2001 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. Most of these methods rely 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 however, 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 also should promote better understanding by stakeholders as it more directly connects coho production with habitat.

Presented in Table 1 are the forecasts of 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 "backed up" to estimate the population in terms of December Age-2 recruits. 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 Prod. Spr. 2000	Adults (Age 3)	Dec. (Age 2)	Adults (Age 3)	Dec. (Age 2)
Puget Sound					
Primary units					
Skagit River	1,453,000	6.0%	8.0%	87,180	116,647
Stillaguamish River	385,000	6.0%	7.9%	23,100	30,238
Snohomish River	1,115,000	8.0%	10.5%	89,200	116,763
Hood Canal	928,000	6.0%	8.0%	55,680	73,776
Straits of Juan de Fuca	406,000	4.5%	6.0%	18,270	24,555
Secondary units					
Nooksack River	90,000	6.0%	8.0%	5,400	7,198
Strait of Georgia	16,000	6.0%	8.0%	960	1,280
Samish River	100,000	6.0%	8.0%	6,000	7,998
Lake Washington	56,000	8.0%	10.2%	4,480	5,730
Green River	103,000	8.0%	10.2%	8,240	10,539
Puyallup River	65,000	8.0%	10.2%	5,200	6,651
Nisqually River	20,000	4.0%	5.1%	800	1,023
Deschutes River	4,000	3.0%	3.8%	120	153
South Sound	143,000	4.0%	5.1%	5,720	7,316
East Kitsap	62,000	8.0%	10.2%	4,960	6,344
Puget Sound Total	4,946,000			315,310	416,210
Coast					
Quillayute River	491,000	3.2%	4.2%	15,712	20,426
Queets River	322,000	3.2%	4.2%	10,304	13,395
Hoh River	212,000	3.2%	4.2%	6,784	8,819
Quinault River	217,000	3.2%	4.2%	6,944	9,027
Independent Tributaries	254,000	3.2%	4.2%	8,128	10,566
Grays Harbor					
Chehalis River	2,176,000	3.2%	4.2%	69,632	90,522
Humptulips River	200,000	3.2%	4.2%	6,400	8,320
Willapa Bay	340,000	3.2%	4.2%	10,880	14,144
Coastal Systems Total	4,212,000	3.2%	4.2%	134,784	175,219
Lower Columbia River	400,000	3.2%	4.2%	12,800	16,640
GRAND TOTAL	9,558,000			462,894	608,070

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. Smolt production has also been measured from significant portions of the Snohomish, Stillaguamish, Hood Canal, Quillayute, and Queets systems. 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 we have measured (Table 2).

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 the 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 2000, we estimated 1,453,000 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 eleven 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 productions which have averaged around 1.2 million have occurred on even years, while production on odd brood years was approximately half. 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 even year production measured in 2000 to good flows during summer 1999. The Puget Sound Summer Low Flow Index (PSSLFI) for water year 1999 had a value of 10.7. Over the previous ten broods, this index has ranged from 5.6 to 11.5, and averaged 7.9. We also observe this positive effect in other systems where we have demonstrated a strong proportional positive relationship between summer flow and smolt production the following spring (Figure 5).

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

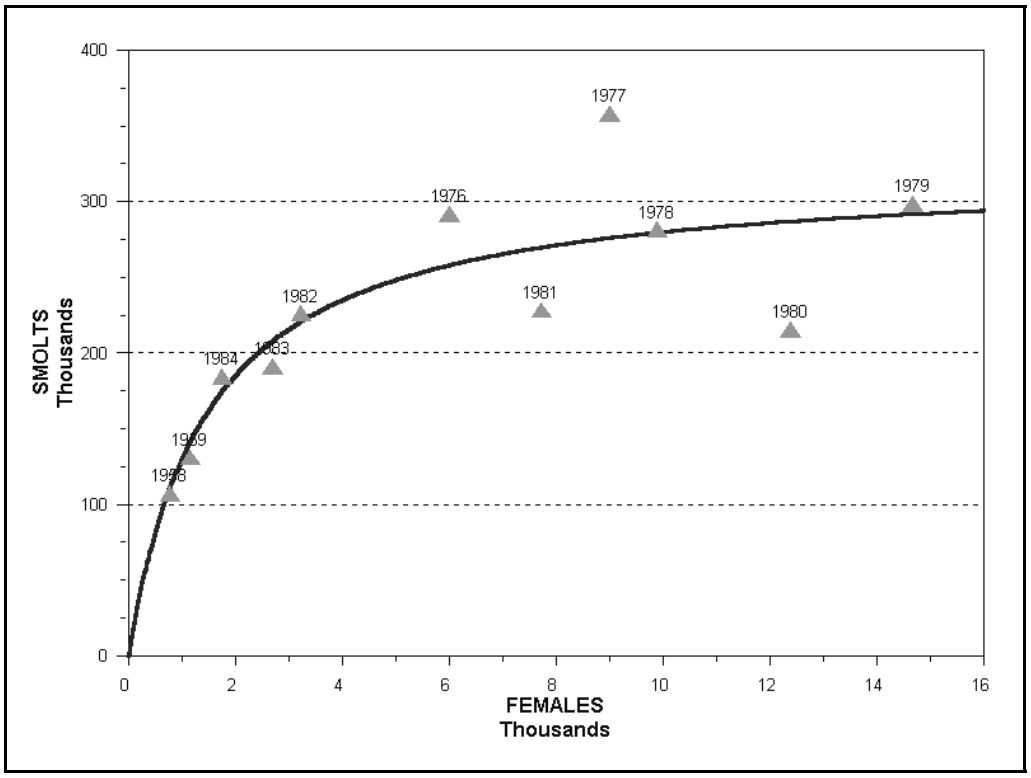

Figure 1. SF Skykomish River wild coho spawners and recruits, by brood year.

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. To account for the slightly better stream flows during Summer 1999, we expanded the average smolt production by the ratio of the PSSLFI values (1.07), which estimates production in 2000 at 385,000 coho smolts.

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.

Given the above-average flows during Summer 1999, we expect that smolt production in the Snohomish Basin was higher in 2000 than the average value we measured. The summer flow index over the six broods that we estimated production averaged 9.6. Therefore, we expanded the average smolt production by the ratio of summer flow index values (10.7 ÷ 9.6 = 1.115). Using this rate, we estimate that the Snohomish River system produced 1,115,000 smolts in 2000.

Hood Canal. In 2000, we trapped 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 2000, Big Beef Creek produced a record high 47,089 coho smolts. Stavis Creek produced 6,065 coho smolts, its second highest production. Seabeck Creek produced only 1,292 coho smolts which is close to its average over the last eight years. Little Anderson Creek, produced only 44 coho smolts, lower than we have measured in any previous year, and less than 20% of its eight-year average (227 smolts). This stream is heavily degraded by stormwater runoff and consequent high sediment loads. In addition, returning adults are subject to extremely high harvest rates in the net fishery conducted at the mouth of this stream at Lone Rock.

