BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES USING UPWARD-LOOKING SONAR, 2002

by

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Regional Information Report[1] No. 2A03-17

Alaska Department of Fish and Game
Division of Commercial Fisheries
Regional Office
333 Raspberry Road
Anchorage, Alaska 99518-1599

April 2003

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ACKNOWLEDGMENTS

We wish to thank the following Alaska Department of Fish and Game, Division of Commercial Fisheries personnel for contributing to the success of the Ugashik River sockeye salmon smolt sonar studies in 2002. Ryan Bill[ab], Susan Klock[a], and Kiana Putman[a] collected smolt data. Cathy Tilly aged the smolt scales. Fred West, Lowell Fair, Corey Schwanke, Brian Bue, Mark Reynolds, Slim Morstad, and Carol Klutsch provided logistical support. Lee McKinley and Fred West provided editorial reviews of this document. We also wish to thank Branch River Air Service for logistical support; and hydroacoustic consultant, Al Menin, for providing technical assistance.

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ABSTRACT

Numbers of sockeye salmon *Oncorhynchus nerka* smolt emigrating to sea from Ugashik River in Bristol Bay, Alaska, were estimated from sonar counts and age-weight-length samples from mid-May to mid-June in 2002. Hydroacoustic equipment was used to estimate total smolt biomass, and age-weight-length samples were used to convert biomass estimates into numbers of smolt by age group. Estimated numbers of smolt emigrating from Ugashik River were 47,627,642. Age-1. smolt, the progeny of 2000 spawners, predominated at Ugashik River (81%).

In the spring of 2002, the following changes were made to the Bristol Bay smolt sonar studies as a result of a program review that was conducted during the winter of 2001/2002: (1) Discontinued use of the Bendix upward-looking smolt sonar system on the Kvichak River. Continue development of the side-looking smolt sonar system and collection of smolt age, length, and weight data at Kvichak River. (2) Collect one last year of Bendix upward-looking smolt sonar data at Ugashik River and discontinue this project in 2003. (3) Discontinue the Egegik River smolt sonar project. (4) If the side-looking smolt sonar methodology being developed at Kvichak River is successful, the department will consider bringing the Egegik and Ugashik River smolt sonar projects back on line with similar side-looking sonar systems as funding and man power allow.

KEY WORDS: smolt, sockeye salmon, *Oncorhynchus nerka*, Bristol Bay, Kvichak River, Egegik River, Ugashik River, sonar, smolt emigration estimate, outmigration timing, age-length-weight relationship

INTRODUCTION

The Bristol Bay Management Area, located in southwestern Alaska, includes all waters east of a line from Cape Newenham to Cape Menshikof (Figure 1). Bristol Bay supports the largest sockeye salmon *Oncorhynchus nerka* fishery in the world. From 1982 to 2001 the commercial catch in Bristol Bay averaged 24.9 million sockeye salmon (ADF&G 2002). To effectively manage this fishery, managers need accurate abundance forecasts of returning sockeye salmon and precise estimates of maximally sustainable spawning escapement goals. Estimates of outmigrating smolt numbers are currently used as an index of production for adult salmon; this information is used to prepare preseason forecasts of adult returns and aids in setting biological escapement goals.

Smolt sonar studies were conducted on Kvichak River and Ugashik River in 2002. A side-looking sonar system was used at Kvichak River and a traditional upward-looking Bendix sonar system was used at Ugashik River. The side-looking sonar work on Kvichak River in 2002 will be written up in a separate Regional Information Report. The upward-looking sonar work that was conducted on Ugashik River is presented in this document.

This is a two-part report. The first part summarizes upward-looking smolt sonar studies conducted on the Ugashik River in 2002. The second part presents a program review of the upward-looking smolt sonar projects on the Kvichak, Egegik, and Ugashik Rivers.

ESTIMATES OF OUTMIGRATING SOCKEYE SALMON SMOLT ABUNDANCE IN UGASHIK RIVER USING UPWARD-LOOKING SONAR, 2002

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INTRODUCTION

Hydroacoustic equipment has been used to estimate sockeye salmon smolt numbers on Ugashik River from 1983 to 1991 and from 1993 to the present. Prior to this, fyke nets were used to calculate abundance indices. Abundance estimates and age composition data have been used to forecast adult salmon returns and to estimate spawning escapement levels needed for optimum production.

Specific objectives of the 2002 Ugashik River studies were to: (1) estimate numbers of outmigrating sockeye salmon smolt; (2) describe smolt migration patterns; (3) collect smolt age, weight, and length data; and (4) record climatological and hydrological parameters which might affect migratory behavior.

METHODS

For step-by-step procedures on the installation, operation, maintenance, troubleshooting, and retrieval of upward-looking smolt sonar and sampling equipment; plus detailed instructions on data collection, recording, and reporting techniques see Crawford and Tilly (1995).

Project Location

The Ugashik River smolt sonar site was located 50 m below the outlet of Lower Ugashik Lake (57°33.89' N latitude, 156°59.90' W longitude, Figures 1-2). This project has operated at the same site since 1983.

The favorable characteristics of this sonar site are: 1) it is located downstream from the lakes where the sockeye salmon smolt are believed to rear which should enable us to assess a large portion of the smolt that outmigrate from this two-lake system., 2) this reach of river has a single-channel that is only 40 m wide, 3) the flow of the current is laminar yet swift enough that smolt pass actively by the site and do not hold or mill, 4) the water is deep enough to fit the equipment and the sonar beams 5) there is a gradual slope with a uniform gravel bottom from the right bank out to a distance of 35 m, and 6) in general the site has remained physically stable over time (Figure 3).

One major problem with this sonar site is its close proximity to the outlet of Lower Ugashik Lake. When Aleutian low pressure systems funnel past this area of the Alaska Peninsula they often generate high winds and waves on this coastal lake, which make it impossible to distinguish smolt from entrained air in the water column on the smolt sonar counter. Unfortunately, we have not found a more suitable sonar sites farther downstream that would enable us to avoid this problem.

Hydroacoustic Equipment

Bendix Corporation[2] constructed the upward-looking hydroacoustic systems that we used to estimate smolt numbers at Ugashik River in 2002. The primary components of this system are listed in Table 1.

Transducers used to transmit and receive sound pulses were housed in a 3.0-m long ladder-shaped array anchored on the river bottom perpendicular to the current. Each array had 10 upward-facing single-element International Transducer Corporation[2], Model 5095 transducers that operate at a frequency of 235 kHz and a half-power beam angle of 9^{o}. Detected echoes from each transducer were transmitted through coaxial cables to a control unit in a wall tent on the right river bank where they were accumulated and printed out as totaled counts by array at prescribed intervals, which were summed and recorded hourly on a field data collection form. A single 12-volt battery recharged by a pair of 43 watt, 2.9 amp solar panels, powered this smolt counting system.

Belcher (2000a) reported that the Bendix smolt counter performs an analog version of echo integration which integrates the mean-square echo voltage over a range of interest which is proportional to fish biomass.

Two arrays of transducers have been used at Ugashik River. In 2002, the inshore and offshore arrays were anchored 24 m and 30 m from the right bank (Figure 3). Each array of ten transducers can ensonify approximately 3.35 m (11 ft) of river width. Therefore, this two-array upward-looking sonar system can ensonify 16.4% of the river width at the Ugashik River sonar site. A summary of river widths and array locations at Ugashik River from 1988-2002 is presented in Appendix A.1.

Hydroacoustic equipment to monitor smolt outmigrations was operated at Ugashik River from mid-May to mid-June. The smolt outmigration at Ugashik River generally peaks during late May or early June and drops off by mid-June. All arrays were removed from the water at the conclusion of the project.

The upward-looking smolt hydroacoustic system used in 2002 was calibrated with a smolt simulator by hydroacoustic consultant, Al Menin, to record one count whenever 41.5 g of biomass passed through each transducer beam during a given period. Because most smolt

[2] Use of a company's name does not constitute endorsement.

migrate within the upper portion of the water column, individual arrays were calibrated independently, which allowed the operator to set the counting range as near the surface as possible. The pulse width of the smolt counter is 0.136 mS, which theoretically allows the counting range to be set within 10 cm of the surface (1/2 pulse width). The counting range was set 1-2 cm below this theoretical limit to avoid common surface disturbances caused by debris, light wind, and rain. The counting range was reduced further or the system was disabled if disturbances penetrated deeper.

Sources of false counts (e.g., boats, wind, rain, snow, debris) were noted and the hydroacoustic equipment was disabled whenever false-count conditions were detected. Known false counts were subtracted from hourly totals, and linear interpolations were used to estimate counts missed while equipment was disabled. The control unit automatically recorded and stored the length of time the system was disabled. Manual control was available for adjusting printing intervals for accumulated counts, transducer pulse rate, and the portion of the water column monitored. Transducer signal characteristics were visually monitored with an oscilloscope.

Changes to the Ugashik River smolt sonar equipment over the years have been minimal. A three-way switch was added to the smolt counter in 1994 which enabled the operator to select shorter print intervals (e.g., 1.875 min or 3.750 min) when the smolt passage was heavy (Crawford and Cross 1996).

Estimation of Smolt Numbers

The process of generating smolt numbers was divided into three steps: (1) estimating total fish biomass emigrating past the study site; (2) sampling the emigrating fish population to estimate species, age, weight, and length composition; and (3) converting fish biomass into numbers of smolt by age and species.

Biomass Estimation

Fish biomass was estimated using hydroacoustic equipment operated 24 h/d. The signal pulse rate or ping rate of the smolt counter was set to correspond with the river velocity.

Belcher (2000a) reported the ping rate (*pr*) for the Bendix smolt sonar system was calculated as–

$$pr = \frac{(v + 0.34)}{(0.47 * h / 3)} \text{ pings/s}$$

where

v = river velocity, and
h = height of the cross beam measurement (m).

The river velocity was measured at a location referred to as the *velocity index*. The velocity index at Ugashik River was measured at the inshore array.

Estimation of River Velocities and Adjustments to Sonar Counts. River velocities at the Ugashik River site was nearly constant; however velocities were measured at regular intervals with a Gurley[2], Model 622, flow meter and the counter was adjusted accordingly.

To account for differences in river velocities between the velocity index and the arrays (i) at Ugashik, readings were taken over each array every 7-10 days and velocity correction factors (vcf_i) were then calculated as:

$$vcf_i = \frac{v_i}{v_{index}},$$

where

v_{i}	=	velocity over array *i*, and
v_{index}	=	velocity over the velocity index array.

Adjustments to daily counts $(ac_{i,z})$ were then made for differences in river velocity:

$$ac_{i,z} = c_{i,z}(vcf_i),$$

where $c_{i,z}$ = counts for array *i* on day *z*.

Ideally, all sonar arrays monitored fish biomass 24 h/d, so daily counts for each array represented actual sonar counts. If an array was not monitored during an hour, counts were linearly interpolated using estimated counts from several hours before and after the missing count.

Expansion of Biomass Estimates. The width of river section $(l_{i,z})$ monitored by array *i* on day *z* depended on array length (3.03 m), water depth over the array, and transducer signal beam width, calculated as:

$$l_{i,z} = 3.03 + 2\left(d_{i,z} \tan\frac{bw}{2}\right),$$

where

$d_{i,z}$ = average water depth over array *i* on day *z*, and

bw = transducer beam width in degrees (9^o for all transducers).

Arrays were placed perpendicular to the river current; distances from each array to a reference point on one riverbank were measured to the nearest meter (Appendix A.1). The inshore and offshore limits of smolt passage were estimated based on past studies with side-looking hydroacoustic equipment (Bue et al. 1988; Huttunen and Skvorc 1991, 1992). Distances were calculated between inshore limit of smolt passage to first array (D_1); first to second array (D_2); and offshore array to offshore limit of smolt passage (D_4).

The estimated biomass of fish $(\hat{B}_z)$ passing the counting site on day *z* was calculated as follows:

$$\hat{B}_z = \frac{1}{2}D_1\left(\frac{ac_{1,z}}{l_{1,z}}\right) + \sum_{i=2}^{na}\left[\frac{1}{2}D_i\left(\frac{ac_{i-1,z}}{l_{i-1,z}} + \frac{ac_{i,z}}{l_{i,z}}\right)\right] + \frac{1}{2}D_{na+1}\left(\frac{ac_{na,z}}{l_{na,z}}\right),$$

where

D_i = the distance for interval *i*, and

na = number of transducer arrays used.

Age, Weight, and Length Estimation

Data on age, weight, and length of sockeye salmon smolt were obtained from samples captured in a fyke net. Smolt weight in grams and length, from tip-of-snout to fork-of-tail, in millimeters were measured. Age was determined from visual observations of scales mounted on glass slides. European ages -- 1., 2., or 3. depending on the number of freshwater annuli -- were used. Parent year escapements that produced 2002 smolt occurred in 2000 for age-1. smolt, 1999 for age-2. smolt, and 1998 for age-3. smolt.

Sample size goals for Ugashik River were set at a minimum of 400 smolt/d. Based on binomial proportions for the two major age groups, a sample size of 400 smolt would simultaneously estimate the percentage of each age class within 5% of the true percentage 95% of the time (Goodman 1965; Cochran 1977). When the daily goal of 400 smolt was not obtained, samples from subsequent days were combined until a total of at least 400 were reached.

Mean length of smolt differs among fyke net samples from a single day (Minard and Brandt 1986). Thus, to ensure that daily age composition estimates were representative of the population, attempts were made daily to obtain 100 smolt from each of six different fyke net catches. Because weight and age of smolt are strongly correlated to length, the time and cost of data collection was reduced by measuring up to a maximum of 600 smolt each day for length and up to 100 of those smolt for age and weight (Bue and Eggers 1989).

Age was estimated for smolt measured only for length using an age-length key (Bue and Eggers 1989). The key used length to categorize age-1. or -2. sockeye salmon smolt by determining a discriminant length that minimized classification error. This discriminant length was chosen such that the number of age-1. smolt classified as age-2. smolt was equal to the number of age-2. smolt classified as age-1. smolt. Age-3. smolt were not included in this analysis because too few samples were collected.

Weight was estimated for smolt measured only for length using a least squares linear regression. Based on paired weight-length data obtained from smolt sampled for age, weight, and length, we estimated weights (W_j) of age j smolt measured only for length as explained by (Ricker 1975):

$$W_j = \alpha L_j^{\beta} ,$$

where

L_j = fork length of an age j smolt, and

α and β = parameters which determine the y-axis intercept and the slope of the line.

Due to the variability of age and size composition estimates among subsamples (e.g., fyke net catches) taken the same day, daily mean weight $(\hat{W})$ and age proportions $(\hat{P}_j)$ were estimated as the mean of subsampled values:

$$\hat{W} = \frac{\sum_{k=1}^{m}\left(\frac{\sum w_k}{n_k}\right)}{m} ,$$

where

m = number of subsamples collected during a sampling period,

w_k = observed weights from subsample k, and

n_k = number of observations in subsample k; and

$$\hat{P}_j = \frac{\sum_{k=1}^{m}\left(\frac{n_{j,k}}{n_k}\right)}{m} ,$$

where $n_{j,k}$ = number of observations of age j in subsample k.

Estimation of Smolt Numbers

Numbers of smolt by age were estimated by combining biomass estimates with estimates of age and weight composition. Mean weight of smolt was used to convert estimates of biomass per count to estimates of smolt per count $(S\hat{P}C)$:

$$S\hat{P}C = \frac{BPC}{\hat{W}} ,$$

where BPC = biomass (g) per count.

