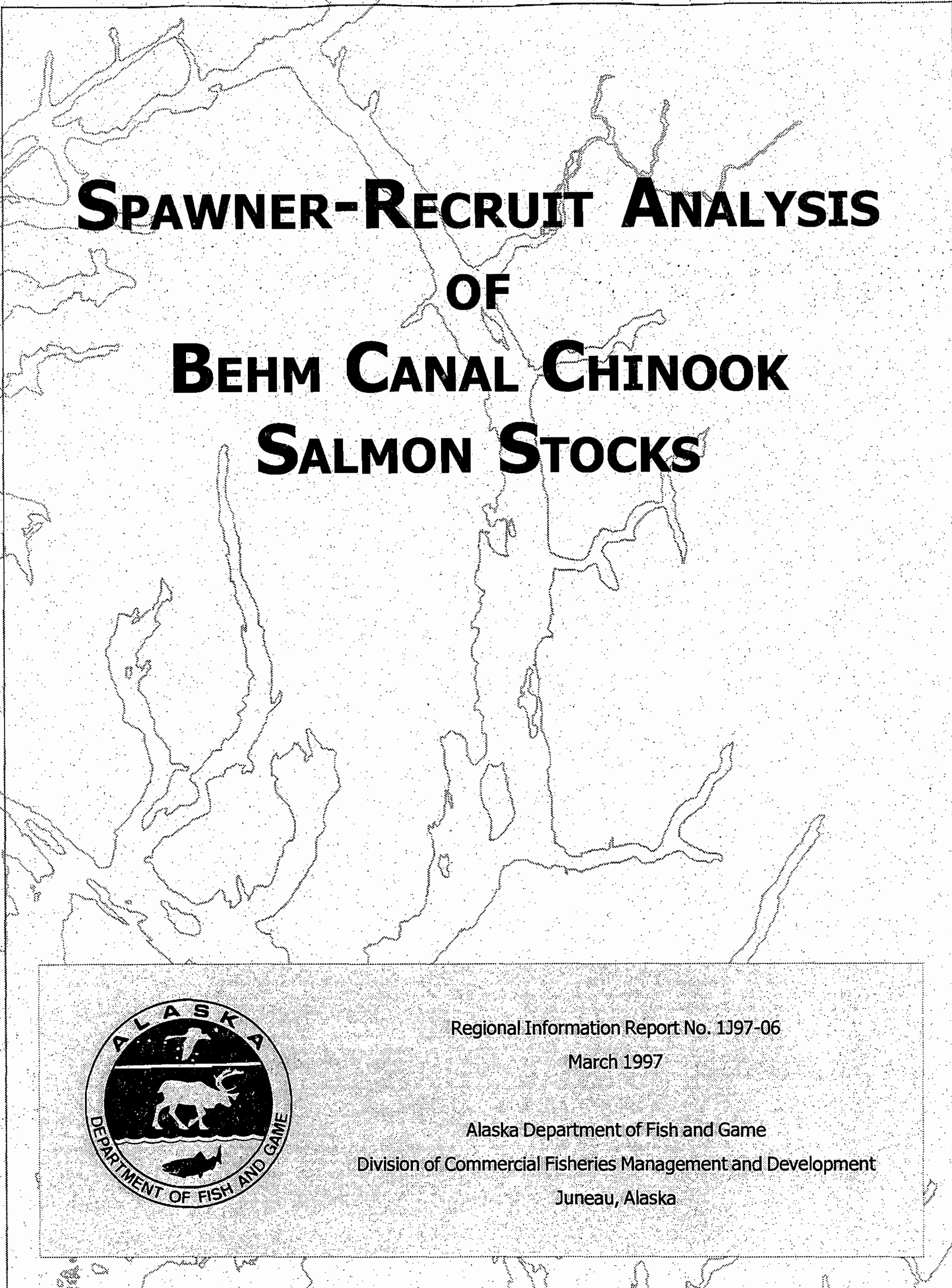

Spawner-Recruit Analysis of Behm Canal Chinook Salmon Stocks

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Division of Commercial Fisheries Management and Development

Juneau, Alaska

SPAWNER-RECRUIT ANALYSIS
OF
BEHM CANAL CHINOOK SALMON STOCKS

By

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and
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ABSTRACT

We estimated the total adult returns of chinook salmon *Oncorhynchus tshawytscha* and spawner-recruit parameters for fish returning to the Unuk, Chickamin, Blossom, and Keta Rivers in the Behm Canal area of southern Southeast Alaska. Utilizing estimated landed and total fishing mortality, escapement and age composition data, estimated total returns were compiled and a Ricker model with log-transformed data and a non-linear least squares subroutine was used to estimate parameters. To determine parameters, the estimated number of large spawners in the parent year was used as the independent variable with estimated total returns from those adults in all subsequent years as the dependent variable. We compiled five sets of data for each river using: two different expansions of the index counts of spawning fish, two measures of the "spawner-variability" and the removal of brood years with poor marine survival. The mortality associated with fishing was estimated from a combination of known hatchery and wild-stock fishing mortality rates. We used bootstrap methodology to estimate bias and precision of parameter estimates, which included variation in spawners.

As a result of this analysis we recommend the following "biological escapement goals" for the four Behm Canal chinook salmon index systems: (1) the Unuk River, a range of 650 to 1,400 large index spawners, (2) the Chickamin River, a range of 450 to 900 large index spawners, (3) the Blossom River, a range of 250 to 500 large index spawners, and (4) the Keta River, a range of 250 to 500 large index spawners.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, spawner-recruit, biological escapement goal, brood tables, marine survival, Unuk River, Chickamin River, Blossom River, Keta River, Behm Canal, Southeast Alaska

INTRODUCTION

The Unuk, Chickamin and Blossom rivers flow through the Misty Fjords National Monument/Wilderness Area into Behm Canal in southern Southeast Alaska. The rivers are pristine, with habitat almost entirely unaltered by human development. The Keta River shares the same pristine habitat, but flows into nearby Boca de Quadra (Figure 1). Collectively, these rivers make up the Behm Canal index systems for the chinook salmon *Oncorhynchus tshawytscha* escapement estimation program in Southeast Alaska (Pahlke 1995a). There are several additional mainland river systems in the Behm Canal area which produce chinook salmon and in which chinook escapements are occasionally surveyed.

In the mid-1970s it became apparent that some chinook salmon stocks in Southeast Alaska (SEAK) were depressed relative to historical numbers of fish (Kissner 1974). As a result, a fishery management and research program was initiated by the Alaska Department of Fish and Game (ADF&G) to rebuild the depressed SEAK chinook salmon stocks (ADF&G 1981). In 1981 a 15-year rebuilding program for these chinook salmon stocks was formally initiated. The program included stocks from transboundary rivers whose headwaters originate in Canada and flow into SEAK coastal waters: Alsek, Chilkat, Taku, Stikine, Unuk, and Chickamin rivers; as well as stocks from rivers that are found entirely in Alaska: Situk, King Salmon, Blossom, and Keta rivers and Andrew Creek (a U.S. tributary of the Stikine River). In 1985 the SEAK rebuilding program was incorporated into a broader north-Pacific coastwide rebuilding program for natural stocks of chinook salmon under the auspices of the U.S./Canada Pacific Salmon Treaty.

One important aspect of the rebuilding process was to establish escapement goals (desired number of spawners) for the chinook systems. Establishing appropriate escapement goals can provide an objective framework for developing management strategies, monitoring status of stocks, and judging the effects of management actions. The initial goals established for these systems were recognized as interim goals that would be reviewed in the future as more data became available. These interim goals were often established as the highest previously observed escapement count. In almost all of these rivers escapement counts were peak survey counts, the highest single day count in all or a portion of each river. These highest peak counts became the index escapement goals.

Spawning chinook salmon are now counted annually in each of the rivers listed above. This information can be used to manage for sustained or maximum sustained yield (Pahlke 1995a). In the Behm Canal index systems, large (3-ocean-age or older) chinook salmon are counted in specified areas as an index of total escapement which represents a standardized fraction of total escapement for each river. Since 1975 to the present, indices of escapement in each of the Behm Canal chinook salmon systems are roughly dome-shaped, with peak values occurring between 1987 and 1990 (Figure 2; Pahlke 1995a). The peak index values of escapement (1986-1989) were 2 to 9 times greater than "baseline" (1975-1980) values. In 1986 and 1987 it appeared that all four systems were rebuilding because index counts were above the interim escapement goals established in 1981 (Figure 2). Subsequently, index counts dropped sharply to levels below the interim escapement goals in all four rivers. Concern for the present status of Behm Canal chinook salmon populations prompted this investigation.

The purpose of this study is to analyze the available Behm Canal chinook salmon spawner-recruit data in relation to stock status and escapement goals.

STUDY AREA AND HISTORICAL ESCAPEMENT GOALS

The number of adult chinook salmon spawners returning to freshwater to spawn is termed escapement. Escapements used in this report were obtained from counts of returning fish in specified index areas of each river. The adult chinook salmon are counted either from the air using a helicopter or during foot surveys, and occasionally both methods are deployed. Adult counting was conducted two to four times per season in each index area (Pahlke 1995a). The highest single-day counts, summed across all index areas in a river system, are used as the escapement index for that river system in a given year.

Only "large" spawners, 3-ocean-age and older are used as escapement in this report (Ages 0.3, 1.3, 2.3, 0.4, 1.4, 2.4, 0.5, 1.5, and 2.5 in European aging notation, where the numeral preceding the decimal point is the number of years the fish spent in freshwater, with 0 as the first year. The numeral after the decimal point is the number of years the fish spent in the marine environment. The total age is the sum of both numerals plus one.). Large spawners are most often ≥ 660 mm mid-eye to fork-of-tail in length. Smaller chinook spawners that have spent one or two years at sea, are not included because they: are almost all males and, though biologically important, are generally considered numerically surplus to spawning needs; and are difficult to count and distinguish from other species of salmon. Additionally, inclusion of only large spawners is more representational of actual egg deposition.

Chinook salmon from the Behm Canal rivers are "spring" or "stream type" stocks. The term spring refers to adult chinook salmon present in terminal marine waters, adjacent to their spawning streams, in June and July. These salmon spawn from early August through early September (Mecum and Kissner 1989). Almost all juveniles rear for one year in freshwater after emergence and enter the sea as yearling smolt (age-1.0). Behm Canal chinook salmon are found principally in U.S. waters of SEAK during most of their marine life history; some also range south into northern British Columbia marine waters (Pahlke 1995b). The spawning population is comprised primarily of ages .2, .3, and .4; age .5 or older fish are uncommon (<5% of the run).

Escapement enumeration in Behm Canal rivers began in 1975 on the Chickamin, Blossom, and Keta rivers and in 1977 on the Unuk River. Following six years, 1975-1980, of escapement assessment, it was commonly believed that most of these as well as the other largest SEAK chinook stocks were at depressed levels. Initial escapement goals were set as the largest escapements observed prior to 1981 (ADF&G 1981). This approach was taken in the absence of direct spawner-recruit or other scientific data and was based on two considerations: evidence available at that time suggested some SEAK chinook salmon runs were substantially below historical levels, and; observations by biologists familiar with the systems indicated recently observed maximum escapements did not exceed the capacity of known spawning areas. At that time we felt the interim goals would more closely approximate optimum levels than would the depressed escapements observed during the late 1970s. It is important to note that we presumed the interim escapement goals would be modified as new information on stock productivity became available.

Unuk River

The Unuk River originates in a heavily glaciated area of northern British Columbia and flows for 129 km to Burroughs Bay 85 km northeast of Ketchikan, Alaska; the lower 39 km of the river are in Alaska (Pahlke 1995a). The Unuk River drainage encompasses an area of approximately 3,885 km^2. Approximately 85% of spawning occurs in clear or partially occluded tributaries in the U.S. portion of the drainage. The index area includes six U.S. tributaries (Eulachon River and Clear Lake, Genes Lake, Kerr and Cripple creeks) where an estimated 83% (SE = 9%) of spawning occurs. This was estimated by tracking returning adults that had been captured and fitted with radio transmitters (Pahlke et al. 1996). An additional 2% were estimated to have spawned in the U.S. outside of the index area. As a result of a mark-recapture study in 1994, we estimated 15% of the large spawners were counted in the index surveys (The survey count was 711 large spawners and the mark-recapture estimate was 4,623; SE = 1,266.) (Pahlke et al. 1996). The peak of spawning activity ranges from about August 6 in the uppermost tributaries to August 20-30 in the lowermost tributaries. The mainstem of the river is glacially occluded from May through early October and is clear over the remainder of the year. Fingerling chinook salmon rear in mainstem areas.

The Unuk River interim index escapement goal of 1,800 was established in 1981 as the maximum observed index count from 1961 to 1980, which was initially recorded as 1,765 fish in 1978 (ADF&G 1981). The 1978 escapement count was revised downward in 1985 when it was discovered that some of the 1978 counts had been entered twice in the database. The resulting escapement was 1,106 fish, which is still the peak index count prior to the rebuilding period (Table 1). Regardless of the adjustment to the 1978 number, the index goal was never lowered. The index goal of 1,800 large spawners has been exceeded three times since 1984 (Figure 2A).

Chickamin River

The Chickamin River is a glacial river that originates in British Columbia and flows into Behm Canal approximately 32 km southeast of Burroughs Bay. Almost all of the drainage occurs in the U.S. (Pahlke 1995a). Like the Unuk River, the Chickamin is glacially occluded during warm months and clear during cold months. Chinook salmon spawning areas are primarily in clear or partially occluded tributaries in the U.S. Chinook salmon fingerlings rear in the U.S. section of the mainstem. The index area includes seven clear-water tributaries and one partially occluded tributary. Peak spawning ranges from about August 12 to September 2. As the result of a mark-recapture study in 1995, we estimated that about 15% of the large spawners are counted in the index area surveys (survey count = 356 large spawners and mark-recapture estimate = 2,309; SE = 723) (Pahlke 1996).

The Chickamin River interim index escapement goal of 900 large fish was established in 1981 based on the 1972 escapement count of 860 fish (ADF&G 1981). This index goal was exceeded five times between 1984 and 1989 (Table 1; Figure 2B).

Blossom River

The Blossom River is a clear-water river, draining an area of approximately 176 km^2 entirely within the U.S. (Bigelow et al. 1995). The river valley is steep sided without low-gradient tributaries. Spawning and rearing occur in the mainstem of the river.

The Blossom River interim index escapement goal was originally established in 1981 as a combined goal for the Wilson and Blossom Rivers. The goal was 800 fish, based on the 1963 escapement of the two rivers of 825 fish, 450 in the Blossom River and 375 in the Wilson River (ADF&G 1981). Prior to 1985, the Wilson River was removed from the index. To be consistent with methodology used to establish other goals in 1981, it should have been lowered to 450, but was not. This index goal of 800 has been surpassed in only two years, in 1986 and 1987 when index counts of 1,278 and 1,349 large spawners were observed (Table 1; Figure 2C).

Keta River

The Keta River is a clear-water stream, draining an area of approximately 192 km^2 entirely within the U.S. (Bigelow et al. 1995). Spawning and rearing occur primarily in the mainstem of the river.

The Keta River interim index escapement goal of 500 large spawners was established in 1981 based on counts of 500 fish in 1948 and 462 fish in 1952 (ADF&G 1981). This index goal was met consistently from 1982 to 1990, but not in 1991-1995 (Table 1; Figure 2D).

METHODS

Database

Spawners

Salmon runs are dynamic because fish continually move into and out of streams, spawn, and die. Therefore, any observer count (i.e. index count) will underestimate the total escapement across the season. Thus, index counts of adult chinook salmon must be expanded to estimate total escapement. Estimates of total escapement are combined with catch data to estimate the total annual run. Information from aging fish is used to determine contributions from a specific brood year. In 1981, when interim escapement goals were set, we assumed that 62.5% of the total escapement was enumerated in each of the four Behm Canal index rivers when the interim escapement goals were set, but new evidence discounts that assumption. In 1994 on the Unuk River (Pahlke et al. 1996) and in 1995 on the Chickamin River (Pahlke 1996), mark-recapture methodology was used to estimate total escapement. In both cases index counts represented about 15% of the mark-recapture estimates. We therefore used the annual index/0.15 to estimate total escapement for the Unuk and Chickamin rivers and also used each annual index/0.25 to provide a range of total escapement. The Blossom and Keta rivers are smaller drainages and have clear-water mainstems (usually). We assumed a higher fraction of total escapement is counted during surveys in those two rivers based on experience in other SEAK rivers where index surveys and total escapement were measured concurrently. Hence, annual index counts for the Blossom and Keta rivers were both divided by 0.40 and 0.25 to provide the range of estimated total escapements for those two rivers.. These expanded counts formed the number of spawners used in the databases.

Returns

The total return for each wild stock was calculated as the sum of the estimated number of returning chinook salmon of all age classes including: escapements, landed catch, and incidental fishing mortality from an individual brood year:

$$\hat{R}_i = \hat{C}_i + I\hat{M}_i + \hat{E}_i; \tag{1}$$

where: $\hat{R}_i$ = estimated total return for brood year *i*;

$\hat{C}_i$ = estimated landed catch for brood *i* (see below);

$I\hat{M}_i$ = estimated incidental mortality for brood *i* (see below); and

$\hat{E}_i$ = estimated escapement returning from brood *i*.

Total returns from a given escapement in brood year *i* are typically caught and counted in escapements over five ocean ages in years, beginning in year *i*+3 with age 1.1. For example, returns from the escapement in 1980 would be found in catches and escapements as age-1.1 fish in 1983 and as age-1.5 fish in 1987.

The estimate of escapement from a given brood year, $\hat{E}_i$, in Equation (1), was calculated from the sum of age classes returning in escapements.

$$\hat{E}_i = \sum_{j=1}^{k} \hat{E}_{ij}\,(AEQ_{ij}) \tag{2}$$

where: $\hat{E}_{ij}$ = the escapement for brood *i* and age *j*, and *k* = the number of age classes.

The estimated escapement from a brood year ($\hat{E}_i$) was calculated from the expanded counts of large chinook salmon and estimated age structure (see Tables 2-5). Age structure was estimated from scales of adult salmon spawning in tributaries on all four rivers. Scale age determinations from Unuk and Chickamin river chinook were validated with scales from fish recovered on spawning grounds carrying coded wire tags. Average age structure was used in years when scales were not collected. Scales were collected from Blossom River escapements only in 1985 and from Keta River escapements only in 1982 and 1984. Because the 1985 data indicated the age structure of Blossom River chinook salmon was similar to the average age composition for chinook salmon from the Unuk and Chickamin (combined), the age structure of Unuk and Chickamin chinook salmon was used to estimate the annual age structure for Blossom River. Because the age structure of chinook salmon returning to the Keta River was dissimilar from that of the other systems, the average for 1982 and 1984 was used.

In order to calculate the total return of naturally reproduced adult chinook salmon, including landed catch and incidental mortality, we had to use harvest estimates of hatchery produced fish because data from naturally reproduced stocks was limited. Naturally produced fish, 1982-1986 broods, from the Unuk and Chickamin were tagged. Because of the presence of tags, we were able to estimate the harvest from these broods of chinook salmon (Pahlke 1995b). Rather than use the average from the 1982-1986 wild-stock data to estimate harvests for the 1975-1981 and 1987-1989 broods, we chose to use within-year hatchery data to estimate fishing mortality.

Landed catch and incidental fishing mortality were estimated with methodology used by the Pacific Salmon Commission Chinook Technical Committee (CTC) in their exploitation rate analysis (CTC 1996; Chapter 3). The CTC exploitation rate analysis estimates total fishing mortality for a particular coded wire tag (CWT) indicator stock by:

$$\hat{FM}_i = \sum_{j=1}^{k} \hat{C}_{ij}\,(AEQ_{ij}) + \sum_{j=1}^{k} \hat{IM}_{ij}\,(AEQ_{ij}); \quad and\ \hat{C}_i = \sum_{j=1}^{k} \hat{C}_{ij}\,(AEQ_{ij});\ \hat{IM}_i = \sum_{j=1}^{k} \hat{IM}_{ij}\,(AEQ_{ij});$$

$$\hat{FM}_i = \hat{C}_i + \hat{IM}_i \qquad (3)$$

where: $\hat{FM}_i$ = estimated total fishing mortality for brood i in adult equivalents (AEQs);

$\hat{C}_{ij}$ = estimated landed catch for brood i of age j;

$\hat{IM}_{ij}$ = estimated incidental mortality for brood i of age j; and

AEQ_{ij} = adult equivalent factor for brood i and age j.

Returns in landed catch and incidental fishing mortality were calculated in adult equivalents (AEQs) because a significant portion of both escapements and fishing mortality occurs at younger ages (total age 3 and 4) for Behm Canal chinook stocks (Pahlke 1995b). Age-specific and brood-specific adult equivalent factors used for Unuk and Chickamin stocks are similar (Appendix A.1.), but slightly different across stocks and broods for each age. These values were estimated from hatchery stocks; AEQ factors averaged 0.58 for age-3 fish, 0.80 for age-4 fish, and 0.97 for age-5 fish (100 age-3 fish caught were calculated as 58 fish in AEQs). Total returns expressed as adult equivalents are always less than the observed number of fish.

