STATE OF WASHINGTON
DEPARTMENT OF FISH & WILDLIFE
FISH MANAGEMENT PROGRAM
RESOURCE ASSESSMENT DIVISION

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TO: Bill Tweit

FROM: Dave Seiler Dave

SUBJECT: **WILD COHO FORECASTS**

Attached for your information and consideration are my 1999 wild coho run forecasts for all Washington state production areas outside the Columbia River. These estimates are based primarily on the results of the *Wild Salmon Production & Survival Evaluation Unit*'s long-term research and monitoring program. I welcome any additional data, comments, and questions.

DS:lek

Attachments

cc: Bruce Crawford
Lew Atkins
Rich Lincoln
Ross Fuller
Pat Pattillo
Chuck Phillips
Tim Flint
Dan Rawding
Phil Anderson
Larrie Lavoy
Doug Milward
Jim Packer
Dick Geist
Teresa Scott
Jim Ames
Bruce Sanford
Lee Blankenship
Tony Floor

1999 WILD COHO FORECASTS
FOR PUGET SOUND & WASHINGTON COASTAL SYSTEMS

Washington Department of Fish & Wildlife
Dave Seiler

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 <u>the</u> 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 marine survival 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 are 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, will be used to determine the extent and shape of fisheries, production from all the other freshwater habitat units can also be approximated by extrapolating measured 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 Tables 1a-b are the forecasts of coho run size derived by combining estimates of natural smolt production and predictions of marine survival for all Puget Sound and Coastal production areas. The resultant 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 1a. Wild coho run forecasts for Puget Sound in 1999, based on estimates of smolt production and marine survival.

Production Unit	FRESHWATER PRODUCTION Projected Smolt Prod. (Zillges)	Est. Actual Smolt Prod. Spr. 1998	Ratio Actual/ Projected	X MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Primary Units							
Skagit River	1,371,058	1,760,000	**128%**	6.9%	9.2%	120,971	161,859
Stillaguamish River	864,094	529,000	61%	6.9%	9.0%	36,360	47,595
Snohomish River	2,027,497	1,470,000	73%	9.8%	12.8%	144,174	188,724
Hood Canal	1,006,577	551,000	**55%**	9.9%	13.2%	54,806	72,618
HCJTC estimate	561,631	422,000	**75%**				
Straits of Juan de Fuca	443,098	161,000	**36%**	5.0%	6.7%	8,007	10,761
Secondary Units							
Nooksack River	451,275	226,000	50%	6.9%	9.2%	15,534	20,706
Strait of Georgia	51,821	26,000	50%	6.9%	9.2%	1,787	2,382
Samish River	169,489	100,000	59%	6.9%	9.2%	6,873	9,162
Lake Washington	842,253	42,000	5%	3.8%	4.8%	1,583	2,025
Green River	541,239	162,000	30%	3.8%	4.8%	6,107	7,811
Puyallup River	575,536	173,000	30%	3.8%	4.8%	6,522	8,342
Nisqually River	200,314	20,000	10%	3.8%	4.8%	754	964
Deschutes River	219,574	6,000	**3%**	3.8%	4.8%	226	289
South Sound	573,770	86,000	15%	3.8%	4.8%	3,242	4,147
East Kitsap	154,973	46,000	30%	3.8%	4.8%	1,734	2,218
Puget Sound Total	10,054,199	5,780,000	57%			408,681	539,605

Note: Ratios in bold indicate "actual" estimates based on smolt trapping in Spring 1998.

Table 1b. Wild coho run forecasts for Washington Coastal Systems in 1999, based on estimates of smolt production and marine survival.

Production Unit	Drainage Area mi^2	SMOLTS Freshwater Production Spr. 1998	x MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Coast						
Quillayute River	629	236,000	2%	2.6%	4,720	6,136
Queets River	450	154,000	2%	2.6%	3,080	4,004
Hoh River	299	102,000	2%	2.6%	2,040	2,652
Quinault River	434	87,000	2%	2.6%	1,740	2,262
Independent Tributaries	424	170,000	2%	2.6%	3,400	4,420
Grays Harbor						
Chehalis River	2,300	2,857,000	2%	2.6%	57,140	74,282
Humptulips River	250	311,000	2%	2.6%	6,220	8,086
Willapa Bay	850	425,000	2%	2.6%	8,500	11,050
Coastal Systems Total	5,636	4,342,000			86,840	112,892

Independent Tribs =

Stream Name	Drainage Area
Waatch River	13
Sooes River	41
Ozette River	88
Goodman Creek	32
Mosquito Creek	17
Cedar Creek	10
Kalaloch Creek	17
Raft River	77
Camp Creek	8
Duck Creek	8
Moclips River	37
Joe Creek	23
Copalis River	41
Conner Creek	12
	424

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 among these systems, 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 in each major system (as presently conducted on the Skagit River) would be optimal, sufficient information exists to approximate production in systems currently unmeasured. The method of extrapolating annual measured results to estimate production from other systems varies, as it depends on the data available. 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; Managed for Natural Escapement

Skagit River. Spring 1998 was the ninth year of estimating total smolt production from this system. 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. In the first eight years, production ranged from 618,000 to 1,174,000 coho smolts. Prior to 1997, all of the high productions occurred on even years, while production during odd years was approximately half. We explained this pattern with the hypothesis that adult pink salmon, which spawn only on odd years, provided a positive interaction. While this relationship may still be valid for most years, for the 1995 brood, which produced the highest number of smolts since 1990, it was apparently overridden by beneficial flows during freshwater rearing. This contention is supported by the record high smolt production we also measured in two other systems in 1997.

In 1998, we estimated 1,760,000 coho smolts emigrated from the Skagit River (Table 3). This is the highest coho smolt production we have yet measured in this system. As with the previous brood, we attribute this record high production in 1998 to beneficial flow effects. From spring through summer 1997, the Skagit system had record high flows. Apparently, this abundance of water, provided by a heavy winter snow pack, reduced the constraint of summer low flows, enabling a higher population to survive into the fall. Throughout the fall and winter, peak flows were relatively benign, which contributed to the high smolt production from the 1996 brood by not displacing juveniles downstream. This was evident from the high smolt counts from the upper tributaries trapped, relative to those lower in the system. Conversely, on broods which experience high winter flows, fewer smolts emigrate from the upper tributaries in the Spring, relative to lower tributaries.

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. Given the record high production we measured in the Skagit River in 1998, we expect Stillaguamish coho smolt production was also well above average. Applying the Skagit factor of 1.94 (the ratio of the 1998 production to its previous eight-year average of 907,367 smolts) to the average Stillaguamish production, estimates 698,000 smolts. This estimate may be high, so we selected the value of 529,000 smolts, which is midway between average production (360,000 smolts) and that estimated with the Skagit factor. This adjustment accounts for the lower average elevation of the headwaters of the Stillaguamish, relative to the Skagit River, and it therefore retains less snow for water supply during the summer.

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 mark 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. Based on the record high production we measured from the Skagit River, we expect Snohomish Basin smolt production was also above average in 1998, but not to the same extent. As with the Stillaguamish, the Snohomish Basin has a lower mean elevation than the Skagit system. In addition, two other factors combine to reduce Snohomish Basin coho smolt production from former levels: development has impacted lower basin tributaries; and the "ice storm" on January 1, 1997, produced high flows in low elevation tributaries, which resulted in high egg mortality. Using the Skagit expansion factor (1.94) estimates Snohomish coho production at 1,940,000 smolts. Because this appears too high, we selected the median value between the average and that estimated with the Skagit factor, to estimate 1,470,000 smolts.

Hood Canal. In previous years we trapped four independent tributaries to Area 12. In 1998 we could not trap one of these streams, Little Anderson Creek, because extreme habitat degradation (sedimentation) resulting from development, obliterated the stream channel. We trapped Big Beef, Stavis, and Seabeck Creeks, which produced 22,222, 5,979, and 1,393 coho smolts, respectively. Production in both Big Beef and Seabeck Creeks were slightly below average, while Stavis Creek was above average. In Big Beef Creek, production from the relatively high spawning escapement of 698 females upstream in 1996 was negated by the record high flow produced by the "ice storm" on January 1, 1997. This storm produced a peak discharge, estimated at 1,600 cfs, over double the previous record high flow. Relatively high flows during Summer 1997 (almost double the average of the last seven years) provided some compensation through above-average rearing survival. The 22,000 smolts produced represent an average production rate of 31.8 smolts/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) has revised this estimate downward to 561,631 smolts. Both of these estimates were predicated upon adequate seeding and average environmental conditions. Assuming our three study streams represent coho smolt production in tributaries to Hood Canal, system production in 1998 is estimated at 550,520 and 422,000 smolts, based on T.R.28 and HCJTC, respectively. Wild coho escapements in Hood Canal in both 1997 and 1998 have been around 100,000 spawners. The run sizes which produced these escapements resulted from higher smolt production levels than projected by the HCJTC. Consequently, for 1999, we selected the higher T.R.28-based projection, of 550,520 coho smolts (Table 4). Even this smolt projection is likely conservative, however, because the three streams we trapped have suffered more development-caused habitat degradation than the major coho-producing systems (Dewatto, Union, and Tahuya Rivers) located further south.