The estimated number of smolt passing the counting site $(\hat{N}_z)$ each day (z) was computed:

$$\hat{N}_z = \hat{B}_z (S\hat{P}C) .$$

The estimated contribution of age j smolt on day z $(\hat{N}_{j,z})$ was estimated by:

$$\hat{N}_{j,z} = \hat{N}_z (\hat{P}_j).$$

Finally, daily estimates of smolt numbers were summed. The seasonal total of all smolt passing the sonar site $(\hat{N}_{tot})$ was

$$\hat{N}_{tot} = \Sigma \hat{N}_z ,$$

and the estimated number of age j smolt that passed the site during the season $(\hat{N}_{jtot})$ was

$$\hat{N}_{jtot} = \Sigma \hat{N}_{j,z} .$$

Climatological Data Collection

Climatological data were recorded at the smolt sonar site. Observations of sky conditions and measurements of wind direction, wind velocity (km/h), daily precipitation (mm), air and water temperatures (^oC) were recorded at 0800 and 2000 hours daily. Wind direction, wind velocity, and air temperature data were measured with a West Marine[2], Model 332356, weather monitor. Precipitation data was collected with a direct-read rain gauge graduated from 0.1 mm to 15.0 mm. Water temperatures were collected with a mercury pocket thermometer graduated in 1^o increments from -10^oC to $+110^oC$.

RESULTS

On April 17, local pilots reported that Upper Ugashik Lake and the SE corner of Lower Ugashik Lake were still ice covered, but there was open water on most of Lower Ugashik Lake. One month later, the Ugashik smolt crew saw no ice on Upper or Lower Ugashik Lakes when they flew into their camp on May 17. With no satellite photos or eyewitness reports to help determine a breakup date for these lakes, I estimated breakup occurred on or around April 30 this year based on a review of climatological data for King Salmon (NWS 2002d, 2002e).

Since 1977, Upper and Lower Ugashik Lakes have averaged 94 ice-covered days per year (Appendix B.1). Historically, the average freeze-up date for these lakes is January 20 and the average lake ice break-up date is April 22.

In 2002, the first two Ugashik crewmembers arrived at the study site shortly after noon on May 17 and the last crewmember arrived later that afternoon. The crew reported no signs of smolt prior to the deployment of their sonar gear.

The Ugashik smolt counter (S/N 8320004) was activated at 2400 hours on May 20. Initial sonar counts indicated little or no smolt passage at the smolt sonar site for the first six days, however strong ESE winds on smolt days 5/22-23, 5/23-24, and 5/24-25 hampered our abilities to count and distinguish smolt on these days. The first daily sonar counts greater than 100,000 occurred on May 25 (Table 2).

A fyke net fished from 2319 hours on May 19 to 0100 hours on May 20 caught 197 sockeye salmon smolt (Appendix C.1). This fyke net catch indicates that smolt were present when the sonar counter was activated, but the catch per unit effort (CPUE=2) for this set suggests smolt abundance was low. Complete summaries of the 2002 Ugashik River fyke net catch by date, species, hour, and time fished are presented in Appendices C.2 to C.4. Other species that were captured in the fyke net were: slimy sculpin *Cottus cognatus*, pink salmon fry *Oncorhynchus gorbuscha*, fourhorn sculpin *Myoxocephalus quadricornis*, threespine stickleback *Gasterosteus aculeatus*, and rainbow trout fry *Oncorhynchus mykiss*.

Five sockeye salmon smolt caught in the Ugashik River fyke net between May 22 and May 26, had a parasitic worm, about 15 mm long with distinct oral and caudal suckers, attached externally to their skin. ADF&G staff at the Fish Pathology Lab in Anchorage examined a preserved specimen and identified it as *Piscicola sp*., commonly known as a leech.

River velocity measurements over the inshore index array ranged from 1.8 to 2.0 m/s (5.8 to 6.5 ft/sec). The average velocity at the inshore array in 2002 was about equal to the 1983-2001 average of 1.9 m/sec (6.2 ft/sec) (Appendix D.1 and D.2). Velocity correction factors (m/s) used to adjust the sonar counter transmit rate for the two arrays were as follows:

Smolt Days	Inshore	Offshore
May 19 - May 27	1.00	0.99
May 28 – Jun 02	1.00	0.97
Jun 03 - Jun 09	1.00	0.89
Jun 10 - Jun 12	1.00	0.96

A total of 4,695,065 sonar counts were recorded at the Ugashik River sonar counting site from May 19 to June 12, 2002 (Table 2). Counts were more numerous over the inshore array (70%) than the offshore array (30%). Daily sonar counts were highest from May 26 to June 3. Eighty-three percent of the total counts were recorded during these days. The peak daily sonar count of 763,024 occurred on May 31. Over the entire sampling season, 87% of all smolt sonar counts were recorded between 2100 hours and 0400 hours, with peak passages occurring at 0100 hours (Table 3).

Based on expanded sonar counts an estimated 47,627,642 sockeye salmon smolt migrated from Ugashik River in 2002 (Table 4). Age-1. smolt (2000 brood year) comprised 81% of the total smolt estimate and they were the predominant age class in all samples. Age-2. smolt (1999 brood year) composed 19% of the total migration and they were most numerous from May 25-30. Mean weights of smolt ranged from 7.4 to 10.5 g per smolt (Table 5), resulting in an average 4.9 smolt per count adjustment factor for the expansion of sonar counts.

Age, weight, and length data were collected from 1,830 sockeye salmon smolt in 2002 (Table 6). Mean length was 91 mm for age-1. smolt, 110 mm for age-2. smolt, and 154 mm for age-3. smolt. Mean weight was 7.7 g for age-1. smolt, 12.7 g for age-2. smolt, and 36.1 g for age-3. smolt. An additional 6,896 sockeye salmon smolt were sampled for length only (Table 7). A discriminating length of 101 mm was calculated to differentiate age-1. smolt from age-2. smolt at Ugashik River.

Weather and river conditions were recorded at the counting site from May 20 to June 13 (Table 8). Weather conditions were fair for enumerating sockeye salmon smolt emigrating from Upper and Lower Ugashik Lakes in 2002. The smolt counter was disabled for 115.2 h (20%) of the 588 h it operated in 2002 because of weather (Figure 4). Wave action and entrained air in the water column from strong ESE, SE, and E winds and rainsqualls were the primary causes. Smolt days with six or more hours of disabled time because of weather were 5/22 (12 h), 5/23 (24 h), 5/24 (7 h), 5/25 (10 h), 6/06 (9 h), 6/07 (24 h), and 6/08 (24 h). Average water temperature was 7.0°C (range 5.5°C to 8.0°C). The water temperature during the peak of the smolt outmigration, on May 31, was 6.0°C.

During 2002, the Ugashik River smolt sonar counter was also disabled for 3.3 h from equipment problems (e.g., solar panel overcharged the smolt counter on 5/22 and a backup smolt counter had to be flown in to replace the Ugashik counter on 6/11 due to printer problems) and 2.0 h from boat-or-floatplane traffic.

DISCUSSION

The 2002 smolt outmigration estimate of 48 million smolt was well above the 1991-2001 average of 28 million smolt (Appendices E.1 and E.2). Only 1991 and 1993 were higher with smolt outmigration estimates of 73 million and 71 million smolt respectively. Seven of the last ten years have had smolt outmigrations composed primarily of age-1. smolt.

Comparing the percent of the total adjusted sonar count by smolt day for 2002 with the 1991-2001 mean, the timing of the peak count was 4 d early (Figure 5). A comparison of the cumulative percent of the total adjusted sonar count by smolt day with the 1991-2001 mean showed that the timing for the front end (25%) of the smolt outmigration was 1 d later, the mid-point (50%) was 1 d earlier, and the later portion (75%) was 3 d earlier than average (Figure 6). Judging from the low sonar counts prior to May 25, we probably counted most of the smolt early in the outmigration. The percent of the total adjusted sonar count by hour for 2002 was similar to the 1991-2001 mean (Figure 7).

The dominant age groups of adult sockeye salmon from the 2002 smolt outmigration will return in 2004 (ages 1.2 and 2.2 fish) and 2005 (ages 1.3 and 2.3 fish).

Age-1. smolt in 2002 were the same length as the 1958-2001 mean and weighed 0.7 g more (Table 9). Age-2. smolts were 2 mm shorter and 0.5 g heavier than the 1958-2001 mean.

The mean water temperature in 2002 was 1.1^{o}C warmer than the 1983-2001 mean of 5.9 ^{o}C (Table 10). The average daily water temperature when the sonar was activated this year was 0.7 ^{o}C warmer than the 1984-2001 average (Appendix F.1). At the peak of the 2002 smolt passage on May 31 the mean daily water temperature was 0.6^{o}C warmer than the 1984-2001 average. See Appendix G for other climatological factors that may have affected the freshwater survival of smolt that outmigrated in 2002.

In the Ugashik River drainage, 1998 is the most recent brood year of sockeye salmon that has spawned and outmigrated as smolt from freshwater to the marine environment. A comparison of total smolt outmigration estimates by age with the 1998 brood year escapement of 892,508 sockeye salmon showed a freshwater survival rate of approximately 9.3 smolt per spawner (Table 11). Since we expect little or no catch of age-3. smolt at Ugashik River in 2003, the freshwater survival rate for the 1999 brood year escapement of 1,647,036 sockeye salmon should remain at 23.0 smolt per spawner. Smolt-per-spawner estimates for 1998 were below and 1999 were slightly less than the recent ten-year average for Ugashik River; mean production from brood years 1988-1997 was 26.2 smolt per spawner.

The most recent brood year of sockeye salmon to have all age groups of adults return from the marine environment to the Ugashik River drainage to spawn was 1995. A comparison of smolt outmigration estimates by age with corresponding adult returns for brood years 1986-1995 (Table 12) shows an average marine survival (i.e. adult salmon returns per smolt) of 0.14 for age-1. smolt and 0.24 for age-2. smolt. For brood year 1996, the last adult sockeye salmon (e.g., ages 2.4 and

3.3) will return to the Ugashik River in 2003 as 7-year-old fish. Seven-year-old fish historically make up < 1% of the total sockeye salmon return to the Ugashik River. Therefore, the average marine survival for age-1. smolt from brood year 1996 (0.12) will be slightly less than the 1986-1995 average for Ugashik River.

We did not calculate the average marine survival of age-2. smolt for the 1996 brood year due to an obvious under estimate of outmigrating age-2. smolt in 1999. Spring came late to the Ugashik area in 1999. The ice in Upper and Lower Ugashik Lakes did not break up until May 19 that spring; the latest breakup date that we have recorded. In addition, ice lingered in the lakes and ice floes in the river prevented deployment of smolt sonar gear until May 26. Even after the ice cleared the water temperatures in the river remained cold through the end of the project on June 12; the average water temperature observed (2.6^{o}C) was 3.4^{o}C below the historical average. Therefore, we believe that a significant number of age-2. smolt outmigrated later in 1999 after the smolt project stopped operating and the water temperatures warmed up.

A comparison of the age composition of outmigrating smolt at Ugashik River with the freshwater age composition of the total adult salmon return showed similarities (± 5%) for brood years 1988, 1991, 1994, and 1995 (Figure 8, Table 13). In brood years 1986, 1987, 1992, and 1993 smolt age composition data showed higher percentages of age-1. smolt and lower percentages of age-2. smolt compared to adult returns.

If the fyke net catches were a representative sample of outmigrating smolt and smolt survival rates by age are equal, then you would expect the freshwater age composition of the smolt to match the freshwater age composition of the total adult return from corresponding brood years. However, differences in freshwater age composition between smolt and their corresponding adult return can be attributed to a number of factors including: (1) differential survival rates of smolt by age; (2) errors in estimates of smolt age composition; (3) errors in estimates of adult total return age composition; and (4) inaccurate estimates of numbers of smolt by age because of not counting the early or late portions of the outmigration.

EVALUATION OF THE UPWARD-LOOKING SMOLT SONAR PROGRAM AT KVICHAK, EGEGIK, AND UGASHIK RIVERS

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INTRODUCTION

Fyke nets were used to estimate smolt numbers on Kvichak River from 1956 to 1970; on Naknek River from 1956 to 1978; on Egegik River during 1957, 1969, and 1978; on Ugashik River from 1955 to 1965, 1967 to 1970, and 1972 to 1975; and on Wood River from 1955 to 1966 (Burgner and Koo 1954; Rietze and Spangler 1958; Kerns 1961; Burgner 1962; Jaenicke 1963, 1968; Church 1963; Church and Nelson 1963; Nelson 1964, 1965a, 1965b, 1966a, 1966b, 1969; Marriott 1965; Nelson and Jaenicke 1965; Pennoyer and Seibel 1965; Pennoyer 1966; Pennoyer and Stewart 1967, 1969; Robertson 1967; Siedelman 1967, 1969; Paulus and McCurdy 1969, 1972; Van Valin 1969a, 1969b; Shroeder 1972a, 1972b, 1974a; McCurdy and Paulus 1972a, 1972b; Paulus 1972; McCurdy 1974a, 1974b; Bill 1975, 1976, 1977; Pella and Jaenicke 1978; Yuen 1978). Although fyke net sampling provided information on age, size, and relative abundance of smolt, it did not provide an accurate estimate of the total number of smolts. To improve estimates of smolt numbers, the department began experimenting with and using hydroacoustic (sonar) equipment in the 1970's.

Hydroacoustic equipment was used to estimate sockeye salmon smolt numbers on Kvichak River from 1971 through 2002; Wood River from 1975 to 1990; Naknek River from 1982 to 1986 and 1993 to 1994; Egegik River from 1982 through 2001; Ugashik River from 1983 to 1991 and 1993 to 2002; Nuyakuk River from 1983 to 1989; and Togiak River in 1988 (Russell 1972; Parker 1974a, 1974b; Krasnowski 1975; Randall 1976, 1977, 1978; Newcome 1978; Yuen 1980a, 1980b; Clark and Robertson 1980; Bucher 1980, 1981, 1982, 1983, 1984, 1986a, 1986b, 1987; Bergstrom and Yuen 1981; Yuen and Wise 1982; Eggers 1984; Eggers and Yuen 1984; Bue 1986a, 1986b; Bue and Fried 1987; Bue et al. 1988; Cross et al. 1990; Woolington et al. 1990, 1991; Crawford et al. 1992; Crawford and Cross 1992, 1994a, 1994b, 1995a, 1995b, 1996, 1997, 1998, 1999; Crawford 2000, 2001; Crawford and West 2001).

In 1997 and 1998, returns of adult sockeye salmon to Bristol Bay were well below forecast. For the Kvichak River, the low returns of adult salmon followed three consecutive years of record high smolt abundance estimates (greater than 300 million smolt per year). Consequently a new study was initiated in the fall of 1999 with Western Alaska Disaster Grant (WADG) monies to evaluate the existing acoustic equipment and sampling design used to estimate smolt abundance on the Kvichak

River and to investigate new equipment and techniques to see if it is possible to improve annual smolt outmigration estimates.

In order to provide a quick inseason comparison of Bendix smolt counter data with sonar counts from other hydroacoustic systems, ADF&G contracted the Applied Physics Laboratory at the University of Washington during the winter of 1999/2000 to design and insert a computer interface into each of three smolt counters and write software to accept and store smolt count data on a computer. This new data collection system was tested and used at Kvichak River and Ugashik River smolt sonar sites in 2000 and at Kvichak River in 2001.

