# STATEWIDE WILD COHO FORECASTS FOR 1997

Runsize forecasts for wild stocks are the most important element of the joint state-tribal pre-season planning process for Washington State coho 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 account for catches in intercepting fisheries. Even if the runsize data bases were reasonably accurate however, in systems that are adequately seeded, coho forecasts based solely on estimated escapement have little or 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 is precluded. Improving our ability to manage wild coho runs depends on learning which factors cause significant variation in abundance for each major system.

Smolts are the measure of freshwater production. In recognition of this, natural coho escapement goals throughout this state are based on the projected smolt carrying capacity of each system. To assess these goals and to improve run forecasts, WDFW and tribes have made substantial investments in monitoring smolt populations in a number of basins. These data have been incorporated into some forecasts, but 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 1997, based on estimates of smolt production and marine survival.

| Production Unit | FRESHWATER PRODUCTION X Projected Smolt Prod. (Zillges) | Est. Actual Smolt Prod. Spr. 1996 | 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 | 1,125,000 | **82.05%** | 10% | 13% | 112,500 | 150,525 |
| Stillaguamish River | 864,094 | 360,000 | **41.66%** | 10% | 13% | 36,000 | 47,124 |
| Snohomish River | 2,027,497 | 1,333,000 | **65.75%** | 14% | 18% | 186,620 | 244,286 |
| Hood Canal | 1,006,577 | 511,000 | **50.77%** | 14% | 19% | 71,540 | 94,791 |
| Straits of Juan de Fuca | 443,098 | 133,000 | 30.00% | 7% | 9% | 9,310 | 12,513 |
| **Secondary Units** | | | | | | | |
| Nooksack River | 451,275 | 181,000 | 40.00% | 10% | 13% | 18,100 | 24,127 |
| Strait of Georgia | 51,821 | 26,000 | 50.00% | 10% | 13% | 2,600 | 3,466 |
| Samish River | 57,923 | 100,000 | 172.64% | 10% | 13% | 10,000 | 13,330 |
| Lake Washington | 768,740 | 231,000 | 30.00% | 13% | 17% | 30,030 | 38,408 |
| Green River | 416,129 | 166,000 | 40.00% | 13% | 17% | 21,580 | 27,601 |
| Puyallup River | 556,243 | 222,000 | 40.00% | 13% | 17% | 28,860 | 36,912 |
| Nisqually River | 200,314 | 80,000 | 40.00% | 13% | 17% | 10,400 | 13,302 |
| South Sound | 544,498 | 218,000 | 40.00% | 13% | 17% | 28,340 | 36,247 |
| East Kitsap | 154,973 | 79,000 | 50.77% | 13% | 17% | 10,270 | 13,135 |
| Deschutes River | 219,574 | 45,000 | **20.49%** | 13% | 17% | 5,850 | 7,482 |
| **Puget Sound Total** | 9,133,814 | 4,810,000 | 52.66% | | | 582,000 | 763,248 |

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

Table 1b. Preliminary wild coho run forecasts for Washington Coastal Systems in 1997, based on estimates of smolt production and marine survival.

| Production Unit | F/W PROD Estimated Smolt Prod. Spr. 1996 | X MARINE SURVIVAL Adults (Age 3) | Dec. (Age 2) | = RECRUITS Adults (Age 3) | Dec. (Age 2) |
|---|---|---|---|---|---|
| **Coast** | | | | | |
| Quillayute River | 259,000 | 3% | 4% | 7,770 | 10,101 |
| Hoh River | 75,000 | 3% | 4% | 2,250 | 2,925 |
| Queets River | 112,500 | 3% | 4% | 3,375 | 4,388 |
| Quinault River | 90,000 | 3% | 4% | 2,700 | 3,510 |
| Independent Tributaries | 127,200 | 3% | 4% | 3,816 | 4,961 |
| Grays Harbor | | | | | |
| Chehalis River | 500,000 | 3% | 4% | 15,000 | 19,500 |
| Humptulips River | 100,000 | 3% | 4% | 3,000 | 3,900 |
| Willapa Bay | 170,000 | 3% | 4% | 5,100 | 6,630 |
| **Coastal Systems Total** | 1,433,700 | | | 43,011 | 55,914 |

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. Total system smolt production has also been estimated for the Stillaguamish and for the Chehalis Basin, which comprises 90% of the Grays Harbor system. Smolt production has been measured from significant portions of the Snohomish, Hood Canal, Quillayute, and Queets. Production from several tributaries to the Straits has also been measured. 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 observed interannual variations in smolt production (Table 2).

While annual smolt monitoring in each 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 measured results to estimate total production varies, as it depends on the data available. Within Puget Sound, Zillges (1977) provides one means of transferring smolt production monitoring results among basins (as detailed below). Additionally, and for coastal systems, smolt production in unmeasured systems can be approximated on the basis of smolt production/$mi^2$ rates.

### Puget Sound Primary Units -- Managed for Natural Escapement

Skagit River. Spring 1996 was the seventh 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 1,125,000 coho smolts emigrated past the traps in 1996 (Table 3). In the previous six years, production has ranged from 618,000 to 1,129,000 coho smolts. It appears that pink salmon have an influence on Skagit River coho smolt production; even year coho broods have averaged around one million, while odd year broods have averaged 650,000.

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 the projected smolt production (*Zillges 1977*) downstream of this point (23%), mean system production is estimated at 360,000 smolts. Although Stillaguamish coho may also benefit from interaction with pink salmon, this has not been demonstrated. We elected to use the average smolt production value of 360,000 smolts.

Snohomish River. We measured smolt production from the South Fork Skykomish River over nine brood years (1976-1984). This basin comprises 20.7% of the Snohomish River system's drainage area. Excluding the three year's in which escapement was artificially reduced, production averaged 276,000 smolts. Expansion of this estimate to the entire system calculates an average total production of 1,333,000 coho smolts. As there appeared to be no reason to expect production was below average in 1996, we used this value.

Hood Canal. In 1996, based on trapping, we estimated a total of 25,531 coho smolts were produced from Big Beef Creek. Over many years, Big Beef Creek has accounted for around 5% of the total Hood Canal wild coho production as estimated by the ratio of escapements. Expanding the smolt production by the inverse of this value estimates total Hood Canal production at 511,000 coho.

The combined coho production potential of tributaries to Hood Canal was estimated at 1,006,577 smolts (*Zillges 1977*). A recent review by the Hood Canal Joint Technical Committee has revised this estimate downward to 563,705 smolts. Both of these estimates were predicated upon adequate seeding and average environmental conditions.

Straits of Juan de Fuca. Lacking a representative index stream, we selected a value of 30% to reduce the projected production (*Zillges 1977*). We chose this rate, lower than the 51% measured in Hood Canal, to reflect the very low escapement in Straits' tributaries (only 2,850 coho were estimated in 1994). Application of this rate to the projected production potential of 443,098 estimates 133,000 coho smolts. Relating this smolt production to the estimated number of females (1,425) yields 93 smolts/female. This value is well within the range of productivities we have measured in other systems when escapement has dropped below optimal levels (Figure 1).

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 1996. We used a value of 40% of the projected value (*Zillges 1977*) to estimate production at 181,000 smolts in 1996. This value is higher than the 30% used last year because smolt production, where it was measured in Puget Sound (Skagit River, Hood Canal, and Deschutes River), was higher.

