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

January 15, 1998

TO: Bill Tweit

FROM: Dave Seiler

SUBJECT: WILD COHO FORECASTS

Attached for your information and consideration are my 1998 wild coho run forecasts for all Washington state production areas outside the Columbia River. These estimates are based primarily on the results of the *Freshwater Production & Survival Evaluation Unit*'s long-term research and monitoring program. As these predictions are preliminary, I am limiting the distribution of this document to the agency managers listed below. Let's get together soon to discuss these numbers. I welcome any additional data, comments, and questions.

DS:lek

Attachments

cc: Bruce Crawford
Rich Lincoln
Bob Gibbons
Pat Pattillo
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Tim Flint
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STATEWIDE WILD COHO FORECASTS FOR 1998

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 the forecast 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 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 one starts with a known -- the number of smolts released.

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 I term "primary" 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 and 1b 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. Preliminary wild coho run forecasts for Puget Sound in 1998, based on estimates of smolt production and marine survival.

Production Unit	FRESHWATER PRODUCTION X Projected Smolt Prod. (Zillges)	Est. Actual Smolt Prod. Spr. 1997	Ratio Actual/ Projected	MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Primary Units							
Skagit River	1,371,058	1,174,000	**86%**	10.0%	13.4%	117,400	157,081
Stillaguamish River	864,094	486,000	56%	10.0%	13.1%	48,600	63,617
Snohomish River	2,027,497	1,333,000	66%	12.6%	16.5%	167,958	219,857
Hood Canal	1,006,577	866,000	**86%**				
HCJTC estimate	561,631	672,000	**120%**	12.6%	16.7%	84,672	112,190
Straits of Juan de Fuca	443,098	222,000	50%	6.3%	8.5%	13,986	18,797
Secondary Units							
Nooksack River	451,275	135,000	30%	10.0%	13.3%	13,500	17,995
Strait of Georgia	51,821	26,000	50%	10.0%	13.3%	2,600	3,466
Samish River	57,923	100,000	173%	10.0%	13.3%	10,000	13,330
Lake Washington	768,740	77,000	10%	8.8%	11.3%	6,776	8,667
Green River	416,129	166,000	40%	8.8%	11.3%	14,608	18,684
Puyallup River	556,243	222,000	40%	8.8%	11.3%	19,536	24,987
Nisqually River	200,314	40,000	20%	8.8%	11.3%	3,520	4,502
Deschutes River	219,574	6,000	**3%**	8.8%	11.3%	528	675
South Sound	544,498	109,000	20%	8.8%	11.3%	9,592	12,268
East Kitsap	154,973	77,000	50%	8.8%	11.3%	6,776	8,667
Puget Sound Total	9,695,445	5,711,000	59%			520,052	684,783

Note: Ratios in bold indicate actual estimates derived from production evaluation studies.

Table 1b. Preliminary wild coho run forecasts for Washington Coastal Systems in 1998, based on estimates of smolt production and marine survival.

Production Unit	Drainage Area mi^2	SMOLTS Freshwater Production Spr. 1997	x MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Coast						
Quillayute River	629	404,000	1%	1.3%	4,040	5,252
Queets River	450	320,000	1%	1.3%	3,200	4,160
Hoh River	299	173,000	1%	1.3%	1,730	2,249
Quinault River	434	90,000	1%	1.3%	900	1,170
Independent Tributaries	424	297,000	1%	1.3%	2,970	3,861
Grays Harbor						
Chehalis River	2,300	2,148,000	1%	1.3%	21,480	27,924
Humptulips River	250	233,000	1%	1.3%	2,330	3,029
Willapa Bay	850	340,000	1%	1.3%	3,400	4,420
Coastal Systems Total	5,636	4,005,000			40,050	52,065

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 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 1997 was the eighth 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. We estimated 1,174,000 coho smolts emigrated from the Skagit River in 1997 (Table 3). In the previous seven years, production has ranged from 618,000 to 1,129,000 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 discrepancy 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, 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.

Stillaguamish River. We estimated smolt production from the Stillaguamish River upstream of R.M. 16 in three years (1981-1983). Production 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 is estimated at 360,000 smolts. To approximate the expected production in 1997, we applied a factor of 135% to the average

production to estimate 486,000 smolts. This factor is the ratio of 1997 Skagit River production to its previous seven-year average production (869,218 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. Expansion of this estimate to the entire system calculates an average total production of 1,333,000 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). While smolt production may have been above average in 1997, we elected to use the computed average value, because it probably already includes an increment in excess of actual average production.

Hood Canal. Based on our results from trapping four Hood Canal streams, coho smolt production in 1997 was approximately twice as high as we have measured in recent years. We estimate 40,800 smolts emigrated from Big Beef Creek, the second highest production on record in 20 years (since 1978). Production from the three adjacent streams varied from quite high in Stavis Creek to very poor in Little Anderson Creek (Table).

Stream	PROJECTED SMOLTS		Actual Production (1997)	RATIO ACTUAL/PROJECTED	
	Zillges	HCJTC		Zillges	HCJTC
Big Beef Creek	38,586	29,638	40,828	106%	138%
Little Anderson Creek	5,100	3,190	100	2%	3%
Seabeck Creek	10,497	6,564	1,639	16%	25%
Stavis Creek	5,027	3,144	8,357	166%	266%
Subtotal	59,210	42,536	50,924	86%	120%
Total Hood Canal	1,006,577	[a]561,631			
Projected proportion (Subtotal/Total)	5.9%	7.6%			

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

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 four study streams

represent coho smolt production in tributaries to Hood Canal, system production in 1997 is estimated at 866,000 and 672,000 smolts, based on T.R.28 and HCJTC, respectively. These estimates are probably conservative because these four streams have suffered more development-caused habitat degradation than the major coho-producing systems (Dewatto, Union, and Tahuya Rivers) located further south. For this forecast, however, we used the HCJTC-based estimate of 672,000 smolts.

Straits of Juan de Fuca. Lacking a representative index stream, we selected a value of 50% to reduce the projected production of 443,098 smolts (T.R.28). We chose this rate, lower than the 86% measured in Hood Canal, to reflect our uncertainty about coho production in this region. In 1995, biologists estimated 5,379 coho spawned in Straits tributaries. Assuming this estimate is correct and that half were females, yields an average production rate of 82 smolts/female. This value is well within the range of production rates we have measured in other systems when escapement has dropped below optimal levels (Figure 2).

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 1997. We used a value of 30% of the production projected by T.R.28 to estimate 135,000 smolts in 1997.

Strait of Georgia. We selected a value of 50% of the projected production (T.R.28), higher than for the Nooksack, because escapements likely were higher in these streams without terminal fisheries.

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 increasing net production, it is likely that resultant smolt production is lower than would be achieved with adequate numbers of natural spawners. Therefore, we applied a value of 40% to 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 20%. 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 over-fishing.

For the Lake Washington system, we used the very low rate of 10% of the projected production (T.R.28) to reflect our belief that in this most urbanized watershed, the estimated 769,000 smolt potential is unrealistically high. Not only has development continued to reduce production potential, but the projection by T.R.28 includes 192,500 smolts estimated as the production component occurring in the lake. Recent investigations of the 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.).

Deschutes River. Based on trapping in 1997, we estimated only 6,000 smolts emigrated from this system. This is the lowest smolt production we have measured in 20 years of continuous monitoring. 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, poor marine survival, and overharvest. During the 1990s, marine survival for Deschutes coho was even lower than other Puget Sound stocks. This may indicate a reduction in the productive potential of the South Sound marine environment.