The 2002 field season was the third and final year of a three-year WADG study ($450,000) to evaluate the smolt sonar project on the Kvichak River. The objectives of this study were to: (1) Clearly document the current acoustic methodology (Bendix counter) for estimating abundance of outmigrating sockeye salmon smolt in the Kvichak River. Identify the potential sources of bias and imprecision in the current estimation method, and mechanisms by which the Bendix system may have failed in any or all of the previous 30 years. (2) Study and describe smolt behavior (e.g., fish speed, school density, and school structure) in the vicinity of the current site and evaluate the assumptions about smolt behavior that must be made to derive acoustic estimates of smolt abundance. (3) Based on (1) and (2) above, determine if the historical smolt abundance estimates are valid and, if not, whether they can be corrected. If the historical estimates can be corrected, develop the means to do so. (4) Compare sockeye salmon smolt abundance estimates among a Bendix array, a Hydroacoustic Technologies, Inc.[2] (HTI) upward-looking multiple transducer array, and a HTI side-looking split beam transducer and recommend the best system to estimate smolt abundance on the Kvichak River. (5) Design an acoustic system that improves upon weaknesses identified in the Bendix smolt counter and deploy this complete system in May 2001. Run the new and old systems side-by-side for two complete seasons and thoroughly compare the results derived from each. Results and findings from this study will be published for ADF&G in a separate report by hydroacoustic consultant, Don Degan of Aquacoustics, Inc.

The objective of this report is to evaluate future operations of the existing Bristol Bay smolt projects, including Kvichak, Egegik, and Ugashik Rivers. There are numerous project operational alternatives available. This report will explore operational choices for 2002 and beyond.

METHODS

On February 1, 2002, regional staff met to discuss the following smolt issues:

1. WADG Kvichak smolt sonar project evaluation

    a. Findings
    b. Video analysis
    c. Future operations

2. Smolt data application

    a. Forecasting performances
    b. General escapement-to-smolt and smolt-to-adult relationships
    c. Value of age composition data
    d. Timeline of Kvichak River smolt project changes

3. 2002 smolt project operations

4. Funding concerns

The meeting was attended by James Brady, James Browning, Brian Bue, Drew Crawford, Doug Eggers, Lowell Fair, Nancy Gove, Suzanne Maxwell, Lee McKinley, Slim Morstad, Jeff Regnart, Keith Weiland, Fred West, and hydroacoustic consultants Don Degan and Anna-Maria Mueller.

RESULTS AND DISCUSSION

Meeting Summary

The WADG smolt evaluation project on the Kvichak River shows promise of a Bendix replacement system that should give a better index of smolt outmigration abundance. However, the replacement system needs further testing and refinement, because similar to the Bendix gear, it is limited in windy or rainy conditions.

Based on a review of the Bendix counts collected since 1976, there are inconsistencies in the data that may be associated with multiple sites and equipment modifications. Given these inconsistencies, it appears that a meaningful correction factor between the new side-looking acoustics and the up-looking Bendix arrays is unlikely.

Video analysis has given us a greater understanding of smolt behavior and will allow a comparison of abundance estimation with the new gear at a given time and space, in addition to a small set of smolt length samples.

Historical, Bristol Bay sockeye salmon forecasting performances with smolt data showed that drastic changes have occurred in smolt-adult forecast reliability within the past 5 to 15 years (Appendices H.1 to H.15). For the Kvichak River, smolt-adult forecasts worked well in the early 1990s, but by 1996 their value waned and began contradicting adult returns. The Egegik River smolt-adult forecasts remained fairly stable throughout the 1990s with a slight improvement in recent years. On the other hand, smolt-adult forecasts for the Ugashik River were untrustworthy in the early 1990s but have since become a reliable alternative to sibling models for some age classes.

Age composition data in conjunction with smolt outmigration numbers are essential to understanding freshwater density-dependant effects and for forecasting adult returns. However, age composition without abundance provides only general qualitative insight and lacks significance with adult returns (Appendices H.16 to H19).

The Kvichak River smolt project has undergone the greatest changes in project operations of any smolt project in Bristol Bay (Appendix I). Sonar abundance estimation began in 1976 on the Kvichak River and continued through 1988 at the original site. In 1989, because of changing river topography and a concern that smolts were passing the site undetected in side channels, a new site was chosen. In combination with a new site, a new counter (1976 model that operated at a frequency of 118 kHz to a 1982 model that operated at a frequency of 235 kHz) and transducer array system was instigated. In 1990, the 1976 model counter was returned to use with further changes in the transducer array system. In 1993, the 1982 model counter was redeployed and the offshore array cables were lengthened. In 1996 the cable length on the center array was also extended. The cumulative effect of these changes appears to have significantly decreased the ability of this project to accurately index smolt outmigration abundance.

Smolt Project Alternatives

This section discusses the pros and cons of various smolt operational avenues available to the region.

Status Quo And Move Forward With Sonar Transition Work

One approach is to continue without change. Existing smolt projects would operate the upward-looking Bendix sonar systems and the Kvichak River project would also operate the side-looking sonar system in 2002 for comparison to the Bendix as originally intended.

Advantages: Simplicity is the advantage of this approach, because changes would not be necessary. Additionally, smolt outmigration numbers for the Ugashik River have proven helpful in recent years making additional data points worthwhile.

Disadvantages: There are multiple disadvantages to this approach. The first is cost. With tightening budgets, only projects with beneficial results should operate. Currently, given its recent poor forecast performance, the Kvichak River smolt project is clearly not justifiable and a meaningful correction factor with the new gear seems unlikely. Conversely, Ugashik River smolt has shown recent promise but funding has been piecemealed since 1993 in the form of cooperative agreements with outside agencies and ongoing funding uncertainties. Another problem with this approach is that technical support for Bendix equipment will soon dissolve. Hydroacoustic consultant, Al Menin, is getting on in years and soon will be unable to calibrate, troubleshoot, and repair the counters as he has for decades. Alternative technical support will be costly or simply unavailable.

Discontinue Kvichak Bendix At Existing Site

Advantages: One big advantage to halting Bendix operations on the Kvichak River is cost; the current budget for this project is about $36,000 in general funds. Furthermore, smolt outmigration estimates from the Kvichak River are suspect in recent years for all age classes.

Disadvantages: Terminating Bendix operations on the Kvichak River will truncate a data set that began in 1976; however, the cessation of Bendix technical support in the near future makes this inevitable.

Operate Kvichak Bendix At A New Site

There were discussions at the smolt meeting about operating the Bendix gear at a new site with a better bottom profile to reduce some of the fish distribution issues present at the existing site.

Advantage: A site that allows us to sample a greater portion of the outmigration should be more reliable. Operating the Bendix at an alternate location extends the historical data series.

Disadvantages: The drawback to this approach is that new "index" counts will likely differ by an unknown magnitude from previous collections rendering the data set untrustworthy for forecasting adult returns until a new baseline is established. Also, if a new site were chosen, we would likely face land issue challenges. If we establish a new site, it makes more sense to begin using the new system, rather than moving the Bendix gear.

Discontinue Bendix Operations For All Existing Projects

Advantages: There are many advantages for discontinuing all Bristol Bay smolt projects, the first is a tremendous cost savings. Terminating all smolt projects would save about $77,000 in general funds and $19,000 in test fish funds. Moreover, continuing to collect data that is not helpful for forecasting Kvichak and Egegik River adult returns, and has never been used to set escapement goals seems wasteful. And even though smolt-adult forecasts for Ugashik River have improved in recent years, overall they still play a secondary role to sibling models.

Disadvantages: The obvious disadvantage of pulling all smolt projects is that data collection will cease, along with smolt-adult forecasting capabilities and any hope of using smolt data for setting escapement goals. Additionally, there would be six permanent-seasonal technicians with shortened field seasons, but none without a job. Similarly, cutting the smolt projects will require increased operating costs (Lines 200-400) for all tower projects that split land leases and share equipment and air charters with smolt projects.

Discontinue Bendix But Maintain Sampling Program For Age, Sex, and Size Data

Advantages: The biggest advantage is that we can stop spending money for the collection of data that is not dependable and hence, not used to any significant degree. An advantage of maintaining a fyke net sampling program is that age composition data provides an idea of future marine survival since age-2. smolt have a greater survival rate than age-1 smolt. Unfortunately, without an abundance estimate from sonar, we will only have a ratio of 1- to 2-freshwater fish and previous studies have shown that fyke net catch-per-unit-effort does not correlate well with sonar abundance estimates. Smolt size data would provide insight into lake productivity. Operating the fyke net sampling program ensures that age, sex, and size data series will continue. Because two technicians are necessary to operate the sampling program at each project, existing technicians would not experience a shortened field season.

Disadvantages: A disadvantage of this approach is an end to the sonar smolt abundance data series, along with smolt-adult forecasting capabilities or hope of using smolt abundance data to set escapement goals.

Discontinue Bendix But Move Forward With The Side-Looking Sonar System And Maintain The Fyke Net Program

Advantages: We have the potential to develop a side-looking sonar system that could reliably index smolt abundance. Over time, this information may lead to more powerful forecasting abilities. The Kvichak River could serve as the pioneer for other systems where smolt data is desired. The sooner we begin to build a time series, the sooner it will become useful for forecasting and setting escapement goals.

Disadvantages: Costs similar or greater to those mentioned above plus the cost of new equipment for each river create an expensive forecast tool. We are still uncertain as to whether or not the side-looking sonar system will work for us and definitive answers won't be available until next winter.

Discussion

A long-term cost-benefit analysis for continuing the smolt projects is not encouraging. For smolt data to play a more important role in forecasting and setting escapement goals, major changes are necessary. Because replacement of Bendix gear is inevitable, a new side-looking sonar system is required at each smolt site.

Al Menin will soon be unable to continue the yearly maintenance of the Bendix smolt counters. The unique design of the counters and the confusing documentation that accompanied the numerous modifications made over the years make it impossible for another electronic engineer or technician to take over the maintenance.

Assuming that no additional side-looking acoustic gear is required at Kvichak River to replace the Bendix, only two additional new systems need to be purchased for Egegik and Ugashik Rivers, costing around $75,000, excluding necessary research and development costs. Because the smolt "index" abundance series would recommence with a new hydroacoustic sampling program, it may take 10 or more years before meaningful biological relationships emerge, costing about $1,000,000 over the next 10 years (about $97,000 annually). Moreover, to apply smolt data in setting escapement goals, a time series of limnology data is necessary for each river-lake system. This added cost to the region could easily run into the hundreds of thousands of dollars over the next 10 years.

In summary, over a ten-year period, including initial Bendix replacement systems, the total cost could conceivably approach $1,500,000. And, as with many things in natural resource management, the potential gains are uncertain. To complicate matters even further, it may not be technically possible to operate replacement equipment on the Ugashik River where wind and rain play a large role in down time with Bendix gear and would likely pose an even greater problem with the new side-looking gear.

Similarly, I believe that if Bendix sonar operations are halted, so too should fyke net sampling. While age, sex, and size statistics give us a gut feeling of marine or freshwater survival, without abundance information it provides only a qualitative understanding at best. Part of the problem on the Kvichak River is that the sampling is based on the assumption that an equal proportion of the smolt population is sampled annually. A single fyke net samples approximately 1% of the river's width in an area with dynamic fish distribution patterns, a tremendous variation in watercolor, size of migration, and size of fish from year-to-year. Any one of these factors could contribute to biases in the fyke net age composition, especially for larger smolt such as age-3. fish, which have been observed swimming upstream out of the nets.

Recommendations

Based on the above analysis, all Bendix smolt-counting operations should cease. Realistically, if all smolt projects were pulled today, we would barely notice. Currently, smolt forecasts play only a small role and smolt data has never been used to any significant extent for setting escapement goals in Bristol Bay. Most escapement goals were set in the early 1960s and have remained remarkably constant since the 1970s using harvest and escapement data. Smolt and limnology data is unlikely to provide significant insight in escapement goal revisions. Monetary savings would be significant ($96,000 annually) and these monies could be shifted to a different project(s) that provides a greater benefit to salmon research and management in Bristol Bay.

Now is the best time to discontinue the smolt program because: 1) Currently, there is very little support or belief in the numbers evidenced by the difficulty in funding sources for Ugashik River smolt every year and the poor performance of smolt forecasts on the Kvichak River; 2) It can be said that with the WADG study on the Kvichak River, we've learned a great deal, including the harsh reality that the data we've previously collected is unreliable and uncorrectable; and 3) The general feeling of regional staff is that the benefits of the current smolt program are outweighed by the cost.

I recommend we continue the Kvichak River smolt abundance estimation and fyke netting operations with only the side-looking sonar system this spring. Keeping this project operational would provide us the opportunity to further refine the system. At the conclusion of the WADG study, we can decide whether to continue using the system on the Kvichak River or move it to another location given considerations discussed in this memo. Regardless of the choice, it is essential that a decision be made in a timely fashion so that budgetary, personnel, and other issues can be resolved prior to the upcoming field season.

The above information was presented to James Brady (Region II Supervisor), Jeff Regnart (Region II Management Coordinator), and Brian Bue (Region II Research Coordinator) and the following course of action was decided on March 18, 2002 (Bue *personal communication*).

1. Discontinue the Bendix portion of the Kvichak River smolt sonar project. Continue collecting smolt age, weight, and length data while continuing to develop the side-looking sonar methodology.

2. Do the Ugashik River upward-looking smolt project using Bendix equipment for the last time this year. At this time, we may not do the Ugashik Smolt project in 2003. Ugashik will most likely be the first smolt project brought back online if the side-looking sonar proves to be a suitable replacement for the Bendix system.

3. Discontinue the Egegik River smolt project. We will examine bringing Egegik smolt back online if a good method of smolt enumeration is found and monies are available.

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TABLES

Table 1. Primary parts of the upward-looking smolt sonar system used at Ugashik River in 2002.

Quantity	Item	Description
1	Smolt Counter	Bendix, Model 1983 smolt counter (serial # 8320004 - 5/20-6/10; serial # 8320003 - 6/11-6/13)
2	Transducer Arrays	Ladder-shaped PVC platform (10' x 3'2", wi/ 10 rungs) anchored on the river bottom at set intervals from shore - 1 transducer mounted on each rung, 10 upward-facing transducers per each array
20	Transducers	International Transducer Corporation, Model 5095 - 235 kHz, 9^{o} half-power beam angle, single element, circular; each transducer connected to the smolt counter on shore via a 330' length of RG-38 coaxial cable
1	Thermal Printer	Datel Intersil, Model DPPQ7A2H (unit built into smolt counter) - prints out hard copy of sonar counts at set intervals and totals each hour
1	Oscilloscope	AW Sperry, Model 315P
1	Flow Meter	Teledyne-Gurley, Model 622 flow meter - to measure river water velocities every 7 to 10 days
2	Solar Panels	Atlantic Solar, 43 watts, 2.9 amps wi/ voltage regulator or diode
1	Batteries, 12V	Optima, Deep Cycle Yellow Top, gel-cell
1	Weather Base Station	West Marine, Model 332356 - digital wind direction, wind speed, and air temperature

Table 2. Sonar counts by smolt day and array at the sockeye salmon smolt counting site on Ugashik River, 2002.

Smolt Day [a]		Sonar Count: Transducer Array: Inshore	Offshore	Total
5/19	[b]	5,009	3,880	8,889
5/20		7,014	3,928	10,942
5/21		10,096	8,345	18,441
5/22	[cd]	14,981	10,766	25,747
5/23	[cd]	37,748	11,279	49,027
5/24	[d]	28,361	7,984	36,345
5/25	[cd]	85,537	27,865	113,402
5/26		369,444	187,442	556,886
5/27		92,655	63,209	155,864
5/28	[c]	324,411	159,090	483,501
5/29		94,266	39,628	133,894
5/30		109,152	38,720	147,872
5/31	[c]	636,177	126,847	763,024
6/01		391,761	203,787	595,548
6/02		406,838	150,371	557,209
6/03		350,227	131,250	481,477
6/04		70,231	45,524	115,755
6/05		52,796	22,487	75,283
6/06	[d]	10,854	4,414	15,268
6/07	[d]	0	0	0
6/08	[cd]	14,625	32,748	47,373
6/09	[d]	6,777	2,892	9,669
6/10		121,259	99,073	220,332
6/11		23,928	19,084	43,012
6/12		17,969	12,336	30,305
Total		3,282,116	1,412,949	4,695,065
Percent		69.9	30.1	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] The sonar counter was activated at 0001 hours on smolt day 5/19.

