HISTORY OF WHITE RIVER SPRING CHINOOK BROODSTOCKING AND CAPTIVE BROOD REARING EFFORTS.

Edited by

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FOREWORD

The following is a compilation of a number of internal agency documents, memos and notes from Washington Department of Fish and Wildlife files. We extend our thanks to Bill Hopley, Chuck Baranski, Bill Tweit, Rich Eltrich, Tom Longley, Denis Popochock and Carol Smith for their assistance in producing this document. We would also like to acknowledge the efforts of Ross Fuller, Howard Fuss, Mark Kimbel, Stan Hammer, Dan Doty, Bill Hopley and Charmane Ashbrook for their work in reviewing the manuscript.

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INTRODUCTION:

The White River spring chinook (*Oncorhynchus tshawytscha)* is the last remaining stock of spring chinook in the South Puget Sound Region (A race of spring chinook that formerly inhabited the Nisqually watershed is now thought to be extinct). The White River (a tributary to the Puyallup) stock is genetically distinct from all remaining Puget Sound stocks as shown by protein electrophoresis (A. Marshall, WDFW, 600 Capitol Way N., Olympia, WA 98501-1091 Personnel Communication, May 1994) and is, therefore, believed to be uniquely adapted to South Puget Sound river systems.

In the mid-1960's, escapement to the White River was reduced to fewer than 600 fish (from an earlier average of 2,000-3,000). By 1977, escapement had declined precipitously to around 50 individuals and the number of wild spawners has remained low ever since (Salo and Jagielo, 1983). At present (1994), the adult population is approximately 1,000 fish and exists, for all practical purposes, entirely under some degree of artificial production, having reached an extremely depressed population size in the White River. These, along with other Puget Sound Basin spring chinook, are among the most depressed stocks in the Pacific Northwest, outside the Columbia River Basin.

The primary goal for White River spring chinook (WRSC) is to restore the native population within the White River watershed. Potential also exists for establishing populations in other South Puget Sound streams such as: Puyallup, Nisqually, Carbon, and Green (not prioritized).

The efforts to culture White River spring chinook are only one part of a larger effort by state, tribal, and federal agencies to rebuild this stock. The White River

Technical Committee continues to work toward habitat restoration, solving passage problems at Mud Mountain dam and other water diversions and maintaining adequate minimum stream flows, in order to rebuild the population (Production Recommendations for White River Spring Chinook; B. Graeber, WDFW memo to Muckleshoot Tribe, December 1987, WDFW 600 Capitol Way N., Olympia, WA 98501).

This paper is intended to document the history of artificial production efforts by describing past and present cultural strategies. The Washington Department of Fish and Wildlife (WDFW) and the Squaxin Island Tribe have made significant progress in the White River Spring Chinook captive broodstock program. As with all segments of the restoration effort, this program was undertaken for the purpose of restoring the spring chinook run indigenous to the White River.

HISTORY OF ARTIFICIAL PRODUCTION

White River spring chinook have been under some degree of artificial production since 1971. The production strategies have ranged from capturing adults returning to the White River to off-site captive broodstock maintenance programs conducted in seawater net pens. During this period, there has been significant change in the role of artificial culture with respect to White River spring chinook. That role will be examined below, first through a historical review, and then by a description of the current production program.

From a historical perspective, hatchery production of White River spring chinook has evolved through three general stages beginning with the 1971 brood year. The first stage involved capture of wild male spring chinook to be used in an enhancement program. The second stage was an attempt to restore declining runs of spring chinook by direct out-plants of smolts into the White River following off-site rearing. The third, and current stage, is designed to build an egg bank of White River spring chinook in an effort to stem the decline in the stock until certain habitat and passage improvements in the White River can be accomplished. Appendix A provides a summary of the results of each year's efforts.

STAGE 1 (1971-72) The first stage involved the 1971 and 1972 broods of White River spring chinook. Male spring chinook were captured at the Puget Sound Power and Light Company's diversion dam at Buckley, Washington. The males were hybridized with females from several other chinook stocks for use in a Washington Department of Fisheries' plan for restoring the south Puget Sound sport fishery, commonly called the "Thirteen Point Plan" (WDF, 1973). While this stage has been included for historical accuracy, WDFW has long since viewed this hybridization approach as undesirable and does not condone or continue this practice.

STAGE II (1974-76) The second stage was directed at restoration of the White River spring chinook in their native habitat, in recognition of the severely depressed status of the run. Adults of both sexes were captured at the Buckley trap (near Buckley, WA) and were spawned at one of two Department of Fisheries (currently WDFW) hatcheries (either Garrison Spr. or Puyallup). The progeny were returned to the White River as fingerlings or smolts. This stage affected the 1974, 1975 and 1976 broods. There was no artificial production of the 1973 brood (reason unknown).

STAGE III (1977-present) The third and current stage was designed to build an egg bank of White River spring chinook for eventual return to the White River System. This stage was initially promoted by harvest management and habitat biologists within WDFW, who cited the inadequacy of the then-existing White River enhancement effort. By mid-1979 habitat and passage problems were also gaining notice and provided further impetus to formalize an off-site egg bank program. The newly-constructed Hupp Springs facility (near Purdy, WA) was identified as the only available site providing the cool, high quality water necessary to hold spring chinook adults, and rear high quality smolts. The stage began when the 1977 brood spring chinook, which were being raised at Skagit Hatchery, were released into Minter Creek rather than the White River. This programming change signalled the beginning of the effort to maintain White River spring chinook through off-site restoration and all subsequent releases (until 1991) were limited to Minter Creek. The third stage went through its own evolutionary process as the current egg bank program emerged. Initially, WDFW and the National Marine Fisheries Service (NMFS) worked to maintain two complimentary programs; (1) an anadromous broodstock program at Hupp Springs Hatchery, and (2) a captive brood program at the NMFS net pen complex near Manchester, WA. (U.S. Department of Commerce, NOAA, NMFS, 7305 Beach Drive East, Port Orchard, WA 98366).

This stage can be further sub-divided by changes in the captive brood rearing operation. This involved a change from NMFS operations at Manchester, WA (1977-1986 broods) to a WDFW program managed cooperatively with the Squaxin Island tribe at the South Sound Net Pen complex (SSNP), near Olympia, WA (1987-present broods).

In addition, the anadromous program expanded when the Muckleshoot Indian Tribe constructed a hatchery on the White River, at the Buckley trapping site. This facility was patterned after the Hupp Springs site and has very similar rearing/incubation capacities. Currently, all White River spring chinook juveniles produced above the needs of the captive brood program (3,500 smolts) and the Hupp Springs program (about 320,000 smolts) are released into the White River at the Muckleshoot hatchery site. Some fish are reared in acclimation ponds in the upper White River drainage, but are currently returned to the hatchery site for release, until downstream passage problems can be corrected. Upon return as adults, the unmarked portion of these "acclimation" fish will be allowed to return and hopefully, spawn in the White River near the pond sites. A detailed listing of the releases and returns of these programs are presented in Appendices A and B.

THE CAPTIVE BROOD PROGRAM

Captive broodstock rearing can differ from fish culture used in agency enhancement programs or aquaculture enterprises. Enhancement programs produce mostly smolted juvenile fish with minimum target sizes and growth uniformity being important objectives. Salmon grown for food are selected for factors such as: fast growth, disease resistance, high fecundity and potential to domesticate. With the captive brood programs these factors are of less importance. The number one priority in this program is to produce viable eggs that meet genetic fitness criteria in order to maintain the health of the stock.

Chinook populations mature at various ages. Each brood has individuals that are in various stages of sexual maturity. This is evident in the net pen populations where sexual dimorphism can be observed in some of the older (3,4,5 year old) fish as early as March, as they progress toward spawning in September. This variation requires our rearing program to change depending on year class. Our program does not focus just on the number of spawners generated or the resulting fecundity, but also must keep in mind the natural fitness of individual fish throughout the life cycle, in order to produce competitive quality offspring.

Many of the current fish handling practices; such as transfer of juveniles, some rearing strategies, and adult transfer methods have their origins in work conducted at the NMFS, Manchester Net Pen site. At the height of their participation, they produced 66% of the eggs available for the rebuilding program (1985). The current phase, conducted at the SSNP site in a cooperative effort with the Squaxin Indian Tribe, is described below (Squaxin Is. Tribe S.E. 70th Squaxin Lane, Shelton WA 98584). The current freshwater adult holding and spawning operations at Hupp Springs are similar to those used historically and are representative of many operations rearing spring chinook in Puget Sound.

The Captive Brood Program at the South Sound Net Pen Complex:

The following section describes the seawater captive broodstock program as it is cooperatively managed by the Squaxin Island Tribe and WDFW. Current practices such as low rearing densities and a lack of monthly sampling or inventorying (which minimizes stress) are in response to the primary goal of maximizing the broodstocks' well being and survival. Included is a description of the net pen site, how the smolts are transferred to saltwater, current fish culture practices and management views on feeding, rearing densities, pathology, and environmental problems at the site. Handling of mature fish and the transfer to freshwater are described in detail.

Site Description:

The net pen complex is composed of 73 pens set in three groups (2 groups of 20 pens and 1 group of 33 pens, a portion of which is used for captive broodstock). These are anchored about 100 m apart, perpendicular to normal current flow in Peale Passage (just east of Squaxin Is. near Olympia WA). Although individual pen size varies, they are approximately 7.7 m x 9.8 m x 3.7 m (see section on pen densities for details). Since the early 1970's, the site has operated as one of the most successful enhancement facilities in Washington State. It continues to produce substantial numbers of coho salmon (*Oncorhynchus kisutch)* for sport and commercial fisheries. Initial programs involved short term rearing and release (from late winter to early June). Before the Squaxin Island Tribe developed a successful steelhead *(Onchorynchus mykiss)* broodstock rearing program (1985-1990), it was not known if the site was suitable for year round rearing programs.

Peale Passage is a tidal channel that connects with Dana Passage on the south and Pickering Passage on the north. An early study of hydrographic conditions in the area, including measurements of physical and chemical parameters was conducted by

Oclay (1959). Moring, 1973 was the first to document detailed water quality and basic information concerning the pen site. Currently, personnel from the Squaxin Island Tribe and WDFW, Deschutes Hatchery crew, collect pertinent water quality information (such as dissolved oxygen, water temperature, salinity, and presences of certain phytoplankton species). Rensel (1989) characterized the seawater as being well mixed during the late fall to spring months.

