BIOLOGICAL ESCAPEMENT GOAL FOR

SPEEL LAKE SOCKEYE SALMON

by

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ABSTRACT

Speel Lake is a small sockeye salmon (*Oncorhynchus nerka*) producing system located approximately 65 kilometers southeast of Juneau, Alaska. We compiled and analyzed stock-recruitment information to form the basis for recommending a biological escapement goal (BEG) for Speel Lake sockeye salmon. Escapement to the system has been monitored annually in all but two years since 1983 using a weir on the outlet stream to Speel Lake. The weir has typically been operated from mid-July through late August. Inspection of weir counts from the three years (1983, 1995 and 2002) when the weir was operated through mid-September or later revealed that a variable but substantial portion of the escapement passed in September. Weir counts therefore are believed to underestimate the actual escapement into the lake in other years. Two methods were developed to expand weir counts for years when weir operations ended in August or early September. An average cumulative migratory timing curve was calculated, based on 1983, 1995 and 2002 data. A logarithmic regression between rainfall and cumulative escapement counts was also developed for these years, since fish passage through the weir is strongly influenced by rainfall. We used both expansion methods to produce estimates of escapement. We used catch data combined with an average estimated exploitation rate to estimate escapements for 1993 and 1994, when the weir was not operated. The escapement estimates for 1983 to 1996 (minus brood stock removals), as well as harvest and age composition data from 1986 to 2001 were combined to develop brood tables. We used these numbers to produce a Ricker analysis of the relationship between stock size and recruitment. Initially, the 1993 and 1994 brood years were not used in the analysis, given the uncertainty in the escapements for those two years. However, the addition of the 1993 and 1994 data points did not materially affect the outcome of the analysis. The stock-recruit analysis indicated that the maximum sustained yield escapement level was 7,766 sockeye salmon. The estimated replacement level, at which escapement equals total return, was about 25,000 fish. An escapement goal range was chosen, based on expected ability to produce 80 to 100% of the estimated maximum sustainable yield. We recommend a biological escapement goal range of 4,000 to 13,000 sockeye salmon. We also recommend that the Speel Lake weir be operated through the third week in September in order to reduce the uncertainty inherent in the historical escapement data.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Speel Lake, brood table, biological escapement goal, maximum sustained yield, spawner-recruit relationship

INTRODUCTION

The goal of sockeye salmon (*Oncorhynchus nerka*) management in Southeast Alaska is to balance the efficient harvest of a salmon stock or group of stocks with escapement, subject to allocation and other constraints placed on fishery management by the Alaska Board of Fisheries. Meeting this goal requires that fishery managers have a scientifically-based objective target for the number of naturally spawning adult fish that escape harvest and ultimately reproduce. This target, or escapement goal, should be periodically re-evaluated to verify if the goal is still appropriate for the salmon population or group of populations in question.

Speel Lake is located south of the Taku River, adjacent to the Speel Arm of Port Snettisham (Figure 1). The lake supports a small run of sockeye salmon. In the 1980s, Alaska Department of Fish and Game (ADF&G) staff informally set an escapement goal of 10,000 sockeye salmon for Speel Lake. In 1992, the escapement goal was revised downward to 5,000 fish. The original escapement goal and the 1992 revision were based on inspection of several years of stock-recruitment data and professional judgment (Andy McGregor, ADF&G, personal communication). Technical reports that documented the analysis associated with the original escapement goal and the revision of the escapement goal in 1992 were not published.

Speel Lake has a surface area of 167.5 hectares (414 acres). The lake is shallow with a maximum depth of 8.5 meters (28 feet) and a mean depth of 3 meters (10 feet). The shallower parts of the lake have extensive aquatic vegetation. Scree slopes on the northeast side of the lake plunge into the lake. This shoreline provides the primary spawning habitat for sockeye salmon.

A weir was used to count sockeye salmon escapements in Speel Lake each year from 1983 to 1992 and 1995 through 2002. On-the-grounds escapement assessment programs were not implemented in 1993 and 1994. Weir operations were usually terminated in late August. For the years 1983, 1995, and 2002, the weir termination dates were November 19, September 12, and September 20, respectively. Weir counts in those years indicate a substantial and highly variable portion of the escapement (14-57%) passed during the month of September. Based on the weir counts for 1983, 1995, and 2003, we believe that the annual escapement of Speel Lake sockeye salmon was substantially undercounted in years when weir operation terminated in late August.

Speel Lake sockeye salmon are harvested in a mixed-stock commercial drift gillnet fishery that takes place in Taku Inlet, Stephens Passage, and Port Snettisham (District 111). Sockeye salmon stocks harvested in this fishery originate primarily from the Taku River watershed and from Speel and Crescent Lakes in Port Snettisham, as well as the Snettisham Hatchery. A stock composition estimation procedure based upon a combination of scale pattern analysis, brain parasite prevalence, and otolith marks has been annually used since 1986 to estimate the contribution of various sockeye salmon stocks to the District 111 fishery (Kathleen Jensen, ADF&G, personal communication).

A hatchery was established in 1976 at the Snettisham hydropower facility, located adjacent to the mouth of the Speel River, six miles down-river from Speel Lake. The hatchery was originally conceived and operated to produce chum (*Oncorhynchus keta*), chinook (*Oncorhynchus tshawytscha*), and coho (*Oncorhynchus kisutch*) salmon for contribution to common property fisheries. Production of sockeye salmon was started at the hatchery in 1988. The facility was retrofitted into a sockeye salmon central incubation and rearing facility in the 1990s and by 1995 had become dedicated exclusively to sockeye salmon production. Speel Lake was used as a source of sockeye salmon eggs for various enhancement projects between 1988 and 1996. Resulting juveniles were stocked in Speel Lake and in Sweetheart Lake and smolts were released from Snettisham Hatchery to develop a self-sustaining run to the facility. Juveniles have been stocked back into Speel Lake on three occasions: (1) 227,00 unfed sockeye salmon fry were stocked into Speel Lake in the spring of 1989, (2) 149,000 sockeye salmon smolt were stocked into Speel Lake in the spring of 1995, and (3) 254,000 sockeye salmon pre-smolt were stocked into Speel Lake in the fall of 1995. All sockeye salmon stocked into Speel Lake were progeny from Speel Lake egg takes.

In 1996, ADF&G contracted with the Douglas Island Pink and Chum Aquaculture Corporation (DIPAC) to take over operations of the Snettisham Hatchery. A basic management plan for facility operation was established at the time of the agreement, as part of a hatchery permit issued by ADF&G (State Hatchery Permit Number 39). Stipulations of the plan include requirements for DIPAC to operate an adult counting weir at Speel Lake, and to conduct egg takes and back-plants at Speel Lake if desired escapement levels are not achieved. DIPAC has operated the Speel weir annually since 1996 and no back plants into the system have occurred during this period.

This report is written to document recent analyses conducted to estimate annual run reconstructions of the Speel Lake sockeye salmon population as well as recent analyses of the estimated stock-recruit relationship. These analyses are used as the basis for recommendations concerning the establishment of a biological escapement goal (BEG) range as well as suggested improvements in the existing stock assessment program for the Speel Lake sockeye salmon population.

RUN RECONSTRUCTIONS

In order to create a picture of annual adult salmon migrations toward their natal streams, we need to develop estimates of harvest and escapement that are as complete as possible. For a variety of reasons, a complete accounting is usually not available, and biologists must make assumptions about numbers and proportions of fish populations present in specific fisheries or in the escapement. The Speel Lake sockeye salmon run is no exception.

Harvest Estimates

The bulk of the harvest of Speel Lake sockeye salmon occurs in the District 111 fishery. In recent years, some harvest of Speel Lake sockeye salmon also occurs in extended commercial openings in upper Speel Arm, and in a DIPAC cost recovery fishery in terminal waters adjacent to the hatchery. It is likely that minor harvests of the Speel Lake sockeye salmon stock occur in areas outside of District 111, but harvest rates in those fisheries are thought to be very low. A commercial purse seine fishery that targets pink salmon (*Oncorhynchus gorbuscha*) is allowed along the Hawk Inlet shoreline of Admiralty Island (Subdistrict 112-16) during years of high pink salmon 0abundance. The Hawk Inlet fishery is limited by regulation to a sockeye salmon harvest of 15,000 fish during the month of July (5 AAC 33.366). Seining also occurs along this shoreline in August during years of large pink salmon returns. Since thermally marked fish from Snettisham Hatchery with similar migratory timing to Speel Lake sockeye stocks have been recovered in the Hawk Inlet fishery, adult Speel Lake sockeye are believed to transit the area between mid-July and early August. The July fishery has occurred 6 times since 1989, and sockeye salmon catches have averaged 10,000 fish during the openings. Speel Lake origin sockeye salmon comprise a small fraction of the Hawk Inlet shoreline sockeye harvest, which includes sockeye salmon from the Chilkat, Chilkoot, and Taku systems, other smaller wild stocks and returns from Snettisham Hatchery releases. We are confident that harvest rates of Speel Lake sockeye salmon in fisheries outside District 111 are minor for most years of the data set, and presumably less than 5% in any year.

Speel Lake origin fish also comprise a small fraction of the total sockeye salmon harvest in the District 111 fishery, which is typically dominated by sockeye salmon of Taku River origin. Total commercial harvests in the District 111 fishery are estimated by tabulation of fish tickets (sales receipts generated when fishermen sell fish to processors). Since the mid 1980s, ADF&G has been allocating District 111 sockeye salmon harvests to stocks of origin, by applying a stock separation protocol. Scale pattern analysis, combined with presence or absence of brain parasites samples were assigned to six wild stocks of sockeye salmon caught in District 111: two stocks (Speel and Crescent Lakes) from Port Snettisham drainages, and four stocks from the Taku River. Scale pattern analysis for District 111 sockeye salmon catches began in 1983, with Speel and Crescent Lake sockeye salmon combined into a wild Snettisham stock (McGregor et al. 1984). Beginning in 1986, the Speel Lake stock was differentiated from the Crescent Lake stock (McGregor et al. 1985). Presence or absence of brain parasites was introduced in the early 1990s, and has evolved into a dichotomous key that routes scales into one of two scale pattern models, thereby increasing the accuracy of the estimates (Kathleen Jensen, ADF&G, personal communication).

Adult returns from the Snettisham Hatchery and remote releases of sockeye salmon juveniles into District 111 and 115 began in the 1990s. All of these “enhanced” releases were tagged with thermal otolith marks, bands of rings in the otoliths of the fish formed via manipulating temperature of the water directed to the hatchery incubators (Volk et al. 1990, Hagen et al. 1995). Since the early 1990s, District 111 catches have been sampled for otolith marks, to determine contribution of enhanced fish to the harvests. Currently, ADF&G uses a paired sampling method for stock assessment, whereby individual fish are sampled for scales, parasites and otoliths, and samples are uniquely labeled to allow the analysis of each of these attributes to be combined, for accurate allocation to specific stocks (Kathleen Jensen personal communication). These procedures provide age-specific estimates by stock of sockeye salmon in the District 111 fishery. This database was used to assemble harvests of naturally spawning sockeye salmon of Speel Lake origin in the District 111 fishery for the years 1986-2001 (Table 1). Stock and age-specific estimates for 2002 are not yet available.

The 1991 Speel Lake escapement was too low for the project staff to collect sufficient numbers of samples from the fish, to develop a standard scale model that differentiated harvests of Speel Lake sockeye salmon from other stocks. As a result, both numbers and age composition for the 1991 harvest were lacking. Average total age composition of the harvests for 1986 to 1990 and 1992 to 2001 were used as a surrogate age composition for 1991. We estimated the numbers of fish harvested in 1991 by multiplying the estimated escapement for 1991 by the mean harvest rate calculated for other years in the data set.

Passage and Escapement Estimates

Adult sockeye salmon migrating into Speel Lake have been counted by means of a picket weir on the outlet stream, which usually has been operated between July 15 and late August. The stream is generally less than 0.5 m deep, but can reach depths of 1.3 m or more at high water flows. Annual passage counts for Speel Lake from 1983-1992 and from 1995-2002 ranged from 299 sockeye salmon in 1991 to 18,905 sockeye salmon in 1990 (Table 2, Appendix A).

While in most years the weir was dismantled in late August, it was operational until November 19 in 1983, September 12 in 1995 and September 20 in 2002. Review of cumulative escapement patterns in 1983 and 2002 indicated that 90% or more of the migration into the lake occurred by September 12, lending credence to the 1995 weir count of 7,668 sockeye salmon as being a reasonably complete estimate of total passage. At the same time, the high percentage of fish counted after August 31 for 1983, 1995, and 2002 indicates that passage estimates for the other years in the data set (1984-1992 and 1996-2001) undercounted the total escapement by 10% or more.

Cumulative weir counts in the years 1983, 1995, and 2002 were used to develop daily mean expansion factors, in order to adjust weir counts for other years of weir operation into total passage estimates (Appendix B). Because weir counts in these years usually ended in late August, sometimes as early as August 24, expansion factors were often substantial. For instance, in 1999 the weir was pulled on August 24; the mean expansion factor for that date was 2.55. In other words, the weir count of 10,277 in 1999 was expanded to a total passage estimate of 26,206. Although this method could be readily used to adjust the weir counts into total passage estimates, the precision associated with many of these expanded estimates of total passage was poor (Table 2, Figure 2). The poor precision is a result of profound differences in passage patterns between August 24 and the end of August for the years 1983, 1995, and 2002. On August 24, the cumulative proportion of the annual weir count of sockeye salmon for the years 1983, 1995, and 2002 were 85.5%, 19.1%, and 80.2%, respectively. Their respective expansion factors for August 24 were 1.17, 5.23, and 1.25, with a mean of 2.55 with a standard error of 2.32. Given the high level of variation associated with most of these expanded passage estimates, we sought another method to improve the total passage estimates.

A review of the passage counts showed a pattern of peaks. ADF&G staff familiar with the weir project and the Speel Lake sockeye salmon stock, observed that many of these escapement "spikes" occurred as a result of increased flows in the outlet stream associated with rainfall events. One of these staff members provided us with the following information:

> The August counts are highly related with freshets and with the stage of the run. The fish school in the highly glacial, very cold water of the Speel River, will not enter the outlet stream to the lake if the flows aren't high enough. Temperatures in the outlet stream can reach 70 degrees F or higher and water levels can be as low as several inches on some gravel bars. From the air one can see large concentrations of fish moving from the glacial water into the lower sections of the stream to hold for short spells. Unless there is a large build-up in the Speel River, only a few fish will migrate upstream to the weir under these conditions. In general, the timing of the run through the District 111 fishery lasts from around mid-July through late August. This is known from stock identification results and fishery CPUE data. When there are significant rainfall events between mid-August and the end of August, large numbers of fish holding in the Speel River will move through the weir and into the lake. This can be seen in 1983 (August 10, 15, 22), 1984 (August 10, 25), 1985 (August 22), etc. If a major freshet occurs between the 15 and 30 of August, it appears that the majority of the fish holding in Speel River move up through the weir. In the absence of significant rainfall, the stream remains low, water temperatures stay warm, and the fish don't move. The data from 1995 is a great example, virtually no rain from August 5 through the 30th, then a couple of rainfall events and over half the fish came through. I venture a guess, from looking at daily rainfall measures and weir counts, that 1987 was another case where there was a major push of fish into the lake in late August, because a small freshet on the 16 and 17 brought in huge numbers, there was no rain until the weir was pulled on the 27 and then major freshets occurred on the 31 and 4 after the weir was pulled.

We decided to examine the relationship between rainfall, as recorded daily at the Snettisham Hatchery (Appendix C), and fish passage through the weir (Appendix A). We developed graphs of weir counts of sockeye salmon and daily rainfall measurements (Appendix D). Our review of this information led us to believe that cumulative rainfall for the period August 10 to August 24 would provide a reasonable prediction of cumulative passage of sockeye salmon past the weir site through the end of that period of time. We used the cumulative rainfall and cumulative passage for the years 1983, 1995, and 2002 to develop a predictive relationship (Figure 3). From this relationship, predictions concerning the proportion of total passage on August 24 were developed based upon cumulative rainfall from August 10 through August 24. We then divided the weir counts on August 24, by the estimated cumulative proportion of run to develop total passage estimates and associated estimates of variability (Table 3, Figure 4).

We then decided to develop a "best blend" data set of total passage estimates. This data set was comprised of weir counts for the years 1983, 1995, and 2002, and the expanded passage estimates from one of the two approaches described above. The analyses provided total passage estimates for the time series 1983-2002, except for the years when the weir was not operated, 1993 and 1994.

There is no on-the-ground data with which to estimate total passage of sockeye salmon into Speel Lake for 1993 and 1994. However, passage did occur and estimates were needed to develop the set of annual run estimates. After considering several approaches to the problem, we elected to simply assume that the harvest rates exerted on Speel Lake sockeye salmon in those two years were similar to average harvest rates in the years before major production of sockeye salmon took place at Snettisham Hatchery. Harvest rates exerted on Speel Lake sockeye salmon in the District 111 fishery in the years 1986-1990, 1992, and 1995 were calculated (Table 5), and the average harvest rate over these seven years was 34.2%. We assumed that the harvest rate in 1991, 1993 and 1994 was 34.2%. By knowing either the catch or the escapement, the total run of sockeye salmon into Speel Lake was directly calculated, and the estimated catch for 1991 and estimated escapements for 1993 and 1994 were then calculated (Table 6).

Once estimates of total passage of sockeye salmon past the weir site were developed for the entire 1983-2002 data set, we calculated estimates of escapement for the years 1983-2002. Brood stock removals of Speel Lake sockeye salmon upstream of the weir site have taken place in several years. These brood stock removals were subtracted from total passage estimates to derive estimates of total escapement (Table 7). Escapements as estimated with our procedures ranged from a low of 359 sockeye salmon in 1991 to a high of 36,000 sockeye salmon in 1987.