South Sound. This production area includes all of the independent tributaries to the Sound, south of Area 10 (Seattle), excluding Lake Washington, and the Green, Puyallup, Nisqually, and Deschutes Rivers. We applied 20% to the production projected by T.R.28. This rate — which is far lower than that measured in Hood Canal (86%), 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.

East Kitsap. Most of the streams in this region tend to be small, but are 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 86% estimated in Hood Canal to 50% 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.

Based on the high smolt production we measured in other systems in 1997 and, in particular, the work conducted by the Quinault Tribe's fisheries department (QFiD) in the Clearwater River, we expect coho smolt production from the Quillayute River was also above average. We estimated this increase in smolt production at 132% by the ratio of Clearwater production in 1997 (81,000 smolts) to the previous sixteen year average (61,375 smolts). This rate estimates system smolt production from the Quillayute at 404,000 smolts in 1997.

Attaining this production level, however, is dependent on achieving adequate seeding. Escapement in 1995 was estimated at 10,000 fall-run coho. Assuming this estimate is accurate and that half were females, we believe this escapement was sufficient to achieve this production level. Relating the 404,000 smolts to 5,000 females yields an average production of 81 smolts/female, a value within the range of rates that we have measured statewide (Figure 2).

Relating estimated smolt production to the total drainage area for the Quillayute River (629 mi^2) yields an average production rate of 642 smolts/mi^2.

Queets River. Smolt production has been measured from the Clearwater River each Spring since 1981. Over the first 15 broods, coho production has 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 have explained none of the variation in smolt production. 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 half the variation in smolt production (Figure 3).

In 1996, however, 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, which limited smolt production in 1996.

Escapement was considerably higher in 1995, estimated at 5,933 adults for the entire Queets River system, including the Clearwater River. Flows during egg incubation peaked at 36,200 cfs on January 15, 1996. In Spring 1997, QFiD biologists estimated 81,000 smolts were produced from the Clearwater River. They expanded this production to estimate 320,000 smolts for the entire Queets system. This estimates an average production/female rate of 108 smolts. Relative to the watershed drainage areas, these productions estimate average production rates of 711 and 579 smolts/mi^2 for the total system (450 mi^2) and the Clearwater River (140 mi^2), respectively.

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 1997. The rate of 579 smolts/mi^2 applied to the drainage area of 299 mi^2 in the Hoh system estimates 173,000 coho smolts were produced. Relating this estimate to half of the estimated escapement of 4,700 spawners in 1995 yields and average production rate of 74 smolts/female.

Quinault River. Low escapement due to hatchery harvest rates and degraded habitat likely combined to limit natural smolt production from this system. To reflect these effects, the relatively low rate of 200 smolts/mi^2 was selected. This rate times the total area in this basin (434 mi^2) estimates total production at around 90,000 smolts.

Independent Tributaries. Smolt production has not been directly measured from any of the independent coastal tributaries. Application of an average production rate of 700 smolts/mi^2 to the total watershed area (424 mi^2) (Table 1b) estimates 297,000 coho smolts were produced from these systems. The value of 700 smolts/mi^2 was selected, higher than the value measured in the Clearwater River in 1997 for several reasons: first, drainage area values were not available for some of the minor tributaries, thus the total area estimate is low; second many of these systems are lower gradient than the Clearwater River and therefore, production/area should be higher; finally, escapement rates were probably higher in these systems because most are too small to warrant terminal fisheries.

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 4). Analysis to understand the components of variation has determined that for 14 of these 15 broods, only one variable, flow during spawning, explains a significant portion (59%) of the interannual variation in estimated smolt production (Figure 4). This 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, which reduced egg survival and triggered mass wasting events in many of the higher-gradient tributaries.
- 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 flow conditions following spawning, the proportion of the watershed available for rearing juveniles is strongly influenced by upstream extent of the spawning population.

Correlation of estimated escapement with the estimates of smolt production explained only 11% of the interannual variation. Other flow periods, winter (incubation), spring (fry distribution), and summer (fry rearing) also yielded insignificant correlations. We excluded the 1990 brood from all of these analyses because tagging on this brood was limited and therefore, also 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 it is likely smolt production was high on this brood.

We also excluded the 1994 brood from this correlation analysis because escapement was extremely low. Upon adult return in 1997, we estimated only around 500,000 smolts were produced from this brood, which experienced the highest minimum flows during spawning. We estimated escapement in 1994 at less than 10,000 spawners.

For the thirteen 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 1995 was relatively high; we estimate around 60,000 spawners. This estimate is the product of our smolt estimate in 1994 (2.4 million smolts) and the survival-to-return rate (2.5%) measured at Bingham Creek in 1995.

In Fall 1995, the minimum spawning flow during November and December was 660 cfs, recorded at Grand Mound. This flow predicts a production of 2,148,000 smolts in Spring 1997. We believe this prediction underestimates actual production, and therefore this run forecast is somewhat conservative. In 1997, we estimated 72,000 smolts were produced from Bingham Creek, a level which exceeded our previous high by 27,000 smolts. We attribute this record high production to beneficial flows: high flows throughout the winter, which enabled adults to seed areas that were formerly inaccessible; and relatively high flows throughout freshwater life, which provided extensive rearing habitat. Smolt production for all previous broods in Bingham Creek was limited by the quantity of flow during the summer rearing period (Figure 5).

Relating the 2,148,000 smolts estimated for the Chehalis Basin to its 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 934 smolts/mi^2. Application of this rate to the 250 mi^2 Humptulips River system estimates 233,000 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 somewhat lower than that measured in other coastal systems. To approximate production of the 1995 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 1997.

While this production level may be approximately correct for the entire Willapa system in 1997, 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 survival-to-return rates measured at Bingham Creek to these respective estimates indicate natural production levels of 130,000 to 200,000 smolts. 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 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 18% over brood years 1975-1993. Over 17 brood years, marine survival of Deschutes River coho has averaged 18%, ranging nearly ten-fold from 3% to 29%. Over the first nine broods (1977-1985), this stock survived at rates similar to those at Big Beef Creek. Beginning with the 1986 brood, however, Deschutes River coho survived at lower rates than other Puget Sound stocks. Marine survival measured at Sunset Falls (SF Skykomish) has ranged three-fold (8% to 24%), and averaged 15%, 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. Survival of Baker River coho (beginning with the 1989 brood), although it appears less variable, tracks the survival we have measured at the other stations (Figure 6).

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 other systems.

Presently, no correlation with ocean environmental conditions has explained the observed inter-annual variation in marine survival; University of Washington research scientists are developing a model that may provide a means to predict marine survival for Puget Sound stocks. 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 survival at our Puget Sound study streams averaged less than 17%; whereas in only one of the succeeding six brood years did survival average higher than 17% (Table 5). Correlation between jack returns and 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. Lacking an 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 1995 brood marine survival, we selected rates that incorporated the averages, by station, for brood years 1988 through 1993 (Table 5). This decision reflects our belief that the recent survival rates may more accurately predict this brood's marine survival than the long-term average rates.

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 6.3%, half of the rate measured at Big Beef Creek over the last six broods.

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 4.6% over 14 years (Figure 8). Although highly variable, marine survival is also somewhat predictable. Tagged jack returns correlated with same brood adult survival explain much 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 1997 of only 0.04% predicts an adult marine survival to the ocean (age 3) of 1%. 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 1991 and 1996) indicate that substantial progress on reducing this problem has 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 this jack return rate, we expect marine survival will be very low coastwide.