Landed catch is estimated directly from recoveries of CWTs from the stock of interest over several ocean ages (age .2 to age .6) in all fisheries. Incidental fishing mortality is calculated based on the assumption that a portion of chinook salmon caught and released die due to handling. Incidental fishing mortality in SEAK occurs from encounters of legal-size ($\geq$ 28 in total length) chinook salmon during periods of nonretention in sport and commercial fisheries as well as from the capture and release of fish in the sport fishery during periods when chinook salmon can be retained. Incidental fishing mortality of sublegal sized chinook salmon occurs both during periods of retention and nonretention in SEAK fisheries. At present the CTC analysis assumes that 30% of chinook caught and released in commercial troll and sport fisheries die after release, and that 90% of chinook caught and released in commercial net fisheries die after release. These assumptions probably overestimate incidental fishing mortality because the mortality rates used at present are higher than those in contemporary literature (Wertheimer et al. 1989; NRC 1994); this estimation procedure is currently under review by the CTC committee.

We used recoveries of coded wire tagged hatchery stocks in order to estimate total fishing mortality rates. First, we separated out hatchery tag codes unique to the Unuk River brood stock. These codes and recovery data were available for the 1978-1988 brood years from three Ketchikan area hatcheries (Deer Mountain, Whitman Lake, and Neets Bay; Figure 1); 1978 was used to estimate 1977 and 1988 was used to estimate 1989. We also separated out hatchery tag codes used on Chickamin River brood stock, which were available from 1983-1989 from Ketchikan area facilities. For the 1978-1982 broods for Chickamin River, we used tag codes for Unuk and Chickamin stock from Ketchikan area facilities as well as from the Little Port Walter facility on southern Baranof Island. These data were used to calculate estimated total fishing mortality in numbers of fish as in Equation (3) for each brood of hatchery Unuk River fish and each brood of hatchery Chickamin River fish. We then calculated the total fishing mortality rates for the hatchery fish by,

$$FM\hat{R}_{ih} = \frac{\hat{C}_{ih} + I\hat{M}_{ih}}{\hat{C}_{ih} + I\hat{M}_{ih} + \hat{E}_{ih}} \tag{4}$$

where: $FM\hat{R}_{ih}$ = estimated total fishing mortality for brood i for hatchery stock h (Unuk or Chickamin) in adult equivalents;

$\hat{C}_{ih}$ = estimated landed catch for brood i for hatchery stock h;

$I\hat{M}_{ih}$ = estimated incidental mortality for brood i for hatchery stock h; and

$\hat{E}_{ih}$ = estimated return in escapement for brood i for hatchery stock h.

Estimated landed catches for the 1982-1986 broods for Unuk and Chickamin wild stocks were calculated from recoveries of wild-stock CWTs (Pahlke 1995b). Wild fingerlings in fall and smolt in spring were coded wire tagged on these two rivers for five broods, 1982-1986. Fish from these brood years were caught from 1985 through 1993. Commercial troll, gillnet, and purse seine fisheries were sampled in those years by the Commercial Fisheries Management and Development Division (CFMDD). Recreational fisheries were sampled in most of those years by the Division of Sport Fish. In addition, fisheries were sampled in British Columbia waters by the Canadian Department of Fisheries and Oceans. These recovery efforts provided estimates of total landed catch by age for fish from the 1982-1986 broods of chinook salmon from the Unuk and Chickamin rivers. Incidental fishing mortality (AEQ) for the wild stocks was calculated from the hatchery stock data, assuming that the ratio of landed catch to incidental fishing mortality for a given brood year was the same for hatchery and wild stocks by,

$$FM\hat{R}_i = \left(CM\hat{R}_{ih} + IM\hat{R}_{ih}\right) p_w \tag{5}$$

where: $FM\hat{R}_i$ = estimated total fishing mortality rate (wild stock) for brood year i;

$CM\hat{R}_{ih}$ = estimated landed catch mortality rate for the hatchery stock h for brood year i;

$IM\hat{R}_{ih}$ = estimated incidental mortality rate for the hatchery stock for brood year i; and

p_w = the average of $FM\hat{R}_i$ / $FM\hat{R}_{ih}$ for brood years 1982-1986 (estimated separately for Unuk and Chickamin stocks).

Fishing mortality rates for all brood years of hatchery produced fish were scaled by p_w observed for Unuk and Chickamin wild stocks for the 1982-1986 brood years because the hatchery rates were generally greater. These rates are higher because it is difficult to fully account for hatchery terminal runs, some fish stray and fisheries in the Ketchikan area specifically target hatchery stocks. For example the average total fishing mortality estimated for Unuk wild stock (1982-1986 for 25% escapement expansion) was 52% of that observed for the Unuk hatchery stock data. Because of this, the Unuk hatchery stock mortality rates for all brood years were multiplied by 0.52 (=p_{Unuk}) to estimate Unuk wild-stock mortality rates for the 25% escapement expansion.

Wild-stock fishing mortality in numbers of fish was calculated by,

$$\hat{FM}_i = \frac{\hat{E}_i}{(1 - FM\hat{R}_i)} \tag{6}$$

where: $\hat{FM}_i$ = estimated fishing mortality (wild stock) for brood year i, and
$\hat{E}_i$ = estimated escapement for brood year i.

Total returns ($\hat{R}_i$) for a wild stock from a given brood were calculated by,

$$\hat{R}_i = \hat{E}_i + \hat{FM}_i . \tag{7}$$

Unuk River fishing mortality rates were used for Blossom and Keta river wild stocks. Total returns were estimated for the 1977-1989 brood years for the Unuk River and for the 1975-1989 brood years for the Chickamin, Blossom, and Keta rivers.

Spawner-Recruit Parameter Estimation

The Ricker stock recruitment curve (Ricker 1954) has been widely used in population dynamics. Many studies have fit the Ricker curve to spawner-recruit data and then calculated optimum escapement (Hilborn 1985). The Ricker (1975; Appendix III, curve 1) spawner-recruit model is,

$$R = S \alpha e^{-\beta S} \tag{8}$$

where: R = total return of all ages;
S = number of large spawners; and
α and β = parameters to be estimated.

This model was used to estimate spawning requirements and other parameters for each stock. Parameter α is an estimate of the number of returning adults, from a given spawning adult, in the absence of density dependence and is a measure of the productivity rate of a stock. The parameter β is a measure of capacity and the inverse of β is the number of spawners that produces the theoretical average maximum return (P_m) for the stock of interest. When estimated, these two parameters are used to calculate expected total return from a given level of spawners. The result is a curvilinear line that is dome-shaped, showing a decrease in total returns to the right of $1/\beta$ (P_m) as the number of spawners increases (Figure 3). The rate of ascent of total returns on the left side of P_m is greater than the rate of descent of total returns on the right side.

Several other parameters of interest to fishery managers can be derived from α and β [see Appendix III, Curve 1 in Ricker (1975)]. Optimal escapement (P_s), is estimated by an iterative solution of,

$$1 = (1 - \beta P_s)\,\alpha(-\beta P_s). \tag{9}$$

In Figure 3 (a hypothetical example) the lower diagonal line is the number of spawners and the difference between spawners and returns (the curved line) is the available harvest. The right-hand-side of Equation (9) is the slope (first derivative) of Equation (8) at a given number of spawners. When the slope = 1.0 (i.e., the tangent at P_s,R_s), the difference between spawners and returns is maximized. This level of spawners (P_s) producing MSY (labeled MSH in Figure 3) is defined as the biological escapement goal (BEG) by ADF&G in the salmon escapement goal policy adopted in 1992.

Parameters were estimated from nonlinear least squares (steepest descent method) using a modification (natural log transformation) of Equation (8),

$$\ln(\hat{R}_i) = \ln(\hat{\alpha}) + \ln(\hat{S}_i) - \hat{\beta}\hat{S}_i + \varepsilon_i \tag{10}$$

where: $\ln(\hat{R}_i)$ = the natural log of estimated total returns for brood i;

$\ln(\hat{S}_i)$ = the natural log of estimated large spawners in brood year i; and

$$\varepsilon_i = \frac{\ln(\hat{R}_i) - \ln(R^+)}{\sqrt{\left(1 - \frac{z}{n}\right)}}; \tag{11}$$

where: R^+ is the predicted return for a given stock, using the estimated α and β for that stock and data set;

z is the number of parameters estimated (two); and

n is the number of brood years in the data set.

The denominator for estimating ε is a correction factor for bias of residuals (Wu 1986).

Estimation of Parameter Precision

Both the variance (mean square error) and confidence intervals for $\hat{\alpha}$, $\hat{\beta}$, and $\hat{P}_s$ for each data run on each stock were estimated with modifications of bootstrap procedures in Buckland and Garthwaite (1991) and McPherson (1990). Five bootstraps, consisting of 1,000 replicates were run for each stock (see below), with two different index expansions to estimate total escapement (e.g., index/0.15 and index/0.25). The estimates were allowed to vary within two ranges for each escapement observation (i.e., ± 20% or ± 30%). In another bootstrap run, years with poor marine survival were removed from the data set. Error structure for Y (returns) was assumed to be multiplicative-lognormal and error structure of X (large spawners) was assumed to be multiplicative (Walters and Ludwig 1981). A uniform probability distribution between 0.8 and 1.2 (i.e., $\hat{S}_i$ ± 20%) or between 0.7 and 1.3 (i.e., $\hat{S}_i$ ± 30%) was used as indicated from the distribution of predicted total escapement seen in other studies for SEAK chinook stocks where index surveys were conducted concurrent with total escapement estimates (Figure 4). Walters and Ludwig (1981) showed that multiplicative error structure for spawners, either normally or uniformly distributed, produced essentially the same results.

For each bootstrap run, the original data set was fit using Equation (10) and bias corrected residuals (ε_i) were stored. For each replicate, the same number of X and Y observations in the original data set were calculated. Each Y observation in a replicate was calculated as $R_i^* = R_i^+ + \varepsilon$ (selected at random with replacement). Each X observation was calculated as $S_i^* = S_i\, p^*$, where p^* was a random number $1.0 \pm$ Xvar. A new set of statistics $\{S_i^*, R_i^*\}$ along with new estimates for $\hat{P}_s^*$, $\hat{\alpha}^*$, and $\hat{\beta}^*$ were generated from each bootstrap sample, and 1,000 such bootstrap samples were drawn creating the empirical distributions $\hat{F}(\hat{P}_s^*)$, $\hat{F}(\hat{\alpha})$, and $\hat{F}(\hat{\beta})$ which are estimates of $F(P_s^*)$, $F(\hat{\alpha})$, and $F(\hat{\beta})$. The difference between the average of bootstrap estimates and the original estimate is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Confidence intervals were estimated from $\hat{F}(\hat{P}_s^*)$, $\hat{F}(\hat{\alpha})$, and $\hat{F}(\hat{\beta})$ with the percentile method (Efron and Tibshirani 1993, Section 13.3). Variance was estimated as $v(\hat{P}_s^*) = (B-1)^{-1} \sum_{b=1}^{B} \left(\hat{P}_{s(b)}^* - \overline{\hat{P}}_s^*\right)^2$ where B is the number of bootstrap samples (1000). The variance of $\hat{\alpha}^*$ and $\hat{\beta}^*$ was estimated similarly. Management ranges for $\hat{P}_s$ were estimated using the 95% confidence interval or $0.8(\overline{\hat{P}}_s^*)$, to $1.6(\overline{\hat{P}}_s^*)$, whichever was greater (Eggers 1993). This method examined optimizing harvests over a wide range of management scenarios. The bootstrap mean for P_s was larger than the point estimate from the original data set and was used as the basis for setting biological escapement goal ranges for all four stocks (see Results).

Marine Survival

Marine survival was calculated in adult equivalents for: the 1982-1986 broods for the Unuk River wild stock; the 1982-1984 broods for the Chickamin wild stock; the 1981-1988 broods for Chickamin hatchery stocks at the Ketchikan and Little Port Walter hatcheries; and for the 1978-1988 broods for Unuk hatchery stocks at the Ketchikan and Little Port Walter hatcheries. Marine survival was calculated by dividing the estimated smolt production by the AEQ total return. These data were used to gain insights into potential affects on parameter estimation.

Bootstrap Data Runs

Five data runs were done for each of the four stocks (see below). For example, for the Unuk stock, the first data run utilized 13 paired X (large spawners) and Y (total returns) observations for the 1977-1989 broods, with escapement measured as the index/0.15, and with $\pm$ 20% spawner variability. The third data run for each stock was done by excluding broods with poor marine survival (1975, 1985 and 1987-1989). These years were removed because the 1985 and 1987-1989 data points were clustered on the right-hand-side of the spawner recruit curve and we felt they might not represent the true spawner-recruit relationship, without balance of an equal number of points in that region of the curve which exhibited average or above-average marine survival.

Data runs to estimate spawner-recruit parameter precision for Behm Canal chinook salmon stocks.

Stock	Data Run	Brood Years	n[a]	Escapement Expansion	Spawner Variability
Unuk	1	1977-1989	13	Index/0.15	±20%
	2	1977-1989	13	Index/0.15	±30%
	3	1977-84+86	9	Index/0.15	±20%
	4	1977-1989	13	Index/0.25	±20%
	5	1977-1989	13	Index/0.25	±30%
Chickamin	1	1975-1989	15	Index/0.15	±20%
	2	1975-1989	15	Index/0.15	±30%
	3	1976-84+86	10	Index/0.15	±20%
	4	1975-1989	15	Index/0.25	±20%
	5	1975-1989	15	Index/0.25	±30%
Keta	1	1975-1989	15	Index/0.25	±20%
	2	1975-1989	15	Index/0.25	±30%
	3	1976-84+86	10	Index/0.25	±20%
	4	1975-1989	15	Index/0.40	±20%
	5	1975-1989	15	Index/0.40	±30%
Blossom	1	1975-1989	15	Index/0.25	±20%
	2	1975-1989	15	Index/0.25	±30%
	3	1976-84+86	10	Index/0.25	±20%
	4	1975-1989	15	Index/0.40	±20%
	5	1975-1989	15	Index/0.40	±30%

[a] n=number of brood years

RESULTS

Unuk River

Among the southern SEAK rivers, the Unuk has the largest run of chinook salmon. Escapements averaged 1,135 large spawners in index surveys and an estimated 7,567 total large spawners (index/0.15) for 1977-1995 (Table 1). The estimated calendar-year age composition in the escapement averaged 9% age 1.1, 20% age 1.2, and 34% for ages 1.3 and 1.4 for 1984-1994 (Table 2). Estimated brood-year returns (with fishing mortality in adult equivalents [AEQs]) for the 1977-1989 broods averaged 14,793 chinook salmon, using the 15% escapement expansion and 9,890 fish using the 25% expansion (Table 3). Exploitation was estimated to be low, with escapements comprising 83% of estimated total returns for the 15% escapement expansion and 74% for the 25% escapement expansion (Appendix A.2.; Table 3). In the spawner-recruit data sets (1977-1989 broods), estimated total escapements ($\hat{S}_i$) ranged from 3,840 (1979) to 14,173 (1986) for the 15% escapement expansion and from 2,304 to 8,506 for the 25% expansion, a four-fold range.

Estimated total fishing mortality averaged 18% for the 1982-1986 brood years, based on the wild-stock tagging and the 15% escapement expansion. The estimated mortality was comprised of 11% landed catch and 7% incidental fishing mortality (Appendix A.3.). Total fishing mortality averaged 17% for all broods using the 15% escapement expansion and mortality rates of hatchery stocks was scaled to wild rates. Total fishing mortality was highest for the 1982 brood (23%), which also had the highest estimated incidental mortality rate (9%). Incidental mortality was lowest for the 1978 brood (3%). Estimated landed catch was highest for the 1978 brood (14%) and lowest for the 1985 and 1988 broods (8%). The fishing mortality rates were similar in trend, but higher in magnitude, for the 25% escapement expansion, averaging 26% total fishing mortality for the 1982-1986 broods and 25% for all broods.

Estimated total returns for the Unuk River were largest for the 1982 brood, 30,432 fish using the 15% escapement expansion and 21,416 for the 25% expansion, lowest for the 1985 brood, 4,539 fish (15% expansion), and averaged about 15,000 fish with the 15% expansion (Table 3; Figure 5). The estimated total return-per-spawner ratio ($\hat{R}_i / \hat{S}_i$) averaged 2.0:1 for the 15% expansion and 2.3:1 for the 25% expansion. A decreasing trend was evident, $\hat{R}_i / \hat{S}_i$ for the 1977-1984 broods ranged from 1.3 to 4.9 and the ratio for the 1985-1989 broods was less than 1.0.

Spawner-recruit parameter estimates are shown in Table 4. Point estimates for the productivity parameter α ranged from 5.8 (SE=3.2) to 6.9 (SE=3.1) and the bootstrap means ranged from 6.1 to 7.6, indicating statistical bias ranged from 6% to 12%. Note that statistical bias was lowest for estimates with 30% spawner variability. Point estimates for $\hat{\beta}$ ranged from 0.000136 (SE=0.00005) to 0.000245 (SE=0.00009) and the bootstrap means were all lower by 3% to 6% except for one data set, without the years of poor marine survival (3% higher).

Point estimates of $\hat{P}_s$ ranged from 2,810 (SE=1,314 or 1,380) for the 25% expansions to 5,180 (SE=1,540) for the 15% expansion with 20% spawner variability and without the years of poor marine survival. When scaled to index values, point estimates ranged from 677 to 777 and bootstrap means ranged from 731 to 818.

<u>We propose a biological escapement goal (BEG) range of 650 to 1,400</u>, based on the interval of 0.8 ($\bar{\hat{P}}_s^*$) where $\bar{\hat{P}}_s^*$ =818 (Lower BEG Range) to the upper end of the 95% confidence interval; utilizing Unuk data run #3 (excluding 1985 and 1987-1989 broods). The 95% confidence interval was used for the upper end of the range because it was greater than 1.6 ($\bar{\hat{P}}_s^*$) interval from Eggers (1993), whereas 0.8 (818) was used for the lower end of the range because it was greater than the lower 95% confidence interval of 525.

Chickamin River

The Chickamin River has the second largest run of chinook salmon in southern SEAK. Escapements averaged 594 large spawners in index surveys and an estimated total 3,957 large spawners (index/0.15) for 1975-1995 (Table 1). The estimated calendar-year age composition of chinook salmon in the escapement averaged 7% age 1.1, 16% age 1.2, 37% age 1.3, and 38% age 1.4 for 1986-1990 and 1995 (Table 5). Estimated brood-year returns (in AEQs) averaged 9,423 chinook salmon using the 15% escapement expansion and 6,886 fish using the 25% expansion for the 1975-1989 broods (Table 6; Appendix A.4.). In the spawner-recruit data sets (1975-1989 broods), estimated total escapements ranged from 1,045 (1976) to 11,634 (1986) for the 15% escapement expansion and from 627 to 6,980 for the 25% expansion, an 11-fold range.

Estimated total fishing mortality averaged 37% for the 1982-1986 brood years, based on the wild-stock tagging and the 15% escapement expansion (Appendix A.5.), rates which were almost double those observed for the Unuk stock. Fishing mortality was estimated to be comprised of 22% landed catch and 15% incidental fishing mortality. Total fishing mortality averaged 36% for all broods using the 15% escapement expansion and the mortality rates of hatchery-produced fish scaled to represent rates on wild fish. Total mortality was highest for the 1986 brood (50%). Estimated landed catch was highest for the 1984 brood (3,808 fish) and lowest for the 1985 brood (746 fish). The fishing mortality rates were similar in trend but higher in magnitude for the 25% escapement expansion, averaging 49% total fishing mortality for the 1982-1986 broods and 47% for all broods.

Estimated total returns for the Chickamin River were largest for the 1981 brood; 18,305 fish using the 15% escapement expansion and 12,819 for the 25% expansion. They were lowest for the 1985 brood; 4,247 fish (15% expansion), and averaged about 9,000 fish with the 15% expansion (Table 5; Figure 6). The total return per spawner, the $\hat{R}_i / \hat{S}_i$ ratio, averaged 3.1:1 for the 15% expansion and 3.7:1 for the 25% expansion. A decreasing trend was evident, $\hat{R}_i / \hat{S}_i$ for the 1977-1984 broods ranged from 1.8 to 8.3 and the ratio for the 1985-1989 broods were all near 1.0.

Estimates of spawner-recruit parameters appeared to be more precise for the Chickamin stock compared to the Unuk stock. Point estimates for $\hat{\alpha}$ ranged from 6.7 (SE=1.9) to 7.6 (SE=1.1) and the bootstrap means ranged from 6.9 to 7.8, indicating statistical bias ranged from 2% to 4%. Point estimates for $\hat{\beta}$ ranged from 0.000197 (SE=0.000032) to 0.000367 (SE=0.00009) and the bootstrap means were all lower by 1% to 2%. Point estimates of $\hat{P}_s$ ranged from 1,980 (SE=429) for the 25% expansions to 3,700 (SE=503) for the 15% expansion with 20% spawner variability excluding the years of poor marine survival. When scaled to index values, point estimates ranged from 437 to 555 and bootstrap means ranged from 451 to 552. <u>We propose a BEG range of 450 to 900 index counts,</u> based on the interval 0.8 ($\overline{\hat{P}_s^*}$), to 1.6 ($\overline{\hat{P}_s^*}$), where $\overline{\hat{P}_s^*}$=562; following methodology per Eggers (1993). This interval was used because it was greater than the 95% confidence interval (422 to 722) for Chickamin data run #3 (excluding 1975, 1985 and 1987-1989 broods).