Strait of Georgia. We selected a value of 50%, slightly 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, then smolt production is well in excess of the value projected in Zillges (1977). 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. This value is almost double the projected production. If harvest rates were higher and/or marine survival lower, then even more smolts were produced. For 1997, we used 100,000 as our best estimate.

Lake Washington, Green River, Puyallup River, and Nisqually River. Coho production in each of these systems are impacted by habitat degradation through urbanization, water withdrawals, and underescapement due to high, hatchery-directed harvest rates. Each of these systems also contains a major dam on the mainstem. 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 production is lower than would be produced from adequate numbers of natural spawners. Therefore, we applied a value of 40%, lower than the 51% measured at Big Beef Creek, to the production projected for the Green, Puyallup, and Nisqually Rivers (*Zillges 1977*). For the Lake Washington system, we used the 30% rate assessed last year. This lower production was

selected to reflect our belief that in this most urbanized watershed, the 769,000 potential estimated by Zillges (1977) is biased high, due to the lake-perimeter component (192,500 smolts) of the estimate.

South Sound. We applied the value of 40% to the production projected by Zillges (1977). This rate, lower than that measured in Hood Canal (51%), but higher than the 20%estimated for the Deschutes, reflects our belief that development and overharvest have impacted production.

Deschutes River. Based on trapping in 1996, we estimated 45,000 coho smolts emigrated from this system. The Deschutes has experienced severe habitat degradation in the upper watershed and low escapements.

East Kitsap. As these streams are similar in size and character to those trapped in Hood Canal, we applied the production ratio measured in Big Beef Creek (51%).

Coastal Units

Quillayute River. Smolt production has been measured 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 over-wintering habitat. Results also indicate this system was 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 521 $mi^2$ of the Quillayute watershed, excluding the Dickey River Basin. 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.

Attaining average production, however, is dependent on achieving adequate seeding. If the total system escapement estimated in 1994 of 4,882 adults is accurate, then it is unlikely that 300,000 smolts were produced, as this would equate to an average productivity of 125 smolts/female -- a high value relative to that measured statewide (Figure 1).

To estimate the likely level of smolt production in 1996, we developed a hypothetical spawner/recruit relationship for the Quillayute River. This relationship, based on the research conducted at Sunset Falls, S.F. Skykomish River (Figure 2), models two levels of carrying capacity -- 400,000 and 500,000 smolts. Using the S.F. Skykomish productivity parameter and these carrying capacities, production resulting from 2,441 females is estimated at 259,000 and 229,000 smolts, and production/female rates of 106 and 94 smolts, respectively (Figure 3). This approach and these estimates assume that escapement was accurately estimated in 1994.

Relating these two estimates to the total Quillayute River drainage area (629 $mi^2$) yields average production rates of 412 and 364 smolts/$mi^2$. As these values are higher than the rate measured for the Clearwater River in 1996 (250 smolts/$mi^2$), it indicates that marine survival and resultant escapement in 1994 was higher on the northern coast and declined southward.

Queets River. Smolt production has been measured from the Clearwater River each Spring since 1981. Over the first 15 broods, coho smolt production has ranged two-fold between extremes, from around 43,000 to 95,000. 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.

In 1996, however, Quinault Fisheries biologists estimated only 35,000 coho smolts were produced from the Clearwater River. This estimate is the lowest on record, and indicates that escapement was inadequate to seed the system. Relating this estimate to the 260 females estimated in the 1994 escapement, yields an average of 134 smolts/female. Average production/area for this system is estimated at 250 smolts/$mi^2$. Application of this rate to the entire Queets System drainage area (450 $mi^2$) estimates 112,500 smolts produced. Quinault Fisheries biologists may favor alternative means of expanding the Clearwater estimate.

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 1996. The rate of 250 smolts/$mi^2$ applied to the drainage area of 299 $mi^2$ in the Hoh system estimates 75,000 coho smolts produced. This estimate may slightly underestimate actual smolt production because escapement in the Hoh was somewhat higher relative to its smolt production potential than that estimated in the Clearwater.

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 per square mile 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 300 smolts/$mi^2$ to their combined watershed area (424 $mi^2$) (Table 1b) estimates 127,000 coho smolts were produced from these systems. The value of 300 smolts/$mi^2$ was selected, slightly higher than the value measured in the Clearwater River in 1996 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 per area should be higher. Finally, escapements were probably higher in these systems because most are too small to warrant terminal fisheries.

Grays Harbor Coho smolt production from the Chehalis River system has been measured each brood since the 1980 brood through wild smolt trapping/tagging and CWT sampling in the Quinault terminal net fishery in the lower Chehalis River. Resultant estimates have ranged threefold, from around one million to over three million (Table 4). Analysis to understand the components of variation has determined that over these 12 broods, only one variable, flow during spawning, explains a significant

portion of the interannual variation in estimated smolt production (Figure 4). Moreover, there is reason to believe that this relationship may be even stronger than indicated by the correlation coefficients. For each of the three points that lie well below the regression line other important brood specific factors were in effect.

- The 1989 brood was likely impacted by the severe storm which produced extremely high flows on January 10, 1990. On this date, the Chehalis River flooded over Interstate-5. This storm also triggered mass wasting events in many watersheds.
- The 1986 brood was undoubtedly reduced by the effects of the devastating drought of summer 1987 which resulted in the lowest production on record from Bingham Creek (Figure 6).
- 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 the watershed is a function of flow. In very dry Falls, such as the 1987 drought, adult spawners simply cannot distribute as widely and as high in tributaries as they can in wetter years.

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 was quite high (1,130 cfs), however, so it is likely smolt production was high on this brood.

For the twelve broods analyzed, this flow correlation indicates that natural seeding rates have been adequate. It also appears that the fry planting program has not produced enough smolts to obscure the effect of flow on spawners. Additional analysis may result in a better understanding of the effects of flows on Chehalis River coho production.

This relationship provides a means to predict freshwater production, **but only for broods with adequate spawning escapements**. Escapement in 1994 was far lower than any of these previous broods. Application of the survival-to-return rate (0.47%) in 1994, measured with Bingham Creek wild tagged coho, to the 1.47 million smolts estimated in 1993, projects 6,900 spawners escaped to the Chehalis River system.

Spawning flows were very high in Fall 1994, with a minimum November to December flow value of 1,680 cfs, recorded at Grand Mound. Had sufficient spawners escaped in 1994, this brood would likely have produced a record high smolt production.

Although we cannot precisely estimate smolt production from this system in 1996, we believe that it was between 500,000 and 1,000,000 smolts. To generate a point estimate, we assumed the following:

- Our catch of 33,000 smolts represents 10% of the production passing the scoop trap at Independence.
- Half of the system production originated downstream of the trap (R.M. 50)
- Given the very low natural escapement, we expect that the 778,000 fry outplanted in Spring 1995 survived at a high rate (10%).

Using these assumptions, system production is estimated at 660,000 smolts, of which 580,000 were naturally-produced. Relating this estimate to the 3,500 females estimated to have spawned, however yields an unreasonably high rate of 166 smolts/female. As this is higher than rates we have measured statewide with low escapements (Figure 1), we believe that it indicates actual smolt production was lower. We selected a rate of 120 smolts/female, which estimates 420,000 smolts were naturally produced from the 2,300 $mi^2$ Chehalis Basin (including the Wishkah, Hoquiam, Johns, and Elk Rivers, and other southside tributaries). This yields a production/area estimate of 253 smolts/$mi^2$, including the 80,000 smolts resulting from fry outplants.