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./ (sq.mi.)	Identified Sources of Variation (see key)
Big Beef Creek	20	14	11,510	45,634	4.0	24,719	1,766	1, 2, 4, 5
Bingham Creek	16	35	15,280	71,708	4.7	28,081	802	2, 3
Deschutes River	18	130	10,101	133,198	13.2	69,243	533	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	17	140	35,000	95,000	2.7	62,529	447	1, 4, 5
Stillaguamish River	3	540	203,072	379,022	1.9	275,940	511	6
Skagit River	8	1,918	617,605	1,174,409	1.9	907,367	473	1, 2, 3, 8
Chehalis River	14	2,114	502,918	3,592,275	7.1	1,912,460	905	1, 2, 3, 4
Total		5,469						
Mean							736	
Wt'd Mean							668	

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, 1997.

	Number	Formula
Total mainstem trap catches	**13,108**	
Baker River	[a]-293	
Skagit Hatchery/Lake Shannon	[b]-696	
Subtotal	-989	
Wild coho captured (c)	**12,119**	
LVs recaptured (r)	494	$N = \frac{(m+1)(c+1)}{(r+1)}$
LVs released (m)	46,406	
Total production (N)	**1,136,268**	
Variance (Var)	2.4751e+09	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+1)}$
Standard deviation (sd)	49,750	
Coefficient of Var (CV)	4.38%	CV = sd ÷ N
Confidence interval (CI)	±97,510	CI = ± 1.96(sd)
Estimated coho production Skagit River	1,136,268	
Baker River	38,109	
Total Production	1,174,377	
Upper CI (95%)	1,271,887	
Lower CI (95%)	1,076,867	

[a] Estimated Baker recoveries: visually identified ad-marks (166) times the tag expansion factor (1.76) = 293 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 (658 Skagit hatchery + 1 Lake Shannon pen fish + 37 brands from Baker Lake = 696).

