BIOLOGICAL ESCAPEMENT GOAL FOR ANDREW CREEK CHINOOK SALMON

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Available data consisting of escapements, age compositions, and estimated harvests of chinook salmon *Oncorhynchus tshawytscha* returning to Andrew Creek, a tributary to the Stikine River in Southeast Alaska, during the years 1975-1997, were analyzed. Ten years of weir operations provided a portion of the escapement database; the remaining annual escapements in the database were estimated based upon peak survey counts of escapement multiplied by an expansion factor estimated from five years of paired weir counts and peak surveys. During 7 of the 23 years in the data set, age compositions of the escapements were sampled; average age compositions from these 7 years were used as surrogate estimates of age compositions during the remaining 16 years of the data set. Jacks were counted during 6 years and age compositions of jacks were sampled during 7 years in the data set. The proportions of jacks in the total returns for 5 brood years in the data set were estimated based upon sampling data. The average proportion of jacks in the returns for these 5 brood years was used as surrogate estimates of the proportions of jacks in returns for other brood years. Once these calculations were complete, inriver runs for both jacks and large-sized chinook by brood year were estimated. Subsequently, the inriver runs were adjusted for assumed fishing mortality using available fishery exploitation rates for the nearby Crystal Lake Hatchery stock of chinook salmon. From these data, escapements and total recruits for brood years 1975-1991 were estimated. These paired data (n = 17) were analyzed with regression techniques to develop a spawner-recruit relationship. Two bootstrap runs were subsequently developed, one that assumed escapements had a coefficient of variation of 20% and another that assumed escapements had a coefficient of variation of 30%. Weaknesses and shortcomings of the Andrew Creek database are discussed and potential improvements in the stock assessment program are identified. From these various analyses, the escapement level predicted to provide maximum sustained yield to fisheries was estimated. Based upon these analyses and statistics, we recommend that the Alaska Department of Fish and Game adopt a biological escapement goal range of 650 to 1,500 total large spawners for the Andrew Creek stock of chinook salmon.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, Andrew Creek, brood table, spawner-recruit, biological escapement goal.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* are known to spawn in 34 streams in Southeast Alaska, including rivers that originate in Canada, cross Southeast Alaska (SEAK) and terminate in coastal waters of SEAK. In the mid-1970s, the Alaska Department of Fish and Game (ADF&G) became concerned with stock status of chinook salmon in SEAK and implemented fishery management measures aimed at increasing chinook salmon escapements. Initial fishery management measures included closing fisheries in terminal and near-terminal areas during the spring migration period. By the early 1980's, continuing conservative fishery management measures included establishment of catch ceilings and implementation of a 15-year chinook salmon rebuilding program. In the mid-1980's, the Alaskan chinook salmon rebuilding program was incorporated into a comprehensive coast-wide rebuilding program as part of the Pacific Salmon Treaty with the objective of increasing escapement levels of wild stocks of chinook salmon returning to Oregon, Washington, British Columbia and SEAK. In order to quantitatively track the rebuilding progress of chinook salmon escapements in SEAK, a group of streams was selected to perform annual escapement surveys to enumerate or index wild chinook salmon spawner abundance. One of the streams selected was Andrew Creek (Figure 1).

Andrew Creek is a lower drainage and U. S. tributary to the trans-boundary Stikine River that supports a significant run of chinook salmon (Figure 1). ADF&G operated a weir on Andrew Creek from 1976-1984 to enumerate chinook salmon spawners and to facilitate collection of spawners for egg takes used to initiate hatchery populations of chinook salmon elsewhere in SEAK. In 1997, a weir was operated on Andrew Creek to estimate chinook salmon spawner abundance and to facilitate sampling of those fish for age and sex composition. Annual aerial and/or foot counts of chinook salmon have been made to index spawner abundance in Andrew Creek during most years since 1956.

At the time that the rebuilding program was begun, stock status data for SEAK chinook salmon was very limited. However, it was believed that definition of specific escapement goals was a needed ingredient of the rebuilding program. Therefore, faced with very limited data, a simple approach to definition and calculation of escapement goals for most stocks was used. Specifically, ADF&G set escapement goals for most SEAK chinook salmon stocks at the highest escapement levels documented in the historic stock assessment data sets.

In the case of the Andrew Creek, in 1985, ADF&G set the escapement goal at 750 large chinook salmon (or 470 chinook salmon counted during peak aerial or foot surveys) and this biological escapement goal has not been changed since then. This goal of 750 fish for the annual Andrew Creek chinook salmon escapement refers to "large" chinook salmon, not to jacks, because only large fish can be accurately counted during aerial surveys, which has been the predominant stock assessment methodology. The goal of 750 large fish was set at a value somewhat higher than counts made at the weir during the 9-year period of 1976-1984 (highest weir count of large fish was 672 in 1982). However, unlike most other SEAK stocks the goal was <u>not</u> set at the level of the highest counts in the historic database (highest count at Andrew Creek was 4,500 fish counted in 1956). This biological escapement goal set in 1985 for the Andrew Creek stock of chinook salmon was based upon a biological judgement at the time, not upon a scientific analysis of escapements and resulting production nor upon any other quantitative nor scientific methodology.

This report is written to document stock assessment data available for the chinook salmon stock that spawns in Andrew Creek and to analyze these data and formulate a recommendation concerning an appropriate biological escapement goal range. To estimate total recruits, available data concerning abundance and age composition in escapements of this stock of chinook salmon are coupled with estimates of marine exploitation of a nearby coded-wire-tagged hatchery stock that is used as an indicator of harvest rates for the Andrew Creek stock. These data are analyzed to develop a spawner-recruit relationship. This estimated relationship is scientifically analyzed to predict the range of escapements expected to provide for maximum sustained yield. This range is then used to formulate a recommendation to ADF&G concerning revision of the biological escapement goal for the Andrew Creek stock of chinook salmon.

AVAILABLE DATA, METHODS, AND RESULTS

Because development and analysis of spawner-recruit relationships is a sequential process with each step building on previous steps of the analysis, each step of this analysis including the available data, methodology applied to that data, and the initial results will be presented sequentially rather than using the more typical technical report format of presenting all methods followed by all results. The following sections of this report describe available data, methodology, and results obtained when applying the methodology to the data for six steps of the analysis: 1) estimation of annual spawning populations; 2) estimation of the age composition of the inriver runs; 3) estimation of jacks and total fish in inriver runs; 4) estimation of marine exploitation rates by brood year and estimation of total recruitment; 5) estimation of the spawner-recruit relationship and corresponding production statistics, and, 6) bootstrap analysis of the spawner-recruit relationship.

ESTIMATION OF ANNUAL SPAWNING POPULATIONS

Chinook salmon spawning in Andrew Creek were enumerated from 1956-1969 by biologists during aerial surveys or while walking the banks of the stream. Survey techniques varied substantially during this 14-year period and annual counts ranged from 12 fish counted in 1969 to 4,500 fish counted in 1956. The Andrew Creek chinook salmon escapement was not assessed in 1970 nor in 1972; aerial surveys to assess spawning escapements were conducted in 1971, 1973, and 1974, with counts ranging from 40 to 305 fish.

The chinook salmon population in Andrew Creek has been assessed annually each year since 1975 with 10 of the 23 annual assessments through 1997 being weir counts and the remaining 13 annual assessments being peak counts of spawning chinook salmon made by biologists while walking the banks of the stream or while flying in helicopters or fixed wing aircraft. Chinook salmon returning to spawn in Andrew Creek mature and return at various ages; fish that return after spending less than three years at sea are smaller and are difficult to see and discern from other species during these surveys; most of these fish are males (jacks) and contribute little if at all to the annual egg deposition leading to future generations. Staff making surveys count large fish, those that have spent three or more years at sea. Hereafter, the term large refers to chinook salmon that are 3-ocean age and older fish; the term jack refers to 1- and 2-ocean age fish.

As the chinook salmon hatchery program in SEAK developed during the mid to late 1970's and early to mid 1980's, the Andrew Creek population of spawning chinook salmon was mined to provide brood stock for various SEAK hatcheries. A weir was constructed across the lower portion of Andrew Creek and this structure was operated annually by ADF&G staff from 1976 to 1984 to enumerate the chinook salmon spawning population and to remove brood stock for hatchery use. ADF&G staff counted jack and large chinook salmon as they passed upstream above the weir and kept track of fish removed for brood stock. The spawning population of chinook salmon upstream of the weir was assessed by peak survey techniques during four of the nine years of weir operation; 1979, 1981, 1982, and 1984.

In 1997, a weir was again placed in Andrew Creek; but the purpose of the weir this time was specifically for stock assessment. However, the lower portion of the stream had changed channels since the mid-1980s and a significant portion of the chinook salmon did not pass upstream. The weir was removed on August 18 and on that date a survey count was conducted downstream of the weir. Based upon counts of chinook through the weir and an expansion of counts made by survey below the weir, an estimate of the total large spawner abundance was made. A survey of the stream to assess peak spawner abundance, similar to previous years was also conducted in 1997.

The 5 annual paired data points consisting of peak surveys and weir counts (data from 1979, 1981, 1982, 1984, and 1997) provide a quantitative basis for expanding peak counts of chinook salmon in Andrew Creek into estimates of total spawning population for the years when only peak survey count data are available. The weir data collected in 1979, 1981, 1982, and 1984 also provides a basis for estimating annual returns of jacks that are not enumerated during surveys.