In addition to the Chehalis River watershed, the 2,550 $mi^2$ Grays Harbor Basin includes the 250 $mi^2$ Humptulips River. While we have no direct estimates for the Humptulips Basin, its smolt production in 1996 was probably not as depressed as the Chehalis. We base this expectation on the relatively high contribution of hatchery fish to natural spawning in this system. We estimated the Humptulips natural smolt production at 100,000 smolts using a production value of 400 smolts/$mi^2$.

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, the generally degraded condition of the habitat, and the environmental conditions affecting the 1994 brood, it is likely that coho production per area was also very low in this basin. To approximate production of the 1994 brood, we selected a value of 200 smolts/$mi^2$. This value applied to the total basin area estimates 170,000 coho smolts were naturally produced in 1996.

## 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 10% to over 30% at Big Beef Creek, and averaged near 20%. In some recent years, we have measured low survival for Deschutes River coho, but believe these estimates are biased because of low sampling rates in certain fisheries and low numbers of smolts tagged. Marine survival measured at Sunset Falls (SF Skykomish) also ranged three-fold (8% to 24%), and has averaged 15%, somewhat lower than the rates estimated for Big Beef Creek and Deschutes River coho. We attribute this lower survival to the smaller smolts produced from this colder, higher-elevation system. Survival of Baker River coho appears to track that of the other stations so far (Figure 7).

In addition to within-brood survival, ocean exploitation rates are also correlated among these three stocks (Figure 8). 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 been found to explain the observed inter-annual variation in marine survival. Clearly, the ocean was in an altered state during the ocean entry period for brood years 1988 through 1990. Prior to this period, we had not measured any consecutive low survival years in Puget Sound. 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 a useful indicator of marine survival for Puget Sound stocks, forecasts must rely on the selection of survival rates which are deemed to reflect future ocean conditions.

For predicting 1994 brood marine survival, we averaged the rates estimated for brood years 1985 through 1992 (Table 5). This decision reflects the belief that the recent past more accurately predicts future marine survival than the long-term average survival 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 would experience intermediate survival. We selected a value of 7%, half of the rate measured at Big Beef Creek over the last eight 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 on the Washington Coast. Marine survival (age 3) of wild Bingham Creek coho has ranged sixteen-fold, from 0.6% to 10%, and averaged 4.24% over 14 years (Figure 9). Although highly variable, marine survival is also somewhat predictable. Tagged jack returns correlated with same brood adult survival explains some of the inter-annual variation in marine survival. Over all broods measured, however, the relationship is poor (Figure 10). When the data set is split into early- and later-years the correlation improves especially if the El Niño broods are excluded (Figure 11). In these broods (1980, 1990, and 1992) adult survival was very low relative to the high jack returns. This phenomenon has been observed elsewhere on the coast, notably in the Oregon Production Index. At present, we are unable to predict the ocean conditions which produce this response. Therefore, because this bias appears to work in only one direction, to over forecast marine survival, we should be conservative.

Based on the relationship developed for the recent years, the wild jack return rate to Bingham Creek in 1996 (0.65%) predicts an adult marine survival to the ocean (age 3) of 2.95%.

.065% ?

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

| Stream | Number of Years | Watershed Area (mi^2) | SMOLT PRODUCTION Range Low | Range High | Ratio Hi/Lo | Average Production | Prod./ Area | Identified Sources of Variation (see key) |
|---|---|---|---|---|---|---|---|---|
| Big Beef Creek | 18 | 14 | 11,510 | 45,634 | 4.0 | 24,203 | 1,729 | 1, 2, 4, 5 |
| Bingham Creek | 14 | 35 | 16,153 | 44,567 | 2.8 | 26,473 | 756 | 2 |
| Deschutes River | 16 | 130 | 9,718 | 130,090 | 13.4 | 75,723 | 582 | 1, 2, 4, 5 |
| SF Skykomish River | 9 | 362 | 181,877 | 353,981 | 1.9 | 249,442 | 689 | 7 |
| Dickey R. | 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 | 13 | 140 | 42,918 | 94,817 | 2.2 | 65,354 | 467 | 1, 4, 5 |
| Stillaguamish River | 3 | 540 | 203,072 | 379,022 | 1.9 | 275,940 | 511 | 6 |
| Skagit River | 7 | 1,918 | 617,605 | 1,129,123 | 1.8 | 817,380 | 426 | 8 |
| Chehalis River | 11 | 2,114 | 1,181,135 | 3,592,275 | 3.0 | 2,124,263 | 1,005 | 1, 2, 3, 4 |
| Total | | 5,469 | | | | | | |
| Mean | | | | | | | 740 | |
| Wt'd Mean | | | | | | | 692 | |

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 - egg scour
2. Summer flows - rearing habitat
3. Fall flows - spawner distribution
4. Seeding
5. Habitat damage
6. No factors identified (measurement error may account for some of the variation).
7. Experimental escapement reduction.
8. Species interactions

Table 3. Estimation of wild coho smolt production by mark-recapture, Skagit River, 1996.

| | | |
|---|---|---|
| Total mainstem trap catches | 22,819 | |
| Baker | -754 | |
| Skagit Hatchery | -2,153 | |
| Lake Shannon | -21 | |
| U-brands | -11 | |
| Subtotal | 19,880 | $N = \frac{(m+1)(c+1)}{r+1}$ |
| Wild coho (c) | 19,880 | |
| LVs recaptured (r) | 942 | $Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2 (r+1)}$ |
| LVs released (m) | 51,257 | |
| Total Production (N) | 1,080,658 | |
| variance (Var) | 1.1580E+09 | $CV = \frac{s.d.}{N}$ |
| standard deviation (s.d.) | 34,029 | |
| coefficient of Var (CV) | 3.15% | |
| confidence interval (CI) | 66,697 | CI = +/-1.96 (s.d.) |
| Lower CI (95%) | 1,013,961 | |
| Upper CI (95%) | 1,147,354 | |
| Est. coho smolt production | 1,124,504 | |
| Skagit River | 1,080,658 | |
| Baker River | 43,846 | |