Straits of Juan de Fuca. In Spring 1998, WDFW and the Lower Elwah S'Klallam Tribe initiated smolt trapping in nine Straits' tributaries, from (east to west) the Dungeness River to Little Hoko Creek (Tables 5a-b). In the Dungeness, we operated a screw trap in the mainstem, and a fence trap in Mattriotti Creek, a lower-river tributary to this system. Our preliminary estimate, based on this work, is 50,000 coho smolts for this 198 mi^2 watershed, a production rate of 253 smolts/mi^2. We used this rate to project smolt production for the other six systems with mainstem habitat (Table 5a). T.R.28 computes smolt production potential on the basis of wetted habitat area in streams with widths less than 6 yds, and uses a linear rate for mainstem areas $\geq$6 yds. To approximate production in the smaller independent streams, we applied the average production rate (5.9 smolts/100 yd^2) measured in the six independent small streams trapped to the total wetted habitat area (Table 5b). This approach estimates 42,000 smolts were produced from the small independent tributaries to the Straits in 1998. We excluded the production information collected from Mattriotti and Little Hoko Creeks from this estimate because these two streams are tributaries to larger systems, and therefore, do not represent independent streams. Summing the large stream and small stream estimates project a total production of 161,049 coho smolts. Continued smolt monitoring in this region will determine what portion of carrying capacity this production level represents. The production estimated in 1998 lies between the 222,000 smolts we projected in 1997 and the 133,000 smolts in 1995 and 1996.

Puget Sound Secondary Units; Managed for Hatchery Harvest Rates

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 1998. We used a value of 50% of the production projected by T.R.28 to estimate 226,000 smolts in 1998. This rate is an increase from the 30% we used last year, based on the higher production we measured in the Skagit River.

Strait of Georgia. We also selected the value of 50% of the projected production (T.R.28), to estimate 26,000 smolts in 1998.

Samish River. Assuming that virtually all of the returning adult coho enumerated at the Samish Hatchery are wild fish (which scale sampling/analysis in 1996 confirmed), production is typically well in excess of the 58,000 smolts projected in (T.R.28). In some recent years, 10,000 adult coho have returned. Even at a relatively low harvest rate of 50% and a high marine survival of 20%, production would be estimated at 100,000 smolts, almost double the projected production. If harvest rates were higher and/or marine survival lower, then even more smolts were produced. We used 100,000 smolts as our best approximation of production.

Lake Washington, Green River, Puyallup River, and Nisqually River. Coho production in each of these systems are impacted by habitat degradation through development, diking, water withdrawals, and underescapement 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 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.

For the Lake Washington system, we used the very low rate of 5% of the projected production (T.R.28) to reflect our belief that in this most urbanized watershed, the estimated 842,253 smolt potential is unrealistically high. Not only has development continued to reduce production potential, but the T.R.28 projection includes 192,500 smolts estimated as the production component occurring in the lake. Recent investigations of its fish populations have found virtually no coho rearing in the littoral or pelagic zones of Lake Washington. In addition, a comprehensive electro-shocking survey of Lake Washington Basin tributaries found very low densities of juvenile coho in late-summer (Kurt Fresh, pers.comm.). In this low-elevation watershed, the 1996 brood was devastated by the January 1, 1997 "ice storm". This rain-on-snow event produced record-high flows in the Sammamish River. One measure of the impact of this storm was the 99% mortality that we measured on naturally-produced sockeye fry in the Sammamish system in 1997. The potential egg deposition (P.E.D.) of 90 million eggs from a spawning escapement of 60,000 sockeye in 1996 produced only 900,000 fry in 1997. Recent, very low coho escapement estimates also indicate natural smolt production is very low in this system. For example, in 1998, the natural spawning escapement estimate will likely be <1,000 coho. At a survival-to-return rate of 3%, this equates to a production of only 30,000-40,000 smolts.

We selected a value of 30% of the production projected by T.R.28 for the Green and Puyallup Rivers.

For the Nisqually River, we discounted projected production even more, with a rate of 10%. We used this lower rate based on 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, poor marine survival, and overfishing.

Deschutes River. A number of factors have combined to severely depress production in this system: habitat degradation, particularly in the upper watershed; low reproductive potential due to small fish size; and low escapement. Escapements have declined as a result of poor smolt production due to habitat degradation, extreme high flows during egg incubation, and poor marine survival. In the 1990s, marine survival for Deschutes coho is even lower than other Puget Sound stocks. This may indicate a reduction in the productive potential of the South Sound marine environment.

Based on trapping in 1998, we estimated only around 6,000 smolts emigrated from this system. As in 1997, this level of production is the lowest we have measured in 20 years of continuous monitoring. In 1996, the spawning escapement, comprised of 188 females and 276 males, was followed in late-December by the "ice storm", which produced a peak flow of 4,350 cfs. While not the highest flow on record, it was certainly destructive to incubating eggs. Relating smolt production to this escapement yields only 32 smolts/female, the same rate we measured at Big Beef Creek on this brood. Typically, coho populations compensate for very low seeding rates through density-dependent survival, producing over 100 smolts/female, as we measured at the South Fork Skykomish (Figure 2). The ice storm caused such high egg mortality, that the surviving fry population was simply too low for compensatory mechanisms to offset this loss. Consequently, the 1998 smolt production represents only one third of the 18,000 smolts that this system should have produced.

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. We applied 15% to the production projected by T.R.28. This rate — which is lower than that measured in Hood Canal (55%), but much higher than the 3% estimated for the Deschutes — reflects our belief that production from these streams has not only suffered many of the same problems that have impacted Deschutes River coho, but even more habitat degradation due to development and, for this brood, the ice storm.

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 discounted the reduction factor from the 55% estimated in Hood Canal to 30% of the production projected by T.R.28.

Coastal Units

Quillayute River. We have measured smolt production in two sub-basins of the Quillayute River — the Bogachiel and Dickey Rivers. Over three years, 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 fry plants, and as a result, we concluded that the system was already seeded to capacity by natural spawners.

Over three years, 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 probably 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.

To estimate production in 1998, we adjusted this average production estimate by the ratio of 1998 Clearwater production to its long-term average. QFiD biologists estimated that the Clearwater River produced 47,800 smolts in 1998, 77% of its 18 year average (61,700 smolts). Application of this rate to the average Quillayute production estimates 236,000 coho smolts were produced in 1998.

Queets River. Smolt production has been measured from the Clearwater River each Spring since 1981. Over the first 15 broods, coho production ranged two-fold between extremes, from around 43,000 to 95,000 smolts. Estimates of parent spawners have ranged six-fold, from around 300 to over 1,900 females but 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 severity of flow on one day during egg incubation explains over half the variation in smolt production (Figure 3).

In brood years 1983 and 1994, however, it appears that low escapements did reduce smolt production. In 1996, QFiD biologists estimated only 35,000 coho smolts were produced from the Clearwater River. Not only is this estimate the lowest on record, but it falls well below the value predicted by the flow relationship (Figure 3). Relating this estimate to the 260 females estimated in the 1994 escapement, yields an average of 135 smolts/female, which is a high value (Figure 2). These outcomes indicate that the low escapement in 1994 was probably inadequate to seed the system, and as a result, smolt production was limited in 1996.

In 1998, QFiD estimated that the Clearwater River produced 47,800 coho smolts (pers.comm. Dan Eastman). This value is considerably lower than the 63,000 smolts the flow relationship predicts, even though spawning escapement in 1996 was more than sufficient to seed the system. We attribute this discrepancy to the effects of the extreme high flows measured in the Queets River (91,000 cfs), which occurred on March 19, 1997. High flows at this time displaced downstream 1996 brood coho fry already emerged from the gravel, leaving upper reaches of the Clearwater underseeded, and caused high mortality on any eggs still incubating.

We estimated coho smolt production for the entire Queets system at 154,000 smolts by applying the production rate measured in the Clearwater (341 smolts/mi^2) to the 450 mi^2 Queets Basin. QFiD biologists may refine this projection through their seining project at the mouth of the Queets River.

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 1998. The rate of 341 smolts/mi^2 applied to the 299 mi^2 drainage area of the Hoh system estimates 102,000 coho smolts were produced.

Quinault River. Low escapement due to high hatchery harvest rates and degraded habitat likely combined to limit natural smolt production from this system. To reflect these effects, we used the relatively low rate of 200 smolts/mi^2. This rate, applied to the total area in this basin (434 mi^2), estimates total production at around 87,000 smolts.