Blossom River

The chinook salmon run in the Blossom River is smaller than the runs in the Unuk and Chickamin rivers. Escapements averaged 362 large spawners in index surveys and an estimated total 1,448 large spawners (index/0.25) for 1975-1995 (Table 1). The estimated calendar-year age composition in the escapement in 1985 was 25% age 1.2, 40% age 1.3, and 33% age 1.4 (Table 7). Estimated brood-year returns (in adult equivalents) averaged 3,301 chinook salmon using the 25% escapement expansion and 2,373 fish using the 40% expansion, for the 1975-1989 broods (Table 8; Appendix A.6.). In the spawner-recruit data sets (1975-1989 broods), estimated total escapements ranged from 216 (1979) to 5,396 (1987) for the 25% escapement expansion and from 135 to 3,373 for the 40% expansion, a 25-fold range.

The estimated total fishing mortality rates for the 25% expansion were the same as those used for the Unuk (18%; Table 8); the estimated fishing mortality rates for the 40% expansion averaged 26%. The estimated total return to the Blossom River was largest for the 1981 brood, 8,155 fish using the 25% escapement expansion and 5,715 for the 40% expansion; and lowest for the 1975 and 1989 broods.

The $\hat{R}_i / \hat{S}_i$ ratio, total return per adult spawner, was 5.4:1 for the 25% expansion and 6.2:1 for the 40% expansion. A decreasing trend in return per spawner was evident, similar to trends for Unuk and Chickamin river stocks.

Estimates of spawner-recruit parameters were consistent across the five data sets. Point estimates for $\hat{\alpha}$ ranged from 8.0 (SE=2.8) to 12.8 (SE=2.9) and the bootstrap means ranged from 8.5 to 13.1, indicating a statistical bias ranging from 3% to 6%. Point estimates for $\hat{\beta}$ ranged from 0.00069 (SE=0.00015) to 0.00110 (SE=0.00023) and the bootstrap means were all lower by 1% to 2%. Point estimates of $\hat{P}_s$, when scaled to index values, ranged from 270 to 280 and bootstrap means ranged from 275 to 293. Based on 0.8 ($\overline{\hat{P}_s^*}$), to 1.6 ($\overline{\hat{P}_s^*}$) (Eggers 1993), where $\overline{\hat{P}_s^*}$ = 300, we propose a BEG range of 250 to 500 large index spawners as the BEG for the Blossom River chinook salmon stock.

Keta River

The size of the chinook salmon run to the Keta River is similar to the size of the run to the Blossom River. Escapements averaged 466 large spawners in index surveys and an estimated total 1,865 large spawners (index/0.25) for 1975-1995 (Table 1). The estimated calendar year age composition in the escapement in 1982 and 1984 was 5% age 1.2, 37% age 1.3, and 53% age 1.4 (Table 9). Estimated brood-year returns (in adult equivalents) averaged 3,100 chinook salmon using the 25% escapement expansion and 2,225 fish using the 40% expansion, for the 1975-1989 broods (Table 10; Appendix A.7.). In the spawner-recruit data sets (1975-1989 broods), estimated total escapements ranged from 336 (1976) to 4,620 (1989) for the 25% escapement expansion and from 210 to 2,888 for the 40% expansion, a 14-fold range.

The estimated total fishing mortality rates for the 25% expansion were the same as those used for the Unuk (18%; Table 10); the estimated fishing mortality rates for the 40% expansion averaged 26%. The estimated total return to the Keta River was largest for the 1983 brood, 4,934 fish using the 25% escapement expansion and 3,493 for the 40% expansion.

The return rate per adult spawner, $\hat{R}_i / \hat{S}_i$, averaged 2.4:1 for the 25% expansion and 2.8:1 for the 40% expansion. There was a decreasing trend in return per spawner, similar to trends for stocks in the Unuk and Chickamin rivers.

Estimates of spawner-recruit parameters were consistent across the five data sets. Point estimates for $\hat{\alpha}$ ranged from 7.21 (SE=2.02) to 8.4 (SE=2.54) and the bootstrap means ranged from 7.1 to 8.6, indicating a statistical bias ranging from 1% to 2%. Point estimates for $\hat{\beta}$ ranged from 0.000681 (SE=0.00014) to 0.00114 (SE=0.00019) and the bootstrap means were all lower by 2% to 5%. Point estimates of $\hat{P}_s$, when scaled to index values, ranged from 253 to 275 and bootstrap means ranged from 259 to 287. Based on 0.8 ($\bar{\hat{P}}_s^*$), to 1.6 ($\bar{\hat{P}}_s^*$) (Eggers 1993), where $\bar{\hat{P}}_s^* = 300$, we propose a BEG range of 250 to 500 large index spawners as the BEG for the Keta River chinook salmon stock.

DISCUSSION

The four Behm Canal chinook salmon index stocks have experienced similar overall trends since the mid-1970s: a dome-shaped distribution of escapements, lower escapements in the 1970s and 1990s, and higher escapements in the 1980s (Figure 9). The index counts for both the Chickamin and Blossom stocks were below the lower end of the recommended range from 1975 to 1981. The returns to the Keta River were within the recommended range of escapement in three of seven years. The escapement of Unuk appears to have been near optimal levels from 1977 to 1981 (no surveys were conducted in 1975 and 1976). Escapements of all four stocks climbed to higher levels from 1982 to 1989. In the last few years, counts have dropped to levels at or slightly above those prior to 1982. Since total estimated fishing mortality rates have been reasonably consistent for both Unuk and Chickamin stocks (Appendices A.3 and A.5), fishing mortality rates alone cannot be used to explain the trends in escapements.

It is probable that the recent decline in chinook salmon escapement was the result of decreased marine survival rates. Density dependent mortality in freshwater may have also played a role in this trend. Estimated marine survival of the Unuk wild stock, from the 1982-1986 brood year CWT data, was lowest for the 1985 brood (Figure 10). Marine survivals seen at Little Port Walter Hatchery, using the Unuk stock, somewhat mirrored these trends. Survival of these fish reared at Little Port Walter Hatchery was lowest for the 1985 brood, followed by an increase in the 1986 brood and a decrease for the 1987 and 1988 broods. This is in contrast to marine survival trends seen in fish produced in the Ketchikan area hatcheries. Using only data from the Unuk stocks, marine survival was low for each brood after 1982 or 1983. However, inspection of Figure 11 shows marine survival decreased by an order of magnitude for all hatchery releases over 400,000 smolt; whereas, no clear trend is evident at Little Port Walter where Unuk releases have remained below 250,000 smolt. Data from the Chickamin River fish, both hatchery and wild stock, is more limited; marine survival has been low for the 1985, 1987, and 1988 broods (Figure 10). This trend has continued for the 1989 brood. Data from only the Unuk wild stock can be used to illustrate a decrease in numbers of smolt with increasing number of spawners, suggesting compensation (Figure 12). But, density dependent factors alone would not explain the changes in subsequent return levels from the peak on the Unuk spawner-recruit curve; where production from the 1984-

1987 broods was predicted to drop by less than 20% from the peak returns of 1979-1983, but actual production dropped by over 50% (Figure 5).

We made several assumptions in order to complete the spawner-recruit analyses: first, escapement numbers were relatively accurate within a river system for a given index expansion; second, fishing mortality summed landed catch and incidental mortality estimates for each brood year were reasonably accurate; and finally, the age structure for escapement was reasonably accurate. Under the first assumption, escapements were counted in index surveys in all four rivers using consistent methods since 1975. We have estimated expansion factors from studies in SEAK to provide a range of total escapements. The Chickamin, Blossom and Keta river surveys have been conducted from a low-flying helicopter, approximately 50 feet above the stream. Surveys on the Unuk River have been conducted by foot on the two largest tributaries and by helicopter on the other four. The index areas have remained the same on all four rivers in all years except the Chickamin, where three tributaries were added to the survey in 1981. Index counts on the Chickamin River from 1975-1980 were adjusted upwards to account for missing values. Two individual surveyors have done almost all of the surveys comprising the database, and the second was trained by the first.

In order to estimate expansion factors for the conversion of index counts to total escapement, we estimated total escapement to the Unuk River in 1994 (Pahlke et al. 1996) and in the Chickamin in 1995 (Pahlke 1996). Those studies indicate we were counting about 15% of the escapement in the index surveys; hence, we used index/0.15 as our best estimate of total escapement and also provided a range by using index/0.25 expansion values. For Blossom and Keta rivers surveys, we expanded the index counts less, index/0.25 and index/0/.40, because these rivers are smaller and are generally clear, usually providing better visibility for surveys. These expansions are more in line with expansions on clear water systems in other areas of SEAK where index surveys were conducted above weirs on a known number of large chinook salmon (Pahlke 1995a). Each total escapement estimate in each bootstrap replicate data set was varied by $\pm$ 20% or $\pm$ 30% for each expansion to account for variability in relative values.

Under the second assumption, the catches for the Unuk and Chickamin Rivers for the 1982-1986 brood years were estimated with an average coefficient of variation (CV = SE/estimate X 100) of 23% for the Unuk and 25% for the Chickamin (Pahlke 1995b). These data should provide a close approximation to the average mortality rate for both wild stocks. Since the number of tag recoveries from hatchery stocks was much greater than the number recovered from wild fish of the same stocks, we used information gathered on hatchery stocks to more precisely estimate fishing mortality. The fishing mortality rate associated with hatchery stocks was scaled to the rates for wild fish. We felt this approach would be an improvement over applying the average harvest rate for the 1982-1986 broods of chinook salmon from the Unuk and Chickamin rivers. The effect of using the estimated Unuk River harvest rates for the Blossom and Keta chinook salmon stocks is not directly available, but estimates of optimal escapement varied little over all five data sets for these two stocks (Table 4).

Using the final assumption, in most years scales were available for estimating the age structure of chinook salmon returning to the Unuk River. Scale collection sample sizes were generally large enough to estimate the percent of a given age class to within $\pm$ 10%. Escapement age structure data was incomplete for the Chickamin returns and lacking for the Blossom and Keta. Since only one or two years of age structure data were available for adult chinook salmon in these three systems, averages were used for almost all annual escapements. This approach introduces error in measurement for years when we did not collect age structure data. However, these errors are somewhat overridden by the fact that succeeding years of low and high escapements are grouped together (Figure 7). For example, the Blossom counts were low in 1981 and 1982 and returns from those broods were high, evidenced by the high index counts and returns in 1986 and 1987. Similarly, the Blossom returns from the peak years in 1986 and 1987 were undoubtedly small as evidenced by the low index counts from 1990 to 1993.

Measurement error can introduce serious bias in estimating spawner-recruit parameters, particularly for stocks that are severely exploited to the point where spawning stock size is much less than optimum levels (Ludwig and Walters 1981; Walters and Ludwig 1981; Hilborn and Starr 1984). One factor that reduces bias in the presence of measurement error is a wide range of spawners in the database, which is the case for Behm Canal stocks. Hilborn and Walters (1992, Chapter 7) note that when spawning stock sizes fluctuate no more than 2-4 times from lowest to highest, biases can be quite severe; but, if small escapements are 1/10th or less of the largest escapements, the biases will probably be of little concern. Observed index counts in the Behm Canal stocks occurred over a relatively wide range: 4-fold for the Unuk, 11-fold for the Chickamin, 25-fold for the Blossom, and 14-fold for the Keta (Table 1; Figures 5-9). Additionally, while the Unuk shows the smallest range (4-fold), this stock has been the most consistent in being at or above optimum spawning stock size with demonstrably low harvest rates, a case in which biases in estimating spawner-recruit parameters in the presence of measurement error would be minimal (Hilborn and Starr 1984). The three remaining stocks include a wide range of observed spawning stock sizes and several observations of relatively large escapements.

Nonstationarity and time-series affects in production relationships can also introduce bias in estimating spawner-recruit parameters (Walters 1987). Key points noted in Walters (1987) and Hilborn and Walters (1992) were that escapements were not decreasing, increasing, nor remaining constant over the entire database. These authors also noted a wide range of escapements was needed. Marine survival in the Behm Canal chinook salmon stocks undoubtedly varied over the time series included in the data sets, where an increasing trend was followed by a decreasing trend.

The procedures used in setting the biological escapement goal ranges for each stock have smoothed some of the sources of bias and are a fair treatment of the existing data. The bootstrap procedure produced a bootstrap mean which was used to set the range for each stock. This procedure accounted for some of the measurement error related bias and should remove affects of differential survival by selecting residuals at random and with replacement for each spawner-recruit observation in each data run. In effect, differential survival is spread across the range of escapements. The bootstrap means used to construct the recommended escapement goal ranges for each stock represented an increase in the estimated optimum from the point estimates; 17% for Unuk (758 vs. 647), 29% for the Chickamin (550 vs. 431), 15% for Keta (300 vs. 253), and 14% for Blossom (300 vs. 263) using index values in Table 4. Removal of broods with poor marine survival increased the estimated optimal escapement; these estimates were used for management recommendations because we believe they are a better representation of the spawner-recruit relationship. The 95% bootstrap confidence intervals were narrower than the 0.8 ($\overline{\hat{P}_s^*}$), to 1.6 ($\overline{\hat{P}_s^*}$) estimates (using the bootstrap means) for all but the Unuk, which were similar. The use of a range is preferred to a point estimate because: 1) it provides a range in which harvest and stock size is large; 2) it provides for management flexibility; and 3) it provides an accommodation for the uncertainty in estimating optimal escapement.

Harvest rates and evidence of density-dependent mortality are important considerations in determining the extent of exploitation and the appropriateness of parameter estimation. Harvest rates for the Unuk and Chickamin stocks has not been excessive, averaging 17% to 25% for the Unuk stock (Appendix A.3.) and 35% to 46% for the Chickamin stock (Appendix A.5.). In addition, these harvest rates are probably maximum rates as they include incidental mortality, which we may have overestimated. Estimated exploitation rates for landed catch, after removing estimated incidental mortality from total returns, averaged 11% to 18% for the Unuk stock (Table 3) and 27% to 37% for the Chickamin stock (Table 6). We have direct evidence of density dependence in freshwater from observations of estimates of the number of smolt in the Unuk River as the number of spawners increased from 1982 to 1986 (Figure 12). The range of estimates for the α parameter (6 to 13) are within the ranges estimated for other chinook populations (Healey 1982; Wong 1982; Hankin and Healey 1986), though spawner-recruit parameter estimates for chinook salmon populations on the Pacific coast are scant at best.

Parameter estimates indicate the Behm Canal chinook systems are productive, with returns expected to average about 30,000 chinook salmon, using the 15% expansions for Unuk and Chickamin and the 25% expansions for Blossom and Keta. These four systems are believed to represent approximately 70% to 80% of the naturally produced chinook salmon in the Ketchikan area. These numbers indicate the chinook salmon of Behm Canal are a substantial resource. Additionally, the recommended index escapement goals, though presented in index survey values, represent several thousand large spawners in the Unuk and Chickamin rivers; and do not include jacks which may comprise 40% of the escapement.

This analysis suggests these stocks are sustainable at present levels of interception, and a higher fraction of the production can be taken in years when return levels are high. Conversely, the annual runs of all four stocks over the last few years did not provide surplus production over what was already being taken. Without adjustments in management, such as opening terminal areas to increase harvests in years with surplus and lowering exploitation rates when production is low, these stocks will likely continue to show alternating periods of low and high returns.

RECOMMENDATIONS

1. We recommend adopting the following biological escapement goal ranges for the Behm Canal chinook salmon stocks:

    - 650 to 1,400 large index spawners for the Unuk River;
    - 450 to 900 large index spawners for the Chickamin River;
    - 250 to 500 large index spawners for the Blossom River; and
    - 250 to 500 large index spawners for the Keta River.

2. We recommend developing a cooperative management plan between sport and commercial fisheries divisions of ADF&G, specifically for these stocks, with the goal of achieving annual escapements within the recommended ranges.

3. We recommend continuing stock assessment to: provide multiple estimates of the index/total escapement fraction in the Unuk and Chickamin rivers; estimate harvests, smolt production and marine survival for the Unuk wild stock; and estimate the precision of spawner and harvest abundance.

4. We recommend reevaluation of these escapement goals after the year 2000, when additional harvest and escapement data with greater precision will be available for Unuk and Chickamin river chinook salmon stocks.

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Table 1. Observed index counts and estimated total escapements of large chinook (age .3 and older) salmon in Behm Canal escapement indicator stocks, 1975-1995.

Calendar Year	Unuk River Index Count	Unuk River Index/ 0.25	Unuk River Index/ 0.15	Chickamin River Index Count	Chickamin River Index/ 0.25	Chickamin River Index/ 0.15	Blossom River Index Count	Blossom River Index/ 0.40	Blossom River Index/ 0.25	Keta River Index Count	Keta River Index/ 0.40	Keta River Index/ 0.25
1975				370	1,481	2,468	146	365	584	203	508	812
1976				157	627	1,045	68	170	272	84	210	336
1977	974	3,896	6,493	363	1,450	2,417	112	280	448	230	575	920
1978	1,106	4,424	7,373	308	1,234	2,056	143	358	572	392	980	1,568
1979	576	2,304	3,840	239	954	1,590	54	135	216	426	1,065	1,704
1980	1,016	4,064	6,773	445	1,779	2,965	89	223	356	192	480	768
1981	731	2,924	4,873	384	1,536	2,560	159	398	636	329	823	1,316
1982	1,351	5,404	9,007	571	2,284	3,807	345	863	1,380	754	1,885	3,016
1983	1,125	4,500	7,500	599	2,398	3,996	589	1,473	2,356	822	2,055	3,288
1984	1,837	7,348	12,247	1,102	4,408	7,347	508	1,270	2,032	610	1,525	2,440
1985	1,184	4,736	7,893	956	3,824	6,373	709	1,773	2,836	624	1,560	2,496
1986	2,126	8,504	14,173	1,745	6,980	11,634	1,278	3,195	5,112	690	1,725	2,760
1987	1,973	7,892	13,153	975	3,900	6,500	1,349	3,373	5,396	768	1,920	3,072
1988	1,746	6,984	11,640	786	3,144	5,240	384	960	1,536	575	1,438	2,300
1989	1,149	4,596	7,660	934	3,736	6,227	344	860	1,376	1,155	2,888	4,620
1990	591	2,364	3,940	564	2,256	3,760	257	643	1,028	606	1,515	2,424
1991	655	2,620	4,367	487	1,948	3,247	239	598	956	272	680	1,088
1992	874	3,496	5,827	346	1,384	2,307	150	375	600	217	543	868
1993	1,068	4,272	7,120	389	1,556	2,593	303	758	1,212	362	905	1,448
1994	711	2,844	4,740	388	1,552	2,587	161	403	644	306	765	1,224
1995	772	3,088	5,147	356	1,424	2,373	217	543	868	175	438	700
Average	1,135	4,540	7,567	594	2,374	3,957	362	905	1,448	466	1,166	1,865
Interim Escapement Goal	1,800			900			800			500		

Table 2. Estimated age composition of chinook salmon in Unuk River escapements, 1980-1995.

Panel A. Percent by age class.

Calendar Year	n[a]	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total
1980	0	0.6	9.4	0.3	20.0	0.0	34.2	34.4	1.2	100.0 [b]
1981	0	0.6	9.4	0.3	20.0	0.0	34.2	34.4	1.2	100.0 [b]
1982	32	0.0	12.5	0.0	9.4	0.0	21.9	56.2	0.0	100.0
1983	0	0.6	9.4	0.3	20.0	0.0	34.2	34.4	1.2	100.0 [b]
1984	102	0.0	2.0	0.0	11.8	0.0	56.8	29.4	0.0	100.0
1985	60	6.7	10.0	1.7	25.0	0.0	44.9	11.7	0.0	100.0
1986	1,206	0.0	21.7	0.0	26.8	0.0	27.6	23.4	0.5	100.0
1987	639	0.0	13.9	0.0	27.7	0.0	28.2	29.9	0.3	100.0
1988	535	0.0	3.6	0.0	25.0	0.0	26.5	44.3	0.6	100.0
1989	288	0.0	15.3	0.0	13.9	0.0	29.5	40.3	1.0	100.0
1990	81	0.0	6.2	1.2	27.2	0.0	14.8	46.9	3.7	100.0
1991	534	0.0	15.2	0.0	18.2	0.0	51.9	13.7	1.1	100.0
1992	486	0.0	4.1	0.0	20.4	0.0	30.5	44.2	0.8	100.0
1993	615	0.0	2.1	0.2	10.4	0.0	36.7	48.0	2.6	100.0
1994	436	0.0	8.9	0.2	13.3	0.3	28.5	46.4	2.4	100.0
1995	0	0.6	9.4	0.3	20.0	0.0	34.2	34.4	1.2	100.0 [b]
Average	313	0.6	9.6	0.3	19.3	0.0	33.4	35.7	1.1	100.0
Avg. 1984-94	453	0.6	9.4	0.3	20.0	0.0	34.2	34.4	1.2	100.0
SD		1.7	5.4	0.5	6.1	0.1	10.5	12.3	1.0	

Panel B. Number of fish expanded to index counts by age class.

