GROVERS CREEK HATCHERY FALL CHINOOK: REARING HISTORY, FISH HEALTH, CODED WIRE TAG STUDY RESULTS, AND OBSERVED ADULT SIZE TRENDS

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Introduction

Fall chinook have been hatchery reared in Washington since 1895, originally to mitigate for declining local catch and more recently to supplement natural production. Hatchery survival and fishery contribution rates have varied greatly as we have learned the intricacies of nutrition, fish health, stock genetics, and the natural and artificial environments' influence on fish behavior. Hatchery cultural practices continue to evolve as we incorporate new knowledge into our programs.

This paper reviews the Suquamish Indian Tribe's (SIT) fall chinook salmon enhancement program at Grovers Creek Hatchery. The program began in 1978 with the cooperation of the Washington Department of Fish and Wildlife (WDFW). The program was designed to restore Tribal chinook fisheries on the west side of central Puget Sound, adjacent to the Kitsap Peninsula. There are no native runs of fall chinook in this area.

Grovers Creek Hatchery received eyed eggs from WDFW of Soos Creek origin between 1978 to 1981. Adults returning to the hatchery in 1982 represented the first mixed age class used to supply 100% of the hatchery broodstock. Eggs surplus to SIT needs are delivered to WDFW for in-state programs, or sold when the in-state production goals are attained. The hatchery annually releases an average of 537,000 smolts that are in proportion to the adult broodstock return timing. Off-station rearing ponds were established, beginning in 1982 that are supported by the hatchery broodstock. The chinook smolts released from the three off-station rearing sites are represented in proportion to the adult run timing spectrum. WDFW provides the balance of chinook fry to meet off-station production goals in years Grovers Creek Hatchery broodstock returns are low. The SIT terminal fishery does not target the hatchery broodstock, focusing exclusively on the off-station rearing ponds. Grovers Creek Hatchery fall chinook have been coded wire tagged annually since brood year 1981.

Hatchery Management

Adult fall chinook salmon return to Grovers Creek Hatchery in mid-September and continue until the end of October. The peak of the return is the last week of September and first week of October. The adults return to the same earthen pond in which they were reared. Grovers Creek Hatchery's water supply limits the incubation capacity of fall chinook eggs to two million. The SIT program goal is 3.2 million eggs and is satisfied by WDFW incubating one million eggs at Minter Creek Hatchery and the Mid Sound Fisheries Enhancement Group incubating one quarter million eggs at Burley Creek Hatchery.

Grovers Creek adult fall chinook are spawned throughout the entire run. Spawning protocols involve stripping eggs from individual females into a small bucket, with sperm from two different males added. The second male is used to increase the probability that the sperm is viable. Jacks (2-year-old males) are generally separated from the adults used for broodstock, and those, which are spawned, contribute to less than 5% of the spawning population. Stream water is introduced to the bucket and the rinsed eggs are transferred to a 5 gallon bucket for water hardening in a 100 ppm iodophor solution for one hour. Chinook eggs that are transferred off-station are delay-fertilized with five males stripped into individual ziplock bags and thirty females stripped into individual bags inside 30 gallon buckets. All delayed gametes are transferred on ice.

The water-hardened eggs are transferred to heath trays or deep matrix boxes for incubation. Pathogen and silt-free 10^{o} C groundwater is used to incubate all Grovers Creek Hatchery fall chinook eggs. A 1:600 formalin treatment is applied three times a week via a 15 minute pumped treatment. The fungus treatment is discontinued at 425 temperature units, after shocking and egg picking but before the eggs hatch. Swim-up fry are ponded indoors into circular ponds for initial feeding, then transferred outdoors into two ponds for rearing with ambient temperature Grovers Creek water. The chinook fry are introduced into the ponds throughout January. The pond temperature averages 2^{o} C during January, slowing the growth rate of the early spawned chinook fry so they are not significantly larger than the chinook fry spawned late in the run. Grovers Creek flow averages 2,500 gpm in January - February, but diminishes to 300 gpm by late May.

Grovers Creek Hatchery chinook fry are reared in two random groups, with half ponded into a 9,100 ft^3 cement pond and the other half ponded into a 29,000 ft^3 unlined earthen pond. Approximately 200,000 of the 9,100 ft^3 group are coded wire tagged (CWT) at 2.2 gms. The CWT fry are released into the earthen pond after tagging and are reared with their untagged cohort. A moist diet is fed at the manufacturers suggested rate, with changes in pellet size dictated by the smallest fry in the population. No grading or handling of the fry, except for weight samples and fish health inspections, occurs for the duration of their freshwater rearing. Outlet screens are removed from the pond when the chinook reach 5 gms to allow volitional outmigration, typically in late April. The station target is to produce a 9 gm smolt, and feeding continues until late May. A smolt counter is positioned in the fish ladder. The rearing pond is 100 meters from saltwater at high tide.