Independent Tributaries. Smolt production has not been directly measured from any of the independent coastal tributaries. Application of an average production rate of 400 smolts/mi^2 to the total watershed area (424 mi^2) estimates 170,000 coho smolts were produced from these systems (Table 1b). The value of 400 smolts/mi^2 was selected, higher than the rate measured in the Clearwater River in 1998, for two reasons: drainage area values were not available for some of the minor tributaries, thus the total area estimate is low; and many of these systems have lower gradients than the Clearwater River and, therefore, production/area should be higher.

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 CWT sampling adults caught in the Quinault Tribe's terminal net fishery in the lower Chehalis River. Resultant estimates have ranged seven-fold, from around 0.5 million to 3.5 million (Table 6). Analysis to understand the components of variation has determined that only one variable, flow during spawning, explains a significant portion (59%) of the interannual variation in estimated smolt production (Figure 4).

We excluded two brood years from this analysis (1990 and 1994). Tagging on the 1990 brood was limited, and therefore, also likely not representative. 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), so although it is likely that smolt production was high on this brood, we have little confidence in this estimate. We also excluded the 1994 brood because escapement was extremely low: less than 10,000 spawners. Upon adult return in 1997, we estimated only around 500,000 smolts were produced from this brood. This brood experienced the highest minimum flows during spawning, however, which helped compensate for the low escapement.

The flow/production relationship is even stronger than indicated by the correlation coefficient. For the three broods with production below the regression line, other important brood-specific factors were in effect.

- 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.
- 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 1982 brood may have been constrained by low escapement.

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. In 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.

Correlation of estimated escapement with the estimates of smolt production explained only 11% of the interannual variation. Analyzing flow effects during other periods — winter (incubation), spring (fry distribution), and summer (fry rearing) — also yielded insignificant correlations.

For the fourteen broods analyzed, this 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 has not produced enough smolts to obscure this effect of flow on natural production.

This relationship provides a means to predict freshwater production, for broods with adequate spawning escapements. Escapement in 1996 was very high, in excess of 100,000 spawners. This estimate is the product of our relatively low smolt estimate in 1995 (1.2 million) and a record high survival-to-return rate (9.0%) we measured at Bingham Creek in 1996. The record high return to the Elk Creek fishway/trap in 1996 (over 1,700 wild adult coho) corroborates this estimate.

In Fall 1996, the minimum spawning flow during November and December, recorded at Grand Mound, was 1,080 cfs. This flow predicts a production of 2,857,000 smolts in Spring 1998. Relating this estimate to the Chehalis Basin drainage area of 2,300 mi^2 (including the Wishkah, Hoquiam, Johns, and Elk Rivers, and other southside tributaries) yields an average production/area of 1,242 smolts/mi^2. Assuming this rate is also correct for the 250 mi^2 Humptulips River system, we estimate 311,000 smolts from this system.

Willapa Bay. The Willapa Basin, with a total 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 considerably lower than that measured in the Chehalis Basin. To approximate production of the 1996 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 1998.

While this production level may be approximately correct for the entire Willapa system in 1998, we believe that production/area was not uniform. Recent adult mark-and-recapture studies in the North River system (240 mi^2 drainage area) have found relatively high natural spawning populations (2,000 to 12,000 adults) over three years (1995-1997). Applying the survival-to-return rates measured at Bingham Creek to these respective estimates indicate natural production levels of 130,000 to 200,000 smolts from the North River system. These estimates translate to production/area rates of 540 and 833 smolts/mi^2, which are considerably higher than the production rates we believe are occurring in most other tributaries to Willapa Bay.

MARINE SURVIVAL

Puget Sound

Marine survival rates for Puget Sound wild coho stocks have been measured for many years at Big Beef Creek, Deschutes River, South Fork Skykomish, and (as of the 1989 brood) Baker River. Marine survival, in terms of age 3 recruits, has varied from 9% to 32% at Big Beef Creek, and averaged 17.9% over brood years 1975-1993. Over the same period, marine survival of Deschutes River coho has averaged 17%, ranging nearly ten-fold from 3% to 29%. Over the first nine broods (1977-1985), survival of this stock averaged 24%, similar to that of Big Beef Creek smolts. Beginning with the 1986 brood, however, survival of Puget Sound coho declined, particularly the Deschutes River population (Figure 6). Although fishery recoveries are not yet available for the 1995 brood, only 1% of the smolts tagged in 1997 returned to the trap in 1998. Given the low harvest rate in 1998, we expect marine survival for this brood will be less than 2%.

Although marine survival measured at Big Beef Creek in Hood Canal has averaged higher than the other three systems outside of Hood Canal, we believe even this represents an underestimate of actual marine survival. Since at least 1991, a significant but unknown portion of the terminal net fishery catch has not been reported and/or sampled. In 1997, for example, WDFW biologists conducted limited on-the-water catch sampling on the mornings of September 24 and 25, in Area 12, near Seabeck. Of the total 225 adult coho they sampled, 75 ad-marks were present, of which 64 contained tags we had implanted in Big Beef Creek wild coho in Spring 1996. However, because catch for the entire season, as recorded on fish tickets (156 coho), was less than even this small sample, the tags observed could not be expanded. Excluding any Puget Sound mixed net and seine recoveries, contribution to other fisheries and escapement was estimated at 14.1%. These data, along with observations of the terminal net fishery, indicate total survival would be considerably higher, perhaps near 20%, if this fishery had reported catch and had sampling occurred.

Marine survival measured at Sunset Falls (SF Skykomish) ranged three-fold (8% to 24%), and averaged 15% over the nine broods that we tagged wild smolts, somewhat lower than the rates estimated for Big Beef Creek and Deschutes River coho. We attribute this lower survival to the smaller size of smolts produced from this colder, higher-elevation system. Although we no longer trap and CWT wild coho smolts in this system, we approximate marine survival at Sunset Falls through applying projected harvest rates to adult returns. Relating these estimates of run size to the average smolt production we measured with full seeding (276,000 smolts), approximates marine survival.

Survival of Baker River coho (beginning with the 1989 brood), has varied from 6-14%, and appears to track the other stocks we have measured (Figure 6). Over these first six broods, Baker River survival alternates, with odd-numbered broods experiencing higher survival than even-numbered broods.

In addition to within-brood survival, ocean exploitation rates are also correlated among these stocks (Figure 7). This suggests that while differences in survival may exist among Puget Sound wild coho stocks, survival for all stocks tends to rise and fall in response to ocean conditions. The importance of this observation is that rates measured for selected stocks can be extrapolated to estimate survival of smolts produced in nearby systems.

Presently, no correlation with ocean environmental conditions has explained the observed inter-annual variation in marine survival. Clearly, the ocean has been less productive beginning around Spring 1990 (brood year 1988). Prior to this period, we had not measured any consecutive years in which marine survival at our Puget Sound study streams averaged less than 17%; whereas in only one of the succeeding seven brood years did survival average higher than 17% for all four stocks (Figure 6, Table 7).

Correlating jack returns with same-brood survival-to-adults at the only stations where jacks are reliably enumerated (Big Beef Creek and Deschutes River) has not indicated any relationship. In 1998, however, only one jack returned to the Deschutes fishway, and less than 100 jacks returned to Big Beef Creek. Both of these counts are extremely low, relative to all previous data and therefore, may indicate poor brood survival.

Lacking any other indicator of marine survival for Puget Sound stocks, forecasts must rely on the selection of survival rates which are deemed to reflect brood-specific marine environmental conditions. For predicting 1996 brood marine survival, we selected rates that incorporated the averages, by station, for brood years 1988 through 1994 (Table 7). This decision reflects our belief that the recent survival rates are more likely to predict this brood's marine survival than the long-term average rates.

- For the north Sound systems (Nooksack through the Stillaguamish River), we selected the average marine survival rate (6.9%) for the three even-numbered brood years measured thus far at the Baker River.
- For the Snohomish River, we used the average of the four even-numbered brood years (1988-1994) estimated at Sunset Falls, on the SF Skykomish River (9.8%)
- Due to the extreme low survival of Deschutes coho, we used the average marine survival of the last three broods (1993-1995) to predict South Sound stocks (Lake Washington and south) at 3.8%.
- For Hood Canal, we used the average marine survival (9.9%) measured at Big Beef Creek for the three even-numbered brood years, 1988, 1990, and 1992. We elected to use this rate, lower than the recent all-brood average (1988-1993) of 12.6% to reflect the low marine survival that may be indicated by the very low jack return rate in 1998.

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 considerably lower than that of inner Puget Sound coho. Given the consistently lower survival of coastal stocks relative to Puget Sound stocks, it is logical that coho emigrating from Straits tributaries experience intermediate survival. We selected a value of 5.0%, half of the rate we used for Hood Canal.