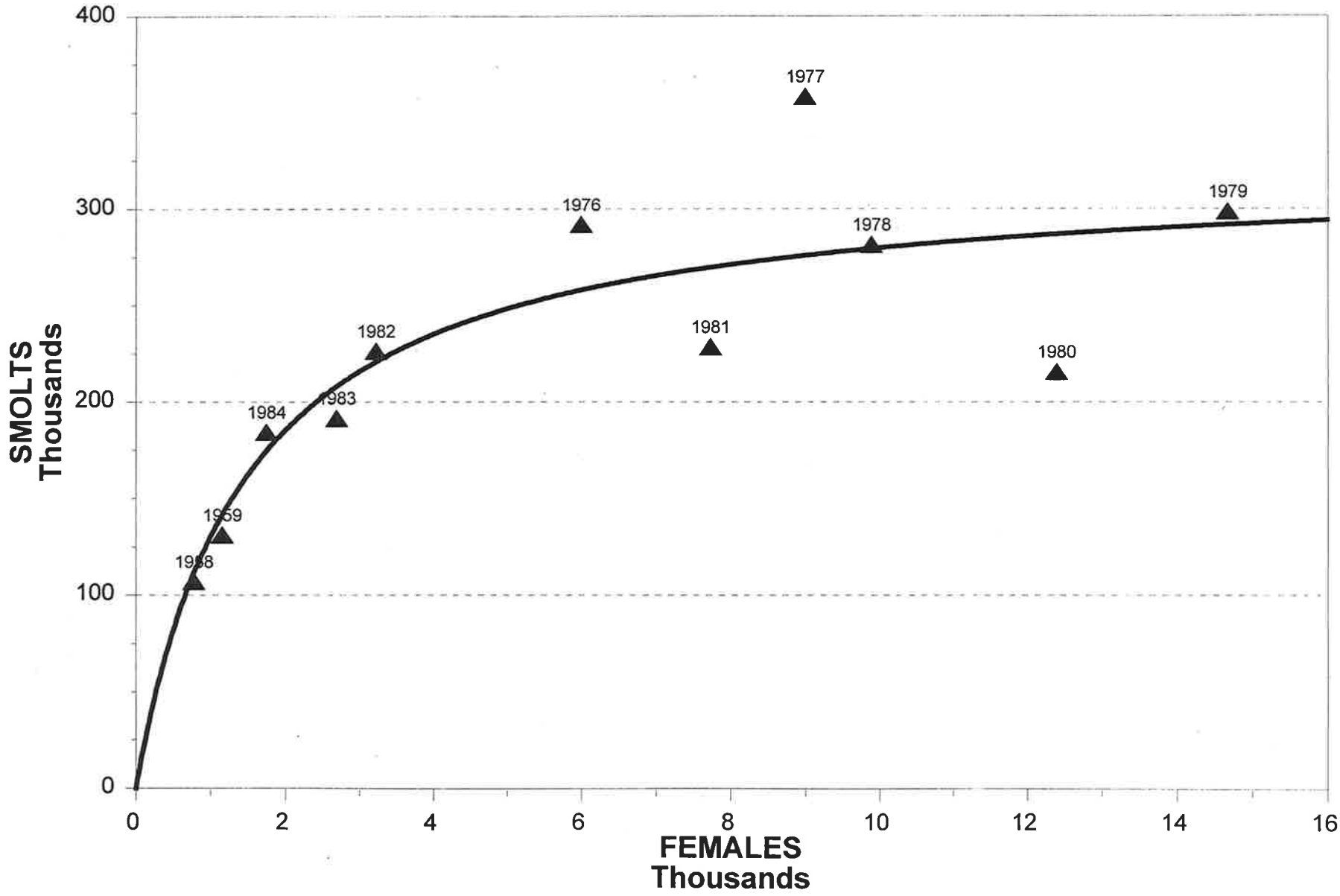

Figure 1. SF Skykomish River wild coho spawners & recruits, by brood year

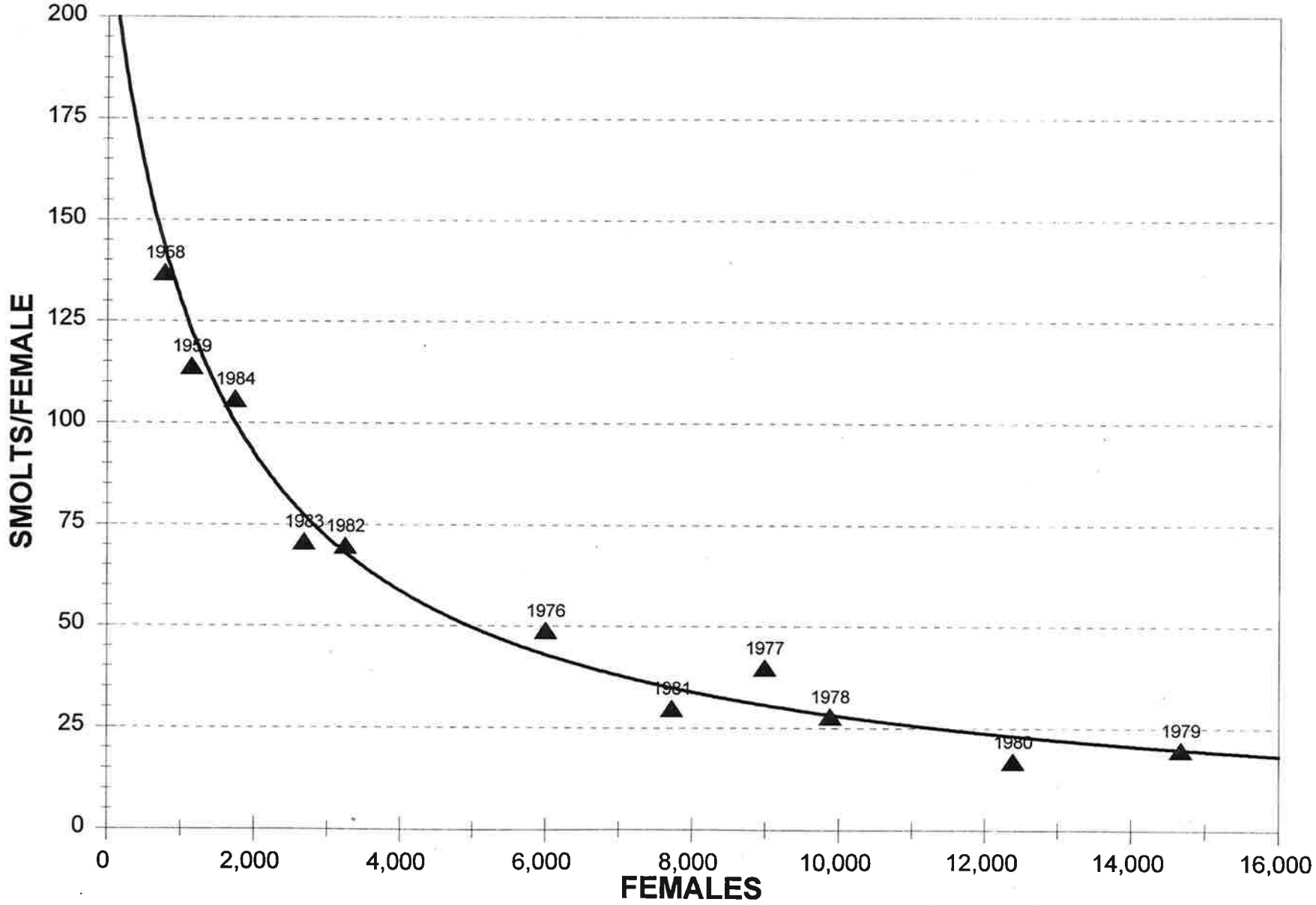

Figure 2. Productivity as a function of spawner abundance, SF Skykomish River wild coho.

Figure 3.

CLEARWATER R. COHO SMOLT PRODUCTION vs. QUEETS R. FLOW, DEC 15 - MAR 31

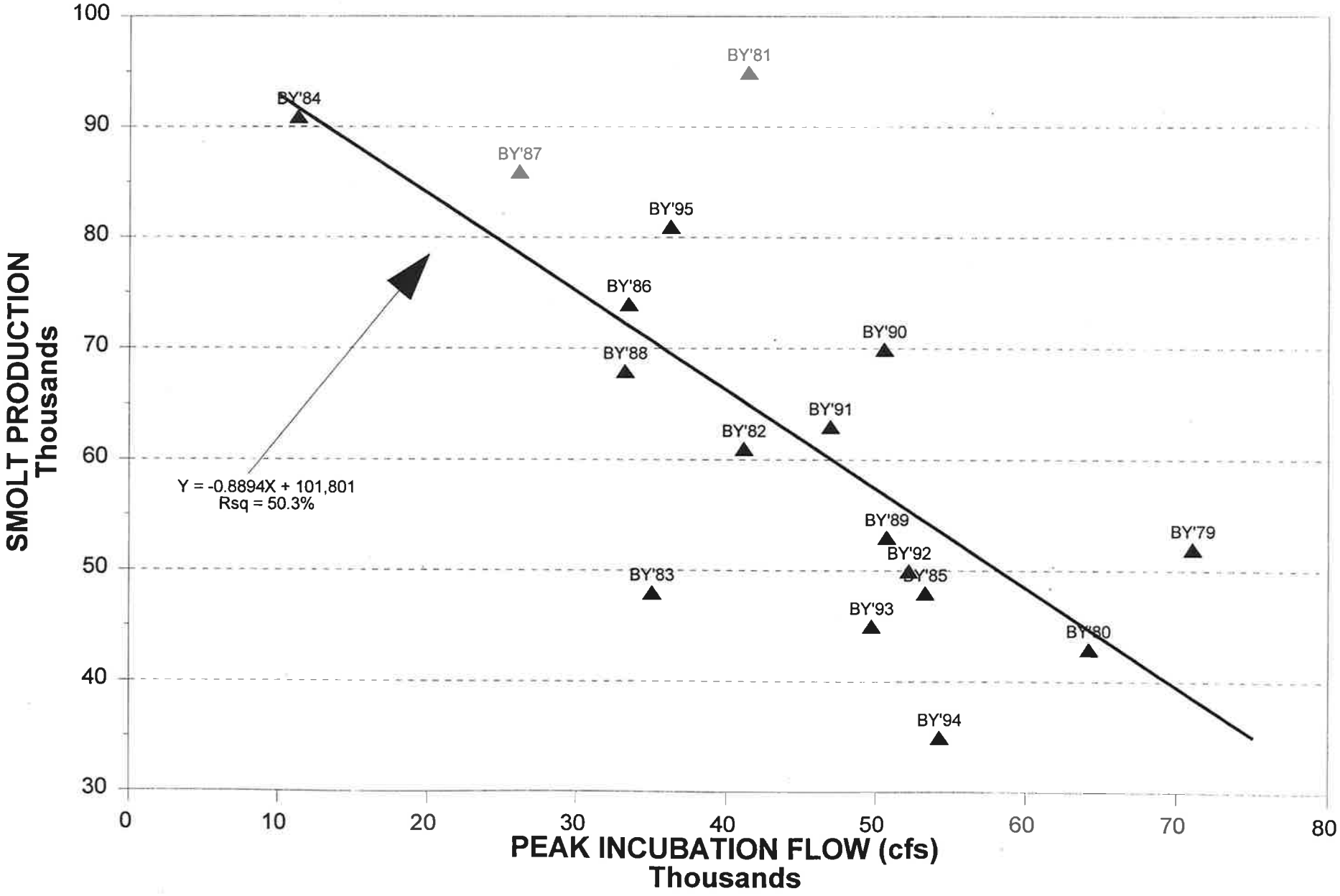

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Table 4. 'Estimation of wild coho smolt production from the Chehalis Basin, via backcalculation. These estimates assume expanded tag recoveries accurately reflect the numbers of hatchery and wild tags caught.

				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))	95% Conf. Interval High (J+(1.96*K))	CV (K/J)
1980	1982	1983		10,115	3,669	6,446	104	1.61%	47,711	0.84	0.96	38,474	2,384,657	207,638	1,977,688	2,791,627	8.71
1981	1983	1984		5,196	1,432	3,764	93	2.47%	78,839	0.84	0.96	63,576	2,573,110	250,223	2,082,672	3,063,547	9.72
1982	1984	1985		6,991	4,025	2,966	164	5.53%	110,020	0.84	0.96	88,720	1,604,536	118,303	1,372,662	1,836,410	7.37
1983	1985	1986		19,600	6,548	13,052	481	3.69%	96,687	0.84	0.96	77,968	2,115,683	86,032	1,947,061	2,284,305	4.07
1984	1986	1987		23,129	4,810	18,319	272	1.48%	74,847	0.84	0.85	53,338	3,592,275	173,901	3,251,429	3,933,121	4.84
1985	1987	1988		3,856	1,490	2,366	39	1.65%	59,860	0.84	0.96	48,271	2,928,447	431,344	2,083,012	3,773,882	14.73
1986	1988	1989		13,824	10,367	3,457	112	3.24%	54,285	0.84	0.96	43,775	1,351,175	118,427	1,119,058	1,583,293	8.76
1987	1989	1990		27,251	17,824	9,427	210	2.23%	44,889	0.84	0.96	36,198	1,624,967	94,459	1,439,829	1,810,106	5.81
1988	1990	1991		45,211	22,073	23,138	690	2.98%	69,701	0.84	0.96	56,207	1,884,804	54,055	1,778,856	1,990,753	2.87
1989	1991	1992	A	12,111	7,745	4,366	213	4.88%	71,457	0.84	0.96	57,623	1,181,135	75,185	1,033,773	1,328,497	6.37
			B	12,111	10,197	1,914	213	11.13%	71,457	0.84	0.96	57,623	517,795	32,589	453,921	581,669	6.29
			C	12,111	8,971	3,140	213	6.78%	71,457	0.84	0.96	57,623	849,465	54,143	743,344	955,585	6.37
1990	1992	1993	B	10,153	4,702	5,451	16	0.29%	21,125	0.84	0.96	17,035	5,803,680	1,060,259	3,725,572	7,881,787	18.27
1991	1993	1994	S	5,375	3,666	1,709	30	1.76%	32,027	0.84	0.96	25,827	1,471,254	241,154	998,591	1,943,917	16.39
1992	1994	1995		23,903	11,755	12,148	263	2.16%	64,035	0.84	0.96	51,638	2,385,157	126,262	2,137,683	2,632,631	5.29
1993	1995	1996		26,824	8,898	17,926	527	2.94%	42,812	0.84	0.96	34,524	1,174,326	34,813	1,106,093	1,242,560	2.96
1994	1996	1997		700	607	93	7	7.53%	46,942	0.84	0.96	37,854	502,918	141,640	225,304	780,532	28.16