Calendar Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Index Total King Esc.	Index Count Large King Esc.[c]
1980	9	136	4	290	0	496	499	17	1,450	1,016
1981	6	98	3	208	0	357	359	12	1,043	731
1982	0	216	0	163	0	379	972	0	1,730	1,351
1983	10	150	5	321	0	549	552	19	1,606	1,125
1984	0	43	0	251	0	1,210	627	0	2,131	1,837
1985	136	203	35	508	0	912	238	0	2,031	1,184
1986	0	896	0	1,106	0	1,139	966	21	4,128	2,126
1987	0	470	0	936	0	953	1,010	10	3,378	1,973
1988	0	88	0	611	0	648	1,083	15	2,445	1,746
1989	0	248	0	226	0	479	654	16	1,623	1,149
1990	0	55	11	241	0	131	416	33	887	591
1991	0	149	0	178	0	510	134	11	983	655
1992	0	47	0	236	0	353	512	9	1,158	874
1993	0	26	2	127	0	448	586	32	1,221	1,068
1994	0	81	2	122	3	260	424	22	914	711
1995	7	103	3	220	0	377	379	13	1,102	772
Average	10	188	4	359	3	575	588	14	1,739	1,182
SD	34	218	9	290		315	285	10	921	493

[a] n is the number of scales aged.

[b] Estimated from average of 1984-94.

[c] Sum of ages 0.3, 0.4, 1.3, 1.4, and 1.5.

Table 3. Estimated total return and mortality rate of Unuk River chinook salmon by brood year with fishing mortality in adult equivalents.

Panel A. Using 15% escapement expansion (index/0.15)

Brood Year	Brood Year Spawners	Returns: Landed Catch	Returns: Incidental Mortality	Returns: Total Catch Mortality	Returns: Escape.	Returns: Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1977	6,493	1,502	320	1,822	8,580	10,401	1.6	14.4%	3.1%	17.5%	14.9%
1978	7,373	1,683	358	2,041	9,612	11,653	1.6	14.4%	3.1%	17.5%	14.9%
1979	3,840	2,315	836	3,151	13,403	16,554	4.3	14.0%	5.0%	19.0%	14.7%
1980	6,773	1,579	727	2,306	15,330	17,636	2.6	9.0%	4.1%	13.1%	9.3%
1981	4,873	2,130	1,110	3.239	18,327	21,566	4.4	9.9%	5.1%	15.0%	10.4%
1982	9,007	4,304	2,798	7,103	23,329	30,432	3.4	14.1%	9.2%	23.3%	15.6%
1983	7,500	2,131	1,882	4,013	21,119	25,132	3.4	8.5%	7.5%	16.0%	9.2%
1984	12,247	1,545	997	2,542	13,252	15,794	1.3	9.8%	6.3%	16.1%	10.4%
1985	7,893	345	271	616	3,923	4,539	0.6	7.6%	6.0%	13.6%	8.1%
1986	14,173	1,792	730	2,522	10,360	12,882	0.9	13.9%	5.7%	19.6%	14.7%
1987	13,153	839	579	1,419	7,962	9,381	0.7	8.9%	6.2%	15.1%	9.5%
1988	11,640	817	646	1,463	8,468	9,931	0.9	8.2%	6.5%	14.7%	8.8%
1989	7,660	527	416	943	5,459	6,402	0.8	8.2%	6.5%	14.7%	8.8%
Averages											
1977-89	8,664	1,655	898	2,552	12,240	14,793	2.0	10.8%	5.7%	16.6%	11.5%
1978-88	8,952	1,771	994	2,765	13,190	15,955	2.2	10.8%	5.9%	16.6%	11.4%
1982-86	10,164	2,024	1,336	3,359	14,397	17,756	1.9	10.8%	6.9%	17.7%	11.6%
1977-79	5,902	1,833	505	2,338	10,532	12,869	2.5	14.3%	3.7%	18.0%	14.8%
1980-89	9,492	1,601	1,016	2,617	12,753	15,370	1.9	9.8%	6.3%	16.1%	10.5%

Panel B. Using 25% escapement expansion (index/0.25)

Brood Year	Brood Year Spawners	Returns: Landed Catch	Returns: Incidental Mortality	Returns: Total Catch Mortality	Returns: Escape.	Returns: Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1977	3,896	1,492	318	1,810	5,148	6,958	1.8	21.4%	4.6%	26.0%	22.5%
1978	4,424	1,672	356	2,028	5,767	7,795	1.8	21.4%	4.6%	26.0%	22.5%
1979	2,304	2,329	841	3,170	8,042	11,212	4.9	20.8%	7.5%	28.3%	22.5%
1980	4,064	1,518	699	2,217	9,198	11,415	2.8	13.3%	6.1%	19.4%	14.2%
1981	2,924	2,076	1,082	3,158	10,996	14,154	4.8	14.7%	7.6%	22.3%	15.9%
1982	5,404	4,500	2,925	7,425	13,991	21,416	4.0	21.0%	13.7%	34.7%	24.3%
1983	4,500	2,092	1,847	3,939	12,666	16,605	3.7	12.6%	11.1%	23.7%	14.2%
1984	7,348	1,518	980	2,497	7,948	10,445	1.4	14.5%	9.4%	23.9%	16.0%
1985	4,736	333	261	595	2,354	2,949	0.6	11.3%	8.9%	20.2%	12.4%
1986	8,504	1,810	738	2,548	6,213	8,761	1.0	20.7%	8.4%	29.1%	22.6%
1987	7,892	819	565	1,384	4,777	6,162	0.8	13.3%	9.2%	22.5%	14.6%
1988	6,984	795	628	1,423	5,081	6,504	0.9	12.2%	9.7%	21.9%	13.5%
1989	4,596	513	405	918	3,275	4,193	0.9	12.2%	9.7%	21.9%	13.5%
Averages											
1977-89	5,198	1,651	896	2,547	7,343	9,890	2.3	16.1%	8.5%	24.6%	17.6%
1978-88	5,371	1,769	993	2,762	7,912	10,674	2.4	16.0%	8.7%	24.7%	17.5%
1982-86	6,098	2,050	1,350	3,401	8,634	12,035	2.1	16.0%	10.3%	26.3%	17.9%
1977-79	3,541	1,831	505	2,336	6,319	8,655	2.8	21.2%	5.5%	26.8%	22.5%
1980-89	5,695	1,597	1,013	2,610	7,650	10,260	2.1	14.6%	9.4%	24.0%	16.1%

Table 4. Estimated spawner-recruit parameters for Unuk, Chickamin, Blossom, and Keta river chinook salmon stocks.

Stock and Brood Years	Escapement Expansion	Spawner Variability		Original Point Estimate	Bootstrap Estimates: Mean	SD	Median	95% Conf. Interval: Lower	Upper	Statistical Bias
Unuk	Index/0.15	± 20%	α	5.77	6.29	3.24	5.60	2.16	14.47	9.1%
1977-89			β	0.000147	0.000143	0.000052	0.000142	0.000047	0.000254	2.9%
			P_s	4,510	4,872	1,449	4,620	3,270	7,720	8.0%
			P_s(Index)	677	731		693	491	1,158	8.0%
Unuk	Index/0.15	± 30%	α	5.77	6.10	3.13	5.54	2.10	13.60	5.7%
1977-89			β	0.000147	0.000139	0.000051	0.000136	0.000048	0.000245	5.5%
			P_s	4,510	5,035	3,469	4,720	3,330	7,980	11.6%
			P_s(Index)	677	755		708	500	1,197	11.6%
Unuk	Index/0.15	± 20%	α	6.78	7.57	3.13	6.88	3.51	15.53	11.7%
1977-84 + 1986			β	0.000136	0.000140	0.000047	0.000136	0.000060	0.000242	3.3%
			P_s	5,180	5,454	1,540	5,230	3,500	9,200	5.3%
			P_s(Index)	777	818		785	525	1,380	5.3%
Unuk	Index/0.25	± 20%	α	6.36	6.98	3.69	6.24	2.29	16.00	9.8%
1977-89			β	0.000245	0.000238	0.000089	0.000235	0.000070	0.000426	2.9%
			P_s	2,810	3,118	1,380	2,880	2,000	5,390	11.0%
			P_s(Index)	703	780		720	500	1,348	11.0%
Unuk	Index/0.25	± 30%	α	6.36	6.77	3.57	6.11	2.30	15.16	6.5%
1977-89			β	0.000245	0.000232	0.000086	0.000226	0.000073	0.000411	5.4%
			P_s	2,810	3,152	1,314	2,960	2,040	5,630	12.2%
			P_s(Index)	703	788		740	510	1,408	12.2%
Chickamin	Index/0.15	± 20%	α	6.71	6.95	1.93	6.72	3.78	11.58	3.5%
1975-89			β	0.000241	0.000239	0.000053	0.000237	0.000141	0.000349	0.6%
			P_s	2,910	3,009	498	2,940	2,250	4,110	3.4%
			P_s(Index)	437	451		441	338	617	3.4%
Chickamin	Index/0.15	± 30%	α	6.71	6.94	1.93	6.68	3.76	11.60	3.4%
1975-89			β	0.000241	0.000237	0.000053	0.000235	0.000141	0.000350	1.5%
			P_s	2,910	3,034	500	2,980	2,270	4,100	4.3%
			P_s(Index)	437	455		447	341	615	4.3%
Chickamin	Index/0.15	± 20%	α	7.62	7.77	1.08	7.64	5.99	10.12	1.9%
1976-84 + 1986			β	0.000197	0.000199	0.000032	0.000196	0.000143	0.000275	0.8%
			P_s	3,700	3,750	503	3,710	2,820	4,880	1.3%
			P_s(Index)	555	562		557	423	732	1.3%
Chickamin	Index/0.25	± 20%	α	7.46	7.77	2.20	7.52	4.18	13.05	4.1%
1975-89			β	0.000367	0.000365	0.000090	0.000363	0.000197	0.000550	0.4%
			P_s	1,980	2,069	429	2,000	1,460	3,040	4.5%
			P_s(Index)	495	517		500	365	760	4.5%
Chickamin	Index/0.25	± 30%	α	7.46	7.78	2.21	7.50	4.15	12.87	4.3%
1975-89			β	0.000367	0.000363	0.000090	0.000361	0.000199	0.000550	1.0%
			P_s	1,980	2,081	425	2,020	1,480	3,010	5.1%
			P_s(Index)	495	520		505	370	753	5.1%

-Continued-

Table 4. (Page 2 of 2).

Stock and Brood Years	Esc. Expansion	Spawner Variability		Original Point Estimate	Bootstrap Estimates Mean	SD	Median	95% Conf. Interval Lower	Upper	Statistical Bias
Keta 1975-89	Index/0.25	± 20%	α	7.21	7.28	2.07	7.02	3.98	12.48	1.0%
			β	0.000711	0.000695	0.000116	0.000696	0.000471	0.000930	2.3%
			P_s	1,010	1,035	105	1,030	860	1,270	2.4%
			P_s(Index)	253	259		258	215	318	2.4%
Keta 1975-89	Index/0.25	± 30%	α	7.21	7.10	2.03	6.83	3.95	12.00	1.5%
			β	0.000711	0.000679	0.000117	0.000678	0.000455	0.000919	4.5%
			P_s	1,010	1,051	110	1,040	870	1,310	4.0%
			P_s(Index)	253	263		260	218	328	4.0%
Keta 1976-84 + 1986	Index/0.25	± 20%	α	8.40	8.57	2.54	8.29	4.44	14.27	2.0%
			β	0.000681	0.000666	0.000142	0.000667	0.000401	0.000949	2.2%
			P_s	1,100	1,149	189	1,120	880	1,610	4.5%
			P_s(Index)	275	287		280	220	403	4.5%
Keta 1975-89	Index/0.40	± 20%	α	8.23	8.32	2.41	8.00	4.52	14.29	1.1%
			β	0.001137	0.001110	0.000189	0.001113	0.000739	0.001495	2.4%
			P_s	660	677	75	670	550	850	2.6%
			P_s(Index)	264	271		268	220	340	2.6%
Keta 1975-89	Index/0.40	± 30%	α	8.23	8.12	2.37	7.81	4.44	13.95	1.4%
			β	0.001137	0.001085	0.000191	0.001085	0.000715	0.001474	4.6%
			P_s	660	688	79	680	560	880	4.3%
			P_s(Index)	264	275		272	224	352	4.3%
Blossom 1975-89	Index/0.25	± 20%	α	8.04	8.49	2.78	8.07	4.37	14.87	5.6%
			β	0.000689	0.000682	0.000141	0.000671	0.000412	0.000974	1.0%
			P_s	1,080	1,113	179	1,090	840	1,530	3.1%
			P_s(Index)	270	278		273	210	383	3.1%
Blossom 1975-89	Index/0.25	± 30%	α	8.04	8.47	2.81	8.06	4.28	15.06	5.3%
			β	0.000689	0.000675	0.000145	0.000661	0.000414	0.000985	2.0%
			P_s	1,080	1,124	184	1,100	820	1,550	4.1%
			P_s(Index)	270	281		275	205	388	4.1%
Blossom 1976-84 + 1986	Index/0.25	± 20%	α	12.77	13.11	2.94	12.74	8.38	20.16	2.7%
			β	0.000767	0.000765	0.000125	0.000755	0.000556	0.001036	0.3%
			P_s	1,080	1,099	150	1,090	830	1,420	1.8%
			P_s(Index)	270	275		273	208	355	1.9%
Blossom 1975-89	Index/0.40	± 20%	α	9.21	9.73	3.21	9.26	4.99	17.20	5.6%
			β	0.001104	0.001092	0.000228	0.001078	0.000662	0.001570	1.1%
			P_s	700	724	121	710	540	1,010	3.4%
			P_s(Index)	280	290		284	216	404	3.4%
Blossom 1975-89	Index/0.40	± 30%	α	9.21	9.70	3.25	9.24	4.82	17.54	5.3%
			β	0.001104	0.001081	0.000234	0.001060	0.000660	0.001579	2.0%
			P_s	700	732	124	720	530	1,020	4.5%
			P_s(Index)	280	293		288	212	408	4.5%

Table 5. Estimated age composition of chinook salmon in Chickamin River escapements, 1978-1995.

Panel A. Percent by age class.

Calendar		Total Age and Age Class								
		3 Year		4 Year		5 Year		6 Year	7 Year	
Year	n[a]	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	Total
1978	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1979	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1980	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1981	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1982	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1983	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1984	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1985	25		0.0	4.0	8.0		52.0	36.0	0.0	100
1986	104		17.3	0.0	12.5		53.9	16.3	0.0	100
1987	253		9.1	0.0	28.9		39.9	21.3	0.8	100
1988	195		0.0	0.0	11.8		51.3	35.9	1.0	100
1989	197		4.1	0.0	6.6		33.5	50.2	5.6	100
1990	130		8.5	0.8	21.5		12.3	53.1	3.8	100
1991	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1992	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1993	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1994	0		6.7	0.1	15.8		37.0	38.2	2.2	100 [b]
1995	232		0.9	0.0	13.4		31.0	52.6	2.1	100
Average	63		6.6	0.4	15.4		38.3	37.2	2.1	100
Avg. 86-90,95	185		6.7	0.1	15.8		37.0	38.2	2.2	100
SD			3.8	1.0	5.0		9.4	8.7	1.3	

Panel B. Number of fish expanded to index counts by age class.

Calendar	Total Age and Age Class								Index Total	Index Count Large
	3 Year		4 Year		5 Year		6 Year	7 Year	King	King
Year	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	Esc.	Esc.[c]
1978		26	1	63		147	152	9	398	308
1979		20	0	49		114	118	7	308	239
1980		38	1	90		212	219	13	573	445
1981		33	1	78		183	189	11	495	384
1982		49	1	116		272	281	16	736	571
1983		51	1	122		286	295	17	773	599
1984		94	2	224		525	543	31	1,421	1,102
1985		0	42	83		540	374	0	1,039	956
1986		430	0	311		1,340	405	0	2,486	1,745
1987		143	0	454		627	335	13	1,573	975
1988		0	0	105		457	320	9	891	786
1989		43	0	69		350	525	59	1,046	934
1990		68	6	173		99	428	31	806	564
1991		42	1	99		232	240	14	628	487
1992		30	1	70		165	171	10	446	346
1993		33	1	79		185	192	11	502	389
1994		33	1	79		185	191	11	500	388
1995		4	0	56		129	219	9	415	356
Average		63	3	129		336	289	15	835	643
SD		98	10	105		297	125	14	540	380

[a] n is the number of scales aged.
[b] Estimated from average of 1986-90, 1995.
[c] Sum of ages 0.3, 0.4, 1.3, 1.4, and 1.5.

Table 6. Estimated total return and mortality rate of Chickamin River chinook salmon by brood year with fishing mortality in adult equivalents.

Panel A. Using 15% escapement expansion (index/0.15)

		Returns									
Brood Year	Brood Year Spawners	Landed Catch	Incidental Mortality	Total Catch Mortality	Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	2,468	1,425	202	1,627	3,287	4,914	2.0	29.0%	4.1%	33.1%	30.3%
1976	1,045	1,716	243	1,959	3,956	5,914	5.7	29.0%	4.1%	33.1%	30.3%
1977	2,417	2,071	293	2,364	4,774	7,138	3.0	29.0%	4.1%	33.1%	30.3%
1978	2,056	2,831	401	3,232	6,527	9,759	4.7	29.0%	4.1%	33.1%	30.3%
1979	1,590	2,024	569	2,593	7,143	9,736	6.1	20.8%	5.8%	26.6%	22.1%
1980	2,965	2,071	733	2,805	8,238	11,042	3.7	18.8%	6.6%	25.4%	20.1%
1981	2,560	3,779	1,839	5,618	12,686	18,305	7.2	20.6%	10.0%	30.7%	23.0%
1982	3,807	3,283	2,211	5,495	8,783	14,278	3.8	23.0%	15.5%	38.5%	27.2%
1983	3,996	3,670	1,204	4,874	12,654	17,528	4.4	20.9%	6.9%	27.8%	22.5%
1984	7,347	3,808	2,547	6,354	6,940	13,294	1.8	28.6%	19.2%	47.8%	35.4%
1985	6,373	746	713	1,459	2,788	4,247	0.7	17.6%	16.8%	34.4%	21.1%
1986	11,634	2,612	1,580	4,192	4,247	8,439	0.7	31.0%	18.7%	49.7%	38.1%
1987	6,500	1,272	1,555	2,827	3,575	6,402	1.0	19.9%	24.3%	44.2%	26.3%
1988	5,240	1,010	770	1,780	3,321	5,101	1.0	19.8%	15.1%	34.9%	23.3%
1989	6,227	1,040	793	1,833	3,420	5,253	0.8	19.8%	15.1%	34.9%	23.3%
Averages											
1975-89	4,415	2,224	1,043	3,267	6,156	9,423	3.1	23.8%	11.4%	35.2%	26.9%
1978-88	4,915	2,464	1,284	3,748	6,991	10,739	3.2	22.7%	13.0%	35.7%	26.3%
1982-86	6,631	2,824	1,651	4,475	7,082	11,557	2.3	24.2%	15.4%	39.6%	28.9%
1975-79	2,021	2,308	421	2,729	6,148	8,877	4.6	26.3%	4.7%	31.0%	27.5%
1980-89	5,665	2,329	1,394	3,724	6,665	10,389	2.5	22.0%	14.8%	36.8%	26.0%

Panel B. Using 25% escapement expansion (index/0.25)

		Returns									
Brood Year	Brood Year Spawners	Landed Catch	Incidental Mortality	Total Catch Mortality	Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	1,481	1,348	191	1,539	1,972	3,511	2.4	38.4%	5.4%	43.8%	40.6%
1976	627	1,622	230	1,852	2,373	4,225	6.7	38.4%	5.4%	43.8%	40.6%
1977	1,450	1,958	277	2,235	2,864	5,099	3.5	38.4%	5.4%	43.8%	40.6%
1978	1,234	2,677	379	3,055	3,916	6,972	5.7	38.4%	5.4%	43.8%	40.6%
1979	954	1,821	512	2,333	4,286	6,618	6.9	27.5%	7.7%	35.2%	29.8%
1980	1,779	1,848	654	2,503	4,943	7,445	4.2	24.8%	8.8%	33.6%	27.2%
1981	1,536	3,503	1,705	5,207	7,612	12,819	8.3	27.3%	13.3%	40.6%	31.5%
1982	2,284	3,267	2,200	5,467	5,267	10,734	4.7	30.4%	20.5%	50.9%	38.3%
1983	2,398	3,259	1,070	4,329	7,589	11,918	5.0	27.3%	9.0%	36.3%	30.0%
1984	4,408	4,144	2,772	6,916	4,162	11,077	2.5	37.4%	25.0%	62.4%	49.9%
1985	3,824	696	665	1,361	1,672	3,034	0.8	22.9%	21.9%	44.9%	29.4%
1986	6,980	2,931	1,773	4,703	2,546	7,249	1.0	40.4%	24.5%	64.9%	53.5%
1987	3,900	1,316	1,608	2,924	2,145	5,068	1.3	26.0%	31.7%	57.7%	38.0%
1988	3,144	970	739	1,710	1,993	3,703	1.2	26.2%	20.0%	46.2%	32.7%
1989	3,736	999	761	1,761	2,052	3,812	1.0	26.2%	20.0%	46.2%	32.7%
Averages											
1975-89	2,649	2,157	1,036	3,193	3,693	6,886	3.7	31.3%	14.9%	46.3%	37.0%
1978-88	2,949	2,403	1,280	3,682	4,194	7,876	3.8	29.9%	17.1%	47.0%	36.5%
1982-86	3,979	2,859	1,696	4,555	4,247	8,802	2.8	31.7%	20.2%	51.9%	40.2%
1975-79	1,213	2,152	389	2,541	3,689	6,230	5.4	34.8%	6.2%	41.0%	37.0%
1980-89	3,399	2,293	1,395	3,688	3,998	7,686	3.0	28.9%	19.5%	48.4%	36.3%

Table 7. Estimated age composition of chinook salmon in Blossom River escapements, 1978-1995.