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 11.5%, and averaged 4.3% over 16 years (Figure 8). Although highly variable, marine survival is also somewhat predictable. Tagged jack returns correlated with same brood adult survival explain some of the inter-annual variation in marine survival. Over all broods measured, however, the relationship is poor (Figure 9). When the data set is split into early- and later-years, however, the correlation improves, especially if the two El Niño broods are excluded (Figure 10). In these 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. Because we are unable to predict the ocean conditions which produce this response, we should discount marine survival on broods with high jack return rates to avoid overestimating run size.

Based on the relationship developed for the recent years (Figure 10), the wild jack return rate to Bingham Creek in 1998 of only 0.04% predicts an adult marine survival to the ocean (age 3) of 1.4%. 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 and 1996) indicate that substantial progress on reducing this problem may have been achieved. Although we expect that near-shore marine environmental conditions and/or predator populations varied somewhat along the coast, both of which would influence survival rates, because of the low jack return rate in 1998, we expect marine survival will be low coastwide.

While marine survival for the 1996 brood will probably be low, we have underestimated marine survival in two of the last three broods (Table).

Return Year	ADULT MARINE SURVIVAL		Error
	Predicted	Actual	
1996	5.4%	11.6%	-115%
1997	3.0%	1.4%	53%
1998	1.0%	3.1%	-210%

The predicted values in this table were the rates we forecasted, based on the correlations developed pre-season. For this reason, they vary relative to the present regression line (later brood years 1987 through 1995). The direction of this error may indicate that the relationship between jacks and adults is trending toward that represented by the steeper line, which fit the early broods' data (1981 through 1986) better (Figure 10).

Another possibility is that, in recent years, a higher proportion of the jacks were caught in the river sport fishery. This likely happened in Fall 1998, because stream flows remained at summer low flows until November 14. As a result, the smaller, earlier-migrating jacks would not only have been more susceptible to capture in the low, clear water but, in the absence of adults, fishermen may have been more likely to retain them. Moreover, because the wild tagged jacks were not outwardly identifiable with an adipose fin-clip, none of the tags would have been voluntarily submitted.

Given these factors, and the empirical results, we elected to increase the survival estimate to 2%. This rate is midway between the two values predicted by the regression lines, but still less than half of average survival (4.3%). Caution in this upward adjustment is supported by the low jack return to the Elk Creek trap in the Upper Chehalis Basin in Fall 1998. Only 20 jacks returned to this trap, the third lowest count in 15 years (average = 45, range 2 to 108).

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	High	Ratio Hi/Lo	Average Production	Avg. Prod./ (sq.mi.)	Identified Sources of Variation (see key)
Big Beef Creek	21	14	11,510	45,634	4.0	24,614	1,758	1, 2, 4, 5
Bingham Creek	17	35	15,280	71,708	4.7	29,259	836	2, 3
Deschutes River	19	130	7,060	133,198	18.9	66,022	508	1, 2, 4, 5
SF Skykomish River	9	362	181,877	353,981	1.9	249,442	689	7
Dickey River	3	87	61,717	77,554	1.3	71,189	818	6
Bogachiel River	3	129	48,962	61,580	1.3	53,751	417	6
Clearwater River	18	140	35,000	95,000	2.7	61,712	441	1, 4, 5
Stillaguamish River	3	540	203,072	379,022	1.9	275,940	511	6
Skagit River	9	1,918	617,600	1,759,600	2.8	1,002,056	522	1, 2, 3, 8
Chehalis River	16	2,114	502,918	3,592,275	7.1	1,940,814	918	1, 2, 3, 4
Total		5,469						
Mean							742	
Wt'd Mean							690	

Notes: Skagit River total drainage area = 3,093 mi^2; 1,175 mi^2 are inaccessible above dams.
Deschutes River total drainage area = 160 mi^2; 30 mi^2 are inaccessible above Deschutes Falls.
Watersheds for Dickey and Bogachiel Rivers are estimated areas above trap locations.
Weighted mean by watershed area.

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, 1998.

	Number	Formula
Total mainstem trap catches	24,546	
Baker River	[a]-603	
Skagit Hatchery/Lake Shannon	[b]-1,651	
Subtotal	-2,254	
Wild coho captured (c)	**22,292**	$N = \frac{(m+1)(c+1)}{(r+1)}$
LVs recaptured (r)	720	
LVs released (m)	55,227	
Total production (N)	**1,707,625**	
Variance (Var)	3.86e+09	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+1)}$
Standard deviation (sd)	62,149	
Coefficient of Var (CV)	3.64%	CV = sd ÷ N
Confidence interval (CI)	±121,812	CI = ± 1.96(sd)
Estimated coho production Skagit River	1,707,625	
Baker River	51,972	
Total Production	1,759,597	
Upper CI (95%)	1,829,437	
Lower CI (95%)	1,585,813	

[a] Estimated Baker recoveries: visually identified ad-marks (298) times the tag expansion factor (2.0229) = 603 total tagged and unmarked Baker River smolts in the catch.

[b] Hatchery ad-marked and unmarked smolt total from counts obtained by visual identification at trapping (1,638 Skagit hatchery + 13 brands from Baker Lake = 1,651).

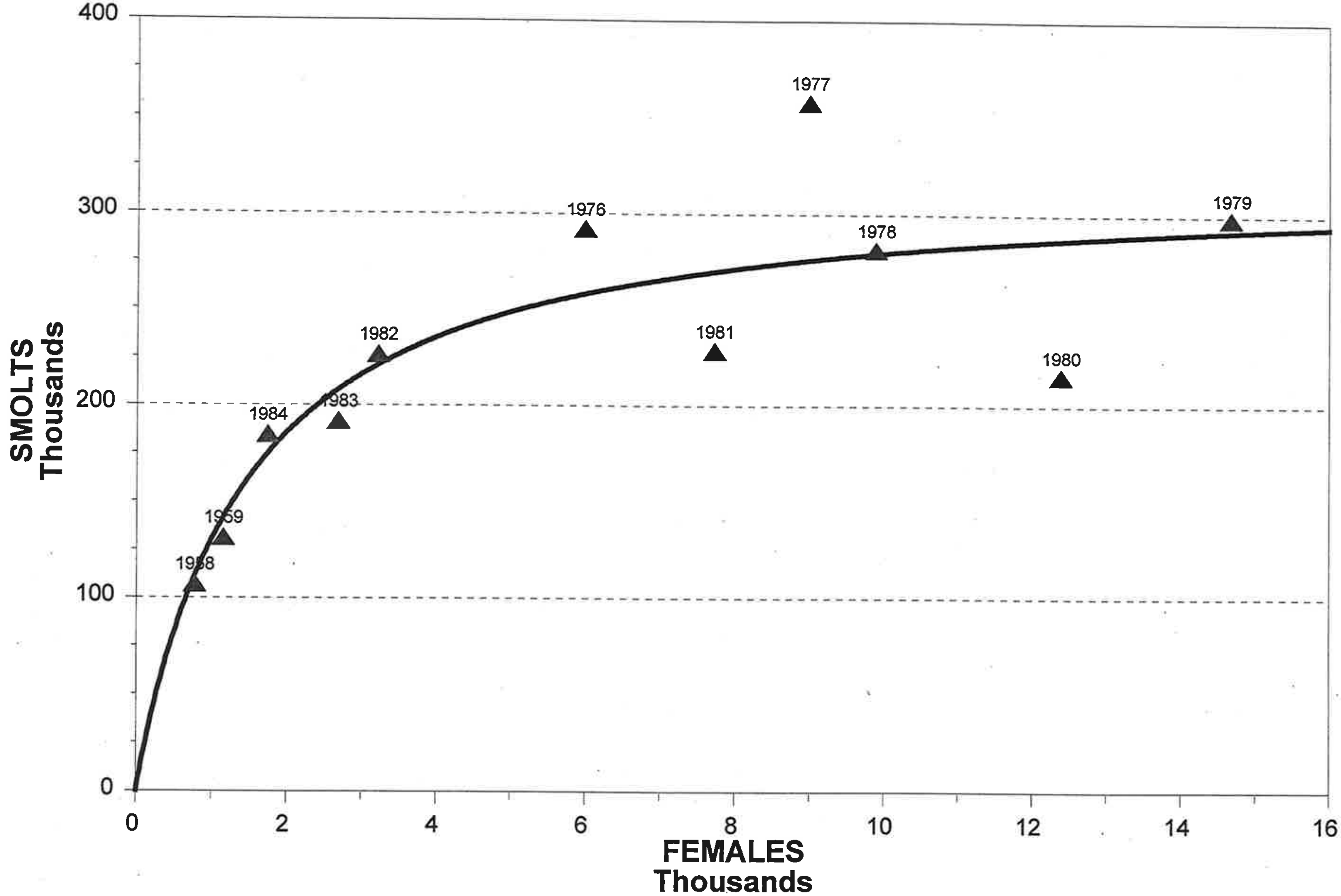

Figure 1. SF Skykomish River wild coho spawners & recruits, by brood year.

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Table 4. Actual and projected wild coho smolt productions in Hood Canal 1998.