In Big Beef Creek, production from the high spawning escapement (1,415 females) in 1998, averaged 33 smolts per female. Also noteworthy was the large body size of the adult coho. After many years of generally decreasing size, this return included many individuals larger than we had previously measured.

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 production we measured to the total Canal's projected potential estimates system production in 2000 at 928,000 and 724,000 coho smolts, based on T.R.28 and HCJTC, respectively (Table 4). We selected the higher estimate for two reasons. First, it appears to more accurately reflect the level of system production given the high recent returns. Second, if the streams in which we are measuring production are more impacted by development-caused degradation than the rest of the stream habitat in Hood Canal watersheds (which is the likely bias), then we would be underestimating total system production.

Straits of Juan de Fuca. In Spring 2000, we conducted the third year of the smolt monitoring work we initiated in tributaries to the Straits of Juan de Fuca in 1998. In 2000, we trapped eight tributaries to the Straits from Bell Creek on the east end to Salt Creek west of Port Angeles. We did not operate the screw trap in the Dungeness River this year.

As observed in the previous years, coho production per unit area varied considerably between streams, ranging from 0.01 to 0.44 smolts/yd^2 of wetted habitat at summer low flow (Table 5a). Among the seven independent streams, Salt Creek, the largest stream trapped, produced the most

smolts per unit area (0.32/yd^2). Over the 199,848 yds of estimated summer low flow habitat in these seven streams, production averaged 14.8 coho smolts/100 yd^2. These streams comprise an estimated 27.9% of the habitat contained in the independent tributaries to the Straits. Expansion of the measured rate to the total area, estimates the total coho production from the independent tributaries at 105,952 smolts. We excluded the production information collected from Mattriotti Creek from this estimate because this stream is a tributary to the Dungeness River.

To approximate production from the seven streams categorized as "large systems" (mainstem widths $6 yds), we applied the rate of increase measured in the independent small streams in 2000 (relative to 1998), to the large-stream estimate in 1998. In this year, we estimated total coho smolt production from the Dungeness River through operating a screw trap in the mainstem. This system accounts for 42% of the drainage area in these seven larger systems. Results in the small streams indicate production in 2000 increased 2.52 times over what we estimated in 1998. Assuming that production in the large systems also increased at this rate, we estimate that the large streams produced 300,000 coho smolts this year (Table 5b). Total production from the Straits watersheds is estimated at 406,000 coho smolts by summing the small and large stream estimates.

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 well below projected potential in 2000. We used a value of 20% of the production projected by T.R.28 to estimate 90,000 smolts in 2000.

Strait of Georgia. We selected a value of 30% of the projected production (T.R.28), to estimate 16,000 smolts in 2000.

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 2000.

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 32,000 and 28,000 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 2000, we installed a smolt trap in Thornton Creek, the most developed watershed in the basin. With the help of Seattle Public Utilities workers who maintained the screens, we enumerated the smolt migration for five days, May 2-7. The total salmonid catch included only 5 coho smolts and 7 cutthroat trout. As the peak of the coho smolt migration occurs in early-May, over these five days we estimate that around 20% of the smolts emigrated. This migration estimate is taken from a timing model based on trapping coho smolts emigrating from numerous streams over many years. Using this ratio, we estimate that Thornton Creek produced less than 100 smolts.

Based on this extremely low production, we estimated only 20,000 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 80,000 coho smolts entering Lake Washington. Ongoing research conducted in 2000, associated with evaluating smolt passage at the Ballard Locks, provided new insights 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, Issaquah 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 56,000 naturally-produced coho smolts from the Lake Washington system.

In 2000 we expanded our smolt monitoring program to include the Green White and Puyallup Rivers. We installed floating screw traps in the lower mainstem of these systems and operated these traps continuously from February and March through the summer. While directed at assessing wild chinook production, we enumerated all salmonids and have preliminarily estimated natural coho smolt production during year 2000.

In the Green River, we estimated 43,000 wild coho were produced above our screw trap, located just upstream from the confluence of Big Soos Creek. We also operated a screw trap in Big Soos Creek, just above the hatchery. We estimate this stream produced 60,000 coho smolts. Summing these estimates yields a total production from the Green River of 103,000 coho smolts.

In the White River, our catch of 2,469 coho smolts over the season expands to an estimated production of 25,000 smolts. Catches in the screw trap in the Puyallup River were slightly lower (2,262 smolts). Given the lower capture rate in this larger river, we estimated 40,000 wild coho smolts were produced in the Puyallup upstream of the confluence with the White River. Summing these two estimates yields a total system production of 65,000 wild coho smolts.

For the Nisqually River, we approximated coho production at 20,000 smolts, through applying a rate of 10% to the estimated potential of 200,000 smolts (TR 28). We used this low rate, to reflect the very 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 in 2000, we estimated 4,000 smolts emigrated from this system, not even 2% of the production potential (220,000 smolts) predicted in T.R.28. In 1998, the spawning escapement included only 44 females and 51 males. Average production per spawner is estimated at around 90 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 2).