[c] Sonar counts interpolated for one or more arrays for the following periods:

2300-1159 hours on smolt day 5/22, strong ESE wind and entrained air
1900-1159 hours on smolt day 5/23, SE 25 and ESE 25-30 winds and entrained air
1800-2259 hours on smolt day 5/25, ESE 20-25 winds
1800-1859 hours on smolt day 5/28, boat traffic
1200-1559 hours on smolt day 5/31, ESE 10-15 winds
1200-2359 hours on smolt day 6/08, E 13-37 winds, waves, and rain

[d] Unable to interpolate sonar counts on one or more arrays for the following periods:

1300-1559 hours on smolt day 5/22, false counts from solar panel overcharging smolt counter
1200-1859 hours on smolt day 5/23, ESE 25 winds
1200-1759 and 0800-1159 hours on smolt day 5/24, ESE 20-30 winds and waves
1200-1759 hours on smolt day 5/25, ESE 20-25 winds
0100-1159 hours on smolt day 6/06, SE 20-35 and E 20-25+ winds and heavy wave action
1200-1159 hours on smolt day 6/07, E 19-26, SE 25-35 winds and heavy wave action
2400-1159 hours on smolt day 6/08, E 13-22 winds and waves on lake and inriver
1200-2259 hours on smolt day 6/09, ESE 14-22 and SE 17-22 winds and large waves

Table 3. Sonar counts by hour and array at the sockeye salmon smolt counting site on Ugashik River, 2002.

		Sonar Count			
		Transducer Array			
Sonar Operating Period	Hour	Inshore	Offshore	Total	Hourly Percent
	1200	4,938	5,777	10,714	0.23
	1300	4,791	4,277	9,068	0.19
	1400	12,446	13,619	26,066	0.56
	1500	31,794	41,772	73,566	1.57
	1600	56,683	24,302	80,985	1.72
	1700	38,259	21,219	59,478	1.27
	1800	47,420	32,353	79,773	1.70
	1900	56,631	29,902	86,534	1.84
	2000	40,093	29,938	70,031	1.49
Smolt	2100	61,496	71,588	133,084	2.83
Days	2200	59,155	86,771	145,925	3.11
5/19	2300 [b]	81,621	84,250	165,871	3.53
to	2400 [c]	452,444	127,627	580,071	12.35
6/12	0100 [c]	723,073	235,906	958,978	20.43
	0200 [c]	616,935	265,679	882,614	18.80
	0300 [c]	693,938	212,682	906,620	19.31
	0400 [c]	217,038	73,513	290,551	6.19
	0500 [c]	42,449	18,020	60,469	1.29
	0600 [b]	8,350	4,355	12,705	0.27
	0700	6,695	6,693	13,388	0.29
	0800	6,048	5,236	11,283	0.24
	0900	7,337	8,364	15,701	0.33
	1000	6,901	6,218	13,118	0.28
	1100	5,581	2,889	8,470	0.18
Total		3,282,116	1,412,948	4,695,064	100.00

[a] Daylight hours unless indicated otherwise.
[b] Twilight hours.
[c] Hours of darkness.

Table 4. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Ugashik River, 2002.

	Age 1.			Age 2.			Age 3.			All Ages	
Smolt Day [a]	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/19	56,529	73.3	56,529	20,612	26.7	20,612	0	0.0	0	77,141	77,141
5/20	72,761	73.3	129,290	26,531	26.7	47,143	0	0.0	0	99,292	176,433
5/21	116,060	73.3	245,350	42,319	26.7	89,462	0	0.0	0	158,379	334,812
5/22	172,696	74.0	418,046	60,645	26.0	150,107	0	0.0	0	233,341	568,153
5/23	361,702	74.0	779,748	127,018	26.0	277,125	0	0.0	0	488,720	1,056,873
5/24	270,063	74.0	1,049,811	94,837	26.0	371,962	0	0.0	0	364,900	1,421,773
5/25	537,756	54.7	1,587,567	445,704	45.3	817,666	0	0.0	0	983,460	2,405,233
5/26	2,485,418	54.7	4,072,985	2,059,969	45.3	2,877,635	0	0.0	0	4,545,387	6,950,620
5/27	1,325,936	85.3	5,398,921	229,231	14.7	3,106,866	0	0.0	0	1,555,167	8,505,787
5/28	2,916,437	66.8	8,315,358	1,450,794	33.2	4,557,660	0	0.0	0	4,367,231	12,873,018
5/29	589,243	53.1	8,904,601	521,489	47.0	5,079,149	0	0.0	0	1,110,732	13,983,750
5/30	872,007	64.2	9,776,608	487,318	35.9	5,566,467	0	0.0	0	1,359,325	15,343,075
5/31	6,093,931	77.1	15,870,539	1,810,000	22.9	7,376,467	0	0.0	0	7,903,931	23,247,006
6/01	5,674,810	90.7	21,545,349	581,871	9.3	7,958,338	0	0.0	0	6,256,681	29,503,687
6/02	6,302,127	94.6	27,847,476	362,558	5.4	8,320,896	0	0.0	0	6,664,685	36,168,372
6/03	5,354,182	94.6	33,201,658	308,024	5.4	8,628,920	0	0.0	0	5,662,206	41,830,578
6/04	1,190,565	94.6	34,392,223	68,492	5.4	8,697,412	0	0.0	0	1,259,057	43,089,635
6/05	650,504	86.0	35,042,727	106,336	14.1	8,803,748	0	0.0	0	756,840	43,846,475
6/06	133,143	86.0	35,175,870	21,764	14.1	8,825,512	0	0.0	0	154,907	44,001,382
6/07	0	92.7	35,175,870	0	7.0	8,825,512	0	0.2	0	0	44,001,382
6/08	376,726	92.7	35,552,596	28,557	7.0	8,854,069	934	0.2	934	406,217	44,407,599
6/09	102,559	92.7	35,655,155	7,774	7.0	8,861,843	254	0.2	1,188	110,587	44,518,186
6/10	2,151,496	92.7	37,806,651	163,090	7.0	9,024,933	5,335	0.2	6,523	2,319,921	46,838,107
6/11	436,018	95.0	38,242,669	22,900	5.0	9,047,833	0	0.0	6,523	458,918	47,297,025
6/12	314,120	95.0	38,556,789	16,497	5.0	9,064,330	0	0.0	6,523	330,617	47,627,642
	38,556,789	81.0		9,064,330	19.0		6,523	0.0		47,627,642	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 5. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Ugashik River, 2002.

Smolt Day [a]	Mean Weight of Smolt (g)	Smolt per Count
5/19	9.3	4.4
5/20	9.3	4.4
5/21	9.3	4.4
5/22	9.2	4.5
5/23	9.2	4.5
5/24	9.2	4.5
5/25	10.5	4.0
5/26	10.5	4.0
5/27	8.3	5.0
5/28	9.5	4.4
5/29	10.5	4.0
5/30	9.7	4.3
5/31	9.1	4.6
6/01	8.1	5.1
6/02	7.4	5.6
6/03	7.4	5.6
6/04	7.4	5.6
6/05	8.5	4.9
6/06	8.5	4.9
6/07	7.6	5.5
6/08	7.6	5.5
6/09	7.6	5.5
6/10	7.6	5.5
6/11	7.5	5.5
6/12	7.5	5.5

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 6. Mean fork length and weight of sockeye salmon smolt captured by fyke net, Ugashik River, 2002.

	Age 1.					Age 2.					Age 3.				
Smolt Day [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/20	91	10.3	8.0	2.78	70	108	14.1	11.8	3.85	30					0
5/21	93	7.4	8.3	2.29	57	115	31.9	14.5	13.27	43					0
5/22	84	13.3	8.0	3.07	4					0					0
5/23	95	16.0	9.0	5.03	47	117	28.4	15.4	10.63	53					0
5/24	95	8.6	9.4	2.44	32	113	16.1	14.9	6.24	62					0
5/25	92	16.7	8.7	4.56	44	113	14.2	14.0	4.65	56					0
5/26	90	13.7	7.6	3.13	88	106	9.5	10.7	2.21	12					0
5/27	92	10.3	8.0	2.23	70	105	8.1	11.1	2.78	30					0
5/28	92	8.6	8.5	2.21	52	110	9.4	12.5	3.13	48					0
5/29	92	12.7	8.2	2.85	75	107	9.8	11.5	2.91	25					0
5/30	92	10.8	8.1	2.66	69	108	10.2	11.8	3.87	31					0
5/31	91	11.2	7.6	2.70	87	109	10.2	11.6	2.38	13					0
6/01	88	12.0	6.4	2.77	12	112		11.7		1					0
6/02	88	16.2	7.3	3.92	99	88		6.4		1					0
6/03	92	13.5	7.6	3.83	95	103	6.0	10.3	2.20	5					0
6/04	94	10.8	7.9	3.30	95	109	8.9	11.2	2.95	5					0
6/05	94	11.0	8.3	3.09	97	111	4.5	12.4	1.86	3					0
6/06	86	13.5	6.4	2.61	19					0					0
6/07	90	15.3	7.1	3.43	92	129	21.4	21.9	10.94	4	154	7.1	36.1	4.70	2
6/08	91	11.4	7.0	2.52	97	105	6.7	10.4	2.13	3					0
6/09	94	9.0	7.4	2.53	98	116	9.5	17.7	9.63	2					0
6/10	88	2.4	5.2	0.24	2					0					0
Total					1,401					427					2
Mean	91		7.7			110		12.7			154		36.1		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 7. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Ugashik River, 2002.

	Age 1.[a]				Age 2.[a]			
Smolt Day [b]	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size
5/20	92	11.9	7.7	82	109	7.2	12.4	15
5/21	92	14.2	7.7	201	110	13.8	12.7	59
5/22	88	23.3	7.0	280	107	3.8	11.7	4
5/23				0				0
5/24	94	14.2	8.2	348	110	25.2	12.8	232
5/25	95	8.5	8.3	41	113	21.7	13.8	71
5/26	91	24.2	7.7	395	110	17.7	12.7	183
5/27	91	20.4	7.5	500	110	13.8	12.7	79
5/28	94	14.5	8.2	364	109	14.9	12.4	202
5/29	95	11.1	8.3	261	112	19.3	13.2	285
5/30	93	15.8	8.1	354	110	17.4	12.7	234
5/31	93	14.6	8.0	439	110	36.7	13.0	120
6/01	92	15.6	7.7	516	109	11.1	12.4	32
6/02				0				0
6/03	87	15.5	6.8	80	115	8.9	14.5	2
6/04	91	18.5	7.5	544	106	8.3	11.6	19
6/05	93	13.4	8.0	200	109	15.2	12.5	50
6/06	91	9.4	7.7	43	110	6.7	12.6	12
6/07	80	9.0	5.6	5	109	0.0	12.2	1
6/08				0				0
6/09				0				0
6/10	90	21.1	7.4	355	124	34.1	18.6	15
6/11	92	16.4	7.7	270	109	7.0	12.3	3
Totals				5,278				1,618
Means	91		7.6		111		13.0	

[a] Length-weight parameters by age group and discriminating length used to separate ages from were:

Age 1. a = -8.8457 b = 2.4068 r^2 = 0.6134 n = 1,401
Age 2. a = -10.4802 b = 2.7669 r^2 = 0.8421 n = 427

Discriminating length = 101.07 mm

[b] Sampling day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 8. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Ugashik River, 2002.

Date	Cloud Cover [a]		Precipitation (mm)	Wind Direction & Velocity (km/h)		Air Temperature [b] (°C)		Water Temperature (°C)		Water Clarity [c]
	0800	2000		0800	2000	0800	2000	0800	2000	
5/20	1	1	0.0	ESE 24	SE 13	10.0	12.0	6.0	8.0	clear
5/21	1	3	0.0	S 0-08	SE 24-32	11.0	n	7.0	n	clear
5/22	4	3	0.0	SE 16-24	na	11.0	11.5	7.0	8.0	clear
5/23	2	3	trace	E 32-40	SE 40	7.0	11.0	7.0	8.0	clear
5/24	2	1	0.0	SE 32-40	SE 16-24	7.0	13.0	6.0	8.0	murky
5/25	3	2	0.0	ESE 32-40	ESE 32	7.0	11.0	6.0	7.0	clear
5/26	4	3	0.0	E 08-16	ESE 08-16	8.0	10.0	6.0	7.0	clear
5/27	4	4	trace	E 0-08	E 24	10.0	12.0	7.0	7.0	clear
5/28	3	3	trace	E 0-16	W 08	8.0	13.0	6.5	7.0	clear
5/29	4	4	trace	SSW 16	W 16	9.0	8.0	5.5	6.0	clear
5/30	4	2	0.0	0	SSE 26	7.0	9.0	5.5	6.0	clear
5/31	3	3	0.0	SE 16-24	SE 23-26	10.0	8.0	6.0	7.0	clear
6/01	4	3	0.0	0	SE 18-21	9.0	8.0	7.0	7.5	clear
6/02	3	3	0.0	SE 08	SSE 18-23	8.0	9.0	7.5	8.0	clear
6/03	3	4	0.0	S 08-16	SSE 18-24	8.0	8.0	7.5	8.0	clear
6/04	3	4	0.0	0	NW 14-18	8.0	7.5	7.0	7.0	clear
6/05	4	3	2.5	NNW 13-16	NW 13-16	7.0	8.0	6.0	7.0	clear
6/06	5	1	0.0	0	SE 16-24	6.0	8.0	6.0	7.5	clear
6/07	4	4	0.0	E 32-40	SE 40-48	8.0	9.0	7.0	8.0	clear
6/08	4	4	7.1	NE 11-13	SSE 40-48	8.0	8.0	6.0	8.0	murky
6/09	4	4	0.8	E 29-35	SE 23-27	7.0	9.0	7.0	8.0	murky
6/10	4	4	3.1	0	SSE 10-14	8.0	8.0	7.0	8.0	clear
6/11	3	3	0.8	0	NW 08-11	8.0	10.0	7.0	8.0	clear
6/12	4	1	0.8	WSW 10-16	0	7.0	13.0	6.0	7.0	clear
6/13	5	n	0.5	0	n	5.0	n	6.0	n	clear

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] na = not available

[c] Water clarity at 0800 hours

Table 9. Age compostion of total migration and mean fork length and weight by age class for sockeye salmon smolt, Ugashik River, 1958-2002.