Stream	PROJECTED SMOLTS		Actual Production (1998)	RATIO ACTUAL/PROJECTED	
	Zillges	HCJTC		Zillges	HCJTC
Big Beef Creek	38,586	29,638	22,222	58%	75%
Little Anderson	5,100	3,190	n/a	n/a	n/a
Seabeck Creek	10,497	6,564	1,393	13%	21%
Stavis Creek	5,027	3,144	5,979	119%	190%
Subtotal (w/o Little Anderson)	54,110	39,346	29,594	55%	75%
Total Hood Canal	1,006,577	[a]561,631	Est. 1998 Production	550,520	422,429
Projected proportion (Subtotal/Total)	5.4%	7.0%			

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

Table 5a. Estimated and projected wild coho smolt production in larger Straits of Juan de Fuca systems (mainstem widths ≥6 yards), 1998.

Large Systems	Watershed Area (mi^2)	Coho Smolt Production	Average Production (mi^2)	Projected Smolt Production
Dungeness River	198.0	50,000	253	50,000
Morse Creek	46.6		253	11,790
Lyre River	66.0		253	16,698
Pysht River	44.4		253	11,233
Clallam River	31.6		253	7,995
Hoko River	51.2		253	12,954
Sekiu River	33.0		253	8,349
Total	470.8			119,018

Table 5b. Measured and projected wild coho smolt production in small Straits of Juan de Fuca systems (mainstem widths <6 yards), 1998.

Small Streams	Wetted Habitat (yds^2)	Coho Smolt Production	Prod. Rate (Smolts/100 yd^2)	Projected Smolt/yd^2
Mattriotti Creek	10,560	3,885	36.8	
Little Hoko Creek	37,664	3,695	9.8	
Seibert Creek	51,040	358	0.7	
Ennis Creek	18,304	972	5.3	
Valley Creek	8,800	3	0.03	
Tumwater Creek	4,576	119	2.6	
Salt Creek	83,072	7,357	8.9	
Deep Creek	52,976	4,022	7.6	
Subtotal	218,768	12,831	5.9	
Total Independent Tribs	716,628		5.9	42,031

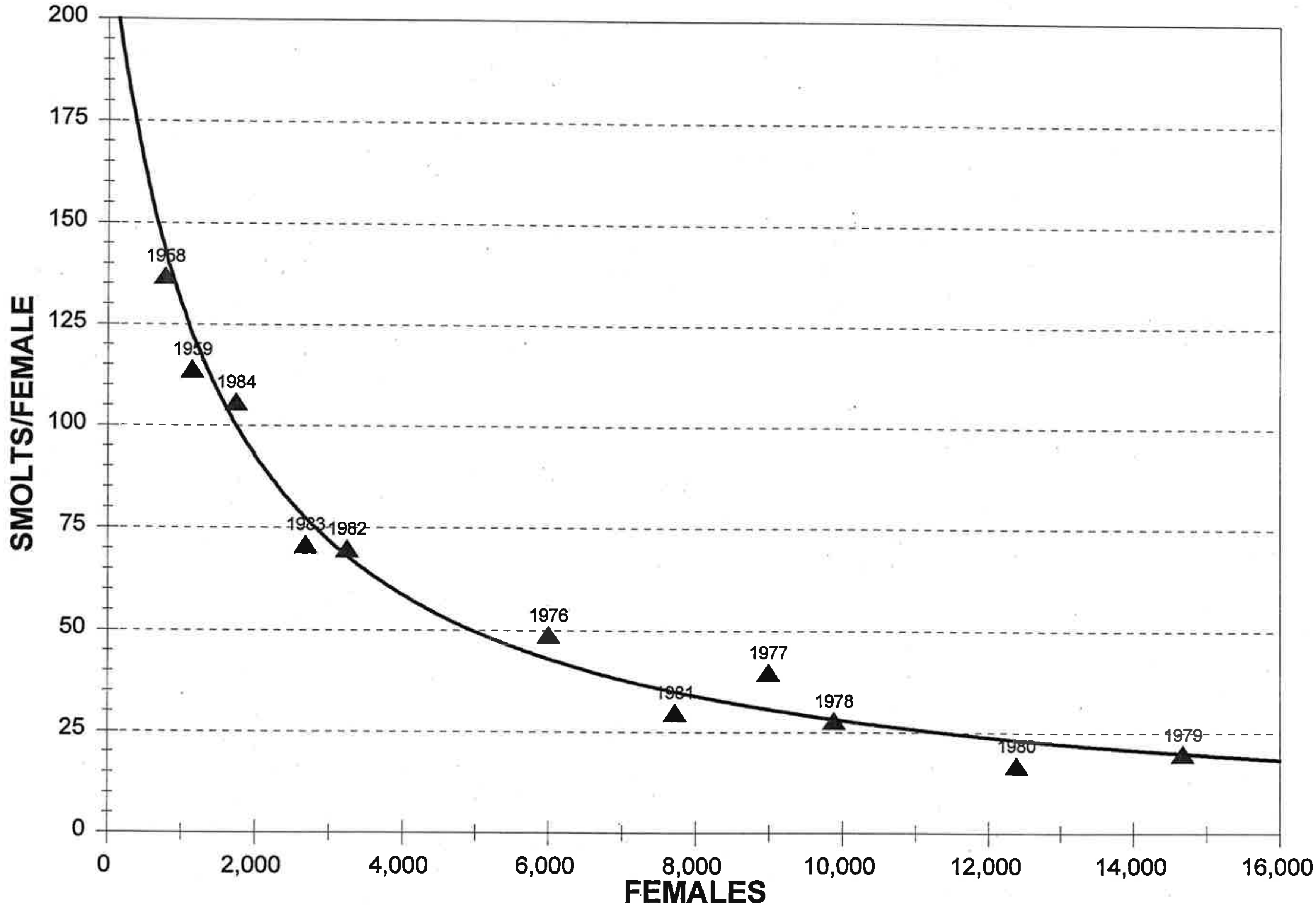

Figure 2. Productivity as a function of spawner abundance, SF Skykomish River wild coho.

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Figure 3. Clearwater River wild coho smolt production & Queets River flow during egg incubation.