Mark-recapture studies of Speel Lake sockeye salmon were conducted in 1995, 1996, 2000 and 2002. In each year, weir personnel marked a percentage of the fish passing through the weir by fin clip(s). Fish were subsequently examined upstream from the weir, either through collection of brood stock or by beach seining or carcass sampling in the lake. Results of this work have not been rigorously documented. The studies were flawed because size compositions of fish in the recovery event were not recorded. Historically, Speel Lake weir counts include only a small portion of the one-ocean jacks returning to the lake; most fish of this size swim through the weir uncounted. The mark-recapture studies included jacks in the recovery sample (second event). Therefore, the mark-recapture estimate was for a “different” population than that counted at the weir. Had size data been collected, jacks could have been excluded from the analysis and an escapement estimate corresponding to weir counts could have been generated.

Age-Specific Total Run and Brood Year Recruit Estimates

Age-specific harvest estimates for Speel Lake sockeye salmon in the traditional District 111 commercial drift gillnet fishery were generated from the department’s otolith-brain parasite-scale pattern stock identification program. Harvest estimates were available for age 1.2, 1.3, 2.2 and 2.3 fish, as well as for freshwater age 0 and other minor age class groups (Table 1). Harvests of Speel Lake sockeye salmon in the terminal area hatchery fisheries were determined by subtracting the estimated otolith marked catches (hatchery fish) from the total catches in the terminal fisheries. The age compositions of the Speel Lake harvest in the terminal fishery were assumed to be the same as in the traditional District 111 fishery.

In order to build comprehensive brood year tables for stock-recruit analyses, we converted the harvest estimates for age 1.2, 1.3, 2.2 and 2.3 fish into fish of total age 4, 5 and 6. We then applied the proportional contributions of these age groups to the total estimated number of fish harvested, since the total age of the other minor age classes was not known. Average total age compositions for the years 1986-1990 and 1992-2001 were used as surrogate values for 1991. This procedure completed the data set of estimated annual harvests of Speel Lake sockeye salmon for the years 1986-2001 (Table 8).

The Speel Lake sockeye salmon escapements have been sampled to document age, sex, and length compositions on an annual basis since 1982. Samples were taken at the weir throughout the return in all years except 1993 and 1994, when samples were obtained on the spawning grounds. Scale samples for age composition taken at the weir precluded sampling precocious males or jacks, as the jacks can swim between the weir pickets. Thus, the age composition is truncated for all years except for 1993 and 1994. Annual sample sizes are large, leading to age composition estimates with high precision (Appendix E). The annual escapement age composition estimates were applied to the “best blend” estimates of total passage (Table 3) to develop age-specific total passage estimates (Table 9). These age-specific total passage estimates were added to age-specific harvest estimates, to provide a set of age-specific total run estimates for the years 1986-2001 (Table 10). The total run estimates ranged from 550 sockeye salmon in 1991 to 54,500 fish in 1993. Due to early weir terminations in certain years, expanded portions of the total passage estimates comprise a significant portion of the estimated run reconstruction for those years, as Figure 5 displays. This adds significant uncertainty to the total run reconstructions.

The total run data set was used to develop estimates of the recruits for brood years 1983 to 1996. The number of recruits for a brood year escapement i for the 1983-1994 brood years were estimated as the sum of the age 3 total run in year i +3, age 4 total run in year i + 4, age 5 total run in year i + 5, and age 6 total run in year i + 6. Because harvest and estimates and age compositions for 2002 are not yet available, recruits for brood year 1996 were estimated in a slightly different manner. The estimated average contribution from age 6 fish for brood years 1983-1994 is 2.9%. The recruits for brood year 1996 were based on an algebraic computation of age 6 sockeye salmon, divided by sum of age 3, 4, 5, and 6 sockeye salmon returning set to equal 0.029. These procedures provided recruit estimates for brood years 1983-1995 that ranged from a low of 6,263 fish for brood year 1983 to a high of 49,405 fish for brood year 1988 (Table 11).

STOCK-RECRUIT RELATIONSHIPS

Once the paired data set was calculated, spawner-recruit relationships were developed by fitting paired data to the following model.

$$R_y = aS_y \exp(-bS_y)\exp(e_y) \qquad (1)$$

such that: R_y = estimated total recruitment by brood y;
S_y = spawning escapement that produced brood y;
a = intrinsic rate of population increase in the absence of density-dependent limitations;
$ß$ = density-dependent parameter; and
e_y = process error with mean 0 and variance s_e^2.

This model, commonly referred to as a Ricker recruitment curve (Ricker 1975), uses a series of observations or estimates of spawners and their respective recruitments, to estimate two parameters, a and b. We assumed the errors were log-normal (a common assumption for salmon returns), resulting in the log-transformed linear equation.

$$\ln(R_y / S_y) = \ln(a) - bS_y + e_y . \qquad (2)$$

Linear regression procedures provided estimates of the intercept (ln a) and the slope (b) in equation 2. Hilborn and Walters (1992; pages 271-2) published the following empirical approximation of S_{MSY}, the estimated spawning size that produces maximum sustained yield or MSY, as a function of estimated parameters:

$$\hat{S}_{MSY} \cong \frac{\ln \hat{a} + \hat{s}_e^2/2}{\hat{b}} [0.5 - 0.07(\ln \hat{a} + \hat{s}_e^2/2)] , \qquad (3)$$

such that: $\hat{s}_e^2$ = the mean square error from the regression.

Stock-recruit analyses of brood years 1983-1996, paired with their respective recruits, provided an estimate of 7,766 spawning sockeye salmon as the escapement level predicted to provide for maximum sustained yield (MSY) fisheries (Table 12). A plot of the linear relationship between estimated escapement and log of the estimated recruits per spawner (Figure 6) showed that the slope of the relationship was significantly different from zero. Testing for auto-correlation and partial auto-correlation showed that the residuals) in the relationship were not significantly auto-correlated. However, a graph of the residuals does show a degree of auto-correlation between years (Figure 7).

Visual examination of the relationship between spawners and adult returns (Figure 8) shows that predicted peak production occurs in the range of about 4,000 to 16,000 spawners. However, observations of recruitment for that range of escapements are substantially less, indicating that the stock recruit relationship was overestimating production for escapements in this range, and might therefore bias estimates of the MSY escapement value, and other related statistics. Estimated MSY escapement from brood years 1983-1996 was 7,766, MSY was estimated as 48,696, replacement was estimated at about 25,000, and exploitation rate at MSY escapement was estimated at 86% (Table 12). In particular, the estimated maximum sustained yield and exploitation rate at MSY escapement seems high. Of greatest concern was whether this was providing an inappropriate estimate of MSY escapement.

We thought the brood year escapements of 1988 and 1991 might be the cause of an inappropriate MSY escapement goal, in that both of these escapements were estimated to be small, with very high estimates of recruits per spawner (Table 11). We calculated stock recruit relationships omitting first the brood year 1991 data point, and then both the 1988 and 1991 brood year data points. Results when omitting brood year 1991 were: MSY escapement equals about 8,500, MSY equals about 27,000, MSY exploitation rate is about 76%, and replacement level (where escapement equals recruitment) is about 27,000. Results when omitting both brood years 1988 and 1991 were: MSY escapement equals about 8,500, MSY is about 13,000, MSY exploitation rate is about 61%, and replacement equals about 22,000. These results indicated to us that estimates obtained from the brood year 1983-1996 stock recruit relationship were reasonably sturdy, in regards to the MSY escapement level and the replacement level. However, estimates of MSY and the corresponding exploitation level were highly dependent upon the faith one has in the escapement estimates for brood years 1988 and 1991. While we are reasonably sure these escapements were small in magnitude, we are not sure the actual size was as small as our estimates.

We consider the brood year escapement estimates for 1993 and 1994 as crude and imprecise. Therefore, we calculated the stock-recruit relationship omitting these two brood years (included only brood years 1983-1992 and 1995-1996). Results of this analysis indicated that the MSY escapement level was 6,479 spawning sockeye salmon (Table 12). The 80% plus of MSY range calculated with this data set was 3,000 to 11,000, somewhat less than the value calculated using the full data set. Results of this analysis provided other stock-recruit estimates not much different than when these two brood years were included. This suggests that these two brood years did not have much effect on the relationship, at least as per the estimates we derived. However, the estimates are crude and had we received better information, results might have been different. Since the inclusion of 1993 and 1994 escapement estimates does not meaningfully affect results, we suggest the full data set be considered as the best available information at this time.

DISCUSSION

There are serious deficiencies in this analysis, particularly as it pertains to the expansion of the weir counts to produce estimates of total escapement. The fundamental problem is that 85% of the annual escapement data sets are incomplete, and too few complete annual data sets exist to properly reconstruct the incomplete ones.

The rain-based method of expanding weir counts fits a non-linear regression line through 3 data points. The dearth of data points allows the line to fit the points almost perfectly, but grievously underestimates the actual underlying variance. Actual values for other years of data are likely to be well outside the confidence ranges associated with the predicted values.

The estimates based on mean cumulative migratory timing curve also have serious shortcomings. August rainfall obviously affects fish passage, and the rainfall regimes for 1983, 1995 and 2002 were not representative of all years in the dataset, thereby casting doubt on the mean migratory timing curve generated from these data. The years 1983 and 2002 had the two highest cumulative August rainfalls, while the 1995 August rainfall was the seventh lowest, and the second lowest rainfall for the period between August 7 and August 30. Thus, the mean migratory timing curve is suspect, as are total escapement estimates generated from the curve. The variance estimates around the migratory timing curve may be overly large. The fact that both methods were needed to produce reasonable estimates of total escapement suggests that serious weaknesses exist in both methods.

The problems in the expansion of Speel Lake weir counts also impact the Ricker analysis of the stock-recruit data. In many classic Ricker analyses, escapement estimates are fairly complete, while catches are not, usually because returning adults transit several fisheries en route to their natal streams, and catch contributions to every transited fishery are not known. For Speel Lake sockeye salmon, the reverse is true, and escapement counts are less complete than the catch data.

Regression analyses are robust concerning errors in the dependent variable number of returning adults, while being very sensitive to errors in the independent variable brood year escapement. We tried to compensate for the truncation and bias in the escapement data, by expanding escapement estimates. However, the two methods we used produced biases of their own, because of the paucity of data, and because the extended weir counts for 1982, 1995 and 2002 were outliers in the historical data set.

Another problem in the regression analysis is that observations at the ends of the data ranges often exert undue influence. At least five Speel Lake escapement estimates, located at both ends of the data ranges, are extreme enough to be implausible. Given the sensitivity of the analysis to errors in the independent variable, the level of uncertainty in the estimates of total escapement, and the influence extreme values have on regression analyses, this analysis should be considered a holding action, and awaiting a review pending the receipt of more complete escapement data.

Nevertheless, we believe that the estimated MSY escapement level of about 7,500 spawning fish for the Speel Lake sockeye salmon stock is reasonable. This is the best estimate that can currently be gleaned from the data available. Improved information in the future may determine whether the expansion methods we used were appropriate. Because of this uncertainty, we believe it best to express the estimated MSY escapement value as a relatively wide management range. Doing so increases the chances that:

(1) the actual MSY escapement value will be included in the recommended range,

(2) the potential for greater contrast in escapements is retained over the next few years, as escapement contrast may be instrumental in future analyses and estimates of the MSY escapement value, and,

(3) the fisheries are not unnecessarily restricted over the next few years based upon an uncertain analysis.

Given these considerations, we believe the best way to translate the point estimate of MSY escapement (about 7,500) into a management range is to determine the estimated range of escapements expected to provide for 80% of more of estimated maximum sustained yield (MSY). Doing so results in a management range of about 4,000 to 13,000 spawning sockeye salmon in Speel Lake.

RECOMMENDATIONS

We believe that preserving long-term stock assessment programs should continue to be one of the highest priorities for the Alaska Department of Fish and Game. These types of programs provide information on the basic biology of the resource that is often poorly understood due to the lack of long-term assessment programs. These programs also provide a continuing time series of data that can be used to understand the causes of abundance fluctuations, allow for comparisons of year-to-year abundance and overall status of the resource, and help improve in-season management. Because of the two to six year life span of sockeye salmon, many years of data are necessary to monitor the spawning abundance and subsequent returns of a few cohorts, and omission of a single year of data can add considerable uncertainty to an analysis.

We recommend that annual monitoring of sockeye salmon escapements in Speel Lake by a weir continue. However, the weir project should be operated through the third week in September in future years. Age, sex, and size composition sampling of the Speel Lake escapement of sockeye salmon should also continue, with target sample sizes of approximately 800 fish annually. We recommend that the annual stock composition estimation program in District 111 continue to be implemented.

We recommend that mark-recapture studies be conducted simultaneously with weir operations to validate the weir counts. We have assumed that during the periods the weir has operated all returning adults passing through the weir are counted, with the exception of an unknown portion of the jacks. However, we do not have corroborating evidence for this, and experience has indicated an undercounting bias at many other weirs operated in Southeast Alaska (Van Alen 2000). A properly designed mark-recapture study will tell us how much reliance we can place on the weir counts. Mark-recapture studies should be structured to enable mark and recovery data to be stratified so influence of jacks on the estimate can be determined, or jacks can be excluded from the analysis.

We recommend that the Alaska Department of Fish and Game adopt an escapement goal range of 4,000 to 13,000 spawning sockeye salmon for Speel Lake. We recommend that this escapement goal be reexamined in about three years. If our recommendation to operate the Speel Lake weir until the third week in September is acted upon, six years of full migratory timing data will be available to use as an improved basis for expanding earlier years. This data has the potential to add a better understanding of stock dynamics and greatly improve run reconstructions.

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TABLES

Table 1. Number of Speel Lake origin sockeye salmon caught in District 111 of Southeast Alaska, 1986-2001, apportioned by fishery and age.

	Wild Fish						Hatchery	
	Age 4	Age 5		Age 6	Mix			
Year	1.2	1.3	2.2	2.3	0.+	Other	All Ages	Total
1986	2,214	2,715	86	300	27	4	0	5,346
1987	111	8,847	12	239	75	0	0	9,284
1988	1,086	1,354	157	40	0	0	0	2,637
1989	1,036	5,551	210	601	0	27	0	7,425
1990	1,190	2,520	92	265	48	28	0	4,143
1991 [a/]								
1992	2,033	5,567	149	270	4	30	0	8,053
1993	2,275	14,833	138	959	358	78	0	18,641
1994	422	1,300	32	551	10	4	0	2,319
1995	2,548	4,175	172	794	22	30	0	7,741
1996	248	5,980	0	0	153	34	2,060	8,475
1997	93	2,410	4	0	0	3	576	3,086
1998	64	415	1	13	6	1	956	1,456
1999	676	1,117	1	9	0	11	0	1,814
2000	1,862	6,977	2	14	210	23	547	9,635
2001	1,099	8,166	0	27	10	29	3,279	12,610

[a/] No estimate developed for 1991, due to low sample sizes preventing development of stock scale template.

Note: The otolith-brain parasite-scale pattern stock identification program provides age specific estimates of the harvest of various stocks of sockeye salmon in District 111. Estimates provided from this sampling program are age specific for the four major age classes (fish of age 1.2, 1.3, 2.2, and 2.3), while the freshwater age 0 fish are lumped together, as are the other age classes that make up a minor portion of the harvest. Columns 2-7 above provide estimates from this sampling program. Since sockeye salmon released from Snettisham Hatchery are otolith marked, when terminal fisheries prosecuted near the hatchery are sampled, the portion of the harvest without otolith marks is assumed to be wild Speel Lake fish (column 8), and age compositions from the general district harvest are assigned to those fish. Sockeye salmon harvest estimates for 2002 are not yet available.

Table 2. Ending dates of weir counts of sockeye salmon at Speel Lake, 1983-1992 and 1995-2002, annual weir counts, **expansion factors based on mean cumulative proportions of escapement** for 1983, 1995 and 2002, expanded weir counts estimating total escapements, had weir remained in place through mid-September, and measures of precision for expansion factors and estimates of total passage for 1983 to 2002.

Year	End Date	Weir Count	Expansion Factor	Coefficient of Variation for Expansion Factor	Estimated Total Passage	Standard Error of Total Passage Estimate
1983	19-Nov	10,484	0	0	10,484	0
1984	8-Sep	9,764	1.17	6%	11,424	685
1985	29-Aug	7,073	2.21	80%	15,631	12,505
1986	29-Aug	5,857	2.21	80%	12,944	10,355
1987	27-Aug	9,353	2.43	88%	22,728	20,000
1988	31-Aug	969	1.58	43%	1,531	658
1989	5-Sep	12,854	1.17	7%	15,039	1,053
1990	29-Aug	18,095	2.21	80%	39,990	31,992
1991	29-Aug	299	2.21	80%	661	529
1992	26-Aug	9,439	2.45	88%	23,126	20,350
1993	*Weir not operated in this year*					
1994	*Weir not operated in this year*					
1995	12-Sep	7,668	1.06	5%	8,128	406
1996	1-Sep	10,442	1.25	9%	13,053	1,175
1997	1-Sep	4,999	1.25	9%	6,249	562
1998	27-Aug	13,358	2.43	88%	32,460	28,565
1999	24-Aug	10,277	2.55	91%	26,206	23,848
2000	29-Aug	6,763	2.21	80%	14,946	11,957
2001	31-Aug	8,060	1.58	43%	12,735	5,476
2002	20-Sep	5,016	1.01	2%	5,066	101

Table 3. Cumulative rainfall from August 10 to August 24 near Speel Lake, observed and predicted cumulative proportion of passage of sockeye salmon past Speel Lake weir from 1983 to 2002, **based on regression of cumulative rainfall on cumulative escapement** for 1983 to 2002, observed cumulative passage of sockeye salmon past Speel Lake weir on August 24, predicted cumulative estimates of total passage based upon the rainfall relationship, and associated measures of precision.