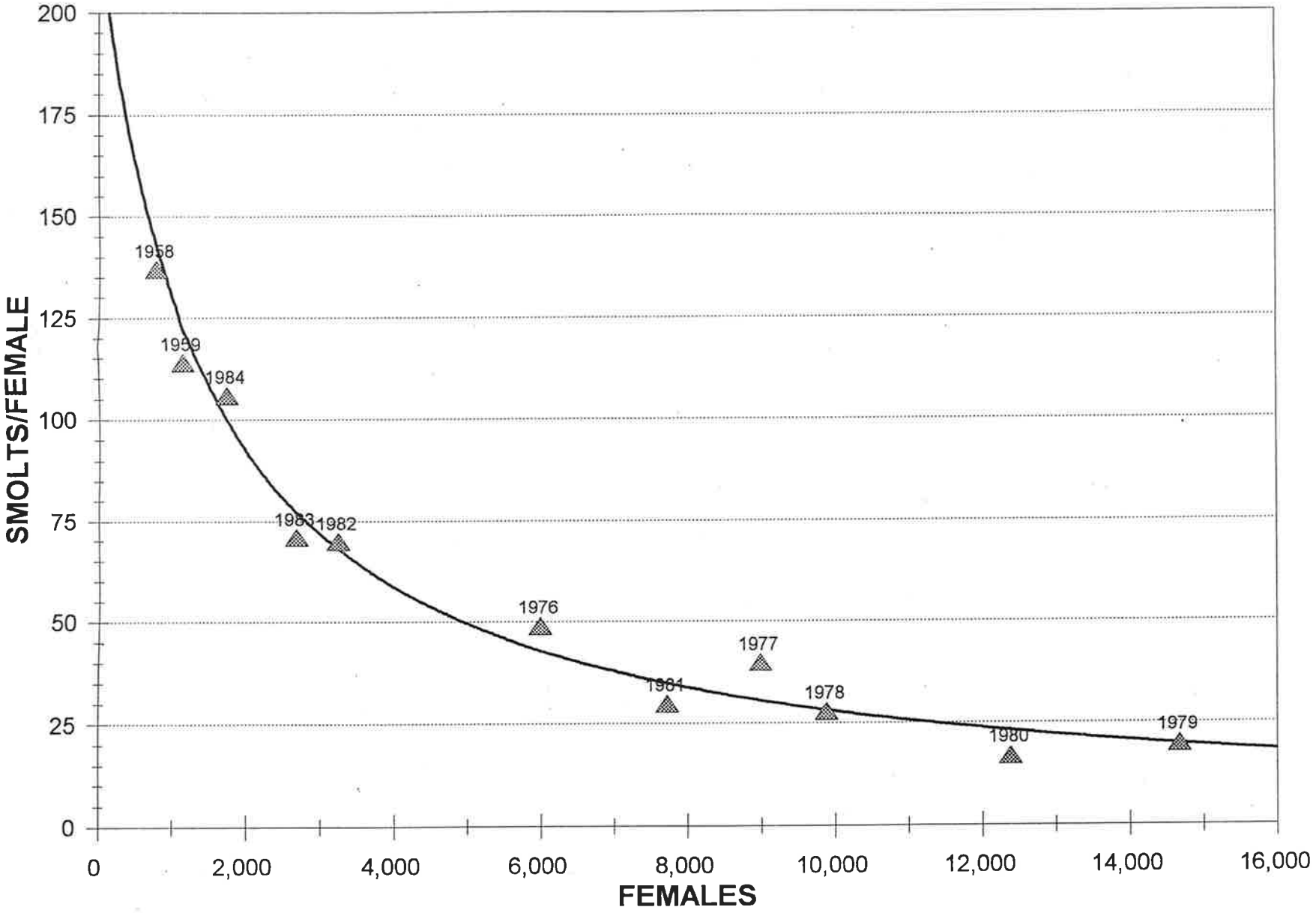
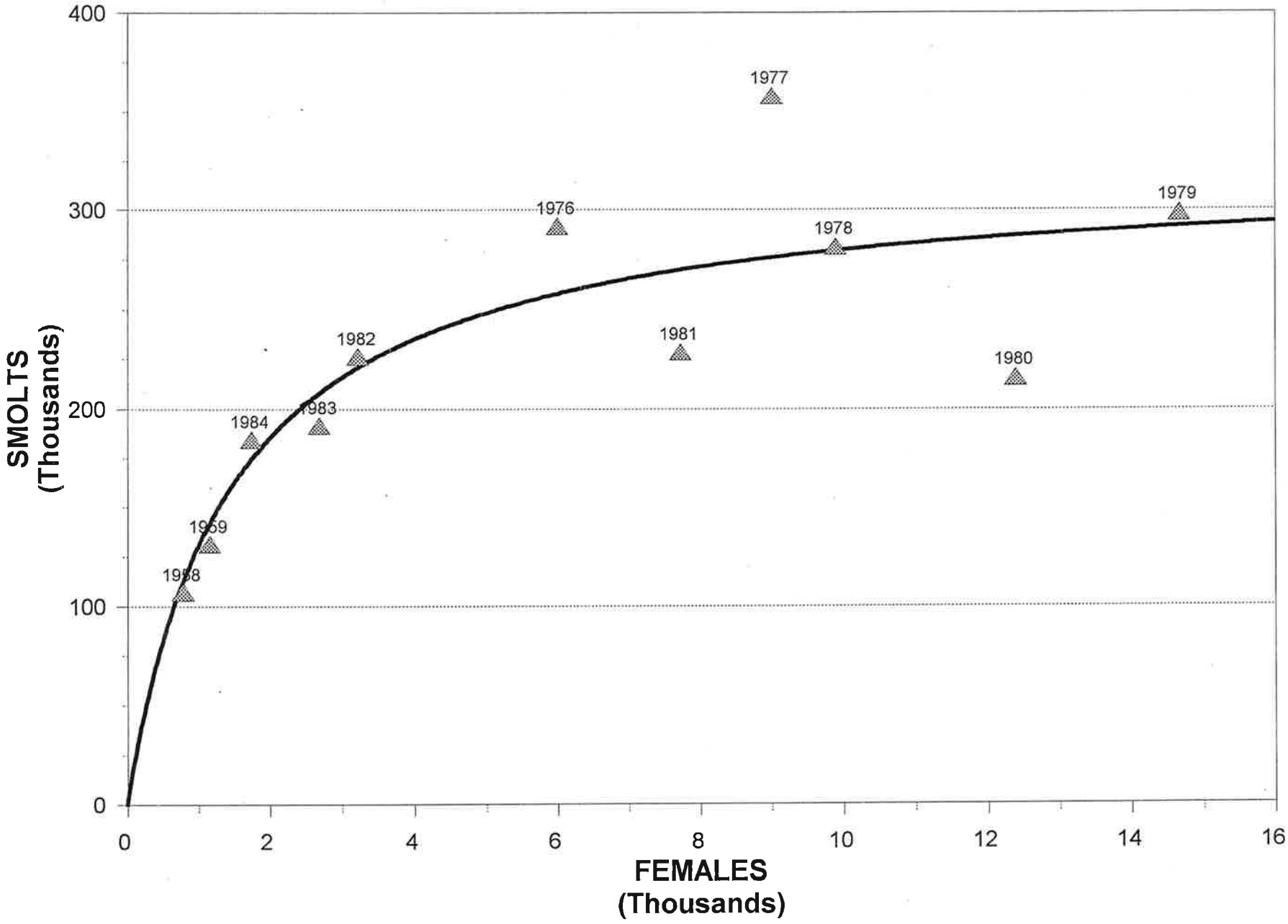



**Figure 1. PRODUCTIVITY AS A FUNCTION OF SPAWNER ABUNDANCE, SF SKYKOMISH RIVER WILD COHO.**

**Figure 2.**

# SF SKYKOMISH RIVER WILD COHO SPAWNERS & RECRUITS, BY BROOD YEAR

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## Figure 3. SPAWNER/RECRUIT RELATIONSHIP QUILLAYUTE RIVER COHO