	Age 1.				Age 2.				Age 3.				
Year of Migration	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Total Estimate [a]
1958	1956	-	93	6.4	1955	-	112	11.7	1954	-	-	-	-
1959	1957	-	90	6.1	1956	-	120	13.5	1955	-	-	-	-
1960	1958	-	90	6.6	1957	-	104	11.0	1956	-	-	-	-
1961	1959	-	90	6.7	1958	-	112	12.2	1957	-	-	-	-
1962	1960	-	88	6.1	1959	-	112	12.3	1958	-	-	-	-
1963	1961	-	90	6.1	1960	-	104	9.6	1959	-	-	-	-
1964	1962	-	92	6.9	1961	-	118	12.7	1960	-	-	-	-
1965	1963	-	94	6.9	1962	-	114	12.5	1961	-	-	-	-
1967	1965	-	88	6.0	1964	-	113	12.2	1963	-	-	-	-
1968	1966	-	93	6.5	1965	-	113	10.7	1964	-	-	-	-
1969	1967	-	97	7.5	1966	-	121	14.5	1965	-	-	-	-
1970	1968	-	97	7.7	1967	-	125	15.9	1966	-	-	-	-
1972	1970	-	81	5.0	1969	-	112	11.2	1968	-	129	14.3	-
1973	1971	-	93	7.2	1970	-	113	11.9	1969	-	132	20.1	-
1974	1972	-	94	7.4	1971	-	119	13.6	1970	-	-	-	-
1975	1973	-	96	7.2	1972	-	116	13.0	1971	-	125	16.7	-
1982	1980	-	88	6.3	1979	-	113	13.0	1978	-	138	22.5	-
1983	1981	71	89	7.6	1980	29	111	13.2	1979	-	-	-	44,033,811
1984	1982	48	87	6.8	1981	52	102	10.3	1980	0	103	11.7	158,174,626
1985	1983	37	94	8.3	1982	63	107	11.8	1981	-	-	-	34,101,390
1986	1984	71	87	5.8	1983	29	114	10.9	1982	-	-	-	53,076,253
1987	1985	20	94	7.9	1984	80	107	11.1	1983	0	138	24.1	26,947,225
1988	1986	85	87	5.7	1985	15	109	10.8	1984	0	128	15.6	215,968,015
1989	1987	74	90	6.5	1986	26	108	10.7	1985	-	-	-	126,298,122
1990	1988	28	90	6.7	1987	72	108	11.8	1986	-	-	-	53,627,347
1991	1989	35	92	7.7	1988	65	107	11.6	1987	-	-	-	73,769,877
1992 [b]	1990	-	-	-	1989	-	-	-	1988	-	-	-	-
1993	1991	83	92	8.0	1990	17	109	12.5	1989	-	-	-	70,747,074
1994	1992	81	89	6.7	1991	19	109	11.2	1990	-	-	-	30,030,624
1995	1993	31	93	7.8	1992	69	106	11.1	1991	-	-	-	22,234,137
1996	1994	44	101	9.9	1993	56	114	13.5	1992	-	-	-	2,576,812
1997	1995	92	92	7.9	1994	8	109	12.1	1993	-	-	-	15,519,783
1998	1996	82	91	6.4	1995	18	110	11.1	1994	-	-	-	12,624,441
1999	1997	99	91	6.8	1996	1	125	17.5	1995	-	-	-	10,631,631
2000	1998	18	95	8.4	1997	82	112	12.5	1996	-	-	-	10,880,559
2001	1999	82	92	7.3	1998	18	108	11.5	1997	-	-	-	35,123,888
Mean			91	7.0			112	12.2			128	17.9	
2002	2000	81	91	7.7	1999	19	110	12.7	1998	0	154	36.1	47,627,642
Difference from Mean			0	0.7			-2	0.5			26	18.2	

[a] No estimates of smolt numbers from 1958-1982 fyke net catches; estimates of smolt numbers from 1983-1991 and 1993-present based on hydroacoustic techniques.
[b] Project not operated in 1992. No smolt data collected.

Table 10. Water temperatures at sockeye salmon smolt counting site, Ugashik River, 1983-2002.

Year	Sample Period	Water Temp (C^o)		
		Minimum	Mean	Maximum
1983	May 23 - June 11	6.0	7.3	8.5
1984	May 20 - June 17	4.8	6.3	8.5
1985	May 17 - June 09	-1.0	4.3	7.0
1986	May 23 - June 28	2.0	5.6	7.0
1987	May 17 - June 13	4.0	5.9	9.0
1988	May 17 - June 13	3.5	6.6	10.0
1989	May 21 - June 16	3.0	5.8	8.8
1990	May 21 - June 14	3.0	5.9	8.0
1991	May 20 - June 14	4.0	5.9	8.5
1992 [a]				
1993	May 18 - June 11	5.0	6.5	9.0
1994	May 20 - June 13	4.5	6.5	10.0
1995	May 23 - June 12	4.0	6.2	9.0
1996	May 19 - June 13	3.0	5.6	7.5
1997	May 10 - June 13	3.5	7.1	12.0
1998	May 18 - June 13	3.5	5.5	7.5
1999	May 18 - June 13	1.0	2.6	6.0
2000	May 20 - June 12	3.0	5.9	10.0
2001	May 20 - June 12	5.5	7.0	8.0
Mean		3.5	5.9	8.6
2002	May 20 - June 13	5.5	7.0	8.0
Difference from Mean		2.0	1.1	-0.6

[a] Project not operated in 1992. No data collected.

Table 11. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production by age class, and number of smolt produced per spawner for 1979-2000 brood years, Ugashik River.

Brood Year	Total Spawning Escapement [a]	Number of Smolt Produced: Age 1.	(%[b])	Age 2.	(%[b])	Age 3.	(%[b])	Total	Per Spawner
1979	1,700,904					0			
1980	3,321,384			12,736,379		26,384			
1981	1,326,762	31,297,432	27	82,656,993	73	0		113,954,425	85.9
1982	1,157,526	75,491,249	78	21,407,762	22	0		96,899,011	83.7
1983	1,000,614	12,693,628	46	15,186,101	54	1,677		27,881,406	27.9
1984	1,241,418	37,890,152	64	21,483,727	36	9,598		59,383,477	47.8
1985	998,232	5,461,821	14	33,238,739	86	0		38,700,560	38.8
1986	1,001,492	182,719,678	85	32,278,743	15	0		214,998,421	214.7
1987	668,964	94,019,379	71	38,789,387	29	0		132,808,766	198.5
1988	642,972	14,837,960	24	47,713,086	76	-[c]		62,551,046[d]	97.3[d]
1989	1,681,302	26,056,791		-[c]		0		[d]	[d]
1990	730,038	-[c]		12,415,518		0		[d]	[d]
1991	2,457,306	58,331,556	91	5,725,543	9	0		64,057,099	26.1
1992	2,173,692	24,305,081	61	15,272,807	39	0		39,577,888	18.2
1993	1,389,534	6,961,330	83	1,429,625	17	0		8,390,955	6.0
1994	1,080,858	1,147,187	49	1,199,949	51	0		2,347,136	2.2
1995	1,304,058	14,319,834	86	2,292,099	14	0		16,611,933	12.7
1996	667,518	10,332,342	99	56,184	1	0		10,388,526	15.6
1997	618,396	10,545,429	54	8,876,726	46	0		19,422,155	31.4
1998	890,508	2,003,833	24	6,248,929	76	6,523	0	8,259,285	9.3
1999	1,647,036	28,874,959	76	9,064,330[d]	24	[d]		37,939,289[d]	23.0[d]
2000	620,040	38,556,789		[d]		[d]		[d]	[d]
1988-1997 Max	2,457,306	58,331,556	99	47,713,086	76			64,057,099	97.3
1988-1997 Avg	1,274,567	18,537,501	68	10,553,504	32			27,918,342	26.2
1988-1997 Min	618,396	1,147,187	24	56,184	1			2,347,136	2.2

[a] Ugashik River tower count only. Does not include aerial survey index counts from King Salmon River or Dog Salmon River.
[b] Percent of total smolt production.
[c] No smolt data collected in 1992, therefore smolt production data for the 1988 (Age 3.), 1989 (Age 2.), and 1990 (Age 1.) brood years are incomplete.
[d] Incomplete returns from brood year escapements.

Table 12. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1979-2000 brood years, Ugashik River.

		Age 1.			Age 2.			Age 3.		
Brood Year	Total Spawning Escapement [a]	Number of Smolt	Adult Returns [b]	Adult Returns per Smolt	Number of Smolt	Adult Returns [b]	Adult Returns per Smolt	Number of Smolt	Adult Returns [b]	Adult Returns per Smolt
1979	1,700,904		3,960,210			2,045,642			0	[c]
1980	3,321,384		3,503,629		12,736,379	4,262,289	0.33	26,384	2,600	0.10
1981	1,326,762	31,297,432	4,241,375	0.14	82,656,993	3,215,237	0.04	0	1,682	[c]
1982	1,157,526	75,491,249	1,146,491	0.02	21,407,762	1,345,244	0.06	0	0	
1983	1,000,614	12,693,628	995,579	0.08	15,186,101	957,765	0.06	1,677	957	[c]
1984	1,241,418	37,890,152	1,052,692	0.03	21,483,727	4,399,295	0.20	9,598	6,732	[c]
1985	998,232	5,461,821	1,233,686	0.23	33,238,739	1,454,422	0.04	0	0	
1986	1,001,492	182,719,678	3,001,968	0.02	32,278,743	3,639,400	0.11	0	4,459	[c]
1987	668,964	94,019,379	2,478,649	0.03	38,789,387	4,215,483	0.11	0	34,612	[c]
1988	642,972	14,837,960	1,193,721	0.08	47,713,086	4,426,031	0.09	[d]	29,819	[c]
1989	1,681,302	26,056,791	1,104,400	0.04	[d]	3,449,364	[c]	0	9,880	[c]
1990	730,038	[d]	1,057,589	[c]	12,415,518	3,535,693	0.28	0	1,733	[c]
1991	2,457,306	58,331,556	5,221,578	0.09	5,725,543	927,616	0.16	0	0	
1992	2,173,692	24,305,081	791,283	0.03	15,272,807	1,852,920	0.12	0	1,181	[c]
1993	1,389,534	6,961,330	636,963	0.09	1,429,625	445,814	0.31	0	771	[c]
1994	1,080,858	1,147,187	676,862	0.59	1,199,949	976,591	0.81	0	1,096	[c]
1995	1,304,058	14,319,834	4,405,733	0.31	2,292,099	269,718	0.12	0	232 [e]	[c]
1996	667,518	10,332,342	1,224,353	0.12	56,184	118,262 [e]	[c]	0	1,196 [e]	
1997	618,396	10,575,429	926,831 [e]	0.09 [c]	8,876,726	1,560,817 [e]		0	0 [e]	
1998	890,508	2,003,833	205,264 [e]		6,248,929	1,413 [e]		6,523		
1999	1,647,036	28,874,959	5,626 [e]		9,064,330					
2000	620,040	38,556,789								
1986-1995 Max	2,457,306	182,719,678	5,221,578	0.59	47,713,086	4,426,031	0.81	0	34,612	[c]
1986-1995 Avg	1,313,022	46,966,533	2,056,875	0.14	17,457,417	2,373,863	0.24	0	8,378	[c]
1986-1995 Min	642,972	1,147,187	636,963	0.02	1,199,949	269,718	0.09	0	0	[c]

[a] Ugashik River tower count only. Does not include aerial survey index counts from King Salmon River or Dog Salmon River.
[b] Includes estimates of adult returns through 2001.
[c] Insufficient smolt data to complete this calculation.
[d] No Ugashik River smolt enumeration project conducted in 1992. Therefore smolt estimates for 1988, 1989, and 1990 brood years are incomplete because no smolt data were collected in 1992.
[e] Future adult returns will increase these values.

Table 13. Comparison of the age composition of outmigrating sockeye salmon smolt at Ugashik River with the freshwater age composition of their total adult returns by brood year, 1981-1995.

Smolt Outmigration Year	Brood Year	Freshwater Age	Proportion of Total: Smolt	Proportion of Total: Adult	Difference	Comments
1983	1981	Age 1.	0.27	0.57	-0.30	No ice or weather problems noted.
	1980	Age 2.	-	-		
1984	1982	Age 1.	0.78	0.46	0.32	No ice or weather problems noted.
	1981	Age 2.	0.73	0.43	0.30	
1985	1983	Age 1.	0.46	0.51	-0.05	Ice present - 5/17-5/21 intermittent
	1982	Age 2.	0.22	0.54	-0.32	
1986	1984	Age 1.	0.64	0.19	0.45	No ice or weather problems noted.
	1983	Age 2.	0.54	0.49	0.05	
1987	1985	Age 1.	0.14	0.46	-0.32	No ice or weather problems noted.
	1984	Age 2.	0.36	0.81	-0.45	
1988	1986	Age 1.	0.85	0.45	0.40	No ice or weather problems noted.
	1985	Age 2.	0.86	0.54	0.32	
1989	1987	Age 1.	0.71	0.37	0.34	No ice or weather problems noted.
	1986	Age 2.	0.15	0.55	-0.40	
1990	1988	Age 1.	0.24	0.21	0.03	Poor Weather - 199 h disabled time
	1987	Age 2.	0.29	0.63	-0.34	
1991	1989	Age 1.	[a]	0.24		Poor Weather - 187 h disabled time
	1988	Age 2.	0.76	0.78	-0.02	
1992	1990	Age 1.	[b]	0.23		No smolt data.
	1989	Age 2.	[b]	0.76		
1993	1991	Age 1.	0.91	0.85	0.06	Bad Weather - 264 h disabled time
	1990	Age 2.	[c]	0.77		
1994	1992	Age 1.	0.61	0.30	0.31	Good Weather - 42 h disabled time
	1991	Age 2.	0.09	0.15	-0.06	
1995	1993	Age 1.	0.83	0.59	0.24	Excellent Weather - 21 h disabled time
	1992	Age 2.	0.39	0.70	-0.31	
1996	1994	Age 1.	0.49	0.41	0.08	Fair Weather - 109 h disabled time
	1993	Age 2.	0.17	0.41	-0.24	
1997	1995	Age 1.	0.86	0.94	-0.08	Good Weather - 41 h disabled time
	1994	Age 2.	0.51	0.59	-0.08	
1998	1996	Age 1.	0.99	[d]		Fair Weather - 115 h disabled time
	1995	Age 2.	0.14	0.06	0.08	

[a] Unable to calculate the proportion of Age-1. smolt for brood year 1989 because the Age-2 smolt for brood year 1989 were not counted in 1992.

[b] The Ugashik Smolt project was not operated in 1992; no smolt data collected that year.

[c] Unable to calculate the proportion of Age-2. smolt for brood year 1990 because the Age-1 smolt for brood year 1990 were not counted in 1992.

[d] Incomplete adult returns from brood year escapement.