During the years that the weir was operated and spawning fish readily passed upstream (1976-1984), annual spawning escapements of large chinook salmon were directly enumerated (Table 1) and the counts are considered almost a complete census (not a complete census because small numbers of chinook spawned in the North Fork of Andrew Creek where they were counted by foot survey and these surveys were expanded). The estimate of spawner abundance in 1997 is not considered a total census because counts made downstream of the weir on August 18th were expanded based on average proportions of spawners observed during surveys in 1979, 1981, 1982, and 1984 (0.531). Thus the estimate of 478 large fish spawning in Andrew Creek in 1997 is based on a weir count of 284 large fish, a survey count of 103 large fish located downstream of the weir and 91 large fish located downstream and assumed to have been present but not directly counted during the August 18th survey.

Estimates of annual spawning escapements of large chinook salmon in Andrew Creek during other years in the 1975-1996 data set were based upon the annual peak survey count divided by an average expansion factor of 0.548 (Table 1). This factor was the average proportion of the estimated total large chinook salmon escapement observed during annual peak surveys in the 5 years of 1979, 1981, 1982, 1984, and 1997 (Table 1). Based upon this methodology, annual spawning escapements of large, three-ocean age and older chinook salmon in Andrew Creek ranged between 282 fish in 1980 to 1,934 fish in 1993, averaging 768 fish per year during the 23-year period of 1975-1997 (Table 1).

Application of the expansion factor methodology to the five years when the annual escapement of large chinook salmon was either directly counted at the weir (1979, 1981, 1982, and 1984) or largely enumerated at the weir (1997) and during which peak surveys were conducted concurrently provides a basis for estimating potential errors associated with estimates of large chinook salmon escapements in years when the weir was not used directly to count escapements (Table 1). Such application to the 1979, 1981, 1982, 1984, and 1997 data sets results in an average absolute error of 15% (64 fish); ranging from a potential error of 28% (underestimate of 108 fish) in 1984 to 23% (overestimate of 76 fish) in 1979.

ESTIMATION OF AGE COMPOSITION OF ANNUAL INRIVER RUNS OF LARGE FISH

The numbers of large chinook salmon removed for brood stock each year from 1976-1983 were added to the annual estimated escapements to estimate total annual inriver runs of large chinook salmon to Andrew Creek. Estimated inriver removal rates for egg takes ranged from 3% in 1978 to 29% in 1982 (Table 2). During other years in the 1975-1997 data set when egg-takes did not take place, annual inriver runs were estimated to be the same as the estimated escapement (Table 2).

Between 45 and 304 large chinook salmon returning to Andrew Creek were sampled annually at the weir and their ages determined during the 7-year period of 1979-1984 and 1997 (Table 3). Annual age compositions of large chinook salmon during this 7-year period ranged from 0 to 7% age-4 fish, from 15% to 76% age-5 fish, from 22% to 82% age-6 fish, and from 0 to 4% age-7 fish (Table 4).

Average age composition of large chinook salmon returning to Andrew Creek during the 7-year period of 1979-1984 and 1997 was 0% age-4 fish, 45% age-5 fish, 53% age-6 fish, and 2% age-7 fish (Table 3). This 7-year average age composition for large chinook salmon was used as a proxy estimate of the annual age composition of large chinook salmon during the period 1975-1978 and during the period 1985-1996, years when direct sampling events to estimate age compositions were not made (Table 4). Annual age composition estimates for large chinook salmon were multiplied by their respective annual estimate of the inriver total run to estimate numbers of age-4 through age-7 fish in the annual inriver runs for the years 1975-1997 (Table 5).

Application of the average age estimates (i.e., 0% age-4 fish, 45% age-5 fish, 53% age-6 fish, and 2% age-7 fish) to the seven years when age estimates used in this report were based on direct sampling provides a basis for estimating potential errors associated with use of average ages when annual sampling to estimate age composition was not conducted (Table 6). Such application to the 1979, 1980, 1981, 1982, 1983, 1984, and 1997 data sets results in a potential average absolute error of 28% for age-4 fish, 48% for age-5 fish, 49% for age-6 fish, and 70% for age-7 fish (Table 6). For some years and age classes, potential errors were non-existent, but for other years and age classes, potential errors were large. Age composition errors associated with the two major age classes, age-5 and age-6, have the potential to introduce large errors into estimates of age specific recruits from specific brood years.

ESTIMATION OF JACKS AND TOTAL FISH IN ANNUAL INRIVER RUNS

Jack chinook salmon passing the Andrew Creek weir were directly enumerated from 1979-1984. Jack counts ranged from 38 fish counted in 1983 to 272 fish counted in 1980 (Table 7). Jacks were sampled at the Andrew Creek weir to estimate age composition with sampling ranging from 26 jacks sampled and aged in 1982 to 139 jacks sampled and aged in 1984 (Table 3). Although a count of jacks passing upstream of the weir in 1997 was made, there was no basis for developing a complete estimate of the jack run because of the inability to accurately directly count or otherwise estimate numbers of jacks downstream of the weir. A total of 22 jacks were sampled at the weir in1997 for age composition (Table 3).

Annual age composition of jacks sampled at the Andrew Creek weir ranged from 5% to 23% age-3 fish, from 77% to 95% age-4 fish, and from 0 to 3 % age-5 fish during the 7-year period of 1979-1984 and 1997 (Table 7). Jack counts multiplied by estimated age composition resulted in estimates ranging from 2 to 40 age-3 jacks returning per year, from 36 to 259 age-4 jacks returning per year, and from 0 to 3 age-5 jacks returning per year during the 6-year period of 1979-1984 (Table 7).

The proportion of jacks in the total inriver run cohorts of chinook salmon for each of the five brood years of 1976-1980 was estimated by dividing the number of jacks returning from the brood year three, four, and five years later by the summation of: 1) the number of jacks returning three years later, 2) the number of jack and large age-4 fish returning four years later, 3) the number of jack and large age-5 fish returning five years later, 4) the number of large age-6 fish returning six years later, and 5) the number of large age-7 fish returning seven years later. The estimated percent jack composition for inriver runs of chinook salmon to Andrew Creek for brood years 1976-1980 ranged from 9.4% jacks returning from brood year 1979 to 31.7% jacks returning from brood year 1977; the 5-year average was 18.8% with the average age-3 jack return estimated at 2.6%, the average age-4 jack return estimated at 16.2%, and the average age-5 jack return estimated at 0.0% (Table 8).

The 5-year average values of 2.6% age-3, 16.2% age-4, and 0.0% age-5 jacks in inriver total runs from brood years 1976-1980 were used as proxy values for other brood years. The estimation procedure for jacks of all ages was first to add the age 4-7 large fish returns from a brood year, assume that summation represented 81.2% of the total brood year return (jacks plus large fish), divide that total by 0.812 or 1.000-0.188, and finally subtract the large fish total from the grand total. Estimation procedures for the number of age-3 and age-4 jacks were similarly done by proportions.

Using the above methodology, the number of jacks of all ages returning from brood years 1975-1991 was estimated to have ranged from 90 to 390 fish per brood year (Table 9). The numbers of age-3 jacks in inriver runs from these 17 brood years was estimated to have ranged from 2 fish from brood year 1980 to 54 fish from brood year 1987 and the number of age-4 jacks in inriver runs was estimated to have ranged from 36 fish from brood year 1979 to 336 fish from brood year 1987. Age-5 jacks were only sampled in 1979 (Table 7); these fish would have been returns from brood year 1974, a brood year not included in the spawner-recruit relationship discussed below; hence, no age-5 jacks are estimated to have returned from brood years 1975-1991, brood years included in the database used to estimate the spawner-recruit relationship.

Total inriver runs of chinook salmon to Andrew Creek for brood years 1975-1991 were estimated by adding annual estimates or counts of jack returns to the annual counts or estimates of returns for large chinook salmon by age class. Estimates of total inriver returns of chinook salmon to Andrew Creek for the 17 brood years of 1975-1991 ranged from 375 fish returning from brood year 1977 to 2,075 fish returning from brood year 1987 (Table 10).

ESTIMATION OF MARINE EXPLOITATION RATES AND TOTAL RECRUITMENT

Chinook salmon returning to Andrew Creek have not been tagged nor are they otherwise marked such that they can be distinguished from chinook salmon returning elsewhere when they are caught in conjunction with other chinook salmon in mixed stock fisheries. Nor is there a directed fishery for this small stock of chinook salmon. However, Crystal Lake Hatchery, located nearby (Figure 1), releases coded-wire-tagged chinook salmon and this hatchery stock can be used as an indicator stock to estimate marine exploitation of the Andrew Creek stock. Estimated exploitation rate (both landed catch and incidental mortality) of the Crystal Lake Hatchery stock ranged from 32.0% to 69.7% during brood years 1979-1991 (Table 11). Because of changing management of the SEAK fisheries since the late 1970's, it is believed that exploitation rate of chinook salmon for earlier brood years would be best approximated by using the average landed catch exploitation rate for brood years 1979-1982 (40.4%) coupled with the incidental mortality rate estimated for brood year 1979 (2.7%); resulting in an estimated exploitation rate for pre-1979 brood years of 43.1%. This approach was used to define proxy estimates for the brood year 1975-1978 total exploitation rates.

Total numbers of recruits resulting from each of the brood years from 1975 to 1991 for the chinook salmon stock that spawns in Andrew Creek were estimated. The estimation procedure was to adjust the total inriver estimates provided in Table 10 by the respective estimates of the marine exploitation rate for each of the brood years provided in Table 11 (divide the brood year total inriver return by 1.000 minus the estimated marine exploitation rate for the indicator stock by brood year). Estimated total brood year recruits from the spawning escapements of 1975-1991 ranged from 659 chinook salmon returning from brood year 1977 to 4,924 chinook salmon returning from brood year 1982 (Table 12).