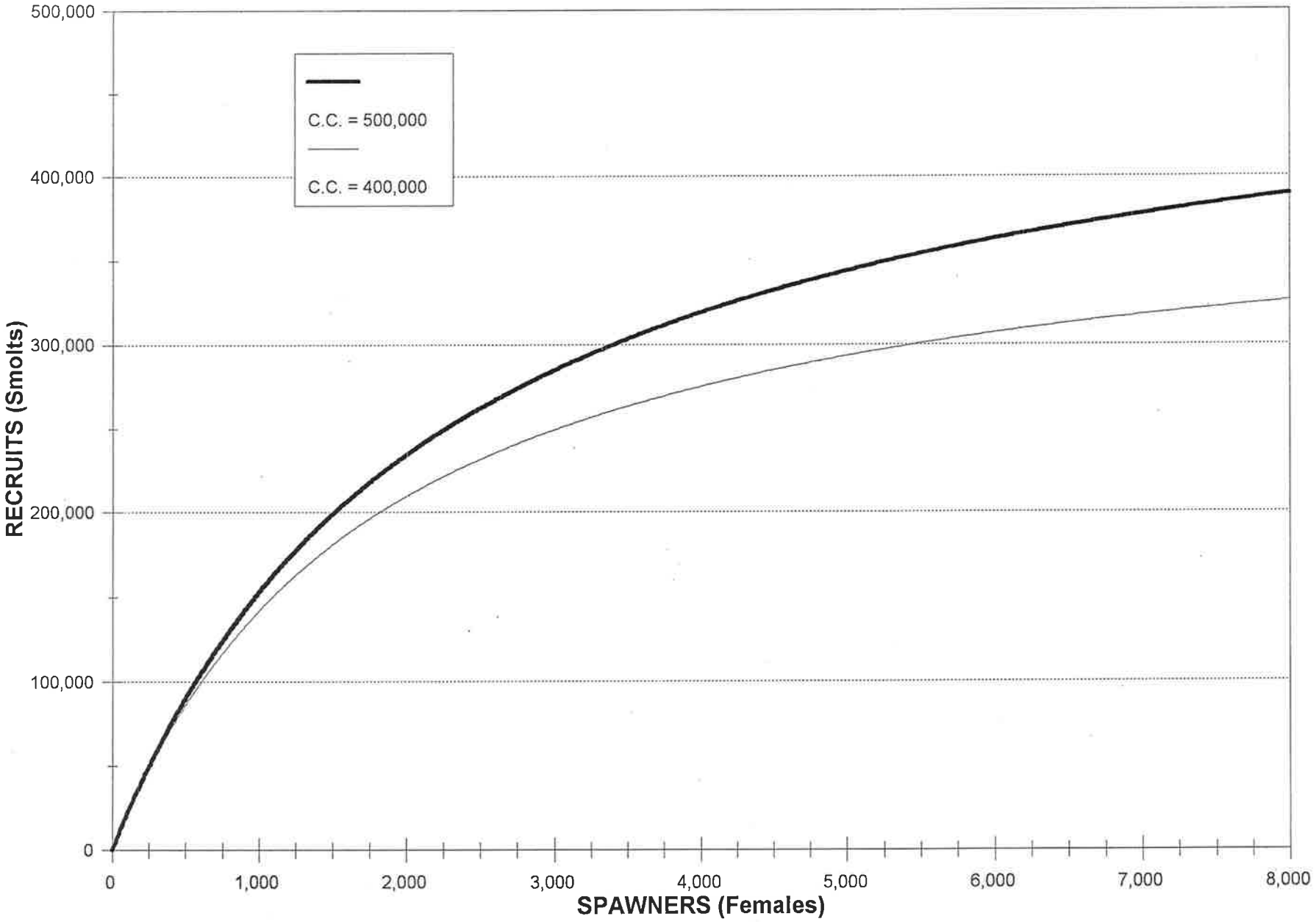


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Table 4.

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 |

Estimate A: Assumes Simpson (late) and Satsop Springs fish survived and contributed 1/2 the rate as Simpson (normal) hatchery stock.

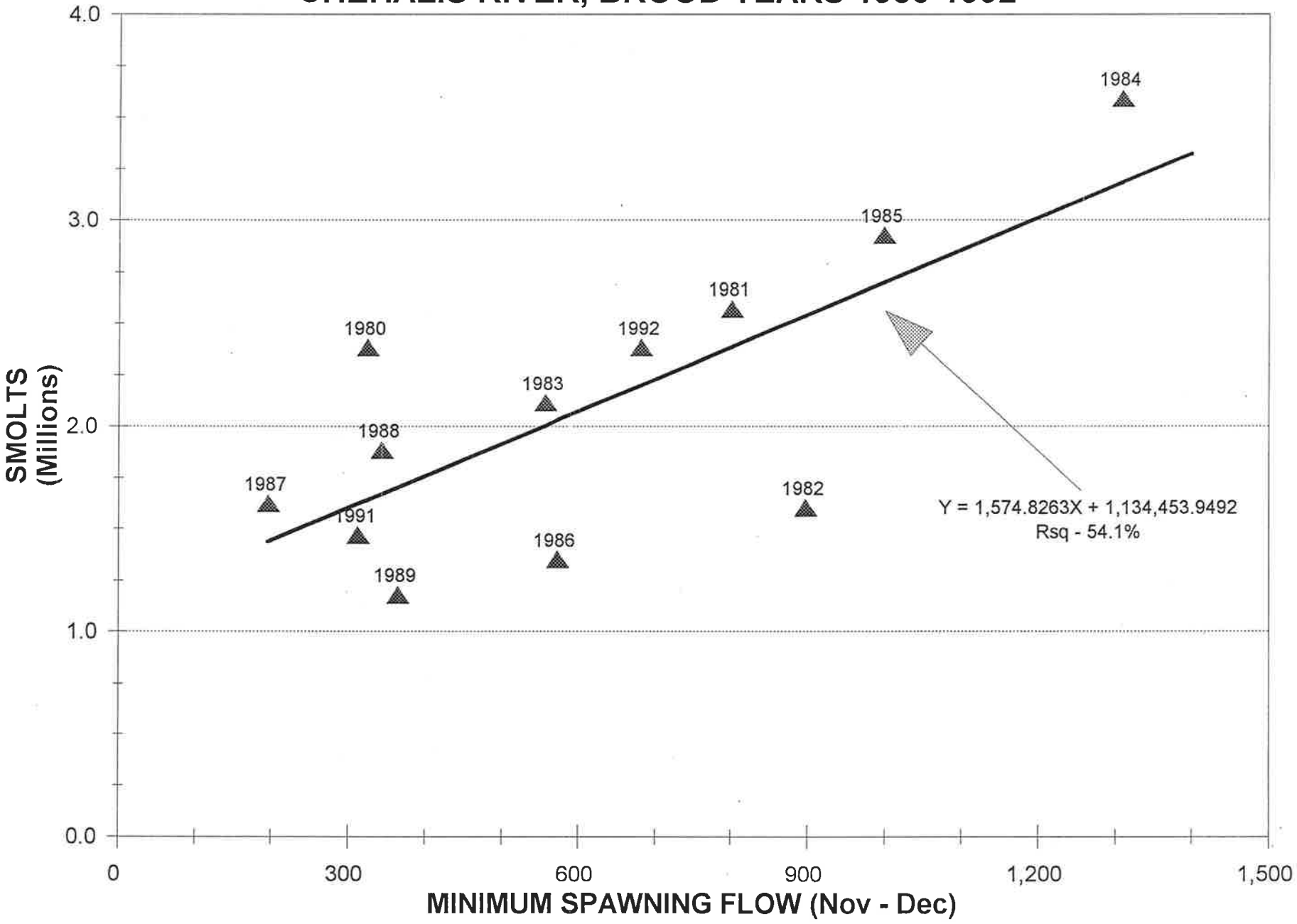
Estimate B: Assumes Simpson (late) and Satsop Springs fish survived and contributed at the same rate as Simpson (normal) hatchery stock.