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.

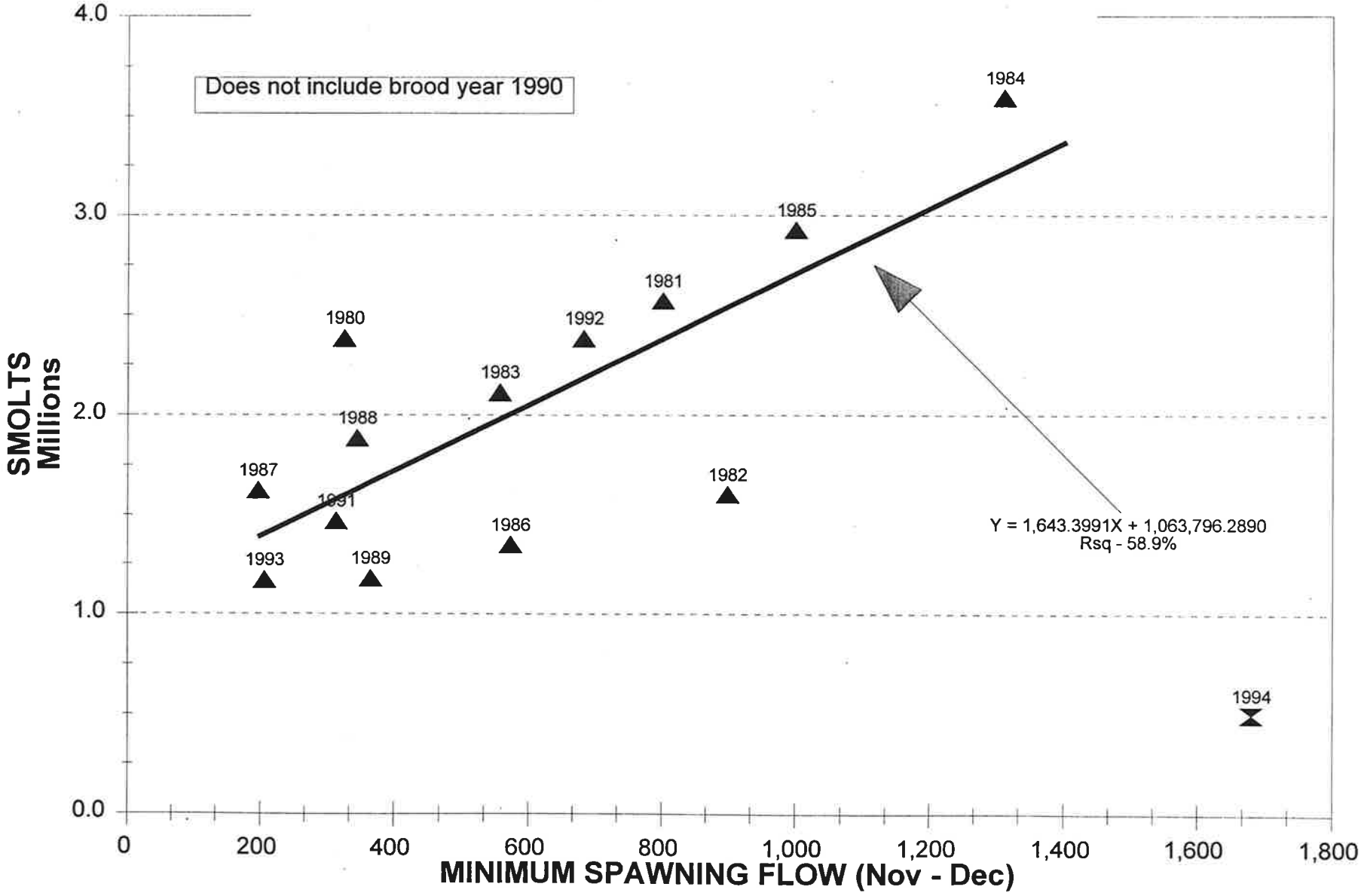
Estimate C: Average of Estimates A&B.

Estimate S: Hatchery/ Wild Catch estimates based on scale analysis

Shaded years are preliminary.

Excludes BY 1990	
1,912,460	**avg**
502,918	**min**
3,592,275	**max**
14	**count**