THE SPAWNER RECUIT RELATIONSHIP AND PRODUCTION ESTIMATES

A paired data set consisting of the annual estimated escapements of large chinook salmon in Andrew Creek (from Table 1) and the estimated total recruits produced from these escapements (from Table 12) for brood years 1975-1991 (n = 17) was used to develop a spawner-recruit relationship by fitting this paired data set to the following model:

$$\mathbf{R = S\ \mathit{exp}[a(1\text{-}S/P_m)]} \qquad (1)$$

where: R = estimated total recruitment (jacks and large fish);
S = spawning escapement of large fish;
exp = base of the natural system of logarithms;
a = intrinsic rate of population increase in the absence of density-dependent limitations;
P_m = carrying capacity.

This model, commonly referred to as a Ricker recruitment curve (Ricker 1975), has two parameters, a and P_m, to estimate, given a series of spawner and resultant recruitment observations or estimates. We assumed the errors were log-normal (as is common for salmon returns), resulting in the log-transformed equation:

$$\mathbf{\mathit{Ln}(R/S) = a - a/P_m(S) + error.} \qquad (2)$$

Linear regression procedures provided estimates of the intercept (a) and the slope (a/P_m) of the equation. The estimated number of large spawners that produce the maximum number of recruits is:

$$\mathbf{S_{max} = P_m/a;} \qquad (3)$$

and, the estimated number of spawners that produce the maximum harvestable surplus (MSY escapement) is estimated by iteratively solving the equation:

$$\mathbf{S_{msy} = P_m/a\ \{1\text{-}\mathit{exp}[-a(1\text{-}S_{msy}/P_m)]\}.} \qquad (4)$$

Once the spawner-recruit relationship was calculated, a series of parameters were estimated including: 1) carrying capacity, or the point on the modeled spawner-recruit line where it intersects the replacement line; 2) the estimated escapement that produces the maximum recruits, or highest point on the curve (estimated maximum recruitment escapement or S_{max}); and, 3) the estimated MSY escapement, or the point on the modeled spawner-recruit line where harvestable surplus is at a maximum, or S_{msy}.

Analysis of the spawner-recruit relationship resulted in an estimate of 802 large spawners as the MSY escapement level for the Andrew Creek stock of chinook salmon (Table 13). The spawner-recruit relationship developed estimated that maximum surplus yield from the Andrew Creek stock of chinook salmon is 1,676 fish, on average. If the Andrew Creek stock of chinook salmon were managed at the indicated MSY escapement level of 802 large spawners per year, a fishery yield of 1,676 fish (jacks and large fish) is estimated to be provided, on average, indefinitely. Replacement escapement, or the point on the spawner-recruit relationship where harvestable surplus falls to zero, is estimated at 2,141 large spawning chinook salmon. The maximum stock size is estimated to occur with an escapement level of

1,187 large chinook salmon in the Andrew Creek escapement; the estimated total annual average stock size at this level of escapement is about 2,650 chinook salmon. A plot of the spawner-recruit relationship is provided in Figure 2; residuals in the relationship were calculated. The residual pattern when plotted against brood year escapements appear random (lower panel of Figure 3); however, when plotted through time, a temporal pattern is apparent (upper panel of Figure 3). Residuals in the spawner-recruit relationship were also plotted against estimated marine survival of the Crystal Lake Hatchery stock of chinook salmon to determine if this proxy estimate of marine survival for the wild stock of chinook salmon spawning in Andrew Creek had an obvious effect on the relationship and might assist in explaining the temporal pattern observed for the residuals. However, marine survival of the proxy stock is not correlated with the residuals in the spawner-recruit relationship developed (Figure 4). The temporal pattern of residuals is likely due to auto-correlation caused by use of common escapement expansions and use of average age and average jack estimates rather than some underlying natural factor.

BOOTSTRAP ANALYSIS OF THE SPAWNER RECRUIT RELATIONSHIP

The variances (mean square errors) for alpha, beta, and the MSY escapement level (S_{msy}) were estimated with modifications of bootstrap procedures in McPherson (1990). Error structure for Y (estimated total recruits) was assumed to be multiplicative-lognormal and error structure of X (estimated escapements of large chinook) was assumed to be multiplicative. Walters and Ludwig (1981) showed that multiplicative error structure for escapements, either normally or uniformly distributed, produced essentially the same results.

In the bootstrap run, the original data set (estimated escapements of large chinook from Table 1 and estimated total cohort recruitment of all size fish from Table 12) was fit using equation [1] and bias corrected residuals (ε_i) were stored. For each replicate, the same number of X and Y observations as in the original data set (n = 17) were used. 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 with a mean of 1.0 and a standard deviation of 0.20 or 0.30[1] for two separate runs of this bootstrap methodology. A new set of statistics $\{S_i^*, R_i^*\}$ along with new estimates for alpha, beta, and S_{msy} escapement (P_s^*) were generated from each bootstrap sample, and 1,000 such bootstrap samples were drawn creating the empirical distributions $\hat{F}(\hat{P}_s^*)$, $\hat{F}(\hat{\alpha})$, $\hat{F}(\hat{\beta})$, 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 $\hat{F}(\hat{P}_s^*)$, $\hat{F}(\hat{\alpha})$, $\hat{F}(\hat{\beta})$ 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 (1,000). The variances for alpha and beta were estimated similarly.

A maximum sustained yield escapement goal range was estimated using the 0.8 ($\overline{\hat{P}}_s^*$), to 1.6 ($\overline{\hat{P}}_s^*$) procedure of Eggers (1993). This method examined optimizing harvests over a wide range of management

[1] Rationale for use of a standard deviation of 0.20 for the first bootstrap run is that the coefficient of variation associated with the expansion factor estimate used to expand index counts of escapement into total estimates of escapement for 8 of the 17 broods used in the analysis was approximately 20%. However, it was felt that additional uncertainty is associated with the data set and that a second bootstrap run using a standard deviation of 0.30 might be even more appropriate.

scenarios. The bootstrap mean for P_s was used as the point value for recommending a revised biological escapement goal and this revised biological escapement goal is expressed as a range.

Based upon the 20% bootstrap run, the mean bootstrap estimate of MSY escapement for the Andrew Creek stock of chinook salmon was 907 large fish (Table 14). This estimate of the MSY escapement level is higher than the regression estimate of 802 large fish, differing by 105 fish and indicating bias is 13%. On the other hand, the median bootstrap estimate of the MSY escapement level is 774 large fish, 3% less than the regression estimate and 15% less than the mean bootstrap estimate of MSY escapement.

The mean bootstrap estimate of MSY escapement for the Andrew Creek stock of chinook salmon was 825 large fish in the 30% bootstrap run (Table 14). This estimate of the MSY escapement level is also higher than the regression estimate of 802 large fish, but differs by only 23 fish, indicating bias is 3%. The median bootstrap estimate of the MSY escapement level using the 30% bootstrap run is 723 large fish, 10% less than the regression estimate and 12% less than the mean bootstrap estimate of MSY escapement.

Based upon these analyses, we believe that the MSY escapement point value for the Andrew Creek stock of chinook salmon is 800-900 large fish and based upon the method of Eggers (1993), we believe that the biological escapement goal for the Andrew Creek stock of chinook salmon should be 650 to 1,500 large fish per year.

DISCUSSION

USE OF SEAK CHINOOK ESCAPEMENT GOALS AND RECENT EVALUATIONS OF THEIR APPROPRIATENESS

Since the early 1980's, the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) has used algorithms to analyze annual stock assessment escapement data and has compared trends in these data with existing management agency escapement goals for various stocks to make conclusions concerning progress toward rebuilding. These analyses provide useful information on a stock by stock basis as well as on a regional and/or coastal basis. For example, in their latest assessment, the CTC used such information to conclude that the Andrew Creek stock of chinook salmon was "rebuilding" (CTC 1998); and, in their 1996 report, the CTC concluded that the stock was "above goal" (CTC 1996). These conclusions were based upon a comparison of escapement trends and the ADF&G goal of 750 large chinook spawning in Andrew Creek.

An inherent assumption of the ADF&G and PSC chinook salmon rebuilding programs has been that chinook salmon stocks coast-wide were declining and/or depressed before rebuilding was implemented by fishery management agencies imposing regulatory restrictions on various coastal fisheries. However, as the CTC (1994) states "*not all chinook stocks were declining*" and further, as is becoming more and more obvious, not all chinook stocks were depressed. There was only scanty scientific information available for many of the chinook salmon stocks assumed to be depressed when the chinook salmon rebuilding program was begun. Such was the case for the Andrew Creek chinook salmon stock. ADF&G assumed the Andrew Creek stock of chinook salmon and all other SEAK wild stocks of chinook salmon were depressed and consequently, ADF&G adopted conservative escapement goal policies. The escapement goals for most stocks were defined at the very upper limits of the available observations concerning prior escapement levels. Coupled with SEAK and international fishery restrictions, these very conservative escapement goal policies were thought to ensure greatly increased annual escapements in future years. However, on a stock by stock basis, this result would only occur if the stock was, in fact, depressed, and if, the escapement goal defined was less than or a reasonable approximation of the maximum sustainable yield escapement level (annual escapement level that would, on average, maximize long-term yield to fisheries).