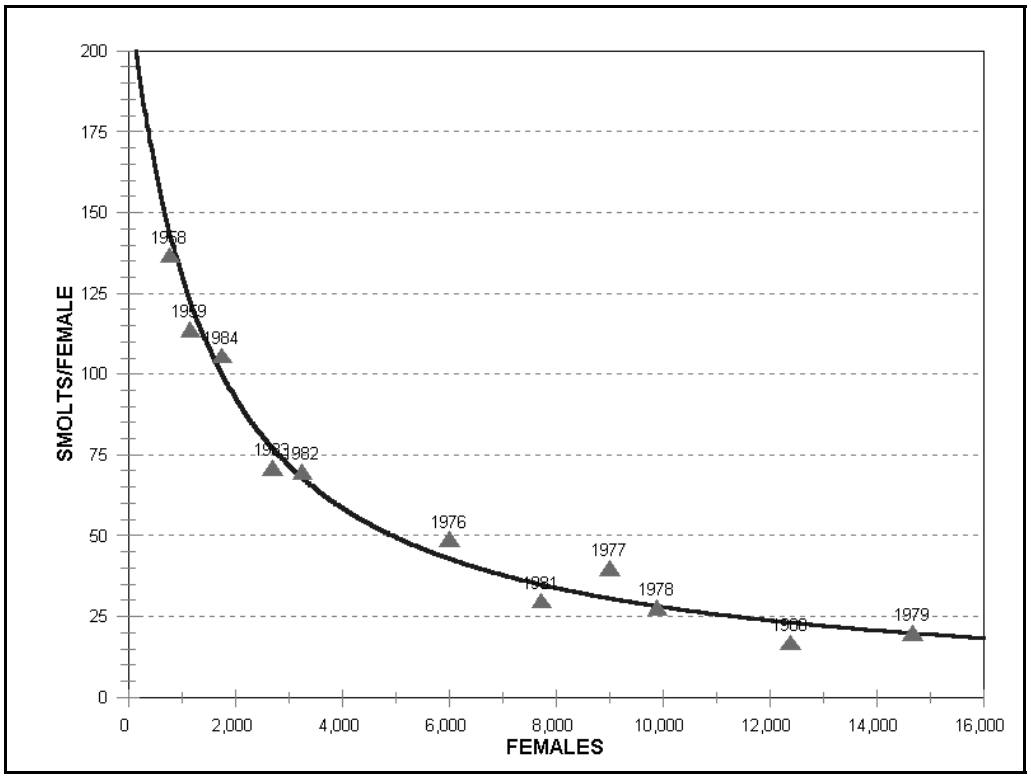

Figure 2. Productivity as a function of spawner abundance, SF Skykomish River wild coho.

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 higher seeding levels. Given the favorable flows during summer 1999, and the record high smolt production measured in some streams, we believe that production from this area is somewhat higher than estimated in recent years. To approximate this level of production we applied a factor of 25% to the potential production of 573,770 smolts projected in T.R.28. This rate estimates 143,000 coho smolts were produced from these South Sound streams in Spring 2000.

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 study streams. Therefore, we applied a factor of 40% to the 154,973 smolts projected by T.R.28 to estimate 62,000 smolts were produced from these streams in 2000.

Coastal Systems

Quillayute River. We 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 2000, was estimated from adjusting average production with the ratio of 2000 Clearwater production to its long-term average. QFiD biologists estimated that the Clearwater River produced 99,354 smolts in 2000 (pers.comm. Scott Chitwood). This production is an increase of nearly 161% of the twenty-year average of 61,874 smolts. Application of this increase to the average Quillayute System production estimates 491,000 coho smolts were produced in 2000.

Queets River. 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 3).
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 2). 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, a fraction of the value predicted by the flow relationship (72,500 smolts).

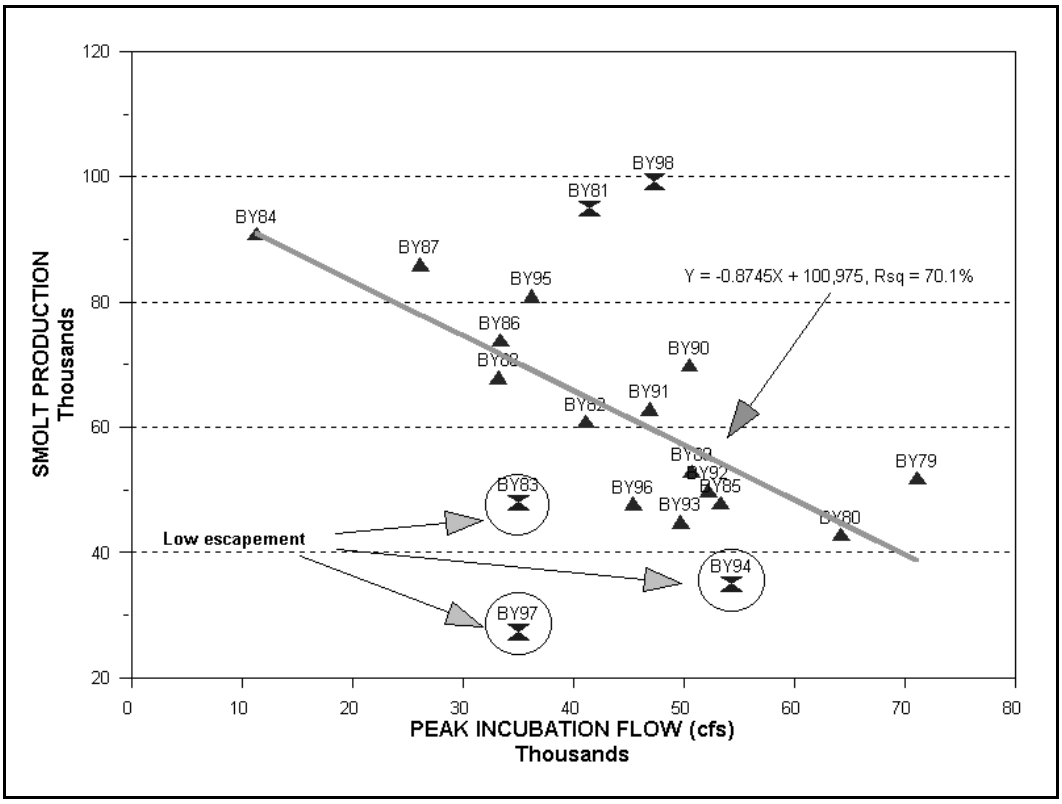

Figure 3. Clearwater River wild coho smolt production and Queets River flow during egg incubation, brood years 1979-1998 (brood years 1981and 1998 not included in regression).

During Spring 2000, Quinault Tribal biologists estimated that the Clearwater River produced a record high 99,354 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 322,000 coho smolts from the entire Queets system, including the Clearwater River (Scott Chitwood pers. comm.).

Relating these smolt production estimates to the drainage areas in the two systems yields production rates of 710/mi^2 and 716/mi^2 in the 140mi^2 and 450mi^2 Clearwater and Queets Basins, respectively.

The high smolt production from these systems in Spring 2000, while consistent with the high production levels we observed elsewhere for this brood, represents a positive departure from the flow relationship (Figure 3). Except for the three underseeded broods noted above, production from all but one of the previous other sixteen broods appeared to be largely regulated by the severity of flow during spawning. It is noteworthy that the one exception to this relationship, the 1981 brood, was also the previous record high production. Flows during egg incubation of the 1998 brood, mid-December through February, peaked twice in the range of 40,000 to 45,000 cfs, nearly identical to the peak flow for brood year 1981. With these flows, the relationship

predicted an average production, around 60,000 smolts. We suspect that favorable flow conditions throughout the rearing period explains most of this improvement. This positive deviation, however, could also signal that the watershed is beginning to heal, and as a result, less sensitive to mid-level flow events. Inclusion of the 1998 brood year reduces the correlation coefficient between production and flow from 58% to 42%. Excluding the two high outliers results in a flow correlation coefficient of 70%. Only continued smolt monitoring will measure watershed scale changes in productivity.