Estimate C: Average of Estimates A&B.

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

* Prelimnary: based on tag recoveries estimated by QFiD.

**Figure 4.** **COHO SMOLT PRODUCTION & FLOW (cfs)**
**CHEHALIS RIVER, BROOD YEARS 1980-1992**



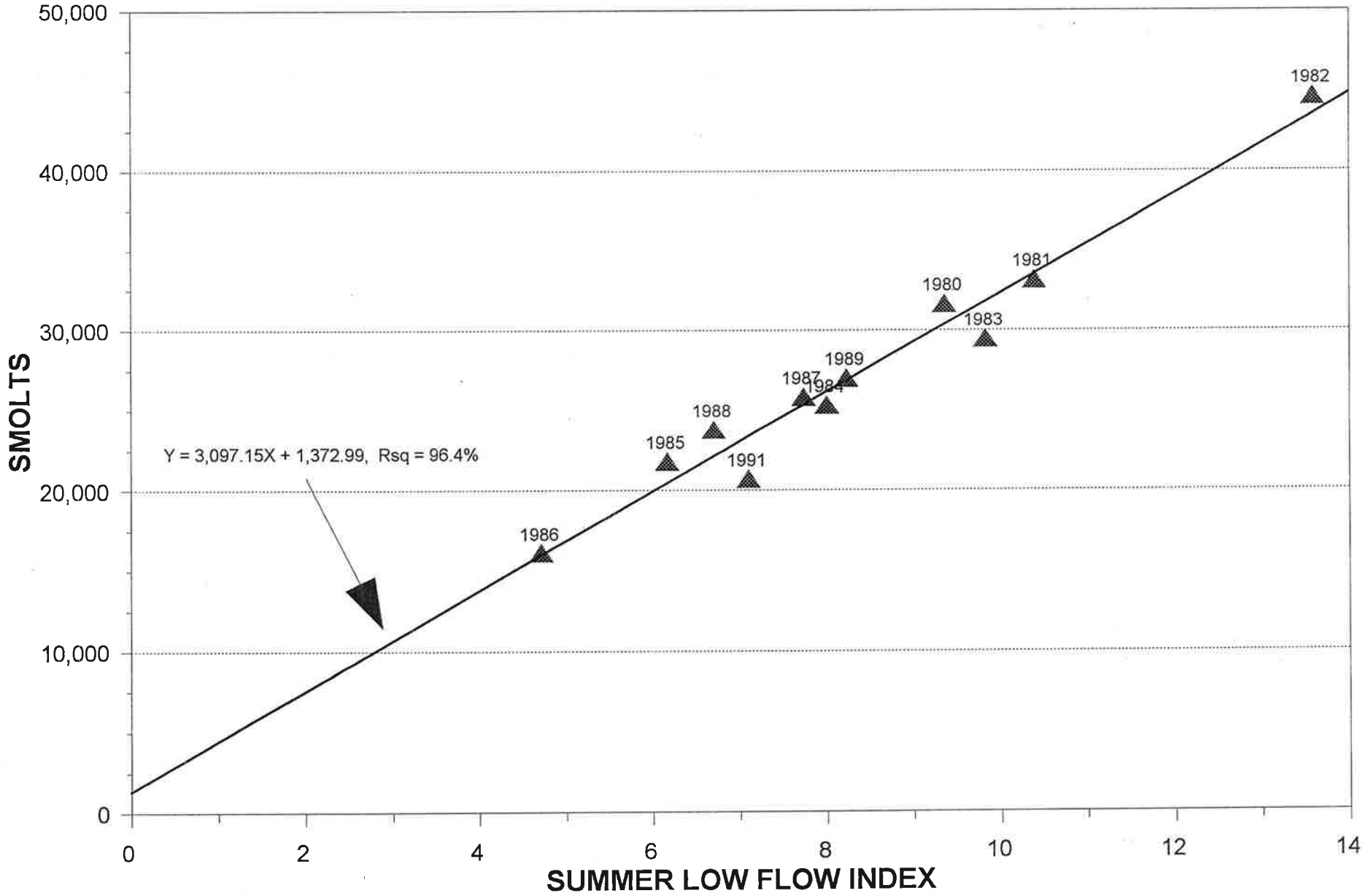
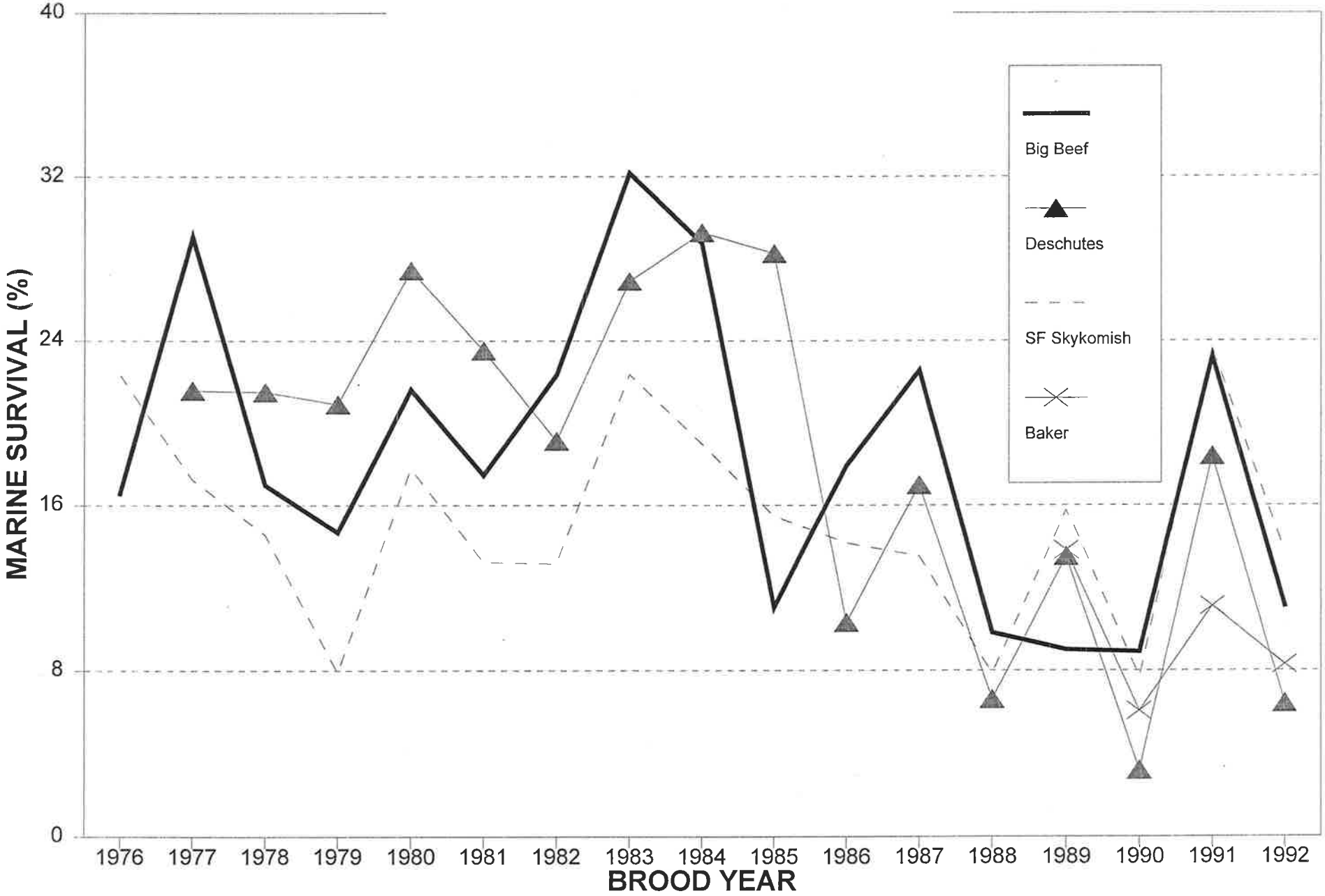