Many ADF&G technical staff and PSC technical committee members have long recognized that the escapement goals developed at the time of the implementation of the ADF&G and PST chinook salmon rebuilding programs were not necessarily good estimates or even estimates of the maximum sustainable yield escapement level (MSY escapement). Further, it has long been recognized by many technical staff associated with these rebuilding programs that: 1) scientific analysis of spawner-recruit relationships was required to develop estimates of MSY escapement for these chinook salmon stocks; 2) these analyses needed to be conducted on a stock by stock basis, and 3) the goals needed to be stated as ranges, not point goals. For instance, in 1991, the escapement goal for the Situk River stock of chinook salmon was lowered to 600 large fish based upon a scientific analysis of the spawner-recruit relationship (McPherson 1991). The escapement goal for this stock of chinook salmon developed at the initiation of the ADF&G rebuilding program was 5,100 fish; thus the scientific analysis, when it was conducted, identified an appropriate MSY escapement goal that was about 12% of the initial goal set in 1981 by simplistic methodology. In 1997, the biological escapement goal for this stock was changed from a point goal of 600 large fish to a range of 500-1,000 large spawners.

Similarly, escapement goals for Behm Canal stocks of chinook salmon have been lowered from initial targets established at the time the rebuilding program was begun; and these changes were also based upon scientific analysis of spawner-recruit relationships (McPherson and Carlile, 1997). Specifically, in 1984, the Unuk River chinook salmon goal was decreased from 1,800 index spawners to a level of 875 index spawners, about 50% of the initial 1981 goal; the Chickamin River chinook salmon goal was decreased from 900 index spawners to a level of 525 index spawners, about 60% of the initial 1981 goal; the Blossom River chinook salmon goal was decreased from 800 index spawners to a level of 300 index spawners, about 38% of the initial 1981 goal; and, the Keta River chinook salmon goal was decreased from 500 index spawners to a level of 300 index spawners, about 60% of the initial 1981 goal. In 1997, the biological escapement goals for the four Behm Canal stocks of chinook salmon were changed from the 1984 point values to the following ranges: 1) Unuk River - 650-1,400 large index spawners; 2) Chickamin River - 450-900 large index spawners; 3) Blossom River - 250-500 large index spawners; and, 4) Keta River - 250-500 large index spawners.

A report summarizing development and analyses of a spawner-recruit relationship for the Klukshu River stock of chinook salmon shows a similar pattern. The previous Klukshu River escapement goal for chinook salmon was 4,700 spawners. The new analysis indicated that an appropriate escapement goal range is 1,100 to 2,300 spawners; about 25% to 50% of the previous goal established by simplistic methodology (McPherson, Etherton, and Clark, *In Press*).

A report summarizing development and analyses of a spawner-recruit relationship for the King Salmon River stock of chinook salmon also shows a similar pattern. The previous King Salmon River escapement goal for chinook salmon was 250 large spawners. The new analysis indicates that the appropriate escapement goal range is 120 to 240 spawners; 48% to 96% of the previous goal established by simplistic methodology (McPherson and Clark, *In Press*).

Thus, each of the seven scientific analyses of the spawner-recruit relationships for SEAK chinook salmon stocks conducted prior to the present analyses indicated that the escapement goals developed in the early 1980's through simplistic means were set too high. The current analyses, on the other hand, indicates that the simplistic goal set for Andrew Creek in 1985 of 750 total large chinook salmon was a reasonable approximation of the MSY escapement level, currently estimated to be 650 to 1,500 total large chinook salmon.

DATA LIMITATIONS IN ESTIMATING AN APPROPRIATE BIOLOGICAL ESCAPEMENT GOAL FOR ANDREW CREEK

In 1985 ADF&G set the Andrew Creek escapement goal at 750 large chinook salmon. This was just a year after the Department had operated a weir on the system over a continuous nine-year period. The highest weir count was 672 large chinook counted in 1982 and in that year the return to the river was 947 large chinook of which 275 were removed during an egg-take. Although ADF&G set the goal at 750 large fish, a number somewhat higher than escapements counted in the system during the years a weir was operated on the stream, this goal was not larger than any of the returns to the stream in those years. Nor, was the goal set at the highest historic count, which was the approach used for almost all other chinook salmon escapement goals set during the late 1970s and early 1980s in Southeast Alaska by ADF&G. The basis for setting the goal at 750 large chinook was a judgement call, not the result of some kind of scientific analysis. This report is the first effort made by ADF&G to scientifically estimate an appropriate escapement goal for the chinook salmon stock that returns to Andrew Creek. Although all available data for the Andrew Creek stock of chinook salmon since 1975 was used in the present analysis, data limitations severely limit the approach. Data limitations and concerns with the current analysis include the fact that 1) eight of the seventeen brood escapements utilized in the analysis are based on an average expansion factor in an effort to estimate total numbers of large spawners; 2) the majority of the return cohorts for large fish are estimated based on average age compositions, not upon sampled age compositions; 3) the majority of the jack returns are based on the average inriver jack composition during a small number of the years included in the analysis; and, 4) fishery exploitation is not measured directly, instead an indicator stock approach is used.

Probably the single largest data limitation is the general lack of age samples from the annual Andrew Creek escapements of chinook salmon since 1975. During the past 23 years, the escapement has only been directly sampled to estimate age composition during 7 (30%) of the years. As a consequence, we had to use average age composition during sampled years as a surrogate estimate of age composition during the remaining years of the data set. This is particularly troubling since age composition of major age classes has shown substantial variability (age 5 varying from 15% to 76% and age 6 varying from 22% to 82% during the 7 sampled years). As demonstrated in Table 6, considerable uncertainty is associated with the use of average age compositions. This data limitation can only be addressed through a long-term consistent stock assessment program. Only if more years of sampled age compositions are collected will researchers be able to determine if the 1982 and 1983 age compositions were atypical or if this chinook population simply tends to exhibit a lot of variability in escapement age composition.

Likely, the next major weakness in the present analysis has to do with accounting for jack returns. Jack returns to Andrew Creek were only counted and sampled for age composition during 6 (26%) of the past 23 years. Jack returns for the majority of years in the data set were estimated based upon an average proportion (18.8%) of the brood year return that was assumed to be composed of jacks; and this estimate was based on the 5 brood years of existing data when jacks could be directly estimated with sampling data. The coefficient of variation in proportion of jacks in the Andrew Creek brood year returns for the five sampled years was about 45%, indicating that considerable uncertainty is associated with the use of this average statistic for the majority of the data set.

The third major weakness in the present analysis is the fact that escapements were directly counted during only nine of the 17 brood years included in the analysis. The remaining eight escapements were estimated based upon peak survey counts and subsequent application of an average expansion factor estimated during five years when the escapement was both counted through a weir and indexed. The coefficient of variation associated with the expansion factor was just under 20%, which is considered moderately acceptable by the authors.

The weaknesses in the current data available for Andrew Creek discussed above could be addressed in the long run through application of an improved stock assessment program. This was exactly the intent in 1997 when ADF&G once again operated a weir in the stream and directly sampled age composition of the chinook salmon escapement. However, because the stream changed channels since the mid 1980s, the weir was only partially successful in that a significant proportion of the escapement would not pass upstream of the weir. This caused not only some difficulty in estimating escapement of large fish, but it also largely prevented ADF&G from obtaining an estimate of the jack return. If continued efforts are made to obtain total escapement estimates for the Andrew Creek population of chinook salmon, a mark-recapture experiment either conducted on its own or in combination with the weir may be required to ensure that both a large fish and a jack estimate is obtainable.

Another weakness of the present analysis is that fishery exploitation rates had to be estimated through the use of available fishery exploitation rates for a nearby hatchery stock, the chinook returns to Crystal Lake Hatchery. Whereas the earlier described data weaknesses could be directly addressed in future years through applied stock assessment activities, this weakness presents a much more difficult programmatic problem. Chinook resulting from spawning in Andrew Creek likely rear in freshwaters of the Stikine River system other than just Andrew Creek. And, it is likely that chinook spawned in other portions of the Stikine River system rear in Andrew Creek to at least some extent. Thus, it would be impractical to put coded-wire tags on rearing juveniles in Andrew Creek in an attempt to directly estimate fishing mortality for this stock. Further, because there is no directed terminal harvest for this stock, and no other methods are available to directly provide harvest rates for the Andrew Creek stock of chinook salmon in mixed stock ocean fisheries, future analyses will likely have to continue to rely on an indicator stock approach as was done in this report.

The Andrew Creek stock of chinook salmon is only moderately abundant with escapements since 1975 estimated to have ranged from about 300 to about 1,900 large spawners. Given the large cost associated with conducting detailed stock assessment programs in remote areas of Alaska, ADF&G will have to give reasoned thought to whether or not it is worth the expense to fully address the past short-comings of the historic Andrew Creek database, given that only consistent long-term programs will make meaningful improvements, the stock is only of moderate size, other larger stocks have similar database concerns, ADF&G only has so much funding available for chinook stock assessment programs in Southeast Alaska, and there is no practical way to directly estimate fishing mortality for this stock of chinook salmon. If ADF&G does decide to embark on an improved database for Andrew Creek, the minimum program needs to ensure that escapements of both large fish and jacks are annually estimated with a field sampling program and that the escapement is directly sampled for age composition. In the event that ADF&G does embark on such a program over the next several years, it would be prudent to again analyze available data in an effort to better determine the escapement level most likely to produce maximum surplus yield in fisheries. With an improved database beginning in 1999, such an analysis should be developed in about the year 2006 and the brood years of 1976, 1977, and 1978 included in this analysis are the best of the current data set to include in a future analysis.