The pen site depth is shallow when compared to other sites in Western Washington, with an average depth of about 5.0 m at mean lower low water (Rensel 1989). On the lowest summer tide cycles, (mean lowest low) the bottom of the pen at the west end of the broodstock complex rests on the sea floor. Mean water current velocity readings are 6 to 7 cm/sec. at the northern end of the pen complex (Weston and Gowan 1989). The current diminishes in the vicinity of the third pen complex (unpublished survey data of B. Wood, Squaxin Island Tribe S.E. 70th Squaxin Lane, Shelton WA 98584). It has been noted that water passing through the net pen site does not completely exit Peale Passage on moderate tides and the situation can lead to an increased abundance of phytoplankton (Rensel 1989). During low tide, zero current events, feeding can reduce dissolved oxygen within net pens compared with water outside the pens. Based on hydrographic conditions, such as mean current velocities and minimum depth guidelines (Science Applications International Corporation 1986), the pen site would not normally be considered a good broodstock rearing location. Mean water temperatures can regularly exceed 15.5° C (60° F) through the summer, and other environmental stresses can accumulate to the point they threaten survival of the broodstock.

Transfer of Smolts to SSNP:

Each spring, the broodstock program receives 3,500 yearling fish (Table 1). These are selected randomly from the pond containing yearling smolts for release. Fish from the first two brood years (1987,1988) were from anadromous returns to Minter Creek (Hupp Springs). Starting with brood year 1989, smolts were progeny of anadromous females, but may have either anadromous or captive broodstock male parents. Approximately 450 days of fresh water rearing are required to grow smolts to the transfer stage (45 g).

In an effort to control Bacterial Kidney Disease (BKD), all yearling smolts receive three Erythromycin (9%) treatments during rearing. Three weeks prior to salt water transfer, fish receive a Vibrio (type A) vaccination bath.

Table 1. Smolt transfers to SSNP:

YEAR	BROOD	DATE	NUMBER OF FISH	AVERAGE FISH WT.	% TRANSFER LOSS
1989	1987	4/20	3485	73.2 g	.014
1990	1988	4/4	3500	56.7 g	.714
1991	1989	3/25	3500	75.6 g	.857
1992	1990	4/9	3500	56.7 g	2.875
1993	1991	4/14	3500	53.4 g	1.428

Smolts are transferred by tanker truck to a saltwater boat launch site and loaded into a circular tank on a transport barge. The 7500 L tank is equipped with an oxygen supply (12-15 ml/L) and a seawater circulation system. Fish and freshwater are loaded from the tanker truck through irrigation pipe into the tank. The freshwater from the tanker truck mixes with an equal amount of seawater in the barge tank. This produces an initial salinity of about 12-15 ppt in the transport barge and buffers temperature between the fresh and saltwater.

The loaded tank and transfer barge are then moved to the pen site by tug. While in route, the barge circulates seawater into the tank. Over flow water is discharged to keep the container volume constant. Complete displacement of the initial fresh and seawater mix occurs during the one hour voyage to the site and ambient salinity (28 to 30 ppt) is achieved in the tank during this time. Survival during the transfer has been high, with little immediate or delayed osmoregulatory problems documented after the transfer.

BROODSTOCK CULTURE PROGRAM

A. Growing Fish:

1) Feeding Strategies:

Diet type and feeding regimes, along with other husbandry practices and environmental cues can dramatically influence fish life cycles (Johnson 1993). The immediate culture goal is to provide adequate nutrition to grow fish to an appropriate size (as it relates to fecundity).

Early attempts at seawater captive broodstock rearing experienced low egg viability that was thought to be caused by poor feed quality or a lack of some nutritional component (Groves 1988). Although the formula composition and quality of feeds have greatly improved, additional research on diet and feeding strategies used on salmonid broodstock is needed, particularly as it relates to egg and fry quality.

In some instances, programs have incorporated natural crustacean and forage fish organisms (R.Coleman, California Fish and Game, 1416 9th St., Sacramento, CA 95814. pers. commun.). Providing a natural food source in conjunction with formulated diets is intriguing, but limited by the difficulties of identification and procurement of food sources. Growing fish from smolt size to mature adults has been successfully accomplished with pelletized feeds. The WRSC program has relied, in-part, on feed manufactures and prevailing professional opinions for nutrition and feeding strategies. Suggestions from feed manufacturers (Bio Products) and other ongoing broodstock programs have been fairly consistent in recommending feed with a high level of protein for the "growing" periods with a reduction in protein levels and feeding rates during the latter stages of maturation and egg development. A more detailed description of the feeding regimes used by year class is presented below and in Figure 1.

2) Feeding Program by Year Classes:

a) 1.5 (yearling) to 2 year old fish:

Although fish will feed aggressively within hours of salt water transfer, food is introduced slowly over the first few days. By the following week, increasing amounts of feed are introduced to determine satiation rates. Food is hand fed twice each day. Through the summer, fish can consume up to 3.5% of body weight per day (%body wt/day). By fall, with fish size increasing and cooling water temperatures, feeding rates are reduced to 2.0 %body wt/day. In early winter, when water temperatures are less than 10° C, feeding rates can drop to 1.25 %body wt./day. During this time frame (late spring to early winter), weight gain is approximately 400 g per fish.

Both moist and semi-moist diets with high protein levels have been used. Feed sizes range from 4.0 mm to 6.0 mm. The choice of moist diets over dry formulations has been due to comfort and familiarity of the culturist and no attempt has been made to weigh the merits or economics between diet types.

b) 2 year - 3 year old fish:

During this period of rearing, feeding rates fluctuate with seasonal water temperatures. When water temperatures drop in winter (< 7°C), feeding rates are reduced to 1.0 %body wt./day. Maximum feeding rates of 1.50 - 2.50 %body wt./day are sustainable when temperatures are 10-15° C. When water temperatures exceed 15.5° C, feed is temporarily reduced to 0.75-1.0 %body wt/day.

Larger fish (> 0.50 kg), are fed a higher protein (> 45%), moist diet that incorporates krill and synthetic carophyll red pigments in pellet sizes of 6.0 mm to 8.0 mm. There is an intuitive preference by fish culturists for fish with normally pigmented flesh and eggs, but reasons for this preference are not well researched (Groves 1989). Individual fish weight increases almost fourfold over the 12 month period from 450 g to 1,589 g each.

c). Fish 4 years and older:

After 650 days of saltwater rearing, the fish begin their 4th year of rearing. Feed management is viewed differently as the four year age group represents the dominant spawning age class. The feed program changes to reflect the fishes investment in gonadal development rather than growth.

A "grower" diet is used for the first three months of the year with "winter" feeding rates of 0.6-1.0 %body wt./day. On March 1st, the diet is changed to a formulated broodstock diet based on feed manufacturers' recommendations.

The broodstock diet is fed to satiation (0.8 - 1.25 %body wt./day), in pellet sizes of 10 mm - 14 mm, until June 1st. Short term environmental stress (temperature, phytoplankton blooms) may require a reduction of feeding rates to 0.50 %body wt./day. At this time, a majority of the population is showing a bronze coloration. On July 1st, feeding is reduced to once a week (equivalent to 0.17 %body wt./day). Feeding ceases on August 15th. A typical four year old fish at this time averages 65 cm -75 cm in length and range in weight from 3.0 -7.0 kg.

After the transfer of mature fish to freshwater, during the first week of September, non-mature fish (age 4+) retained at the pens are placed back on the grower diet and fed at normal rates until the following March.

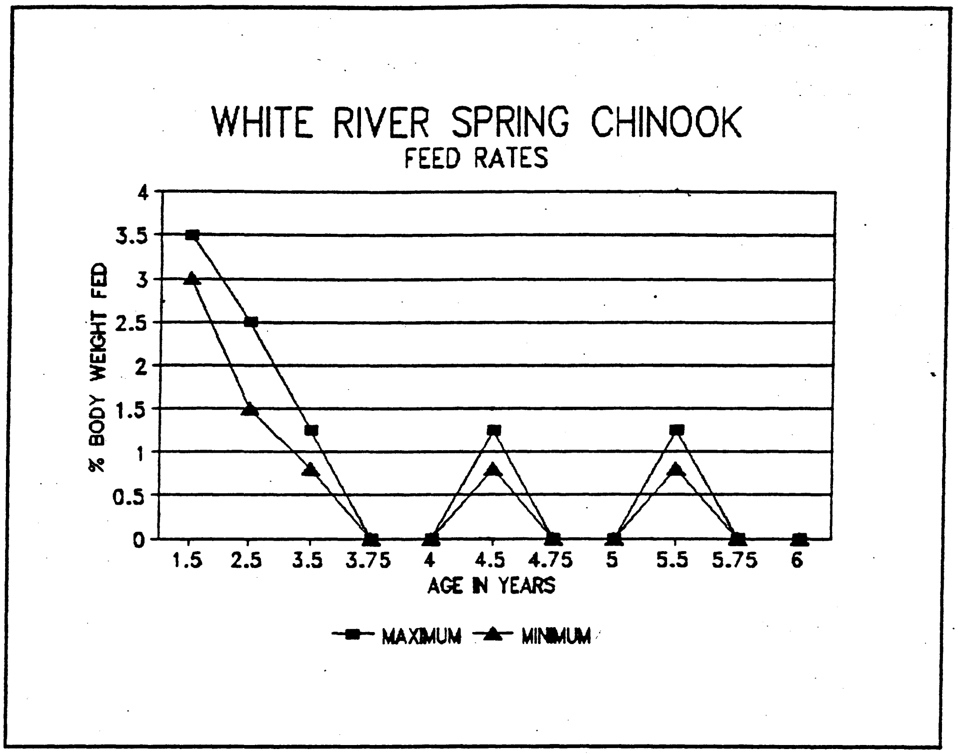

Figure 1. Feeding Rates for SSNP.

B. Rearing in Net Pens:

1) Rearing Densities:

Providing plenty of space in the pens for growing broodstock is a management priority. Keeping fish rearing densities low, is believed to reduce the impacts of environmental stressors (low tides, water temperatures, phytoplankton blooms). The maximum allowable density for each age class is reduced as fish age (Table 2 and Figure 2). To alleviate handling stress, pen inventory and density adjustments occur only once each year (in conjunction with separating mature fish).