Panel A. Percent by age class.

Calendar Year	n[a]	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total
1978			8.0		18.0		35.8	36.5	1.7	100.0
1979			8.0		18.0		35.8	36.5	1.7	100.0
1980			8.0		18.0		35.8	36.5	1.7	100.0
1981			8.0		18.0		35.8	36.5	1.7	100.0
1982			8.0		18.0		35.8	36.5	1.7	100.0
1983			8.0		18.0		35.8	36.5	1.7	100.0
1984			8.0		18.0		35.8	36.5	1.7	100.0
1985	52		0.0		25.0	1.9	40.4	32.7	0.0	100.0
1986			8.0		18.0		35.8	36.5	1.7	100.0
1987			8.0		18.0		35.8	36.5	1.7	100.0
1988			8.0		18.0		35.8	36.5	1.7	100.0
1989			8.0		18.0		35.8	36.5	1.7	100.0
1990			8.0		18.0		35.8	36.5	1.7	100.0
1991			8.0		18.0		35.8	36.5	1.7	100.0
1992			8.0		18.0		35.8	36.5	1.7	100.0
1993			8.0		18.0		35.8	36.5	1.7	100.0
1994			8.0		18.0		35.8	36.5	1.7	100.0
1995			8.0		18.0		35.8	36.5	1.7	100.0
Average			8.0		18.0		35.8	36.5	1.7	100.0

Panel B. Number of fish expanded to index counts by age class.

Calendar Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Index Total King Esc.	Index Count Large King Esc.[b]
1978		16		35		69	71	3	193	143
1979		6		13		26	27	1	73	54
1980		10		22		43	44	2	120	89
1981		17		39		77	78	4	215	159
1982		38		84		167	170	8	466	345
1983		64		143		285	291	14	796	589
1984		55		123		246	251	12	687	508
1985		0		236		382	309	0	945	709
1986		139		310		618	631	30	1,728	1,278
1987		147		328		652	666	31	1,823	1,349
1988		42		93		186	189	9	519	384
1989		37		84		166	170	8	465	344
1990		28		62		124	127	6	347	257
1991		26		58		116	118	6	323	239
1992		16		36		73	74	3	203	150
1993		33		74		146	150	7	410	303
1994		18		39		78	79	4	218	161
1995		24		53		105	107	5	293	217
Average		40		102		198	197	8	546	404

a Scales collected from Blossom River escapement only in 1985; estimated annual escapement age structure from average of Unuk and Chickamin, which were very similar.

b Sum of ages 0.3, 0.4, 1.3, 1.4, and 1.5.

Table 8. Estimated total return and mortality rate of Blossom River chinook salmon by brood year with fishing mortality in adult equivalents.

Panel A. Using 25% escapement expansion (index/0.25)

		Returns									
Brood Year	Brood Year Spawners	Landed Catch	Incidental Mortality	Total Catch Mortality	Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	584	183	39	222	633	855	1.5	21.4%	4.6%	26.0%	22.5%
1976	272	334	71	405	1,153	1,558	5.7	21.4%	4.6%	26.0%	22.5%
1977	448	600	128	728	2,070	2,798	6.2	21.4%	4.6%	26.0%	22.5%
1978	572	738	157	895	2,546	3,441	6.0	21.4%	4.6%	26.0%	22.5%
1979	216	886	320	1,206	3,059	4,265	19.7	20.8%	7.5%	28.3%	22.5%
1980	356	813	374	1,187	4,924	6,111	17.2	13.3%	6.1%	19.4%	14.2%
1981	636	1,196	623	1,820	6,336	8,155	12.8	14.7%	7.6%	22.3%	15.9%
1982	1,380	1,492	970	2,463	4,640	7,103	5.1	21.0%	13.7%	34.7%	24.3%
1983	2,356	547	483	1,030	3,312	4,342	1.8	12.6%	11.1%	23.7%	14.2%
1984	2,032	411	266	677	2,155	2,832	1.4	14.5%	9.4%	23.9%	16.0%
1985	2,836	210	165	375	1,484	1,859	0.7	11.3%	8.9%	20.2%	12.4%
1986	5,112	345	141	486	1,186	1,672	0.3	20.7%	8.4%	29.1%	22.6%
1987	5,396	214	148	361	1,247	1,608	0.3	13.3%	9.2%	22.5%	14.6%
1988	1,536	184	145	329	1,174	1,502	1.0	12.2%	9.7%	21.9%	13.5%
1989	1,376	172	136	308	1,099	1,407	1.0	12.2%	9.7%	21.9%	13.5%
Averages											
1975-89	1,674	555	278	833	2,468	3,301	5.4	16.8%	8.0%	24.8%	18.2%
1978-88	2,039	640	345	984	2,915	3,899	6.0	16.0%	8.7%	24.7%	17.5%
1982-86	2,743	601	405	1,006	2,555	3,562	1.9	16.0%	10.3%	26.3%	17.9%
1975-79	412	741	202	943	2,558	3,501	10.7	21.2%	5.5%	26.8%	22.5%
1980-89	2,302	558	345	903	2,756	3,659	4.2	14.6%	9.4%	24.0%	16.1%

Panel B. Using 40% escapement expansion (index/0.40)

		Returns									
Brood Year	Brood Year Spawners	Landed Catch	Incidental Mortality	Total Catch Mortality	Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	365	182	39	221	395	616	1.7	29.5%	6.3%	35.8%	31.5%
1976	170	331	71	402	721	1,123	6.6	29.5%	6.3%	35.8%	31.5%
1977	280	595	127	722	1,294	2,016	7.2	29.5%	6.3%	35.8%	31.5%
1978	358	732	156	888	1,591	2,479	6.9	29.5%	6.3%	35.8%	31.5%
1979	135	895	323	1,219	1,912	3,131	23.2	28.6%	10.3%	38.9%	31.9%
1980	223	769	354	1,123	3,078	4,201	18.9	18.3%	8.4%	26.7%	20.0%
1981	398	1,154	601	1,756	3,960	5,715	14.4	20.2%	10.5%	30.7%	22.6%
1982	863	1,605	1,043	2,648	2,900	5,549	6.4	28.9%	18.8%	47.7%	35.6%
1983	1,473	533	471	1,004	2,070	3,074	2.1	17.3%	15.3%	32.7%	20.5%
1984	1,270	402	259	661	1,347	2,008	1.6	20.0%	12.9%	32.9%	23.0%
1985	1,773	200	157	356	927	1,284	0.7	15.5%	12.2%	27.8%	17.7%
1986	3,195	352	143	495	741	1,236	0.4	28.4%	11.6%	40.0%	32.2%
1987	3,373	206	143	349	779	1,128	0.3	18.3%	12.6%	30.9%	20.9%
1988	960	177	140	316	733	1,050	1.1	16.8%	13.3%	30.1%	19.4%
1989	860	165	131	296	687	983	1.1	16.8%	13.3%	30.1%	19.4%
Averages											
1975-89	1,046	553	277	830	1,542	2,373	6.2	23.2%	11.0%	34.1%	25.9%
1978-88	1,274	639	345	983	1,822	2,805	6.9	22.0%	12.0%	34.0%	25.0%
1982-86	1,715	618	415	1,033	1,597	2,630	2.2	22.1%	14.2%	36.2%	25.8%
1975-79	258	741	202	943	1,599	2,542	12.4	29.2%	7.6%	36.9%	31.6%
1980-89	1,439	556	344	900	1,722	2,623	4.7	20.1%	12.9%	33.0%	23.1%

Table 9. Estimated age composition of chinook salmon in Keta River escapements, 1978-1995.

Panel A. Percent by age class.

Calendar Year	n[a]	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total
1978					5.0	2.2	36.8	53.3	2.8	100.0
1979					5.0	2.2	36.8	53.3	2.8	100.0
1980					5.0	2.2	36.8	53.3	2.8	100.0
1981					5.0	2.2	36.8	53.3	2.8	100.0
1982	18				4.3	4.3	34.8	56.5	0.0	100.0
1983					5.0	2.2	36.8	53.3	2.8	100.0
1984	23				5.6	0.0	38.9	50.0	5.6	100.0
1985					5.0	2.2	36.8	53.3	2.8	100.0
1986					5.0	2.2	36.8	53.3	2.8	100.0
1987					5.0	2.2	36.8	53.3	2.8	100.0
1988					5.0	2.2	36.8	53.3	2.8	100.0
1989					5.0	2.2	36.8	53.3	2.8	100.0
1990					5.0	2.2	36.8	53.3	2.8	100.0
1991					5.0	2.2	36.8	53.3	2.8	100.0
1992					5.0	2.2	36.8	53.3	2.8	100.0
1993					5.0	2.2	36.8	53.3	2.8	100.0
1994					5.0	2.2	36.8	53.3	2.8	100.0
1995					5.0	2.2	36.8	53.3	2.8	100.0
Avg. 1982-84	21				5.0	2.2	36.8	53.3	2.8	100.0

Panel B. Number of fish expanded to index counts by age class.

Calendar Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Index Total King Esc.	Index Count Large King Esc.[b]
1978				20	9	152	220	11	412	392
1979				22	10	165	239	12	448	426
1980				10	4	74	108	6	202	192
1981				17	8	128	184	10	346	329
1982				34	34	274	446	0	788	754
1983				43	19	319	461	24	865	822
1984				36	0	251	323	36	646	610
1985				33	14	242	350	18	657	624
1986				36	16	267	387	20	726	690
1987				40	18	298	430	22	808	768
1988				30	13	223	322	17	605	575
1989				60	26	448	647	34	1,215	1,155
1990				32	14	235	340	18	638	606
1991				14	6	105	152	8	286	272
1992				11	5	84	122	6	228	217
1993				19	8	140	203	11	381	362
1994				16	7	119	171	9	322	306
1995				9	4	68	98	5	184	175
Average				27	12	200	289	15	542	515

a Scales collected from Keta River escapements only in 1982 and 1984.

b Sum of ages 0.3, 0.4, 1.3, 1.4, and 1.5.

Table 10. Estimated total return and mortality rate of Keta River chinook salmon by brood year with fishing mortality in adult equivalents.

Panel A. Using 25% escapement expansion (index/0.25)

Brood Year	Brood Year Spawners	Returns: Landed Catch	Returns: Incidental Mortality	Returns: Total Catch Mortality	Returns: Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	812	331	70	401	1,141	1,543	1.9	21.4%	4.6%	26.0%	22.5%
1976	336	713	152	864	2,458	3,323	9.9	21.4%	4.6%	26.0%	22.5%
1977	920	953	203	1,156	3,288	4,445	4.8	21.4%	4.6%	26.0%	22.5%
1978	1,568	827	176	1,003	2,851	3,854	2.5	21.4%	4.6%	26.0%	22.5%
1979	1,704	769	278	1,047	2,655	3,702	2.2	20.8%	7.5%	28.3%	22.5%
1980	768	463	213	676	2,804	3,480	4.5	13.3%	6.1%	19.4%	14.2%
1981	1,316	576	300	876	3,051	3,928	3.0	14.7%	7.6%	22.3%	15.9%
1982	3,016	910	591	1,501	2,828	4,329	1.4	21.0%	13.7%	34.7%	24.3%
1983	3,288	622	549	1,170	3,764	4,934	1.5	12.6%	11.1%	23.7%	14.2%
1984	2,440	650	420	1,070	3,406	4,476	1.8	14.5%	9.4%	23.9%	16.0%
1985	2,496	265	208	472	1,871	2,343	0.9	11.3%	8.9%	20.2%	12.4%
1986	2,760	321	131	452	1,102	1,553	0.6	20.7%	8.4%	29.1%	22.6%
1987	3,072	216	149	365	1,260	1,625	0.5	13.3%	9.2%	22.5%	14.6%
1988	2,300	211	166	377	1,346	1,723	0.7	12.2%	9.7%	21.9%	13.5%
1989	4,620	152	120	272	970	1,242	0.3	12.2%	9.7%	21.9%	13.5%
Averages											
1975-89	2,094	532	248	780	2,320	3,100	2.4	16.8%	8.0%	24.8%	18.2%
1978-88	2,248	530	289	819	2,449	3,268	1.8	16.0%	8.7%	24.7%	17.5%
1982-86	2,800	553	380	933	2,594	3,527	1.3	16.0%	10.3%	26.3%	17.9%
1975-79	1,397	850	219	1,069	2,932	4,000	3.2	21.2%	5.5%	26.8%	22.5%
1980-89	2,608	438	285	723	2,240	2,963	1.5	14.6%	9.4%	24.0%	16.1%

Panel B. Using 40% escapement expansion (index/0.40)

Brood Year	Brood Year Spawners	Returns: Landed Catch	Returns: Incidental Mortality	Returns: Total Catch Mortality	Returns: Escape.	Total Return	Total Return/ Spawner	Landed Catch ER	Incidental Mortality Rate	Total Mortality Rate	Landed Catch/ (Landed Catch + Escape.)
1975	508	328	70	398	713	1,111	2.2	29.5%	6.3%	35.8%	31.5%
1976	210	707	150	857	1,536	2,394	11.4	29.5%	6.3%	35.8%	31.5%
1977	575	946	201	1,147	2,055	3,202	5.6	29.5%	6.3%	35.8%	31.5%
1978	980	820	175	994	1,782	2,776	2.8	29.5%	6.3%	35.8%	31.5%
1979	1,065	777	281	1,058	1,660	2,717	2.6	28.6%	10.3%	38.9%	31.9%
1980	480	438	202	640	1,753	2,392	5.0	18.3%	8.4%	26.7%	20.0%
1981	823	556	290	845	1,907	2,753	3.3	20.2%	10.5%	30.7%	22.6%
1982	1,885	978	636	1,614	1,768	3,382	1.8	28.9%	18.8%	47.7%	35.6%
1983	2,055	606	535	1,141	2,352	3,493	1.7	17.3%	15.3%	32.7%	20.5%
1984	1,525	635	410	1,045	2,129	3,173	2.1	20.0%	12.9%	32.9%	23.0%
1985	1,560	252	198	449	1,169	1,618	1.0	15.5%	12.2%	27.8%	17.7%
1986	1,725	327	133	460	688	1,148	0.7	28.4%	11.6%	40.0%	32.2%
1987	1,920	209	144	353	788	1,140	0.6	18.3%	12.6%	30.9%	20.9%
1988	1,438	203	160	363	841	1,204	0.8	16.8%	13.3%	30.1%	19.4%
1989	2,888	146	115	261	606	868	0.3	16.8%	13.3%	30.1%	19.4%
Averages											
1975-89	1,309	528	247	775	1,450	2,225	2.8	23.2%	11.0%	34.1%	25.9%
1978-88	1,405	527	287	815	1,531	2,345	2.0	22.0%	12.0%	34.0%	25.0%
1982-86	1,750	559	382	942	1,621	2,563	1.5	22.1%	14.2%	36.2%	25.8%
1975-79	873	848	219	1,066	1,832	2,899	3.7	29.2%	7.6%	36.9%	31.6%
1980-89	1,630	435	282	717	1,400	2,117	1.7	20.1%	12.9%	33.0%	23.1%

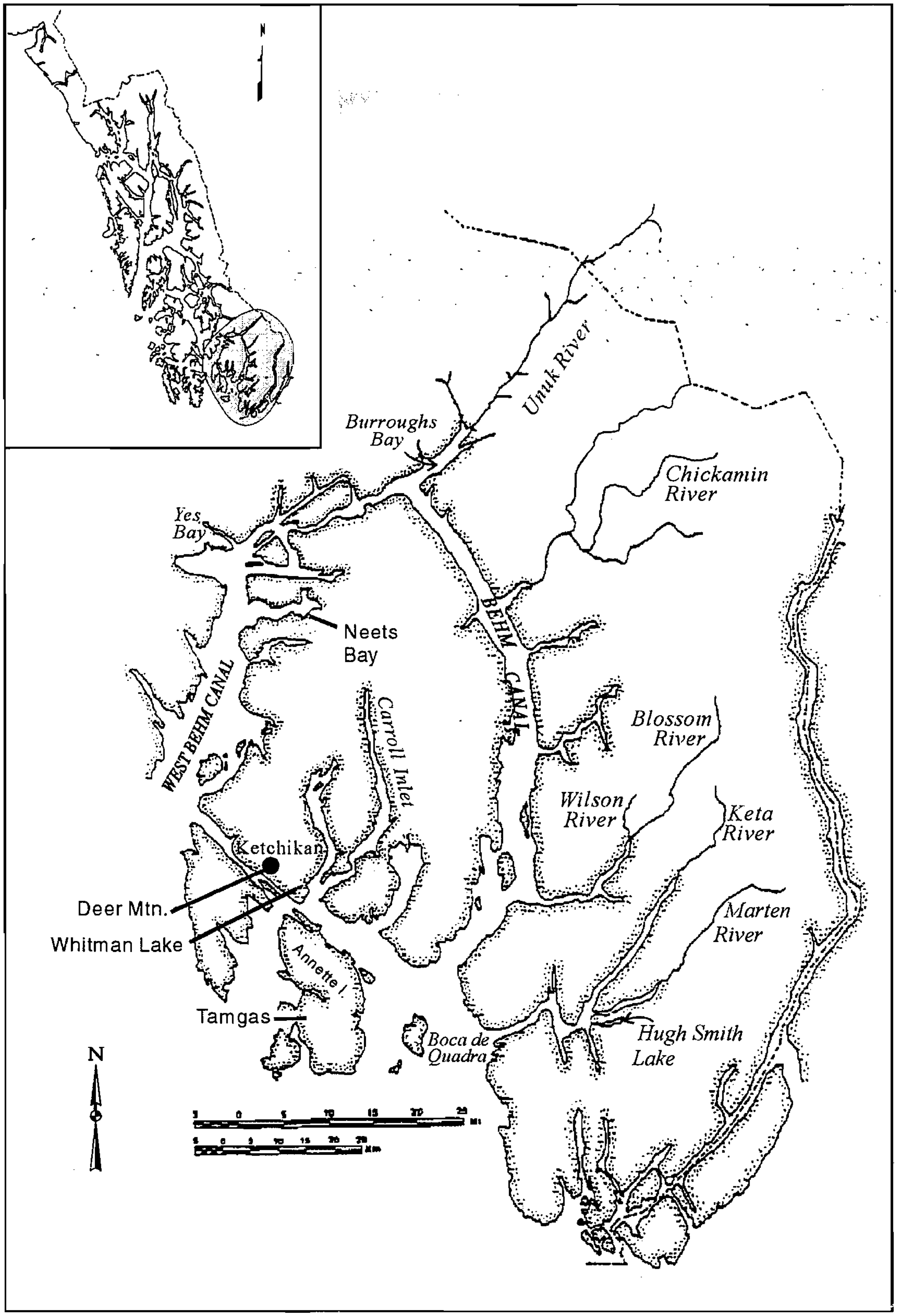


Figure 1. Ketchikan area showing Behm Canal, Unuk, Chickamin, Blossom, and Keta Rivers and location of chinook salmon hatcheries.