During initial reviews of this report, the authors were asked to justify the use of the Ricker curve rather than using a Beverton-Holt model. Use of a Beverton-Holt model was subsequently investigated. However, when fitting the Beverton-Holt model with multiplicative error, unstable solutions resulted (broad, indistinct global minimum in the least-squares function), all of which gave ridiculously low estimates for the MSY escapement value. Subsequently, both Ricker and Beverton-Holt models assuming additive error were computed. When additive error was assumed, the Ricker model estimated the MSY escapement level at 769 large fish and the Beverton-Holt model estimated the MSY escapement level at 720 large fish. Both of these estimates are reasonably similar to the value of 802 large fish obtained through the Ricker model assuming multiplicative error. Because multiplicative error is the more theoretically correct formulation (Walters and Ludwig 1981) and the Beverton-Holt model failed to provide useable estimates using multiplicative error, we chose to rely on the Ricker model and assumed multiplicative error.

Although as authors of this report we are fully cognizant of the many shortcomings of the present analysis, we believe the analysis represents a contribution. The existing escapement goal of 750 large fish for chinook salmon returning to Andrew Creek is simply based upon a judgement call made in the mid-1980s. In this analysis, we have tried to incorporate all available data, make assumptions as needed to proceed with the analysis and thus scientifically to the best of our ability, estimate the escapement level currently expected to provide for maximum sustained yield fisheries. Our results as expressed in point values of 802 large fish from regression analysis or 825 or 907 large fish from the two bootstrap analyses (mean values) or our suggested biological escapement goal range of 650-1,500 large total chinook salmon are not meaningfully different from the existing goal of 750 large chinook. The kind of fishery management required to achieve any of these four chinook escapement goals is not meaningfully different. We believe the most appropriate biological escapement goal for the Andrew Creek stock of chinook salmon is best expressed as a range of 650 to 1,500 large fish, thus incorporating a reasoned level of uncertainty in our present ability to estimate the escapement level most likely to produce maximum sustained yield from this chinook salmon stock. While we recommend ADF&G formally adopt a biological escapement goal for the Andrew Creek stock of chinook salmon of 650 to 1,500 large fish in lieu of the existing goal of 750 large fish, we do not anticipate this change in goal requiring ADF&G to alter substantially the management of this stock.

Were ADF&G to adopt our recommendation, the pattern of escapements since 1975 would be as follows:

Comparison	Escapement Below Goal Range (650-1,500)	Escapement Within Goal Range (650-1,500)	Escapement Above Goal Range (650-1,500)
Years	1975, 1976, 1977, 1978, 1979, 1980, 1981, 1983, 1984, 1985, 1995, 1996, and 1997	1982, 1986, 1987, 1988, 1989, 1990, 1991, 1992, and 1994	1993
Number of Years	13	9	1
Percent of Years	57%	39%	4%

as contrasted to the pattern below associated with the current goal of 750.

Comparison	Escapement Below Goal (750)	Escapement at Goal (750)	Escapement Above Goal (750)
Years	1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1991, 1995, 1996, and 1997	none	1986, 1987, 1988, 1989, 1990, 1992, 1993, 1994,
Number of Years	15	0	8
Percent of Years	65%	0%	35%

RECOMENDATIONS

We recommend that ADF&G formally adopt a biological escapement goal for the Andrew Creek stock of chinook salmon as follows: 650 to 1,500 large fish.

We recommend that ADF&G seriously and carefully consider implementing an improved stock assessment program for the Andrew Creek stock of chinook salmon that emphasizes enumeration of both large and jack escapements and that ensures that escapements are annually monitored for age composition. If such a program is implemented, we recommend a renewed effort be made to estimate the escapement level needed to produce maximum sustained yield to fisheries in the year 2006.

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Table 1. Peak annual survey counts and annual weir counts of large fish in Andrew Creek, estimated proportion of the total escapement of large fish observed during peak surveys, potential error in estimates of total annual escapement of large fish when average proportion observed is multiplied by peak counts, and annual estimates of total escapement of large chinook salmon, 1975-1997.

Year	Peak Survey Count of Large Chinook Salmon	Weir Count of Large Fish	Estimated Proportion of Escapement Observed During Survey	Peak Survey Divided by Average Proportion (0.548)	Number of Fish Removed for Egg Take	Estimated Escapement (large fish)	Potential Expansion Error (obs.-est.)	Potential Absolute Percent Expansion Error (obs - est)/obs
1975	260			474		474		
1976		404			64	404		
1977		456			78	456		
1978		388			12	388		
1979	221	327	68%	403	55	327	-76	23%
1980		282			81	282		
1981	300	536	56%	547	118	536	-11	2%
1982	332	672	49%	606	275	672	66	10%
1983		366			78	366		
1984	154	389	40%	281		389	108	28%
1985	320			584		584		
1986	708			1,292		1,292		
1987	788			1,438		1,438		
1988	564			1,029		1,029		
1989	530			967		967		
1990	664			1,212		1,212		
1991	400			730		730		
1992	778			1,420		1,420		
1993	1,060			1,934		1,934		
1994	572			1,044		1,044		
1995	343			626		626		
1996	335			611		611		
1997	293	478[a]	61%	535		478	-57	12%
Avg.			54.8%			768	6	15%

[a] In 1997, a weir was operated on Andrew Creek. However, the lower portion of the stream changed channels since the mid-1980s and a significant portion of the chinook salmon did not pass upstream. The weir was removed on August 18 and as of that date, 284 large chinook salmon had passed through the weir and on that date a survey count conducted downstream of the weir resulted in 103 large chinook salmon being observed. Based upon the mean proportion of chinook salmon counted during surveys of Andrew Creek in 1979, 1981, 1982, and 1984 of 53.1%, the downstream count was expanded to an estimated escapement of 194 large chinook salmon. The 1997 estimated escapement of chinook salmon was thus estimated to have been 478 large fish (284 above the weir on August 18th and 194 below the weir).

Table 2. Estimates of the annual inriver runs of large chinook salmon, Andrew Creek, 1975-1997.

Calendar Year	Estimated Escapement (large fish)	Number of Fish Removed for Egg Take	Estimated Inriver Run	Inriver Removal Rate
1975	474	0	474	-
1976	404	64	468	14%
1977	456	78	534	15%
1978	388	12	400	3%
1979	327	55	382	14%
1980	282	81	363	22%
1981	536	118	654	18%
1982	672	275	947	29%
1983	366	78	444	18%
1984	389	0	389	-
1985	584	0	584	-
1986	1,292	0	1,292	-
1987	1,438	0	1,438	-
1988	1,029	0	1,029	-
1989	967	0	967	-
1990	1,212	0	1,212	-
1991	730	0	730	-
1992	1,420	0	1,420	-
1993	1,934	0	1,934	-
1994	1,044	0	1,044	-
1995	626	0	626	-
1996	611	0	611	-
1997	478	0	478	-

Table 3. Number of chinook salmon sampled and aged from the annual escapements in Andrew Creek for age composition; upper panel-large fish, lower panel-jacks.

Large Chinook Salmon:

Calendar Year	Number of Large Chinook Salmon Aged:				Total Large Chinook Salmon Age Sampled
	Age-4	Age-5	Age-6	Age7	
1979	0	69	50	4	123
1980	0	31	29	0	60
1981	0	149	105	2	256
1982	1	46	249	8	304
1983	1	86	25	1	113
1984	3	28	12	2	45
1997	0	63	91	1	155
Sums	5	472	561	18	1,056
Average Age Composition of Large Fish	0.5%	44.7%	53.1%	1.7%	100%

Jack Chinook Salmon:

Calendar Year	Number of Jack Chinook Salmon Aged:			Total Jack Chinook Salmon Age Sampled
	Age-3	Age-4	Age-5	
1979	4	28	1	33
1980	2	39	0	41
1981	4	34	0	38
1982	5	21	0	26
1983	2	33	0	35
1984	28	111	0	139
1997	5	17	0	22
Sums	50	283	1	334
Average Age Composition of Jack Fish	15.0%	84.7%	0.3%	100%

Table 4. Estimated age composition of large chinook salmon in the annual inriver runs to Andrew Creek, 1975-1997 (age composition estimates listed in italics are average values based upon the 7 sampled years of 1979-1984 and 1997; the age composition estimates based upon sampling are listed in bold).

Calendar Year	Estimated Annual Inriver Run	Estimated Age Composition (large fish): Age-4	Age-5	Age-6	Age-7	Number of Fish Aged	Annual Percent of Inriver Run that was Age Sampled
1975	474	*0%*	*45%*	*53%*	*2%*	0	0%
1976	468	*0%*	*45%*	*53%*	*2%*	0	0%
1977	534	*0%*	*45%*	*53%*	*2%*	0	0%
1978	400	*0%*	*45%*	*53%*	*2%*	0	0%
1979	382	**0%**	**56%**	**41%**	**3%**	123	32%
1980	363	**0%**	**52%**	**48%**	**0%**	60	16%
1981	654	**0%**	**58%**	**41%**	**1%**	256	39%
1982	947	**0%**	**15%**	**82%**	**3%**	304	32%
1983	444	**1%**	**76%**	**22%**	**1%**	113	25%
1984	389	**7%**	**62%**	**27%**	**4%**	45	12%
1985	584	*0%*	*45%*	*53%*	*2%*	0	0%
1986	1,292	*0%*	*45%*	*53%*	*2%*	0	0%
1987	1,438	*0%*	*45%*	*53%*	*2%*	0	0%
1988	1,029	*0%*	*45%*	*53%*	*2%*	0	0%
1989	967	*0%*	*45%*	*53%*	*2%*	0	0%
1990	1,212	*0%*	*45%*	*53%*	*2%*	0	0%
1991	730	*0%*	*45%*	*53%*	*2%*	0	0%
1992	1,420	*0%*	*45%*	*53%*	*2%*	0	0%
1993	1,934	*0%*	*45%*	*53%*	*2%*	0	0%
1994	1,044	*0%*	*45%*	*53%*	*2%*	0	0%
1995	626	*0%*	*45%*	*53%*	*2%*	0	0%
1996	611	*0%*	*45%*	*53%*	*2%*	0	0%
1997	478	**0%**	**41%**	**58%**	**1%**	155	32%

Table 5. Estimated numbers of large chinook salmon by age in the annual inriver runs to Andrew Creek, 1975-1997 (estimates listed in italics are based upon average age composition data available for the 7 sampled years of 1979-1984 and 1997; estimates listed in bold are based on aged samples collected at the weir).

