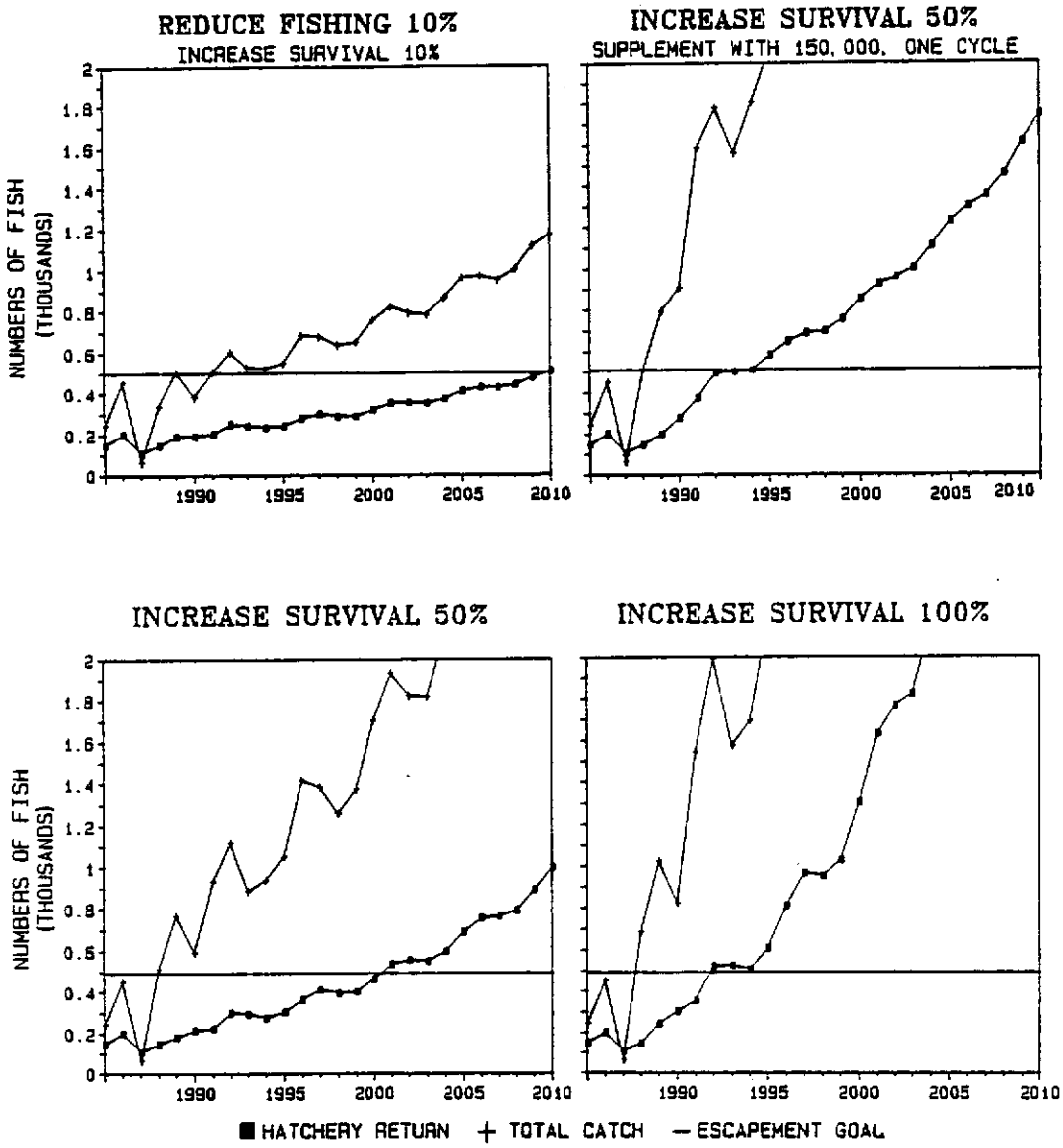


Figure 3. Projected hatchery returns and total catches of Quilcene spring chinook under various supplementation, fishery management, and survival enhancement scenarios.