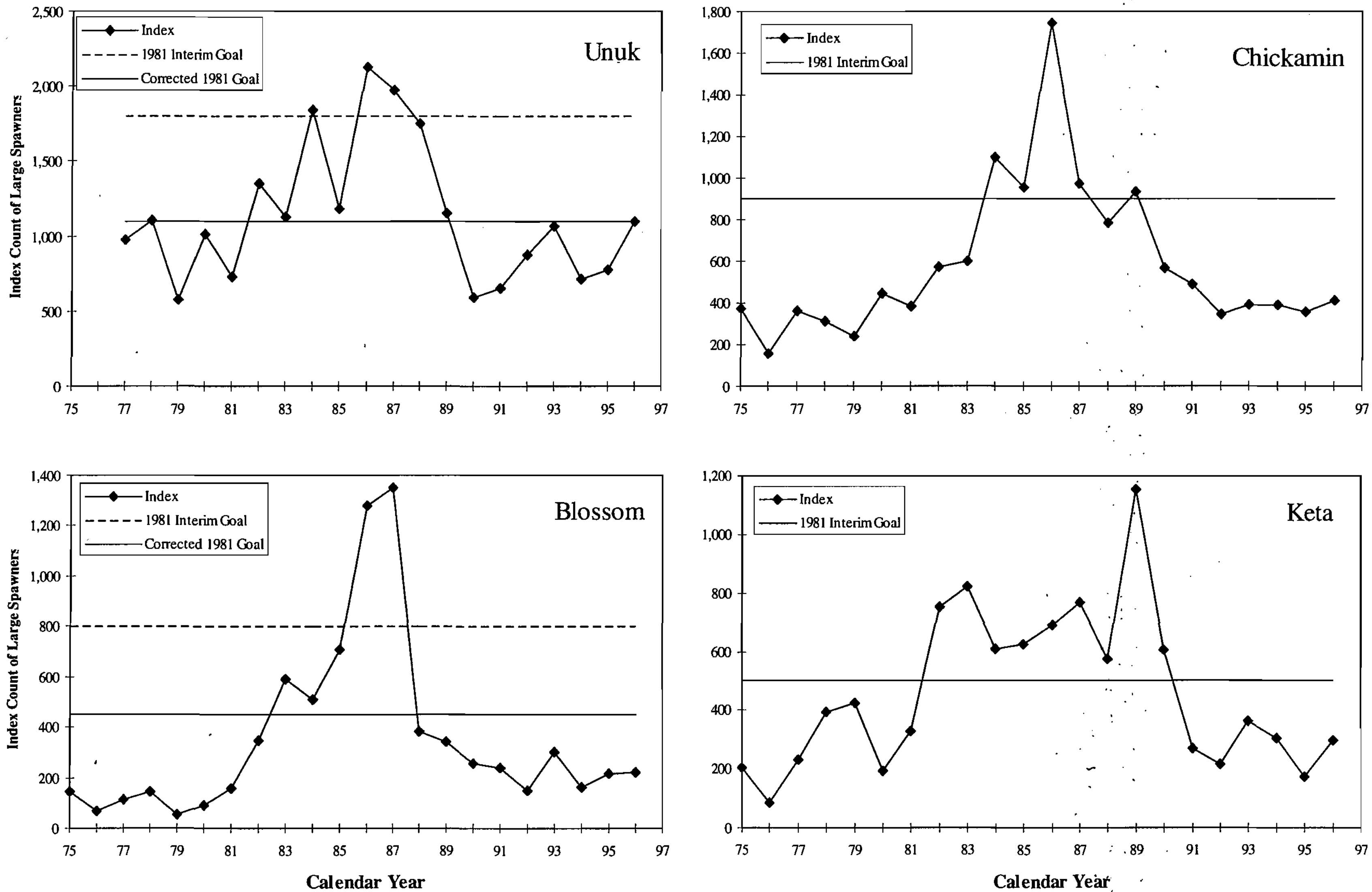


Figure 2. Observed index escapement counts of large chinook salmon in the Unuk, Chickamin, Blossom and Keta Rivers, 1975 to 1996.

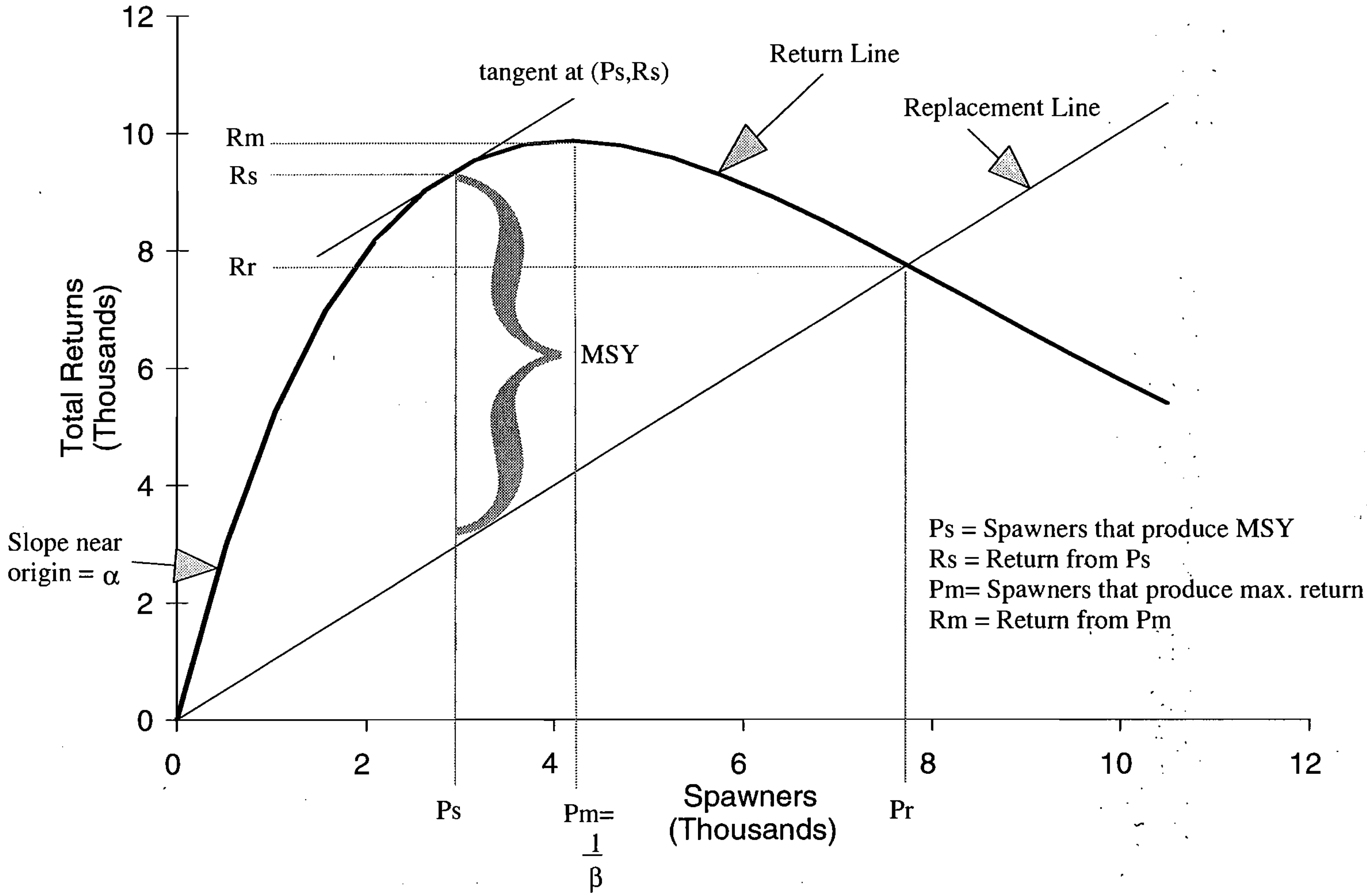


Figure 3. Ricker curve illustrating spawners (P) and total returns (R) at replacement (r), maximum return (m), and maximum sustained yield (s) levels.

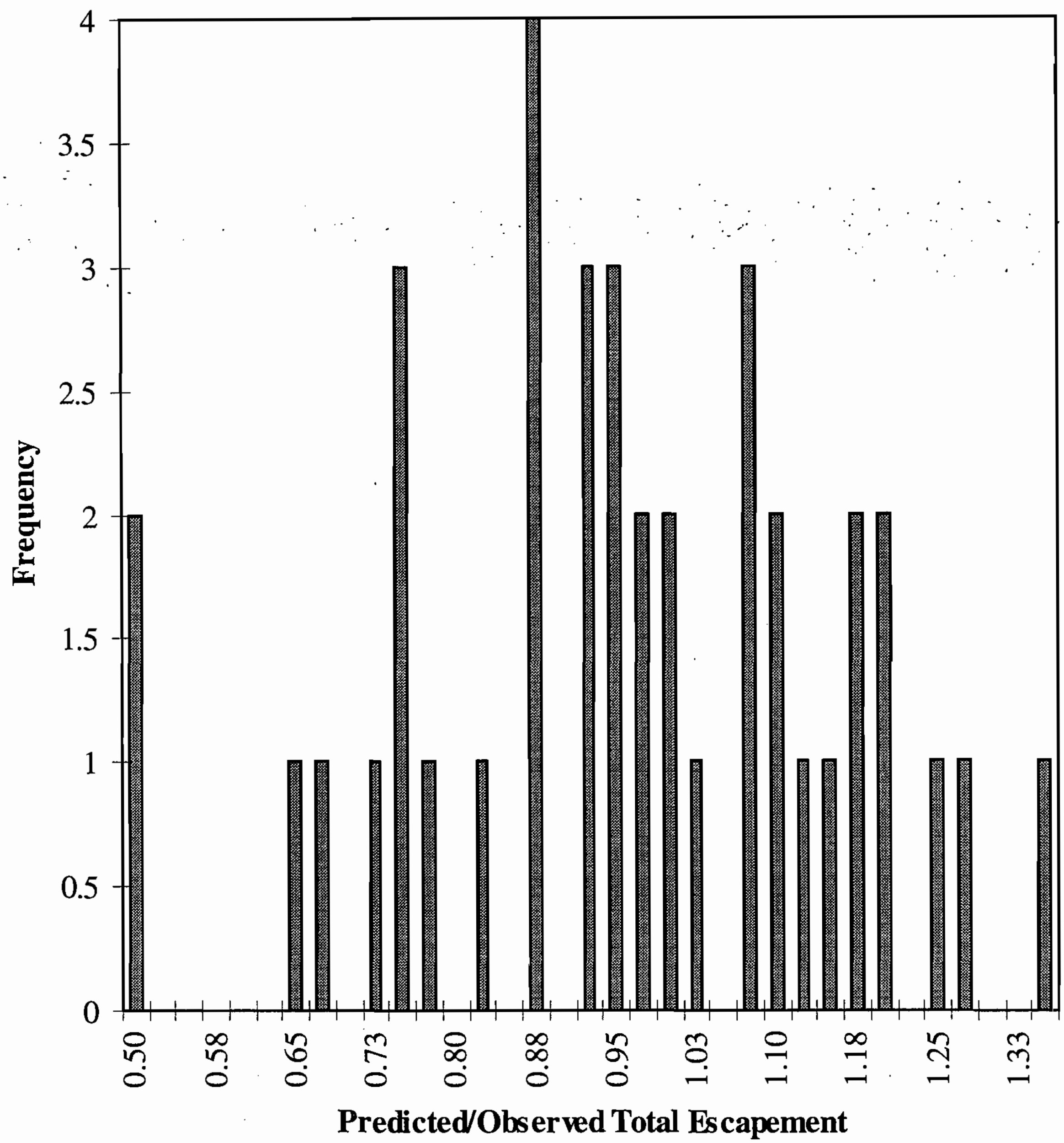
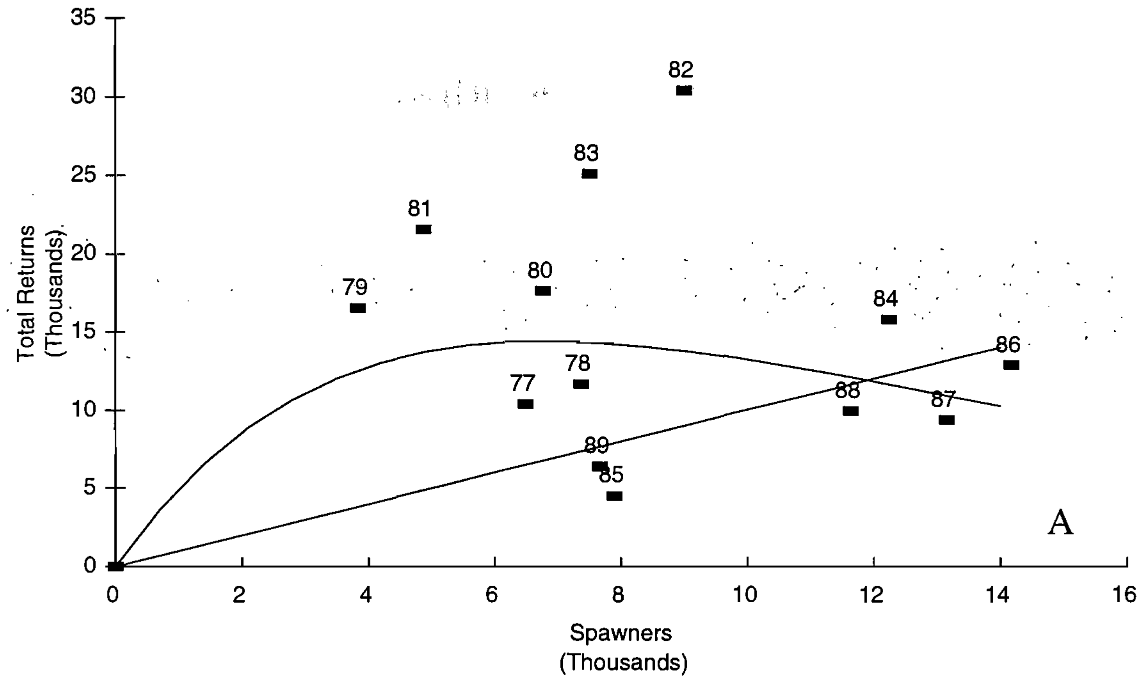


Figure 4. Predicted/observed fraction of total escapement by using average fraction of total escapement counted in 40 studies of chinook salmon in Southeast Alaska where index counts and total escapement were estimated concurrently.



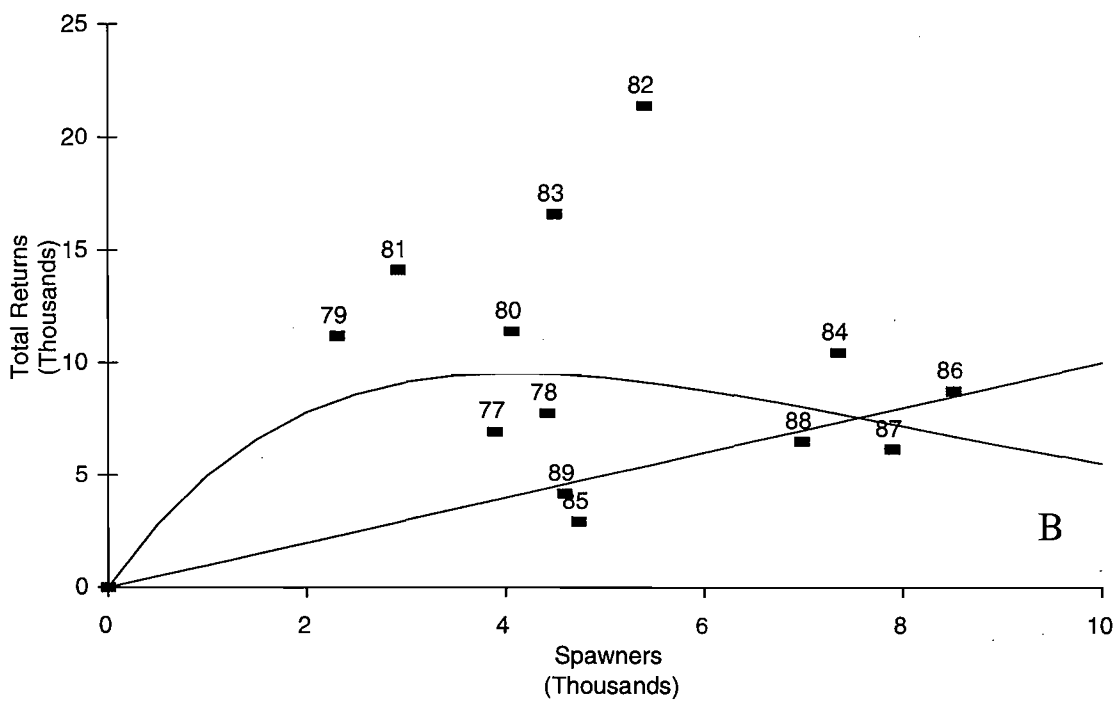


Figure 5. Estimated total returns for Unuk River chinook salmon for the 1977-1989 broods, assuming index counts are 15% of total escapement (A) and 25% of total escapement (B).

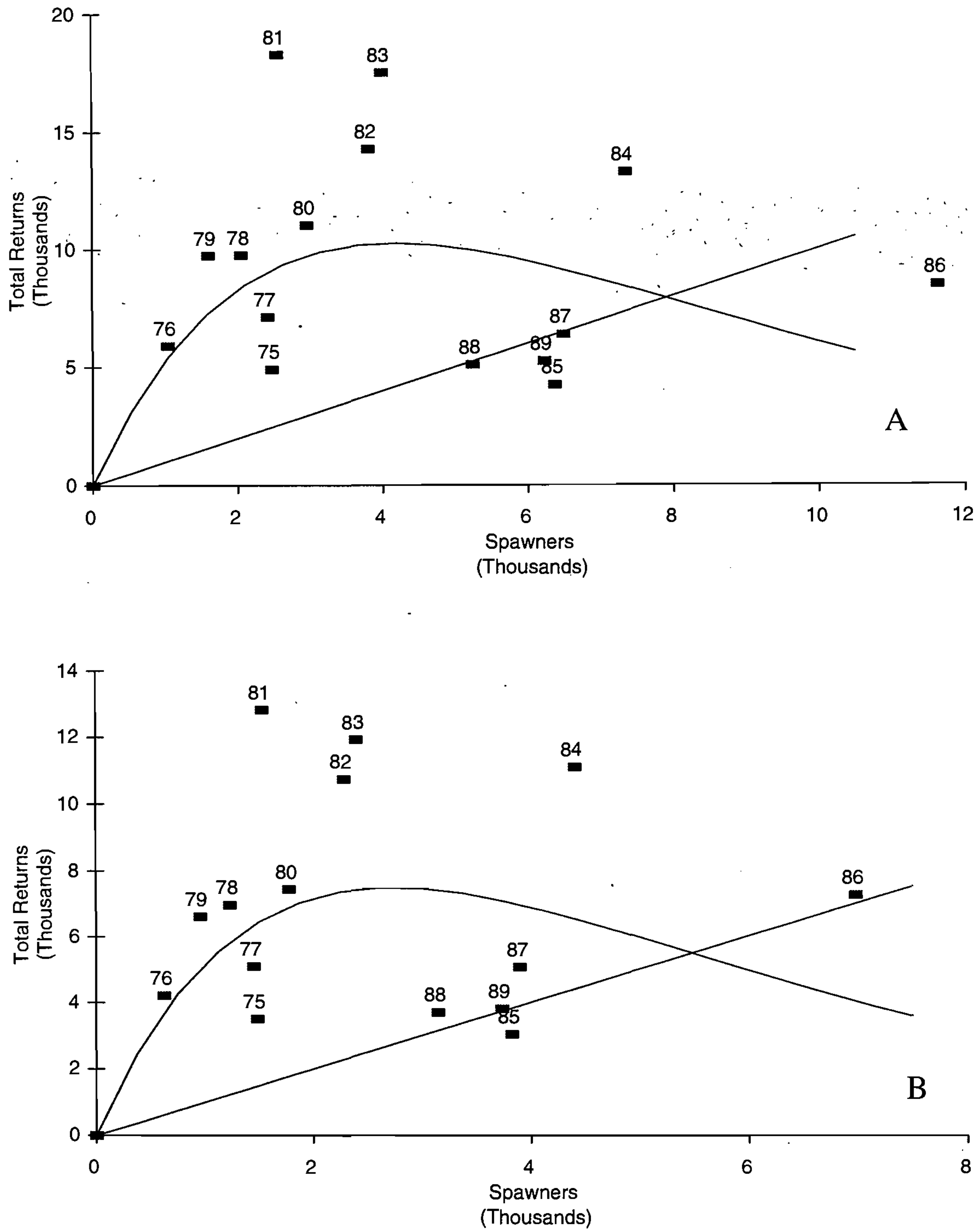


Figure 6. Estimated total returns for Chickamin River chinook salmon for the 1975-1989 broods, assuming index counts are 15% of total escapement (A) and 25% of total escapement (B).

