2002 Wild Coho Forecasts
for Puget Sound & Washington Coastal Systems

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Run size forecasts for wild coho stocks are an important element of the joint state-tribal pre-season planning process for Washington State salmon fisheries. Accurate forecasts on a stock basis are required to ensure adequate spawning escapements, while realizing harvest benefits and achieving allocation goals.

Various approaches have been used across this state's coho producing systems to predict ocean recruits. In the past, many of these methods have relied on the relationship between adult escapement estimates and resultant run sizes. Reconstructing coho run sizes, however, is notably difficult due to the problems of accurately estimating escapements and the inability to allocate catches in intercepting fisheries, by stock. Even if the run size data bases were reasonably accurate, in systems that are adequately seeded, coho forecasts based solely on estimated escapement have no predictive value. Such forecasts do not account for the two primary **and** independent components of interannual variation in run size, freshwater and marine survival. Moreover, because adult to adult forecasts combine these two parameters, understanding the components of error in such forecasts post-season are precluded. Improving our ability to manage wild coho runs depends on learning which factors cause significant variation in abundance for each major system.

Smolts are the measure of freshwater production. In recognition of this, natural coho escapement goals throughout this state are based on the projected smolt carrying capacity of each system. To assess these goals and to improve run forecasts, WDFW and tribes have made substantial investments in monitoring smolt populations in a number of basins. These data have been incorporated into some forecasts, but, until recently, have not been used on a consistent basis or in all systems.

Marine survival rates for wild coho stocks have also been measured over many years at several stations in Puget Sound and at one station in the Grays Harbor system. These data describe the patterns of interannual and inter-system variation in survival within broods. Given the extreme difficulty in estimating coho escapements with survey-based approaches, only those tag groups returning to trapping structures with 100% capture capability throughout all flows estimate survival-to-return without bias.

Adult recruits are the product of smolt production and marine survival. Therefore, any estimate of adult recruits can be expressed in a simple matrix as combinations of these two components. Through a process of comparing the outcomes for each term relative to measured and or likely values, the veracity of forecasts derived from methodologies not employing smolt and marine survival

estimates can be assessed. Understanding variation in hatchery runs, for example, is reduced to analyzing the components of post-release survival because the number of smolts released, the starting population, is known.

Fisheries have been managed to achieve escapement goals for natural/wild coho stocks returning to eight production areas. These systems include; Skagit, Stillaguamish/Snohomish, Hood Canal, Straits, Quillayute, Hoh, Queets, and Grays Harbor. While the forecasts to these systems, which are considered the "primary" wild coho management units, have been used to determine the extent and shape of fisheries, management objectives for other areas are also under discussion. Production from these other freshwater habitat units can also be approximated by extrapolating measured smolt production and marine survival rates. Expressing natural coho production in the common terms of smolts will enable useful interannual comparisons within systems and annual comparisons across systems. This approach will also promote better understanding by stakeholders as it more directly connects coho production with habitat.

Presented in Table 1 are the forecasts of wild coho run size derived by combining estimates of natural smolt production and predictions of marine survival for all Puget Sound, Coastal, and Lower Columbia River stream systems. The resulting estimates of three-year old ocean recruits were adjusted to estimate the population in terms of December age-2 and January age-3 recruits to provide the appropriate coho management model inputs. The following sections detail each estimate of smolt production and marine survival.

Table 1. Wild coho run forecasts in 2001, based on estimates of smolt production and marine survival.

Production Unit	PRODUCTION X MARINE SURVIVAL			= RECRUITS		
	Estimated Smolt Production: Spr '01	Adults (Age 3)	Dec. (Age 2)	Adults (Age 3)	Dec. (Age 2)	Jan (Age 3)
Puget Sound						
Primary units						
Skagit River	1,014,000	11.0%	14.7%	111,540	148,680	137,380
Stillaguamish River	360,000	9.0%	12.0%	32,400	43,200	39,920
Snohomish River	1,000,000	12.0%	16.0%	120,000	160,000	147,840
Hood Canal	479,000	7.0%	9.3%	33,530	44,700	41,300
Straits of Juan de Fuca	380,000	5.0%	6.7%	19,000	25,330	23,400
		10.0%	13.3%			0
Secondary units						
Nooksack River	90,000	10.0%	13.3%	9,000	12,000	11,090
Strait of Georgia	30,000	10.0%	13.3%	3,000	4,000	3,700
Samish River	100,000	10.0%	13.3%	10,000	13,330	12,320
Lake Washington	92,000	12.0%	16.0%	11,040	14,720	13,600
Green River	95,000	12.0%	16.0%	11,400	15,200	14,040
Puyallup River	86,000	8.0%	10.7%	6,880	9,170	8,470
Nisqually River	10,000	5.0%	6.7%	500	670	620
Deschutes River	1,000	3.0%	4.0%	30	40	40
South Sound	86,000	5.0%	6.7%	4,300	5,730	5,290
East Kitsap	62,000	10.0%	13.3%	6,200	8,260	7,630
Puget Sound Total	3,885,000			378,820	505,030	466,640
Coast						
Quillayute River	395,000	5.0%	6.7%	19,750	26,330	24,330
Hoh River	200,000	4.0%	5.3%	8,000	10,660	9,850
Queets River	257,000	4.0%	5.3%	10,280	13,700	12,660
Quinault River	217,000	3.0%	4.0%	6,510	8,680	8,020
Independent Tributaries	212,000	3.0%	4.0%	6,360	8,480	7,840
Grays Harbor						
Chehalis River	1,977,000	3.0%	4.0%	59,310	79,060	73,050
Humptulips River	200,000	3.0%	4.0%	6,000	8,000	7,390
Willapa Bay	425,000	3.0%	4.0%	12,750	17,000	15,710
Coastal Systems Total	3,883,000			128,960	171,910	158,850
Lower Columbia River	873,000	3.0%	4.0%	26,190	34,910	32,260
GRAND TOTAL	8,641,000			533,970	711,850	657,750

Smolt Production

A substantial level of coho smolt production evaluation work has been conducted in each of the eight major natural production systems except the Hoh. In the Skagit River, total smolt production has been estimated annually since 1990. We have also estimated total system smolt production from the Chehalis Basin, the largest watershed in the state accessible to anadromous fish outside of the Columbia River, annually since 1986. Beginning in the 1970's, smolt production has also been measured from significant portions of the Snohomish, Stillaguamish, Hood Canal, Quillayute, and Queets systems and more recently, in tributaries to the Straits of Juan de Fuca. In aggregate, this work has produced a body of information that describes wild coho carrying capacity, largely as a function of habitat quality and quantity. Seeding levels, environmental effects (flows), and human-caused habitat degradation explain much of the interannual variations in smolt production that have been measured (Table 2).

Table 2. Summary of coho smolt production evaluations in ten Western Washington streams, and sources of interannual variation.

Stream	Number of Years	Watershed Area (sq. mi.)	SMOLT PRODUCTION Range Low	Range High	Ratio Hi/Lo	Avg. Prod.	Avg. Prod./ (mi^2)	Identified Sources of Variation (see key)
Big Beef Creek	24	14	11,510	47,089	4.1	25,283	1,806	1, 2, 4, 5
Bingham Creek	20	35	15,280	71,708	4.7	30,743	878	2, 3
Deschutes River[a]	23	130	1,000	133,198	133.0	60,002	462	1, 2, 4, 5
SF Skykomish River	9	362	181,877	353,981	1.9	249,442	689	7
Dickey River[b]	3	87	61,717	77,554	1.3	71,189	818	6
Bogachiel River[b]	3	129	48,962	61,580	1.3	53,751	417	6
Clearwater River	21	140	27,314	99,354	3.6	63,378	453	1, 4, 5
Stillaguamish River	3	540	203,072	379,022	1.9	275,940	511	6
Skagit River[c]	12	1,918	617,600	1,759,600	2.8	1,015,608	530	1, 2, 3, 8
Chehalis River	19	2,114	502,918	3,592,275	7.1	1,824,849	863	1, 2, 3, 4
Total		5,469						
Mean							743	
Wt'd Mean[d]							661	

[a] Deschutes River total drainage area = 160 mi^2, of which 30 mi^2 are inaccessible above Deschutes Falls.
[b] Dickey and Bogachiel River watersheds are estimated areas above trap locations.
[c] Skagit River total drainage area = 3,093 mi^2, of which 1,175 mi^2 are inaccessible above dams.
[d] Weighted by catch.

Key

1. Winter flows – gravel scour/ egg survival
2. Summer flows – rearing habitat
3. Fall flows – spawner distribution
4. Seeding
5. Habitat damage
6. No factors identified
7. Experimental escapement reduction
8. Species interactions

While annual smolt monitoring within each major system would be optimal, sufficient information exists to approximate production in systems currently unmeasured. Within Puget Sound, **WDF Technical Report 28** Zillges 1977 (T.R.28), provides one means of transferring smolt production monitoring results to other basins. This document, which is the basis for most Puget Sound wild coho escapement goals, contains estimates of the wetted habitat at summer low flow, and projections

of potential coho smolt production for each stream in Puget Sound (east of Cape Flattery). For coastal systems, smolt production in unstudied watersheds can be approximated by extrapolating the smolt production per square mile of drainage basin rates measured in the study streams.

Puget Sound Primary Units

Skagit River

In 2001, we estimated that 1,014,000 coho smolts emigrated from the Skagit River (Table 3). This estimate is based on trapping and marking wild coho in tributaries, and sampling emigrants in the lower mainstem river with floating scoop and screw traps. Over the twelve years that we have measured Skagit River smolt production, it has ranged from 618,000 to 1,760,000 coho smolts. Except for 1997, all of the high production levels, which have averaged around 1.2 million, have occurred on even years, while those occurring on odd brood years have averaged approximately half of this level.

Table 3. Estimation of wild coho smolt production, Skagit River, 2001.

	Number	Formula
Total mainstem trap catches	7,436	
Skagit Hatchery/Lake Shannon	-501	
Wild coho captured (c)	**6,935**	$N = \frac{(m+1)(c+1)}{(r+1)}$
RVs recaptured (r)	47	
RVs released (m)	7,013	
Total production (N)	**1,013,523**	
Variance (Var)	2.07e+10	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+2)^2(r+1)}$
Standard deviation (sd)	143,793	
Coefficient of Var (CV)	14.19%	CV = sd ÷ N
Confidence interval (CI)	281,833	CI = ± 1.96(sd)
Estimated coho production Skagit River	1,013,523	
Upper CI (95%)	1,295,356	
Lower CI (95%)	731,690	

[a] Hatchery ad-marked and unmarked smolt total from counts obtained by visual identification at trapping.