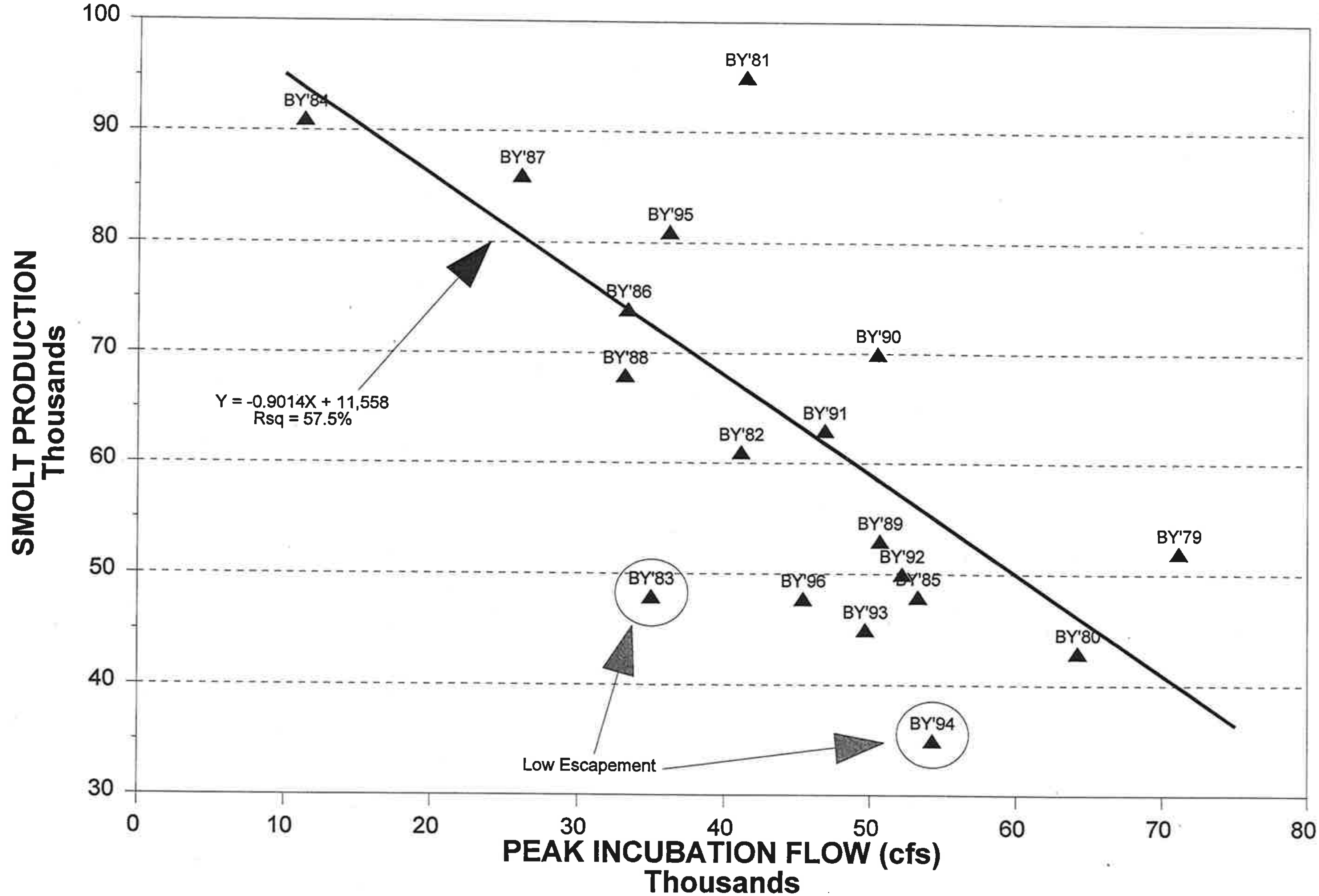

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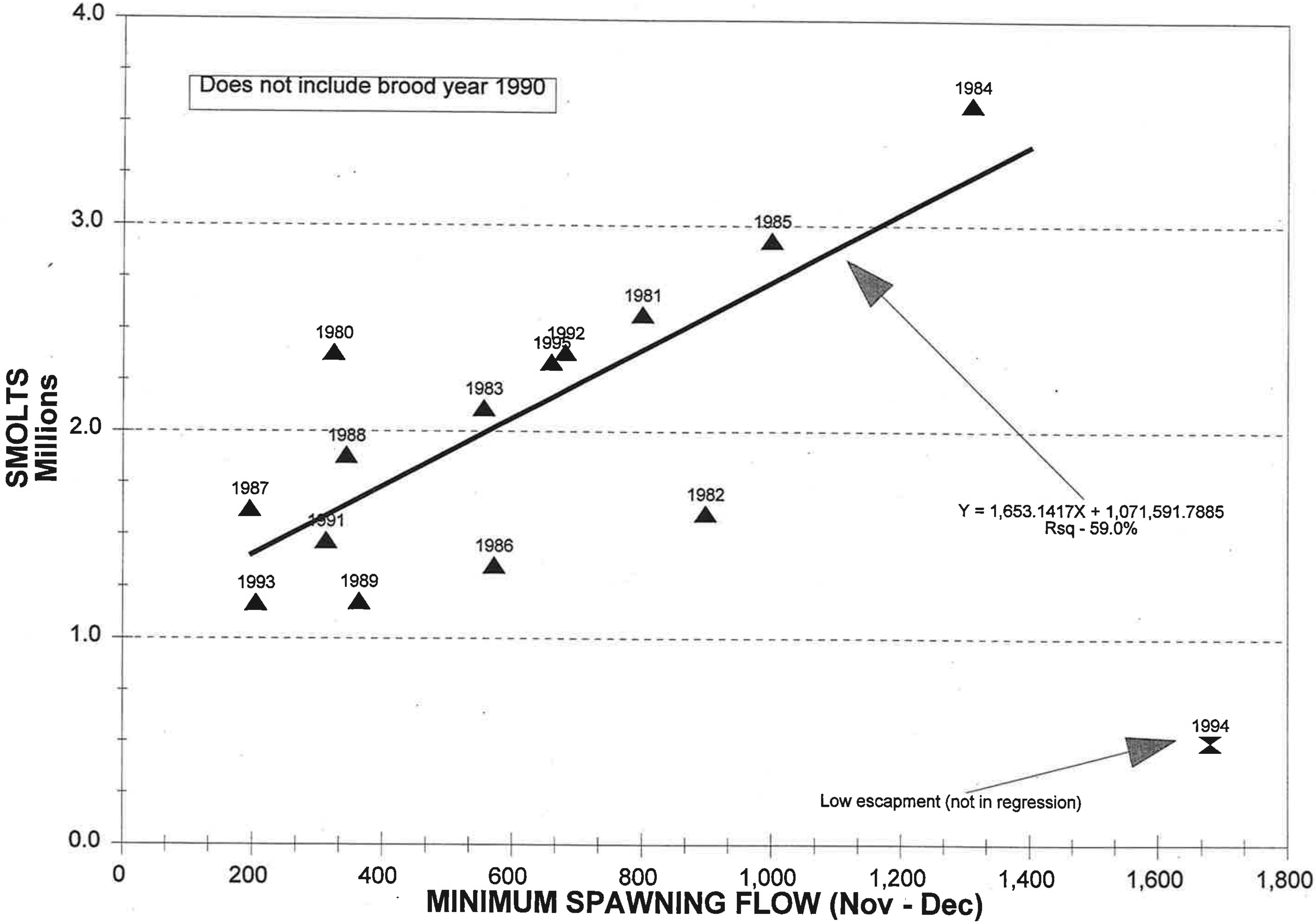
Table 6. Estimation of wild coho smolt production from the Chehalis Basin, via back-calculation. These estimates assume expanded tag recoveries accurately reflect the numbers of hatchery and wild tags caught.

				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 (Var.)^2	95% Conf. Interval Low (J-(1.96*K))	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	2,129	5,690	154	2.71%	78,462	0.84	0.96	63,272	2,337,768	175,004	1,994,759	2,680,777	7.49

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
1,940,814 **avg**
502,918 **min**
3,592,275 **max**
15 **count**

Figure 4. COHO SMOLT PRODUCTION & FLOW (cfs) CHEHALIS RIVER, BROOD YEARS 1980-1995



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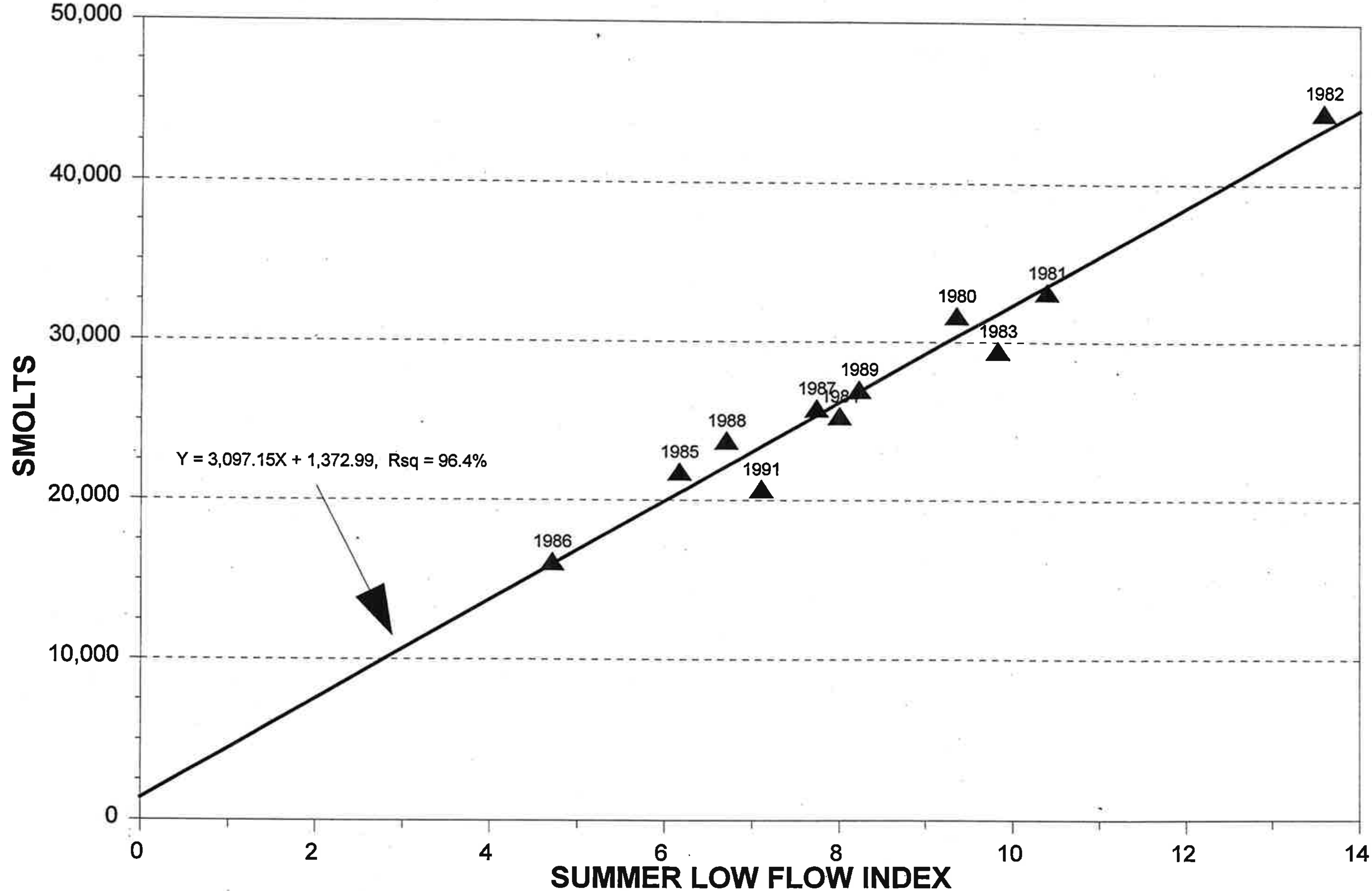

Figure 5. Wild coho smolt production vs. summer low flow, Bingham Creek, brood years 1980-1991 (broods 1990, & 1992-1995 omitted).