**Figure 6. Wild coho smolt production vs. summer low flow, Bingham Creek, brood years 1980-1991.**

# Figure 7. MARINE SURVIVAL: PUGET SOUND WILD COHO (age 3)

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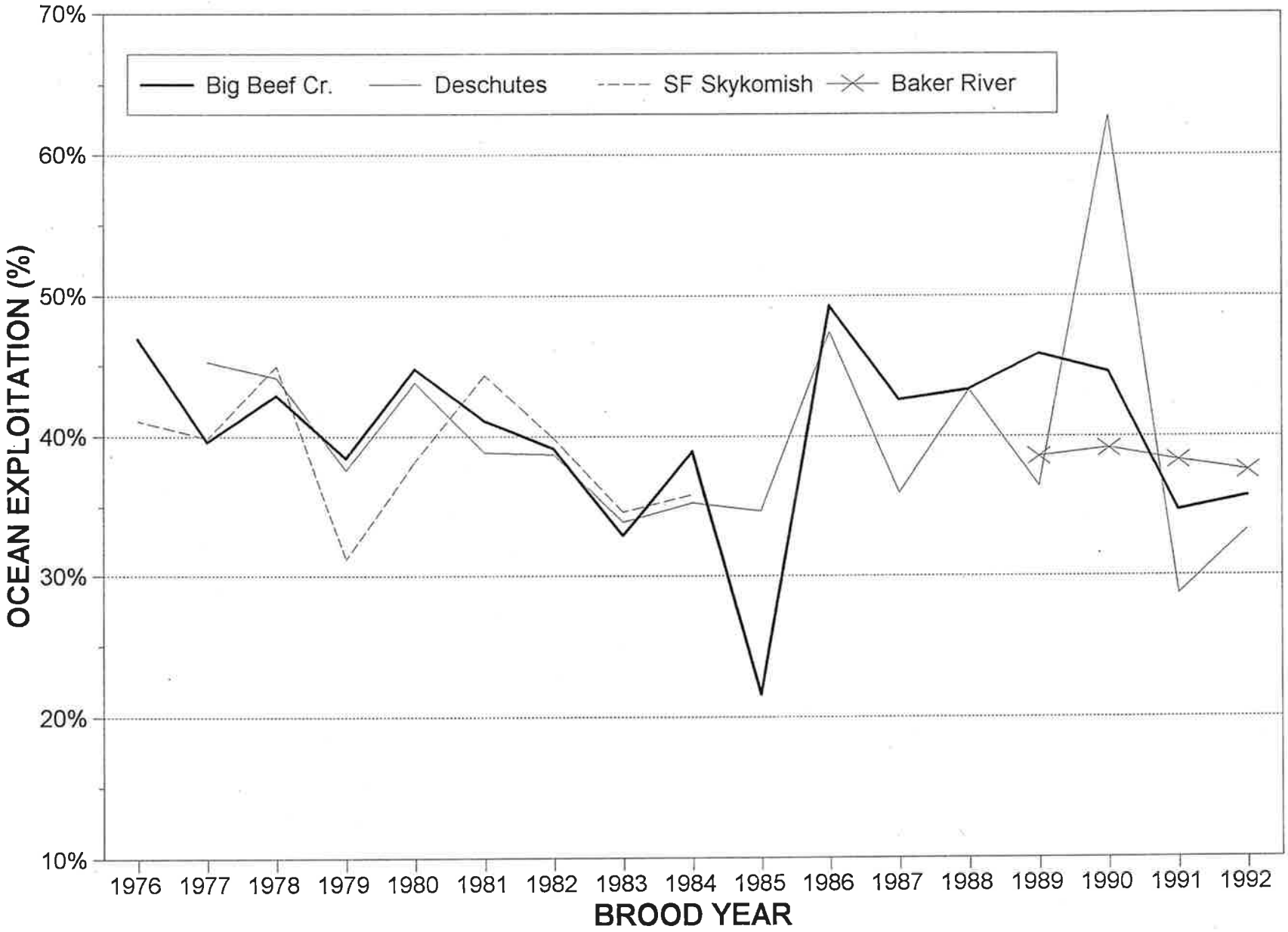


**Figure 8. Wild coho ocean exploitation rates from four Puget Sound streams.**

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

| YEAR Br. | Rtn | Big Beef | Desch. River | SF Sky | Big Beef | Desch. River | SF Sky | Baker River |
|---|---|---|---|---|---|---|---|---|
| 1975 | 1978 | 13.24 | | | | | | |
| 1976 | 1979 | 16.58 | | 22.32 | | | | |
| 1977 | 1980 | 29.07 | 21.55 | 17.25 | | | | |
| 1978 | 1981 | 16.97 | 21.49 | 14.54 | | | | |
| 1979 | 1982 | 14.66 | 20.90 | 7.87 | | | | |
| 1980 | 1983 | 21.61 | 27.44 | 17.79 | | | | |
| 1981 | 1984 | 17.47 | 23.52 | 13.22 | | | | |
| 1982 | 1985 | 22.32 | 19.12 | 13.15 | | | | |
| 1983 | 1986 | 32.16 | 26.90 | 22.34 | | | | |
| 1984 | 1987 | 28.76 | 29.28 | 18.97 | | | | |
| 1985 | 1988 | | | | 11.06 | 28.27 | 15.47 | |
| 1986 | 1989 | | | | 17.93 | 10.31 | 14.14 | |
| 1987 | 1990 | | | | 22.54 | 16.98 | 13.51 | |
| 1988 | 1991 | | | | 9.83 | 6.58 | 7.86 | |
| 1989 | 1992 | | | | 9.01 | 13.50 | 15.76 | 13.80 |
| 1990 | 1993 | | | | 8.90 | 3.18 | 7.67 | 6.02 |
| 1991 | 1994 | | | | 23.23 | 18.39 | 23.64 | 11.12 |
| 1992 | 1995 | | | | 11.11 | 6.39 | 13.71 | 8.30 |
| 1993 | 1996 | | | | | | | |
| AVG | | 21.28 | 23.78 | 16.38 | 14.20 | 12.95 | 13.97 | 9.81 |