We believe this pattern results from a positive interaction with adult pink salmon, which spawn only on odd years. We attribute the higher than average odd-year production measured in 2001 to the extremely anomalous 2001 water year. From Fall 2000 through Spring 2001, precipitation and stream flows were just a fraction of normal. We believe that this fall-winter drought allowed higher production from the 1999 brood than would have resulted from a normal winter discharge pattern that included numerous high flow spikes. In large, high-energy systems such as the Skagit River, a

substantial portion of the coho parr population redistributes from summer rearing areas into lower gradient overwintering refuge areas with the onset of high flows. Because flows never increased over this winter, this major redistribution did not occur to the extent that it does in a normal flow year. This is apparent by the low number of smolts emigrating from Mannser Creek, a low gradient winter refuge stream that we trap in the lower Skagit Basin. On broods which experienced high winter flows, we capture around 40,000 coho smolts emigrating from this stream. During Spring 2001, a record low of only 7,000 coho emigrated from this stream.

Another factor that regulates coho production, particularly in smaller streams, is the amount of low-flow habitat available (Figure 7). While late-fall and winter flows affecting parr survival from this brood were anomalously low, summer flow was nearly average. The Puget Sound Summer Low Flow Index (PSSLFI) for water year 2000 had a value of 8.7, just slightly below its 37 year average of 9.0 but above the average of 8.1 recorded over the previous eleven broods for which we have measured coho smolt production from the Skagit River.

Stillaguamish River

We estimated smolt production from the Stillaguamish River upstream of R.M. 16 in three years (1981-1983). Production from these broods, which we deemed were fully-seeded, ranged from 203,000 to 379,000, and averaged 276,000 coho smolts. Expanding for the portion of projected smolt production (T.R.28) downstream of this point (23%), mean system production was estimated at 360,000 smolts. Over these three broods, the PSSLFI averaged 10 with little deviation between years. In a more normal brood year, we would adjust the average smolt production by the ratio of the current index value to the average over the years we measured smolt production. As indicated by results in the Skagit River and other systems, however, the winter drought may have overridden the negative effects of the slightly below-average summer flows on the 1999 brood. Therefore, we elected to use the three-year average production of 360,000 coho smolts to approximate production in Spring 2001.

Snohomish River

We measured smolt production from known numbers of spawners in the South Fork Skykomish River over nine brood years (1976-1984) (Figure 1). This basin comprises 20.7% of the Snohomish River system's drainage area. Excluding the three years in which we reduced escapement, production averaged 276,000 smolts. These estimates were generated using "back-calculation" — determining coded-wire tag ratios upon adult return. Consequently, they include production which reared downstream of Sunset Falls. Trapping-based estimates for these six broods indicate that around 75% of these estimated productions emigrated as smolts from above Sunset Falls. Adjusting the estimates by this rate yields an average production of 207,000 smolts that remained above Sunset Falls until spring. Expansion of this estimate to the entire system calculates an average total production of 1,000,000 coho smolts. This estimate may be biased high because 450 mi^2, 26% of the 1,714 mi^2 Snohomish Basin, is inaccessible to anadromous fish. This area includes the Snoqualmie River, above Snoqualmie Falls (375 mi^2), and the Sultan River above the dam (75 mi^2). Countering this bias, however, is the fact that much of the rest of the basin is lower gradient than the watershed above Sunset Falls, and therefore, more productive.

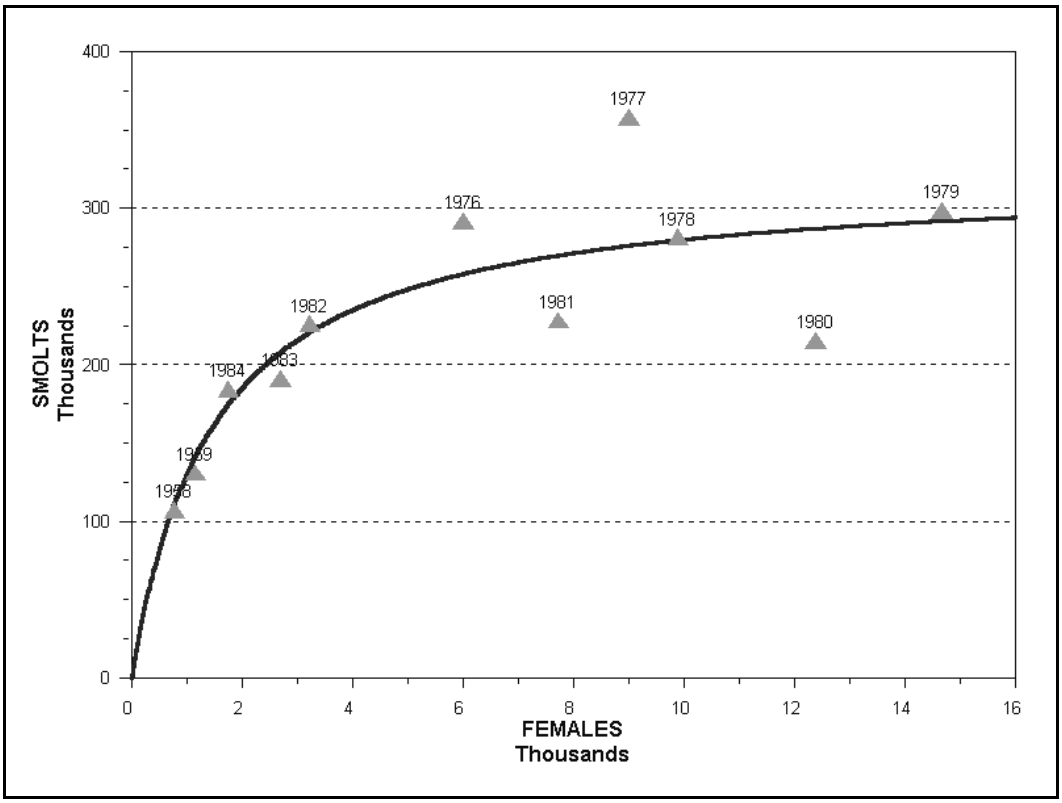

Figure 1. SF Skykomish River wild coho spawners and recruits, by brood year.

Based on the results in the Skagit River, we elected to use the average production for the Snohomish Basin in 2001 of 1,000,000 coho smolts.

Hood Canal

In 2001, we continued trapping four streams on the east side of Hood Canal: Big Beef, Stavis, Seabeck, and Little Anderson Creeks. We have measured smolt production each year since 1978 in Big Beef Creek, and since 1992 in these adjacent streams. In 2001, these streams produced 21,855, 6,008, 1,116 and 411 coho smolts, respectively. Habitat in both Seabeck and Little Anderson Creeks are degraded by development, stormwater runoff and consequent high sediment loads.

In Big Beef Creek, production from the spawning escapement of 278 females in 1999, averaged 78.6 smolts per female.

The coho production potential of tributaries to Hood Canal was originally estimated at 1,006,577 smolts (T.R.28). A more recent review by the Hood Canal Joint Technical Committee (HCJTC) revised this estimate downward to 561,631 smolts. Both of these estimates were predicated upon adequate seeding and average environmental conditions. These habitat-based projections estimate that the four streams we trap account for 5.9% and 7.6% of Hood Canal's coho smolt production potential. Expansion of the combined smolt populations from these four streams projects production for the entire Hood Canal in 2001 at 500,000 and 388,000 coho smolts based on the habitat estimated by T.R.28 and the HCJTC.

In previous years, we have selected one of these approaches to estimate production. Beginning with the 1999 brood, however, we have developed a new rate based on the HCJTC forecast review (Summer 2001), which compared predicted cohorts with those computed post season via run reconstruction. This analysis estimated that expanding Big Beef Creek smolt production by a factor of 21.93 (1 ÷ 0.0456) best predicts Hood Canal run size. Inherent in this analysis are two main assumptions: (1) that marine survival as estimated with tagging Big Beef Creek wild coho represents survival for the entire Canal's production; and (2) that run reconstruction accurately represents total Hood Canal recruits.

Expanding the 21,855 coho from Big Beef Creek in 2001 with this rate estimates total production at 479,300 smolts.

Straits of Juan de Fuca

To estimate wild coho smolt production in 2001, Strait of Juan de Fuca (SJF) streams were stratified into four categories: eastern SJF small independent streams, eastern SJF large streams, western SJF small streams, and western SJF large streams. Eastern SJF streams were defined as those east of and including the Elwha River, whereas western SJF streams were west of the Elwha. Large streams were defined as those having an average mainstem width of greater than 5-yds. Small streams were those with a mainstem width of 5-yds or less.

Smolt trapping was not conducted in the eastern SJF in 2001, however, we operated a number of traps in this area over the previous three years (1998-2000), which provided the general range of smolt abundances expected from these streams. To estimate smolt production from the eastern SJF small streams in 2001, we employed a relationship that was found between smolt production and peak winter stream flows during the incubation period (Figure 2). This relationship estimated a smolt production rate of 0.0435 smolts/yd^2 of low flow habitat. Applying this rate to the total estimated low flow habitat available, estimates 16,000 smolts from eastern SJF small streams.

To estimate production from the eastern SJF large streams, we scaled the estimate of wild Dungeness River coho measured by smolt trapping in 1998 (253 smolts/mi^2 watershed area) by the ratio of the eastern SJF small stream production estimate for 2001, 0.0435 smolts/yd^2, over the 1998 value of 0.0196 smolts/yd^2. Using this ratio by itself would estimate Dungeness smolt production at 2.2 times the production measured in 1998. However, data from other trapping sites around the state indicates that the inter-annual variability in smolt production within large systems is less than observed for small systems. During the three years that we measured smolt production in eastern SJF streams (1988 - 2000), the mean inter-annual variability in smolt production measured in the Skagit and Clearwater Rivers was 66% of that measured in these small streams. Therefore, we scaled the 2001/1998 eastern SJF small stream smolt production ratio of 2.2 by the big stream/small stream inter-annual variability ratio (66%) to estimate a 2001 production rate of 1.47 times the 1998 Dungeness production rate. Using this approach, we estimate Dungeness River production at 372 smolts/mi^2 watershed or 74,000 smolts. The other eastern SJF large streams are the Elwha River and Morse Creek. Wild coho production from these two streams is likely very low due to the impassable dams in the lower mainstem on the Elwha and poor habitat condition in Morse Creek. From spawning ground data provided by the Lower Elwha Tribe (Pat Crain pers. comm.), it is estimated that only 10 female coho spawned in Morse Creek in 1999. Assuming at these low spawner densities

that 100 smolts/female were produced, we estimate Morse Creek smolt production at 1,000 smolts. We estimate an additional 5,000 smolts are produced from the Elwha, which results in a total eastern SJF large stream production estimate of 80,000 smolts.