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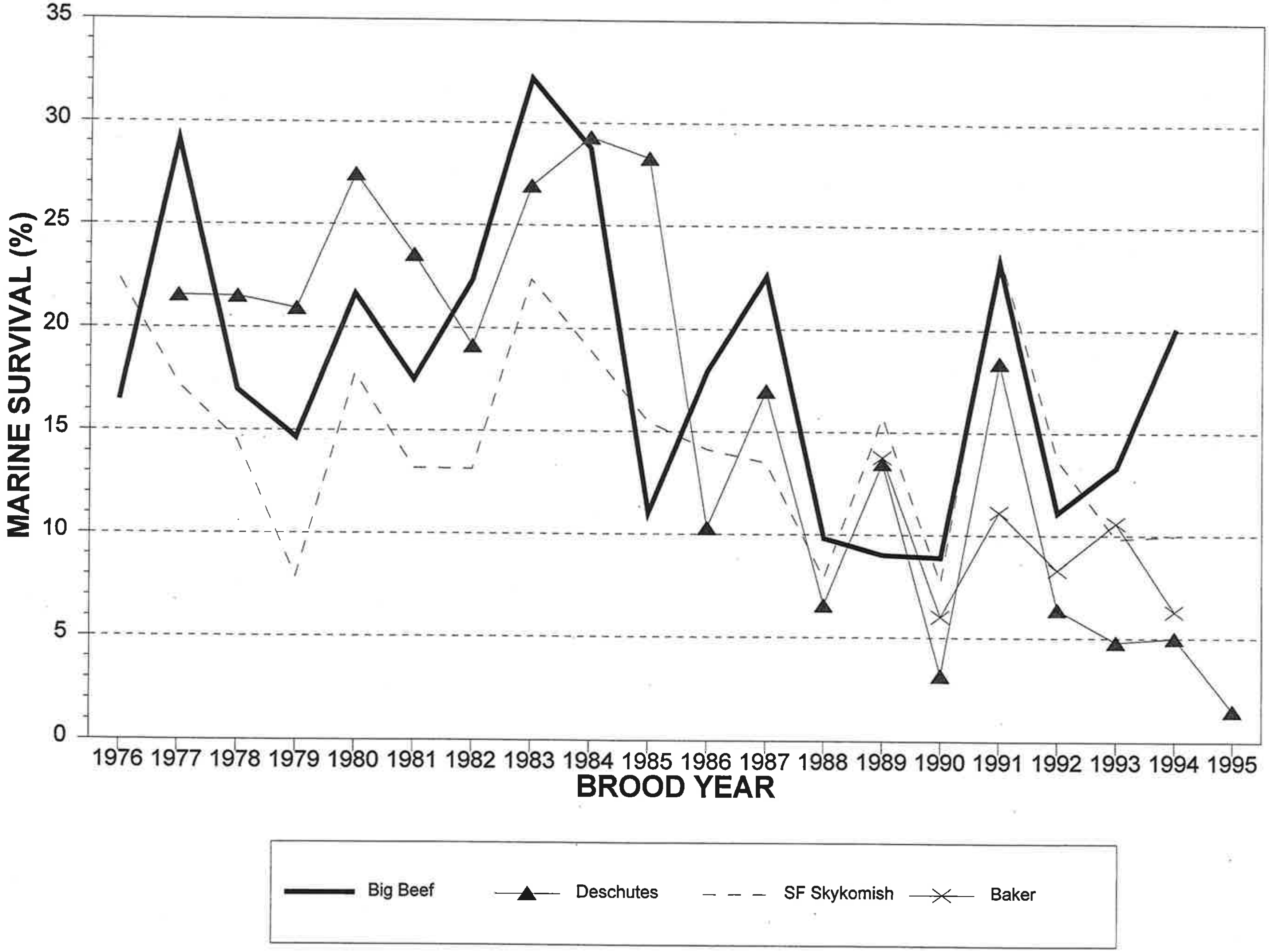
Figure 6. MARINE SURVIVAL: PUGET SOUND WILD COHO (age 3)



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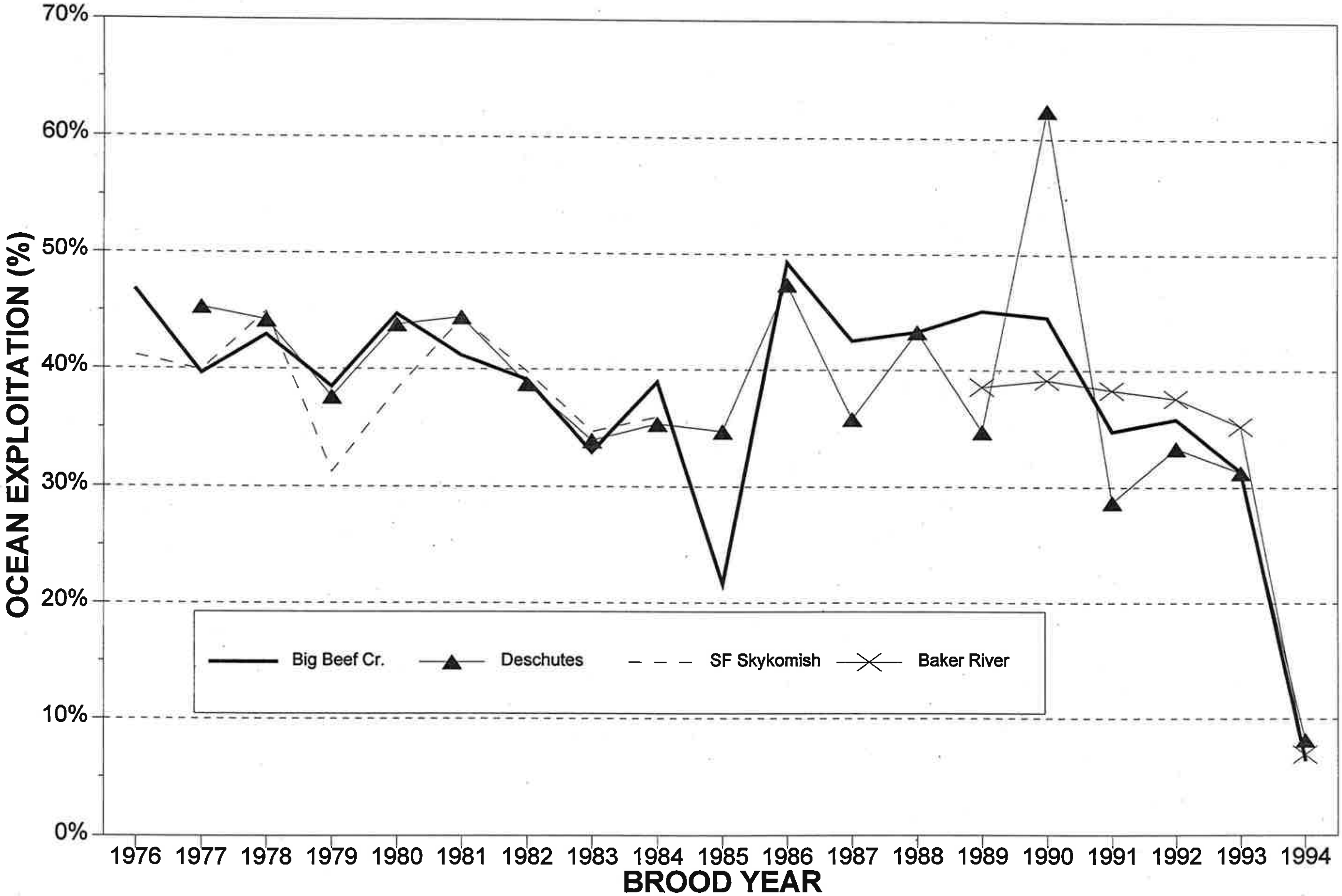

Figure 7. Wild coho ocean exploitation rates from four Puget Sound streams.