Year	Cumulative Rainfall 8/10 to 8/24	Cumulative Proportion Of Total Passage on 8/24		Cumulative Weir Count On 8/24	Total Passage Estimate	Passage Estimate Statistics of Variability	
		Observed	Predicted			Std. Error	Coeff. Variation
1983	48.8	85.5	87.4	8,968	10,257	0	-
1984	14		46.8	7,085	15,132	1,140	8%
1985	14.7		48.4	7,014	14,483	1,048	7%
1986	16.6		52.3	5,790	11,062	733	7%
1987	7.3		25.6	9,201	35,927	5,591	16%
1988	11.7		41.1	782	1,903	167	9%
1989	5.3		15.4	10,553	68,393	18,967	28%
1990	15		49.2	16,959	34,463	2,448	7%
1991	22.8		62.8	225	359	20	5%
1992	20.3		58.9	9,208	15,623	910	6%
1993	13.3		45.2	*Weir not operated in this year*			
1994	17.5		54.2	*Weir not operated in this year*			
1995	6	19.1	19.4	1,465	7,563	0	-
1996	21.7		61.1	9,901	16,215	910	6%
1997	24.4		64.9	4,484	6,906	365	5%
1998	14.7		48.4	12,667	26,155	1,893	7%
1999	13.8		46.5	10,277	22,115	1,680	8%
2000	29.7		71.3	6,717	9,426	459	5%
2001	5.4		16	7,136	44,489	11,823	27%
2002	36.5	80.2	78	4,023	5,160	0	-

Note: Rainfall relationship used above is:

Cumulative proportion of escapement = 32.44(ln cumulative rainfall) – 38.724, such that;
the cumulative proportion of escapement is for the date August 24th, and
the cumulative rainfall (measured in centimeters) is from August 10th through August 24th

Table 4. Comparison of estimates of Speel Lake sockeye salmon escapement, based on mean cumulative proportion of escapement, and on regression of escapement on cumulative rainfall, associated estimates of precision, and annual estimates chosen used in the analysis, for 1983 to 2002.

Year	Total Weir Count	Total Passage Estimate Based on Cum. Migration	Total Passage Estimate Based on Rainfall	Total Passage Estimate Based on 'Best Blend'	Coefficient of Variation, Cum. Migration Passage Est.	Coefficient of Variation, Rainfall Based Passage Est.	Coefficient of Variation, 'Best Blend' Passage Est.
1983	10,484	10,484	10,257	10,484	0%	0%	0%
1984	9,764	11,424	15,132	11,424	6%	8%	6%
1985	7,073	15,631	14,483	14,483	80%	7%	7%
1986	5,857	12,944	11,062	11,062	80%	7%	7%
1987	9,353	22,728	35,927	35,927	88%	16%	16%
1988	969	1,531	1,903	1,903	43%	9%	9%
1989	12,854	15,039	68,393	15,039	7%	28%	7%
1990	18,095	39,990	34,463	34,463	80%	7%	7%
1991	299	661	359	359	80%	5%	5%
1992	9,439	23,126	15,623	15,623	88%	6%	6%
1993	*Weir not operated in this year*						
1994	*Weir not operated in this year*						
1995	7,668	8,128	7,563	7,668	5%	0%	0%
1996	10,442	13,053	16,215	16,215	9%	6%	6%
1997	4,999	6,249	6,906	6,906	9%	5%	5%
1998	13,358	32,460	26,155	26,155	88%	7%	7%
1999	10,277	26,206	22,115	22,115	91%	8%	8%
2000	6,763	14,946	9,426	9,426	80%	5%	5%
2001	8,060	12,735	44,489	12,735	43%	27%	43%
2002	5,016	5,066	5,160	5,016	2%	0%	0%

Table 5. Estimated annual harvest rates of Speel Lake sockeye salmon in District 111 of Southeast Alaska, 1986-1992 and 1995. These are years of available data before the annual harvests in the Snettisham Hatchery terminal area took place.

Year		Best Blend Estimate of Weir Passage	Estimated Harvest	Estimated Total Return	Estimated Harvest Rate
1986		11,062	5,346	16,408	32.60%
1987		35,927	9,284	45,211	20.50%
1988		1,903	2,637	4,540	58.10%
1989		15,039	7,425	22,464	33.10%
1990		34,463	4,143	38,606	10.70%
1991	a/	359	--	--	--
1992		15,623	8,053	23,676	34.00%
1993	b/	--	18,641	--	--
1994	b/	--	2,319	--	--
1995		7,668	7,741	15,409	50.20%
Average Harvest Rate					34.20%

a/ Insufficient sample size for scale template used in estimating harvest.

b/ Weir was not operated in this year.

Table 6. Estimated harvest rates, total run size based on harvest rates, and comparison of escapement estimates based on harvest rates with "best blend" escapement estimates for Speel Lake sockeye salmon, 1986-1995.

Year	Harvest Rate	Estimated Harvest	Est. Total Run Size Based on Harvest Rate	Estimated Escapement Based on Harvest Rate	Estimated 'Best Blend' Escapement	Difference between Esc. Ests.
1986	32.6%	5,346	15,632	10,286	11,062	-776
1987	20.5%	9,284	27,146	17,862	35,927	-18,065
1988	58.1%	2,637	7,711	5,074	1,903	3,171
1989	33.1%	7,425	21,711	14,286	15,039	-753
1990	10.7%	4,143	12,114	7,971	34,463	-26,492
1991	**34.2%**	**187**	**546**	**--**	359	--
1992	34.0%	8,053	23,547	15,494	15,623	-129
1993	**34.2%**	18,641	**54,506**	**35,865**	--	--
1994	**34.2%**	2,319	**6,781**	**4,462**	--	--
1995	50.2%	7,741	22,635	14,894	7,668	7,226
Mean	34.2%	6,578	19,233	14,022	15,256	

Note: Numbers in bold are based on the mean estimated harvest rate for 1986 to 1990, 1992, and 1995.

Table 7. Annual number of sockeye salmon removed for brood stock from Speel Lake, and resulting change in “best blend” estimate of total escapement, 1983-2002.

Year	Best Blend' Estimate of Total PassagePast the Weir	Fish Removed forBrood Stock Upstream of Weir	Estimated Total Escapement
1983	10,484	0	10,484
1984	11,424	0	11,424
1985	14,483	0	14,483
1986	11,062	0	11,062
1987	35,927	0	35,927
1988	1,903	259	1,644
1989	15,039	2,115	12,924
1990	34,463	1,197	33,266
1991	359	0	359
1992	15,623	1,517	14,106
1993	35,865	1,042	34,823
1994	4,462	628	3,834
1995	7,668	1,703	5,965
1996	16,215	1,927	14,288
1997	6,906	0	6,906
1998	26,155	0	26,155
1999	22,115	0	22,115
2000	9,426	0	9,426
2001	12,735	0	12,735
2002	5,016	0	5,016

Table 8. Proportion and number by age of Speel Lake sockeye salmon harvested, from 1986 to 2001.

Year	Proportion Age 4	Proportion Age 5	Proportion Age 6	Number Age 4	Number Age 5	Number Age 6	Total Harvest
1986	0.42	0.53	0.06	2,227	2,817	302	5,346
1987	0.01	0.96	0.03	112	8,931	241	9,284
1988	0.41	0.57	0.02	1,086	1,511	40	2,637
1989	0.14	0.78	0.08	1,040	5,782	603	7,425
1990	0.29	0.64	0.07	1,212	2,661	270	4,143
1991 [a/]	**0.21**	**0.74**	**0.05**	**40**	**138**	**9**	**187**
1992	0.25	0.71	0.03	2,042	5,740	271	8,053
1993	0.12	0.82	0.05	2,329	15,330	982	18,641
1994	0.18	0.58	0.24	425	1,340	554	2,319
1995	0.33	0.57	0.1	2,565	4,376	799	7,741
1996	0.04	0.96	--	337	8,138	--	8,475
1997	0.04	0.96	--	114	2,972	--	3,086
1998	0.13	0.84	0.03	189	1,229	38	1,456
1999	0.37	0.62	0	680	1,125	9	1,814
2000	0.21	0.79	0	2,026	7,594	15	9,635
2001	0.12	0.88	0	1,491	11,082	37	12,610
Average	0.21	0.74	0.05	1,120	5,048	26	6,428

[a/] Bold type denotes mean proportion by age, and mean estimated harvest rate (Table 5) was used to calculate age composition estimate.

Table 9. Estimated age composition of sockeye salmon passing the Speel Lake weir site, from 1983 to 2001.

	Age 2	Age 3		Age 4			Age 5		Age 6		Age 7	
Year	0.1	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.3	Total
1983		25	102	22	1,887	2	8,097	111	2	236		10,484
1984				136	4,891		6,196	128		74		11,425
1985			846		3,323		10,060	125	41	88		14,483
1986		28		8	5,687		4,982	96	11	249		11,061
1987				419	1,398		33,530	19		561		35,927
1988			2		772		953	141	2	33		1,903
1989		4			4,033		9,507	398	1	1,096		15,039
1990		170		23	15,611	2	17,283	463	63	848		34,463
1991		2		10	77		248	10	5	7		359
1992				3	9,145		5,936	314	35	190		15,623
1993				413	11,909	69	21,891	413		1,170		35,865
1994		26	143		986		3,099	182		26		4,462
1995		10	6	8	3,876	45	2,506	249		939	29	7,668
1996		50	121	385	1,772		13,882			5		16,215
1997		90	31	21	4,824		1,876		17	47		6,906
1998		783		517	14,912		9,720	125		98		26,155
1999	39	9	454		7,288		14,116	71	9	129		22,115
2000		266	190	38	5,663		3,231	19	19			9,426
2001			1,064	41	6,629		4,959		14	28		12,735

Table 10. Estimated total return of Speel Lake sockeye salmon by age from 1986 to 2001.

Year	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Est. Total Harvest
1986		28	7,922	7,895	562		16,407
1987		0	1,929	42,480	802		45,211
1988		2	1,858	2,605	75		4,540
1989		4	5,073	15,687	1,700		22,464
1990		170	16,848	20,407	1,181		38,606
1991 [a/]		2	127	**396**	**21**		546
1992		0	11,190	11,990	496		23,676
1993		0	14,720	37,634	2,152		54,506
1994		169	1,411	4,621	580		6,781
1995		16	6,494	7,131	1,738	29	15,408
1996		171	2,494	22,020	5		24,690
1997		121	4,959	4,848	64		9,992
1998		783	15,618	11,074	136		27,611
1999	39	463	7,968	15,312	147		23,929
2000		456	7,727	10,844	34		19,061
2001		1,064	8,161	16,041	79		25,345

[a/] Mean proportion by age, and mean estimated harvest rate (Table 5) was used to calculate age composition estimate.

Table 11. Estimated escapement and total return of Speel Lake sockeye salmon by age from brood years 1983 to 2001.

Year	Estimated Escapement	Age of Offspring at Return Age 3	Age 4	Age 5	Age 6	Estimated Total Return	Estimated Return Per Spawner
1983	10,484	28	1,929	2,605	1,701	6,263	0.60
1984	11,424	0	1,858	15,687	1,180	18,725	1.64
1985	14,483	2	5,073	20,407	21	25,503	1.76
1986	11,062	4	16,849	396	496	17,745	1.60
1987	35,927	170	126	11,990	2,152	14,438	0.40
1988	1,644	2	11,190	37,633	580	49,405	30.05
1989	12,924	0	14,720	4,622	1,738	21,080	1.63
1990	33,266	0	1,410	7,131	5	8,546	0.26
1991	359	169	6,523	22,020	64	28,776	80.16
1992	14,106	16	2,494	4,848	136	7,494	0.53
1993	34,823	171	4,960	11,073	147	16,351	0.47
1994	3,834	121	15,618	15,367	24	31,130	8.12
1995	5,965	783	7,973	11,336	53	20,145	3.38
1996	14,288 [a/]	442	7,336	16,443	288	24,509	1.72
1997	6,906	368	7,706			8,074	*Incomplete return*
1998	26,155	1,121				1,121	*Incomplete return*
1999	22,115						*Incomplete return*
2000	9,426						*Incomplete return*
2001	12,735						*Incomplete return*
2002	5,016						*Incomplete return*

[a/] the median proportion of age 6 fish in brood years 1983 to 1995 (1.12%) was used to estimate the number of age 6 sockeye salmon from brood year 1996 returning to Speel Lake.

Table 12. Statistics from stock-recruit relationships calculated for Speel Lake origin sockeye salmon, brood years 1983-1996, including and excluding brood years 1993 and 1994.

Statistic from Stock-Recruit Relationship	Relationship Using All Brood Years 1983-1995	Relationship Omitting Brood Years 1993 & 1994
Escapement versus Natural Log of (Recruit/Spawner) Relationships:		
No. of observations	14	12
R-squared	0.63	0.61
Regression significance	0.0007	0.0026
Mean square errors – regression	22.398	19.297
Mean square errors –residuals	1.089	1.211
Intercept (estimate)	2.3015	2.3754
S. E. of intercept	0.4538	0.5303
P value of intercept	0.00027	0.0012
Slope (estimate)	-0.00011	-0.00012
S. E. of slope	0.0000245	0.0000307
P value of slope	0.0007	0.0026
Ricker Stock-Recruit Values:		
Ricker α (unadjusted)	9.99	10.76
Ricker α (adjusted by MS-residuals)	17.22	19.71
Ricker β	0.00011	0.00012
Replacement value approximate)[a]	25,000	20,000
Predicted Escapement at MSY Related Values Using Stock-Recruit Relationship with Adjusted Ricker a Value:		
Estimated escapement at MSY	7,766	6,479
Estimated MSY	48,696	25,012
Exploitation at MSY escapement	86%	79%
80% of estimated MSY	38,957	20,010
Escapement at 80% of MSY (lower)[a]	4,000	3,000
Escapement at 80% of MSY (upper)[a]	13,000	11,000

[a] Rounded to the nearest 500 fish.

FIGURES

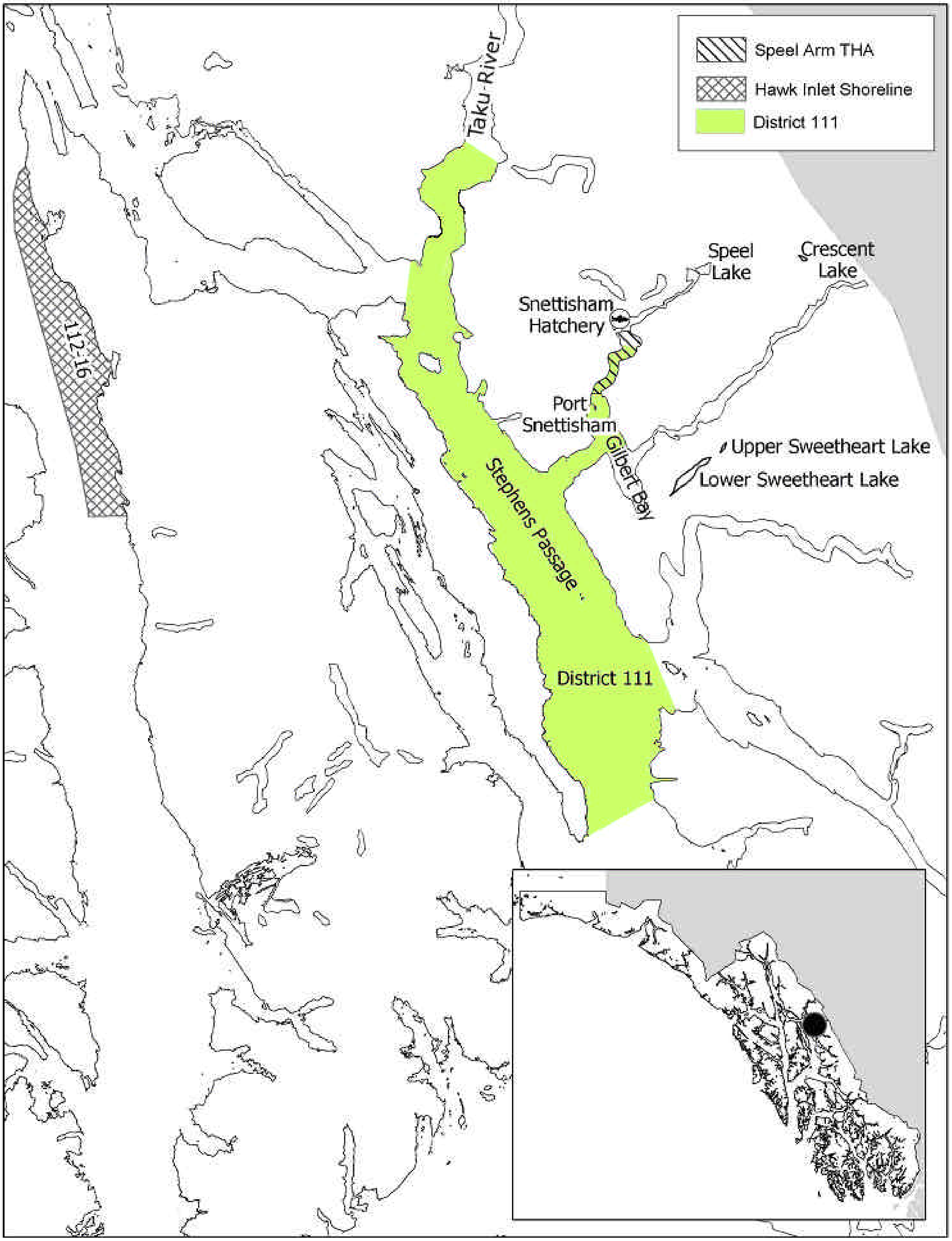


Figure 1. Map of Speel Lake and surroundings, with inset of Southeast Alaska. Striped area denotes the hatchery Special Harvest Area (SHA).