Figure 4. COHO SMOLT PRODUCTION & FLOW (cfs) CHEHALIS RIVER, BROOD YEARS 1980-1994



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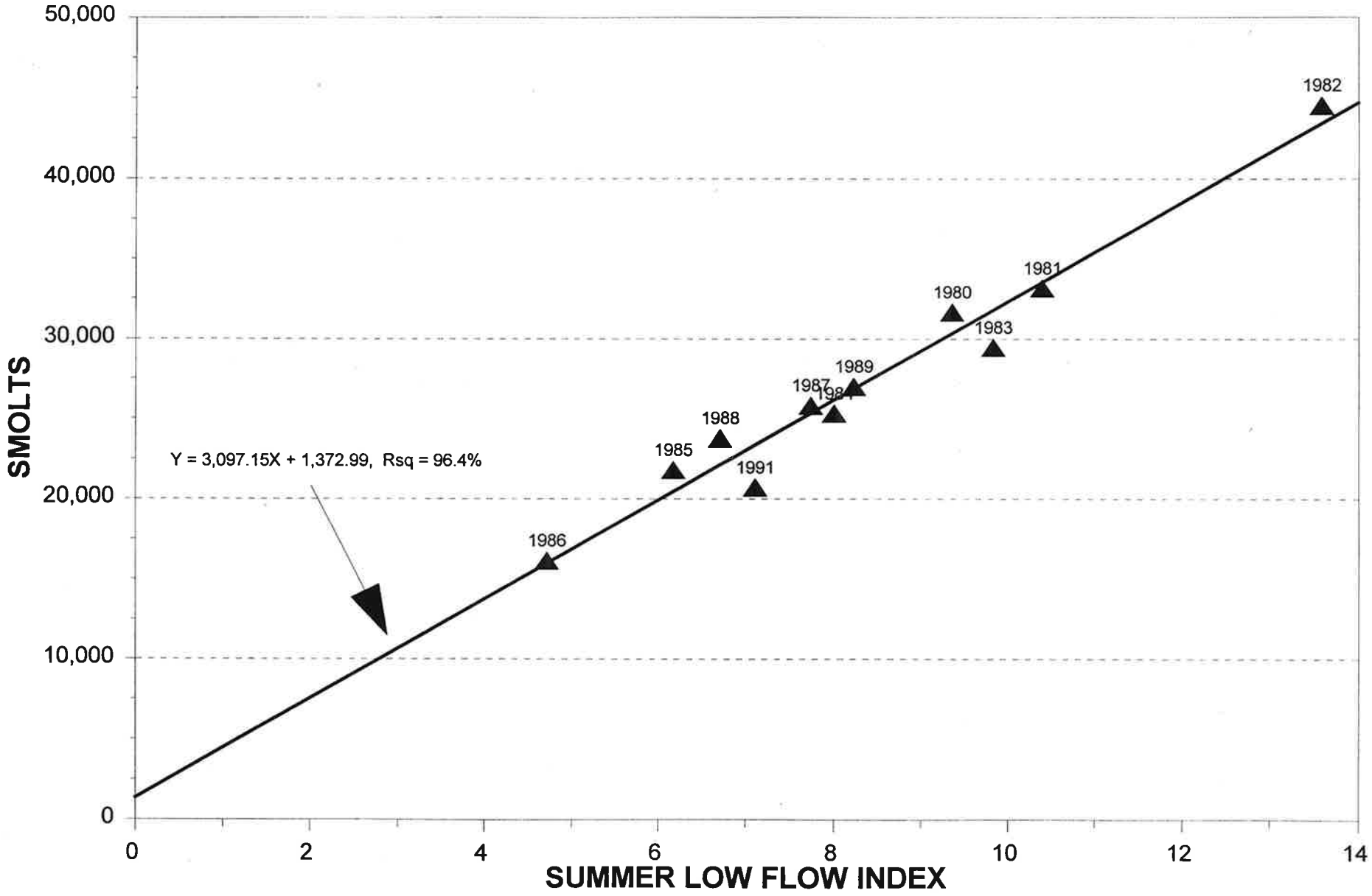
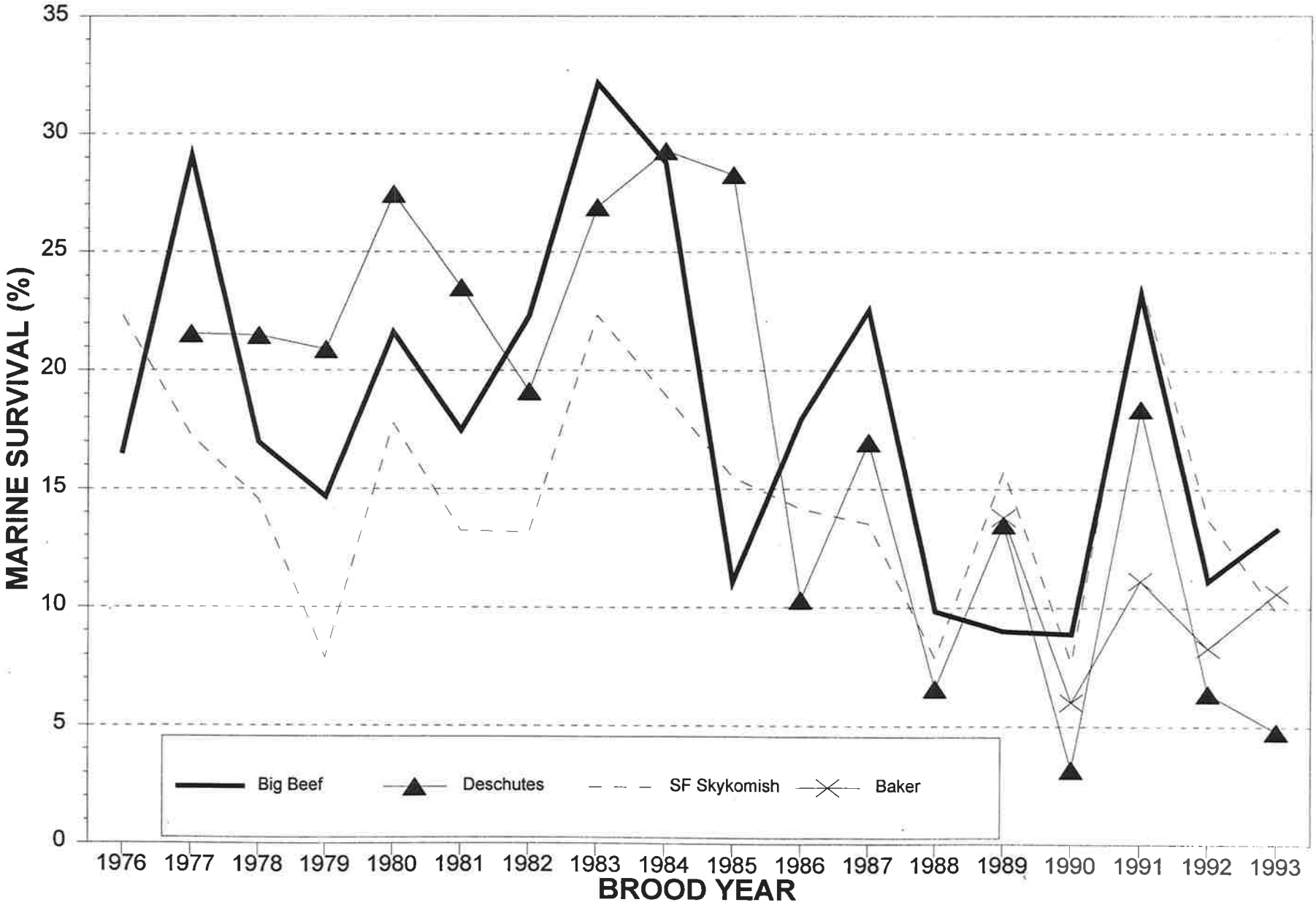


Figure 5. Wild coho smolt production vs. summer low flow, Bingham Creek, brood years 1980-1991 (broods 1990, & 1992-1994 omitted).