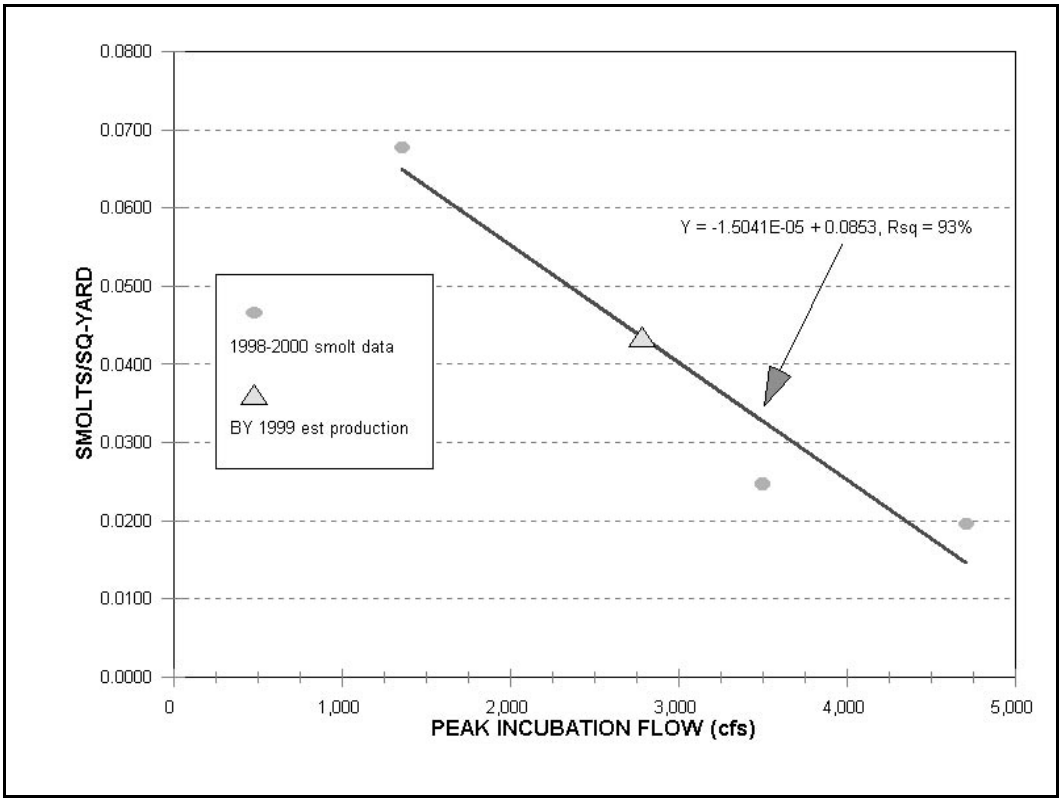

Figure 2. Smolts/yd^2 of summer low-flow habitat in eastern Straits of Juan de Fuca small streams as a function of peak flows during the incubation period (November - March) measured at the USGS Dungeness River gage (#12048000).

In 2001, the Lower Elwha Tribe operated smolt traps in a number of western SJF small streams including Salt, E. Twin, W. Twin, and Deep Creeks. The Makah Tribe operated smolt traps on two tributaries of the Hoko River, Little Hoko River and Johnson Creek. From trapping on the western SJF small streams, Elwha biologists estimate 50,563 smolts were produced from 68.5% of the available small stream habitat (Salt, E. Twin, W. Twin, and Deep Creeks). Applying this rate to the rest of the western SJF small streams estimates that 74,000 wild smolts were produced in 2001.

To estimate production from the western SJF large streams, the estimated smolt production from the Little Hoko River in 2001 (5,259 smolts) was applied to a Little Hoko production-to- total Hoko production relationship that was developed using data collected by the PNPTC in 1987 through 1989 and analyzed by WDFW (Greg Volkhardt. 1994. Draft Hoko River wild coho smolt production analysis) (Figure 3). This relationship predicted 2001 Hoko River smolt production at 61,500, or 854 smolts/mi^2 of watershed area. Applying this rate to western SJF large streams results in an estimated 2001 production of 210,000 smolts. Summing across strata, total wild production for the Strait of Juan de Fuca is estimated at 380,000 smolts.

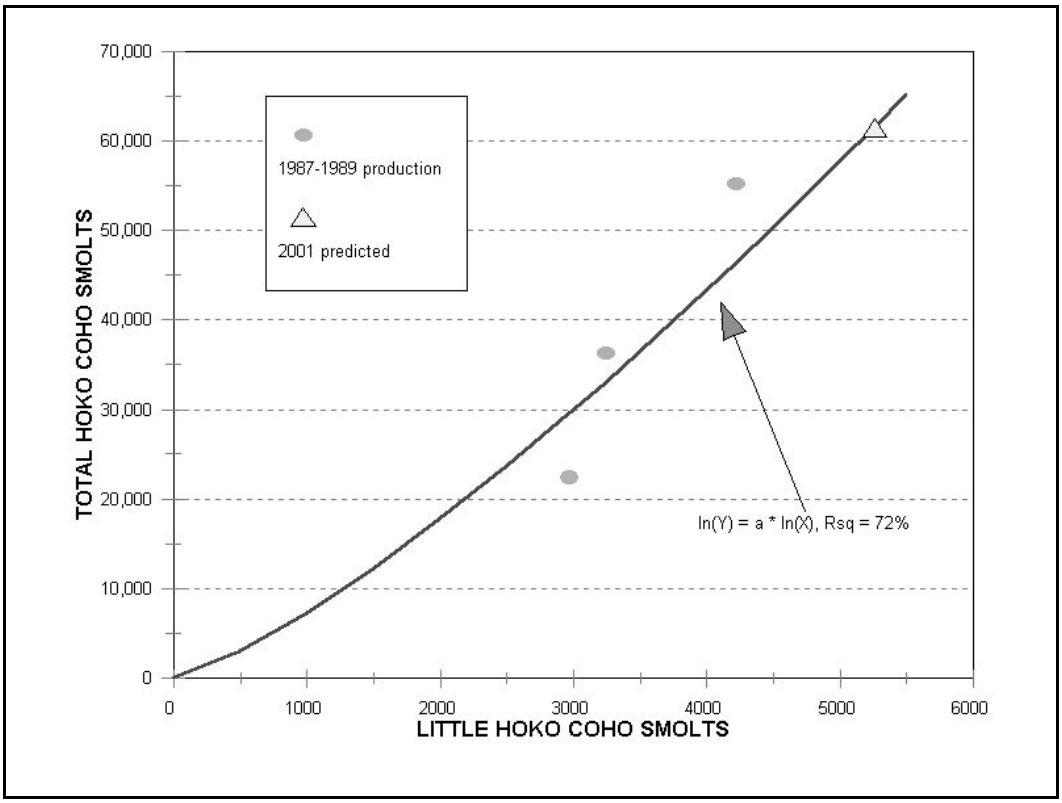

Figure 3. Log-log relationship through zero between Little Hoko wild coho smolt production and total Hoko River wild coho smolt production estimated using 1987-1989 smolt trapping data.

Puget Sound Secondary Units

Nooksack River

Considering the extent of habitat degradation and underseeding due to high harvest rates, we expect natural smolt production from the Nooksack River system was below projected potential in 2001. We used a value of 20% of the production projected by T.R.28 to estimate 90,000 smolts in 2001.

Strait of Georgia

We selected a value of 30% of the projected production (T.R.28), to estimate 30,000 smolts in 2001.

Samish River

Scale sampling/analysis has indicated that virtually all of the adult coho returning to the weir at the Samish Hatchery are wild. In some recent years, 10,000 adult coho have returned. Even at a relatively low harvest rate and a high marine survival, production would exceed 100,000 smolts. If harvest rates were higher and/or marine survival lower, then even more smolts were produced. We selected a value of 100,000 smolts as our best approximation of production in 2001.

Lake Washington, Green River, Puyallup River, and Nisqually River

Coho production in each of these systems is impacted by habitat degradation through development, diking, water withdrawals, and under-escapement due to high, hatchery-directed harvest rates. Each of these systems also contains a dam on the mainstem, which blocks access to the upper watershed. Hatchery fry are outplanted in portions of some of these systems in an attempt to mitigate for the presumed underseeding by natural spawners. While these outplants may contribute to production, it is likely that resultant smolt production is lower than would be achieved with adequate numbers of natural spawners.

In the Lake Washington system, we estimated coho smolt production through downstream-migrant trapping in the two major tributaries: Cedar River and Bear Creek. We estimate that the Cedar River and Bear Creek produced 84,000 and 22,000 coho smolts, respectively. Given that these systems contain some of the best habitat in the basin, production from the other smaller, more urbanized tributaries would be considerably lower. To begin assessing the production levels in such streams, in Spring 2001 for the second year we installed and operated a smolt trap in Thornton Creek, the most developed watershed in the basin. With the help of Seattle Public Utilities workers and volunteers who maintained the screens, smolts were enumerated over a seven day interval in early-May during the peak of the migration. The salmonid catch which was dominated by 650 cutthroat trout, included only 34 coho smolts. From a migration timing model derived at Big Beef Creek, over this interval we estimate that 20% of the season coho smolt migration occurred. Using this rate, we estimate that Thornton Creek produced less than 200 coho smolts in 2001.

Considering the production measured from Issaquah Creek in 2000 (18,000 smolts), and the extremely low production assumed for the other urban streams, we estimated only 25,000 coho smolts were produced from all the other habitat (including the lakes) outside of the Cedar River and Bear Creek. Adding this estimate to that of the measured production, yields an estimate of 131,000 coho smolts entering Lake Washington. Ongoing research conducted in 2001, associated with evaluating smolt passage at the Ballard Locks, provided additional insight into smolt survivals from the tributaries to the Locks. The relative survival to the Locks was assessed through tagging smolts caught in our traps in Bear Creek and the Cedar River with Passive Integrated Transponder (PIT) tags. Initial results indicate that survival through the lake system is lower than previously thought. To project the number of migrants entering saltwater, we applied a survival rate of 70% to estimate that 92,000 naturally-produced coho smolts entered Puget Sound from the Lake Washington system at the Ballard Locks.

In 2001 we installed floating screw traps in the lower mainstem of the Green and White and Rivers, and operated these traps continuously from February through the summer. While directed at assessing wild chinook production, we enumerated all salmonids and have preliminarily estimated natural coho smolt production during year 2001. The Puyallup Tribe also operated a screw trap in the lower Puyallup River in 2001.