FIGURES

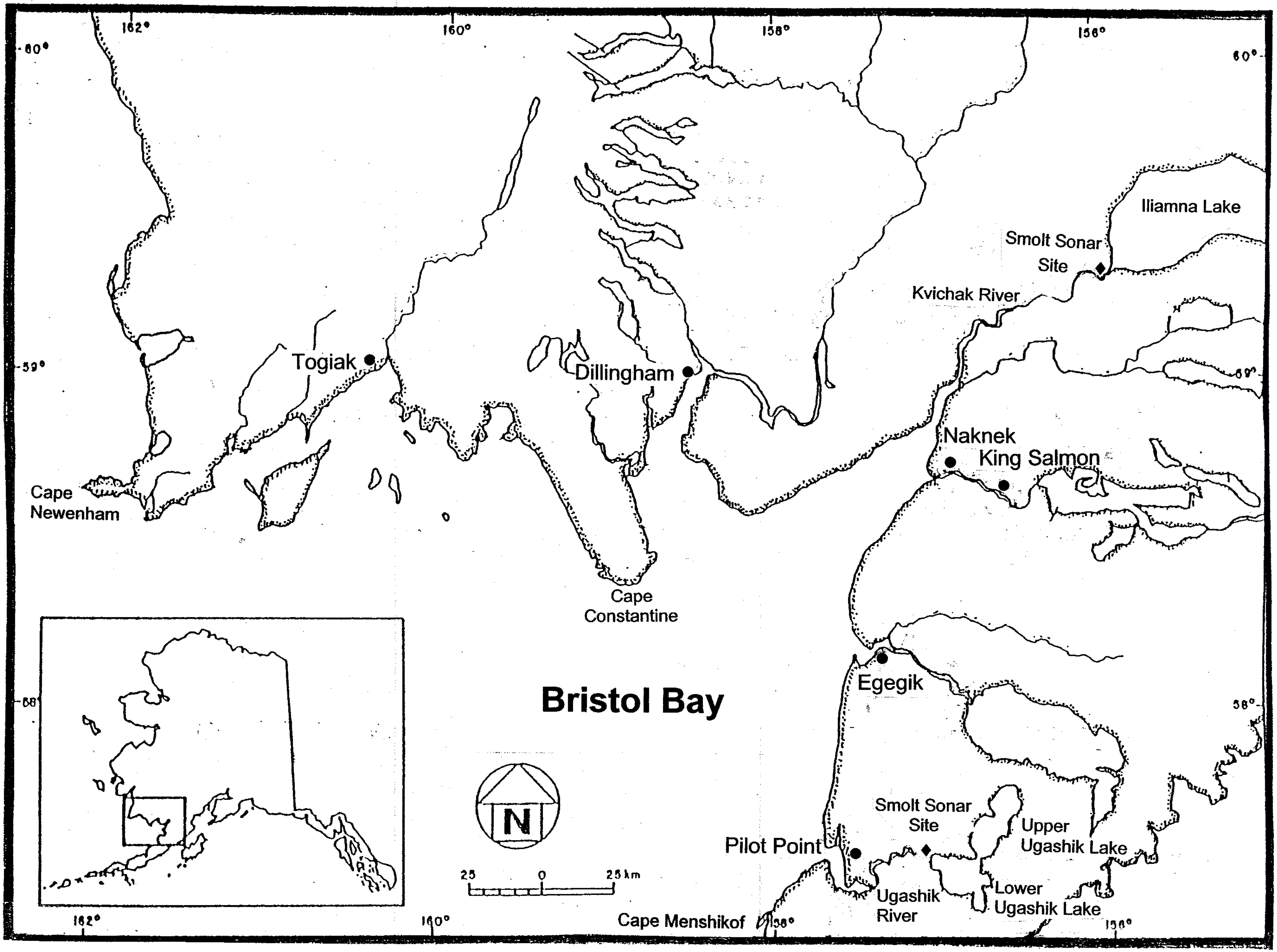


Figure 1. Map of Bristol Bay showing the locations of smolt sonar sites.

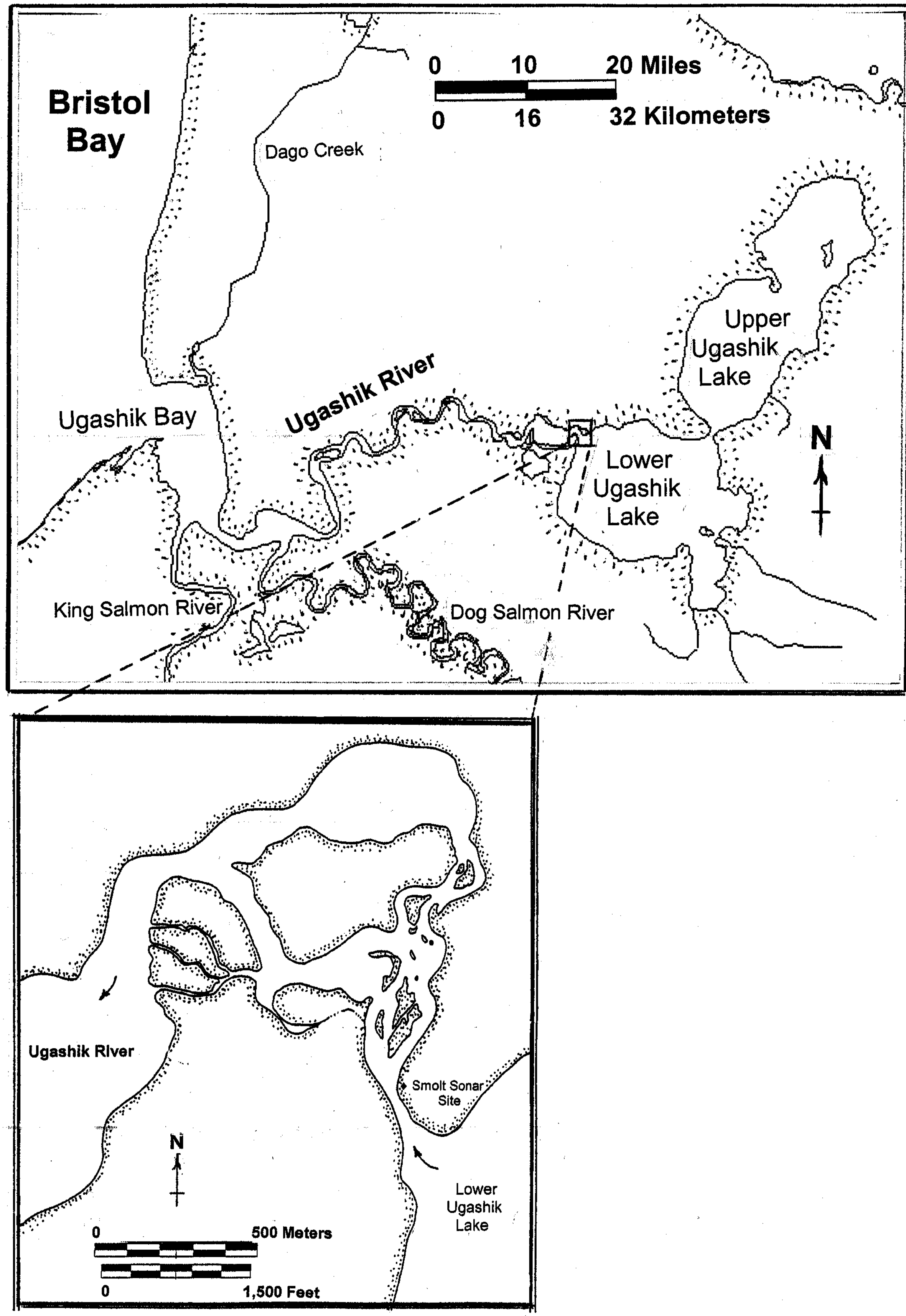


Figure 2. Map of Ugashik River drainage showing the location of the sockeye salmon smolt sonar site.

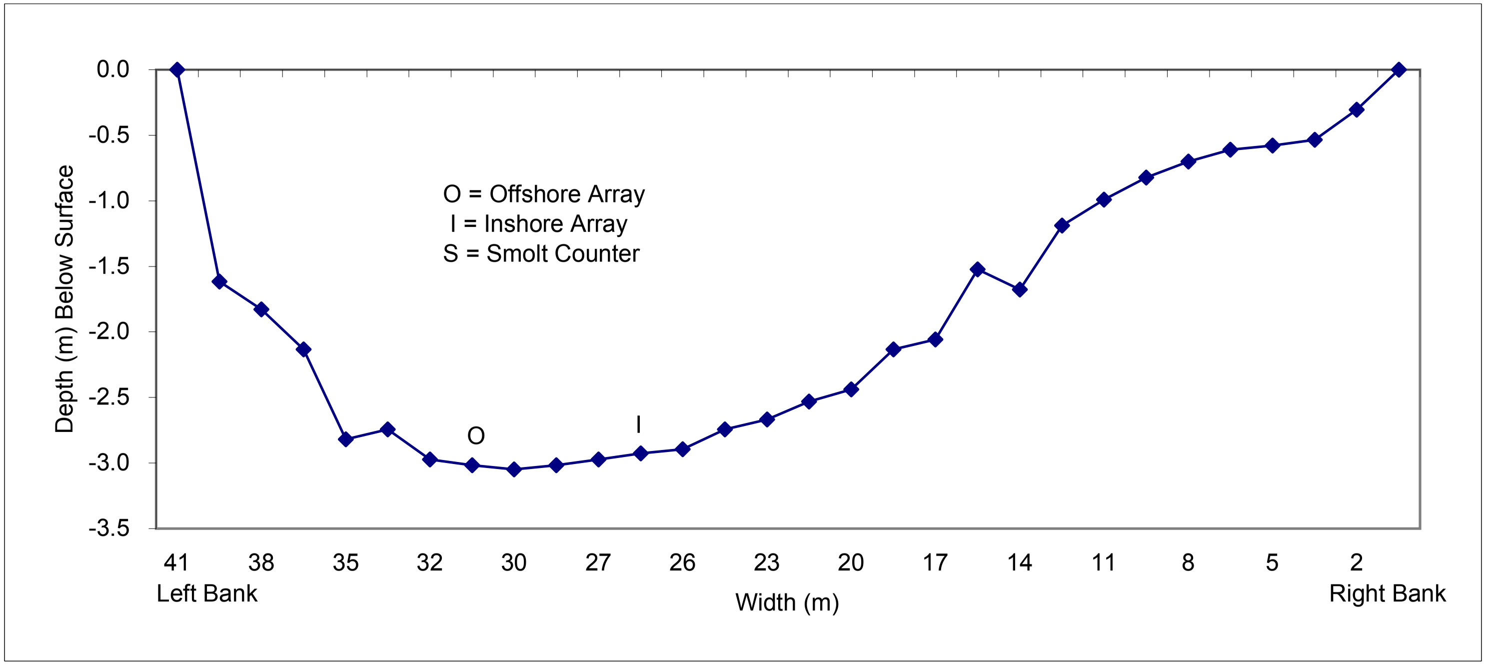
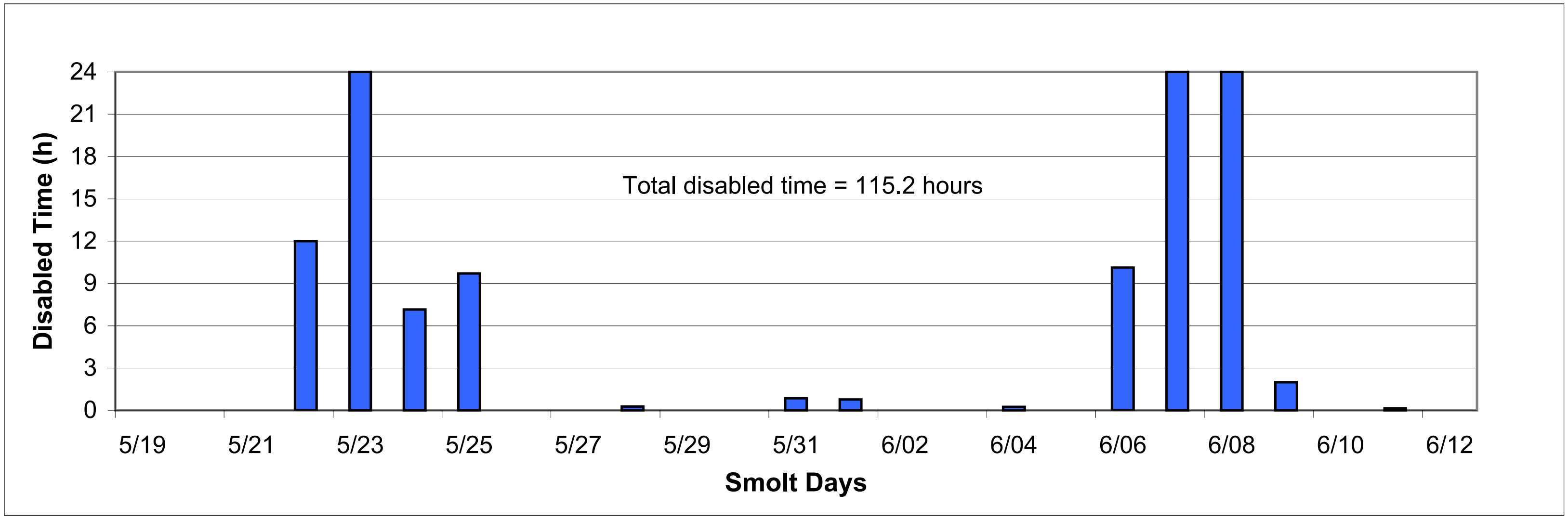


Figure 3. River bottom profile and sonar array placement at Ugashik River smolt sonar site, 2002.



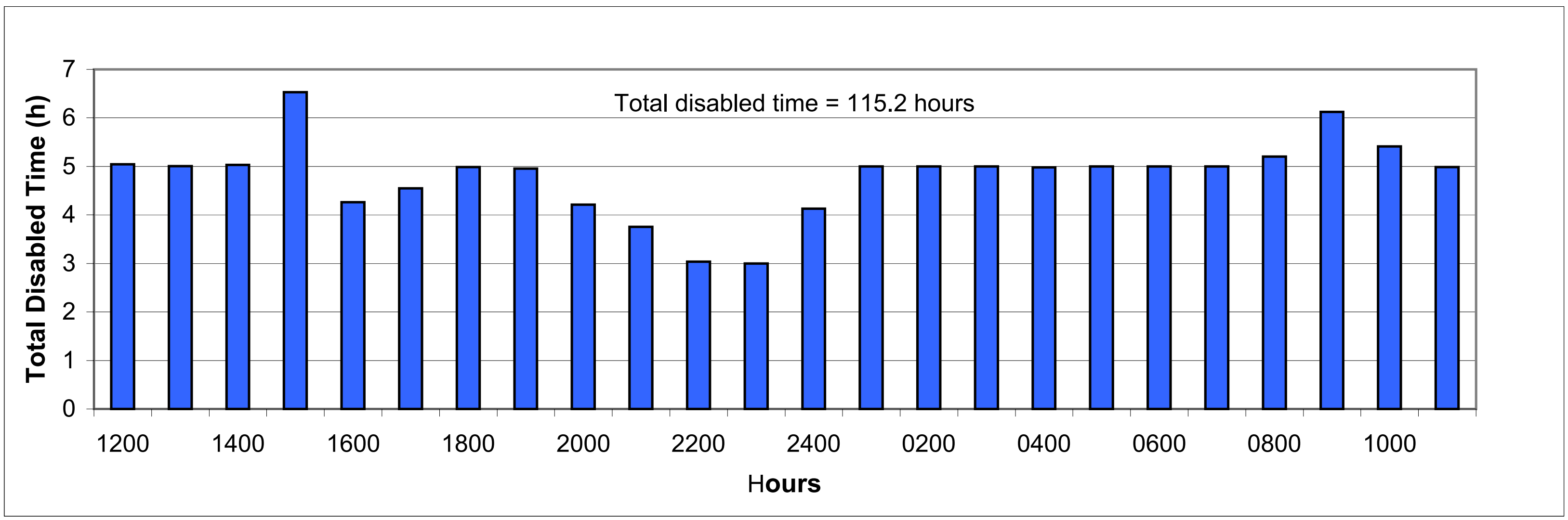


Figure 4. Ugashik River smolt sonar disabled time because of weather by smolt day and hour, May 19 to June 12, 2002.