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 2000. At a production rate of 710 smolts/mi^2 , the 299 mi^2 drainage area of the Hoh system produces an estimated 212,000 coho 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 measured elsewhere. To approximate smolt production from this 434 mi^2 system, we applied a rate of 500 smolts per square mile. Use of this rate 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 600 smolts/mi^2 to the total watershed area (424 mi^2 see table below) estimates 254,000 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 each year since the 1980 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 6). Analysis to understand the components of variation has determined that flow during spawning, explains most (72%) of the interannual variation in estimated smolt production (Figure 4). We excluded three brood years (1990, 1994 and 1997) from this analysis. Tagging on the 1990 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 given the low tag rate, we could not make an estimate. We excluded the 1994 brood because escapement was extremely low – less than 10,000 spawners. The return from this brood in 1997 which we estimated at 7,000 adults was even lower. 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 2).

For the 15 broods analyzed, the flow/production relationship is even stronger than indicated by the correlation coefficient. Other important brood-specific factors reduced production 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 5);
- 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, which reduced egg survival and triggered mass wasting events.

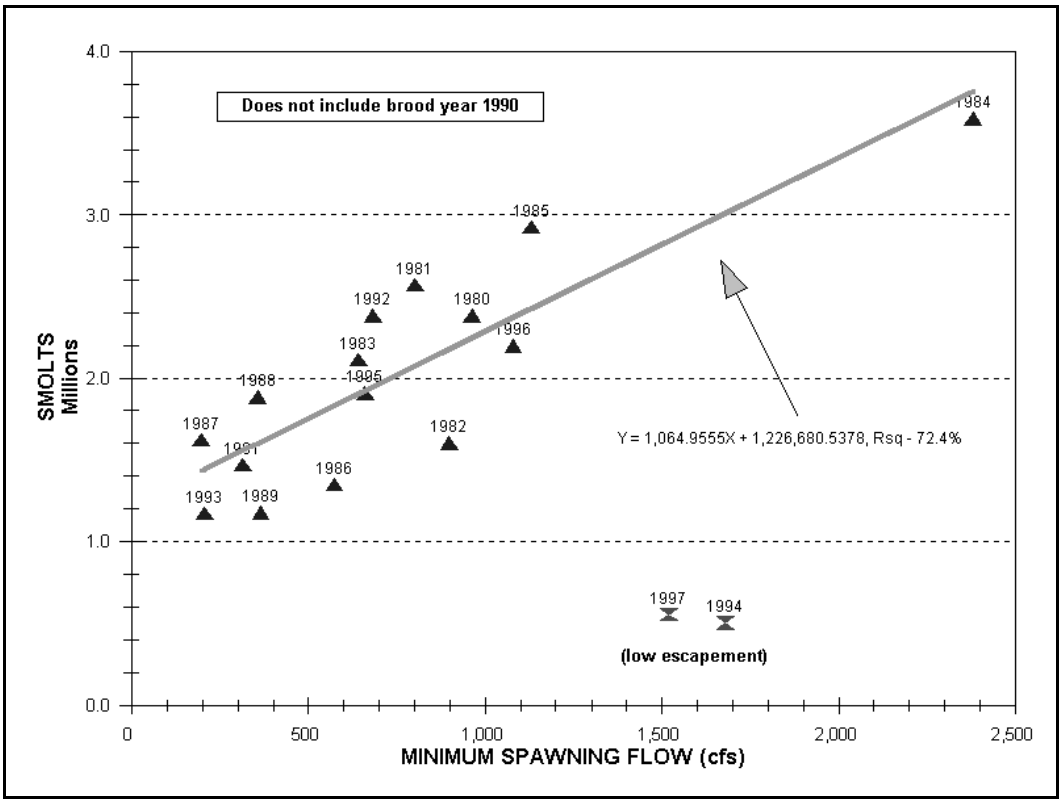

Figure 4. Coho smolt production as a function of minimum spawning flow, Nov. 02 through Dec. 15, Chehalis River, brood years 1980-1997.

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 5), 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 three of four recent broods, however, we have measured positive deviations exceeding values predicted with the summer flow model by more than two-fold. Interestingly, production on these three broods declines with increasing summer flow (Figure 5). Instead, production of these broods is positively correlated with mean flows during spawning (November and December). This

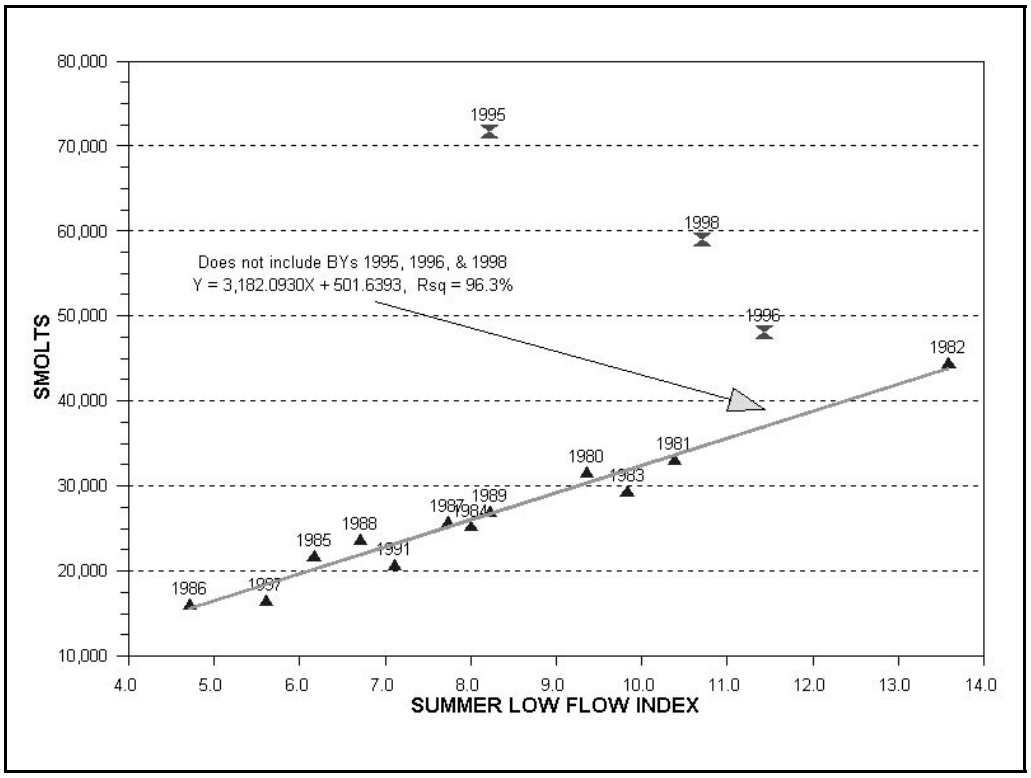

Figure 5. Wild coho smolt production vs. Puget Sound summer low flow, Bingham Creek, brood years 1980-1997 (broods 1990, and 1992-1994 omitted)

outcome suggests that with summer flows above some threshold level, spawning flows determine 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 inlet 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 fifteen 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 1997 and survival-to-return in 1998, we estimate 50,000 to 60,000 adult coho escaped to spawn in the Chehalis Basin in 1998. We deem this level of spawning is sufficient to seed the watershed. Flows during Fall 1998, which declined from an early spike of 1,500 cfs in mid-October, began to increase in early-November. From a low of 336 cfs on November 1, flow at the Grand Mound station increased to 1,130 cfs on November 6. To understand the effects of such variation in early-November flow values, we reexamined the interval for selecting minimum flows. As a result, we narrowed the window of the critical low flows to between November 2 and December 15.