For the Green River, we estimated a system production of 95,000 coho smolts. This estimate includes two components; 46,000 smolts from above our screw trap located in the mainstem, just upstream from the confluence of Big Soos Creek and 49,000 smolts from Big Soos Creek. We trapped this stream in 2000, but not in 2001. Because we believe that coho production from this low-

gradient stream is primarily regulated by the quantity of water available for rearing in late-summer/early-fall, we adjusted the year 2000 production of 60,000 smolts by the ratio of PSSLFI values between these two brood years (8.7 ÷ 10.7=81%). With this reduction, we estimate that Big Soos Creek produced 49,000 coho smolts in 2001.

In the White River, we caught 5,154 coho smolts over the season which we expanded to estimate a production of 52,000 smolts. Relating this estimate to the 479 females in the adult coho passed upstream of the diversion dam yields an average production of 109 smolts/female. This relatively high rate (Figure 4) is further evidence that in higher gradient systems such as the White River, the lack of peak flow events through fall and winter 2000-2001 allowed higher than average over-winter survival. The estimate of female spawners is 45% of the actual number of adult coho (1,065) trapped in 1999 at the Buckley trap and passed upstream.

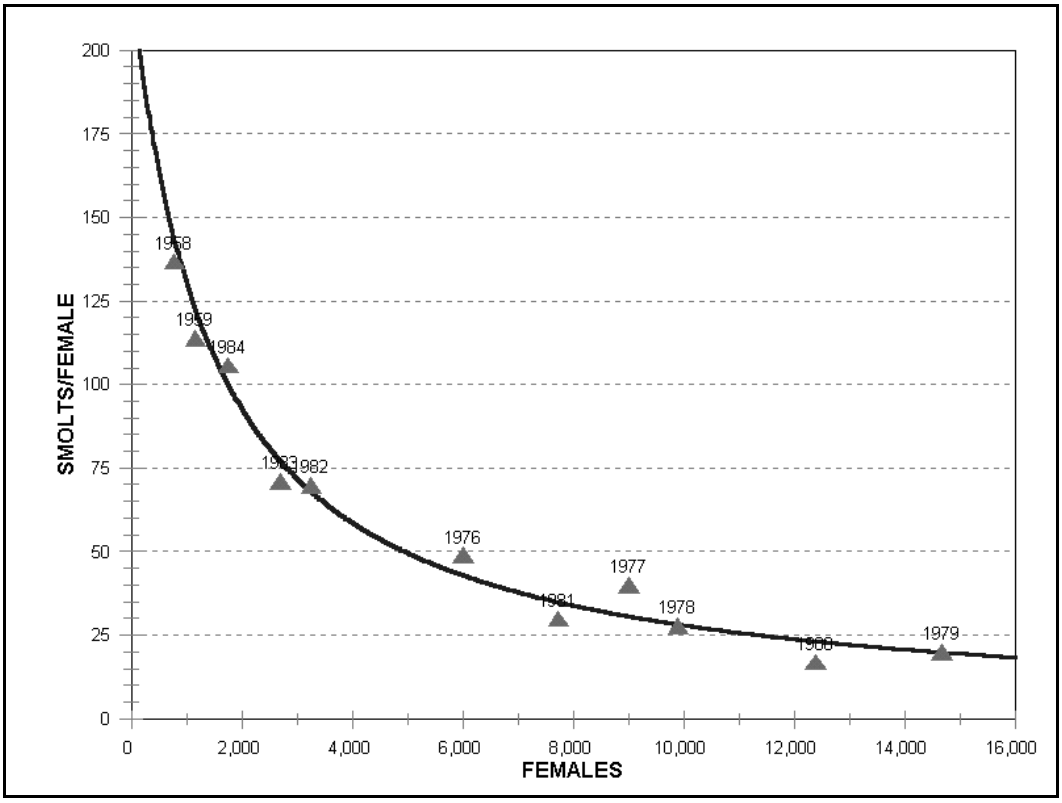

Figure 4. Productivity as a function of spawner abundance, SF Skykomish River wild coho.

For the Puyallup, we expanded the Puyallup Tribe's catch of 1,354 wild coho with an average capture rate of 4% to estimate 34,000 smolts. Combining these two estimates yields a Puyallup/White River total of 86,000 coho smolts.

For the Nisqually River, we approximated coho production at 10,000 smolts, through applying a rate of 5% to the estimated potential of 200,000 smolts (TR 28). We selected this low rate based on the extremely low smolt production we have measured from the nearby Deschutes River. Natural coho production in the Nisqually has also suffered from very low escapement as a result of habitat degradation and poor marine survival.

Deschutes River

A number of factors have combined to severely depress production in this system: habitat degradation, particularly in the upper watershed; extreme high flows during egg incubation; low reproductive potential due to small spawner size; and low escapement. In addition to these factors affecting freshwater production, escapements have declined as a result of extremely low marine survival. In the 1990s, marine survival for Deschutes coho declined lower than that of the other Puget Sound stocks for which survival is measured.

Based on trapping, we estimated that only 1,000 smolts emigrated from this system in 2001, less than 1% of the production potential (220,000 smolts) predicted in T.R.28. In 1999, the spawning escapement included only 13 females and 33 males. Average production per female is estimated at around 77 smolts per female on this brood. Typically, coho populations compensate for very low seeding rates through density-dependent survival, producing well over 100 smolts/female, as measured at the South Fork Skykomish (Figure 4).

South Sound

This production area includes all of the independent tributaries to Puget Sound, south of Area 10 (Seattle), excluding Lake Washington, and the Green, Puyallup, Nisqually, and Deschutes Rivers.

Production from tributaries entering deep South Sound have suffered from the same factors described for the Deschutes River. However, the more northerly tributaries, while impacted by increasing urbanization, have probably realized somewhat higher seeding levels. We applied a factor of 15% to the potential production of 573,770 smolts projected in T.R.28. This rate estimates 86,000 coho smolts were produced from these South Sound streams in Spring 2001.

East Kitsap

The streams in this region are small and similar in character to those we trap in Hood Canal. However, habitat degradation, largely from development, has probably had a greater impact in the East Kitsap region than in our Hood Canal study streams which, in 2001, produced 50% of the production projected in T.R. 28. Therefore, we applied a factor of 40% to the 154,973 smolts projected by T.R.28 for the East Kitsap area to estimate 62,000 smolts in 2001.

Coastal Systems

Quillayute River

We have measured smolt production in two sub-basins of the Quillayute River — the Bogachiel and Dickey Rivers. Over three years (1987, 1988 and 1990), production from the Bogachiel River averaged 53,751 smolts. Relating this production to the 129 mi^2 upstream of the trap estimates an average of 417 smolts/mi^2. This work also included evaluating smolt production resulting from large numbers of hatchery fry outplanted throughout the system. Results of these assessments indicated that the system was already seeded to capacity by natural spawners.

Over three years (1992-1994), production from the Dickey River averaged 71,189 smolts from the 87 mi^2 upstream of the trap. Production/area in this system averaged 818 smolts/mi^2. We attributed this production rate, higher than that measured in the Bogachiel, to this system's low gradient and resultant abundant summer and winter rearing habitat. Results also indicate this system was also seeded to capacity.

To estimate average system smolt production, we applied these average production/area values to the Quillayute system (629 mi^2). Based on stream character, we assumed the Bogachiel average production/area value (417 smolts/mi^2) best represents production in the majority (521 mi^2) of the Quillayute watershed (excluding the Dickey River Basin), which is relatively high gradient. Including the average estimated production from the Dickey River's 108 mi^2 drainage area (88,344 smolts) calculates an average system production of 306,000 smolts.

Smolt production in 2001 was estimated by adjusting average production with the ratio of Clearwater smolt production in 2001 to its previous average. QFiD biologists estimated that the Clearwater River produced 93,469 smolts in 2001 (pers. comm. Steve Meadows). Relative to the average production of 66,304 smolts over the seventeen previous broods in which escapement was deemed adequate to seed the system (brood years 1979-1998, excluding the1983, 1994 and 1997 broods) the production in 2001 represents 140.97% of this long-term average. Application of this rate to the average Quillayute System production (excluding the Dickey River) of 217,527 estimates 306,649 smolts for this portion of the basin. Addition of the average Dickey River production (88,344) estimates a total of 395,000 coho smolts were produced from the Quillayute River in 2001. We elected to use the average production from the Dickey because we believe that the increase in overwinter survival due to the extremely low flows throughout the fall and winter of 2000-2001 occurred primarily in the higher gradient reaches of the system rather than in the relatively low gradient Dickey River system.

Queets River

During Spring 2001, Quinault Tribal biologists estimated that the Clearwater River produced 93,469 coho smolts. They also conducted a seining program at the mouth of the Queets River to estimate wild coho smolt production from the entire system. This mark-recapture program produced an estimate of 256,919 coho smolts from the entire Queets system, including the Clearwater River (Steve Meadows pers. comm.).

Relating these smolt production estimates to the drainage areas in the two systems yields production rates of 668/mi^2 and 571/mi^2 in the 140mi^2 and 450mi^2 Clearwater and Queets Basins, respectively.

Smolt production has been measured from the Clearwater River each spring since 1981 (brood year 1979). Over the first 15 broods, coho production ranged two-fold between extremes, from around 43,000 to 95,000 smolts. Estimates of parent spawners ranged six-fold, from around 300 to over 1,900 females, but, with the exception of the 1983 brood, explained none of the variation in smolt production prior to brood year 1994. Instead, we found, through an analysis of flows during the entire freshwater life, that the highest one day flow during egg incubation explained over half the variation in smolt production (Figure 5).

In brood year 1994, however, it appears that low escapement did limit smolt production. In 1996, QFiD biologists estimated only 35,000 coho smolts were produced from the Clearwater River. Not only was this estimate the lowest on record, but it falls well below the value predicted by the flow relationship. Relating this estimate to the 260 females estimated in the 1994 escapement, yields an average of 135 smolts/female, which is a high value that also indicates underseeding (Figure 4). These outcomes confirm that the low escapement in 1994 was inadequate to seed the system, and as a result, smolt production was limited in 1996. Low marine survival continued to limit the spawning population for this brood line – only around 600 coho were estimated to have spawned in the Clearwater in 1997. As a result, in 1999, the Clearwater River produced only 27,000 coho smolts, just a fraction of the 72,500 smolts predicted by the flow relationship.

The high smolt production from the Clearwater system in Spring 2001, while consistent with the high production levels we observed elsewhere for this brood, represents a positive departure of 13,000 smolts from the 80,000 predicted using the flow relationship (Figure 5). Except for the three underseeded broods noted above, production from all but two of the previous other eighteen broods appeared to be largely regulated by the severity of flow during spawning. It is noteworthy that the two exceptions to this relationship, the 1981 and 1998 broods, are also the highest productions estimated thus far.