Avian predation is controlled by the use of a 5 cm knotless polypropylene net stretched over the entire pond. The net is suspended over three cables running the length of the pond. The center cable is the highest and can be raised or lowered by a manual boat winch to prevent snowload damage. An electric fence set 8 cm above the ground eliminates river otter predation upon the young growing chinook fry.

Fish Health

The health status of Grovers Creek chinook has been monitored since 1981 (Table 1). Adult broodstock are screened for the presence of viral or bacterial pathogens and juvenile fish are monitored on a monthly basis to assess general fish health and identify any potential problems occurring in the population. To date, adult broodstock have been relatively disease free. Inspection examinations of returning adults have identified low levels of the bacterium *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease. This pathogen has also been identified in juveniles at very low levels but no mortality has been attributed to this disease. No viral pathogens have been isolated from this stock of fish. However, between 1991 and 1996, two non-pathogenic viral agents (*reovirus, paramyxovirus*) were isolated during normal adult inspection screening.

Surface water flow constraints and variable environmental conditions have made fish rearing challenging. Juvenile chinook reared at Grovers have had a variety of parasites and bacteria. Between 1981 and 1990, environmental gill disease and bacterial gill disease were major problems that resulted in significant losses. These conditions were brought on by a variety of conditions including decreased water flows, increased water temperatures, low dissolved oxygen levels and overcrowding. The parasites *Ichtyobodo* and *Ichthiopthiurius multifiliis* have also caused some elevated mortality over the years. All these diseases were managed through the application of chemical treatments.

In an effort to improve the rearing environment, three rearing strategy changes were implemented between 1989 and 1991: providing aeration to the rearing pond, adding an additional well water source to supplement stream flow, and establishing an in-house fish health monitoring program. A microscope was purchased in 1991 and personnel were trained to evaluate gill condition and identify gill disease bacteria. This allowed for frequent gill condition monitoring. These three factors have made a significant improvement to the program. Environmental and bacterial gill disease are kept under control without experiencing the high mortalities that had occurred in the past. Currently, chemical treatments are used infrequently and due to the increased monitoring capabilities most potential problems are detected early and the appropriate corrective actions are applied.

GROVERS CREEK FACILITY - FALL CHINOOK
FISH HEALTH OBSERVATIONS

(includes any detection of a pathogen or condition, but doesn't necessarily mean a disease condition was associated)

MONITORING YEAR	JUVENILES	AVERAGE MORTALITY	TREATMENT	ADULT INSPECTIONS
1981				*Renibacterium salmoninarum*
1982	Bacterial gill disease	Moderate (0.031-0.10%/day)	Hyamine.	
1983	*Ichtyobodo* (Costia)	Normal to low (<0.01 - 0.03%/day)		*Renibacterium salmoninarum*
1984	Environmental gill disease *Ichtyobodo* (Costia), *Epistylis*	Normal to low (<0.01 - 0.03%/day)		*Renibacterium salmoninarum*
1985	Environmental gill disease Bacterial gill disease, *Ichtyobodo* (Costia)	Low to moderate (0.011-0.10%/day)	Diquat and formalin for gill disease and costia.	*Renibacterium salmoninarum*
1986	Environmental gill disease, *Phoma* sp.	Normal to low (<0.01 - 0.03%/day)		*Renibacterium salmoninarum*
1987	*Ichtyobodo* (Costia), *Ichthyopthirius multifiliis*	Low to moderate (0.011-0.10%/day)	Formalin for costia and ich.	
1988	Environmental gill disease Bacterial gill disease, *Ichtyobodo* (Costia)	Moderate to high (0.31%->0.11%/day)	Diquat for gill disease.	*Renibacterium salmoninarum*
1989	Environmental gill disease Bacterial gill disease *Aeromonas* sp., *R. salmoninarum*	Moderate to high (0.31%->0.11%/day)	No chemical treatments applied.	*Renibacterium salmoninarum*
1990	Environmental gill disease Bacterial gill disease, *Epistylis, Ambiphrya* Coagulated yolk syndrome	Low to moderate (0.011-0.10%/day)	Diquat for gill disease.	
1991	Environmental gill disease Bacterial gill disease *Icthyobodo* (Costia)	Normal to low (<0.01 - 0.03%/day)	Prophylactic diquat treatment initiated prior to tagging for gill disease.	Reovirus
1992	Environmental gill disease *Ichtyobodo* (Costia), *Hexamita sp.* Coagulated yolk syndrome Bacterial kidney disease	Normal (<0.01%/day)	Prophylactically treated for gill disease with KMnO4. Formalin used to treat costia.	
1993	Environmental gill disease Bacterial gill disease *Pseudomonas* sp., *Epistylis, Ambiphrya* Coagulated yolk syndrome	Normal (<0.01%/day)	No chemical treatments applied	Paramyxovirus
1994	Coagulated yolk syndrome	Normal (<0.01%/day)	No chemical treatments applied	Reovirus
1995	*Flavobacterium psychrophilum*	Normal (<0.01%/day)	No chemical treatments applied	
1996	Environmental gill disease Bacterial gill disease *Flavobacterium psychrophilum* *Ambiphrya*, *Phoma* sp. Coagulated yolk syndrome	Normal to low (<0.01 - 0.03%/day)	No chemical treatments applied	Paramyxovirus
1997	Environmental gill disease Bacterial gill disease *Ichthyopthirius multifiliis* Coagulated yolk syndrome	Normal to low (<0.01 - 0.03%/day).	Formalin for ICH, used only on chinook held for yearling program.	