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

YEAR Br.	Rtn	Big Beef	Desch. River	SF Sky	Big Beef	Desch. River	SF Sky	Baker River	AVERAGE 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	13.50	15.76	13.80		13.02	4
1990	1993				8.90	3.18	7.67	6.02		6.44	4
1991	1994				23.23	18.39	23.64	11.12		19.10	4
1992	1995				11.11	6.39	13.71	8.30		9.88	4
1993	1996				13.30	4.80	9.83	10.60		9.63	4
1994	1997				20.00	5.01	9.98	6.30		10.32	4
1995	1998					1.50					
Average		20.34	22.34	15.88	13.63	8.26	12.64	9.36	18.13	10.93	
Min		11.06	10.31	7.87	8.90	3.18	7.67	6.02	14.13	6.44	
Max		32.16	29.28	22.34	23.23	18.39	23.64	13.80	27.13	19.10	
Count		13	11	12	7	7	7	6	13	7	

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 could not be directly estimated due to large unreported/unsampled catch 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, perhaps around 20% if this fishery had reported catch and had sampling occurred.

Figure 8. MARINE SURVIVAL
BINGHAM CREEK TAGGED WILD COHO

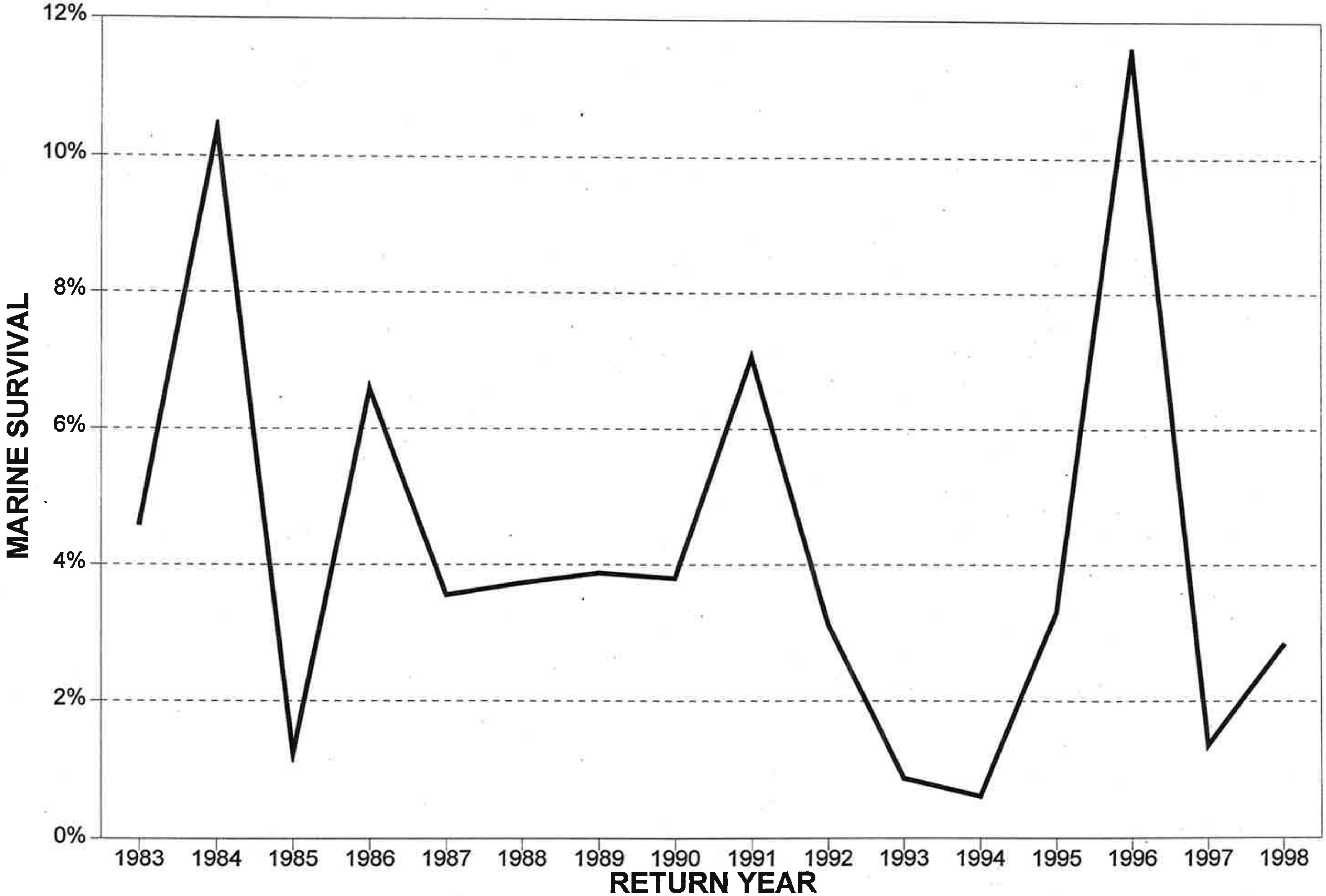

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Figure 9. JACK RETURN vs ADULT MARINE SURVIVAL BINGHAM CREEK, BYs 1980-1995

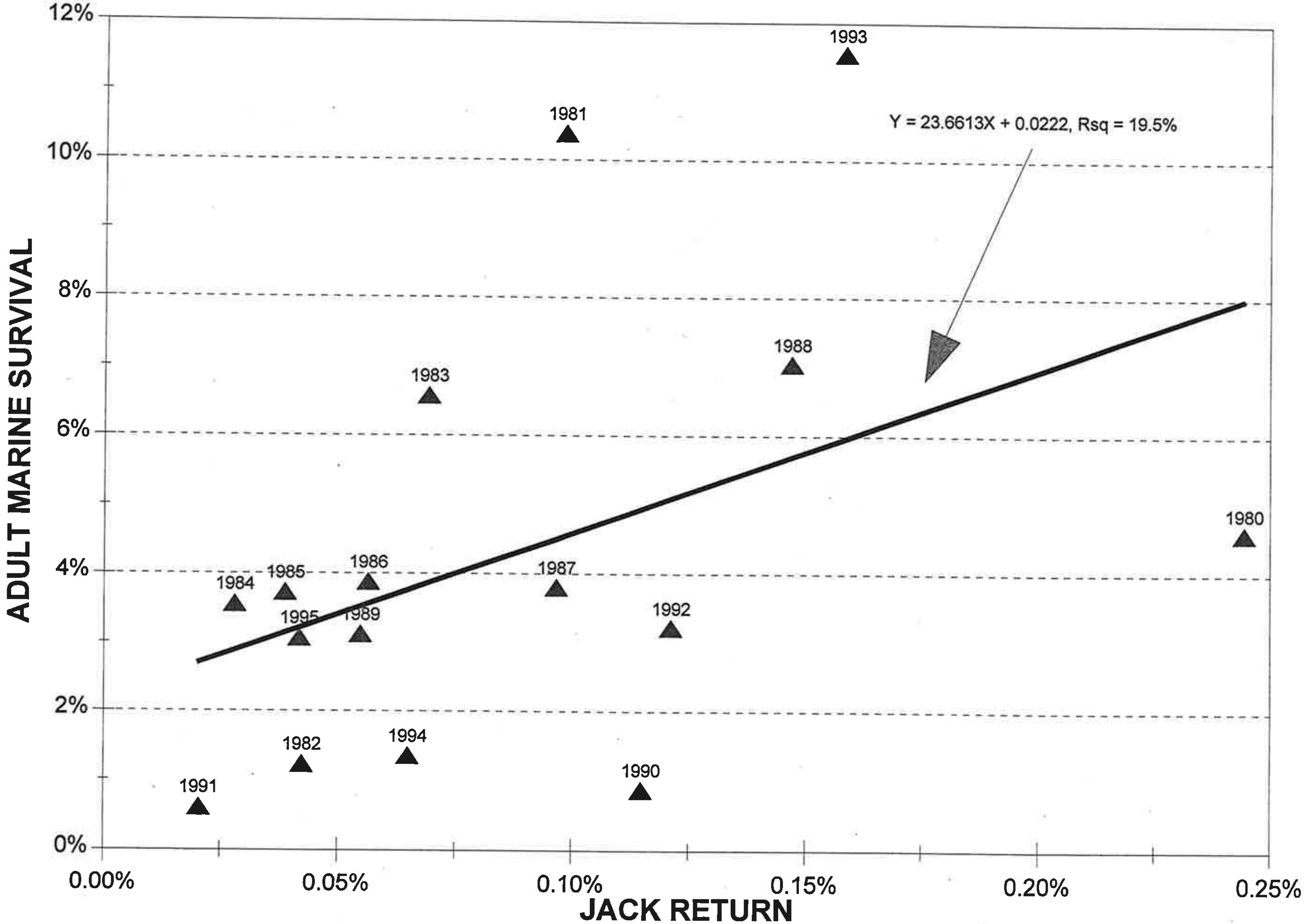

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Figure 10. JACK RETURN vs ADULT MARINE SURVIVAL BINGHAM CREEK, BYs 1980-1995