Calendar Year	Estimated Annual Inriver Run of Large Chinook by Age: Age-4	Age-5	Age-6	Age-7	Estimated Annual Chinook Salmon Inriver Run
1975	*0*	*213*	*251*	*10*	474
1976	*0*	*211*	*248*	*9*	468
1977	*0*	*240*	*283*	*11*	534
1978	*0*	*180*	*212*	*8*	400
1979	**0**	**214**	**157**	**11**	382
1980	**0**	**189**	**174**	**0**	363
1981	**0**	**379**	**268**	**7**	654
1982	**0**	**142**	**777**	**28**	947
1983	**4**	**338**	**98**	**4**	444
1984	**27**	**241**	**105**	**16**	389
1985	*0*	*262*	*310*	*12*	584
1986	*0*	*581*	*685*	*26*	1,292
1987	*0*	*647*	*762*	*29*	1,438
1988	*0*	*463*	*545*	*21*	1,029
1989	*0*	*435*	*513*	*19*	967
1990	*0*	*545*	*643*	*24*	1,212
1991	*0*	*328*	*387*	*15*	730
1992	*0*	*639*	*753*	*28*	1,420
1993	*0*	*870*	*1,025*	*39*	1,934
1994	*0*	*470*	*553*	*21*	1,044
1995	*0*	*281*	*332*	*13*	626
1996	*0*	*275*	*324*	*12*	611
1997	**0**	**196**	**277**	**5**	478

Table 6. Potential errors in numbers of large chinook salmon by age in the inriver runs to Andrew Creek for the 7 sampled years of 1979-1984 and 1997 if average age estimates were used for all years (i.e., use of 0% for age-4, 45% for age-5, 53% for age-6, and 2% for age-7 instead of using age estimates based upon sampling data).

Part 1: Number of Large Chinook Salmon by Age Using Average Age Composition:

Calendar Year	Estimated Annual Inriver Run of Large Chinook by Age: Age-4	Age-5	Age-6	Age-7	Estimated Annual Chinook Salmon Inriver Run
1979	0	172	202	8	474
1980	0	164	192	7	468
1981	0	294	347	13	534
1982	0	426	502	19	400
1983	0	200	235	9	382
1984	0	175	206	8	363
1997	0	215	253	10	654

Part 2: Potential Errors (estimates based upon sampling - estimates based upon use of average values):

Calendar Year	Potential Errors in Inriver Return of Large Chinook by Age: Age-4	Age-5	Age-6	Age-7	Estimated Annual Chinook Salmon Inriver Run
1979	0	42	-45	3	474
1980	0	25	-18	-7	468
1981	0	85	-79	-6	534
1982	0	-284	275	9	400
1983	4	138	-137	-5	382
1984	27	66	-101	8	363
1997	0	-19	24	-5	654
Averages	4	8	-12	0	468

Part 3: Potential Absolute Errors (estimates based upon sampling - estimates based upon use of average values divided by estimates based upon sampling):

Calendar Year	Potential Absolute Errors of Large Chinook by Age: Age-4	Age-5	Age-6	Age-7	Estimated Annual Chinook Salmon Inriver Run
1979	0%	20%	29%	27%	474
1980	0%	13%	10%	-	468
1981	0%	22%	29%	86%	534
1982	0%	200%	35%	32%	400
1983	100%	41%	140%	125%	382
1984	100%	27%	96%	50%	363
1997	0%	10%	4%	100%	654
Averages	28%	48%	49%	70%	468

Table 7. Estimated age compositions and estimated annual inriver runs of jack chinook salmon by age, Andrew Creek, 1979-1984 and 1997 (upper panel-age compositions; lower panel-returns by age).

Estimated Age Composition of Jacks:

Calendar Year	Jack Count at Weir	Age Composition Estimates for Jacks: Age-3	Age-4	Age-5	Number of Jacks Aged	Percent of Jacks Sampled
1979	89	12%	85%	3%	33	37%
1980	272	5%	95%	0%	41	15%
1981	119	11%	89%	0%	38	32%
1982	124	19%	81%	0%	26	21%
1983	38	6%	94%	0%	35	92%
1984	200	20%	80%	0%	139	69%
Averages	140	12%	87%	0%	52	44%
1997[a]	-	23%	77%	0%	22	-
Averages	-	14%	86%	0%	48	-

[a] In 1997, a significant proportion of the chinook salmon escapement did not pass upstream of the weir prior to its removal. As a result, an estimate of the escapement of jacks was not obtained.

Estimated Numbers of Jacks in Inriver Returns by Age:

Calendar Year	Jack Count at Weir	Estimated Number of Jack Chinook Salmon by Age: Age-3	Age-4	Age-5
1979	89	11	75	3
1980	272	13	259	0
1981	119	13	106	0
1982	124	24	100	0
1983	38	2	36	0
1984	200	40	160	0
Average	140	17	123	0

Table 8. Estimated proportions of jacks in total inriver runs of chinook salmon to Andrew Creek for brood years 1976-1980.

Brood Year	Number of Jacks and Large Chinook Salmon by Age: Age-3 Jacks	Age-4 Jacks	Age-4 Large	Age-5 Jacks	Age-5 Large	Age-6 Large	Age-7 Large	All Jacks	All Fish	Percent Jacks
1976	11	259	0	0	379	777	4	270	1,430	18.9%
1977	13	106	0	0	142	98	16	119	375	31.7%
1978	13	100	0	0	338	105	12	113	568	19.9%
1979	24	36	4	0	241	310	26	60	641	9.4%
1980	2	160	27	0	262	685	29	162	1,165	13.9%
Average as percent of Brood Year	2.6%	16.2%		0.0%						18.8%

Table 9. Estimated numbers of jacks in inriver runs of chinook salmon to Andrew Creek for brood years 1975-1991.

Brood Year	Estimated Large Chinook Salmon in Cohort	Estimated Number of Jack Chinook Salmon in Cohort:[b] Age-3	Age-4	Age-5	All Ages	Estimated Number of Chinook Salmon in Cohort
1975	485	*15*	**75**	**0**	90	575
1976	1,160	**11**	**259**	**0**	270	1,430
1977	256	**13**	**106**	**0**	119	375
1978	455	**13**	**100**	**0**	113	568
1979	581	**24**	**36**	**0**	60	641
1980	1,003	**2**	**160**	*0*	162	1,165
1981	1,364	**40**	*272*	*0*	312	1,676
1982	1,211	*39*	*242*	*0*	281	1,492
1983	1,000	*32*	*200*	*0*	232	1,232
1984	1,093	*35*	*218*	*0*	253	1,346
1985	960	*31*	*192*	*0*	223	1,183
1986	1,120	*36*	*223*	*0*	259	1,379
1987	1,685	*54*	*336*	*0*	390	2,075
1988	1,436	*46*	*287*	*0*	333	1,769
1989	814	*26*	*162*	*0*	188	1,002
1990	610	*20*	*122*	*0*	142	752
1991	562	*18*	*112*	*0*	130	692

[a] The number of large chinook salmon in inriver runs for a specific brood year (BYi) was calculated by adding the inriver runs of large age-4 fish in BYi+4, large age-5 fish in BYi+5, large age-6 fish in BYi+6, and large age-7 fish in BYi+7; age-specific estimates are provided in Table 4.

[b] The age-specific estimates for jacks listed in bold are from age composition estimates multiplied by numbers of jacks counted at the Andrew Creek weir from 1979-1984 when age sampling was conducted. Estimates of the number of jacks in inriver runs for all other years are based on the assumption that jacks represent 18.8% of the total inriver run (2.6% age-3 jacks and 16.2% age-4 jacks) and those estimates are listed in italics.

Table 10. Estimated age-specific inriver runs of chinook salmon, Andrew Creek, brood years 1975-1991.

Brood Year	Estimated Age-Specific Numbers of Chinook Salmon in Cohort: Jacks Age-3	Jacks+Large Age-4	Jacks+Large Age-5	Large Age-6	Large Age-7	Estimated Total Cohort Inriver Recruits (Jacks+Large; All Ages)
1975	15	75	189	268	28	575
1976	11	259	379	777	4	1,430
1977	13	106	142	98	16	375
1978	13	100	338	105	12	568
1979	24	40	241	310	26	641
1980	2	187	262	685	29	1,165
1981	40	272	581	762	21	1,767
1982	39	242	647	545	19	1,492
1983	32	200	463	513	24	1,232
1984	35	218	435	643	15	1,346
1985	31	192	545	387	28	1,183
1986	36	223	328	753	39	1,379
1987	54	336	639	1,025	21	2,075
1988	46	287	870	553	13	1,769
1989	26	162	470	332	12	1,002
1990	20	122	281	324	5	752
1991	18	112	275	277	10[a]	692

[a] The seven-year component of the 1991 brood year will not return until 1998. This component of the total inriver run was estimated based upon the assumption that it will represent 1.7% of the large fish component of this brood year, the long-term average.