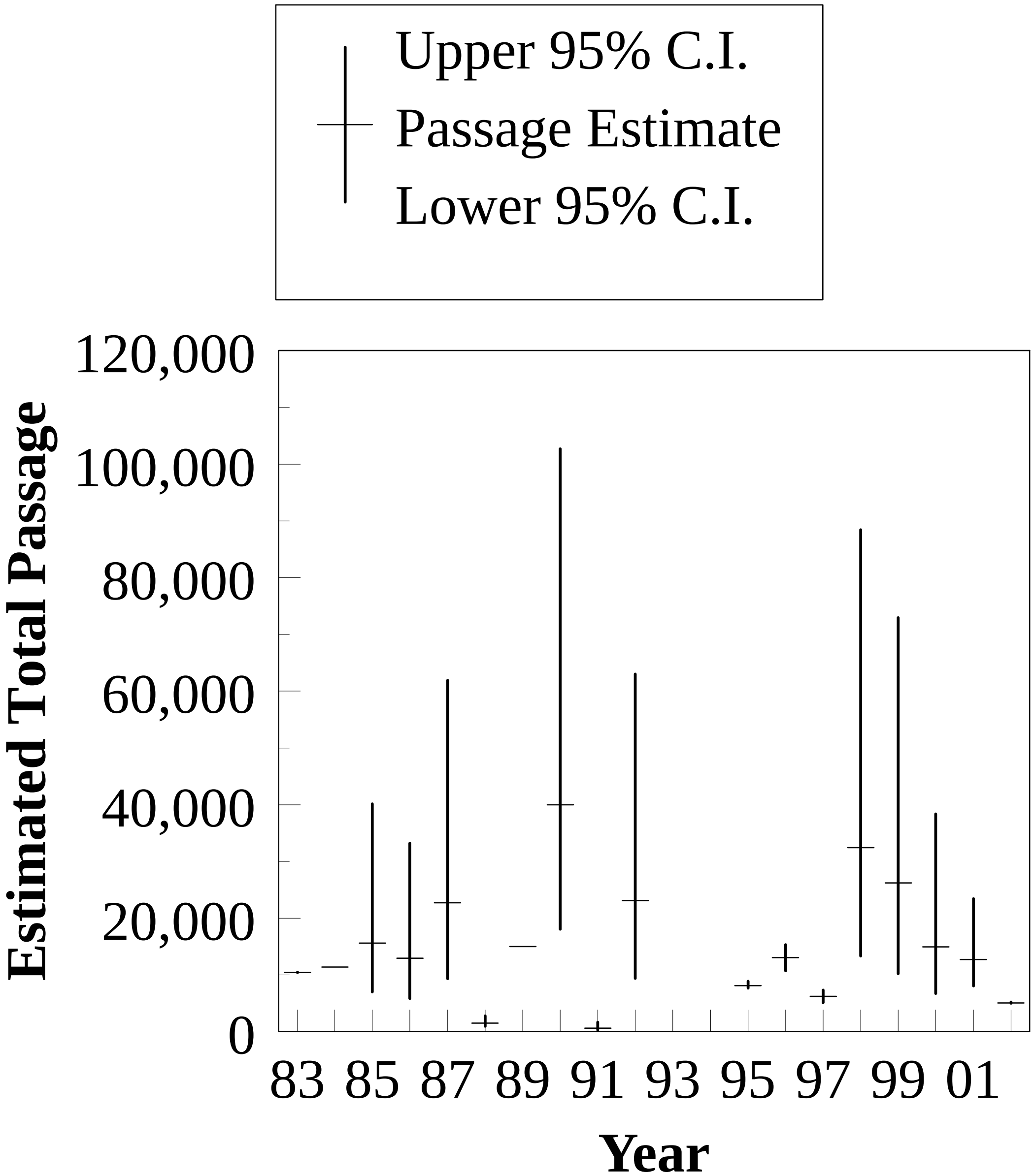
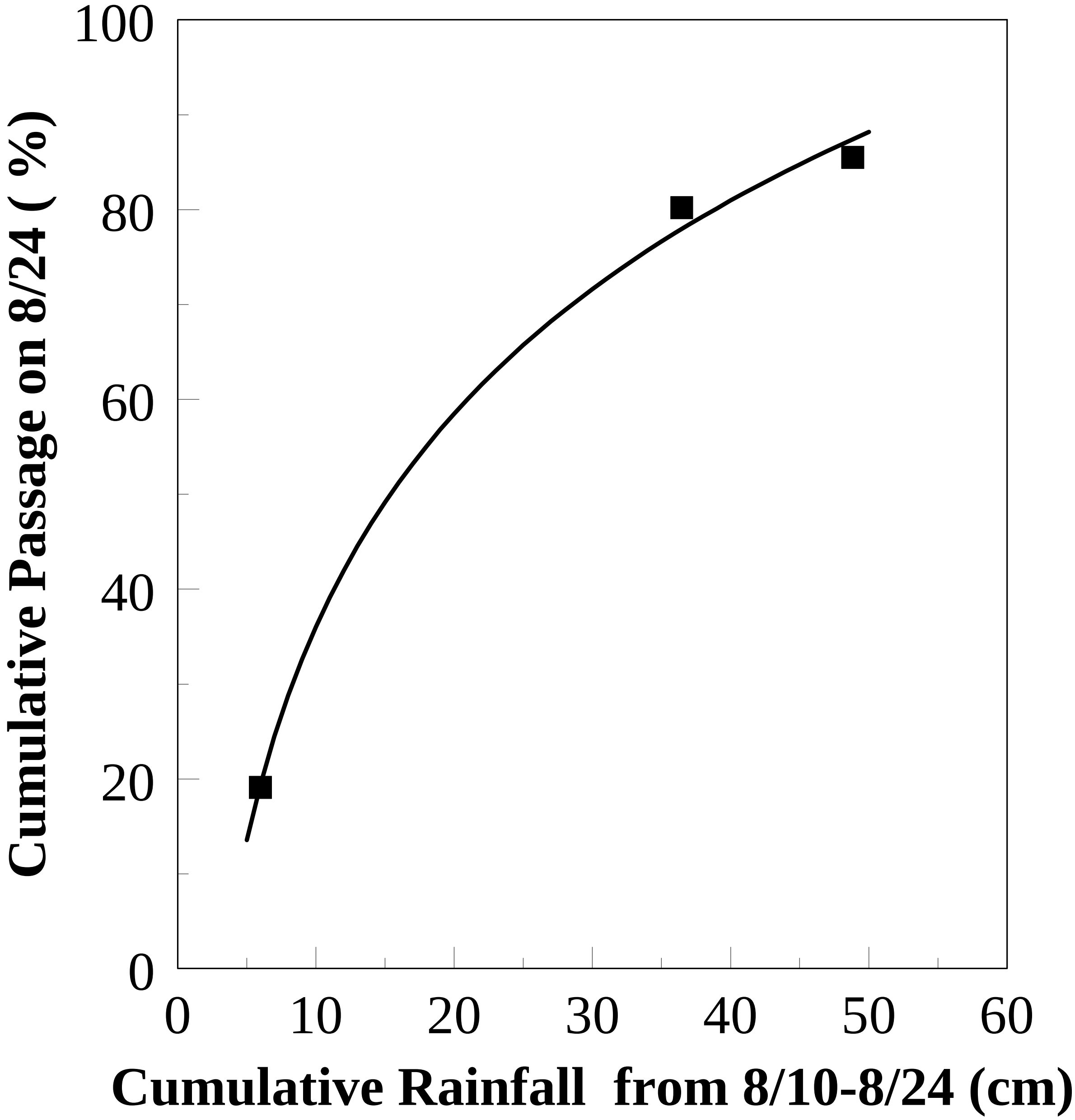


Figure 2. Precision of estimates of Speel Lake sockeye salmon passage above the weir site, 1983-1992 and 1995-2002 based upon average migratory timing. Point estimates and 95% confidence intervals are shown. The estimates and their precision are calculated from cumulative migratory timing data for 1983, 1995, and 2002. The annual weir counts are adjusted and expanded based upon average expansions and variances associated with the date of weir removal as calculated for that date with the 1983, 1995, and 2002 cumulative weir count data sets.



$y = 32.444\ln(x)-38.724$

$P=0.036$, $r = 0.998$

Figure 3. Estimated relationship between cumulative rainfall from August 10 through August 24 and cumulative passage of sockeye salmon past the Speel Lake weir on August 24.

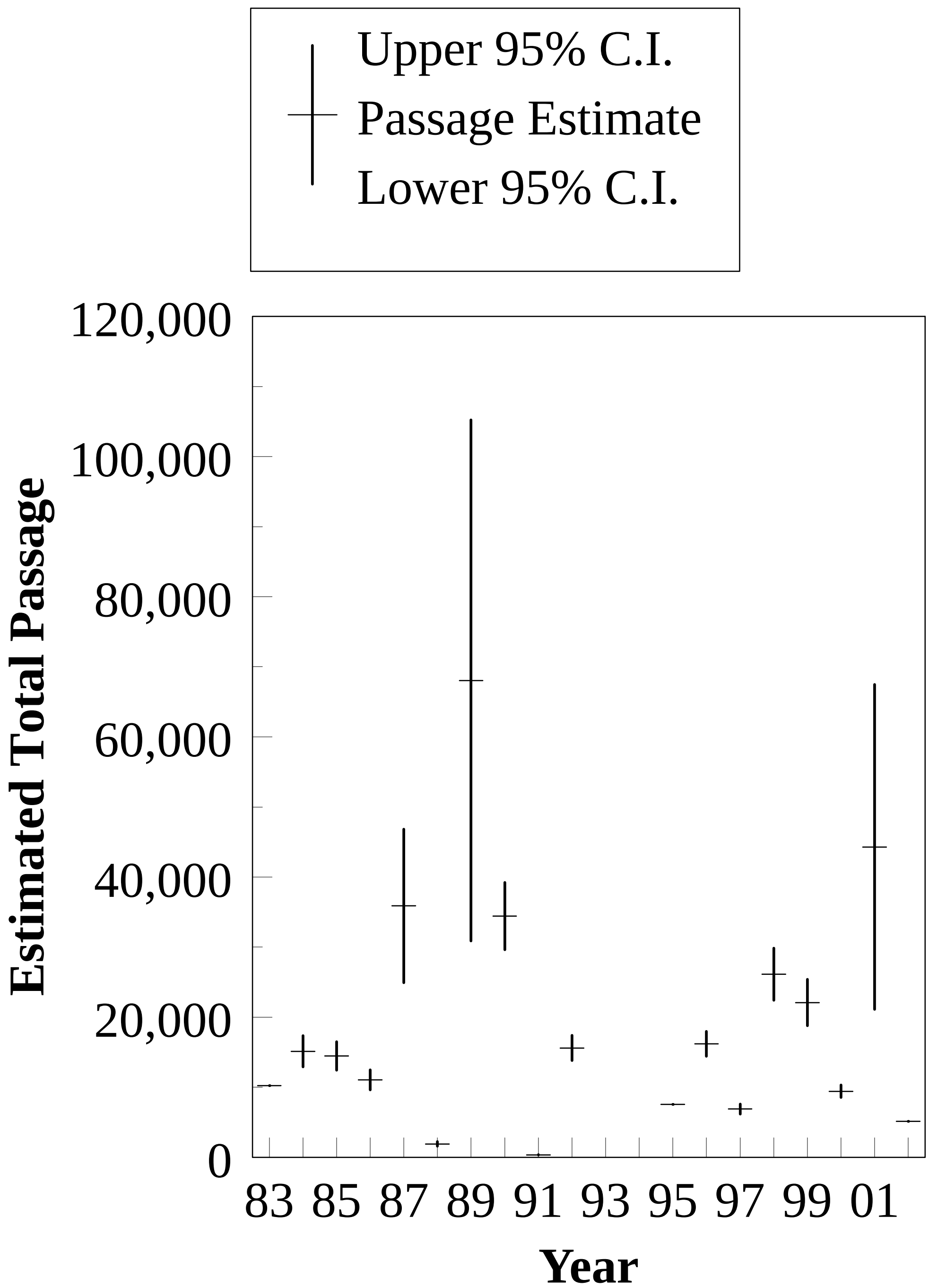


Figure 4. Precision of estimates of Speel Lake sockeye salmon passage above the weir site, 1983-1992 and 1995-2002 based upon the rain relationship. Point estimates and 95% confidence intervals are shown. The estimates and their precision are calculated based upon estimating the cumulative passage on August 24 (see Figure 3) and dividing that estimate by the weir count on August 24.

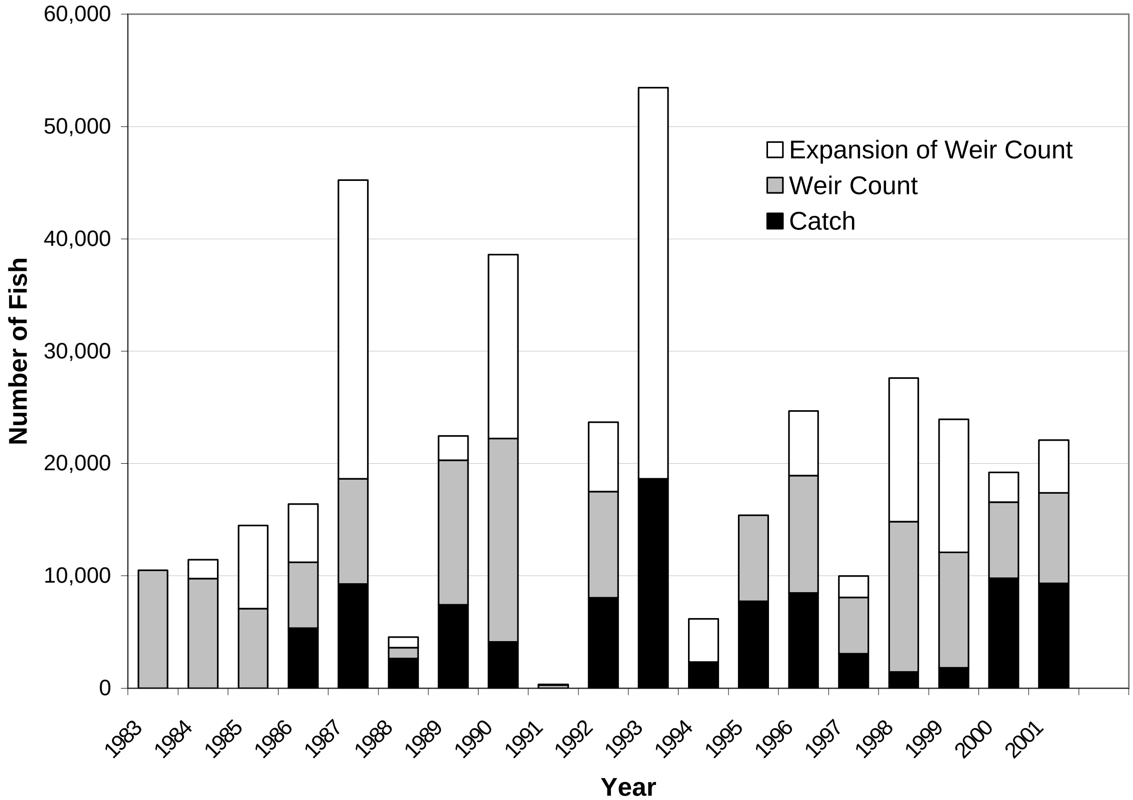


Figure 5. Estimated total annual runs of Speel Lake origin sockeye salmon, 1986-2001. Harvest estimates for the years 1983-1985 are not available: data displayed for the years 1983-1985 only include estimates of escapement.