Net pen dimensions are rectangular, 7.7 m x 9.8 m x 3.7 m, with an effective rearing volume of 228 m^3/pen. Currently, four brood years are maintained simultaneously in a total of 14 net pens:

Table 2. Net Pen Rearing Density.

Age Fish	# Pens	# Fish*	# Fish/Pen	Individual Fish/wt.**	Start kg/m^3	End kg/m^3	Max@ kg/m^3
1.5-2.0	1	3400	3400	400 g	.89	5.96	6.5
2.0-3.0	4	2800	700	1362 g	1.48	4.53	5.0
3.0-4.0	8	800	100	4540 g	1.59^	2.00	3.0
4.0-5.0	1	120	120	6356 g	2.62^^	1.60	2.5

* Typical September inventory.

** Typical September fish Wt.

^ Figured at initial # fish stocked, significant loss of inventory (3.0-4.0 age fish) occurs by the following Sept.

^^ Figured at initial # fish stocked, significant loss of inventory (4.0 + age fish) occurs by the following Sept.

@ Represents maximum target density managed.

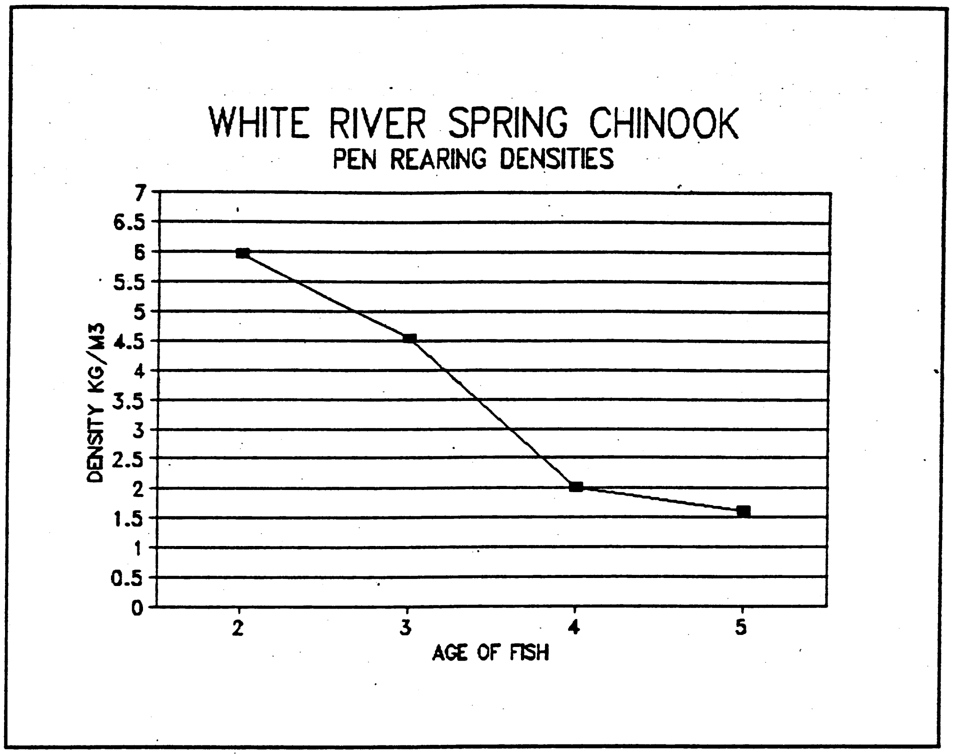

Figure 2. Pen rearing densities at SSNP.

2) Pen Environment:

Netting used to construct pens can be of nylon or polyester fabrics in a variety of strands and weaves. Pens can be dipped in water soluble treatments to toughen the material or to administer antifouling properties (waxing, flexdip). Polyester fabric is currently the only material used at SSNP. Besides defining the limits of confinement, pen systems can sometimes effect fish in negative ways. Consequently, the, physical characteristics of the pens are changed as fish grow, in order to minimize stress on broodstock.

a) Mesh Size:

As the fish increase in size and age, the nets are replaced with those having larger mesh openings. Fish from 1.5 - 2 years of age are reared in pens having 2.0 cm mesh (stretch). Fish 3 years old are reared in 5.85 cm (stretch) mesh. Pens for fish of 4 and 5 years of age have mesh sizes up to 7 cm. During the summer, rapid exchange of water in and around the pens is critical. The larger mesh insures complete water exchanged during tidal movements. Fish are normally reared in pens with as large a mesh size as possible. This allows better dispersal of metabolic wastes and reduces surface area available for fouling organisms.

b) Shading:

Unlike Atlantic salmon *(Salmo salar)* and Steelhead *(Onchorynchus mykiss)* which are frequently observed hovering in the upper water column (Squaxin Seafarm Observations), spring chinook adults (3+ and older) appear to favor the bottom of the water column. Fish come to the surface when feeding, but quickly retreat to the deepest water possible.

To provide some relief from sunlight in the comparatively shallow pens, shade screens (1 mm mesh) have been used to cover a portion (40%-60%) of the existing bird net covering. Completely shading the pens would require the removal of covers during each feeding period. Field observations suggest fish prefer the shaded portions of the pens.

c) Billowing:

Moderate billowing of the net pen side walls during tidal exchange indicates the strength of the current and the amount of water passing through individual pens. Concrete filled containers (1 gallon) are suspended along the inside walls of the pens in order to maintain a rectangular configuration during tidal exchanges.

Excessive billowing, when a side or bottom panel is forced to the surface, has been observed during extreme tidal surging or as the result of organisms fouling the mesh. We believe this stresses fish and requires action (either cleaning or replacing nets, or adding more weight bottles) to reduce it. This is especially true if fish are forced to the surface or continually have to negotiate folds in the net pen. During these events, adults have been observed "porpoising" out of the water (significance unknown).

C. Retrieving Mortalities:

Floating mortalities are removed as they occur, mortalities that sink to the pen bottom are removed by dip nets when visible. At times, one side of a net pen must be lifted to access the bottom. During this procedure, care is taken not to overcrowd fish and the activity is timed to avoid other environment stress (bright sun, high temperature, slack tide).

Constant net pen replacement during the spring and summer is required due to growth of marine organisms. Dealing with this fouling problem provides a regular opportunity to retrieve mortalities on the pen bottom. Divers are used to retrieve mortalities when disease is suspected, although regimented daily diving to retrieve mortalities is avoided.

When minimal daily mortality is occurring (< 0.05%), much of it decomposes rapidly or is consumed by red rock crabs *(Cancer productus)*, that are purposely stocked within the net pens for this purpose. A distribution of the documented mortality by cause is presented in Figure 3.

D. Pathology:

Fish that become lethargic or cease feeding show symptoms of physiological developmental problems (such as crinkle back, lack of tolerance for seawater), or are hosting debilitating pathogens. When moribund fish are observed, they are collected for examination by a pathologist.

Of the five brood years reared at the pens, one clinical outbreak of Bacterial Kidney Disease (*Renibacterium salmoninarum)* occurred. This outbreak occurred in the 1990 brood, when the fish were two years old. Mortality in excess of five percent was documented. It is believed that horizontal transmission from an adjacent fall chinook pen was the cause. In addition, medicated feed (Romet) has been fed in response to a outbreak of Vibriosis (type A) (*Vibrio anguillarum)* occurring in the 1987 brood fish.

Although clinical mortalities due to some infectious diseases have been documented, it is impossible to determine the cause of death in most cases due to the decomposition of mortalities.

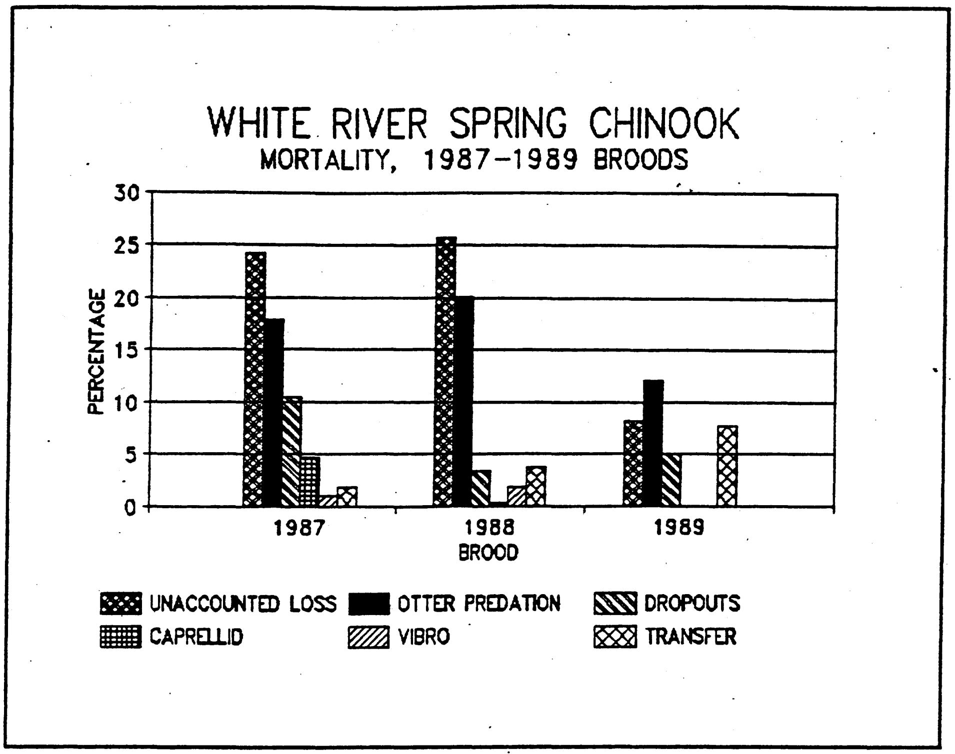

Figure 3. Source of Mortality for Spring Chinook Broodstock.

Environmental Problems:

A. Caprellids:

During the early spring and summer months, serious infestations of caprellid amphipods *(Caprella sp.)* have been observed. This organism attaches to the sides of net pens. Densities as high as 60,000/m^2 have been estimated. High densities of caprellids block water flow through the pens and many end up floating or swimming through the water within the pens. In 1989, caprellids were observed attached to fish, causing open wounds that resulted in significant mortality (4.6%) to the 1987 brood. To remove attached caprellids around the dorsal and caudal areas, all fish were bathed in a 1:2000 solution of formalin (F) for 20 minutes.