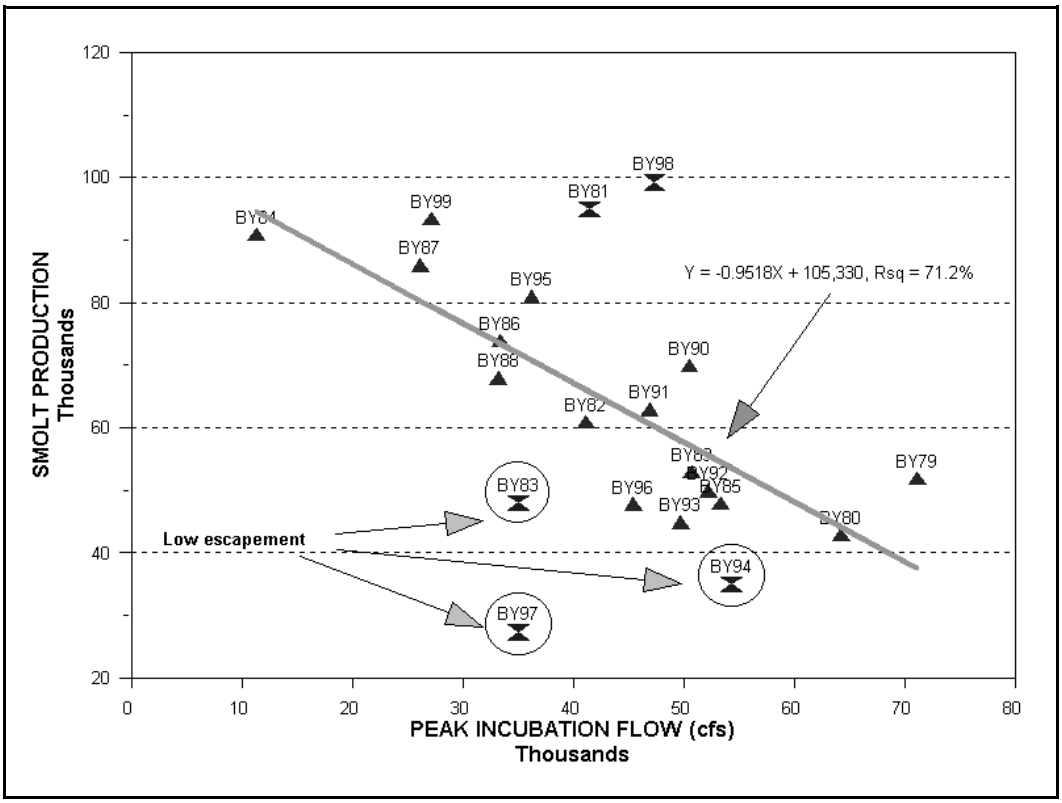

Figure 5. Clearwater River wild coho smolt production and Queets River flow during egg incubation, brood years 1979-1999 (brood years 1981and 1998 not included in regression).

Hoh River

Due to the similarity and proximity of the Hoh watershed to that of the Clearwater River, we used the Clearwater rate to approximate Hoh River coho smolt production in 2001. At a production rate of 668 smolts/mi^2, the 299 mi^2 drainage area of the Hoh River system produced an estimated 200,000 smolts.

Quinault River

Low escapement due to high harvest rates and degraded habitat likely combined to limit natural smolt production from this system lower than estimated elsewhere. To approximate smolt production from this 434 mi^2 system, we selected the lower rate of 500 smolts/mi^2. This results in an estimated production of 217,000 coho smolts.

Independent Tributaries

Smolt production has not been directly measured from any of the independent coastal tributaries. Application of an average production rate of 500 smolts/mi^2 to the total watershed area (424 mi^2 see table below) estimates 212,000 coho smolts were produced from these systems.

Stream	Drainage Area mi^2	Stream	Drainage Area mi^2
Waatch River	13	Raft River	77
Sooes River	41	Camp Creek	8
Ozette River	88	Duck Creek	8
Goodman Creek	32	Moclips River	37
Mosquito Creek	17	Joe Creek	23
Cedar Creek	10	Copalis River	41
Kalaloch Creek	17	Conner Creek	12
Subotal	218		206
		Total	424

Grays Harbor

We have estimated coho smolt production from the Chehalis River system in each of the previous nineteen years, 1980 brood through the 1998 brood. This estimate relies upon annually trapping/tagging wild smolts, and sampling adults caught in the Quinault Tribe's terminal net fishery in the lower Chehalis River for coded-wire tags. Resultant estimates have ranged seven-fold, from around 0.5 million to 3.6 million (Table 4). Analysis to understand the components of variation hasdetermined that flow during spawning, explains most (73%) of the interannual variation in estimated smolt production, providing seeding levels are adequate (Figure 6).

Table 4. Estimation of wild coho smolt production from the Chehalis Basin, via back-calculation. These estimates assume expanded tag recoveries accurately reflect the numbers of hatchery and wild tags caught.

				ESTIMATION OF WILD TAG RATE					WILD SMOLT TAGGING				ESTIMATED SMOLT PRODUCTION				
				A	B	C	D	E	F	G	H	I	J	K			
Br. Yr.	Tag Yr.	Rtn. Yr.		Total Catch	Est. Hatch.	Wild Catch (A-B)	# Est. W-tags	Tag Inc. (D/C)	Number Tagged	Mort Adj.	Tag Rtnt'n	Adj. Tag Grp (FGH)	Total Smolts (I/E)	SE Sqrt(Var.)	95% Conf. Interval Low (J-(1.96*K))	95% Conf. Interval High (J+(1.96*K))	CV (K/J)
1980	1982	1983		10,115	3,669	6,446	104	1.61%	47,711	0.84	0.96	38,474	2,384,657	207,638	1,977,688	2,791,627	8.71
1981	1983	1984		5,196	1,432	3,764	93	2.47%	78,839	0.84	0.96	63,576	2,573,110	250,223	2,082,672	3,063,547	9.72
1982	1984	1985		6,991	4,025	2,966	164	5.53%	110,020	0.84	0.96	88,720	1,604,536	118,303	1,372,662	1,836,410	7.37
1983	1985	1986		19,600	6,548	13,052	481	3.69%	96,687	0.84	0.96	77,968	2,115,683	86,032	1,947,061	2,284,305	4.07
1984	1986	1987		23,129	4,810	18,319	272	1.48%	74,847	0.84	0.85	53,338	3,592,275	173,901	3,251,429	3,933,121	4.84
1985	1987	1988		3,856	1,490	2,366	39	1.65%	59,860	0.84	0.96	48,271	2,928,447	431,344	2,083,012	3,773,882	14.73
1986	1988	1989		13,824	10,367	3,457	112	3.24%	54,285	0.84	0.96	43,775	1,351,175	118,427	1,119,058	1,583,293	8.76
1987	1989	1990		27,251	17,824	9,427	210	2.23%	44,889	0.84	0.96	36,198	1,624,967	94,459	1,439,829	1,810,106	5.81
1988	1990	1991		45,211	22,073	23,138	690	2.98%	69,701	0.84	0.96	56,207	1,884,804	54,055	1,778,856	1,990,753	2.87
1989	1991	1992	A	12,111	7,745	4,366	213	4.88%	71,457	0.84	0.96	57,623	1,181,135	75,185	1,033,773	1,328,497	6.37
			B	12,111	10,197	1,914	213	11.13	71,457	0.84	0.96	57,623	517,795	32,589	453,921	581,669	6.29
			C	12,111	8,971	3,140	213	6.78%	71,457	0.84	0.96	57,623	849,465	54,143	743,344	955,585	6.37
1990	**1992**	**1993**	**B**	**10,153**	**4,702**	**5,451**	**16**	**0.29%**	**21,125**	**0.84**	**0.96**	**17,035**	**5,803,680**	**1,060,259**	**3,725,572**	**7,881,787**	**18.27**
1991	1993	1994	S	5,375	3,666	1,709	30	1.76%	32,027	0.84	0.96	25,827	1,471,254	241,154	998,591	1,943,917	16.39
1992	1994	1995		23,903	11,755	12,148	263	2.16%	64,035	0.84	0.96	51,638	2,385,157	126,262	2,137,683	2,632,631	5.29
1993	1995	1996		26,824	8,898	17,926	527	2.94%	42,812	0.84	0.96	34,524	1,174,326	34,813	1,106,093	1,242,560	2.96
1994	1996	1997		700	607	93	7	7.53%	46,942	0.84	0.96	37,854	502,918	141,640	225,304	780,532	28.16
1995	1997	1998		7,819	3,170	4,649	154	3.31%	78,462	0.84	0.96	63,272	1,910,068	143,826	1,628,168	2,191,967	7.53
1996	1998	1999		6,836	2,030	4,806	181	3.77%	102,667	0.84	0.96	82,791	2,198,298	153,884	1,896,685	2,499,911	7.00
1997	1999	2000		8,300	3,706	4,594	292	6.36%	43,788	0.84	0.96	35,311	555,538	29,146	498,411	612,665	5.25
1998	2000	2001		10,436	7,077	3,359	214	6.37%	111,313	0.84	0.96	89,763	1,408,940	90,601	1,231,363	1,586,518	6.43

Estimate A: Assumes Simpson (late) and Satsop Springs fish survived and contributed 1/2 the rate as Simpson (normal) hatchery stock.
Estimate B: Assumes Simpson (late) and Satsop Springs fish survived and contributed at the same rate as Simpson (normal) hatchery stock.
Estimate C: Average of Estimates A&B.
Estimate S: Hatchery/ Wild Catch estimates based on scale analysis
Shaded years are preliminary.