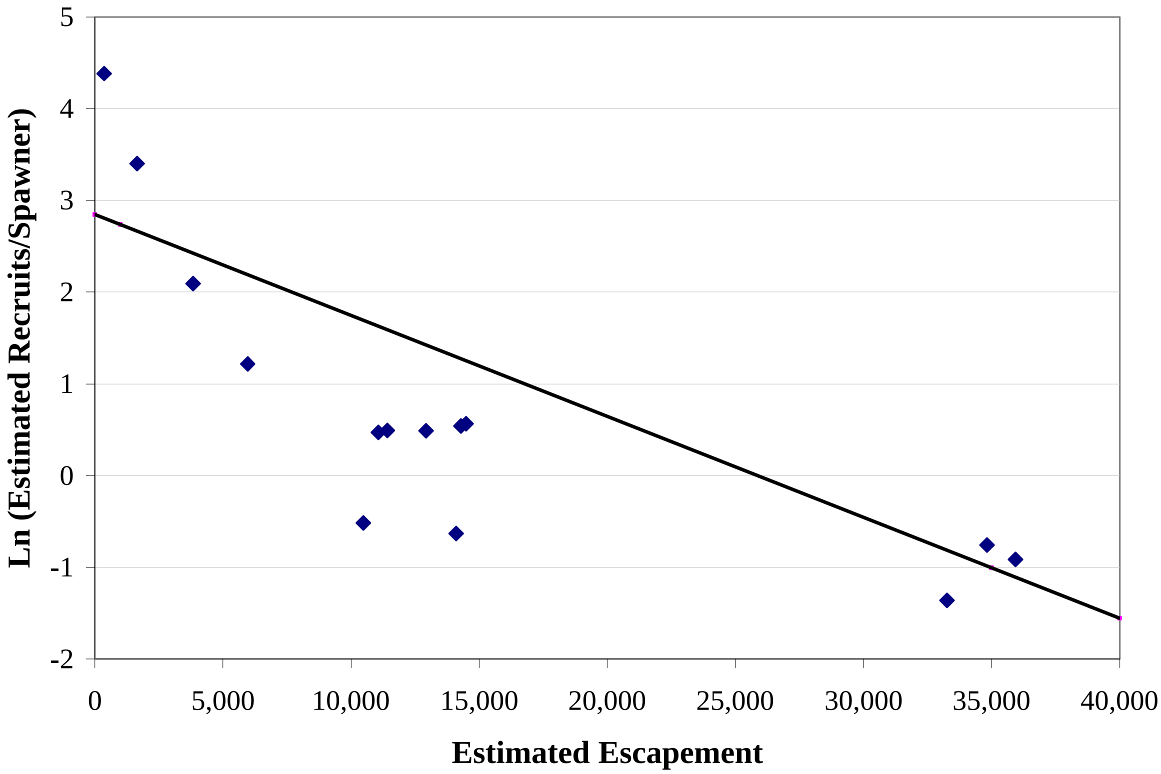


Figure 6. Estimated linear relationship between escapement and log of recruits per spawner for Speel Lake sockeye salmon, brood years 1983-1996. Stars are 1983-1996 paired estimates of escapement and the log of recruits per spawner; the diagonal line is the estimated linear relationship.

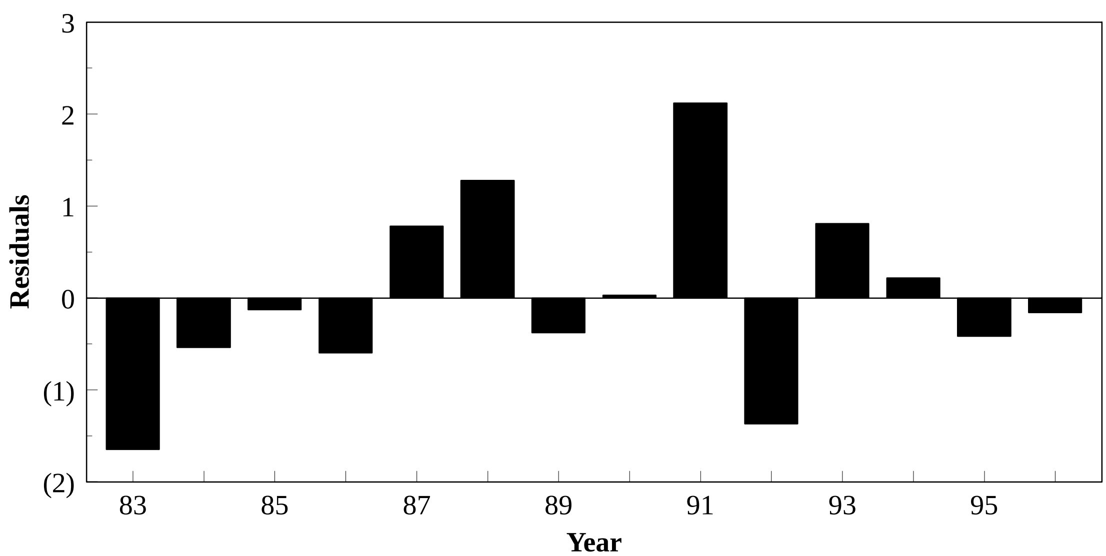


Figure 7. Residuals in the relationship between estimated escapement and log of the estimated recruits per spawner, brood years 1983-1996.

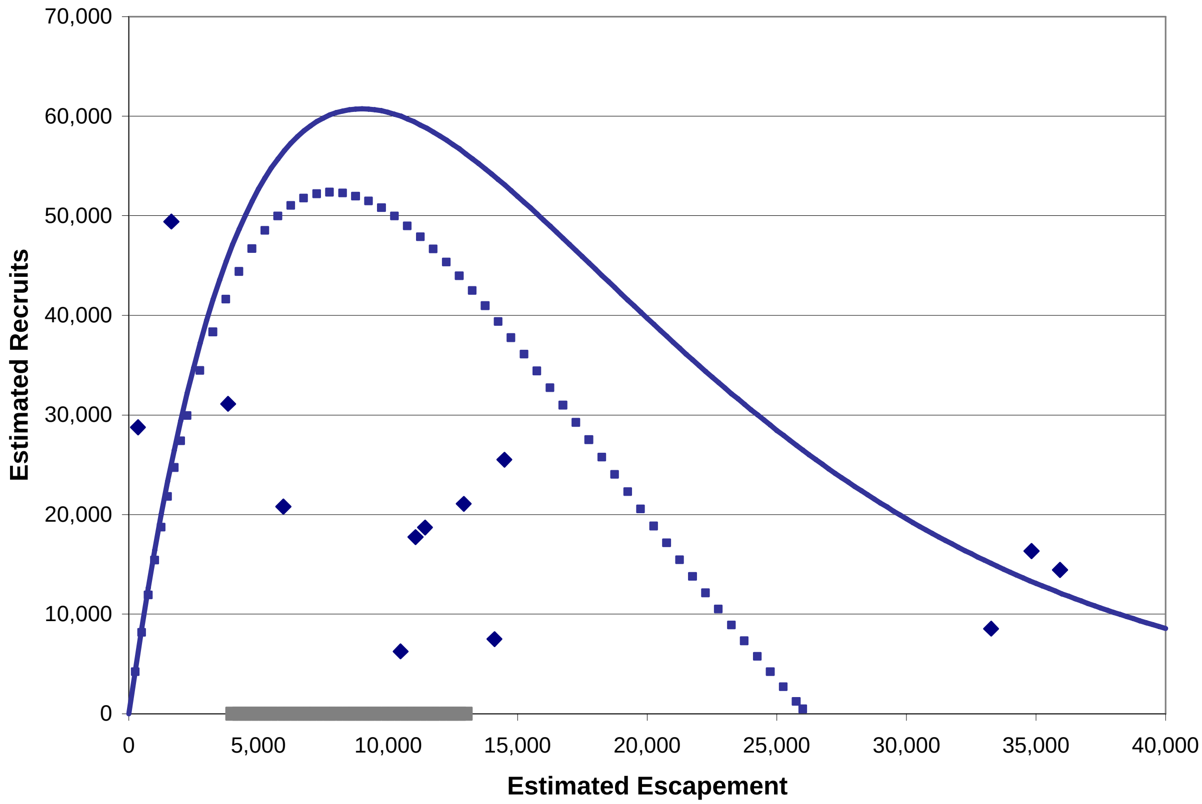


Figure 8. Estimated stock-recruit relationship for Speel Lake sockeye salmon, based on brood years 1983 to 1995. Diamonds represent the observed estimates of escapement and returning recruits. The upper curve represents production predicted by Ricker's model, the dotted curve represents yield predicted by Ricker's model. Shaded line on x-axis denotes the recommended biological escapement goal range.

APPENDICES

Appendix A.1. Daily escapement counts of sockeye salmon at Speel Lake weir, 1983 to 1992.

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
7/1	0									
7/2	5									
7/3	0									
7/4	3									
7/5	0									
7/6	1									
7/7	4									
7/8	0									
7/9	3									
7/10	1									
7/11	0									
7/12	0						0		0	
7/13	2						0	0	0	
7/14	1						0	0	0	
7/15	4	0	0		0	0	0	3	1	0
7/16	3	0	0	0	0	0	0	10	7	2
7/17	12	0	3	0	0	0	0	9	1	5
7/18	2	0	5	0	0	0	0	24	0	1
7/19	4	0	2	0	0	0	1	40	6	11
7/20	11	0	2	0	6	0	0	19	4	4
7/21	4	0	8	0	10	0	0	15	2	2
7/22	7	0	1	0	12	1	3	21	1	1
7/23	11	0	0	0	6	0	0	36	0	39
7/24	4	1	1	11	36	0	5	46	0	84
7/25	2	0	4	0	268	0	14	55	0	132
7/26	0	1	0	246	26	16	21	39	2	104
7/27	2	0	2	176	23	16	2	580	1	91
7/28	0	0	9	30	613	14	101	140	0	2,367
7/29	0	2	26	73	228	9	424	524	5	99
7/30	0	19	18	10	32	17	459	3,331	3	78
7/31	48	0	138	110	279	3	343	94	2	364
8/1	0	0	752	123	33	0	368	93	2	707
8/2	4	0	203	135	148	1	331	123	2	368
8/3	15	0	6	25	533	45	4,253	101	12	892
8/4	61	0	50	175	143	12	28	2,912	3	217
8/5	60	0	201	337	117	23	169	37	0	588
8/6	151	0	376	497	49	21	5	65	0	289
8/7	2,025	0	117	230	103	33	199	53	0	136
8/8	47	0	270	220	28	20	133	56	0	20
8/9	74	622	296	39	8	41	222	2,239	0	252
8/10	2,237	3,860	402	649	994	42	229	23	0	56
8/11	587	0	408	269	44	26	182	522	0	77
8/12	328	220	6	12	1,252	31	1,188	305	0	371
8/13	75	1,311	12	2,140	10	21	47	56	0	286
8/14	485	0	30	18	39	20	95	1,042	12	85
8/15	1,390	0	4	0	527	30	40	415	20	77
8/16	119	0	17	0	2,950	55	15	825	5	326

Appendix A.1. Continued (page 2 of 3).

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
8/17	19	44	9	18	277	12	93	176	0	71
8/18	29	70	9	32	70	7	8	208	21	31
8/19	62	61	21	112	23	121	10	818	30	28
8/20	38	0	31	28	42	15	88	677	7	164
8/21	70	764	3,431	23	16	16	894	93	5	219
8/22	805	94	101	6	218	69	400	170	33	278
8/23	100	0	14	30	0	34	123	476	17	130
8/24	53	16	29	16	38	11	60	488	21	156
8/25	6	2,540	1	13	2	66	138	162	0	171
8/26	1	64	1	18	0	29	166	139	0	60
8/27	0	42	31	6	150	18	85	91	36	
8/28	1	14	1	0		29	38	713	8	
8/29	3	2	25	30		34	3	31	30	
8/30	16	3				11	0			
8/31	18	6				0	34			
9/1	13	1					0			
9/2	117	3					20			
9/3	67	1					1,114			
9/4	270	1					18			
9/5	60	2					685			
9/6	18	0								
9/7	2	0								
9/8	13	0								
9/9	14									
9/10	6									
9/11	5									
9/12	22									
9/13	20									
9/14	70									
9/15	120									
9/16	27									
9/17	36									
9/18	6									
9/19	7									
9/20	161									
9/21	235									
9/22	60									
9/23	49									
9/24	29									
9/25	9									
9/26	3									
9/27	1									
9/28	2									
9/29	0									
9/30	0									
10/1	0									
10/2	0									

Appendix A.1. Continued (page 3 of 3).

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
10/3	1									
10/4	12									
10/5	0									
10/6	0									
10/7	1									
10/8	1									
10/9	0									
10/10	0									
10/11	0									
10/12	7									
10/13	2									
10/14	0									
10/15	1									
10/16	0									
10/17	0									
10/18	0									
10/19	1									
10/20	0									
10/21	0									
10/22	1									
10/23	0									
10/24	0									
10/25	0									
10/26	0									
10/27	2									
10/28	0									
10/29	0									
10/30	0									
10/31	0									
11/1	0									
11/2	0									
11/3	0									
11/4	0									
11/5	0									
11/6	0									
11/7	0									
11/8	0									
11/9	0									
11/10	0									
11/11	0									
11/12	0									
11/13	0									
11/14	0									
11/15	0									
11/16	0									
11/17	0									
11/18	0									
11/19	0									
Total	10,484	9,764	7,073	5,857	9,353	969	12,854	18,095	299	9,439

Appendix A.2. Daily escapement counts of sockeye salmon at Speel Lake weir, 1995 to 2002.

Date	1995	1996	1997	1998	1999	2000	2001	2002
7/14						0		0
7/15		15						0
7/16		0						0
7/17		0				0		0
7/18		0	10					0
7/19		0	30			0		0
7/20		0	36					3
7/21		0	70		35			0
7/22		0	46	7	100	0		19
7/23		28	77	202	108	0		22
7/24		62	119	87	8	2	22	17
7/25		179	120	47	1	6	2	9
7/26		116	90	33	30	4	1	10
7/27		86	66	19	33	16	2	7
7/28		66	567	405	43	48	5	14
7/29		64	130	284	18	40	7	0
7/30		156	76	127	74	89	24	0
7/31	0	111	27	1,151	104	210	188	7
8/1	24	97	15	335	21	188	100	5
8/2	26	162	29	643	103	168	229	110
8/3	66	237	7	45	311	412	5	239
8/4	31	270	22	36	39	412	161	190
8/5	1	166	14	86	30	318	821	228
8/6	43	3,802	33	286	40	64	36	220
8/7	46	215	147	6,090	2,732	3,432	628	1,671
8/8	43	81	42	50	1,572	204	626	499
8/9	1	104	96	26	29	27	215	103
8/10	47	78	100	234	91	65	677	127
8/11	169	68	124	69	195	6	157	8
8/12	282	112	103	105	594	8	58	54
8/13	285	110	1,017	44	112	0	139	157
8/14	152	86	137	195	22	813	440	9
8/15	44	167	65	435	25	0	607	0
8/16	32	118	72	145	691	31	291	0
8/17	17	76	57	196	45	19	75	0
8/18	11	62	92	166	13	3	1,383	0
8/19	32	64	33	40	106	49	111	1
8/20	25	83	240	152	71	30	50	3
8/21	4	332	80	63	20	2	17	15
8/22	30	1,163	254	1	2,189	47	2	43
8/23	50	1,354	200	188	187	1	35	228
8/24	4	11	41	675	485	3	22	5
8/25	33	110	63	30		0	42	13
8/26	54	106	63	108		35	751	9
8/27	16	137	80	553		0	37	3
8/28	7	44	100			11	4	56
8/29	233	32	64			0	5	21

Appendix A.2. Continued (page 2 of 2).

Date	1995	1996	1997	1998	1999	2000	2001	2002
8/30	56	72	64				12	0
8/31	1,386	28	49				73	14
9/1	2,283	12	32					4
9/2	357							0
9/3	210							5
9/4	33							34
9/5	22							73
9/6	3							34
9/7	11							26
9/8	11							8
9/9	194							15
9/10	1,185							7
9/11	98							58
9/12	11							210
9/13								86
9/14								51
9/15								2
9/16								0
9/17								18
9/18								220
9/19								26
9/20								0
Total	9,663	12,438	6,996	15,356	12,276	8,763	10,061	7,018

Appendix A.3. Cumulative escapement counts of sockeye salmon at Speel Lake weir, 1983, 1995, and 2002.

Date	1983 Cumulative Count	1983 Cumulative Percent	1995 Cumulative Count	1995 Cumulative Percent	2002 Cumulative Count	2002 Cumulative Percent
up to 7/20	56	0.5%			3	0.1%
7/21	60	0.6%			3	0.1%
7/22	67	0.6%			22	0.4%
7/23	78	0.7%			44	0.9%
7/24	82	0.8%			61	1.2%
7/25	84	0.8%			70	1.4%
7/26	84	0.8%			80	1.6%
7/27	86	0.8%			87	1.7%
7/28	86	0.8%			101	2.0%
7/29	86	0.8%			101	2.0%
7/30	86	0.8%			101	2.0%
7/31	134	1.3%			108	2.2%
8/1	134	1.3%	24	0.3%	113	2.3%
8/2	138	1.3%	50	0.7%	223	4.4%
8/3	153	1.5%	116	1.5%	462	9.2%
8/4	214	2.0%	147	1.9%	652	13.0%
8/5	274	2.6%	148	1.9%	880	17.5%
8/6	425	4.1%	191	2.5%	1,100	21.9%
8/7	2,450	23.4%	237	3.1%	2,771	55.2%
8/8	2,497	23.8%	280	3.7%	3,270	65.2%
8/9	2,571	24.5%	281	3.7%	3,373	67.2%
8/10	4,808	45.9%	328	4.3%	3,500	69.8%
8/11	5,395	51.5%	497	6.5%	3,508	69.9%
8/12	5,723	54.6%	779	10.2%	3,562	71.0%
8/13	5,798	55.3%	1,064	13.9%	3,719	74.1%
8/14	6,283	59.9%	1,216	15.9%	3,728	74.3%
8/15	7,673	73.2%	1,260	16.4%	3,728	74.3%
8/16	7,792	74.3%	1,292	16.8%	3,728	74.3%
8/17	7,811	74.5%	1,309	17.1%	3,728	74.3%
8/18	7,840	74.8%	1,320	17.2%	3,728	74.3%
8/19	7,902	75.4%	1,352	17.6%	3,729	74.3%
8/20	7,940	75.7%	1,377	18.0%	3,732	74.4%
8/21	8,010	76.4%	1,381	18.0%	3,747	74.7%
8/22	8,815	84.1%	1,411	18.4%	3,790	75.6%
8/23	8,915	85.0%	1,461	19.1%	4,018	80.1%
8/24	8,968	85.5%	1,465	19.1%	4,023	80.2%
8/25	8,974	85.6%	1,498	19.5%	4,036	80.5%
8/26	8,975	85.6%	1,552	20.2%	4,045	80.6%
8/27	8,975	85.6%	1,568	20.4%	4,048	80.7%
8/28	8,976	85.6%	1,575	20.5%	4,104	81.8%
8/29	8,979	85.6%	1,808	23.6%	4,125	82.2%
8/30	8,995	85.8%	1,864	24.3%	4,125	82.2%
8/31	9,013	86.0%	3,250	42.4%	4,139	82.5%
9/1	9,026	86.1%	5,533	72.2%	4,143	82.6%

Appendix A.3. Continued (page 2 of 2).