To reduce the impact of caprellids, clean nets are installed every two weeks during the spring and summer months. The overall extent of caprellid infestations are believed to be species/site specific, as they don't appear to pose the same problems for adjacent pens of yearling coho.

B. Predation:

When rearing salmon in net pens for extended periods of time, culturists realize a certain portion of the population will be lost to predators. Some commercial growers have estimated loss to predation to range from 10% to 30% (Lindsay 1980, Coche 1983 in Moring 1989). Mortality caused by predation at Puget Sound net pen sites ranged from 8.4% to 38% after 214-260 days of rearing (Moring 1989).

With broodstock programs extending to 1,200 days of rearing, plenty of opportunity exists for predation. Even with significant time and labor investments to secure pens, predators can still be successful.

A small mesh cover netting (5 cm stretch) is stretched over the pen to prevent birds such as kingfishers *(Megaceryle alcyon)* from forcing their way in to the pens. Mounting this cover up to 1 m above the water level (by extending the height of the pen side) will prevent birds such as herons (*Ardeidae sp.)* from sitting on the cover and stabbing fish. Avian predation is minimal and generally targets fish smaller than 450 g).

Predation by aquatic mammals is consistently a problem. River otters (*Lutra canadensis),* from adjacent Squaxin Is., can be very damaging. They can consume all sizes of fish, from 50 g up to the largest individuals (> 6 kg). Mink (*Mustela vison)* have also been observed on the pen walkways. These animals gain access into the pens by chewing or lifting the cover netting. Fish mortality is suspected when openings are observed in the cover nets. Mortality is confirmed by observing fish scales or blood stains on the walkways. Even when the cover is physically tied down to the pen rails (electrical ties, rope, nails and staples have all been used), animals will chew through the cover netting to gain access to the fish. This behavior can also create holes in the net pen sides. If a hole is created just under the water surface, immediate detection is difficult and can cause additional loss due to fish escaping.

Harbor seal *(Phoca vitulina*) activity at the net pen site has been infrequent but is always possible. Predator nets (15 cm stretch mesh) that encompass the pens below the water line are used when possible. However, with the need to regularly replace pens to avoid excess fouling, the use of predator nets has been limited. Predator nets frequently entangle pens being changed and are also subject to fouling. Even when predator nets are used, spiny dogfish *(Squalus acanthias)* still gain access the pens by chewing holes through the bottom panels. As many as 46 dogfish have been removed from an individual pen in a single day.

Alternative mesh materials that can withstand most predatory animals are being investigated (Dilonet, Super Mesh). The ultimate protection, a metal sea cage system, has not been considered for this program. However, it may be warranted in other programs if success is based on reducing the impact of predators.

C. Unaccounted-for Loss:

Even when preventive measures appear to have successfully eliminated predators, and mortality is collected in a regular manner, approximately 20% (5% per year) of a cohort (brood year) is unaccounted for after the life cycle is completed (Figure 4). We believe this unaccounted-for loss is due to variations in original inventory, underestimated mortality and underestimated predation, although it is unknown which factor plays the most significant role.

D. Phytoplankton:

In Puget Sound, mortality of pen reared salmon has been caused by several dinoflagellates (*Certatium fusus, Gymnodinium sipendens*), (Rensel and Prentice, 1980). In addition, some diatoms (*Chaeticeros convolutus, C. concavicornis*) and a microflagellate (*Heterosigma akashiwo*) have been implicated in mortalities from British Columbia to Manchester Bay, Washington (Gains and Taylor 1986, In Moring 1989, Manken and Harrell, NMFS, Port Orchard, WA. personnel communication, April 1990). Other species of noxious algae occur in Puget Sound with unknown impacts to aquaculture operations.

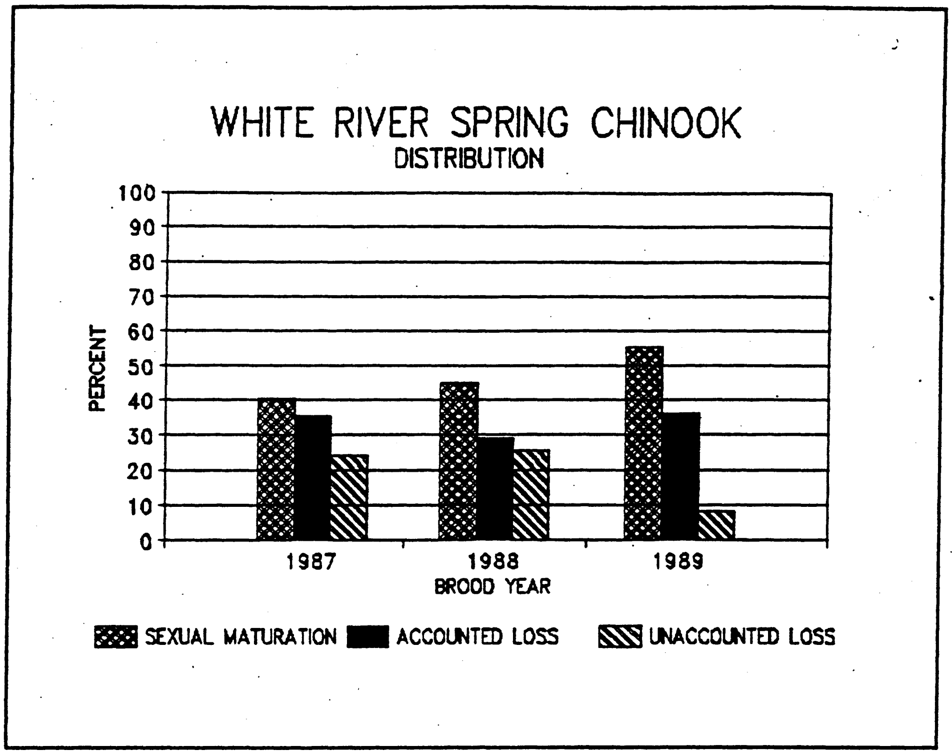

Figure 4. Distribution of Spring Chinook cohort.

The SSNP site has had only one verified occurrence (1973) of mortalities attributed to noxious phytoplankton, *Ceratium fusus*, (Rensel, 1989). The SSNP site does not have extensive documentation of either occurrence or abundance of various phytoplankton populations which occur in Peale Pass. It is possible that phytoplankton blooms may add to the stress on the captive brood and contribute to the chronic, low level of mortality that occurs each summer.

Routine sampling is conducted at the SSNP site in order to document blooms and

information is shared with the University of Washington, School of Oceanography phytoplankton hotline (206) 685-3756. This program is seeking to add to the known phytoplankton data base for Washington waters.

State and Tribal staff regularly take secchi disc readings, measure dissolved oxygen and temperatures from May to October. Qualitative phytoplankton sampling is accomplished by weekly 2 meter and 6 meter net tows (20 micron mesh). When species of interest are noted, quantitative densities (cells/L) are determined by taking 100 ml fixed volume samples from a depth sampler (Van Dorn style). Species are identified and counted from a Palmer/Maloney 0.1 ml chamber slide. Various stratified layers are sampled to determine the depth of blooms. When species of concern are present, fish cultural activities are temporarily reduced to lower stress (full ration feeding, pen changes, etc.).

Contingency plans for dealing with blooms of known toxic phytoplankters have been explored for the WRSC broodstock program. Early transfers of adults to freshwater, transfer of adults to other saltwater facilities, circulating water from below stratified phytoplankton layers and towing the pen complex to areas without toxic levels of phytoplankton have all been considered. Currently, emergency transfers of adults to other facilities with saltwater and physically towing the net pens to other areas of Puget Sound are the two acceptable strategies for dealing with this situation. Transferring adults to other facilities has the best chance of success but could only save a limited number of fish (only 4 year old females). Since these pen structures have never been moved from their current location, it is unknown if this can be accomplished without causing additional fish loss (through stress or unintentional release of a large number of fish).

Identification of Mature Fish and Transfer Practices:

A. Seawater or Freshwater Spawning:

WDFW performed an informal field experiment to test the feasibility of seawater maturation and spawning in the fall of 1991. After completing the main freshwater transfer segment, 13 mature females (4 year old) were retained at the pen site to complete oogenesis. Of the 13 females, only 6 survived to a stage of complete maturity. Out of the 6 spawned, only 2 fish provided eggs. (Approximately 2500 eggs each that were 80% viable). The other four had visibly poor egg quality and much reduced fecundity. This experience, plus similar results from another saltwater chinook broodstock program, Big Qualicum B.C., confirmed our decision to continue final egg maturation in freshwater (Redfern, 1988). All WRSC are now transferred to freshwater facilities for final maturation and subsequent spawning.

B. Timing of Transfers:

Although sexual dimorphism is fully evident in maturing fish by early summer, it was not clear when to transfer maturing adults to freshwater. Results from the NMFS Manchester Research Pens WRSC broodstock program in the mid 1980's, recommended delaying transfer of the fish until late summer or early fall (Report on the 1985 brood White River Spring Chinook. Eltrich 1986, memo to files, WDFW 600 Capitol Way N., Olympia, WA 98501).

WDFW conducted an informal field trial using 23 fish (4 year olds) exhibiting slight coloration (bronzing). These fish were transferred from the SSNP complex to freshwater holding ponds on June 20, 1991. This trial was in response to a contingency plan developed by staff in case noxious phytoplankton blooms during the summer required the immediate transfer of all mature broodstock to freshwater. Of the 23 fish transferred, few survived to maturation (Report on the 1991 brood White River Spring Chinook. Eltrich 1992, memo to files, WDFW 600 Capitol Way N., Olympia, WA 98501). The results convinced salmon culture staff to reject this option for dealing with algae blooms.

Currently, all maturing fish (age classes 3,4,5) are transferred during the first week of September. Catastrophic mortality caused by phtyoplankton blooms are still a concern and levels of specific algae populations are monitored in conjunction with the University of Washington. This time frame takes into consideration water temperatures (seawater temperatures are decreasing to less than 16° C) and occurs before complete ovulation renders the females too fragile to handle.

C. Logistical Operation:

Successful handling and freshwater transfer of 900-1200 maturing broodstock is a critical step. The operation requires a significant investment in equipment and labor. Fish are placed in fish transport trucks (tanker) that have been driven on board Washington National Guard LCM's (Landing Craft:Medium). LCMs are moored parallel to the pen complex where crews can load the adult fish into the tankers. The LCMs are used to ferry the trucks back and forth from the pen site to a mainland access ramp. Four, 3,750 L tank trucks and two LCM's are required for the most efficient operation.