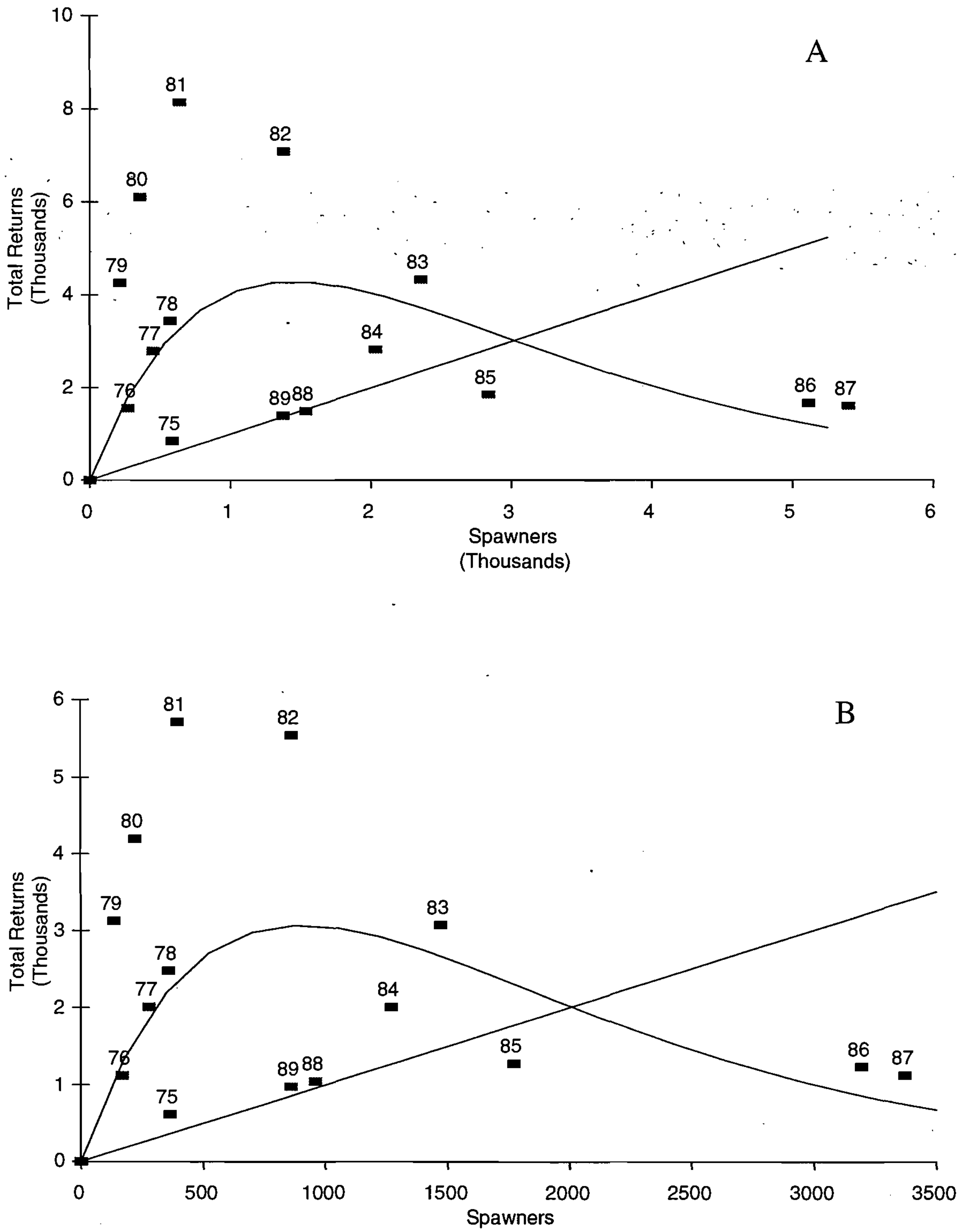


Figure 7. Estimated total returns for Blossom River chinook salmon for the 1975-1989 broods, assuming index counts are 15% of total escapement (A) and 25% of total escapement (B).

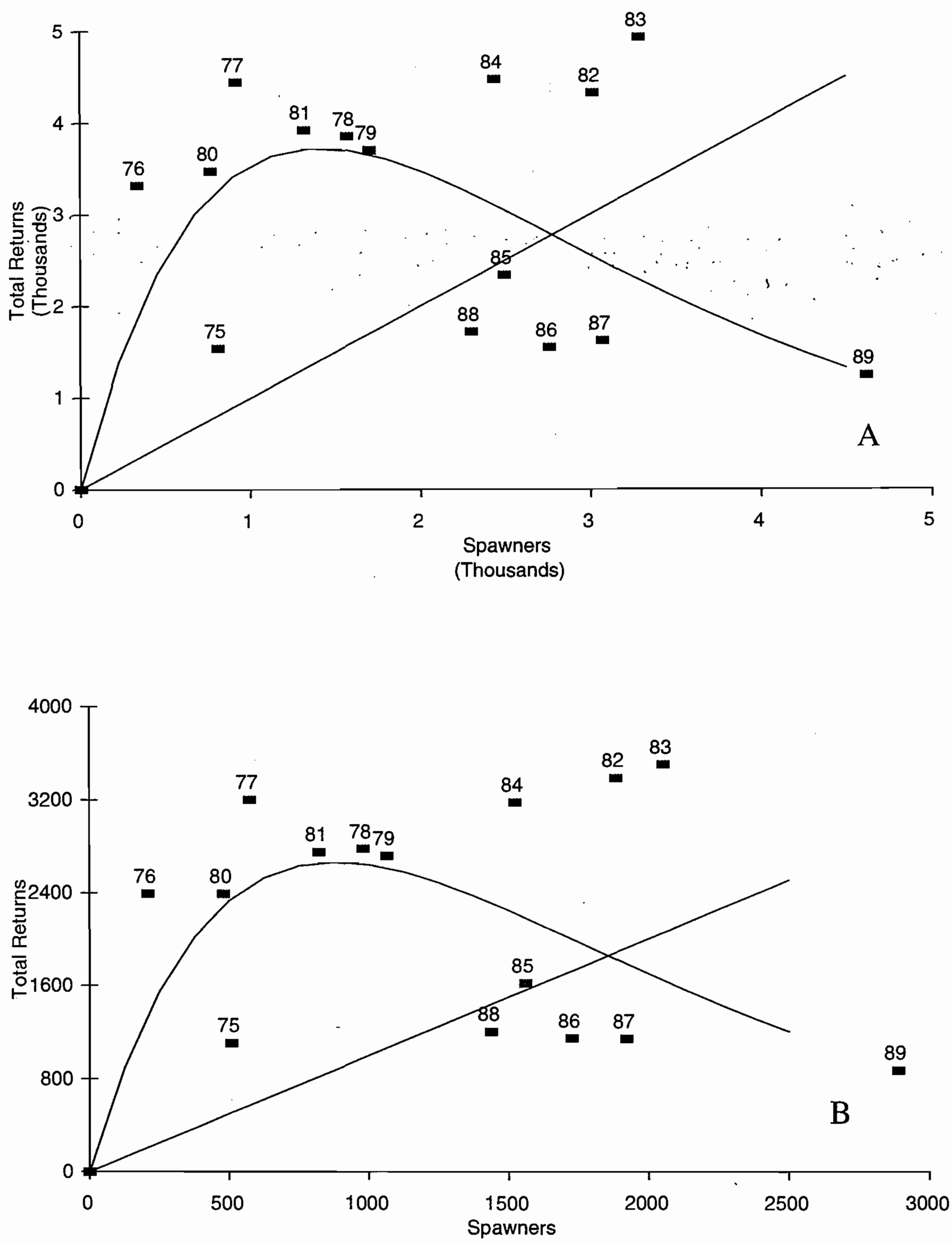


Figure 8. Estimated total returns for Keta River chinook salmon for the 1975-1989 broods, assuming index counts are 15% of total escapement (A) and 25% of total escapement (B).

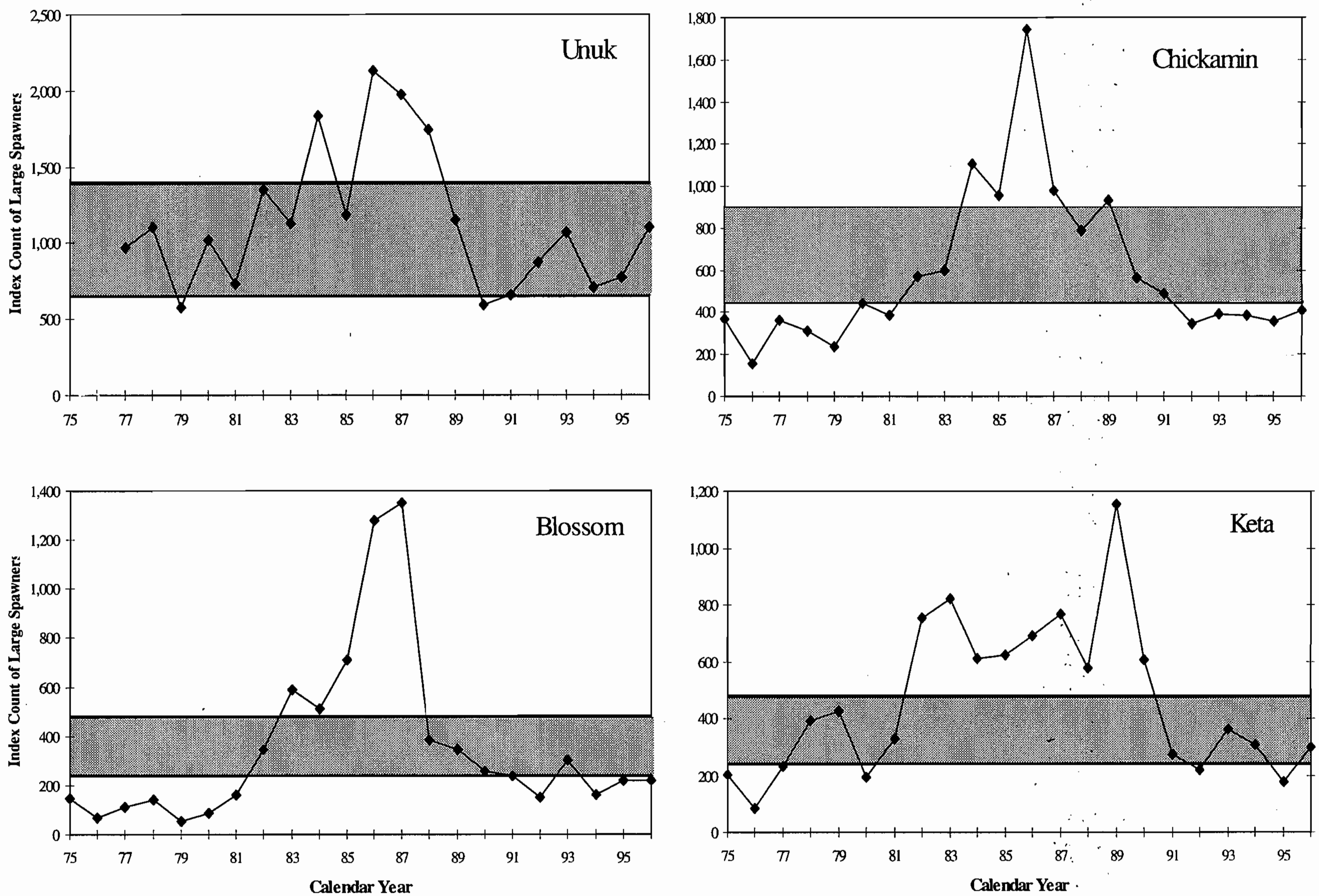


Figure 9. Observed index escapement counts of large chinook salmon in the Unuk, Chickamin, Blossom, and Keta Rivers, 1975 to 1996, with recommended biological escapement goal ranges.

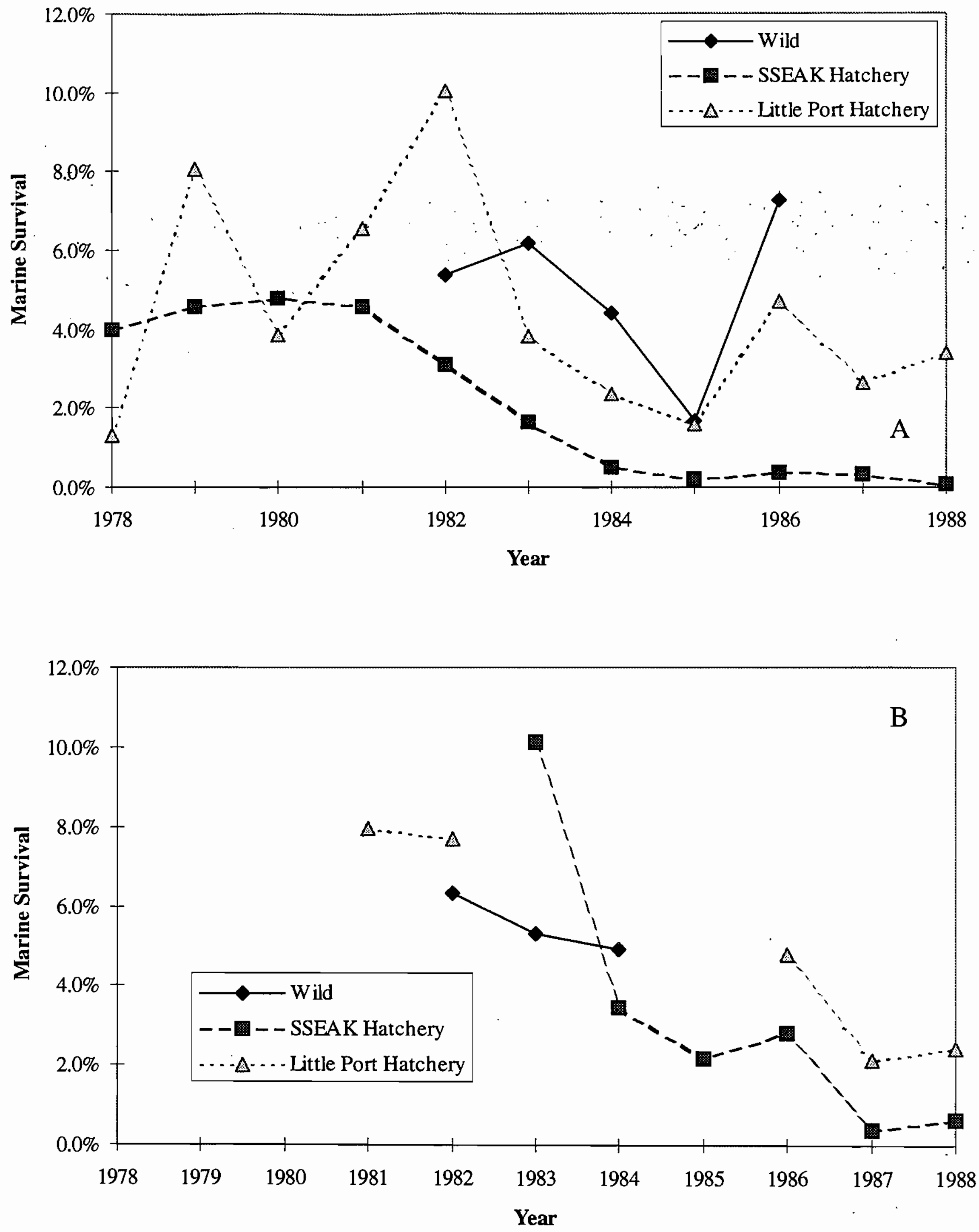


Figure 10. Estimated marine survival for wild and hatchery stocks of (A) Unuk and (B) Chickamin river chinook salmon for the 1978-1988 broods.

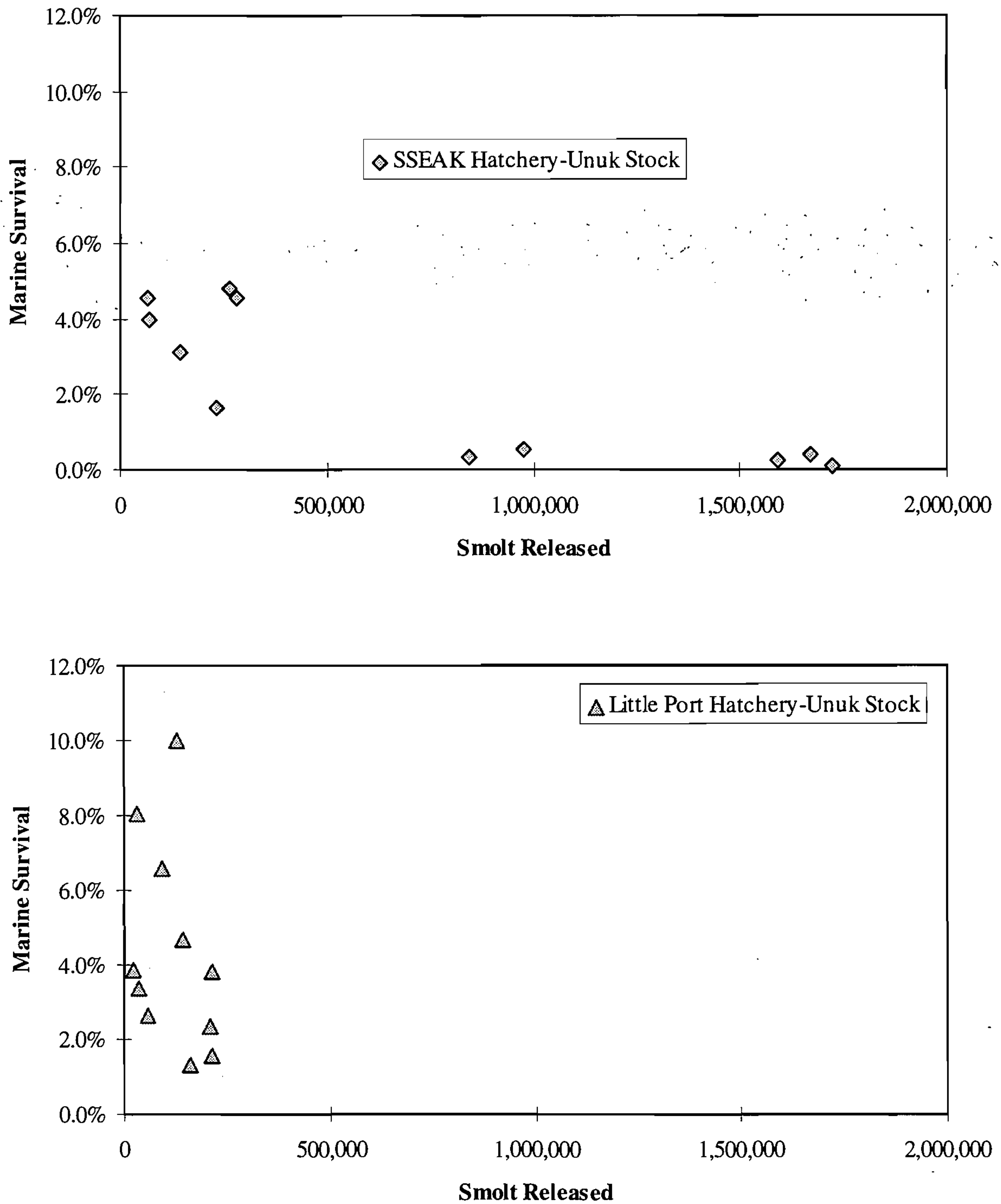


Figure 11. Estimated marine survival versus the number of smolt released for Unuk stock from hatcheries near Ketchikan in southern Southeast Alaska and at the Little Port Walter facility on southern Baranof Island.

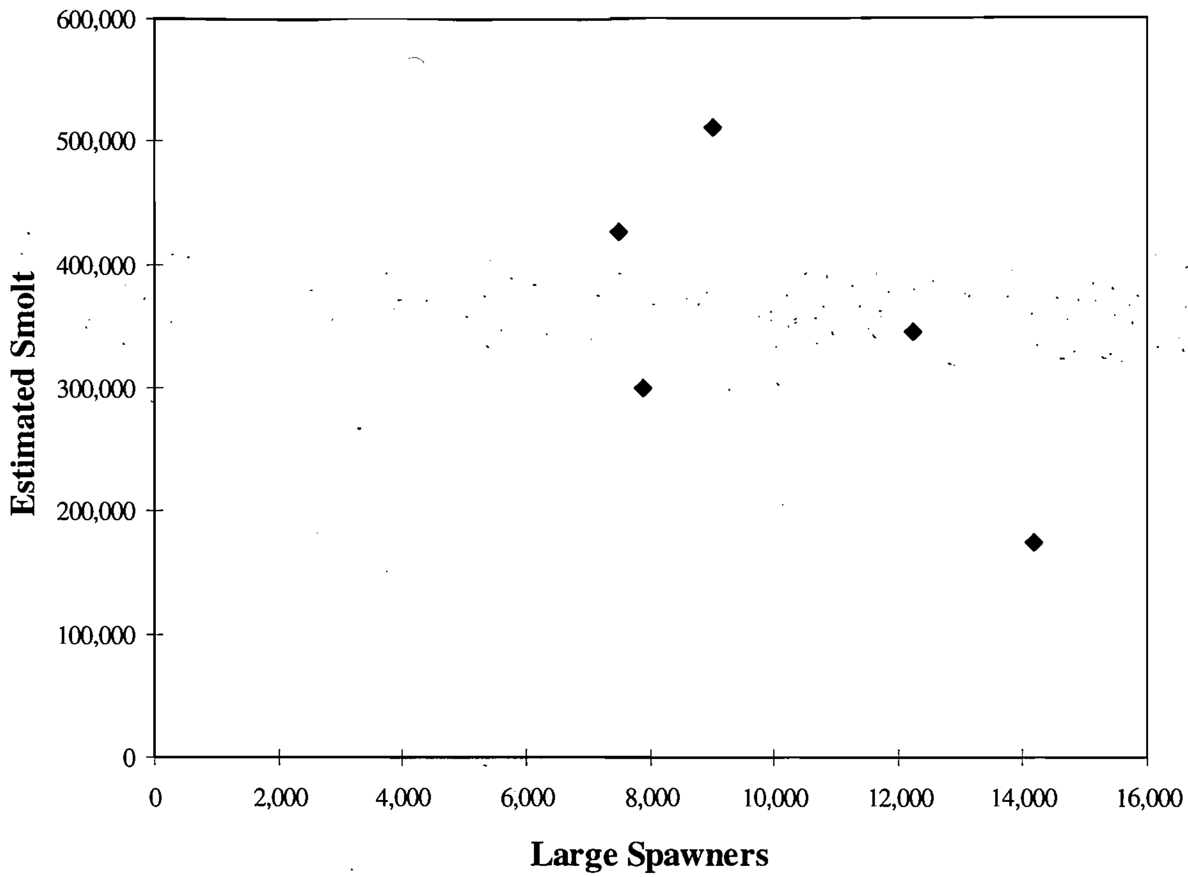


Figure 12. Estimated smolt versus estimated total escapement (index/0.15) for the Unuk wild stock, 1982-1986 broods.