Excludes BY 1990	
1,824,849	avg
502,918	min
3,592,275	max
18	count

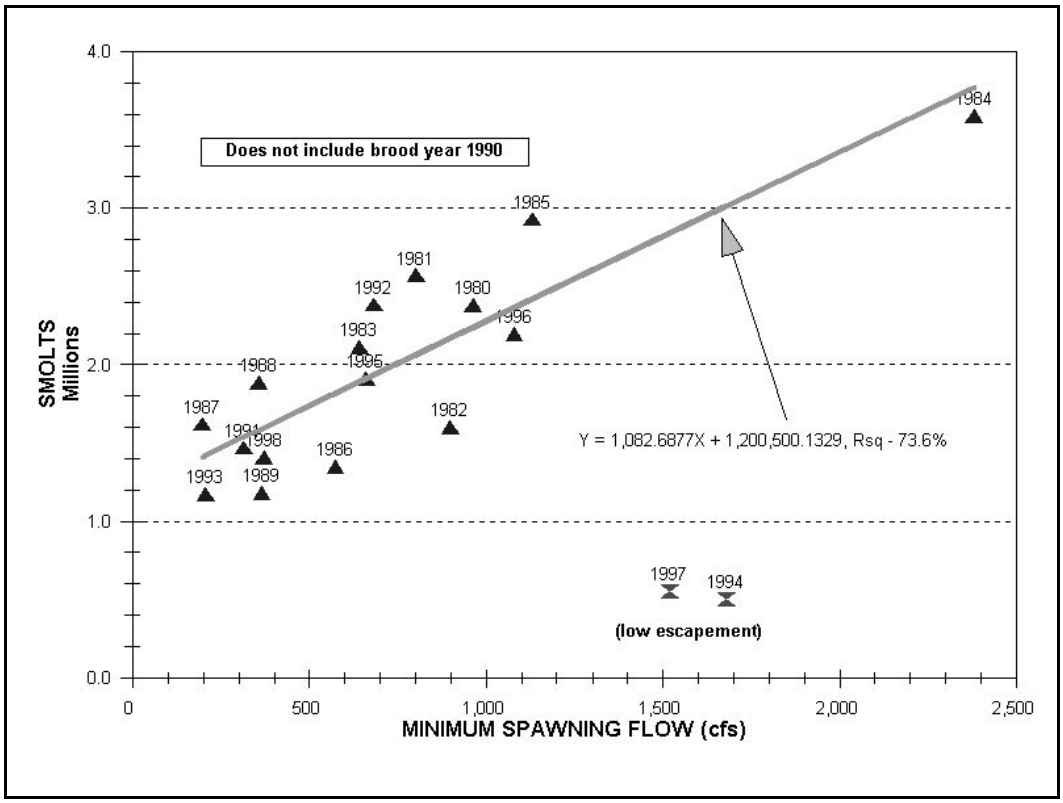

Figure 6. Coho smolt production as a function of minimum spawning flow, Nov. 02 through Dec. 15, Chehalis River, brood years 1980-1997.

We excluded three brood years (1990, 1994 and 1997) from this analysis for the following reasons:

1990 brood: Tagging on this brood was limited. As a result, only six wild tagged adult coho were recovered in an estimated 2,104 wild fish sampled, a very low incidence of 0.29%. This value estimated an unreasonably high wild production of almost six million smolts. The minimum spawning flow in 1990, however, was quite high (1,130 cfs). As a result, we believe production for this brood was high, but the low tag rate precluded making a valid estimate.

1994 brood: Escapement in 1994 was extremely low – less than 10,000 spawners.

1997 brood: Escapement in 1997 was even lower than its parent brood (1994). We estimated only 7,000 adults spawned in 1997. Fortunately, these spawners experienced a very high minimum flow, in excess of 1,500 cfs. As a result, this brood achieved the very high average production per spawner of 159 smolts/female (Figure 4).

Other important brood-specific factors which serve to reduce the correlation coefficient contributed to the negative deviations observed on at least three broods:

- The 1982 brood may have been constrained by low escapement;
- The 1986 brood was reduced by the effects of the devastating drought of summer 1987 which resulted in the lowest production on record from Bingham Creek (Figure 7);

C The 1989 brood was impacted by the severe storm which produced extremely high flows on January 10, 1990. On this date, the Chehalis River flooded, closing Interstate-5. This storm scoured spawning gravels in higher-gradient stream reaches, and triggered mass wasting events which reduced egg survival.

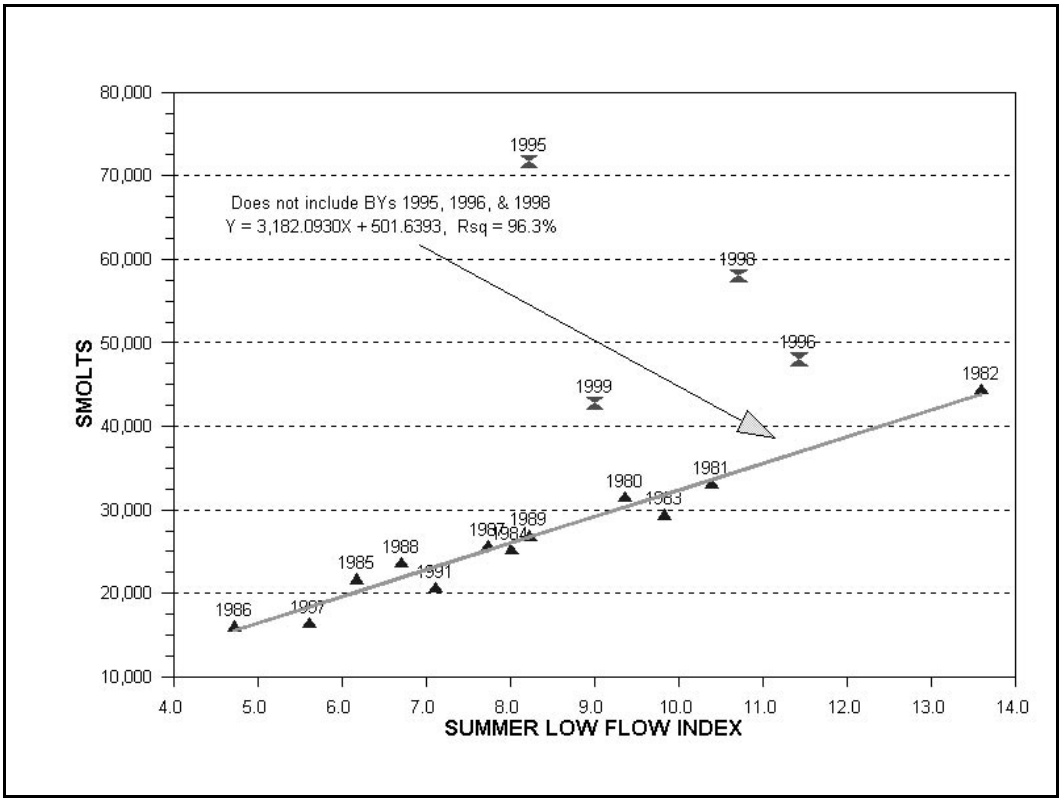

Figure 7. Wild coho smolt production vs. Puget Sound summer low flow, Bingham Creek, brood years 1980-1997 (broods 1990, and 1992-1994 omitted)

Apparently, in the low gradient, rain-fed, over-appropriated-for-water-withdrawals Chehalis River system, the level and timing of significant flow increases during spawning (November and December) is an important determinant of natural coho production. The most plausible hypothesis we have to explain this finding is that access to the upper portions of streams throughout this watershed is a function of flow. During such very dry fall seasons as the 1987 drought, adult spawners simply cannot ascend as high in tributaries as they can in wetter years. Because fry emerge from redds and distribute generally downstream, despite favorable flow conditions following spawning, the proportion of the watershed available for rearing juveniles is largely determined by the upstream extent of the spawning population.

The importance of this factor is also evident in the coho smolt production data record we have generated since the 1980 brood at Bingham Creek (Figure 7), a tributary to the East Fork Satsop River. Seeding rates have not constrained smolt production on any of these broods due to the contribution of Bingham Creek Hatchery-produced coho spawners. Consequently, for this low gradient stream, the relationship between smolt production and flow the previous summer is clear: production is a positive and proportional function of flow – water equals fish. In four of the last five broods, however, we have measured positive deviations exceeding values predicted with the summer

flow model by more than two-fold. Production on these four high broods which appears to be independent of the summer flow level is instead positively correlated with mean flows during spawning (November and December). This outcome suggests that for broods with summer rearing flows above some threshold level, flows during spawning affects spawner distribution which in turn determines total rearing habitat available for each brood. In Bingham Creek, high production results only when all of the following elements occur:

- Sufficient numbers of spawners return.
- High flows during November and December provide spawners access to the upper watershed.
- Access to Lake Nahwatzel permits adults to spawn in the tributaries to the lake. A drum screen, placed on the lake outlet to retain trout, blocked anadromous fish access prior to its removal in 1992. (In 1995, residents around Lake Nahwatzel reported observing large numbers of adult coho in the lake.)
- Sufficient flows throughout incubation and emergence permits large numbers of fry to seed the lake and Outlet Creek. Abundant coho fry and fingerling presence in the lake has also recently been observed and reported (Frank Haw, former WDF director and Lake Nahwatzel resident, pers. comm).
- Sufficient flows throughout the summer rearing period.
- Sufficient flows in Outlet Creek during spring to maintain connectivity between the lake and Bingham Creek for smolt emigration.

For the sixteen broods of Chehalis River smolt production analyzed, the flow correlation indicates that natural seeding rates have been adequate, perhaps with the exception of the 1982 brood. It also appears that the fry planting program, in effect through the mid-1990s, did not produce enough smolts to obscure the positive effect of flow during spawning on natural production.

This relationship provides a means to predict system freshwater production for broods with adequate spawning escapements. Based on estimates of system smolt production in 1998 and survival-to-return in 1999, we estimated around 50,000 adult coho escaped to spawn in the Chehalis Basin in 1999. We deem this level of spawning sufficient to seed the watershed.

During the coho spawning and flow correlation window (November 2 - December 15) in 1999, the minimum flow value of 569 cfs at Grand Mound occurred on November 4. Using this value, the relationship predicts a production of 1,817,000 smolts from the Chehalis Basin during Spring 2001.

Relating this production to the 2,114 mi^2 in the Chehalis Basin (including the Wishkah River) yields an average rate of 860 smolts/mi^2. Application of this rate to the 2,300 mi^2 Chehalis Basin (including the Hoqiuam, Johns, and Elk Rivers, and other southside tributaries) estimates 1,977,000 coho smolts.

In addition to the Chehalis River watershed, the 2,550 mi^2 Grays Harbor Basin includes the 250 mi^2 Humptulips River. While we have no direct estimates for the Humptulips Basin, we used the slightly lower production rate of 800 smolts/mi^2 to estimate system production at 200,000 coho smolts

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Willapa Bay

The Willapa Basin, with a total watershed area of 850 mi^2, is drained by four main river systems and a number of smaller tributaries. Little empirical smolt production evaluation work has been conducted in this system. Given the presumed high harvest rates in Willapa Bay, and the generally degraded condition of its freshwater habitat, it is likely that coho production/area was somewhat lower than that estimated in the Chehalis Basin. To approximate production of the 1999 brood, we selected a value of 500 smolts/mi^2. This rate, applied to the total basin area, estimates 425,000 coho smolts were naturally-produced in 2001.

Lower Columbia River

In Spring 2001, we initiated smolt monitoring in three tributaries to the lower Columbia River; Germany, Mill and Abernathy Creeks. In total, these systems which drain an area of 80 mi^2, produced 21,500 coho smolts, an average production rate of 269 smolts/mi^2. Application of this rate to the 2,000 mi^2 of accessible watersheds draining into the Columbia River downstream of Bonneville Dam, excluding the Cowlitz and Lewis Rivers above their dams, estimates 538,000 coho smolts were produced from the Lower Columbia system. In addition, a record high coho smolt production was estimated and partially collected at Cowlitz Falls Dam. Over the season, 335,000 coho smolts were collected, transported and released from the acclimation pond to the lower Cowlitz River (personal communication Charles Morrill). Summing this production and that estimated for all the other tributaries yields a lower Columbia River natural coho production estimate, from the Washington side, of 873,000 smolts.