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



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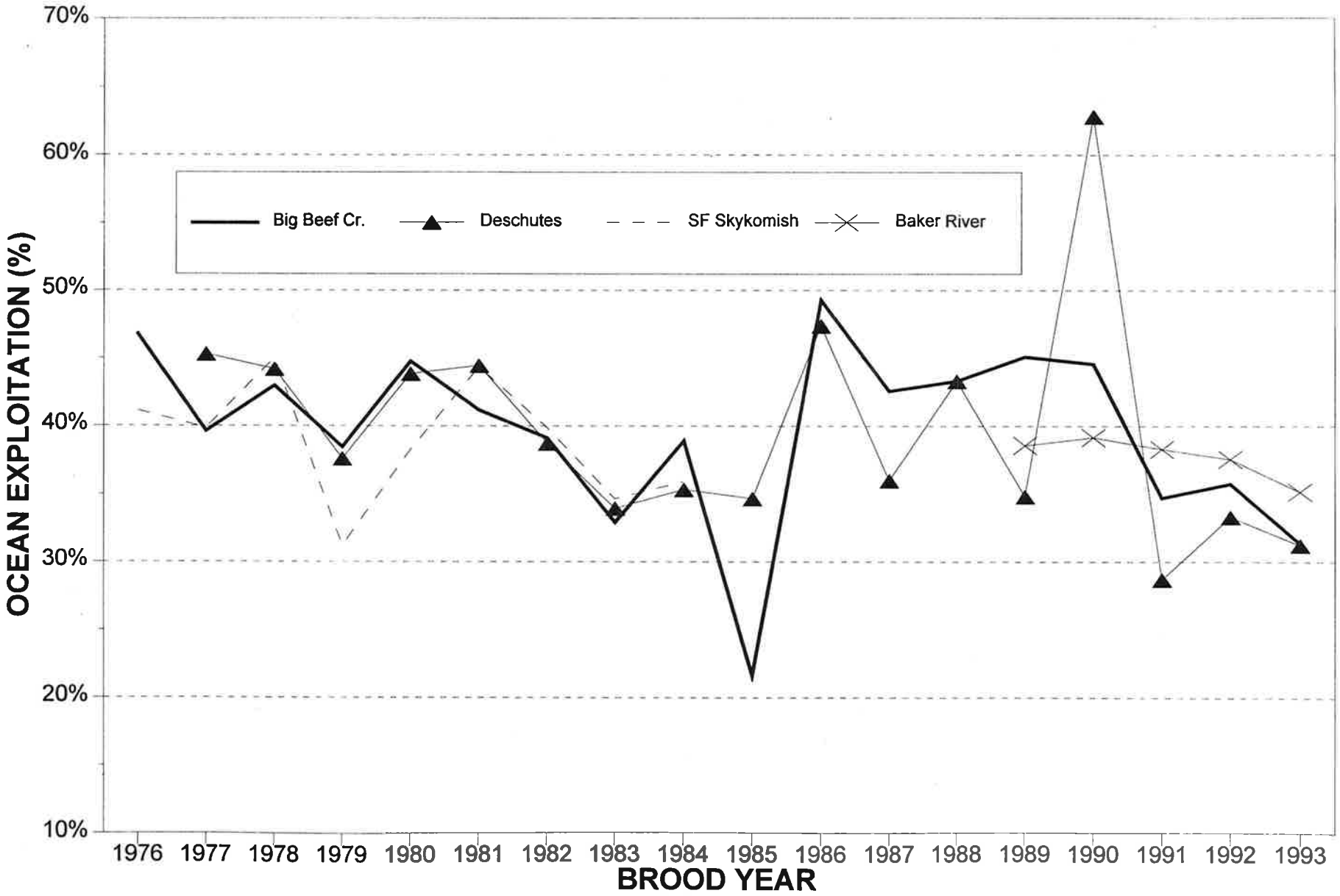

Figure 7. Wild coho ocean exploitation rates from four Puget Sound streams.

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

YEAR		Big	Desch.	SF	Big	Desch.	SF	Baker	AVERAGE		
Br.	Rtn	Beef	River	Sky	Beef	River	Sky	River	Early	Late	Count
1975	1978	13.24							----		
1976	1979	16.58		22.32					19.45		2
1977	1980	29.07	21.55	17.25					22.62		3
1978	1981	16.97	21.49	14.54					17.67		3
1979	1982	14.66	20.90	7.87					14.48		3
1980	1983	21.61	27.44	17.79					22.28		3
1981	1984	17.47	23.52	13.22					18.07		3
1982	1985	22.32	19.12	13.15					18.20		3
1983	1986	32.16	26.90	22.34					27.13		3
1984	1987	28.76	29.28	18.97					25.67		3
1985	1988	11.06	28.27	15.47					18.27		3
1986	1989	17.93	10.31	14.14					14.13		3
1987	1990	22.54	16.98	13.51					17.68		3
1988	1991				9.83	6.58	7.86			8.09	3
1989	1992				9.01	13.50	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
Average		20.34	22.34	15.88	12.56	8.81	13.08	9.97	18.13	11.03	
	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	6	6	6	5	13	6	

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).

Figure 8. MARINE SURVIVAL
BINGHAM CREEK TAGGED WILD COHO

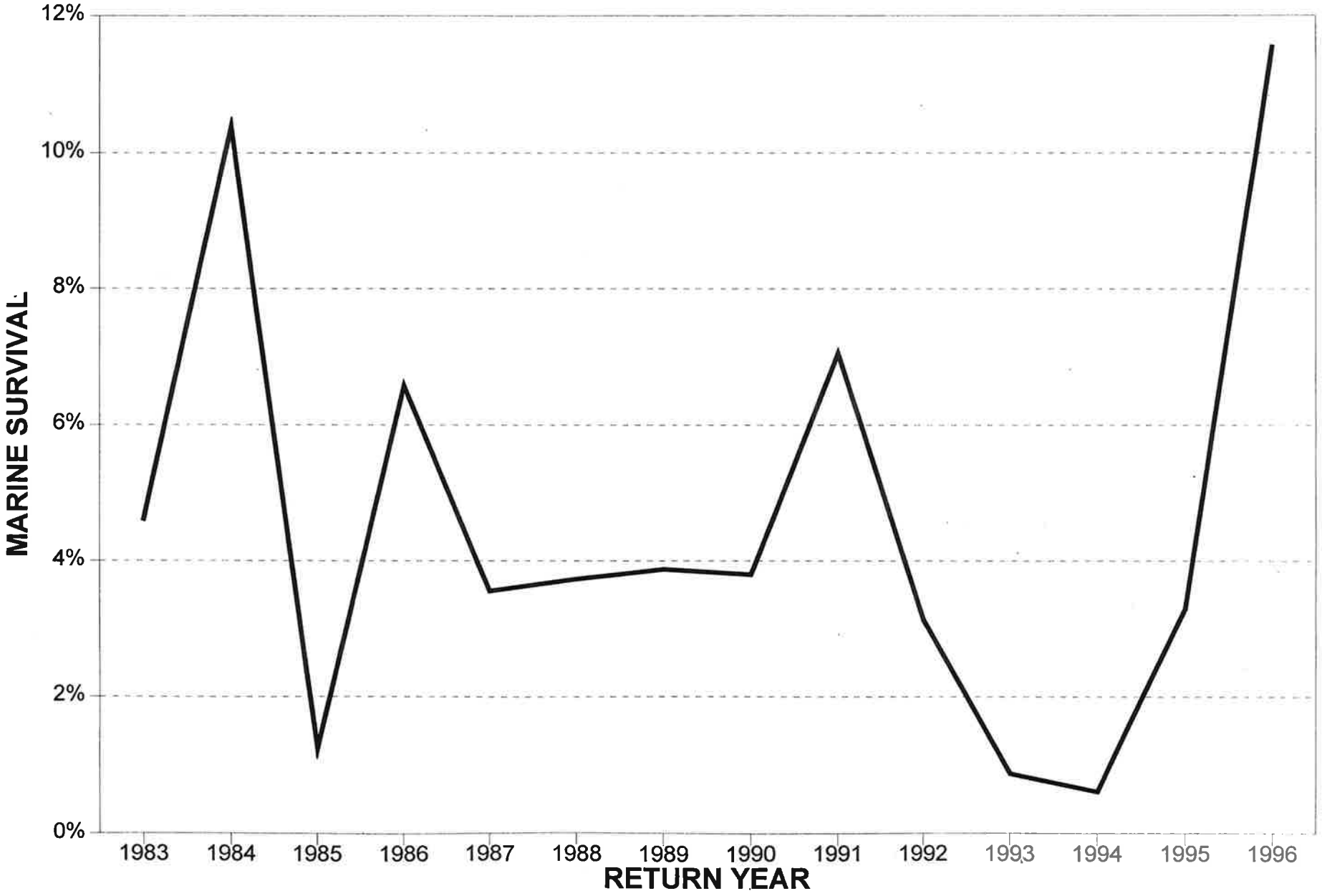

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Figure 9. **JACK RETURN vs ADULT MARINE SURVIVAL**
BINGHAM CREEK, BYs 1980-1994