Table 11. Estimated marine fishery-related mortality of coded-wire-tagged chinook salmon released from Crystal Lake Hatchery for brood years 1979-1991.

Brood Year	Number of Chinook Salmon Released	Estimated Exploitation Rates: Landed Catch	Incidental Mortality	Total Mortality	Estimated Marine Survival
1979	39,117	31.9%	2.7%	34.6%	8.0%
1980	56,660	43.5%	7.5%	51.0%	4.6%
1981	58,156	39.6%	12.9%	52.5%	4.7%
1982	93,465	46.8%	22.9%	69.7%	5.4%
1983	28,285	35.2%	17.5%	52.7%	2.7%
1984	41,825	30.4%	19.8%	50.2%	4.1%
1985	42,165	40.2%	15.3%	55.5%	1.9%
1986	31,107	40.3%	16.1%	56.4%	4.1%
1987	50,096	21.7%	20.2%	41.9%	2.8%
1988	44,765	20.1%	22.6%	42.7%	0.6%
1989	89,216	16.1%	15.9%	32.0%	1.2%
1990	90,070	45.3%	15.0%	60.3%	1.2%
1991	49,495	38.4%	14.1%	52.5%	1.6%

Note: Fishery related mortality for brood years 1975-1978 estimated as the average landed catch mortality for brood years 1979-1982 (40.4%) plus the incidental mortality estimated for brood year 1979 (2.7%) for a total estimated fishing related mortality of 43.1%.

Table 12. Estimated parent-year escapements of large fish and estimated total recruitment from those escapements for brood year 1975-1991 chinook salmon from Andrew Creek.

Brood Year	Estimated Brood-Year Escapement (large fish)	Estimated Total Inriver Run	Estimated Marine Exploitation Rate	Estimated Total Cohort Recruitment (all fish)
1975	474	575	0.431	1,011
1976	404	1,430	0.431	2,513
1977	456	375	0.431	659
1978	388	568	0.431	998
1979	327	641	0.346	980
1980	282	1,165	0.510	2,378
1981	536	1,767	0.525	3,720
1982	672	1,492	0.697	4,924
1983	366	1,232	0.527	2,605
1984	389	1,346	0.502	2,703
1985	584	1,183	0.555	2,658
1986	1,292	1,379	0.564	3,163
1987	1,438	2,075	0.419	3,571
1988	1,029	1,769	0.427	3,087
1989	967	1,002	0.320	1,474
1990	1,212	752	0.603	1,894
1991	730	692	0.525	1,457

Table 13. Estimates of the spawner-recruit relationship statistics for chinook salmon returning to Andrew Creek.

Spawner-Recruit Relationship Statistic	Estimate of Spawner-Recruit Relationship Statistic
Ricker alpha Ricker a	6.07 1.8037974
beta	-0.0008426
Number of Data Pairs Used in Relationship	17
Replacement Escapement	2,141 large spawners
Maximum Recruitment Escapement (S_{max})	1,187 large spawners
MSY Escapement Level (S_{msy})	802 large spawners
Maximum Sustainable Yield (MSY)	1,676 chinook salmon (all sizes)

Table 14. Bootstrap estimates of the spawner-recruit relationship statistics for chinook salmon returning to Andrew Creek.

Spawner-Recruit Statistics	Original Spawner-Recruit Estimates	Bootstrap Estimates with Spawner Coefficient of Variation Assumed to be 20%	Bootstrap Estimates with Spawner Coefficient of Variation Assumed to be 30%
Est. Max. Sustained Yield Escapement Level (S_{msy})	802		
Mean Bootstrap Estimate of S_{msy}		907	825
S. Dev. of Mean Bootstrap Estimate of S_{msy}		475	475
Median Bootstrap Estimate of S_{msy}		774	723
90% Confidence Interval of S_{msy}		510 to 1,713	488 to 1,443
95% Confidence Interval of S_{msy}		482 to 2,302	458 to 1,865
Ricker alpha	6.07		
Mean Bootstrap Estimate of Ricker alpha		6.70	7.5
S. Dev. Of Mean Bootstrap Estimate of Ricker alpha		1.9	2.2
Median Bootstrap Estimate of Ricker alpha		6.5	6.1
beta	-0.00084		
Mean Bootstrap Estimate of beta		-0.00090	-0.00100
S. Dev. of Mean Bootstrap Estimate of beta		0.00035	0.00037
Median Bootstrap Estimate of beta		-0.00089	-0.00094

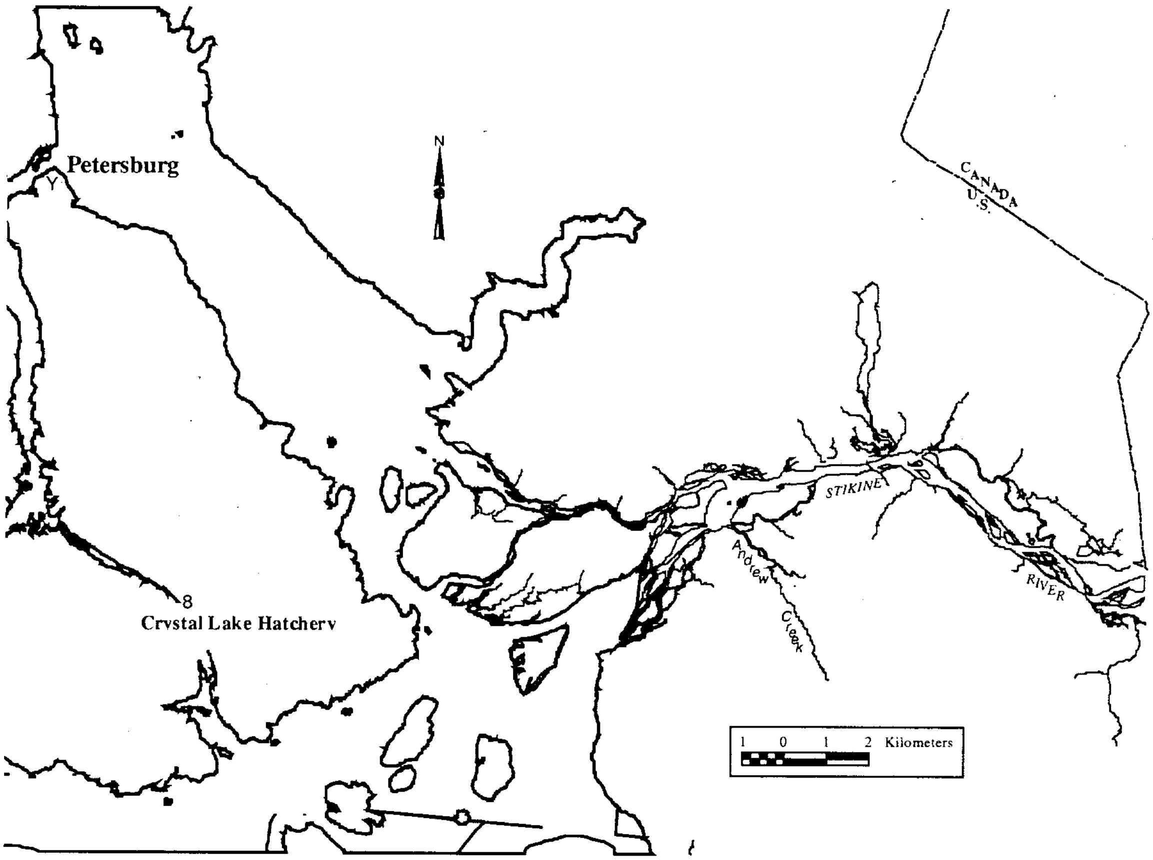

Figure 1. Map of Southeast Alaska showing Andrew Creek.