In 1998, the low value of 371 cfs (November 2), predicts a production of 1.6 million smolts from the Chehalis Basin. The following indicators, however, strongly suggest that production in 2000 was higher.

- Spawning flows may have been low initially, but within several days increased to exceed 1,000 cfs. Beginning in mid-November, flows increased substantially, reaching a peak of 31,000 cfs on November 27. Over the months of November and December 1998, flow averaged 8,605 cfs. This value is the second highest over the last 19 broods, exceeded only slightly by the mean in 1995 of 8,760 cfs, on which the parent brood spawned. This brood produced an estimated 1.9 million smolts with a lower summer flow.
- Rearing flows, during Summer 1999, were also good, the third highest over the last twenty years (Figure 5). As a result, record high smolt productions were measured at several streams (Salt Creek, Big Beef Creek, Clearwater River). At the Bingham Creek station, we trapped nearly 60,000 smolts, the second highest production measured in 18 years.
- During Spring 2000, we also trapped 62,500 coho smolts in our scoop trap in the mainstem Chehalis River. While this is not a record catch it is large enough to indicate that smolt production was at least average, and probably larger.

Based on this additional information, we estimate production for the 1998 brood at 2 million coho smolts. Relating this production to the 2,114 mi^2 in the Chehalis Basin (including the Wishkah River) yields an average rate of 946 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 2,176,000 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, its smolt

production in 2000 was probably also above average. We used a value of 800 smolts/mi to estimate system production at 200,000 coho smolts.

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 1998 brood, we selected a value of 400 smolts/mi^2. This rate, applied to the total basin area, estimates 340,000 coho smolts were naturally-produced in 2000.

Lower Columbia River. To approximate the smolt production from the watersheds downstream of Bonneville Dam, we applied a rate of 200 smolts/mi^2 to the total estimated drainage area (2,000 mi^2). This rate estimates 400,000 coho smolts were naturally-produced from these systems. This estimate represents a modest increase over last year's projection (300,000 smolts), considerably less than that measured elsewhere. This conservative increase results from our uncertainty regarding actual production levels in this area.

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 ten-fold over brood years 1975-1996, from a high of 32%, to a low in 1999 of 3%. Over the last decade, 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 example, in 1999, the marine survival estimate of 3% is almost entirely comprised of adults enumerated at the upstream trap, as the net fishery in Area 12 was not monitored or sampled. For the 1997 brood, which returned in 2000, as of late-December 2000, we estimate a marine survival rate of 6%. This estimate is based on 700 tagged adults returning to the trap from the 16,286 smolts tagged in 1999, and an assumed harvest rate of 30%. Subsequent processing and compilation of catch and tag recovery data (not presently available) may produce a somewhat different estimate.

From brood year 1977 to present, marine survival of Deschutes River coho has averaged 15%, and ranged nearly a hundred-fold from a high of 29%, to a low of only 0.3% in 1999. For the

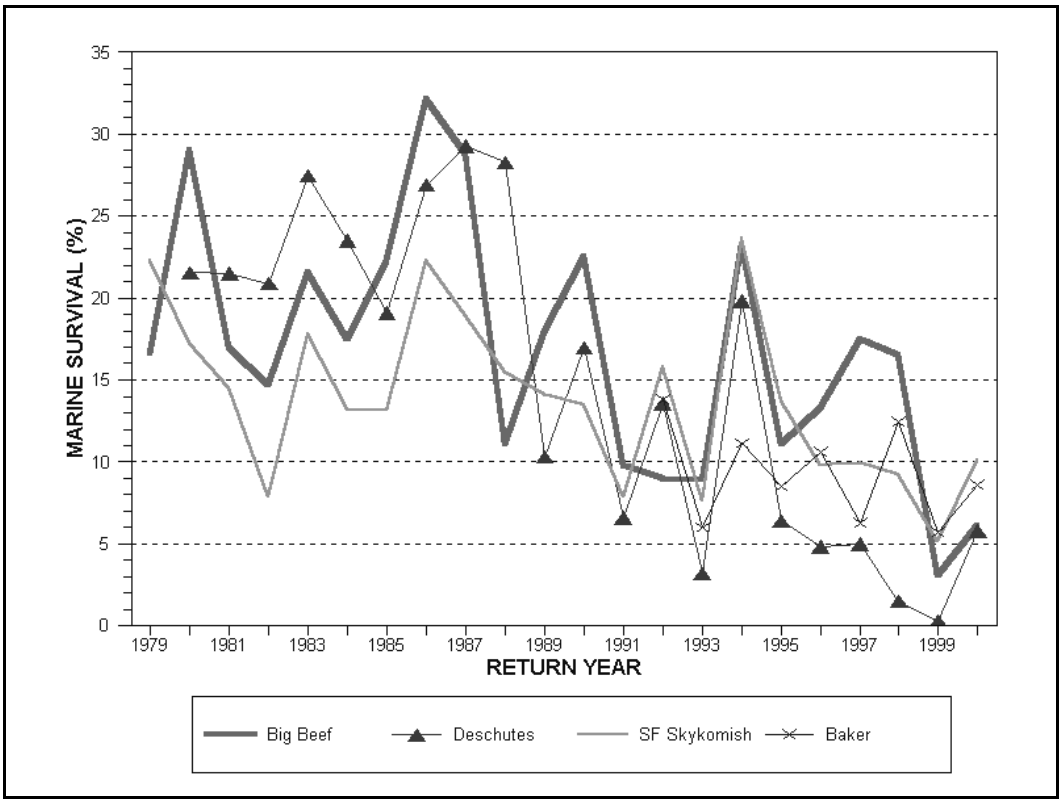

Figure 6. Marine survival of wild coho (age-3) measured at four Puget Sound streams.

first nine broods (1977-1985), survival of this stock averaged 24%, similar to that of Big Beef Creek smolts (22%). Beginning with the 1986 brood, however, survival of Puget Sound coho declined, particularly the Deschutes River population. Beginning with return year 1995, survival of Deschutes River coho declined more sharply than the other Puget Sound stocks (Figure 6).