Marine Survival

Puget Sound

Background

Marine survival rates for Puget Sound wild coho stocks have been measured for many years at Big Beef Creek, Deschutes River, South Fork Skykomish River, and (as of the 1989 brood) Baker River. Survival rates are based on estimated coastwide recoveries of tagged, age-3 wild coho and returns of same to upstream migrant trapping facilities where the entire escapement is enumerated.

Marine survival at Big Beef Creek, in terms of age-3 recruits, has varied more than ten-fold over brood years 1975-1996, from a high of 32%, to a low in the 1996 brood of 3%. Over the last nine years, the marine survival rates we have measured at Big Beef Creek represent an unknown portion of total adult recruits. This bias results from unreported and unsampled coho caught in Hood Canal net fisheries.

For brood years 1977 through 1996, marine survival of Deschutes River coho has ranged nearly a hundred-fold from a high of 29%, to a low of only 0.3% (1996 brood). For the first eleven broods (1977-1985), survival of this stock averaged 22%, just slightly higher than tagged Big Beef Creek

(21%) over these same years. Beginning with the 1988 brood, however, marine survival of Puget Sound coho declined. This sharp decline was most evident with the Deschutes River population which experienced lower survival rates than the other stocks measured (Table 5)(Figure 8).

Table 5. Comparison of marine survival (age 3), Big Beef Creek, Deschutes River, SF Skykomish River, and Baker River wild tagged coho.

YEAR		Big	Desch.	SF	Big	Desch.	SF	Baker	AVERAGE		
Br.	Rtn	Beef	River	Sky	Beef	River	Sky	River	Early	Late	Count
1975	1978	13.24							----		
1976	1979	16.58		22.32					19.45		2
1977	1980	29.07	21.55	17.25					22.62		3
1978	1981	16.97	21.49	14.54					17.67		3
1979	1982	14.66	20.90	7.87					14.48		3
1980	1983	21.61	27.44	17.79					22.28		3
1981	1984	17.47	23.52	13.22					18.07		3
1982	1985	22.32	19.12	13.15					18.20		3
1983	1986	32.16	26.90	22.34					27.13		3
1984	1987	28.76	29.28	18.97					25.67		3
1985	1988	11.06	28.27	15.47					18.27		3
1986	1989	17.93	10.31	14.14					14.13		3
1987	1990	22.54	16.98	13.51					17.68		3
1988	1991				9.83	6.58	7.86			8.09	3
1989	1992				9.01	13.56	15.76	13.8		13.03	4
1990	1993				8.90	3.20	7.67	6.02		6.45	4
1991	1994				23.23	19.81	23.64	11.12		19.45	4
1992	1995				11.11	6.39	13.71	8.3		9.88	4
1993	1996				13.30	4.80	9.83	10.59		9.63	4
1994	1997				17.50	5.01	9.98	6.3		9.70	4
1995	1998				16.50	1.50	9.25	12.45		9.77	4
1996	1999				3.08	0.30	5.17	5.73		3.50	4
1997	2000				6.14	5.79	10.11	8.60		7.90	4
Average		20.34	22.34	15.88	11.86	6.69	11.30	9.21	18.13	9.94	
Min		11.06	10.31	7.87	3.08	0.30	5.17	5.73	14.13	3.50	
Max		32.16	29.28	22.34	23.23	19.81	23.64	13.80	27.13	19.45	
Count		13	11	12	10	10	10	9	13	9	

Notes: Marine survival for the SF Skykomish 1981 brood is estimated ([mean ratio of the average BBC + Deschutes survival]/[SF Sky survival, by year]}; because a portion of the adult return would not enter the fishway.
SF Skykomish marine survival for the 1985 brood and later is estimated ([adult returns/ escapement rate]/ 276,000 smolts).
Marine survival for the Big Beef Creek 1994 brood is underestimated due to large unreported/ unsampled catches in the terminal area. Without Puget Sound mixed net and seine recoveries, 14.1% of tagged smolts were estimated captured in fisheries and escapement. These data, along with observations of the terminal net fishery, indicate total survival would be considerably higher.

Over the nine broods (1976-1984) that we tagged wild smolts at Sunset Falls, marine survival of this stock ranged nearly three fold (8% to 22%) and averaged 16%, somewhat lower than the rates estimated for Big Beef Creek and Deschutes River coho over the same period. We attribute this lower survival to the smaller size of smolts produced from this colder, higher-elevation system. Although we no longer trap and coded-wire tag wild coho smolts in this system, from the 1985 brood on we have annually approximated marine survival through relating run size estimates to the average production we measured with full seeding (276,000 smolts -- Figure 1). Run sizes are estimated by applying projected harvest rates to the adult returns enumerated at the Sunset Falls trap. As observed at the other monitoring stations and at hatcheries, survival of fish returning to Sunset Falls in1999 also hit an all-time low (5.2%). For example, to estimate survival of the 1997 brood, we assumed that

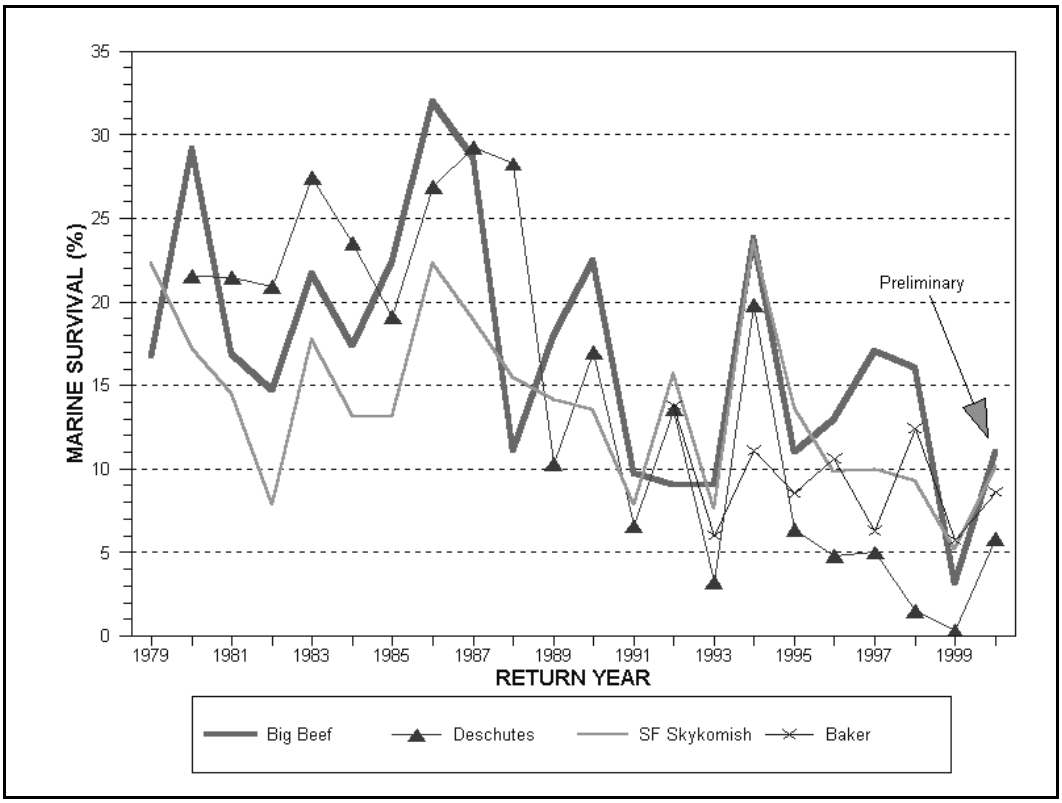

Figure 8. Marine survival of wild coho (age-3) measured at four Puget Sound streams.

the return of 23,726 adults to the trap represented 85% of the run, resulting in a total run of 27,913 coho. Relating this estimate to the average smolt production yields a marine survival rate of 10%. Survival of Baker River coho, over eight brood years (1989-1996), has ranged just over two-fold, from a high of 13.8%, to a low of 5.7%. While survival of Baker River coho appears to generally track the other stocks we have measured (Figure 8), over these broods it has exhibited a biannual pattern , with odd-numbered brood years experiencing higher survivals than even-numbered brood years (Table 5). As with the other stations, Baker River coho returning in 1999 had the lowest marine survival measured thus far (5.7%).

Predicting 1999 Brood Marine Survival

Correlating jack returns to Big Beef Creek with same-brood survival-to-adults (ocean age-3) indicates a strong relationship (Figure 9). Using this correlation, the tagged wild jack return rate in 2001 of 0.54 % (85 jacks from 15,776 smolts tagged in 2001), predicts an adult marine survival rate of 7%.

For predicting 1999 brood marine survival in other Puget Sound areas, we selected the following age-3 survival rates, which incorporate recent trends and patterns in marine survival (Table 5). This decision reflects our belief that, absent any system-specific predictive models, the recent survival rates are more likely to indicate this brood's marine survival than the long-term average rates. In the last several years, coho produced from Central Puget Sound systems have experienced higher survival rates than those from systems to the north and, particularly, to the south.