APPENDICES

A.1. Adult equivalent (AEQ) factors used for Behm Canal chinook stocks.

Brood Year	AEQ factor for Unuk stock				AEQ factor for Chickamin stock			
	Age 3	Age 4	Age 5	Age 6	Age 3	Age 4	Age 5	Age 6
1975					0.5865	0.8048	0.9686	1.0000
1976					0.5865	0.8048	0.9686	1.0000
1977	0.5601	0.7957	0.9694	1.0000	0.5865	0.8048	0.9686	1.0000
1978	0.5601	0.7957	0.9694	1.0000	0.5440	0.7741	0.9503	1.0000
1979	0.6126	0.8155	0.9781	1.0000	0.6226	0.8131	0.9679	1.0000
1980	0.5935	0.8206	0.9834	1.0000	0.5891	0.8158	0.9808	1.0000
1981	0.6053	0.8360	0.9913	1.0000	0.5768	0.8038	0.9676	1.0000
1982	0.5758	0.8191	0.9744	1.0000	0.5564	0.7857	0.9547	1.0000
1983	0.5609	0.7969	0.9751	1.0000	0.6096	0.8241	0.9904	1.0000
1984	0.5605	0.7904	0.9617	1.0000	0.5543	0.7866	0.9663	1.0000
1985	0.5628	0.7869	0.9646	1.0000	0.6514	0.8177	0.9608	1.0000
1986	0.5694	0.8107	0.9705	1.0000	0.5877	0.8303	0.9861	1.0000
1987	0.5648	0.8016	0.9650	1.0000	0.5867	0.8139	0.9650	1.0000
1988	0.5632	0.7960	0.9724	1.0000	0.5729	0.7877	0.9643	1.0000
1989	0.5632	0.7960	0.9724	1.0000	0.5729	0.7877	0.9643	1.0000
AVG.	0.5754	0.8063	0.9733	1.0000	0.5865	0.8048	0.9686	1.0000
SD	0.0193	0.0152	0.0087	0.0000	0.0318	0.0184	0.0125	0.0000
CV	3%	2%	1%	0%	5%	2%	1%	0%

A.2. Estimated returns of Unuk River chinook salmon in escapements by age class for the 1977-1989 brood years.

Panel A. Numbers of fish are the index count in an age class divided by 0.25.

Brood Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total Return in Esc.
1977	35	543	13	833	0	1,515	2,208	0	5,148
1978	25	391	0	650	0	2,195	2,506	0	5,767
1979	0	865	19	1,283	0	4,842	950	83	8,042
1980	39	601	0	1,006	0	3,647	3,864	41	9,198
1981	0	170	138	2,031	0	4,557	4,041	59	10,996
1982	544	812	0	4,425	0	3,811	4,333	65	13,991
1983	0	3,583	0	3,743	0	2,592	2,616	131	12,666
1984	0	1,878	0	2,445	0	1,915	1,665	44	7,948
1985	0	352	0	902	0	525	537	37	2,354
1986	0	993	43	965	0	2,039	2,047	127	6,213
1987	0	220	0	714	0	1,412	2,343	88	4,777
1988	0	596	0	945	0	1,792	1,696	52	5,081
1989	0	190	10	508	11	1,042	1,515		3,275
Avg. 1977-89	50	861	17	1,573	1	2,453	2,332	61	7,343
SD	149	936	38	1,249	3	1,356	1,159	42	3,558

Panel B. Numbers of fish are the index count in an age class divided by 0.15.

Brood Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total Return in Esc.
1977	59	905	21	1,389	0	2,526	3,680	0	8,580
1978	42	651	0	1,084	0	3,658	4,177	0	9,612
1979	0	1,442	32	2,138	0	8,070	1,584	138	13,403
1980	65	1,002	0	1,676	0	6,079	6,440	68	15,330
1981	0	284	230	3,385	0	7,596	6,734	98	18,327
1982	907	1,354	0	7,376	0	6,351	7,222	108	23,318
1983	0	5,972	0	6,239	0	4,320	4,360	219	21,110
1984	0	3,131	0	4,076	0	3,192	2,775	74	13,246
1985	0	587	0	1,504	0	876	895	62	3,923
1986	0	1,655	71	1,609	0	3,398	3,411	212	10,356
1987	0	367	0	1,190	0	2,354	3,906	146	7,962
1988	0	994	0	1,574	0	2,986	2,827	87	8,468
1989	0	316	16	846	18	1,736	2,525		5,459
Avg. 1977-89	83	1,435	28	2,622	1	4,088	3,887	101	12,238
SD	249	1,561	64	2,081	5	2,260	1,932	70	5,929

A.3. Estimated total fishing mortality rates for the Unuk River stock in adult equivalents (AEQs), 1977-1989 broods.

Panel A. Unuk River chinook stock with 15% of escapement counted in index surveys

	Unuk wild stock data			Unuk hatchery data[a]			Unuk hatchery scaled to wild[b]		
Brood Year	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate
1977				41.5%	8.8%	50.3%	14.4%	3.1%	17.5%
1978				41.5%	8.8%	50.3%	14.4%	3.1%	17.5%
1979				40.2%	14.5%	54.7%	14.0%	5.0%	19.0%
1980				25.7%	11.8%	37.5%	9.0%	4.1%	13.1%
1981				28.4%	14.8%	43.1%	9.9%	5.1%	15.0%
1982	8.9%	5.8%	14.7%	40.6%	26.4%	67.0%	14.1%	9.2%	23.3%
1983	10.5%	9.3%	19.8%	24.4%	21.5%	45.9%	8.5%	7.5%	16.0%
1984	7.9%	5.1%	13.0%	28.1%	18.1%	46.2%	9.8%	6.3%	16.1%
1985	12.8%	10.1%	22.9%	21.8%	17.1%	39.0%	7.6%	6.0%	13.6%
1986	12.9%	5.2%	18.1%	39.9%	16.3%	56.2%	13.9%	5.7%	19.6%
1987				25.7%	17.7%	43.4%	8.9%	6.2%	15.1%
1988				23.6%	18.7%	42.3%	8.2%	6.5%	14.7%
1989				23.6%	18.7%	42.3%	8.2%	6.5%	14.7%
Avg. 1978-88				30.9%	16.9%	47.8%	10.8%	5.9%	16.6%
Avg.	10.6%	7.1%	17.7%	31.0%	19.9%	50.9%	10.8%	6.9%	17.7%
SD	2.2%	2.4%	3.9%	7.9%	4.7%	8.7%	2.7%	1.6%	3.0%
CV	21%	33%	22%	25%	28%	18%	25%	28%	18%
Scaler			0.348						

Panel B. Unuk River chinook stock with 25% of escapement counted in index surveys

	Unuk wild stock data			Unuk hatchery data			Unuk hatchery scaled to wild		
Brood Year	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate
1977				41.5%	8.8%	50.3%	21.4%	4.6%	26.0%
1978				41.5%	8.8%	50.3%	21.4%	4.6%	26.0%
1979				40.2%	14.5%	54.7%	20.8%	7.5%	28.3%
1980				25.7%	11.8%	37.5%	13.3%	6.1%	19.4%
1981				28.4%	14.8%	43.1%	14.7%	7.6%	22.3%
1982	13.5%	8.8%	22.3%	40.6%	26.4%	67.0%	21.0%	13.7%	34.7%
1983	15.5%	13.7%	29.1%	24.4%	21.5%	45.9%	12.6%	11.1%	23.7%
1984	12.2%	7.8%	20.0%	28.1%	18.1%	46.2%	14.5%	9.4%	23.9%
1985	18.5%	14.5%	33.1%	21.8%	17.1%	39.0%	11.3%	8.9%	20.2%
1986	19.2%	7.8%	27.0%	39.9%	16.3%	56.2%	20.7%	8.4%	29.1%
1987				25.7%	17.7%	43.4%	13.3%	9.2%	22.5%
1988				23.6%	18.7%	42.3%	12.2%	9.7%	21.9%
1989				23.6%	18.7%	42.3%	12.2%	9.7%	21.9%
Avg. 1978-88				30.9%	16.9%	47.8%	16.0%	8.7%	24.7%
Avg.	15.8%	10.5%	26.3%	31.0%	19.9%	50.9%	16.0%	10.3%	26.3%
SD	3.0%	3.3%	5.2%	7.9%	4.7%	8.7%	4.1%	2.4%	4.5%
CV	19%	31%	20%	25%	28%	18%	25%	28%	18%
Scaler			0.517						

[a] Based on releases and recoveries of chinook salmon from Unuk River brood stock in southern SEAK hatcheries near Ketchikan.
[b] Hatchery mortality rate scaled to wild mortality rates seen for 1982-86 broods.

A.4. Estimated returns of Chickamin River chinook salmon in escapements by age class for the 1975-1989 brood years.

Panel A. Numbers of fish are the index count in an age class divided by 0.25.

Brood Year	Total Age and Age Class								Total Return in Esc.
	3 Year		4 Year		5 Year		6 Year	7 Year	
	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	
1975	0	106	2	194	0	848	757	65	1,972
1976	0	82	3	362	0	732	1,126	69	2,373
1977	0	152	3	313	0	1,089	1,182	126	2,864
1978	0	132	4	465	0	1,143	2,173	0	3,916
1979	0	196	4	488	0	2,102	1,496	0	4,286
1980	0	206	8	897	0	2,161	1,621	50	4,943
1981	0	378	166	333	0	5,359	1,340	36	7,612
1982	0	0	0	1,243	0	2,510	1,280	234	5,267
1983	0	1,720	0	1,818	0	1,829	2,100	122	7,589
1984	0	572	0	421	0	1,402	1,711	56	4,162
1985	0	0	0	276	0	396	960	40	1,672
1986	0	172	26	693	0	929	682	44	2,546
1987	0	274	3	396	0	660	767	44	2,145
1988	0	167	2	282	0	742	765	35	1,993
1989	0	119	3	317	0	740	874		2,052
Avg. 1975-89	0	285	15	566	0	1,509	1,256	66	3,693
SD	0	422	42	443	0	1,241	484	61	1,963

Panel B. Numbers of fish are the index count in an age class divided by 0.15.

Brood Year	Total Age and Age Class								Total Return in Esc.
	3 Year		4 Year		5 Year		6 Year	7 Year	
	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	
1975	0	176	3	324	0	1,413	1,262	109	3,287
1976	0	136	5	603	0	1,221	1,876	114	3,956
1977	0	254	4	521	0	1,815	1,970	210	4,774
1978	0	219	7	775	0	1,905	3,621	0	6,527
1979	0	326	7	813	0	3,503	2,494	0	7,143
1980	0	343	13	1,495	0	3,602	2,701	84	8,238
1981	0	630	277	554	0	8,932	2,233	59	12,686
1982	0	0	0	2,072	0	4,183	2,133	390	8,778
1983	0	2,867	0	3,030	0	3,048	3,500	204	12,649
1984	0	954	0	701	0	2,336	2,852	93	6,936
1985	0	0	0	460	0	661	1,600	66	2,787
1986	0	286	43	1,155	0	1,548	1,137	74	4,243
1987	0	457	6	661	0	1,100	1,278	74	3,575
1988	0	278	4	469	0	1,236	1,275	58	3,321
1989	0	198	4	528	0	1,233	1,457		3,420
Avg. 1975-89	0	475	25	944	0	2,516	2,093	110	6,155
SD	0	704	71	738	0	2,068	806	101	3,272

A.5. Estimated total fishing mortality rates for the Chickamin River stock in adult equivalents (AEQs), 1975-1989 broods.

Panel A. Chickamin River chinook stock with 15% of escapement counted in index surveys

	Chickamin wild stock data			Hatchery data[a]			Hatchery scaled to wild		
Brood Year	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate
1975				45.1%	6.4%	51.5%	29.0%	4.1%	33.1%
1976				45.1%	6.4%	51.5%	29.0%	4.1%	33.1%
1977				45.1%	6.4%	51.5%	29.0%	4.1%	33.1%
1978				45.1%	6.4%	51.5%	29.0%	4.1%	33.1%
1979				32.3%	9.1%	41.4%	20.8%	5.8%	26.6%
1980				29.2%	10.3%	39.5%	18.8%	6.6%	25.4%
1981				32.1%	15.6%	47.8%	20.6%	10.0%	30.7%
1982	14.2%	9.5%	23.7%	35.8%	24.1%	59.9%	23.0%	15.5%	38.5%
1983	18.9%	6.2%	25.2%	30.7%	10.1%	40.8%	20.9%	6.9%	27.8%
1984	27.6%	18.4%	46.0%	42.0%	28.1%	70.1%	28.6%	19.2%	47.8%
1985	22.8%	21.8%	44.7%	25.8%	24.6%	50.4%	17.6%	16.8%	34.4%
1986	27.3%	16.5%	43.8%	45.4%	27.4%	72.8%	31.0%	18.7%	49.7%
1987				29.1%	35.6%	64.7%	19.9%	24.3%	44.2%
1988				30.8%	23.5%	54.3%	19.8%	15.1%	34.9%
1989				30.8%	23.5%	54.3%	19.8%	15.1%	34.9%
Avg. 1978-88				34.4%	19.5%	53.9%	22.7%	13.0%	35.7%
Avg. 1982-86	22.2%	14.5%	36.7%	35.9%	22.9%	58.8%	24.2%	15.4%	39.6%
SD	5.7%	6.5%	11.2%	6.8%	9.6%	11.7%	4.6%	6.6%	8.4%
CV	26%	44%	31%	20%	49%	22%	20%	51%	24%

Panel B. Chickamin River chinook stock with 25% of escapement counted in index surveys

	Chickamin wild stock data			Hatchery data			Hatchery scaled to wild		
Brood Year	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate	Landed Wild ER	Incidental Mortality Rate	Total Fishing Mortality Rate
1975				45.1%	6.4%	51.5%	38.4%	5.4%	43.8%
1976				45.1%	6.4%	51.5%	38.4%	5.4%	43.8%
1977				45.1%	6.4%	51.5%	38.4%	5.4%	43.8%
1978				45.1%	6.4%	51.5%	38.4%	5.4%	43.8%
1979				32.3%	9.1%	41.4%	27.5%	7.7%	35.2%
1980				29.2%	10.3%	39.5%	24.8%	8.8%	33.6%
1981				32.1%	15.6%	47.8%	27.3%	13.3%	40.6%
1982	20.4%	13.7%	34.1%	35.8%	24.1%	59.9%	30.4%	20.5%	50.9%
1983	27.0%	8.9%	35.9%	30.7%	10.1%	40.8%	27.3%	9.0%	36.3%
1984	35.2%	23.5%	58.7%	42.0%	28.1%	70.1%	37.4%	25.0%	62.4%
1985	29.3%	28.0%	57.4%	25.8%	24.6%	50.4%	22.9%	21.9%	44.9%
1986	35.2%	21.3%	56.5%	45.4%	27.4%	72.8%	40.4%	24.5%	64.9%
1987				29.1%	35.6%	64.7%	26.0%	31.7%	57.7%
1988				30.8%	23.5%	54.3%	26.2%	20.0%	46.2%
1989				30.8%	23.5%	54.3%	26.2%	20.0%	46.2%
Avg. 1978-88				34.4%	19.5%	53.9%	29.9%	17.1%	47.0%
Avg. 1982-86	29.4%	19.1%	48.5%	35.9%	22.9%	58.8%	31.7%	20.2%	51.9%
SD	6.2%	7.7%	12.4%	6.8%	9.6%	11.7%	6.0%	8.6%	10.8%
CV	21%	40%	25%	20%	49%	22%	20%	51%	23%

[a] Unuk and Chickamin brood-stock hatchery data from southern SEAK and Little Port Walter for 1978-82 and 1988-89 broods, and southern SEAK Chickamin hatchery data (for Chickamin brood-stock releases only) 1983-1987.

A.6. Estimated returns of Blossom River chinook salmon in escapements by age class for the 1975-1989 brood years.

Panel A. Numbers of fish are the index count in an age class divided by 0.40.

Brood Year	Total Age and Age Class								Total Return in Esc.
	3 Year		4 Year		5 Year		6 Year	7 Year	
	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	
1975	0	39	0	33	0	108	196	20	395
1976	0	15	0	54	0	192	426	34	721
1977	0	24	0	97	0	417	727	29	1,294
1978	0	43	0	210	0	712	627	0	1,591
1979	0	94	0	358	0	614	773	74	1,912
1980	0	160	0	309	0	954	1,576	78	3,078
1981	0	138	0	591	0	1,545	1,664	22	3,960
1982	0	0	0	776	0	1,631	474	20	2,900
1983	0	348	0	819	0	464	424	15	2,070
1984	0	367	0	233	0	416	317	14	1,347
1985	0	104	0	209	0	311	295	9	927
1986	0	94	0	156	0	289	185	18	741
1987	0	70	0	145	0	181	374	9	779
1988	0	65	0	91	0	366	199	13	733
1989	0	41	0	184	0	195	268		687
Avg. 1975-89	0	107	0	284	0	560	568	25	1,542
SD	0	111	0	250	0	473	465	23	1,054

Panel B. Numbers of fish are the index count in an age class divided by 0.25.

Brood Year	Total Age and Age Class								Total Return in Esc.
	3 Year		4 Year		5 Year		6 Year	7 Year	
	0.2	1.1	0.3	1.2	0.4	1.3	1.4	1.5	
1975	0	62	0	52	0	172	314	32	633
1976	0	23	0	86	0	307	681	54	1,153
1977	0	39	0	155	0	667	1,162	47	2,070
1978	0	69	0	335	0	1,139	1,003	0	2,546
1979	0	150	0	572	0	982	1,236	118	3,059
1980	0	256	0	494	0	1,527	2,522	125	4,924
1981	0	221	0	945	0	2,472	2,662	35	6,336
1982	0	0	0	1,242	0	2,609	758	32	4,640
1983	0	556	0	1,311	0	743	679	24	3,312
1984	0	587	0	373	0	665	507	22	2,155
1985	0	167	0	334	0	497	472	14	1,484
1986	0	150	0	250	0	462	296	28	1,186
1987	0	112	0	232	0	290	598	15	1,247
1988	0	104	0	146	0	586	318	20	1,174
1989	0	65	0	294	0	311	428		1,099
Avg. 1975-89	0	171	0	455	0	895	909	40	2,468
SD	0	178	0	400	0	757	744	37	1,686

A.7. Estimated returns of Keta River chinook salmon in escapements by age class for the 1975-1989 brood years.

Panel A. Numbers of fish are the index count in an age class divided by 0.40.

Brood Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total Return in Esc.
1975	0	0	0	55	11	186	461	0	713
1976	0	0	0	25	19	319	1,114	60	1,536
1977	0	0	0	43	86	685	1,152	90	2,055
1978	0	0	0	86	47	796	807	46	1,782
1979	0	0	0	107	0	628	874	50	1,660
1980	0	0	0	90	36	605	967	56	1,753
1981	0	0	0	81	39	669	1,076	42	1,907
1982	0	0	0	90	44	744	806	84	1,768
1983	0	0	0	100	33	557	1,618	44	2,352
1984	0	0	0	75	66	1,119	849	20	2,129
1985	0	0	0	150	35	587	381	16	1,169
1986	0	0	0	79	16	264	304	26	688
1987	0	0	0	35	12	210	507	22	788
1988	0	0	0	28	21	351	429	13	841
1989	0	0	0	47	17	296	245		606
Avg. 1975-89	0	0	0	73	32	534	773	41	1,450
SD	0	0	0	34	23	260	384	26	593

Panel B. Numbers of fish are the index count in an age class divided by 0.25.

Brood Year	3 Year 0.2	3 Year 1.1	4 Year 0.3	4 Year 1.2	5 Year 0.4	5 Year 1.3	6 Year 1.4	7 Year 1.5	Total Return in Esc.
1975	0	0	0	89	18	298	737	0	1,141
1976	0	0	0	40	30	510	1,782	96	2,458
1977	0	0	0	69	137	1,097	1,842	144	3,288
1978	0	0	0	137	75	1,274	1,292	73	2,851
1979	0	0	0	171	0	1,005	1,399	81	2,655
1980	0	0	0	144	57	967	1,547	90	2,804
1981	0	0	0	130	63	1,070	1,721	67	3,051
1982	0	0	0	144	70	1,191	1,289	135	2,828
1983	0	0	0	160	53	891	2,589	71	3,764
1984	0	0	0	120	106	1,790	1,358	32	3,406
1985	0	0	0	241	55	939	610	25	1,871
1986	0	0	0	126	25	422	486	42	1,102
1987	0	0	0	57	20	336	811	36	1,260
1988	0	0	0	45	33	561	686	20	1,346
1989	0	0	0	75	28	474	392		970
Avg. 1975-89	0	0	0	116	51	855	1,236	65	2,320
SD	0	0	0	55	36	417	614	42	949