Date	1983 Cumulative Count	1983 Cumulative Percent	1995 Cumulative Count	1995 Cumulative Percent	2002 Cumulative Count	2002 Cumulative Percent
9/2	9,143	87.2%	5,890	76.8%	4,143	82.6%
9/3	9,210	87.8%	6,100	79.6%	4,148	82.7%
9/4	9,480	90.4%	6,133	80.0%	4,182	83.4%
9/5	9,540	91.0%	6,155	80.3%	4,255	84.8%
9/6	9,558	91.2%	6,158	80.3%	4,289	85.5%
9/7	9,560	91.2%	6,169	80.5%	4,315	86.0%
9/8	9,573	91.3%	6,180	80.6%	4,323	86.2%
9/9	9,587	91.4%	6,374	83.1%	4,338	86.5%
9/10	9,593	91.5%	7,559	98.6%	4,345	86.6%
9/11	9,598	91.5%	7,657	99.9%	4,403	87.8%
9/12	9,620	91.8%	7,668	100.0%	4,613	92.0%
9/13	9,640	91.9%		100.0%	4,699	93.7%
9/14	9,710	92.6%		100.0%	4,750	94.7%
9/15	9,830	93.8%		100.0%	4,752	94.7%
9/16	9,857	94.0%		100.0%	4,752	94.7%
9/17	9,893	94.4%		100.0%	4,770	95.1%
9/18	9,899	94.4%		100.0%	4,990	99.5%
9/19	9,906	94.5%		100.0%	5,016	100.0%
9/20	10,067	96.0%		100.0%	5,016	100.0%
9/21	10,302	98.3%		100.0%		100.0%
9/22	10,362	98.8%		100.0%		100.0%
9/23 & after	10,484	100.0%		100.0%		100.0%

Appendix B.1. Expansion factor statistics for estimation of total escapements for years when weir counts ended before mid-September based upon run timing of escapements into Speel Lake in 1983, 1995, and 2002.

	Cumulative Entry Patterns:			Expansion Factors:			Mean Expansion Factors and Standard Error	
Date	1983	1995	2002	1983	1995	2002	Average	S.E.
8/24	85.5%	19.1%	80.2%	1.17	5.23	1.25	2.55	2.32
8/25	85.6%	19.5%	80.5%	1.17	5.12	1.24	2.51	2.26
8/26	85.6%	20.2%	80.6%	1.17	4.94	1.24	2.45	2.16
8/27	85.6%	20.4%	80.7%	1.17	4.89	1.24	2.43	2.13
8/28	85.6%	20.5%	81.8%	1.17	4.87	1.22	2.42	2.12
8/29	85.6%	23.6%	82.2%	1.17	4.24	1.22	2.21	1.76
8/30	85.8%	24.3%	82.2%	1.17	4.11	1.22	2.17	1.69
8/31	86.0%	42.4%	82.5%	1.16	2.36	1.21	1.58	0.68
9/1	86.1%	72.2%	82.6%	1.16	1.39	1.21	1.25	0.12
9/2	87.2%	76.8%	82.6%	1.15	1.30	1.21	1.22	0.08
9/3	87.8%	79.6%	82.7%	1.14	1.26	1.21	1.20	0.06
9/4	90.4%	80.0%	83.4%	1.11	1.25	1.20	1.19	0.07
9/5	91.0%	80.3%	84.8%	1.10	1.25	1.18	1.17	0.07
9/6	91.2%	80.3%	85.5%	1.10	1.25	1.17	1.17	0.07
9/7	91.2%	80.5%	86.0%	1.10	1.24	1.16	1.17	0.07
9/8	91.3%	80.6%	86.2%	1.10	1.24	1.16	1.17	0.07
9/9	91.4%	83.1%	86.5%	1.09	1.20	1.16	1.15	0.05
9/10	91.5%	98.6%	86.6%	1.09	1.01	1.15	1.09	0.07
9/11	91.5%	99.9%	87.8%	1.09	1.00	1.14	1.08	0.07
9/12	91.8%	100.0%	92.0%	1.09	1.00	1.09	1.06	0.05
9/13	91.9%	100.0%	93.7%	1.09	1.00	1.07	1.05	0.05
9/14	92.6%	100.0%	94.7%	1.08	1.00	1.06	1.05	0.04
9/15	93.8%	100.0%	94.7%	1.07	1.00	1.06	1.04	0.04
9/16	94.0%	100.0%	94.7%	1.06	1.00	1.06	1.04	0.03
9/17	94.4%	100.0%	95.1%	1.06	1.00	1.05	1.04	0.03
9/18	94.4%	100.0%	99.5%	1.06	1.00	1.01	1.02	0.03
9/19	94.5%	100.0%	100.0%	1.06	1.00	1.00	1.02	0.03
9/20	96.0%	100.0%	100.0%	1.04	1.00	1.00	1.01	0.02
9/21	98.3%	100.0%	100.0%	1.02	1.00	1.00	1.01	0.01
9/22	98.8%	100.0%	100.0%	1.01	1.00	1.00	1.00	0.01
9/23 & after	100.0%	100.0%	100.0%	1.00	1.00	1.00	1.00	0.00

Appendix C.1. Daily July rainfall in centimeters at the Snettisham power plant switchyard, 1983 to 1994.

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
7/1	0.71	0.25	1.09					0.74	0.08			0.05
7/2	0.23	1.42	0.25	0.64		0.13		0.10	0.15			0.00
7/3	0.20	0.58		0.00					1.14		0.18	0.76
7/4	0.33			0.05				0.05			1.30	0.86
7/5		0.23				0.48					0.38	1.14
7/6	0.08		0.38		0.05		0.03				0.43	6.05
7/7								0.15		0.20	0.03	0.86
7/8	0.08	0.53						0.97		0.08		0.43
7/9	1.47	2.44						2.67	0.28	0.64		0.00
7/10	2.87	4.11	0.43	0.00		0.76		1.30	0.03	0.08		0.05
7/11	1.78	0.89	1.73	0.10	0.51			2.13	0.76			0.00
7/12	0.05	0.53	0.51	0.10	0.46	0.61		0.13	0.91	4.98		
7/13	0.56	0.71	0.71	0.30	2.54	0.23	0.10	0.94		2.84		
7/14		1.17	1.68	0.05	3.78		1.02	0.20		2.69		
7/15		0.41		0.66	2.08	0.38	0.38	0.81		0.51		0.00
7/16		2.87				0.76	0.20	0.38		0.25		1.27
7/17		5.08				0.33	0.08	0.10	5.97			1.07
7/18		0.23		0.43		0.23	0.76		4.29		0.13	2.46
7/19	1.98	1.91					0.18		1.63		0.51	2.95
7/20	0.03	0.05					0.66		0.51	0.13		3.61
7/21			2.31			0.84	1.42		0.36			1.09
7/22	0.53		0.61	0.28		0.86	1.40		0.05			0.00
7/23			1.45	1.22		0.64	0.43		0.51	0.03	0.18	
7/24			2.59	1.50		0.23	0.10				0.18	
7/25		0.66	3.45	1.42		4.14			1.22	0.71		0.00
7/26	0.43		0.13	0.18		3.43		0.18	0.28	1.27	0.74	0.23
7/27	0.20			2.92	0.89	0.81		0.43	0.43	1.32	0.23	0.15
7/28	0.13			0.38	1.88	0.18			0.51	3.53		0.00
7/29	0.23				1.40	1.32			0.99	2.36		0.03
7/30	0.61	0.33			0.13	3.38			0.46	0.74		0.30
7/31	0.56					0.74	2.21	1.50	0.10		1.40	0.00
Total	13.06	24.41	17.32	10.24	13.72	20.47	8.97	12.78	20.65	22.35	5.66	23.37

Appendix C.2. Daily August rainfall in centimeters at Snettisham power plant switchyard, 1983 to 1994.

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
8/1	0.86	1.02		0.69				0.05			0.08	0.36
8/2	0.51		1.73	1.60		0.46	0.23	0.03	3.38	0.43		
8/3	0.15		1.45	0.79		2.44	0.74	1.60	4.32	1.83		
8/4	0.03	0.13		0.71		2.92	2.79	3.81	1.78	0.76		
8/5			0.38	0.74		2.79		1.93	1.78			0.05
8/6	0.43		0.18	3.35	0.28		0.51	0.38	0.38	0.81		
8/7	1.35	0.86		0.97	1.35	0.30	0.33	1.09				
8/8	0.53	0.03	0.13		0.33	3.05	0.41	1.02		2.11		
8/9		1.78	1.09			1.75	0.38	4.06	0.53	0.51		
8/10	1.57	3.96	1.52			0.28		6.76	0.51			
8/11	1.47	0.36	1.98	1.14		0.08			0.23	0.30		
8/12	1.17	1.75		1.27		0.30			1.27	1.27	5.08	
8/13	0.53	0.86	0.25	5.08		0.58			0.08	1.27	1.22	
8/14	1.07		0.86	0.64		0.56				1.91		
8/15	6.53			0.18	0.84	0.03		0.38		0.89	0.84	0.89
8/16	3.02			0.99	2.01			0.28		3.38	0.89	0.38
8/17	2.29			1.60	2.13			0.08		9.65	0.08	
8/18	0.58	0.23		0.25	1.63			0.00	1.19	0.86	0.23	
8/19	2.36	0.41		0.25		2.87	1.14	0.71	4.14			
8/20	0.15	2.01	0.15	0.30		0.71	2.13	6.83	8.94			
8/21	4.39	1.57	0.97		0.51	2.54	1.07		1.45			1.80
8/22	10.41		7.75		0.15	2.41			4.11		4.80	5.72
8/23	7.54		0.97	4.32		0.81	0.03		0.91	0.18	0.08	5.77
8/24	5.74	2.82	0.23	0.53		0.53	0.94			0.58	0.08	2.97
8/25	0.81	8.51		0.64		1.45	0.03		3.86	2.51	0.15	0.18
8/26	3.00	6.65	0.97						3.76	0.38		
8/27	3.99	0.76	0.28	0.05	0.33	0.74		0.10	0.81	1.07		
8/28	0.64	0.69	0.53	0.64		0.51		2.77			0.15	
8/29				3.48		1.60		1.88		0.03		
8/30		1.57			2.51	1.98			0.61			
8/31	0.15	1.27	0.94	1.04	4.47	2.54			0.99	0.05	0.08	0.71
Total	61.29	37.24	22.35	31.24	16.54	34.24	10.72	33.76	45.03	30.78	13.74	18.82

Appendix C.3. Daily September rainfall in centimeters at the Snettisham power plant switchyard, 1983 to 1994.

Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
9/1	1.73	0.36	0.30	3.91	1.04	8.00				3.48	1.55	
9/2	3.99	1.52	2.77	0.64	0.10	4.90	0.28	1.91		1.12	0.36	0.66
9/3	5.44	0.15	1.04	0.05	2.74		3.94	0.99	1.75	4.01	0.13	0.03
9/4	7.77	0.25	3.23		5.46		3.76	8.13	4.57	0.10	0.10	0.86
9/5	4.01	0.89			4.17	0.38	0.25	2.16	3.30			1.42
9/6	1.47					2.67	0.23	0.30	3.61	0.15		2.24
9/7					0.97		0.05	1.47	2.18	4.88	3.05	0.08
9/8					4.06				0.20	2.62	3.40	
9/9				0.25	4.42	0.15			1.32	3.94	0.36	
9/10			3.61	0.71	11.25	0.05		1.60	3.99	6.58	0.25	0.23
9/11			0.48	0.08	8.28	8.03		2.34	7.54	4.78	1.02	0.56
9/12	1.63	0.08			1.35	5.89			1.75	1.96	0.13	6.38
9/13	0.36	0.10			2.18	5.31	0.03	2.54	0.05	0.08	4.78	4.75
9/14	2.03	0.10					1.27	0.58				1.80
9/15	3.53	0.84	2.49		1.22	0.05	1.32	6.02	3.30	1.30		9.25
9/16	1.68	2.34	3.78		1.55			0.66	0.51	8.51		5.13
9/17		3.35	0.15		3.25				1.19		1.12	1.85
9/18		1.98			4.22	0.13	2.03	1.83	5.18	6.05	2.84	2.16
9/19		1.73	0.89		2.31		2.67	1.70	7.44	4.75	0.25	3.76
9/20	5.08	2.03	1.40		2.59	1.73	5.08	1.83	7.54	3.86	0.56	0.61
9/21	5.94		0.89	0.38	1.70	5.77	1.02	2.90	2.18	3.10	1.35	8.36
9/22	1.68		0.20	2.72	0.25	2.92	9.04	7.75	0.71		14.12	24.03
9/23	3.56		7.01	3.15		0.18	7.21	3.81	6.91		13.39	0.46
9/24	5.97		0.76	0.10		0.05	0.15	8.08	7.98		0.05	1.27
9/25	1.42		5.72	2.62	1.37			8.03	9.14	2.49	0.36	5.36
9/26	0.71		0.81	0.33	2.69		2.82	0.64	0.74	2.79	8.69	4.62
9/27				0.00	4.83	0.84	0.05		0.81	0.66	2.46	0.43
9/28		0.58		0.23	4.60	3.10	2.59	4.32	1.22	2.92	0.25	1.24
9/29		1.35		0.20	6.48	6.53	4.09	7.21	0.28	2.26	5.87	0.05
9/30	0.15	1.65	1.14	0.23	6.38	9.04	0.05	8.31	5.44	2.92	0.48	0.30
Total	58.14	19.30	36.68	15.60	89.46	65.71	47.93	85.09	90.86	75.29	66.90	87.88

Appendix C.4. Daily July rainfall in centimeters at Snettisham power plant switchyard, 1995 to 2002.

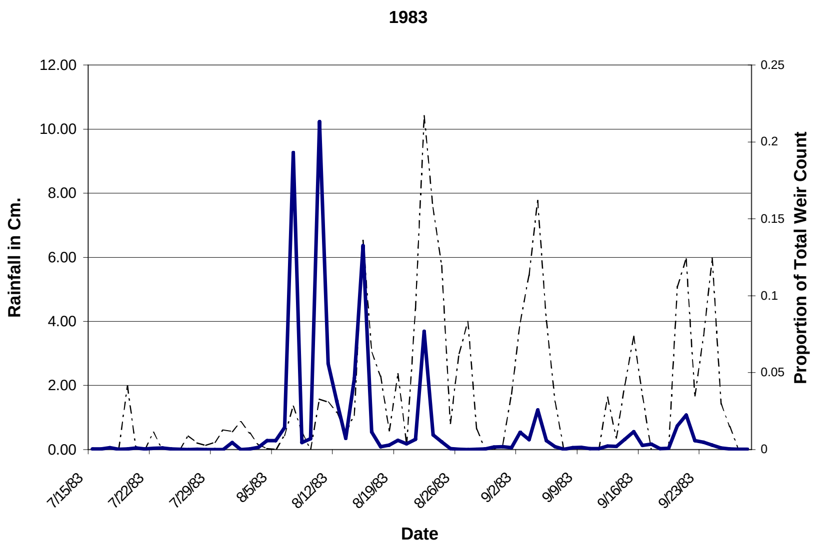
Date	1995	1996	1997	1998	1999	2000	2001	2002
7/1	0.33	8.15				0.25	0.10	0.79
7/2	0.41	0.46						2.03
7/3	0.25	0.05						1.12
7/4							1.27	0.41
7/5	0.28	0.03					2.36	0.86
7/6	0.13		0.94	1.50		0.38	2.95	0.84
7/7			2.97	0.64		0.03	2.74	
7/8			0.03	0.15			3.68	
7/9		0.13	0.08		0.08		1.14	0.15
7/10		1.80	0.28	0.08	0.30	0.05	2.79	0.08
7/11		1.30	0.00	2.03	0.91	0.03	0.25	0.58
7/12	0.64	0.36	3.96	0.08	1.73	0.13	0.25	0.05
7/13	0.15	0.43	3.30		0.05		1.37	0.15
7/14	0.51	0.38	0.51	0.91			0.89	1.75
7/15	0.13	0.43	0.86	0.41		0.10	0.18	0.08
7/16	0.51	0.15	0.18	1.22		0.20	0.13	
7/17	0.66		0.20			0.41	0.05	0.51
7/18			0.18	0.15		1.60		0.46
7/19			3.73		0.56	3.61		0.08
7/20			3.66		1.35	6.22		0.69
7/21		0.15	0.05	0.08	1.04	0.28		0.05
7/22	0.05	0.66	1.50	3.35	3.81	0.28	0.05	2.39
7/23	0.41	0.13	4.57	0.20	0.18	6.65	1.45	0.61
7/24	0.86		2.24	1.57		5.77	0.36	1.14
7/25	3.76		2.51	3.05	0.46	6.58	0.61	2.36
7/26	1.07		0.03	0.13	1.22	0.30	0.38	1.02
7/27	0.38				2.54	0.15	0.03	1.19
7/28	0.25		0.97		3.35	1.17	0.03	2.31
7/29					1.98	1.47	0.36	1.42
7/30	1.57	0.36	0.05				0.97	0.03
7/31	2.03	0.91	0.13			0.30	0.38	
Total	14.38	15.88	32.92	15.54	19.56	35.97	24.77	23.14

Appendix C.5. Daily August rainfall in centimeters at Snettisham power plant switchyard, 1995 to 2002.