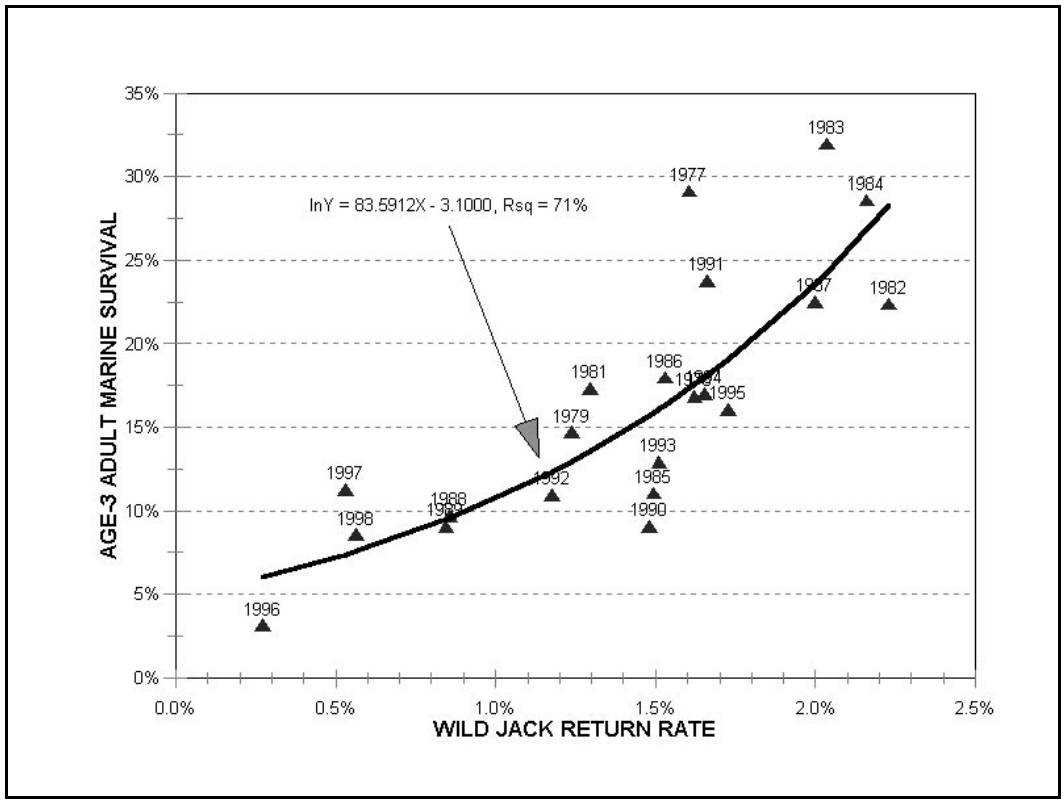

Figure 9. Wild coho adult marine survival relative to same-brood jack return rates, Big Beef Creek, brood years 1978-1998.

- For the Skagit River, we used the average of the five odd brood years (1989-1997), 11%.
- For the other north Puget Sound systems (Nooksack, Strait of Georgia and Samish Rivers) and East Kitsap systems, we used a survival rate of 10%
- For the Stillaguamish River, we selected a rate of 9%. Historically, marine survival in this system was lower than that measured in the Snohomish River.
- For the Snohomish River, Lake Washington and Green River, we selected the rate of 12%.
- For the Puyallup River we selected a rate of 8%.
- For the Nisqually River and South Puget Sound, we selected a rate of 5%.
- The Deschutes River received the lowest survival rate of 3%.

Straits of Juan de Fuca

We currently lack any direct measurement of marine survival in tributaries to the Straits of Juan de Fuca. Observations at Snow Creek and spawning ground information from other systems, however, indicate that coho marine survival in this region is generally lower than that of inner Puget Sound. Given the lower survival of coastal stocks relative to Puget Sound stocks, we expect that coho emigrating from Straits tributaries experience survival rates which are intermediate between Puget Sound and the coast. Based on this assumption, we selected a survival rate of 5%, midway between that predicted for Big Beef Creek (7%) and Grays Harbor (3%).

Coast

The wild coho trapping and tagging conducted annually at Bingham Creek (Grays Harbor) since the 1980 brood represents the only direct measurement of marine survival for jacks and adults on the Washington Coast. Marine survival (age-3) of wild Bingham Creek coho has ranged nineteen-fold, from 0.6% to 11.6%, and averaged 4.5% over 19 years (Figure 10). Over all broods measured, the relationship between jack returns and same-brood adult marine survival is poor. However, when the two El Niño broods are excluded jack returns explain over half the interannual variation in adult survival. When the data set is split into early- and later-years, the correlations improve even more (Figure 11). In the two El Niño broods (1980 and 1990), adult survival was low relative to the high jack returns. This phenomenon was also observed elsewhere on the coast, notably in the Oregon Production Index.

Based on the relationship developed for the recent years (Figure 11), the wild jack return rate to Bingham Creek in 2001 of 0.0482% predicts an adult marine survival to the ocean (age 3) of 2.5%. However, because this relationship has under-forecasted marine survival in four of the last six years (Table 6), this may indicate that ocean productivity is improving relative to the first six years (1987-1992) of this now twelve-year data set. If this is true, then the "early" relationship may more accurately reflect marine survival, as indicated by jack return rates. This relationship predicts adult marine survival at 4.1% for the 1999 brood.

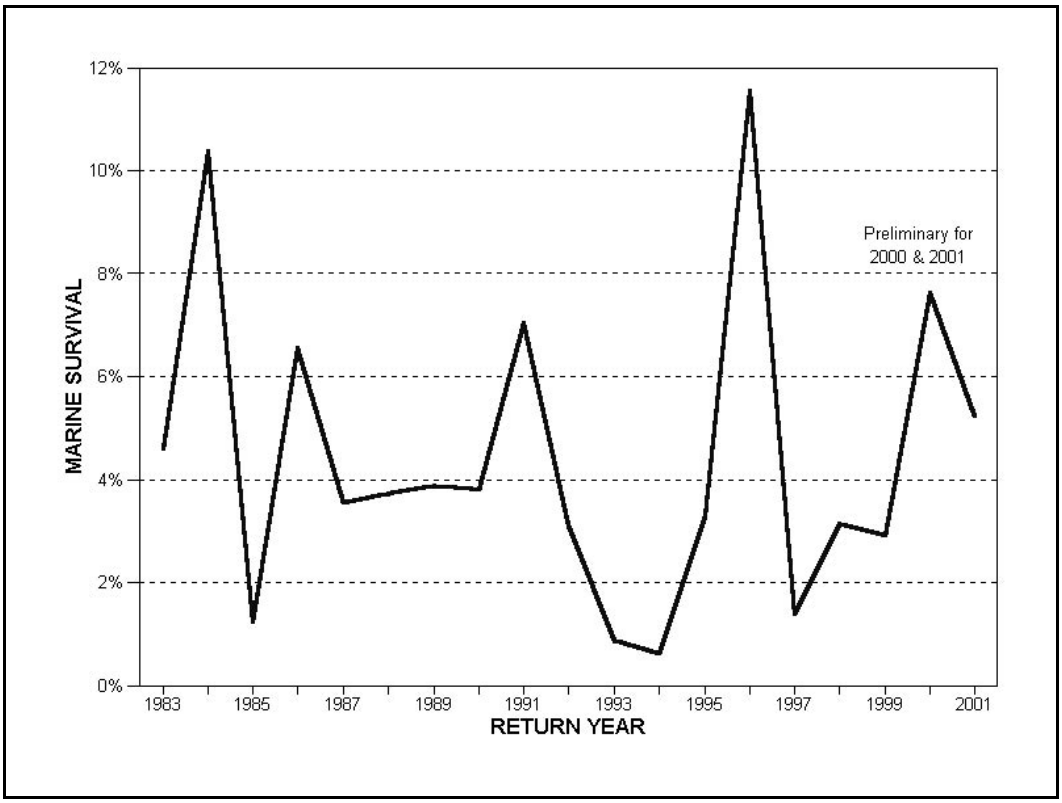

Figure 10. Marine survival of Bingham Creek wild tagged coho.

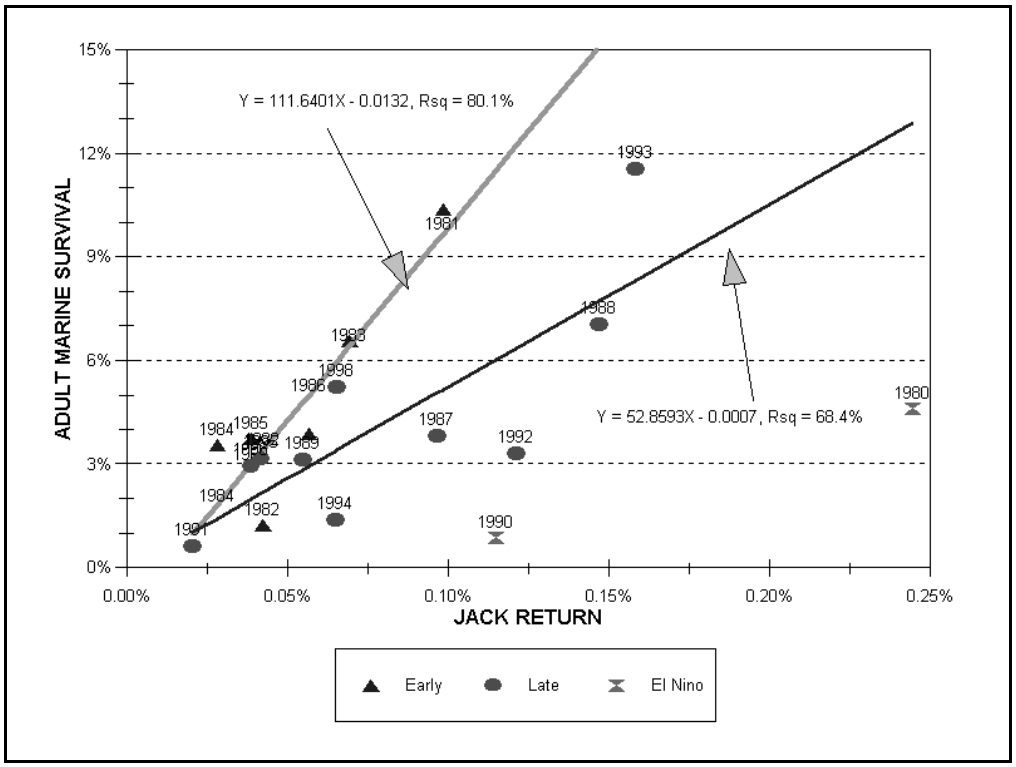

Figure 11. Jack return and adult marine survival, Bingham Creek, brood years 1980-1998.

Given these uncertainties, we selected the intermediate adult marine survival rate of 3% for Grays Harbor, Willapa Bay and coastal tributaries north, through the Quinault River. For coho produced in the Queets and Hoh Rivers, we selected a marine survival of 4%. For production from the Quillayute River, we selected the higher rate of 5%, equivalent to that for the Straits of Juan de Fuca. These positive adjustments are consistent with the general trend of higher marine survival in the more northerly systems along the Washington coast.

Lower Columbia River

Lacking any indicators for wild coho survival, we applied the 3% rate indicated from the Bingham Creek analysis

Table 6. Forecasted and measured adult marine survival for 1993-1998 brood Bingham Creek wild coho.

Brood Year i	Return Year i+3	ADULT MARINE SURVIVAL		Error
		Predicted	Actual	
1993	1996	5.4%	11.6%	-115%
1994	1997	3.0%	1.4%	53%
1995	1998	1.0%	3.2%	-220%
1996	1999	2.0%[a]	2.9%	-45%
1997	2000	6.0%[b]	7.6%	-27%
1998	2001	3.2%	5.2%	-63%

[a] The model predicted 1.4%, which we elected to increase.
[b] The model predicted 7.6%, which given the very low smolt production, we discounted to be conservative.