Tanker trucks carry 3,750 L of freshwater (from Hupp Springs @ 10° C) with a 5% salt solution. Oxygen is added at 1.0 L for each 135 kilograms of adult fish. Approximately 50-70 adults are hand placed into each tanker truck. The LCMs transport the trucks to the boat ramp where they drive to their destination (Hupp Springs, White River Hatchery). Adults are unloaded from the tanker truck by tilting the truck bed and sliding the fish down a ramp into the pond. Travel time is 1.5 -2.5 hours depending on destination. This system requires that broodstock be handled only once during the entire transfer process.

D. Handling Procedures:

The operation is coordinated to move all fish out of a given pen as quickly as possible. Fish that are crowded in the net pen are continually stressed while waiting to be moved. The last 20% of the adults handled in each pen show obvious signs of stress (lethargic, change in skin color, etc.). Once fish are placed into the tanker trucks, they acclimate to the cooler freshwater (10-12° C.) and calm significantly. Sporadic mortality occurs with the last few fish remaining in the pen (0%-6%/pen). Non-mature older fish (known as 4+ brights) are exceedingly fragile when handled in conjunction with mature fish.

"Sanctuary dipnets" are used to move fish. These dipnets are constructed with a vinyl pouch that contains the fish in a portion of water and prevents net mesh chaffing during dip netting. Two separate dipnet and injection teams concentrate on a single pen at a time to speed up the process. After dipping out 1 or 2 adults at a time, the sanctuary net is placed directly in a watered tote. While in the sanctuary net, mature fish are injected in the dorsal sinus with Erythromycin (ethro-200 @ 0.5 ml/10 lb). After injection, fish are placed into a watered inner tube carrier and taken to the truck on-board the LCM. Non-mature fish are carried to designated pens in the inner tube carriers. This process attempts to keep fish in a watered environment most of the time to ensure maximum survival (Flagg and Harrell 1990). With approximately 100 adults (4yr) per pen, a coordinated, intense effort of about 20 minutes is required to remove all fish from each pen. The total transfer takes 1.5 - 3 working days.

The use of anesthetics (MS 222 - Tricaine Methane Sulfonate) has been tried, but discontinued. The time spent waiting for the drug to take effect was better used by reducing the time fish spent under stress in the pen, waiting their turn.

Mature fish and Eggs:

Captive broodstock are transferred to Hupp Springs facility and White River Hatchery. Both systems currently combine net pen broodstock adults with available anadromous WRSC returns to make up the total brood year escapement.

The majority of captive broodstock are ready for spawning approximately 15-30 days after transfer. The majority of the anadromous WRSC spawning occurs from Sept. 10 - 30. The captive broodstock spawning overlaps at a slightly later date (Sept. 20 - Oct. 10). The percentage of sexually maturing fish by age class is presented in Figure 5.

Egg Comparisons:

Although the captive broodstock program has greatly increased the number of viable WRSC eggs (800,000 plus yearly), fecundity and egg viability have been less than those from anadromous sources (Table 3). Individual broodstock egg quality varies greatly from fish to fish within the spawning population.

Table 3. Comparisons of Fecundity and Egg Viability.

	ANADROMOUS			CAPTIVE BROOD		
	* Fecundity	Eggs/lb.	** %Viable	* Fecundity	Eggs/lb.	** %Viable
1991	3668/fish	1840	94.0	2700/fish	1820	63.4
1992	3268/fish	1750	96.0	2536/fish	1775	70.5
1993	3220/fish	1695	95.0	2200/fish	1650	65.7

* Breakdown of age class fecundity not available.
** Viability does not take into account eggs that are discarded.

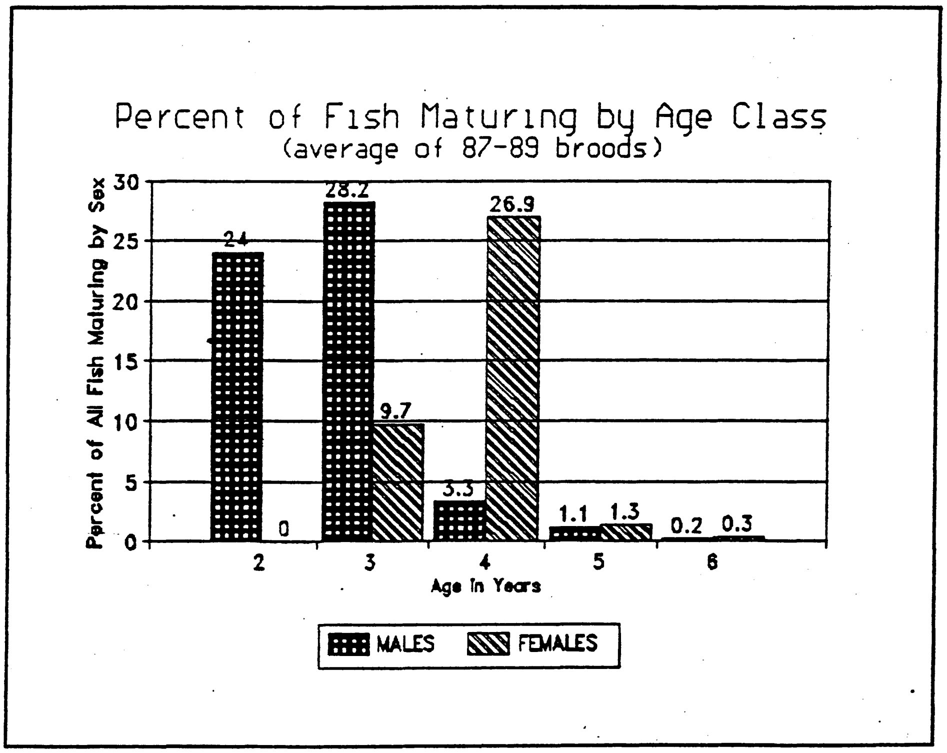

Figure 5. Percent of Sexually Maturing Fish by Age Class.

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ANADROMOUS BROODSTOCK PROGRAM

White River spring chinook returning to Minter Creek are captured at the hatchery trapping facility. The mid-point of escapement (50%) has ranged from the week ending July 21st to the week ending August 10th (1983-1993 escapement records). The earliest hatchery recoveries occurred on June 7th in 1984. Returns have been as late as July 12 (1983). It should be noted that 1983 escapement was quite low relative to the ensuing years and may not adequately reflect overall run timing.

The final arrival time probably extends into October as evidenced by the final spring chinook arrival time of October 30th, (1986 brood). The opportunity to define final arrival time is constrained by operational necessities of handling coho adults. When adult coho begin to arrive, the opportunity to separate spring from fall chinook is lost. Before the arrival of coho, however, spring chinook can be handled individually and ponded separately from fall chinook even though their return timing overlaps. Hatchery escapement records demonstrate that spring chinook have been identified and separated upon arrival as late as September 23rd (1986). That same year, spring chinook were subsequently recovered from among fall chinook adults as late as October 30th. Evidence demonstrates with certainty that spring chinook can arrive at least through the third week in September and probably well into October.

The adults are inoculated for BKD and Furunculosis (using erythromycin and liquimycin) and transported immediately by tanker to Hupp Springs hatchery. Thereafter they are held to maturation under the same conditions as adults from South Sound Net Pens.

Performance of Anadromous Production:

In an effort to understand the role cultural practices have on the survival of White River spring chinook yearlings released from Hupp Springs Hatchery the data base of coded-wire tag information was analyzed. The following areas were investigated: 1) effect of fish size at release (expressed in fish per pound) and date of release (expressed in days reared) on total survival (total catch plus total escapement), 2) effect of fish size and date of release (both as defined above) on escapement of adults to Minter Creek hatchery (adults being 3 years old or older). Survival data were regressed using the actual percentages as the dependent variable and also the arcsine transformed equivalent. Since the relationships did not change, this discussion will concentrate only on those regressions using the actual percent survivals. Some comparisons were made graphically. Only yearling releases of spring chinook were included. The returns of some zero age releases have not been completely analyzed at this time. Brood years up to and including 1985 were used.

Size at Release:

Size at release, expressed in fish per pound, was analyzed graphically and the results are presented in Figure 6. Survivals for a single size of fish at release were averaged before graphing. Results from this analysis suggest survival increases as fish grow toward 7 or 8 fish per pound, then decrease as fish grow above this level. This is somewhat counter intuitive. All things being equal, experience at other hatcheries would suggest survival should do no worse than remain constant as fish grow larger before release.

Thus, there must be a factor masking the survivals of those larger fish. As noted on this graph, those groups showing the highest survivals were from fish released in late April or early May. A regression analysis of percent survival on size (in fish per pound) at release found no relationship between variables. When escapement (as defined below) was regressed on size at release no relationship was detected either.

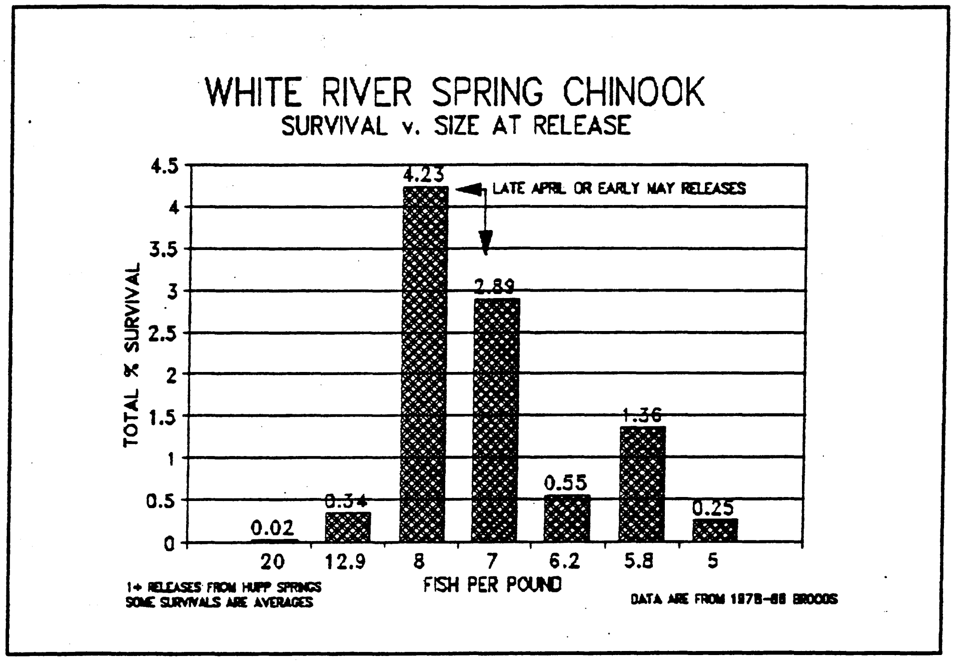

Figure 6. Survival of White River Spring Chinook v. size at release.