Table 1. Fish health history of Grovers Creek fall chinook

Production and Adult Returns

Grovers Creek Hatchery fall chinook have been raised in a low capital cost facility within a suburbanizing watershed. The earthen pond approach produced quality smolts for the first seven years, but declining water quality and quantity (seasonally) impacted production (Figure 1). Environmental gill disease and bacterial gill disease decreased production in 1987, 1988, and significantly in 1989. Aggressive aeration (with a 5 hp blower and air stone matrix suspended just off the pond bottom), well water supplementation during low stream flows, and application of a soil bacteria solution at water temperatures above 10^{o} C restored fish health and smolt quality at release. Station production has been over 500,000 smolts annually except for the early years and 1993, which was impacted in part by low adult returns and low fecundity.

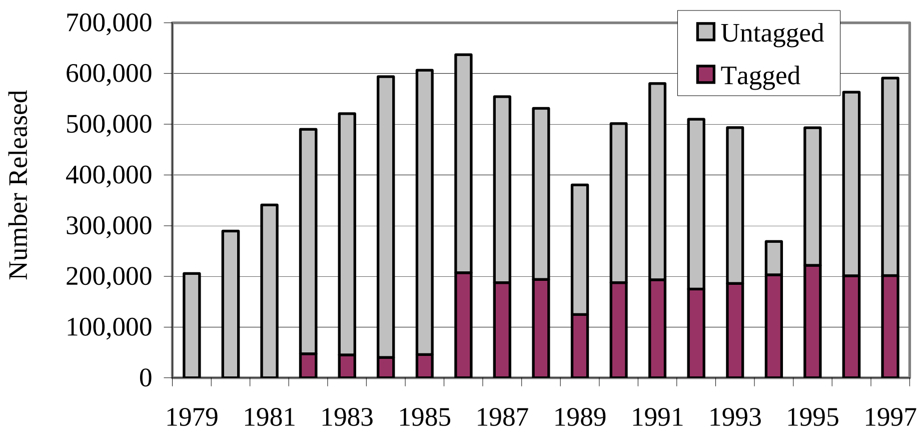

Figure 1. Grovers Creek Hatchery fall chinook releases with coded wire tagged component

The average Grovers Creek Hatchery rack return is 2,500 adults per year, but has varied significantly (Figure 2). Scales are removed from 200 adult fall chinook each week at the hatchery rack for age analysis. The results are used to forecast future runs, both to the hatchery and the off-station rearing ponds, and to evaluate changes to the hatchery population over time. 100% of Grovers Creek fall chinook are inspected for adipose clips and snouts are removed at the time of spawning The length and weight of each fish is recorded on both the scale card and hatchery field logs.

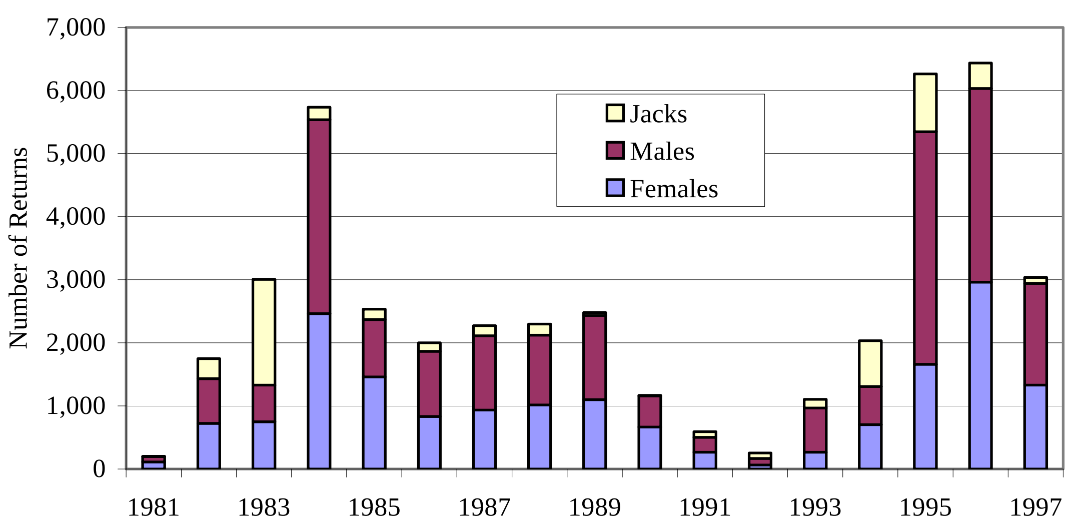

Figure 2. Grovers Creek Hatchery Adult Fall Chinook Return by Sex

Coded Wire Tag Study Results

Expanded coded wire tag recovery data were obtained from the Pacific States Marine Fisheries Commission (PSMFC) and summarized by the NWIFC Coded wire tag Recovery and Analysis System (CRAS). Percent recoveries of brood years 1981 to 1991 were summarized by geographic area and fishery, and the following were estimated: survival rates (Table 2), total marine catch (Table 3), and total catch by area and fishery (Table 3).