Date	1995	1996	1997	1998	1999	2000	2001	2002
8/1	0.30	0.99	2.29	0.20		0.53	0.20	
8/2	0.20	0.28	0.30	0.18			0.03	
8/3	4.37	0.66	0.03				0.03	
8/4	6.99	0.43	0.25				0.15	
8/5	4.06	0.00	1.14			0.05	0.18	
8/6	0.18	2.59						
8/7		3.56		2.62				2.11
8/8		0.43	0.46	4.37	0.51	0.08		7.14
8/9		4.19	0.05	0.94	2.49	2.62		5.89
8/10		0.30		4.37	0.84			1.52
8/11	0.76	0.51		1.65	0.03			1.07
8/12	0.86	1.14	0.69	0.00				5.13
8/13	1.52	3.00	7.52	0.33	0.13			8.94
8/14	1.91	0.25	3.05	0.13	3.66	0.15		1.19
8/15	0.74	0.00	0.25	2.16	0.03	5.23		
8/16	0.05	0.08			0.38	0.56		
8/17		0.00		0.23	0.51	0.05		
8/18		0.15		1.83	0.94		0.46	0.10
8/19		0.00	1.02			1.52	3.40	0.18
8/20		1.60	1.52		0.74	4.78	0.41	0.46
8/21		1.88			0.15	6.73	0.13	5.21
8/22	0.13	2.59	4.60	0.97	2.29	7.90	0.15	3.43
8/23	0.03	8.64	5.49	1.65	2.31	2.03	0.36	8.38
8/24		1.52	0.28	1.37	1.83	0.71	0.51	0.86
8/25	0.43	0.00	0.51	3.68	1.70	0.36	0.53	4.55
8/26	0.13	4.83	0.43	1.17	0.97	0.56	2.16	4.57
8/27		2.54	0.23	4.19		0.25	5.08	5.33
8/28	0.33	1.24	0.13	2.24	3.20	1.37	3.33	3.48
8/29	0.18	0.89	0.15	4.06	2.84		0.36	6.40
8/30		2.39		1.02	1.27	0.69	0.46	2.49
8/31	3.76	0.69		1.30	0.97	0.13	1.35	3.89
Total	26.92	47.37	30.38	40.64	27.76	36.30	19.25	82.32

Appendix C.6. Daily September rainfall in centimeters at Snettisham power plant switchyard, 1995 to 2002.

Date	1995	1996	1997	1998	1999	2000	2001	2002
9/1	4.70	0.66		3.81			0.69	0.81
9/2	3.38	3.51	0.36	2.03	0.05		1.78	0.89
9/3	0.33		0.51	7.11	2.90		0.41	
9/4			0.64	3.18	0.64	3.51	1.80	
9/5			1.73	0.08	0.00	9.22	3.73	
9/6				0.33	0.03	1.30	4.95	
9/7				2.84	0.91	3.18	1.12	2.06
9/8	0.05		2.03	3.25	1.07	0.05	10.01	1.22
9/9	6.50	3.00	0.38	0.05	1.45	4.65	0.43	1.60
9/10	8.74	2.82	0.08		3.86			1.19
9/11	11.33	6.17		5.21	0.66	4.32		4.70
9/12	7.87	4.09		8.81	0.76	3.00	1.17	1.98
9/13	0.38	0.89		2.21		0.71	9.60	0.76
9/14	4.75	0.30		2.24		4.11	5.46	0.51
9/15		0.30		0.05	1.19	2.06	0.25	1.91
9/16			0.15		5.92	4.37	2.21	1.09
9/17					0.86	5.92	0.05	1.85
9/18		2.90			8.43	4.19	0.91	5.59
9/19		4.50	10.57		10.21	0.05	0.41	3.71
9/20		2.64	4.32		4.57	0.76	2.34	3.15
9/21		0.18	1.91	0.18	5.33		0.25	3.53
9/22		2.34	0.46		2.51		3.20	1.12
9/23		10.31	2.84	0.25	6.99	0.58	3.05	0.18
9/24		10.29	4.09	2.67	9.86		0.79	0.56
9/25		5.87	2.92	1.12	3.40		1.80	0.05
9/26		12.22	2.03	1.45	3.86	0.20	0.84	0.71
9/27	1.24	0.18	0.97	0.46	0.13	0.05	0.46	2.67
9/28	0.18		3.89	2.24	0.03	2.74	0.38	0.28
9/29	4.11		0.10	0.05		4.85	0.28	0.64
9/30	2.44			4.22	0.46	0.97	7.57	0.05
Total	56.01	73.15	39.95	53.82	76.07	60.78	65.94	42.80


1983
Rainfall in Cm.
Proportion of Total Weir Count
Date
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.25
0.2
0.15
0.1
0.05
0
7/15/83
7/22/83
7/29/83
8/5/83
8/12/83
8/19/83
8/26/83
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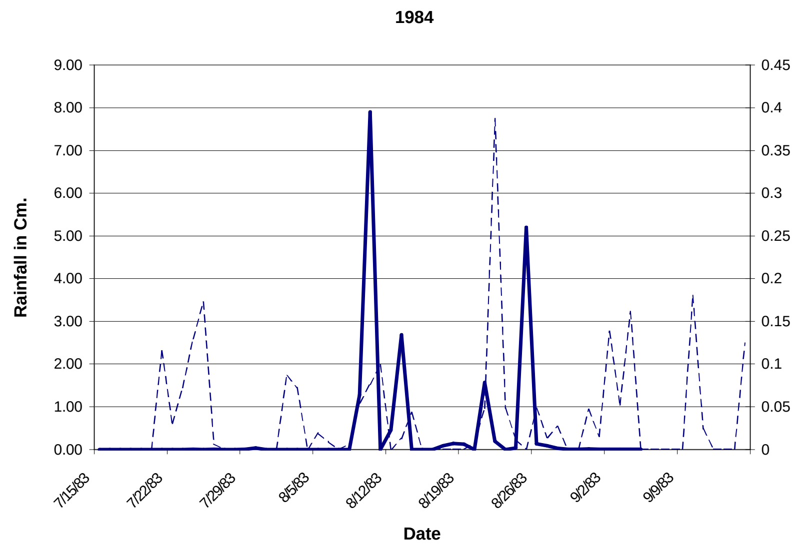
9/9/83
9/16/83
9/23/83


1984
Rainfall in Cm.
Proportion of Total Weir Count
Date
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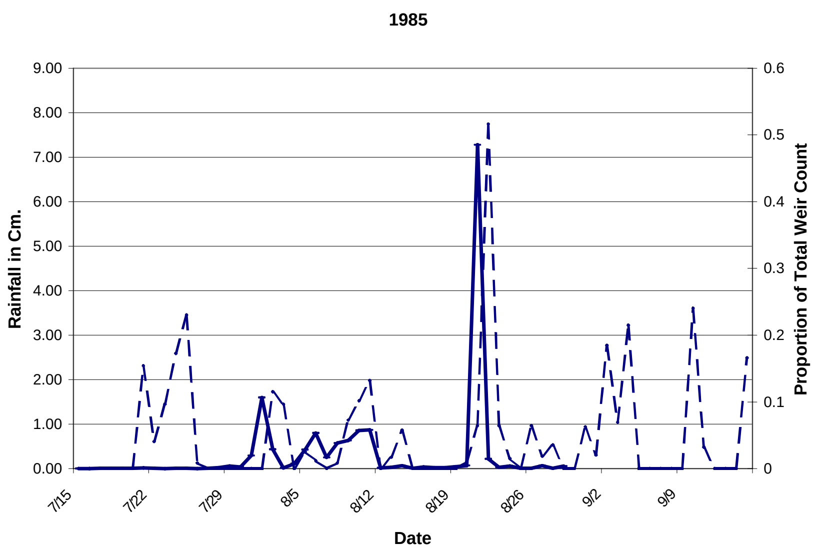
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/15/83
7/22/83
7/29/83
8/5/83
8/12/83
8/19/83
8/26/83
9/2/83
9/9/83


1985
Rainfall in Cm.
Proportion of Total Weir Count
Date
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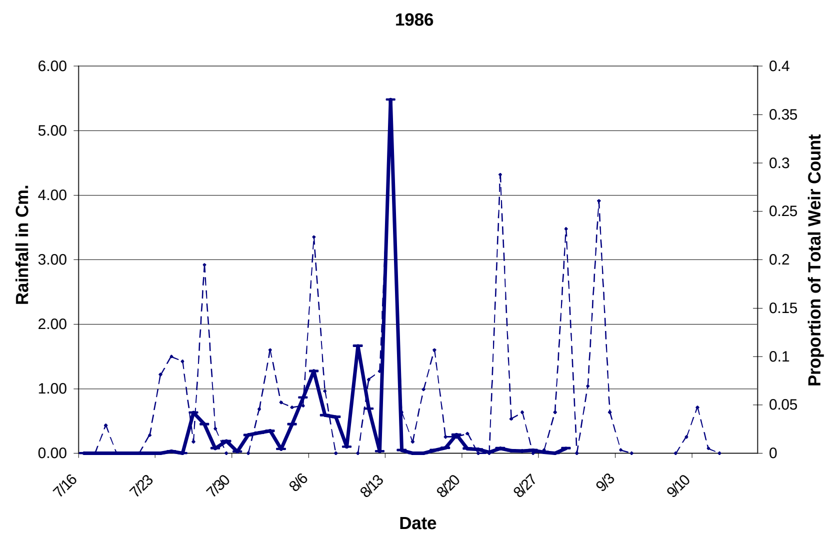
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.6
0.5
0.4
0.3
0.2
0.1
0
7/15
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9


1986
Rainfall in Cm.
Proportion of Total Weir Count
Date
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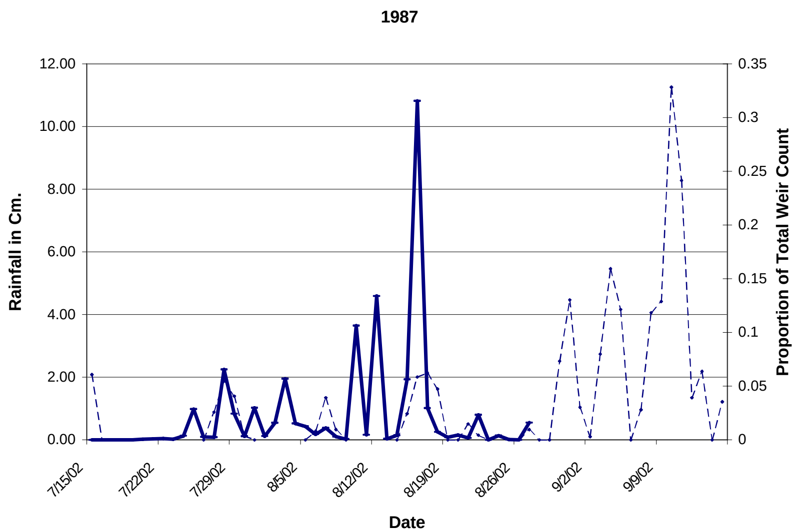
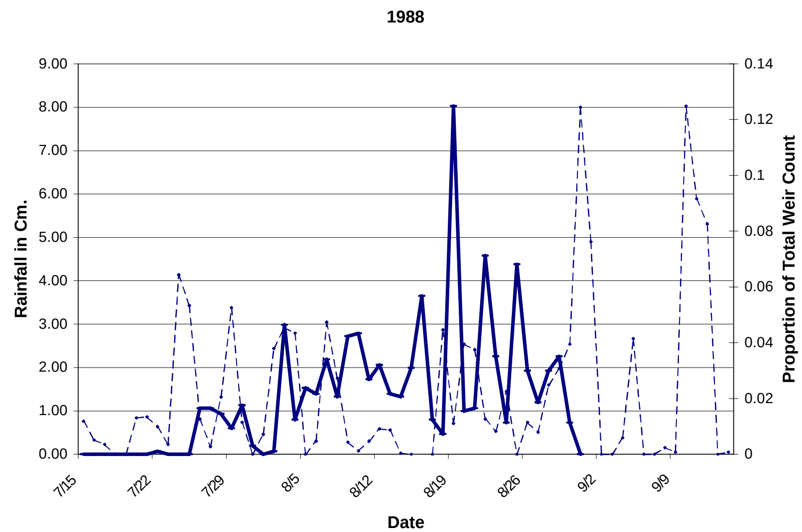
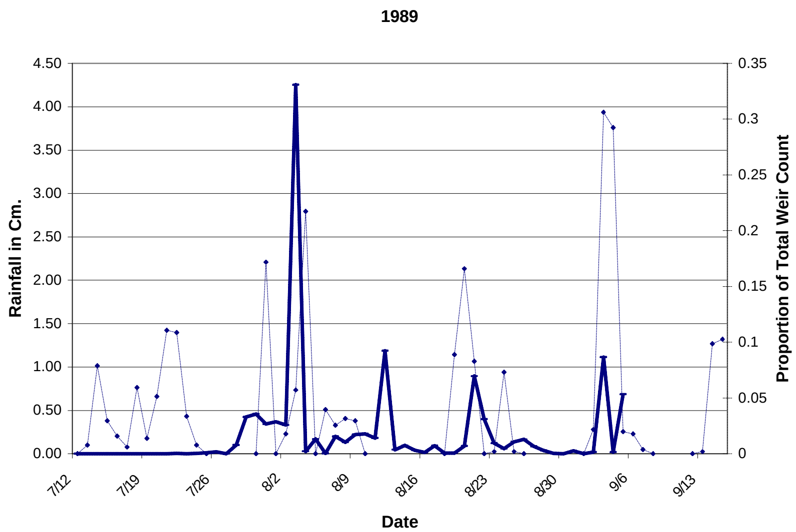
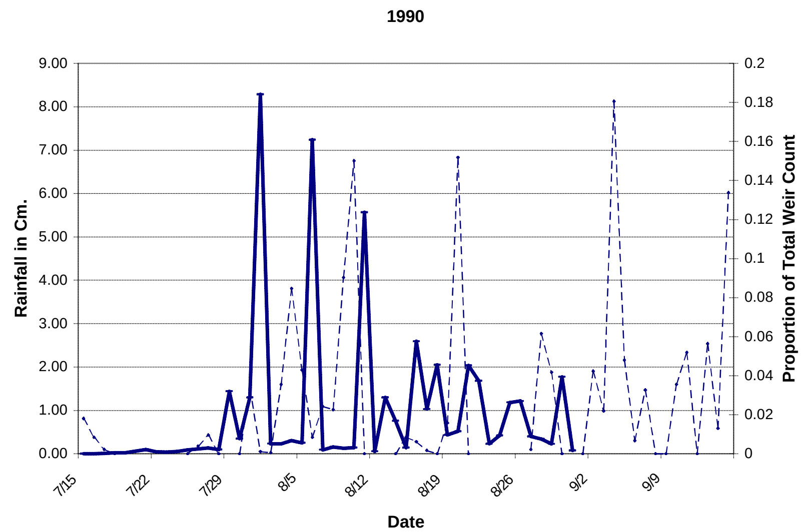
5.00
4.00
3.00
2.00
1.00
0.00
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/16
7/23
7/30
8/6
8/13
8/20
8/27
9/3
9/10

Appendix D.1. Daily rainfall in centimeters at Snettisham power plant switchyard, compared with daily proportion of annual weir count of sockeye salmon passing Speel Lake weir, 1983-1986. Heavy line is daily proportion of weir count, dotted line is rainfall.