Other stocks in South Puget Sound showed similar low survival rates in 1999:

- only a few thousand adult coho returned to Squaxin Island from a release of 2 million saltwater net pen-reared smolts;
- only 18 wild coho returned to an adult trap in the fishway on Cranberry Creek, operated by the Squaxin Tribe.

We estimate marine survival for the 1997 brood, returning to the Deschutes River fishway in 2000, at 5.8%. This rate is based on a return of 4% and an assumed harvest rate of 30%.

Over the nine broods that we tagged wild smolts at Sunset Falls, marine survival of this stock ranged 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, we approximate marine survival through applying projected harvest rates to the adult returns enumerated the Sunset Falls trap.

Relating resultant estimates of run size to the average smolt production we measured with full seeding(276,000 smolts), yields marine survival. As observed elsewhere, survival hit an all-time low in 1999 (5.2%). To estimate survival of the 1997 brood, we assumed that 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 (beginning with the 1989 brood), has ranged nearly three-fold, from a high of 14%, to a low of 5%, and appears to generally track the other stocks we have measured (Figure 6). Over these nine broods, Baker River coho survival alternates, with odd-numbered brood years experiencing higher survival than even-numbered brood years. As with the other stations, survival of Baker River coho in 1999 was the lowest measured thus far (5.7%). To project marine survival for the 1997 brood, we used the average harvest rate of the previous two broods (14.4%). Therefore, the return of 1,188 tagged adults in 2000 represents 85.6% of the total run, and we estimate total recruits 1,388 adults. Relating this estimate to the 13,818 smolts coded-wire tagged in 1999, yields a marine survival of 8.6%.

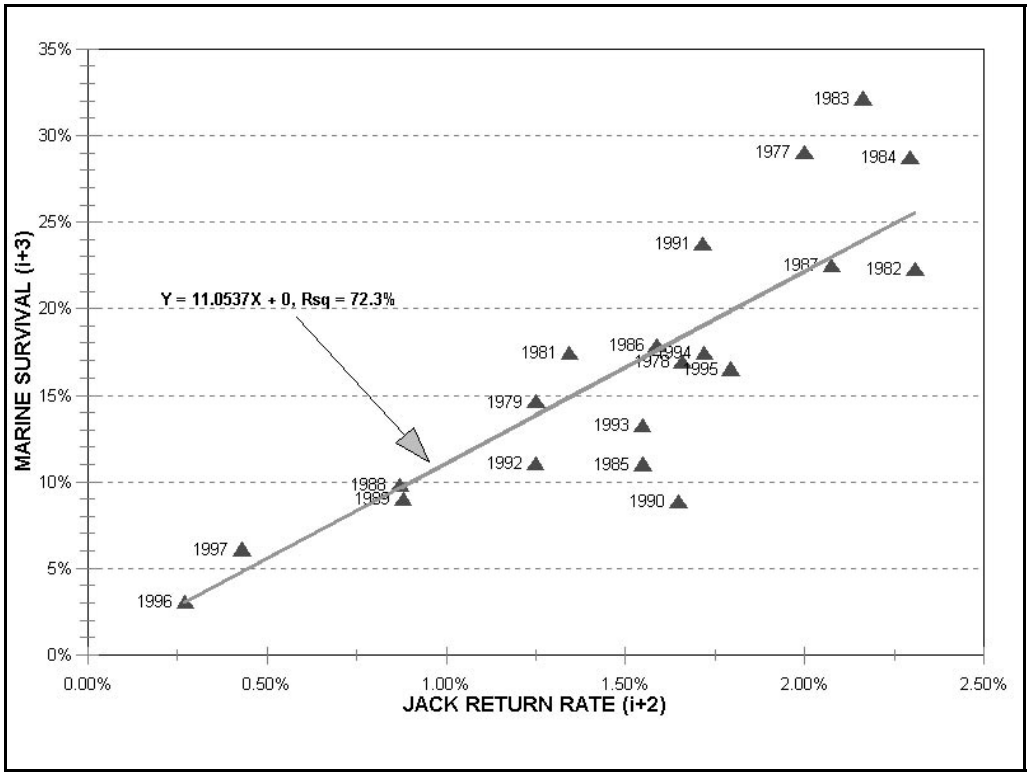

Figure 7. Jack and adult marine survival, Big Beef Creek wild coho, brood years 1977-1997.

Predicting 1998 brood marine survival. Correlating jack returns to Big Beef Creek with same-brood survival-to-adults indicates a strong relationship (Figure 7). Using this correlation, the tagged wild jack return rate in 2000 of 0.56% (178 jacks from 31,632 smolts tagged in 2000), predicts an adult marine survival rate of 6%. Due to the late return in 2000, as of late-December, we have not yet determined the age and origin from a number of small male coho (through scale

analysis). Therefore, at this time, based on data from previous years, we assumed that 21 of the 64 unanalyzed, unmarked, coded-wire tagged small males were wild jacks. Addition of this estimate to the 157 confirmed tagged jacks (which we presently assume are wild), results in the estimate of 178 wild jacks.

Analysis of wild jack and adult coho return rates to the Deschutes River fishway also indicates a relationship. Over the entire 20 brood years (1978-1997), jack return rates explain only 35% of the variation in adult marine survival. In the last ten years, however, during which marine survival has sharply declined, the correlation coefficient between jack and adult survival rates improves to 55% (Figure 8). In eight of these broods, marine survival has been extremely low, averaging only 4%. In 2000, only 1 jack (from an estimated 4,400 smolts) returned to the Deschutes fishway. This very low rate (0.02%) predicts an adult marine survival rate of only 3%.