					Percent CWT Recoveries by Area and Fishery											
Brood Year	# Tagged	# Released	# Estimated Recoveries	Estimated % Survival	Alaska	Canada	Juan de Fuca Sport	Juan de Fuca Commercial	WA Coast and South	N Puget Sound Sport	N Puget Sound Commercial	Mid Puget Sound Sport	Mid Puget Sound Commercia	S Puget Sound Sport	S Puget Sound Commercial	Hatchery
1981	47,471	489,965	1524.5	3.2	0.2	17.3	3.4	1.7	0.3	0.6	1.0	25.9	7.1	3.9	0.6	37.6
1982	45,284	520,800	345.8	0.8	0.0	32.0	2.9	1.3	2.0	0.7	1.1	18.9	1.3	2.8	0.6	29.9
1983	40,324	594,000	307.9	0.8	0.0	21.5	1.9	11.2	0.7	0.0	0.0	13.2	11.8	0.0	0.0	39.0
1984	45,907	606,500	602.8	1.3	0.3	31.0	4.2	9.9	1.3	0.0	0.2	11.3	9.8	0.8	0.2	31.2
1985	207,155	637,032	1367.2	0.7	0.2	20.7	5.8	11.5	2.5	0.0	2.8	2.5	4.9	0.0	0.4	48.0
1986	187,757	554,163	3045.2	1.6	0.0	18.1	5.6	13.3	1.7	0.7	0.5	10.7	9.7	0.7	0.5	38.3
1987	193,906	531,351	911.2	0.5	0.0	22.2	6.4	16.3	0.7	1.0	0.4	7.4	7.1	0.3	0.3	36.2
1988	124,626	380,239	130.2	0.1	0.0	17.7	6.1	17.0	0.0	3.2	0.0	8.2	5.1	0.0	1.5	41.2
1989	187,640	501,391	303.6	0.2	1.5	16.1	16.3	12.4	2.0	0.0	0.0	6.4	6.7	0.0	0.6	32.6
1990	193,496	580,288	1435.7	0.7	0.1	22.0	5.0	6.3	0.3	2.4	0.2	10.6	4.3	0.1	0.0	48.6
1991	174,949	509,815	477.1	0.3	0.5	14.0	4.1	0.9	0.0	1.8	0.0	12.4	4.8	0.8	0.0	55.8
				Average	0.3	21.2	5.6	9.3	1.0	0.9	0.6	11.6	6.6	0.8	0.4	39.8

Table 2. Estimated Grovers Creek fall chinook survival rate estimates and CWT recoveries by area and fishery

		Estimated Total Catch by Area											
Brood Year	Total Catch	Alaska	Canada	Juan de Fuca Sport	Juan de Fuca Commercial	WA Coast and South	N Puget Sound Sport	N Puget Sound Commercial	Mid Puget Sound Sport	Mid Puget Sound Commercial	S Puget Sound Sport	S Puget Sound Commercial	Escapement
1981	15,681	31	2,726	539	275	44	102	155	4,075	1,118	608	99	5,910
1982	3,719	0	1,274	116	51	79	29	44	750	53	110	23	1,190
1983	4,499	0	977	84	507	31	0	0	600	533	0	0	1,768
1984	7,964	21	2,472	334	789	100	0	13	900	777	62	15	2,481
1985	4,155	7	872	243	484	87	0	119	105	204	0	16	2,017
1986	8,901	0	1,629	501	1,193	91	63	43	962	869	66	43	3,440
1987	2,448	0	555	159	407	12	25	10	186	177	7	6	905
1988	397	0	70	24	67	0	13	0	33	20	0	6	164
1989	758	12	130	132	100	8	0	0	52	54	0	5	265
1990	4,295	6	949	213	273	9	102	10	455	184	3	0	2,091
1991	1,320	7	194	57	12	0	24	0	173	66	11	0	775

Table 3. Estimated total catch of Grovers Creek fall chinook by area, including escapement

Straying

Recoveries of coded-wire tags provide some information on Grovers Creek fall chinook straying, as well as straying of other stocks to Grovers Creek Hatchery. Table 4 shows all Grovers Creek fall chinook freshwater recovery locations from 1985 to 1995. Table 5 shows the hatchery origins of fall chinook recovered at Grovers Creek Hatchery in the same years.