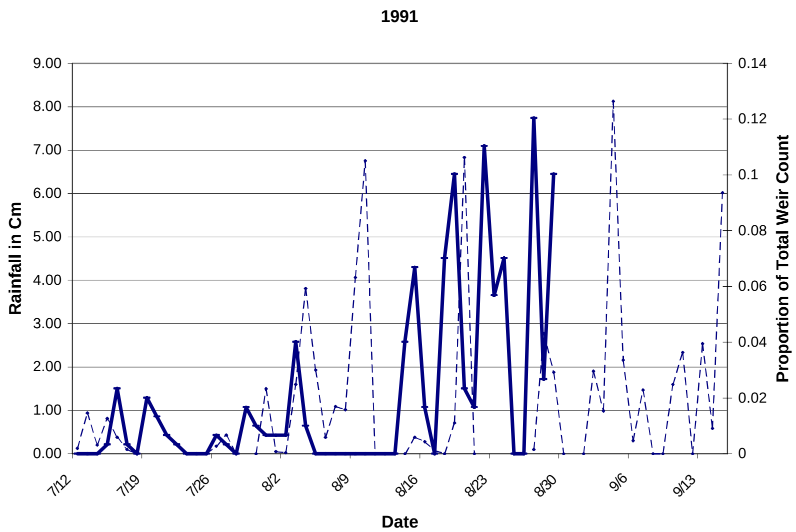


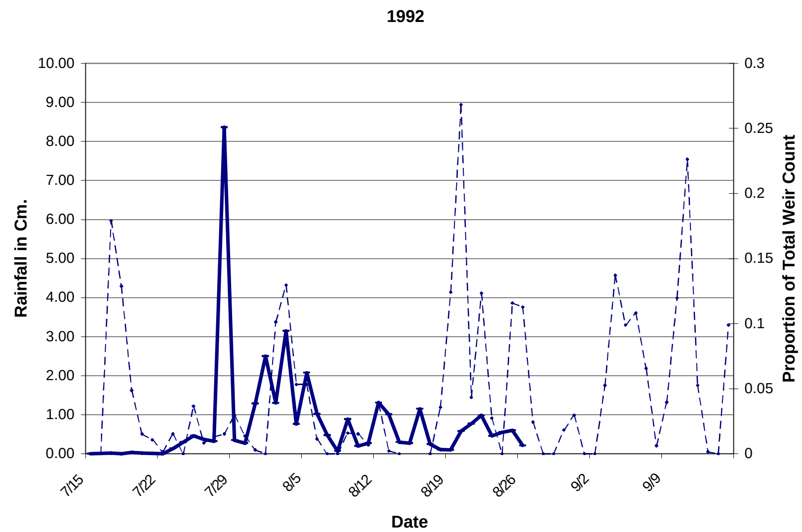


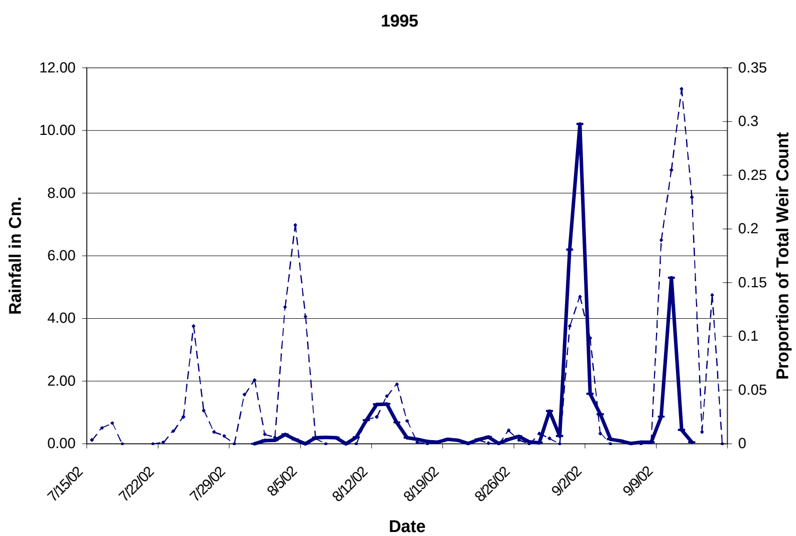


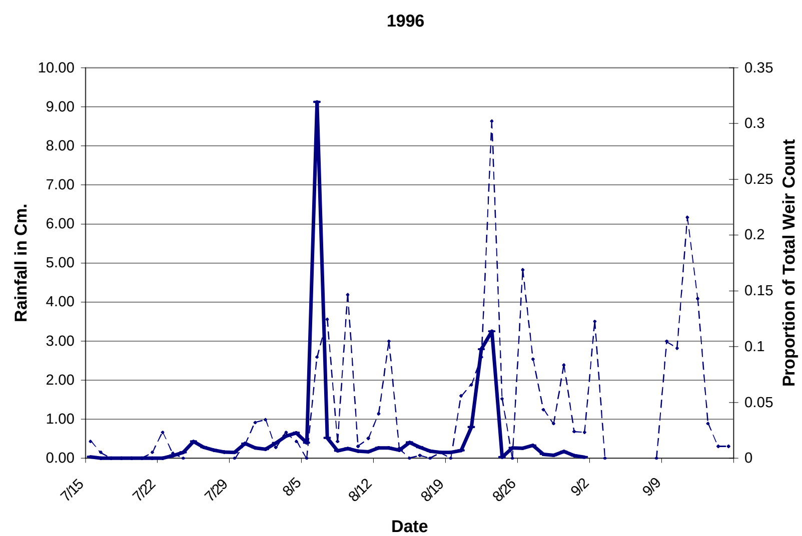


Appendix D.2. Daily rainfall in centimeters at Snettisham power plant switchyard, compared with daily proportion of annual weir count of sockeye salmon passing Speel Lake weir, 1987-1990. Heavy line is daily proportion of weir count, dotted line is rainfall.

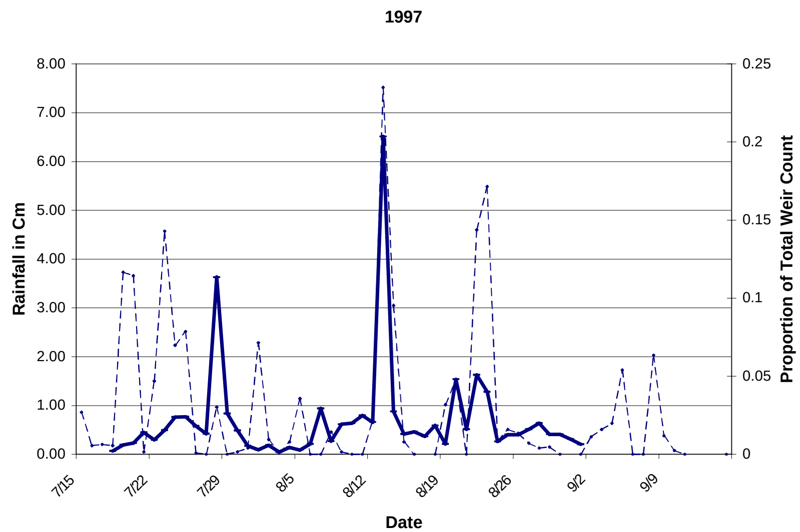

1991
Rainfall in Cm
Proportion of Total Weir Count
Date
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7/12
7/19
7/26
8/2
8/9
8/16
8/23
8/30
9/6
9/13

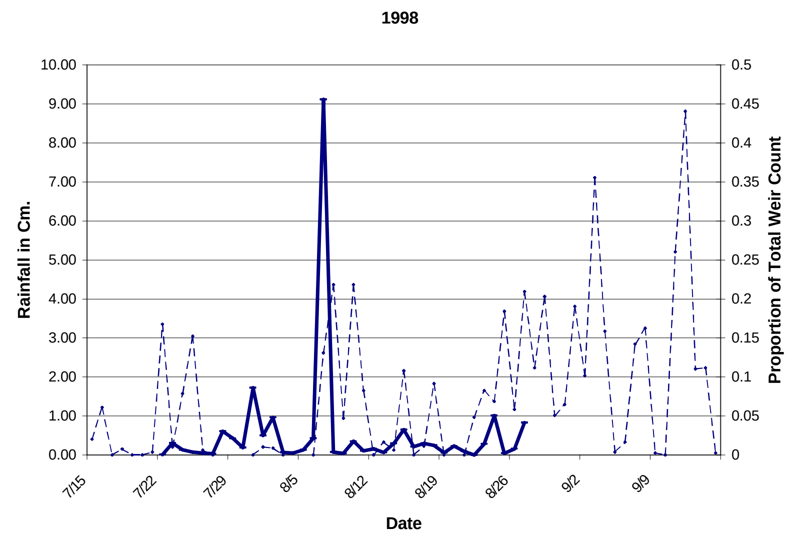

1992
Rainfall in Cm.
Proportion of Total Weir Count
Date
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.3
0.25
0.2
0.15
0.1
0.05
0
7/15
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9

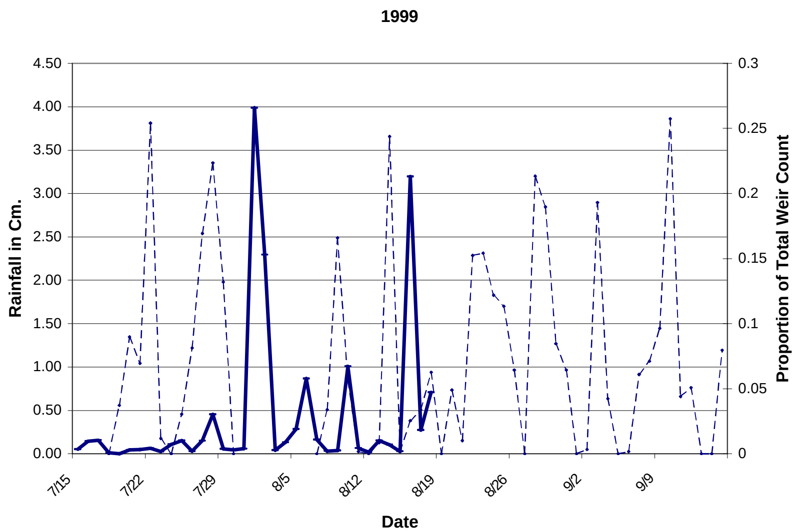

1995
Rainfall in Cm.
Proportion of Total Weir Count
Date
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/15/02
7/22/02
7/29/02
8/5/02
8/12/02
8/19/02
8/26/02
9/2/02
9/9/02

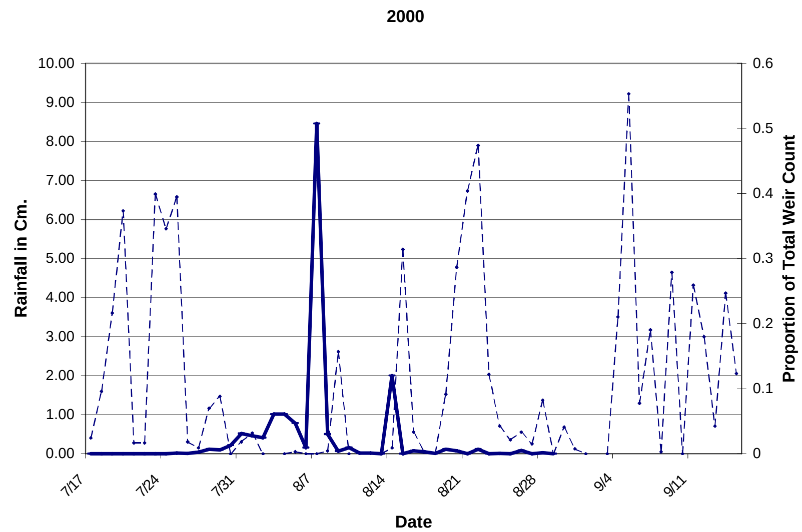

1996
Rainfall in Cm.
Proportion of Total Weir Count
Date
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/15
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9

Appendix D.3. Daily rainfall in centimeters at Snettisham power plant switchyard, compared with daily proportion of annual weir count of sockeye salmon passing Speel Lake weir, 1991, 1992, 1995, and 1996. Heavy line is daily proportion of weir count, dotted line is rainfall.

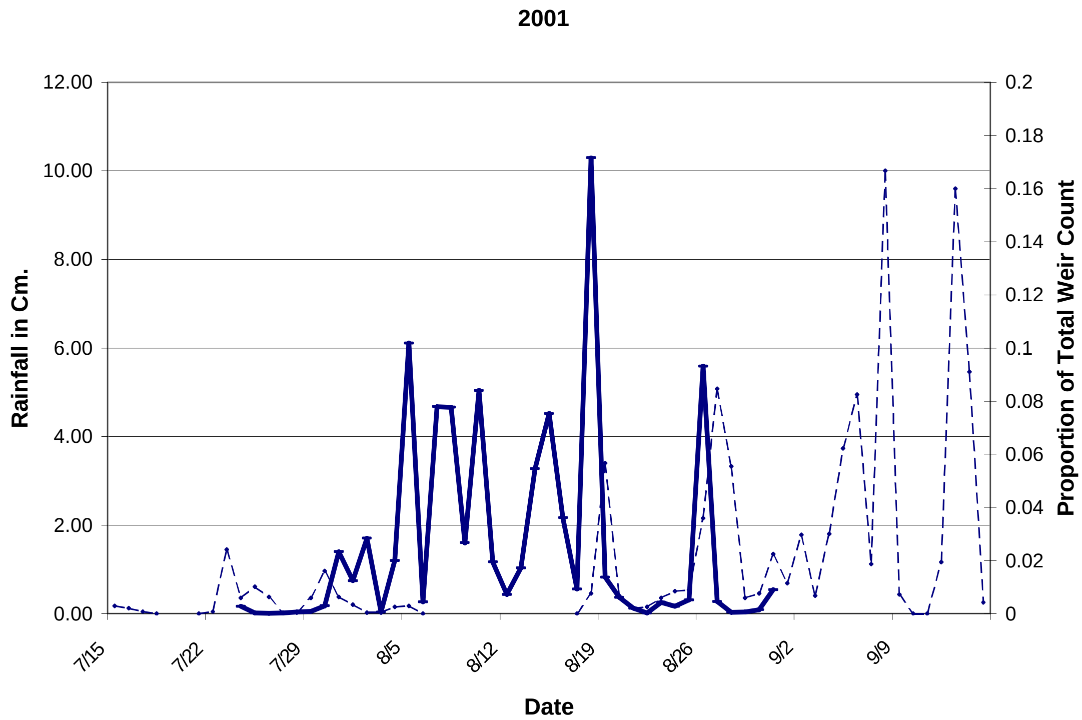


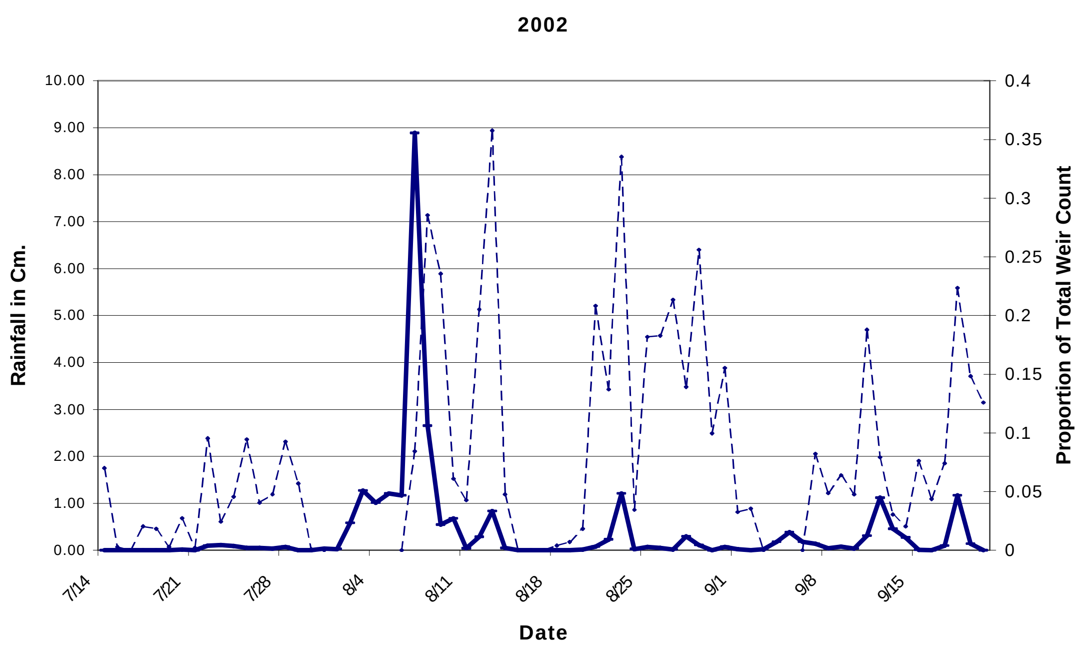






Appendix D.4. Daily rainfall in centimeters at Snettisham power plant switchyard, compared with daily proportion of annual weir count of sockeye salmon passing Speel Lake weir, 1997-2000. Heavy line is daily proportion of weir count, dotted line is rainfall.





Appendix D.5. Daily rainfall in centimeters at Snettisham power plant switchyard, compared with daily proportion of annual weir count of sockeye salmon passing Speel Lake weir, 2001 and 2002. Heavy line is daily proportion of weir count, dotted line is rainfall.

Appendix E.1. Proportion by age of Speel Lake sockeye salmon in the escapement, estimates of variability, and sample size, 1982-2001.

	Sample	Proportion of Total						Standard Error					
Year	Size	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1982	307	--	0.036	0.557	0.394	0.013	--	--	0.011	0.028	0.028	0.006	--
1983	793	--	0.012	0.182	0.783	0.023	--	--	0.004	0.014	0.015	0.005	--
1984	765	--	--	0.44	0.554	0.006	--	--	--	0.018	0.018	0.003	--
1985	396	--	0.058	0.229	0.703	0.009	--	--	0.012	0.021	0.023	0.005	--
1986	589	--	0.003	0.515	0.459	0.024	--	--	0.002	0.021	0.021	0.006	--
1987	1,341	--	--	0.051	0.934	0.016	--	--	--	0.006	0.007	0.003	--
1988	659	--	0.001	0.406	0.575	0.019	--	--	0.001	0.019	0.019	0.005	--
1989	1,128	--	0	0.268	0.659	0.073	--	--	0	0.013	0.014	0.008	--
1990	1,862	--	0.005	0.454	0.515	0.026	--	--	0.002	0.012	0.012	0.004	--
1991	154	--	0.007	0.241	0.719	0.033	--	--	0.007	0.035	0.036	0.015	--
1992	798	--	--	0.586	0.4	0.014	--	--	--	0.017	0.017	0.004	--
1993	521	--	--	0.345	0.622	0.033	--	--	--	0.021	0.021	0.008	--
1994	344	--	0.038	0.221	0.735	0.006	--	--	0.01	0.022	0.024	0.004	--
1995	638	--	0.002	0.512	0.359	0.122	0.004	--	0.002	0.02	0.019	0.013	0.002
1996	580	--	0.011	0.133	0.856	0	-	--	0.004	0.014	0.015	0.001	--
1997	396	--	0.018	0.702	0.272	0.009	-	--	0.007	0.023	0.022	0.005	--
1998	900	--	0.03	0.59	0.376	0.004	-	--	0.006	0.016	0.016	0.002	--
1999	957	0.002	0.021	0.33	0.642	0.006	-	0.001	0.005	0.015	0.016	0.003	--
2000	496	-	0.039	0.564	0.397	0.001	-	-	0.01	0.022	0.021	0.002	--
2001	922	-	0.088	0.488	0.421	0.004	-	-	0.009	0.016	0.016	0.002	--
Average		0	0.018	0.391	0.569	0.022	0						

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