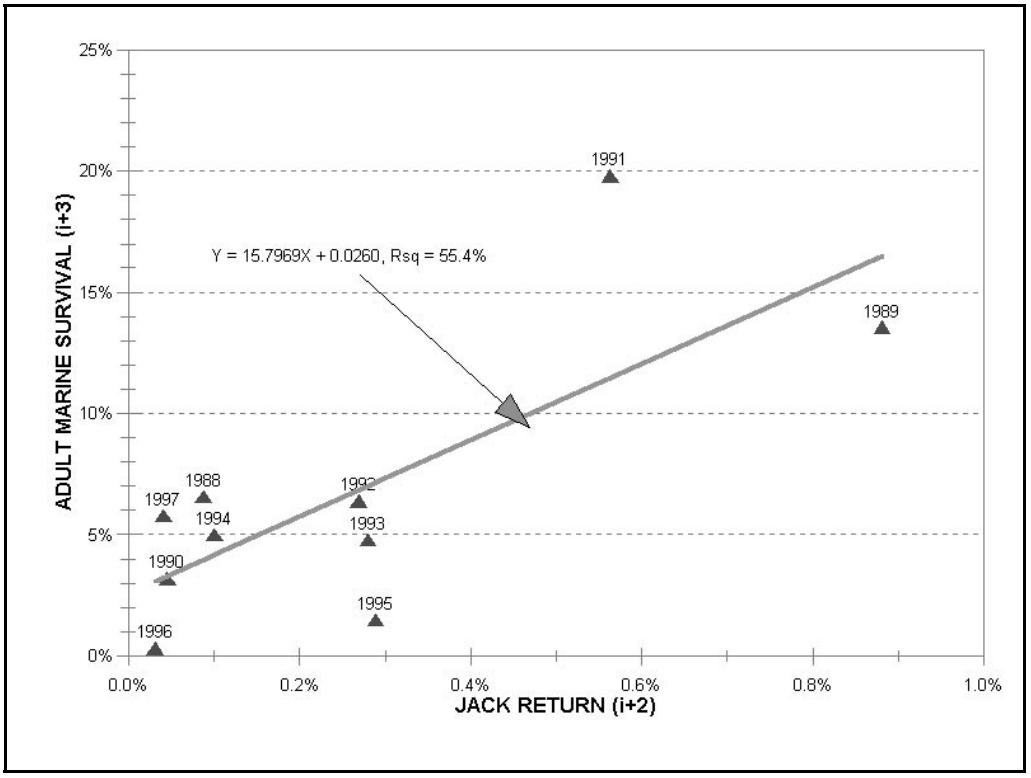

Figure 8. Jack and adult marine survival, Deschutes River wild coho brood years 1988-1997.

For predicting 1998 brood marine survival in other Puget Sound areas, we selected the following rates, which incorporate recent trends and patterns in marine survival (Table 7). 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.

- For the north Sound systems (Nooksack, Skagit and Stillaguamish Rivers), we used a survival rate of 6%, slightly less than the average (6.7%) of the four even-numbered brood years measured thus far at the Baker River. We also decided to use this rate for

the Stillaguamish River because, historically, marine survival in this system was lower than that measured in the Snohomish River.

- For the Snohomish River, we selected the rate of 8%, lower than the recent five-year average (8.9%) estimated at Sunset Falls.
- for the Lake Washington, Green River, Puyallup River, and East Kitsap systems, we selected a rate of 8%.
- For the Nisqually River and South Puget Sound, we selected a rate of 4%.

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 marine survival in this region is historically lower than that of inner Puget Sound coho. Given the generally lower survival of coastal stocks relative to Puget Sound stocks, we expect that coho emigrating from Straits tributaries experienced survival rates which are intermediate between Puget Sound and the coast. We selected the intermediate survival rate of 4.5% to predict marine survival of Straits wild coho.

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

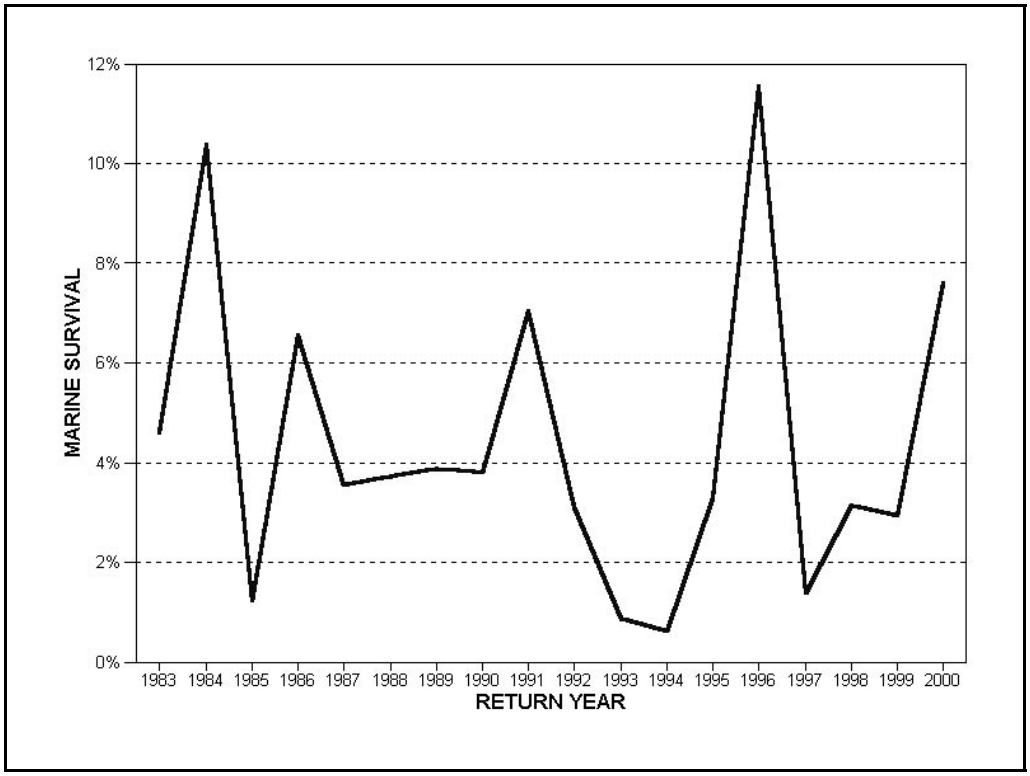

Figure 9. Marine survival of Bingham Creek tagged wild coho.