## Figure 9. MARINE SURVIVAL
## BINGHAM CREEK TAGGED WILD COHO

**Figure 10.**

## JACK RETURN vs ADULT MARINE SURVIVAL
## BINGHAM CREEK, BYs 1980-1992

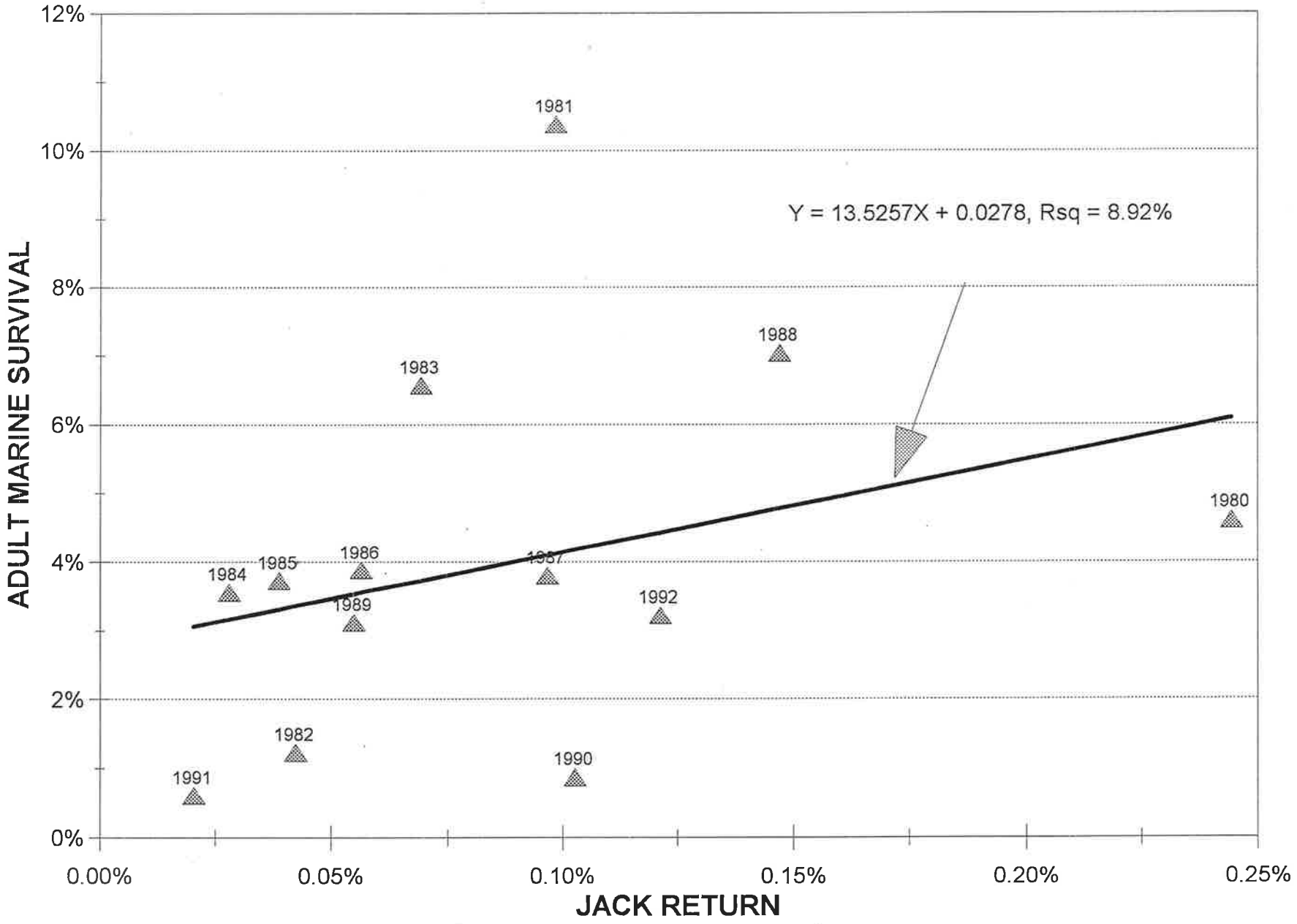


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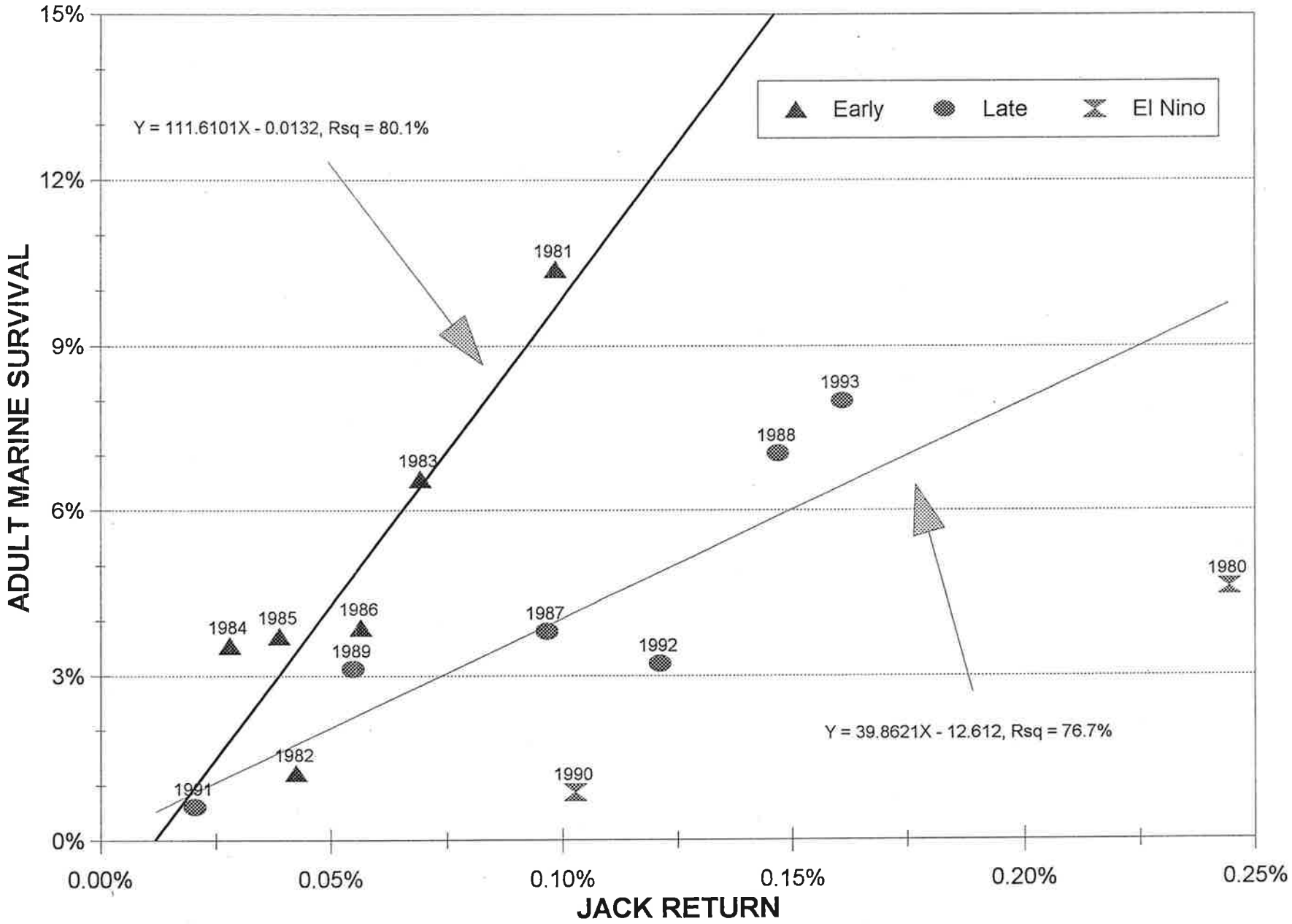
**Figure 11.** **JACK RETURN vs ADULT MARINE SURVIVAL**
**BINGHAM CREEK, BYs 1980-1992**

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