Date of Release:

Survival v. date of release was graphically analyzed (Figure 7). Survivals for each release date were averaged before graphing.

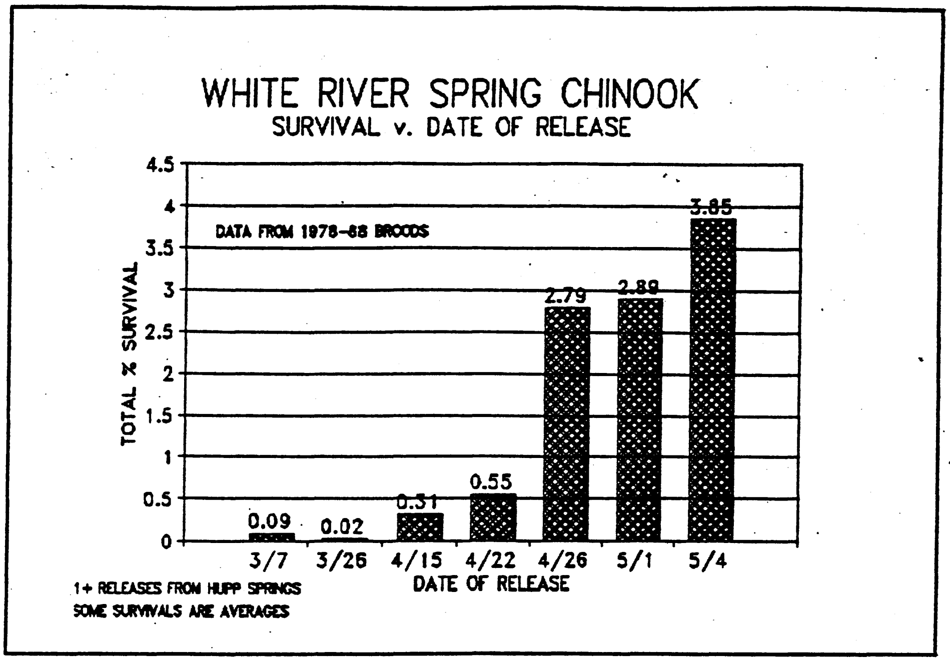

Figure 7. Survival of White River Spring Chinook v. date of release

A trend toward higher survival for later release dates was found and is very similar to that found at other Puget Sound spring chinook hatcheries (Performance of Spring and Summer Chinook Hatchery Programs in Puget Sound, A. Appleby, unpub. data. 600 Capitol Way N. Olympia, WA 98501). A regression analysis of data produced the following equation: Survival = -35.5 + 0.0789 x time (where time is expressed as days reared); df=12; r^2=.48; (p=.005).

Escapement v. date of release was also analyzed using simple liner regression. Escapement is defined as percent return to the hatchery rack as 3 year old or older fish. The regression produced the following equation: Escapement= -7.46 + 0.0166 x date; df=12; r^2= .43; (p=.025). Based on this analysis, attempts at increasing survival by changing date of release should also increase escapement. Extreme caution is advised when analyzing this variable. Changes in harvest regulations could have a large influence on the results.

A multiple regression of date of release and size at release on survival reduced the amount of variation in the survival that can be explained by these two variables. This was expected given the corresponding r^2 values calculated for each regression.

CONCLUSIONS:

The current program at Hupp Springs calls for production of a fixed number of yearling and zero-age White River spring chinook. The production of the zero-age component requires that we release the yearling group earlier than the current analyses would recommend. The past few brood years (1986 to current) releases have contained tagged groups of both yearling and zero-age fish. The returns of these marked fish will allow additional analyses. Preliminary estimates of the survival of these groups are presented in Figures 8 and 9. The two aspects which will continue to be examined are: 1) total percent survival and 2) percent survival as escapement. These analyses will allow adult and egg production to be maximized.

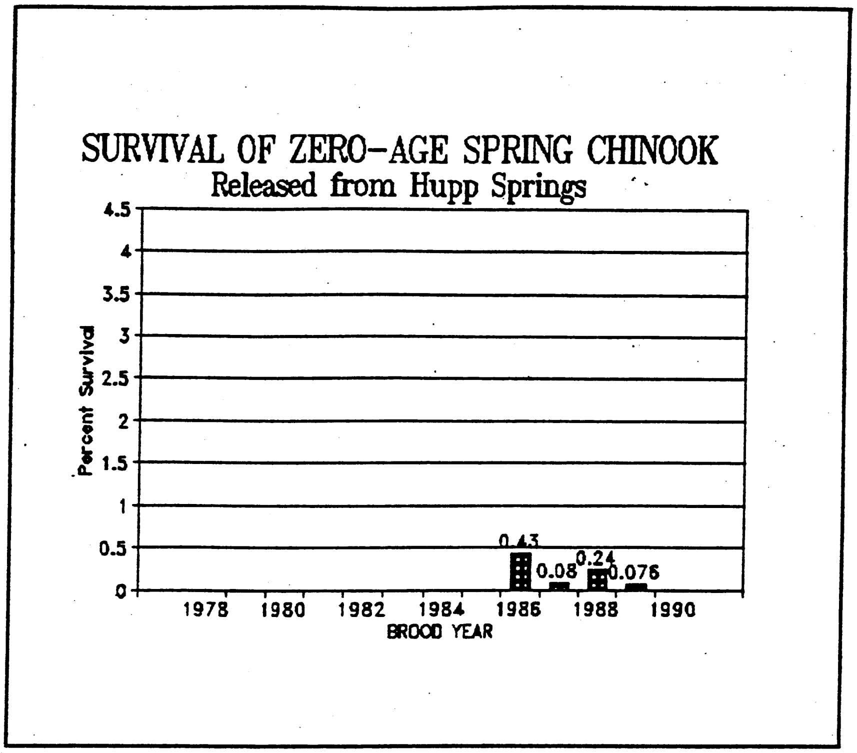

Figure 8. Survival of zero-age at release White River Spring Chinook.

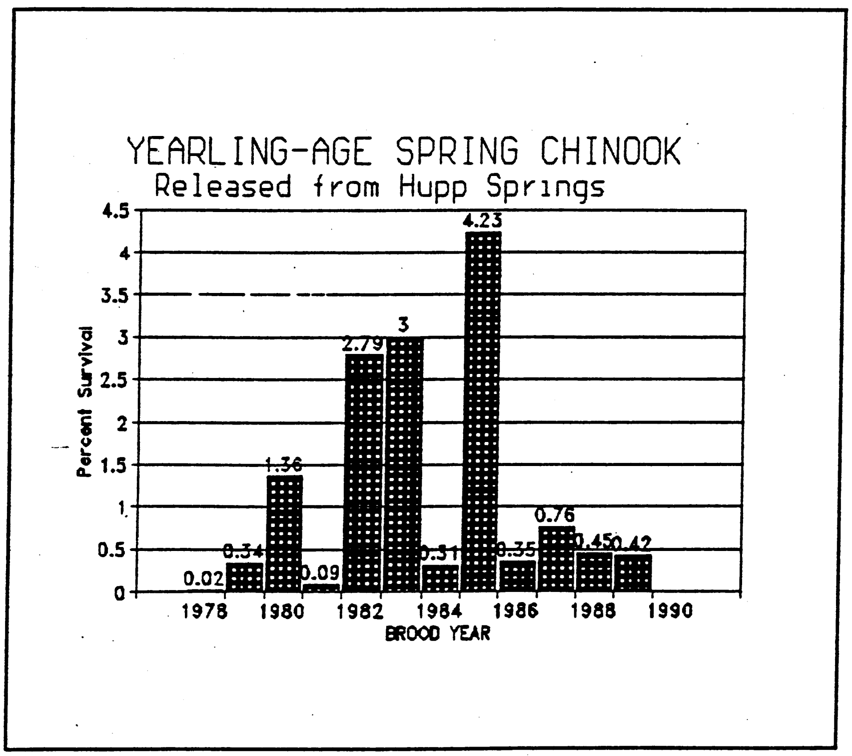

Figure 9. Survival of yearling age at release spring chinook.

SUMMARY OF CURRENT SPAWNING/REARING OPERATIONS FOR BOTH CAPTIVE BROOD AND ANADROMOUS PROGRAMS.

At the time of spawning, anadromous females and captive brood females are held in separate ponds. The males of each group are together in one pond at Hupp Springs, with additional net pen males held at Minter Creek. All anadromous fish are marked with a hole punched through the operculum at the time of transfer.

The eggs from each group are kept separate throughout spawning and incubation. All adult males and jacks are randomly selected for use in fertilizing eggs from both groups, producing the following possible matings:

1) anadromous male x anadromous female

2) captive brood male x captive brood female

3) anadromous male x captive brood female

4) captive brood male x anadromous female

A maximum of thirty females are taken at a time. The fish are assigned a number, the length is recorded, and fish are spawned. Each bucket containing a female's eggs is marked with her corresponding number. Both the fish and eggs are checked for any obvious abnormalities (gross kidney lesions, water hardened eggs, etc.). Snouts of anadromous fish are removed and transferred to the coded wire tag recovery lab in Olympia for tag recovery and analysis (all juveniles in the anadromous program are 100% coded wire tagged prior to release). Eggs from adults with either coded wire tag uncertainties (lost or no-tags) or with tags identifying them as being from other stocks (most often fall chinook), are removed from the population prior to the eyed stage of development.

Historically, all tags were read at the time of spawning (prior to combining of gametes). This prevented the creation of fish of uncertain parentage. As the program has grown to its current level, the need for reasonable speed in handling large numbers of fish has outweighed the need for real time analysis.