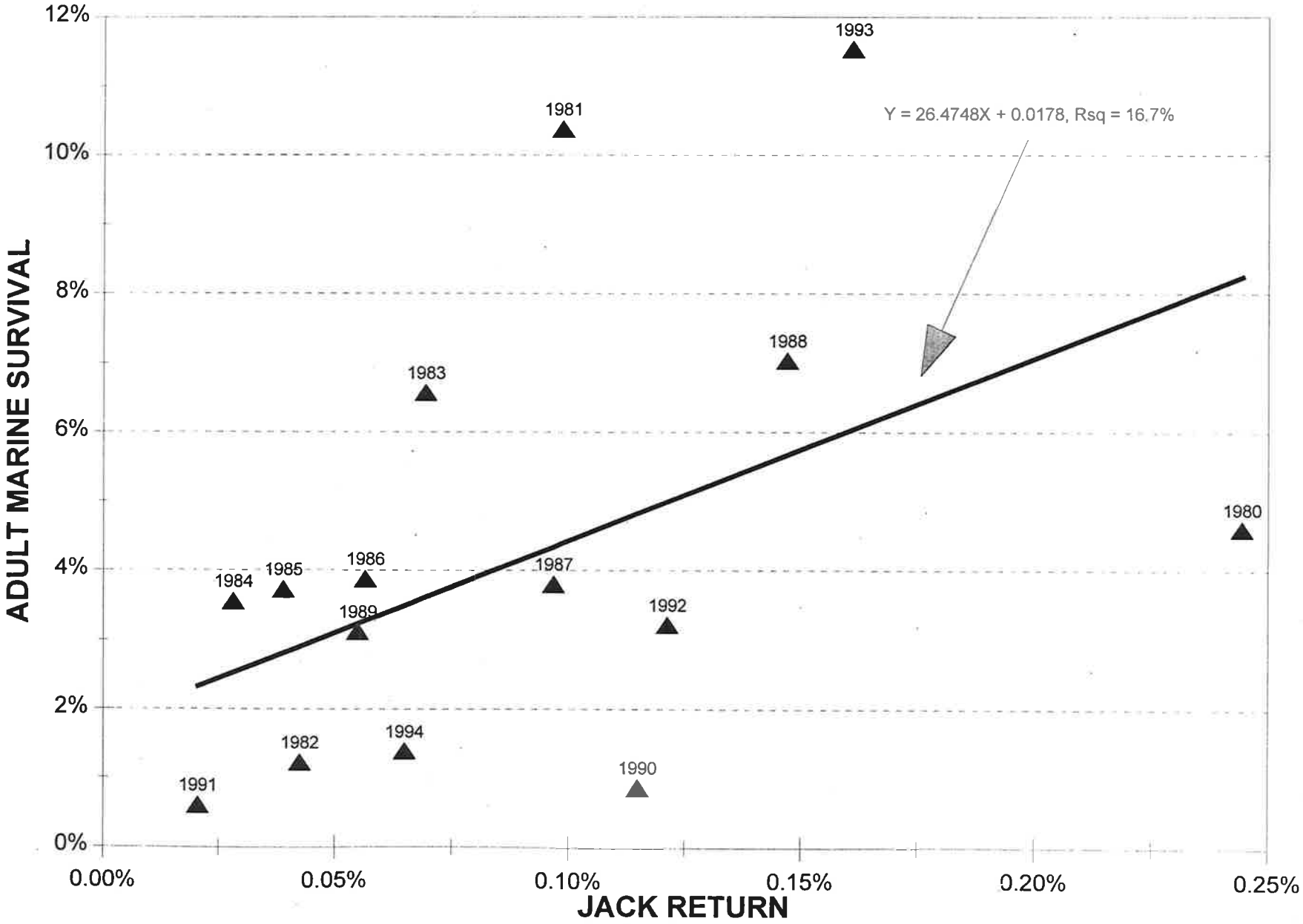

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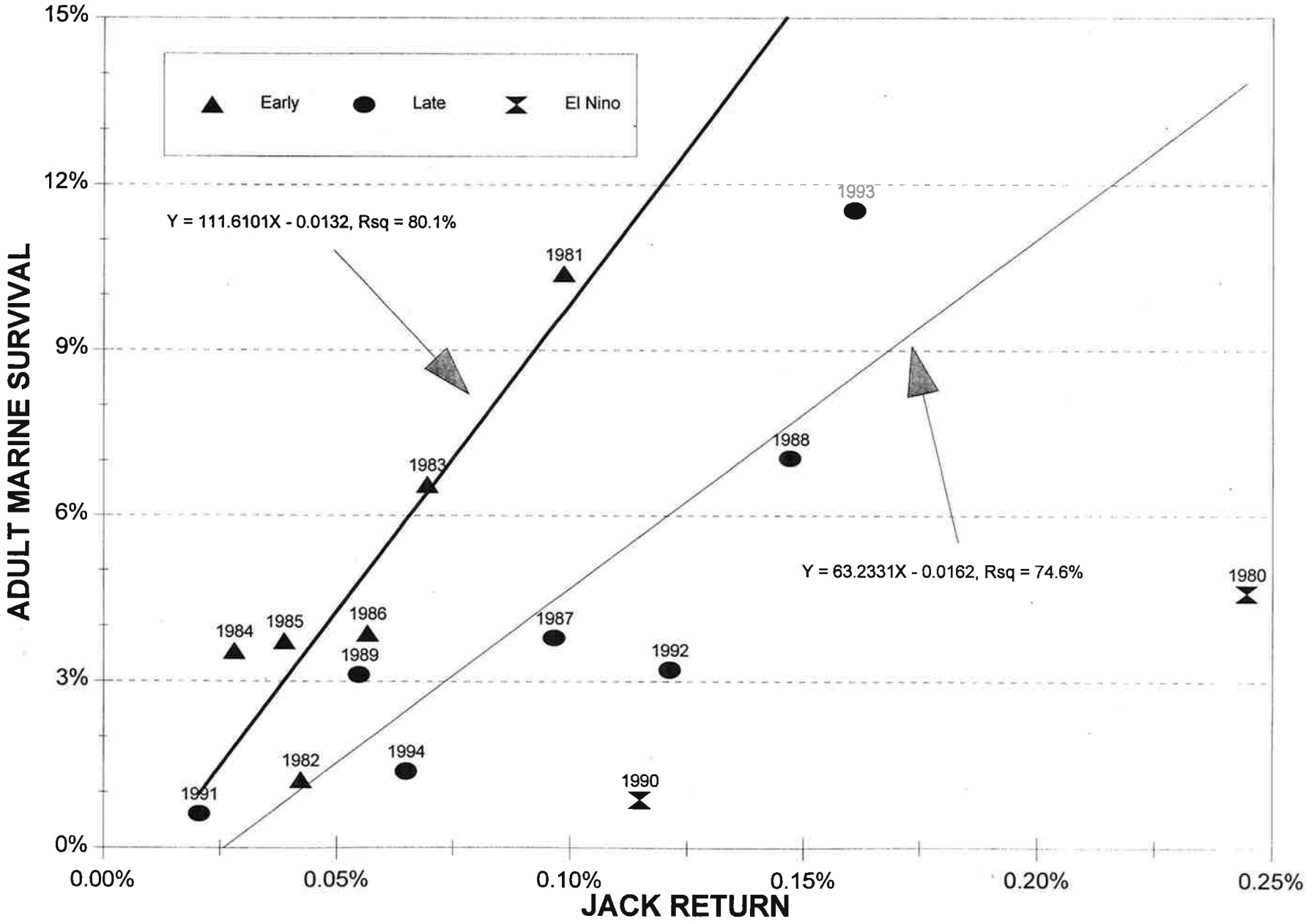
Figure 10. **JACK RETURN vs ADULT MARINE SURVIVAL**
BINGHAM CREEK, BYs 1980-1994



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