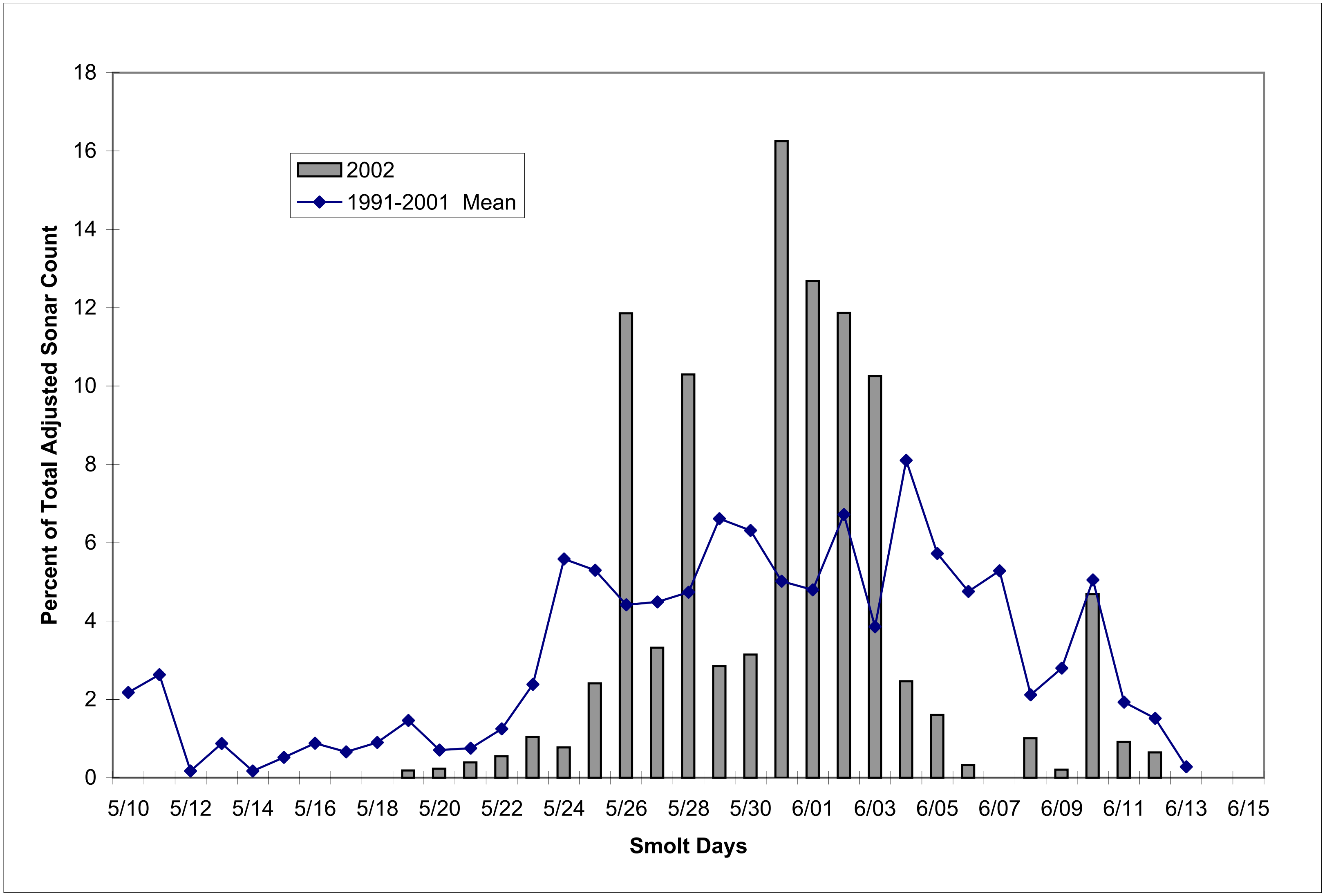


Figure 5. Comparison of the percent of the 2002 total adjusted sonar counts by smolt day at Ugashik River smolt sonar with the 1991-2001 mean.

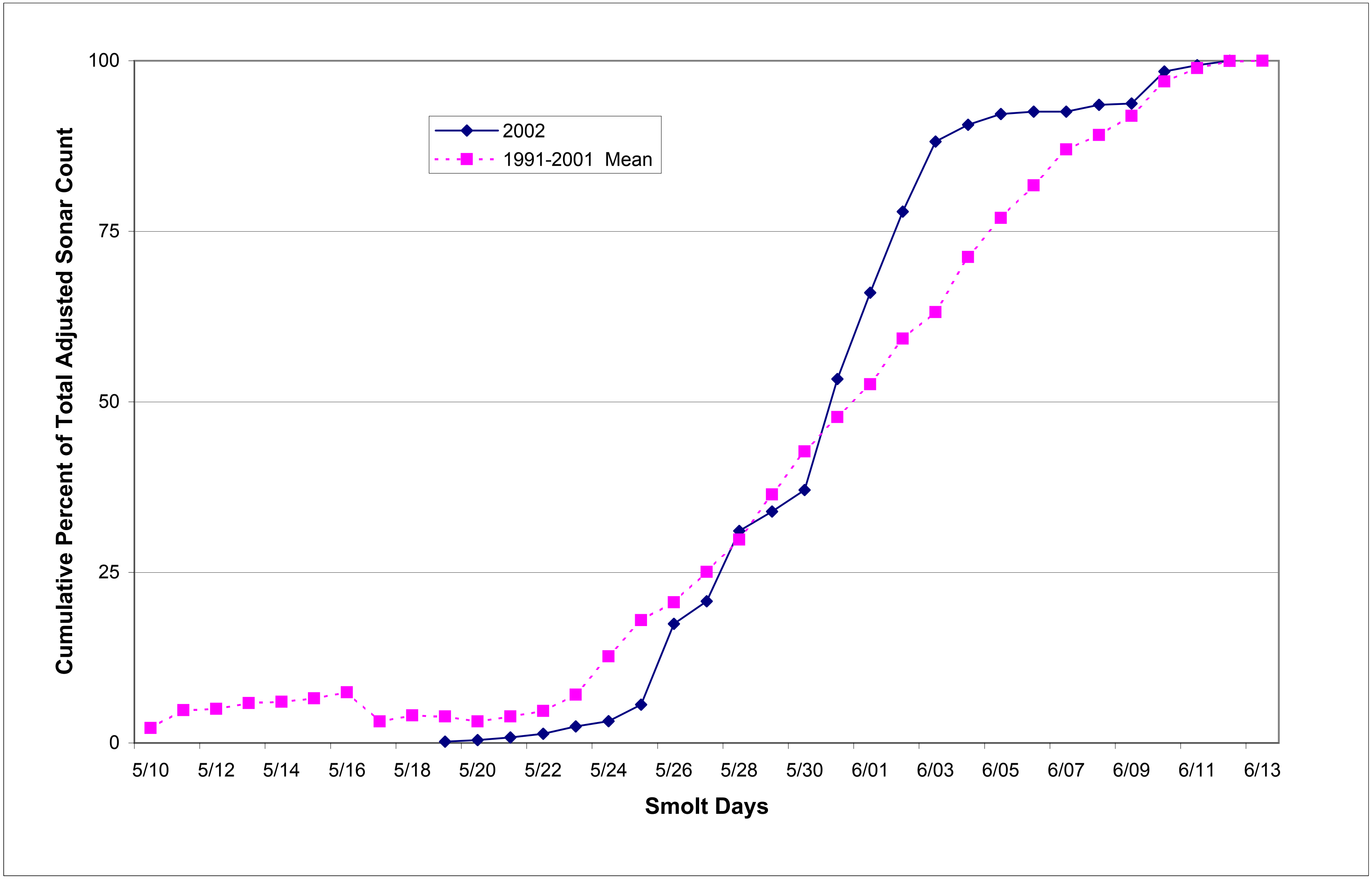


Figure 6. Comparison of the cumulative percent of the 2002 total adjusted sonar counts by smolt day at Ugashik River smolt sonar with the 1991-2001 mean.

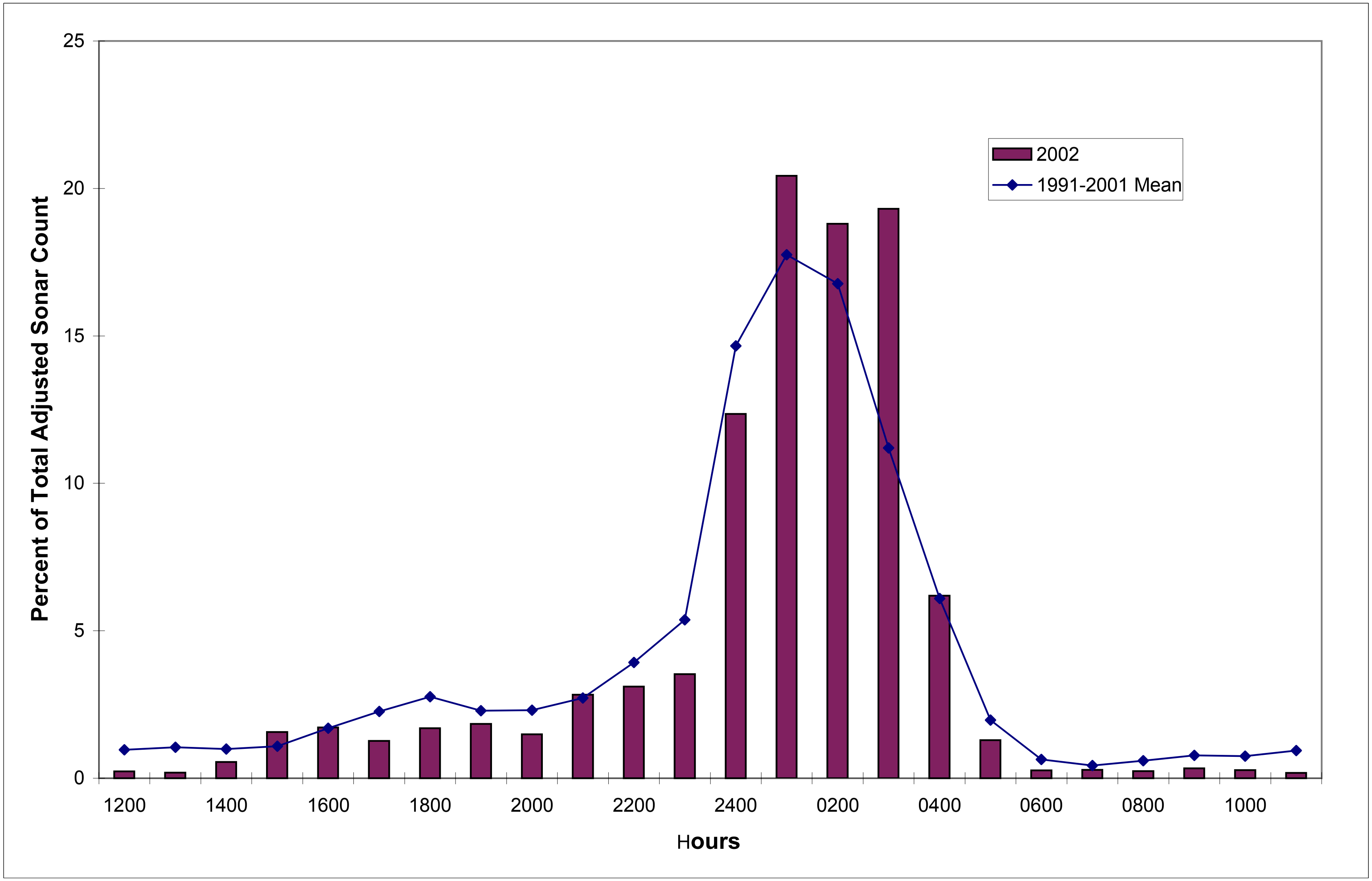


Figure 7. Comparison of the percent of the 2002 total adjusted sonar counts by hour at Ugashik River smolt sonar with the 1991-2001 mean.

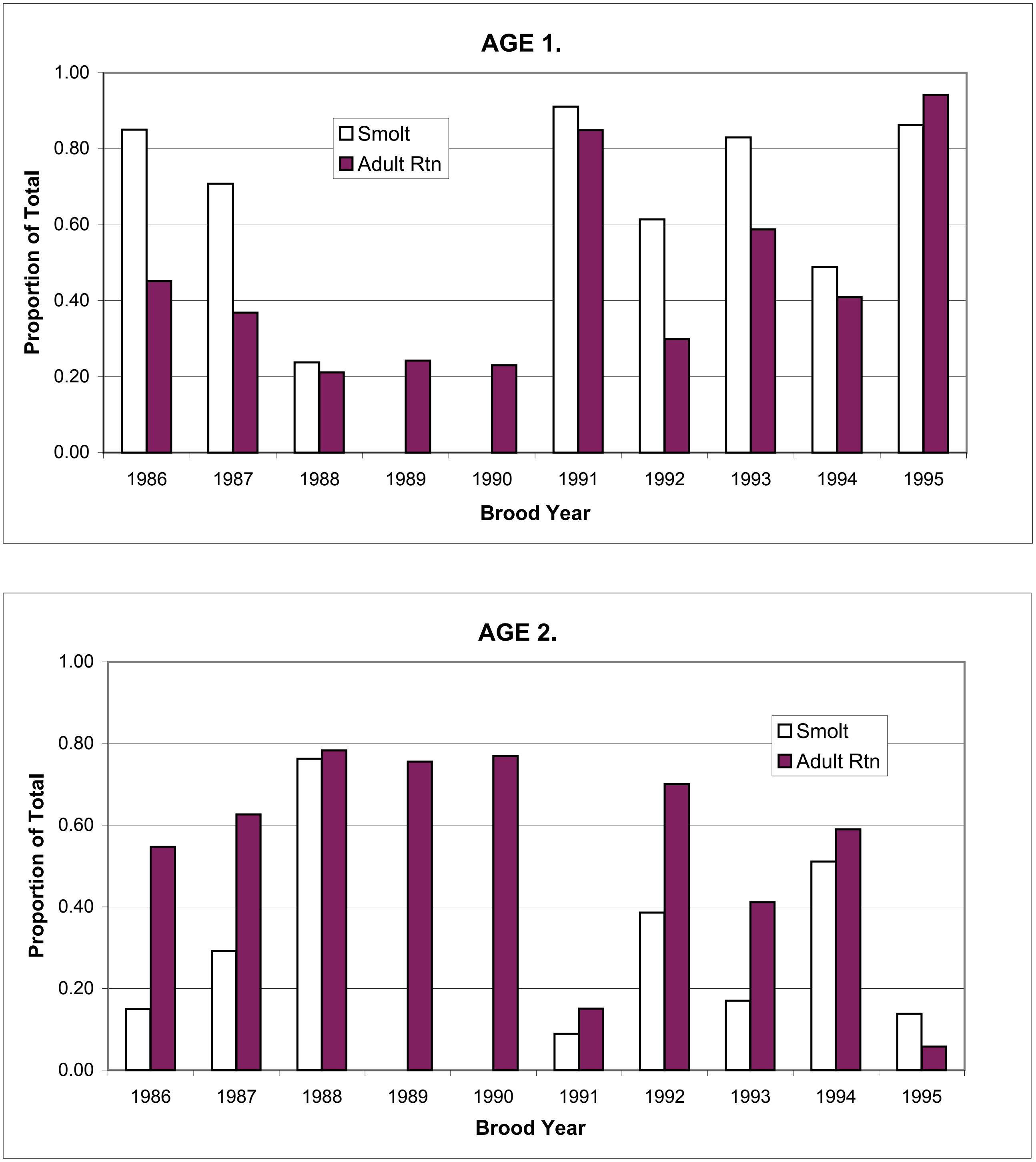


Figure 8. Comparison of the age composition of outmigrating sockeye salmon smolt at Ugashik River with the freshwater age composition of the total adult returns by brood year, 1986-1995.

APPENDIX A: RIVER WIDTH AND DISTANCE BETWEEN ARRAYS

Appendix A.1. River width and distance between arrays at Ugashik River smolt sonar site[a], 1988-2002.