Region	Recovery Location	# Estimated CWT Recoveries
Puget Sound	Baker River	1
	Coulter Creek Hatchery	1
	Hupp Springs Rearing Facility	1
	Issaquah Creek	1
	Minter Creek	1
	Tulalip Salmon Hatchery	1
	Issaquah Hatchery	2
	Newaukum Creek (Green R)	3
	Burley Creek	6
	Capitol Lake Rearing Facility	6
	Soos Creek Hatchery	4
	Minter Hatchery	5
	McAllister Hatchery	7
	Garrison Hatchery	16
	Grovers Creek Hatchery	6478 (99.2% of total)
	TOTAL	6533

Table 4. Freshwater recovery locations of Grovers Creek fall chinook, 1985-1995

Region	Releasing Hatchery	# Tagged Recoveries
Canada	Chemainus River	2
	Cowichan River	1
Columbia River	Little White Salmon	1
	Cowlitz Hatchery	1
Hood Canal	Sund Rock Hatchery	1
	Big Beef Hatchery	2
	Quilcene Hatchery	3
Strait of Juan de Fuca	Elwha Hatchery	1
Puget Sound	Fox Island	1
	Garrison Hatchery	2
	Allison Springs	1
	Portage Bay Hatchery	1
	Grovers Creek Hatchery	6478 (99.7% of total)
	TOTAL	6495

Table 5. Origins of fall chinook recovered at Grovers Creek Hatchery, 1985-1995

Observed Trends in Hatchery Broodstock Size

The body size of adults returning to the hatchery can provide an integrated assessment of the environmental and genetic factors that have affected the fish (Gall 1987). Data were analyzed to determine the trend for body weight and length of Grovers Creek Hatchery fall chinook returning to the hatchery between 1986-96.

For each sex, 3 and 4 year old fish were analyzed separately. A systematic random sample size of 50 was determined necessary to estimate mean weight and length. This sample size was not available for both sexes of each year class because of low returns in 1991, 1992, and 1994, and inadequate data in 1990.

The null hypothesis that the observed mean weight and length from a random sample of the population would not significantly change between 1986-96 was tested against the alternative hypothesis that the observed mean weight and length from a random sample of the population would significantly decrease between 1986-96. The null hypothesis was rejected for 6 of the 8 trends analyzed (all but weight of 3 year old males and length of 4 year old males) (Figures 3 and 4). Therefore, we concluded that fish lengths and weights of the other 6 groups decreased over the time period of the study, but it could not be demonstrated by this study that weight of 3 year old males and length of 4 year old males decreased over time.

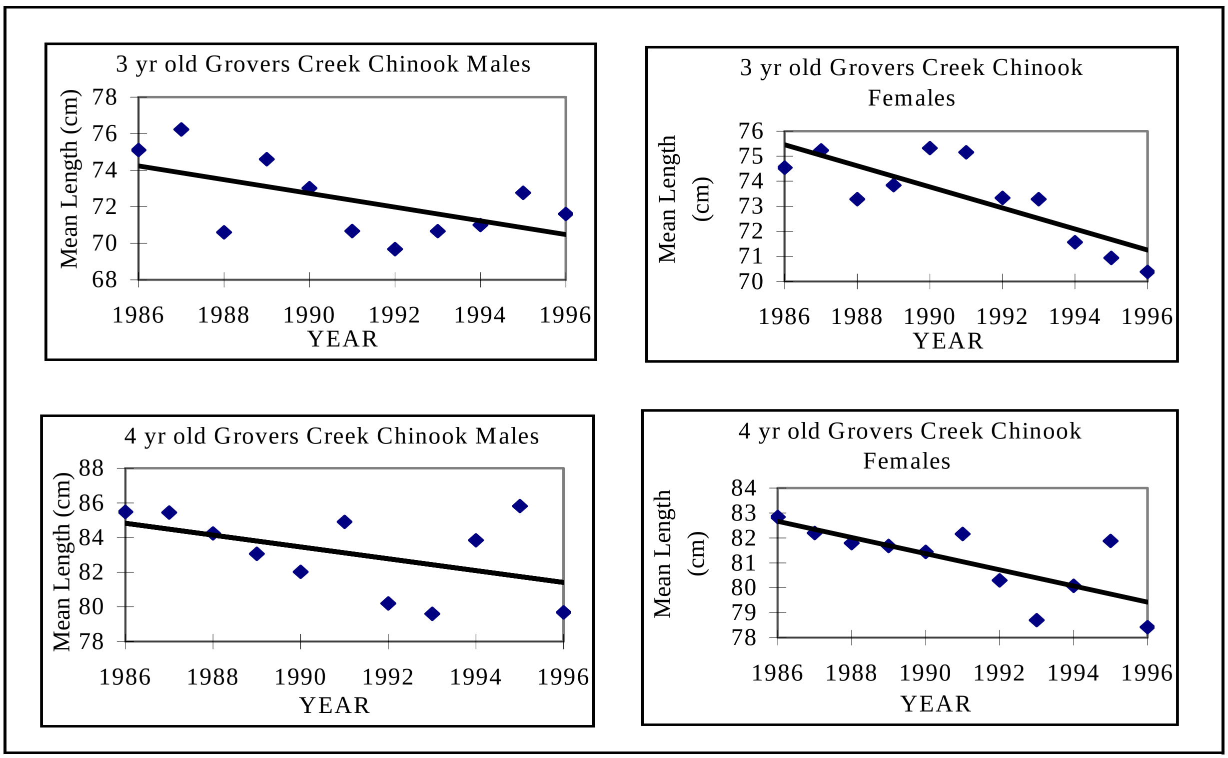

Figure 3. Changes in length of returning Grovers Creek fall chinook, by age and sex, for years 1986-1996.