After the females have been spawned, 30 males are selected and killed. Lengths and origin (anadromous or captive) are recorded with the corresponding female's number they are spawned with. A one to one male to female ratio is the goal on each spawning day, however, on some days a shortage of ripe males may alter this (the spawning protocol is currently under review). After fertilization, eggs are combined into 2 fish pools and are transferred to Minter Creek hatchery for water hardening (in iodine at a 1:100 ratio) for one hour prior to being place into incubation units.

The eggs are treated daily with a formalin flush (10ml/ 1/2 gal/min of inflow) to control fungus and soft-shell (soft-shell is more common in the captive brood eggs). Well water is used throughout the incubation period. After the eggs reached the "eyed" stage, they are "shocked", dead eggs are removed (picked) and the live eggs are placed in vertical incubators containing a rugose substrate. Tray loadings are approximately 7,000 eggs/tray.

Rearing procedures:

Hupp Springs:

After hatching, fry are transferred directly from incubators to raceways at Hupp

Springs, normally in December or January. Rearing procedures are routine and consistent with current technology and practices. The typical program at Hupp is to rear as many fish as possible to yearling smolts (currently about 80,000). An additional 250,000 zero-age smolts are reared and released as well. During the early rearing phase fingerlings are held in raceways (10 x 100). Each release group receives a unique coded-wire tag (every fish is tagged) in order to monitor the performance of each rearing strategy (Figures 8,9). Each year 3,500 yearlings are transferred to the South Sound Net pen complex in order to maintain the captive brood program. The remaining yearling smolts are released in April or May and the zero age fish are released in late May or early June.

REFERENCES

Flagg, T.A. and Harrell,L.W. 1990. Use of Water-to-Water Transfers to Maximize Survival of Salmonids Stocked Directly into Seawater. The Progressive Fish-Cultrist 52:127-129.

Groves, Dave 1988. In Summary of Workshop, Proceedings on Broodstock Management. Dr. A.J.Castledine (editor), June 15, 1988, Sechelt, B.C.p.2-4. Capilano College, Sechelt, B.C.

Johnson, Keith, 1993. In Proceeding of Broodstock Summary Workshop 1993, Boise,Idaho Fish and Game. Box 25, Boise, ID 83707.

Moring, J.R. 1973. Aspects of growth, and the effects of some environmental factors on pen reared chinook salmon, Onchorynchus tshawytscha in Puget Sound,Washington. Ph.D. Thesis, University of Washington, Seattle. 222p.

Moring, R.M. 1989. Documentation of Unaccounted-for Losses of Chinook Salmon from Saltwater Cages. The Progressive Fish Culturist 51:173-176.

Redfern, B. 1988. In Summary of Workshop Proceedings on Broodstock Management. Dr.A.J.Castledine (editor); June 15, 1988 Sechelt, B.C. p. 13-14. Capilano College, Sechelt, B.C.

Rensel, J.E. 1989. Phytoplankton and Nutrient Studies Near Salmon Net Pens At Squaxin Island, Washington. Addition to The Washington Department of Fisheries and the Technical Appendices of the Draft Programmatic Environmental Impact Statement: Fish Culture in Floating Net Pens. January 1989. 31p.

REFERENCES cont.

Salo, E. and T.Jagielo, 1983. The Status of the Anadromous Fishes of the White-Puyallup River system. Unplubl. mansuscr. 200 p. (Document submitted to the Seattle District office of the U.S. Army Corps of Engineers, September 1983.) P.O.Box C-3755 Seattle WA 98124.

Science Applications International Corporation: Recommended Interim Guidelines For the Management of Salmon Net Pen Culture in Puget Sound. Report to Washington Department of Ecology in conjunction with WDFW and NDR. 1986 87-5 Ecology contract No. c-0087110 SAIC Project No. 2-817-02-344.

Thirteen Point Plan: A Salmon Angling Program for the Puget Sound Region. Washington Department of Fisheries (currently Dept. of Fish and Wildlife), 1973. Information Booklet No. 2. 1973. 29p.

Weston, D.P. and R.J. Gowan 1989. Assessment and Prediction of the Effects of Salmon Net Pen Culture on the Benthic Environment. Addition to The Washington Department of Fisheries and the Technical Appendices of the Draft Programmatic Environmental Impact Statement: Fish Culture in Floating Net Pens. January 1989. 62p.

APPENDIX A

ADULT PRODUCTION BY SOURCE AND EGG TAKE FOR WHITE RIVER SPRING CHINOOK:

(WDFW hatchery records unpubl. data. 600 Capitol Way N. Olympia, Wa 98501-1091).

Brood Year	Source	Adults Spawned Males	Females	Eggs Taken	
1972[1]	White	40	6	19,400	(plus hybrids)
1973	no program				
1974	White	8	5	20,000	
1975[2]	White / Puyallup	22	13	49,300	
1976[3]	White	6	27	116,000	
1977[4]	White	10	7	40,000	(1,271 smolts to Manchester)
1978	White	4	4	11,500	
1979	White	12	18	81,500	
1980	White	21	17	71,795	(744 smolts to Manchester)
1981[5]	White/ Manchester	4	18	81,118	(1,155 smolts to Manchester)
1982[6]	White	9	4	28,233	(1,090 smolts to Manchester)
	Manchester	7	7	(combined)	
1983[7]	White	16	6	17,800	(500 smolts to Manchester)
	Minter	12	8	19,900	(combined)
1984	White	1	1	5,429	(530 smolts to Manchester
	Minter	17	16	42,800	combined).
	Manchester	28	16	27,200	
1985	Minter	17	11	29,600	(1,857 smolts to Manchester)
	Manchester	25	27	58,659	(1,648 smolts to Manchester)
1986	White		2	7,000	
	Minter	47	43	122,850	
	Manchester	0	60	103,700	

APPENDIX A CONT.

1987	Minter	52		56	177,270	(3,485 smolts to SSNP)
	Manchester	0		5	11,350	
1988	Minter	88		68	206,603	(3,500 smolts to SSNP)
	Manchester	0		9		(combined)
1989	Minter	117		219	689,000	(3,500 smolts to SSNP)
	Manchester	0		50	98,000	
1990	Minter	74		105	341,800	(3,500 smolts to SSNP)
	SSNP	0		68	161,700	
1991	Minter	94		95	348,500	(3,500 smolts to SSNP)
	SSNP[8]	405		493	1,232,400	
1992	Minter	173		139	451,000	(3,500 smolts to SSNP)
	SSNP[8]	494		477	1,052,500	
	Muckleshoot[9]		20		24,000	
1993	Minter	172		181	579,700	(expect 3,500 smolts to SSNP)
	SSNP[8]	268		503	898,100	
	Muckleshoot		154		234,544	

Adult numbers include only those used for spawning, for total adults/year, see text.

FOOTNOTES:

[1] Several groups of hybrid chinook using White River spring chinook were released in other rivers.

[2] Adults returned to Puyallup Hatchery (most likely from an unrecorded on-station release of 1971 brood White River spring release and were used for spawning.

[3] No coded-wire tags were applied because of bacterial kidney disease.

[4] Includes five adults that returned to Puyallup hatchery and were used for egg take. Smolts released into Minter Creek without imprinting. Coded-wire tags were not applied.

[5] A small group of smolts (670) resulted from eggs provided by NMFS from Manchester. These were tagged separately.

[6] Four adults, presumably males, were transferred back to Manchester.

[7] Jacks from Manchester consisted of 53 three-year-olds and 21 two-year-olds.

[8] Includes fish and resulting eggs transferred to the Muckleshoot hatchery on the White River.

[9] Returns from the 1989 brood released from Muckleshoot hatchery.

CHRONOLOGY OF ARTIFICIAL PRODUCTION

1971- Fifty-two adults were taken to the Department of Fisheries' Puyallup Hatchery to produce sperm for the hybridization program. Approximately 19,000 eggs were taken from seven females captured incidental to the male collection program. The exact history of those pure stock springs is clouded, but they were probably planted on-station at Puyallup Hatchery judging from an unexpected return to the hatchery in 1975. White River males were crossed with females from Green River, Issaquah, and Cowlitz and hybrids were planted in Soos Creek, the Hoko River, Whidbey Island net pens, and the Sultan River. All the hybrid groups were coded-wire tagged.

1972- Fifty-three adults were captured to provide sperm for the hybrid program. Six females were taken incidently and produced 19,400 eggs. The pure stock progeny were released in Minter Creek and into the White River. Each group had a unique coded-wire tag. Several hybrid crosses were made with White River spring chinook males including: Cowlitz River spring chinook released in Finch Creek (Hood Canal), Hood Canal fall chinook released in Finch Creek, Hood Canal fall chinook released in the Hoko River, Hood Canal fall chinook released in Capitol Lake (Olympia), Green River fall chinook released in Issaquah Creek, and Issaquah fall chinook released in Issaquah Creek. All groups were uniquely identified with coded-wire tags.

1973- No program.

1974- During the spring of 1974, 29 adults and 9 jacks were transferred from the White

River to Puyallup Hatchery. Eight males and eight females died prior to spawning. Five females were eventually spawned and approximately 20,000 eggs were taken. The fish were raised at the Department of Fisheries' Minter Creek Hatchery and 8,340 were planted as yearlings into the White River. The group was represented by a unique coded-wire tag (Table 1).

1975- Twenty-one adults were transferred from the Buckley trap to Puyallup Hatchery. Twenty-two spring chinook returned to Puyallup Hatchery, most likely the return from an unrecorded on-station plant of the 1971- brood White River springs. Six females and two males died during the holding period and thirteen females provided 49,300 eggs. The fingerlings were raised at Minter Creek Hatchery and 40,580 yearlings were planted in the White River represented by a unique coded-wire tag.

1976- Forty-four adult White River spring chinook were captured at the Buckley trap and transported to Puyallup Hatchery. Eight females and three males died during the holding period. Twenty-seven females were spawned, producing 116,500 eggs. After losing 36,000 eggs, probably from a disturbance by a visitor during the critical stage of development, 81,000 fry were transferred to Minter Creek Hatchery for rearing. A total of 47,525 yearlings were released in the White River. Tagging was precluded because fish were infected with bacterial kidney disease (BKD). Due to the disease problem a low survival rate was anticipated.

1977- The 1977-brood was made up of 14 adults from the White River and 5 returns to Puyallup Hatchery. Adults were trapped at the Buckley site by sport fish staff from the Department of Fisheries and spawned at Puyallup Hatchery. The resulting fry were transferred to Skagit Hatchery with the expectations of reducing disease problems that had plagued the program in earlier years. Smolts were to be released into the White River.