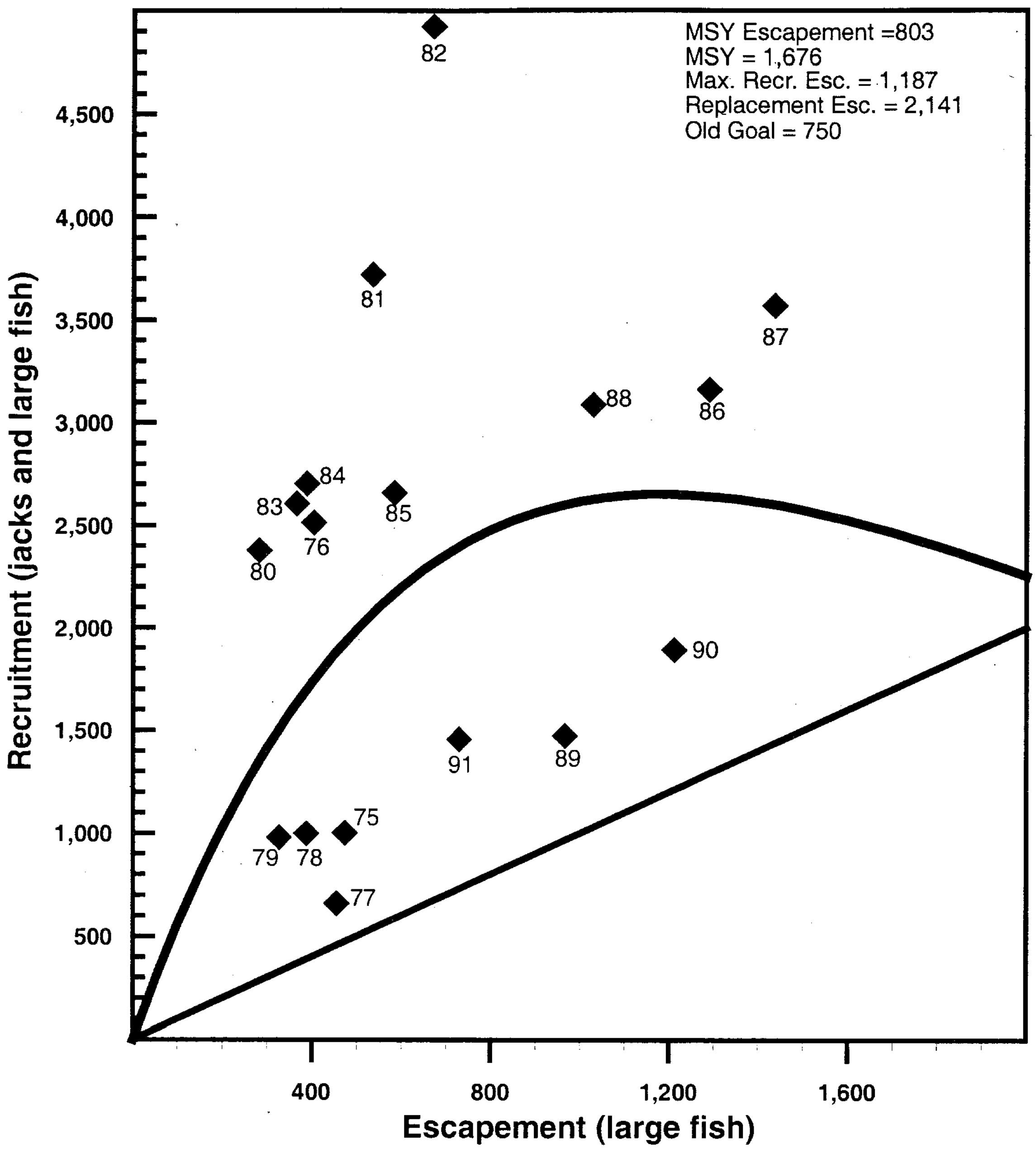

Figure 2. Spawner-recruit relationship for chinook salmon from Andrew Creek, brood years 1975-1991.

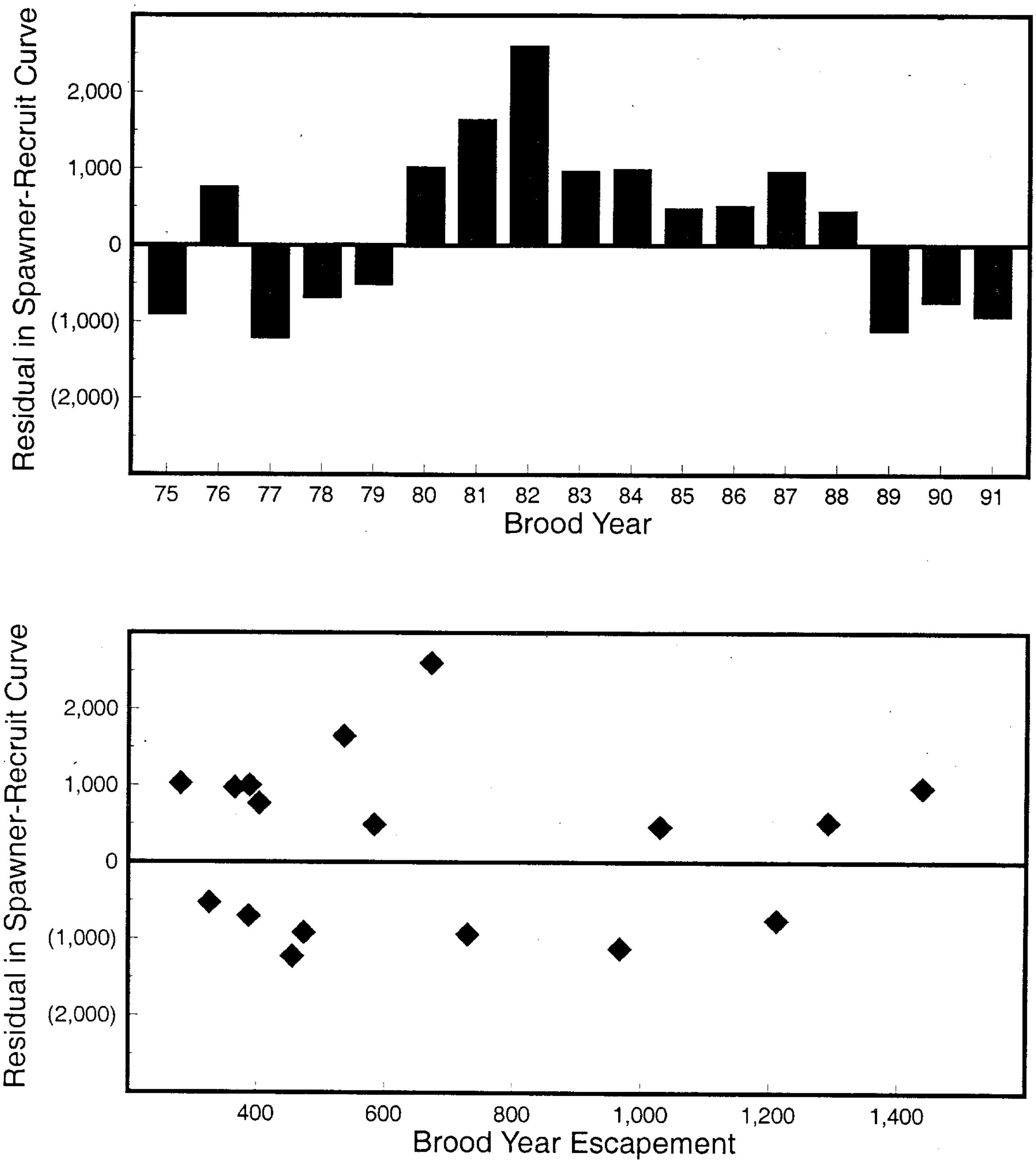

Figure 3. Residuals in the Andrew Creek chinook salmon spawner-recruit relationship, by brood year (upper panel) and by spawner abundance (lower panel).

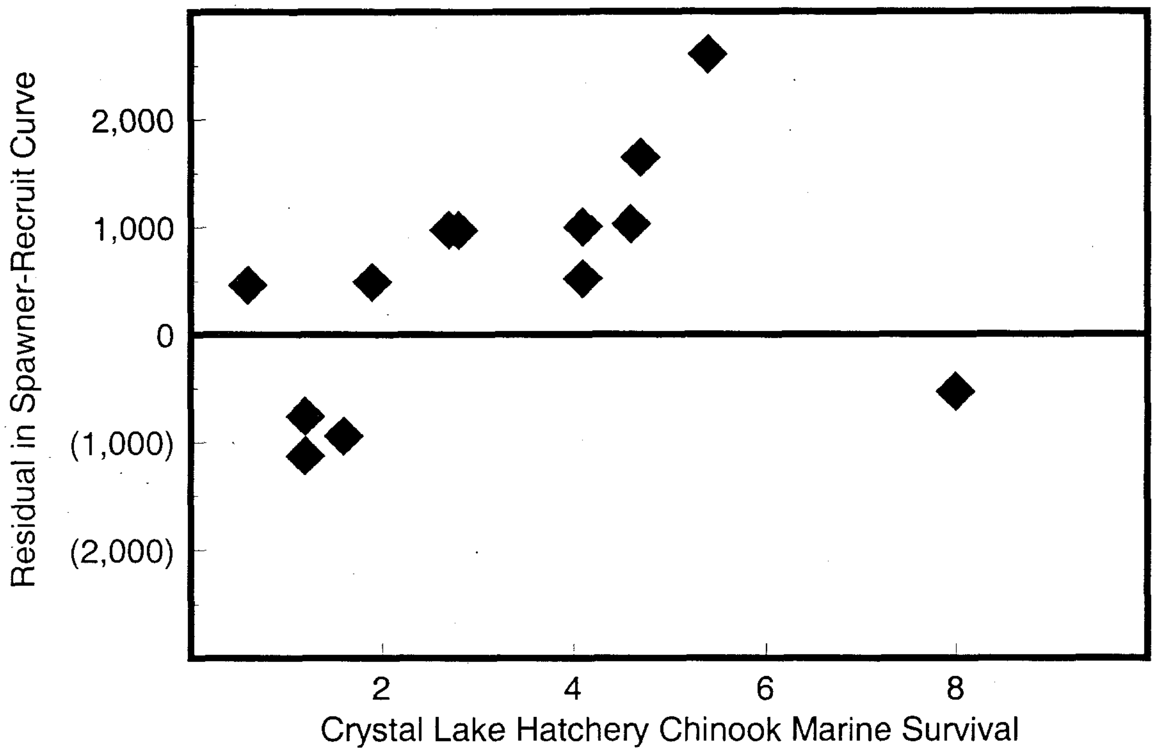

Figure 4. Residuals in the Andrew Creek chinook salmon spawner-recruit relationship versus estimated percent marine survival for the Crystal Lake Hatchery stock of chinook salmon.

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