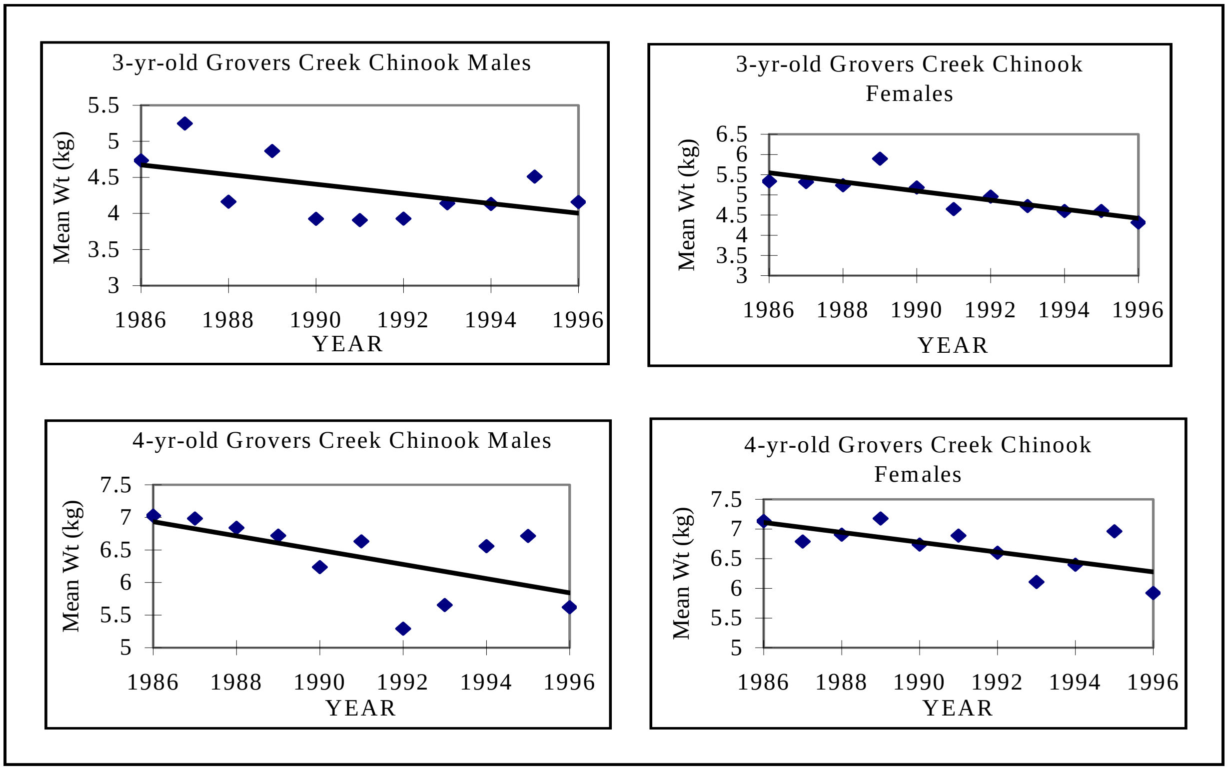

Figure 4. Changes in weight of returning Grovers Creek fall chinook, by age and sex, for years 1986-1996.

The trend toward decreasing body size of Grovers Creek Hatchery fall Chinook corresponds to that seen in other studies of North Pacific salmon (Bigler et al. 1993, Healey 1986, Ricker 1995). Possible causes for the decrease in body size of the Grovers Creek fall chinook stock include fish health effects noted above, as well as ocean climate conditions, density dependent competition, and genetic changes due to size selective fishing or hatchery management practices.

Beamish (1993) found that an increase in the intensity of the Aleutian low pressure system correlated well with strong year classes and above average survival of salmon. But, an inverse relationship between population abundance and mean body size occurred during the same period. This suggests there may be a limit to the salmon sustaining resources of the ocean (Bigler et al.1996).

Pacific salmon enhancement programs have assisted in the near doubling of salmon harvests over the past two decades in the North Pacific (Bigler et al 1996). During the period of favorable ocean climate conditions from 1973-1993, 45 of 47 North Pacific salmon populations studied by Bigler et al (1996) decreased in average body size. Washington chinook salmon stocks caught in the troll and Columbia River fishery declined in average body size 10.09% - 46.70% between 1976-93, possibly due in part to increasing hatchery releases causing a reduction in the available food supply through density dependent competition (Bigler et al 1996).