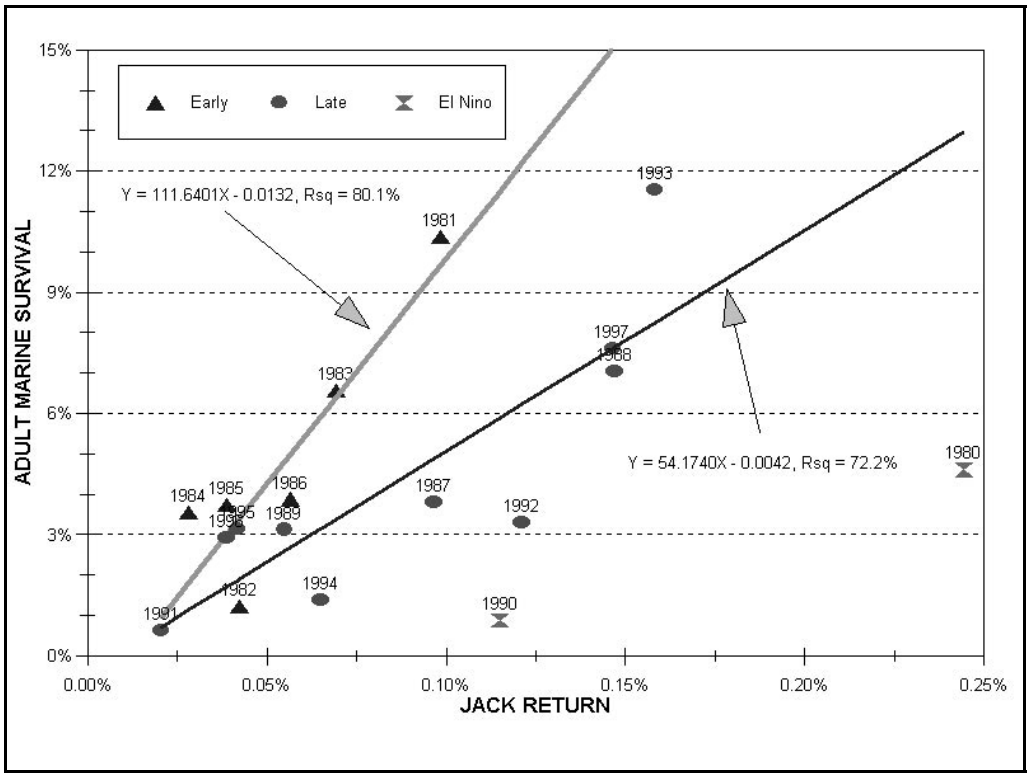

Figure 10. Jack return and adult marine survival, Bingham Creek, brood years 1980-1997.

the Washington Coast. Marine survival (age 3) of wild Bingham Creek coho has ranged nineteen-fold, from 0.6% to 11.6%, and averaged 4.4% over 18 years (Figure 9). 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 10). 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 10), the wild jack return rate to Bingham Creek in 2000 of 0.065% predicts an adult marine survival to the ocean (age 3) of 3.2%. This rate may underestimate the marine survival of other, non-Chehalis Basin, coastal stocks if the differential survival problem, which has long impacted Chehalis Basin coho, has not been resolved. Presently this remains uncertain, although the high survival of some recent returns (notably in 1991, 1996, and 2000) indicates substantial progress in reducing this problem. Therefore, we used this rate for the entire coast. In addition, in four of the last five broods, we have underestimated marine survival:

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%

[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.

The predicted values in this table were the rates we forecasted, based on the correlations developed pre-season, and which we modified based on judgement in each of the last two years, as noted. Because we update the model each year with new data, the regression equation varies slightly from year to year. As adults are still returning, the 1997 brood results are preliminary as of late-December 2000.

Lower Columbia River

Lacking any indicators for wild coho survival, we applied the rate predicted by the Bingham Creek model (3.2%).

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	Average Production	Avg. Prod./ (mi^2)	Identified Sources of Variation (see key)
Big Beef Creek	23	14	11,510	47,089	4.1	25,432	1,817	1, 2, 4, 5
Bingham Creek	19	35	15,280	71,708	4.7	30,159	862	2, 3
Deschutes River[a]	22	130	4,400	133,198	30.3	58,515	450	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	20	140	27,314	99,000	3.6	61,874	442	1, 4, 5
Stillaguamish River	3	540	203,072	379,022	1.9	275,940	511	6
Skagit River[c]	11	1,918	617,600	1,759,600	2.8	1,015,800	507	1, 2, 3, 8
Chehalis River	18	2,114	502,918	3,592,275	7.1	1,849,315	875	1, 2, 3, 4
Total		5,469						
Mean							741	
Wt'd Mean[d]							667	

[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.

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

Table 3. Estimation of wild coho smolt production, Skagit River, 2000.

	Number	Formula
Total mainstem trap catches	28,297	
Skagit Hatchery/Lake Shannon	[a]-1538	
Wild coho captured (c)	**26,759**	N = (m+1)(c+1) / (r+1)
RVs recaptured (r)	408	
RVs released (m)	22,201	
Total production (N)	**1,452,630**	
Variance (Var)	4.99e+09	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+1)}$
Standard deviation (sd)	70,617	
Coefficient of Var (CV)	4.86%	CV = sd ÷ N
Confidence interval (CI)	138,410	CI = ± 1.96(sd)
Estimated coho production Skagit River	1,452,630	
Upper CI (95%)	1,591,040	
Lower CI (95%)	1,314,220	

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

Table 4. Actual and projected wild coho smolt productions in Hood Canal 2000.

Stream	PROJECTED SMOLTS		Actual Production (2000)	RATIO Actual/projected	
	Zillges	HCJTC		Zillges	HCJTC
Big Beef Creek	38,586	29,638	47,089	122%	159%
Little Anderson	5,100	3,190	44	n/a	n/a
Seabeck Creek	10,497	6,564	1,292	12%	20%
Stavis Creek	5,027	3,144	6,143	122%	195%
Subtotal	59,210	42,536	54,568	92%	128%
Total Hood Canal	1,006,577	[a]561,631	**Est. 2000**	927,662	720,497
Projected proportion (Subtotal/Total)	5.9%	7.6%			

[a]Includes catch area 9A tributaries (7,027 smolts).

Table 5a. Measured and projected wild coho smolt production in small Straits of Juan de Fuca streams (mainstem widths <6 yards), 2000.

Small Streams	Wetted Habitat (yds^2)	Coho Smolt Catch	Prod. Rate (Smolts/100 yd^2)	Projected Smolt Production
Mattriotti Creek	10,560	4,656	44.1	
Cassalary Creek	3,960	672	17.0	
Bell Creek	4,224	359	8.5	
Siebert Creek	51,040	511	1.0	
Ennis Creek	18,304	908	5.0	
Tumwater Creek	4,576	67	1.5	
Salt Creek	83,072	26,652	32.1	
McDonald Creek	34,672	378	1.1	
Subtotal	199,848	29,547	14.8	
Total Independent Tribs	716,628		14.8	105,952

Table 5b. Estimated and projected wild coho smolt production in larger Straits of Juan de Fuca systems (mainstem widths $6 yards), 2000.

Large Systems	Watershed Area (mi^2)	Average Production (mi^2) in 1998	Projected Smolt Production		
			1998	1999[a]	2000
Dungeness River	198.0	253	50,000	65,857	126,200
Morse Creek	46.6	253	11,790	15,529	29,700
Lyre River	66.0	253	16,698	21,993	42,100
Pysht River	44.4	253	11,233	14,796	28,300
Clallam River	31.6	253	7,995	10,530	20,100
Hoko River	51.2	253	12,954	17,062	32,600
Sekiu River	33.0	253	8,349	10,997	21,000
Total	470.8		119,018	156,763	300,000

[a] Based on the average 1999:1998 smolt production ratio(26,880÷20,408 = 1.32) for the seven streams trapped both years.

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Table 6. 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.

Table 7. Comparison of marine survival (age 3), Big Beef Creek, Deschutes River, SF Skykomish River, and Baker River wild tagged coho.

YEAR Br.	YEAR Rtn	Big Beef	Desch. River	SF Sky	Big Beef	Desch. River	SF Sky	Baker River	AVERAGE Early	AVERAGE Late	AVERAGE 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