Citing dismal performance from enhancement efforts within the White River, a decision was made within the Department of Fisheries to discontinue smolt plants into the White River in favor of releases into Minter Creek. The change occurred late in the rearing period for the 1977 brood juveniles and resulted in the reprogramming of this brood for release into Minter Creek. As a result of this decision, 20,461 yearlings were planted from Skagit Hatchery directly into Minter Creek in March 1979. During the same period of time WDFW agreed to transfer 1,000 smolts to the National Marine Fisheries Service (NMFS) for captive saltwater rearing at their Manchester Bay site. The NMFS had, for several years, been involved in captive brood rearing programs for Atlantic salmon.

1978- At the time the 1978-brood adults were trapped (all 13, 6 females, 7 males, from the White River), the production plan was still aimed at putting the progeny back into the White River. The determination to release smolts in Minter Creek was made in 1979, after the trapping period for the 1978 brood stock was complete. Note that the 1977-brood fingerlings were still on hand at Skagit Hatchery and were affected by this decision as described above.

The adults were hauled to Puyallup Hatchery by WDF Salmon Culture Division personnel and, after spawning, eyed eggs were transferred to Skagit Hatchery as in 1977. Following the decision to plant smolts at Minter Creek, the 1978-brood fingerlings were transferred to the Department of Fisheries' Garrison Springs Hatchery and then to Minter Creek Hatchery where 4,220 smolts were planted after five months of rearing.

1979- This brood of adults was the first to be taken with the planned objective of releasing smolts into Minter Creek from WDFW's new Hupp Springs Hatchery. The hatchery has a spring-fed water supply with excellent water temperatures for holding and rearing spring chinook (10 C). During the period of adult collection at the Buckley trap (33 total, 21 females, 12 males)), Hupp Springs was under construction. Garrison Springs Hatchery, a spring-fed facility located near the Hupp Springs site, was chosen as the interim adult holding and spawning site. The quality spring water was thought to be the best available in the project area.

After spawning the unfertilized eggs were transferred to Minter Creek Hatchery where they were fertilized, incubated and hatched. The fingerlings were transferred to Hupp Springs Hatchery for final rearing and 48,575 smolts were released into Minter Creek in March, 1981.

1980- Adults were trapped at the Buckley site (42 total, 21 females, 21 males) and delivered by Corps of Engineers personnel to Garrison Springs Hatchery. Eggs were sent to Minter Creek Hatchery for incubation and hatching. Fry were started at Minter Creek and fingerlings were sent to Hupp Springs in March, 1981. These fish were reared to yearlings and 19,600 smolts were released in March, 1982. The NMFS received 744 smolts for rearing as captive broodstock.

1981- Adults from the Buckley trap (22 total, 19 females, 3 males) were held at Garrison Springs Hatchery. The eggs were incubated and hatched at Garrison Springs rather than Minter Creek Hatchery. The NMFS program provided the first group of eyed eggs produced from the saltwater captive brood stock program, derived from the 1977-brood. All fry were transferred from Garrison Springs to Hupp Springs. NMFS received 1,155 yearling smolts and 37,300 yearlings were released into Minter Creek.

1982- Beginning with the 1982 brood year, adult holding was shifted to Hupp Springs Hatchery, representing the last facility change leading to the present production strategy. Also of note, in 1982, the first transfer of mature adults from the saltwater captive broodstock program at Manchester (21 total, 13 females, 8 males) to the freshwater holding site at Hupp Springs was complete. Adult spring chinook from the White River were again captured at the Buckley (13 total, 3 females, 10 males) trapping facility and transported to Hupp Springs.

Eggs were incubated and hatched at Minter Creek Hatchery. Fry were returned to Hupp Springs for yearling smolt release. NMFS received 1,090 smolts and 21,000 were released into Minter Creek.

1983- Broodstock came from three complimentary components of the program including the first significant 4 year old returns from the Minter creek release program (28 total, 9 females, 18 males) and 3 year old brood stock from the 1980 brood at Manchester (74 total, all jacks). This was also the last major contribution from the Buckley trapping facility (24 total, 6 females, 18 males). All adults were spawned at Hupp Springs and the eggs were incubated and hatched at Minter Creek Hatchery. Fry were returned to Hupp Springs and released as yearling smolts in May, 1985. WDFW released 34,500 smolts and 500 smolts were provided to NMFS for seawater rearing.

1984- Adult brood production was provided from previous Hupp Springs on-site releases (45 total, 21 females, 24 males) and from the Manchester brood program (65 total, 20 females, 45 males). There was also a small return to the White River (7 total, 5 females, 2 males). As in recent years, adults were held and spawned at Hupp Springs and eggs were moved to Minter Creek Hatchery. The fry were returned to Hupp Springs and reared for yearling release. There were 47,300 smolts released into Minter Creek in June 1986.

<u>1985-</u> Two brood sources provided the 1985 egg take, Minter Creek returns (35 total, 12 females, 23 males) and Manchester saltwater brood (66 total, 32 females, 34 males). Transfer of adults captured at the Buckley facility was discontinued after a disagreement between WDFW and the Puyallup and Muckleshoot tribes concerning the removal of spring chinook from the White River and the protocol for reinstatement of the fish. Manchester received 3,505 smolts and 45,986 yearlings smolts were released into Minter Creek on May 1, 1987.

<u>1986-</u> Adult broodstock returned as a result of on-station releases at Minter Creek (186 total, 70 females, 114 males) and from the saltwater captive brood program at Manchester (100 total, 73 females, 27 males). Additional adults were provided from trapping operations initiated by the Muckleshoot tribe at Buckley (3 total, 3 females, 0 males). The egg take from all sources was 236,350.

An agreement between the Muckleshoot tribe and the Department of Fisheries provided for return of a number of progeny from this brood to the White River system and 5,296 fingerlings were planted in the White River on May 15, 1987. The yearling rearing capacity at Hupp Springs (80,000) was exceeded for the first time, triggering a release of 91,825 zero-age smolts on May 19, 1987. An additional plant of 1,100 occurred on July 10, 1987. There were 86,755 fish planted as yearling smolts on April 22, 1988.

1987- Broodstock came from Manchester (19 total, 7 females, 12 males), which produced about 11,500 eggs) and from returns to Minter Creek (144 total, 68 females, 77 males), which produced about 177,270 eggs. The total number of eggs was 188,620. Of the resulting smolts, 83,074 were released as yearlings in 1989, and 84,250 were released as zero-age smolts in 1988. This brood year marked the first year smolts (3,500) were transferred to the South Sound Net Pen Complex at Squaxin Is. (near Olympia) rather than Manchester for captive brood rearing.

1988- Broodstock came from returns to Minter Creek (504 total, 77 females, 426 males) and Manchester (9 total, 9 females, 0 males). The number of eggs taken totaled 206,850. Of the resulting smolts 89,737 were released as yearlings, 3,500 were transferred to the South Sound Net Pens (spring of 1990), and 95,524 were released as zero-age smolts in June, 1989.

1989- Broodstock came from returns to Minter Creek (355 total, 232 females, 123 males) and Manchester (86 total, 52 females, 34 males) from Manchester (all 4 year olds). The number of eggs taken totaled 98,000 Manchester plus 689,000 Minter = 787,000. Of the resulting smolts, 91,172 were released as yearlings, 3,500 were transferred to the South Sound Net Pens. Also, 384,500 fingerlings were transferred to the new Muckleshoot Hatchery on the White River, and 249,773 zero-age smolts were released into Minter Creek in May, 1990. All the Manchester eggs were transferred to the White River Hatchery.

1990- Broodstock came from returns to Minter Creek (242 total, 116 females, 119 males) and from the South Sound Net Pens (580 total, 68 females, 512 males, all 3 year olds). The number of eggs taken totaled 161,700 SSNP plus 341,800 Minter = 503,500. Of the resulting smolts, 81,023 were released as yearlings, and 3,500 were transferred to the South Sound Net Pens (both in the spring of 1992). Also, 16,300 Minter origin plus 125,000 SSNP origin (total 141,300 eggs/fingerlings) were transferred to the Muckleshoot Hatchery on the White River and 189,800 zero-age smolts were released into Minter Ck. in June, 1991.

1991- Broodstock came from two sources; returns to Minter Creek (236 total, 113 females, 119 males,) and the South Sound Net Pens (974 total, 532 females, 442 males; 3 and 4 year olds). The number of eggs taken totaled 1,581,400 (1,232,900 SSNP plus 348,500 Minter). Of the resulting smolts, 84,493 were released as yearlings and 3,500 were transferred to South Sound Net Pens. Also, 13,400 Minter origin plus 193,000 SSNP (total 206,400) were transferred to the Muckleshoot Hatchery on the White River as eggs or fry and 266,030 were released as zero-age smolts into Minter Ck. in June 15, 1992.

1992- Broodstock came from three sources; returns to Minter Creek ((463 total, 179 females, 286 males) and SSNP (985 total, 477 females, 494 males, 3,4 and 5 year olds). The number of eggs taken totaled 1,504,000 (1,052,500 SSNP plus 451,500 Minter). An additional 24,000 eggs were taken from a small number of 3 year old chinook which returned to the Muckleshoot hatchery. Of the resulting smolts, about 90,000 are being held for yearling release in 1994 and 3,500 will be transferred to SSNP. Also 112,000 Minter origin plus 447,500 SSNP origin (total 559,500 eggs/fish) were transferred to the Muckleshoot Hatchery on the White River and 85,330 Minter origin and 168,664 SSNP origin (total 253,994) zero-age smolts were released into Minter Ck. in 1993.

1993- Broodstock came from three sources; returns to Minter Creek (332 total, 177 female, 155 males,) and SSNP (742 total, 485 females, 257 males, 3,4 and 5 year olds). The number of eggs taken totaled 1,648,459 (1,068,759 SSNP plus 579,700 Minter). An additional 234,544 eggs were taken from 3 and 4 year old fish that returned to the Muckleshoot hatchery. Of the resulting smolts, about 90,000 will be held for yearling release and 3,500 will be transferred to South Sound Net Pens (spring of 1995). Also, 179,600 Minter origin plus 295,700 SSNP origin (total 475,300 eggs/fish) have been transferred to the Muckleshoot Hatchery. A release of about 250,000 (combination of Minter and SSNP) zero-age smolts was conducted in June 1994 into Minter Creek.