Ricker (1995) concluded the mean weight of chinook salmon caught by commercial trolling in Puget Sound between 1975-80 decreased ~1.5 kg, and showed little recovery to 1990, although chinook caught between 1985-1987 were larger. He suggests that because early maturing fish grow faster than those that mature at an older age, the selection of larger, slower growing older fish by a fishery may affect the heritable aspects of the growth rate and age at maturity causing a population to shift toward faster growth and younger age at maturity.

Despite using strict genetic conservation measures, hatcheries risk genetic change because their populations are relatively small and closed (Gall 1987). This is mainly due to genetic drift, the random loss of certain genes in small populations and to inbreeding (breeding closely related individuals). Generally, the greater the inbreeding, the more pronounced the reduction in viability, growth, survival and fecundity (Tave 1986 and Gall 1987).

In contrast to our observations of Grovers Creek fall chinook, a study of fall chinook salmon produced at four Washington State Department of Fish and Wildlife hatcheries found no decrease in length over brood years 1971-1992 (Vander Haegen and Appleby 1996). Unlike the Grovers Creek study, however, mean lengths in their study were calculated for males and females combined.

A second analysis was performed using mean lengths of Grovers Creek fish with sexes combined for brood years 1985-1991. The results are shown in Figure 5, along with WDFW Soos Creek Hatchery study results. Soos Creek data were not available for brood year 1989. Grovers Creek results were similar to those from Soos Creek for this interval for this combined-sex study. The data suggest a decrease in length, but the trend line plotted is not statistically significant. It is not known if analysis of the Soos Creek fish by sex would be statistically significant.

The observed decreases in size of 6 of the 8 Grovers Creek Hatchery fall chinook age-sex combinations may not reflect the long-term trend because only 11 years of data were analyzed.

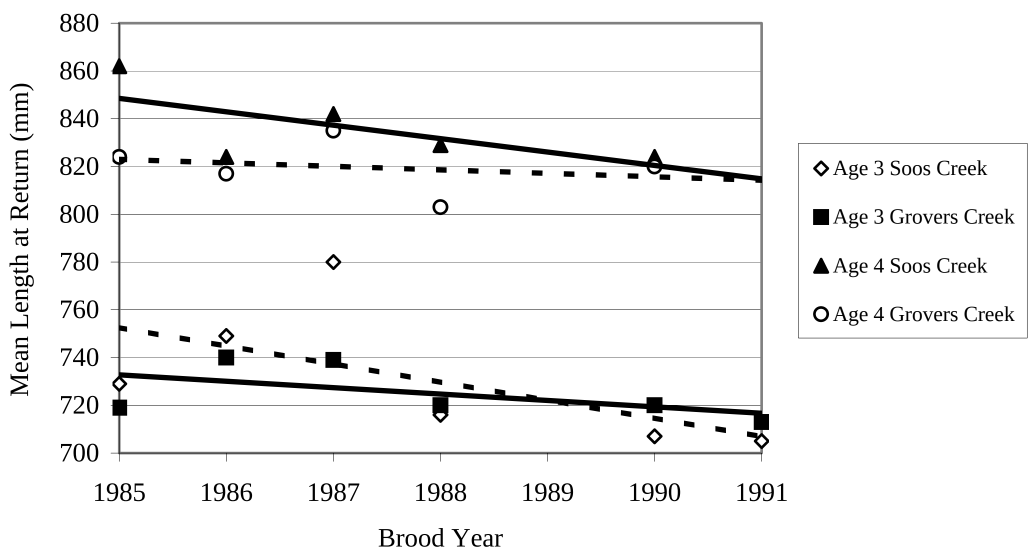

Figure 5. Changes in mean length of Grovers Creek and Soos Creek fall chinook , brood years 1985-1991

Off-station Rearing Pond Production and Fishery Contribution

Grovers Creek Hatchery production supports three off-station rearing ponds that contribute to an important Suquamish treaty fishery (Figures 6 and 7) and local sports fishery. All three sites are operated primarily with sports club volunteers and have limited operations and maintenance funding. SIT provides technical support, project oversight, and Grovers Creek fall chinook fry. WDFW provides fry to make up Grovers Creek broodstock shortfalls and also contributes most of the fish food. No hatchery personnel live on-station and emergencies are handled on a volunteer phone tree basis. This operational strategy-- low budget and limited personnel-- increases the risk of fish loss, and losses have occurred. All the parties recognize the risk of fish loss but have maintained support for the rearing ponds in order to produce fall chinook available to harvest. Efforts to secure additional funding continue, and would be expected to increase smolt quality and survival.

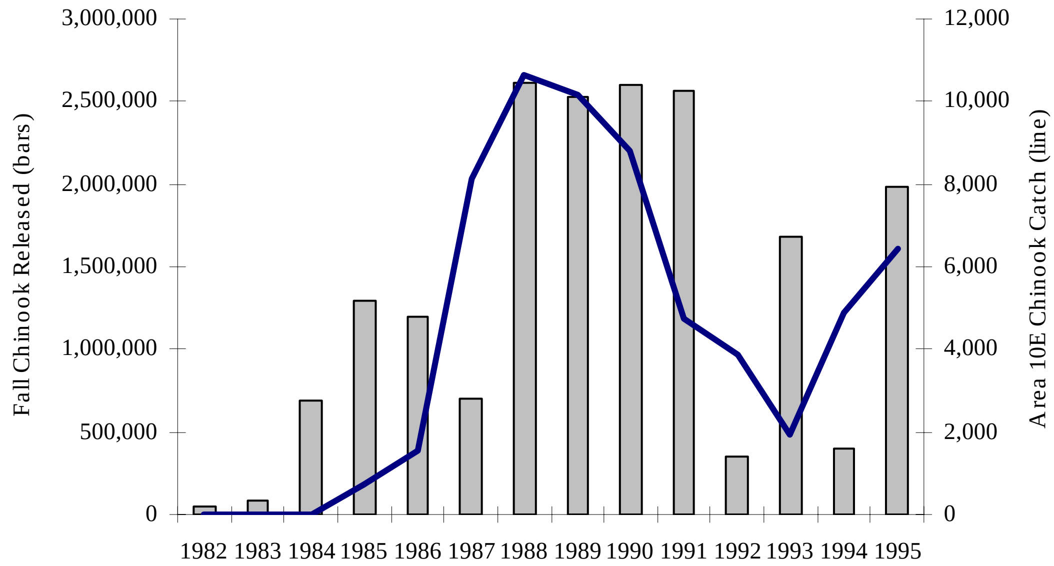

Figure 6. Number of Suquamish off-station fall chinook smolts released (bars) and number of chinook caught in Tribal terminal fishery (line), 1982-1995

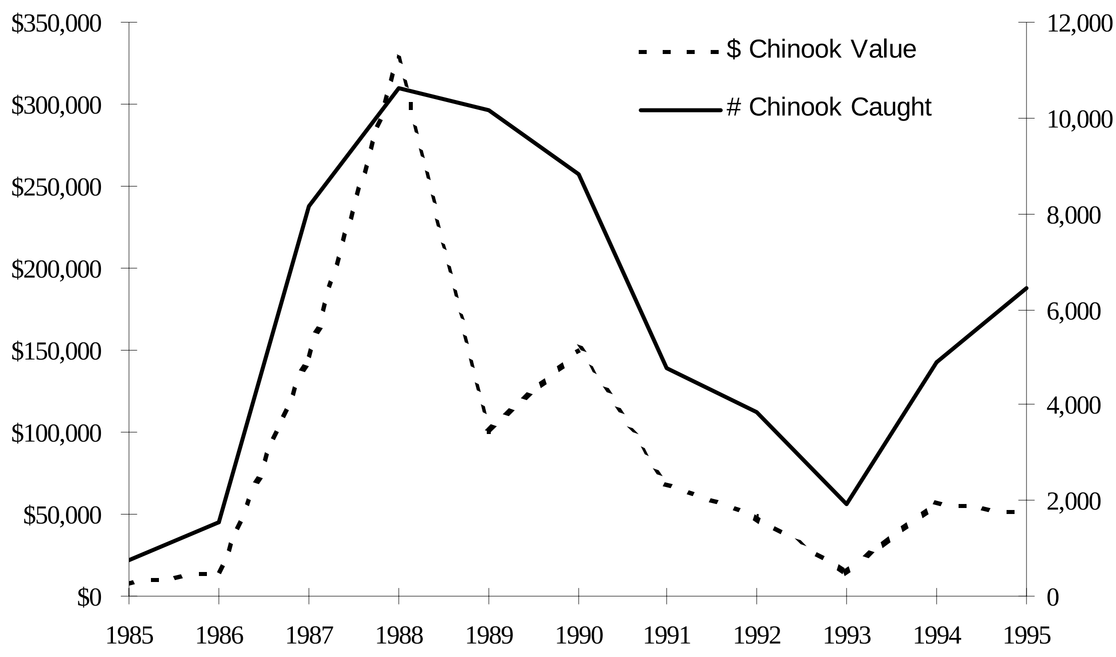

Figure 7. Suquamish Tribe Area 10E commercial chinook harvest and value, 1985-1995

Chinook not caught in the fishery return to spawn in their rearing pond creeks, generating public enthusiasm and ecological benefits. These ecological benefits may be significant. There are no hatchery/wild stock chinook interactions since the only chinook present in East Kitsap streams are Grovers Creek stock. The spawning chinook significantly clean the gravels later used by coho and chum salmon and cutthroat trout The chinook carcasses boost the nutrients available from local salmon and trout populations, enriching the stream ecosystem.

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