	Distance (m)					
Year	Left Bank Shore	Offshore Limit Dead Zone[b]	Offshore Array	Inshore Array	Inshore Limit Dead Zone[b]	Right Bank Shore
1988	49	na	29	23	na	0
1989	43	34	28	23	12	0
1990	43	37	31	26	12	0
1991	43	37	30	26	12	0
1992 [c]						
1993	43	35	30	26	12	0
1994	43	37	32	27	12	0
1995	43	37	30	24	12	0
1996	41	35	30	26	11	0
1997	42	38	32	27	11	0
1998	44	38	33	27	14	0
1999	44	38	31	27	12	0
2000	45	38	33	28	14	0
2001	40	34	30	24	12	0
2002	41	36	31	27	13	0
1989-01 Max	45	38	33	28	14	0
1989-01 Avg	43	36	31	26	12	0
1989-01 Min	40	34	28	23	11	0

[a] The Ugashik River smolt sonar site was located 50 m downstream from the outlet of Lower Ugashik Lake, 1988-2002. The smolt sonar tent is located on the right bank of the river at - 57°33.89' N latitude 156°59.90' W longitude.

[b] na = not available

[c] Due to budget cuts, the smolt outmigration was not monitored on the Ugashik River in 1992.

APPENDIX B: WINTER ICE-COVER DATES

Appendix B.1. Ice-cover dates for Upper and Lower Ugashik Lakes, 1977-2002.

	Freeze-up Date [a]		Break-up Date [a]		Total Days of	
Winter of	(dd-mmm)	Julian Day	(dd-mmm)	Julian Day	Ice Cover	Comments [a]
1976-1977			6-Apr	96		
1977-1978						
1978-1979						
1979-1980						
1980-1981						Still open 16-Dec
1981-1982			12-May	132		
1982-1983	18-Jan	18				Partially open 31-Mar
1983-1984	16-Jan [b]	16				
1984-1985	11-Feb	42	14-May	134	92	
1985-1986	26-Feb	57	9-May	129	72	
1986-1987	12-Mar [b]	71				
1987-1988	9-Dec	-22	24-Mar	84	106	
1988-1989	17-Jan	17	10-May	130	113	
1989-1990	21-Feb	52	25-Apr	115	63	
1990-1991	8-Jan	8				
1991-1992	27-Jan	27	4-May	125	98	
1992-1993	20-Jan	20	31-Mar	90	70	
1993-1994	16-Feb	47	8-Apr	98	51	
1994-1995	24-Jan	24	28-Apr	118	94	
1995-1996	8-Jan	8	15-Apr	106	98	
1996-1997	13-Dec [c]	-18	26-Apr [d]	116	134	
1997-1998	5-Jan	5	4-Apr	94	89	
1998-1999	22-Jan	22	19-May	139	117	
1999-2000	25-Dec	-6	7-Apr	98	103	
2000-2001	[e]					
2001-2002	*10-Jan*	10	*30-Apr*	120	110	*Estimated freeze-up & break-up dates.*
1977-2002 Min	9-Dec		24-Mar		51	
1977-2002 Avg	20-Jan		22-Apr		94	
1977-2002 Max	12-Mar		19-May		134	

[a] Most data is anecdotal, provided by pilots from local air charter companies (R. Russell, ADF&G retired, King Salmon, personal communication).
[b] Last date area was observed with open water; may have frozen over even later.
[c] Mostly frozen on 13-Dec except SW shoreline of Upper Ugashik Lake by Blue Mt and the NW shore of Lower Ugashik Lake between the outlet and the Narrows.
[d] Upper Ugashik Lake ice free by 24-Apr. Lower Ugashik Lake 90% open by 26-April. Lake ice flows cleared in Ugashik River about 4-May.
[e] Some new (<5 cm thick), thin (5-15 cm thick), and medium (15-30 cm thick) ice may have formed on the protected bays and shores of Upper and Lower Ugashik Lakes from March 18-25 and March 29-April 1, when King Salmon air temperatures dipped into the teens and single-digits. However because of unseasonably warm temperatures and prevailing winds, open water was observed on most of the lake throughout the winter of 2000-2001.

APPENDIX C: FYKE NET CATCH

Appendix C.1. Ugashik River smolt fyke net catch log, 2002.

Smolt Day	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Smolt Day	Smolt Catch per Set	Smolt Catch per Smolt Day	CPUE [b]
5/20	001	2319	0100	101	101	197	197	2
5/21	002	2325	2354	29		100		3
	003	0005	0023	18		104		6
	004	0025	0055	30	77	156	360	5
5/22	005	2315	2339	24		87		4
	006	2342	2358	16		108		7
	007	0008	0048	40	80	28	223	1
5/23	008	2318	0050	92	92	4	4	0
5/24	009	2333	2335	2		121		61
	010	2337	2349	12		115		10
	011	2350	2358	8		124		16
	012	0001	0006	5		109		22
	013	0008	0021	13		100		8
	014	0022	0033	11	51	110	679	10
5/25	015	2356	0016	20		88		4
	016	0018	0022	4		106		27
	017	0023	0050	27	51	12	206	0
5/26	018	2311	2317	6		143		24
	019	2319	2321	2		103		52
	020	2323	2324	1		106		106
	021	2326	2333	7		110		16
	022	2334	2337	3		105		35
	023	2340	2352	12	31	114	681	10
5/27	024	2321	2327	6		110		18
	025	2330	2333	3		117		39
	026	2335	2336	1		127		127
	027	2339	2341	2		100		50
	028	2344	2347	3		112		37
	029	2350	2352	2	17	113	679	57
5/28	030	2332	2340	8		109		14
	031	2343	2345	2		115		58
	032	2347	2349	2		111		56
	033	2351	2353	2		106		53
	034	2355	2357	2		119		60
	035	2359	0001	2	18	106	666	53
5/29	036	2333	2340	7		102		15
	037	2342	2345	3		113		38
	038	2347	2352	5		111		22
	039	2354	0033	39		100		3
	040	0035	0039	4		107		27
	041	0041	0044	3	61	113	646	38
5/30	042	2321	2327	6		105		18
	043	2329	2333	4		105		26
	044	2336	2337	1		124		124
	045	2339	2345	6		119		20
	046	2349	0002	13		112		9
	047	0005	0008	3	33	123	688	41
5/31	048	2326	2328	2		109		55
	049	2330	2332	2		115		58
	050	2334	2335	1		114		114
	051	2339	2340	1		110		110
	052	2342	2343	1		111		111
	053	2346	2347	1	8	100	659	100
6/01	054	2316	2318	2		110		55
	055	2322	2324	2		113		57

-continued-

Appendix C.1. Ugashik River smolt fyke net catch log, 2002 (page 2 of 2).

Smolt Day	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Smolt Day	Smolt Catch per Set	Smolt Catch per Smolt Day	CPUE [b]
	056	2326	2327	1		104		104
	057	2329	2331	2		106		53
	058	2333	2337	4		107		27
	059	2340	2345	5	16	109	649	22
6/02	060	2322	0055	93	93	13	13	0
6/03	061	2326	0002	36		174		5
	062	0004	0050	46	82	8	182	0
6/04	063	2315	2316	1		117		117
	064	2320	2326	6		12		2
	065	2329	2331	2		105		53
	066	2334	2336	2		110		55
	067	2338	0003	25		110		4
	068	0005	0030	25	61	109	563	4
6/05	069	2312	2341	29		108		4
	070	2344	0004	20		109		5
	071	0008	0012	4		114		29
	072	0015	0050	35	88	19	350	1
6/06	073	2321	0036	75		100		1
	074	0038	0050	12	87	55	155	5
6/07	075	2317	0050	93	93	6	6	0
6/08	076	2314	0050	96	96	19	19	0
6/09	077	2333	0050	77	77	98	98	1
6/10	078	2311	2329	18		106		6
	079	2333	0002	29		104		4
	080	0005	0012	7		111		16
	081	0015	0021	6		108		18
	082	0024	0050	26	86	41	470	2
6/11	083	2325	2355	30		106		4
	084	2359	0009	10		124		12
	085	0013	0015	2		115		58
	086	0019	0050	31	73	28	373	1
6/12	087	2315	0050	95	95	2	2	0
Max				101	101	197	688	127
Avg				18	65	98	357	31
Min				1	8	2	2	0

[a] Military time - 24 hour clock (hhmm).
[b] CPUE = catch per unit effort

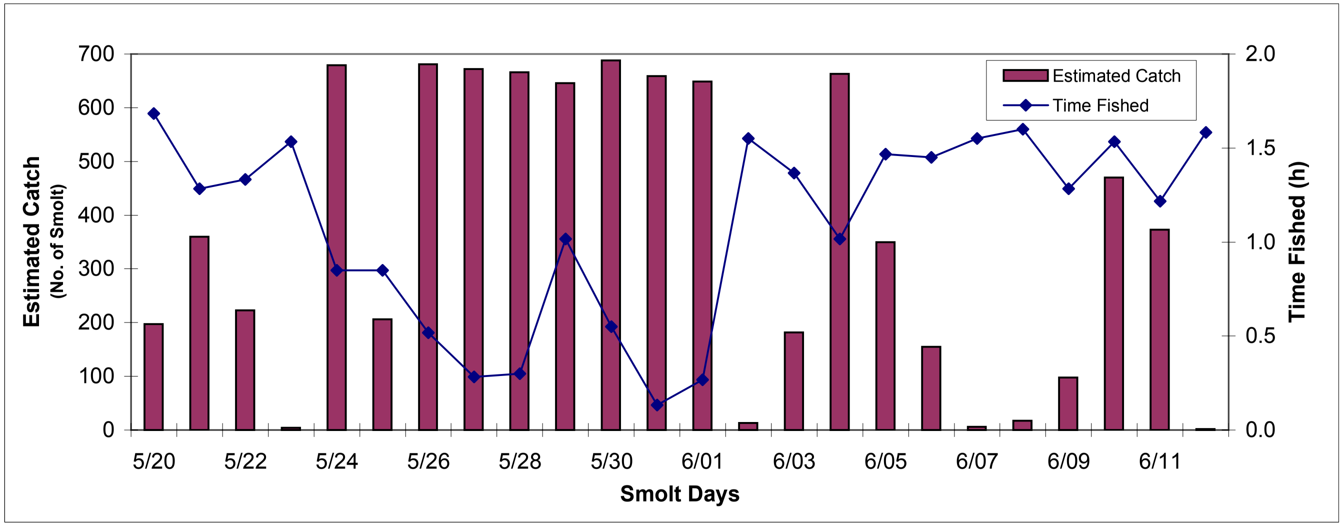
Appendix C.2. Ugashik River fyke net catches by smolt day and species, May 20 to June 12, 2002.

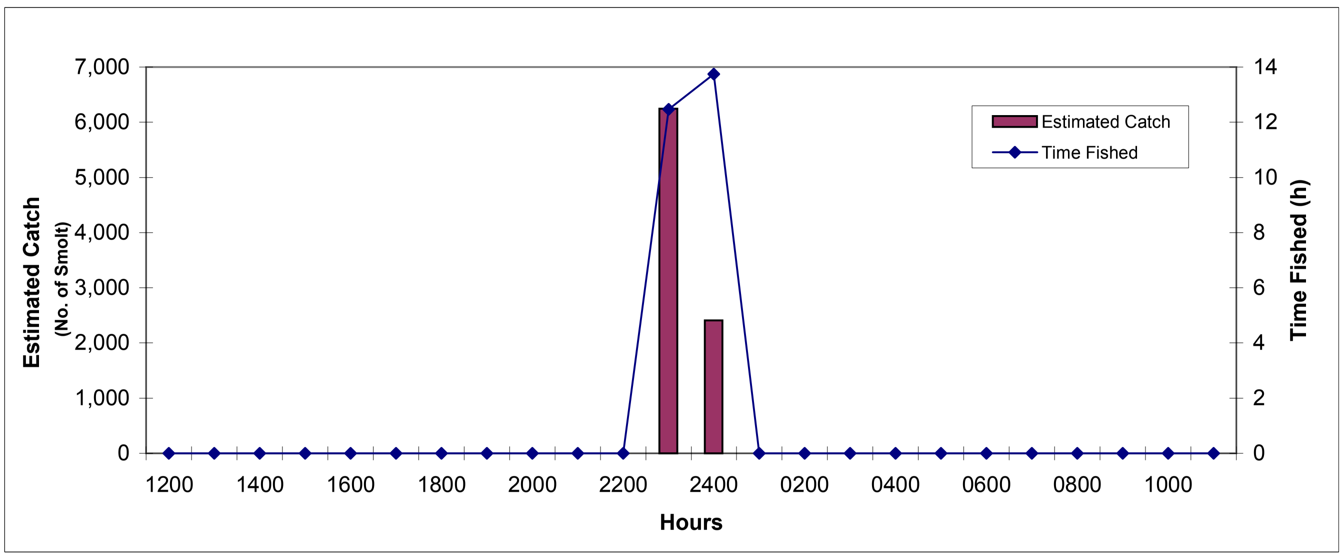
		Catch Estimate (No. of Fish)														
			Sticklebacks		Sculpin											
Smolt Day	Time Fished (h)	Sockeye Smolt	Threespine	Ninespine	Coastrange	Fourhorn	Slimy	Chinook Juvenile	Coho Juvenile	Chum Fry	Pink Fry	Lamprey (Species)	Whitefish (Species)	Pond Smelt	Rainbow Trout (fry)	Northern Pike
5/20	1.7	197	0	0	0	0	6	0	0	0	0	0	0	0	0	0
5/21	1.3	360	0	0	0	0	25	0	0	0	1	0	0	0	0	0
5/22	1.3	223	0	0	0	1	16	0	0	0	1	0	0	0	0	0
5/23	1.5	4	1	0	0	0	8	0	0	0	6	0	0	0	0	0
5/24	0.9	679	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/25	0.9	206	0	0	0	0	5	0	0	0	4	0	0	0	0	0
5/26	0.5	681	0	0	0	0	1	0	0	0	0	0	0	0	0	0
5/27	0.3	672	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/28	0.3	666	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/29	1.0	646	0	0	0	5	0	0	0	0	0	0	0	0	0	0
5/30	0.6	688	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/31	0.1	659	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/01	0.3	649	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/02	1.6	13	0	0	0	0	3	0	0	0	0	0	0	0	0	0
6/03	1.4	182	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/04	1.0	663	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/05	1.5	350	0	0	0	1	3	0	0	0	2	0	0	0	0	0
6/06	1.5	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/07	1.6	6	0	0	0	0	15	0	0	0	5	0	0	0	0	0
6/08	1.6	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/09	1.3	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/10	1.5	470	0	0	0	0	0	0	0	0	0	0	0	0	1	0
6/11	1.2	373	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12	1.6	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Total	26.2	8,659	1	0	0	7	84	0	0	0	19	0	0	0	1	0
Max	1.7	688	1													
Avg	1.1	361	0													
Min	0.1	2	0													

Appendix C.3. Ugashik River fyke net catches by hour and species, May 20 to June 12, 2002.

		Catch Estimate (No. of Fish)														
	Time Fished	Sockeye	Sticklebacks		Sculpin			Chinook	Coho	Chum	Pink	Lamprey	Whitefish	Pond	Rainbow	Northern
Hour [a]	(h)	Smolt	Threespine	Ninespine	Coastrange	Fourhorn	Slimy	Juvenile	Juvenile	Fry	Fry	(Species)	(Species)	Smelt	Trout (fry)	Pike
1200	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1300	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1400	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1500	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1600	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1700	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1800	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2100	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2200	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300 [b]	12.5	6,248	0	0	0	3	16	0	0	0	5	0	0	0	0	0
2400 [c]	13.8	2,411	1	0	0	4	68	0	0	0	14	0	0	0	1	0
0100 [c]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0200 [c]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0300 [c]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0400 [c]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0500 [c]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0600 [b]	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0700	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0800	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0900	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1000	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	26.2	8,659	1	0	0	7	84	0	0	0	19	0	0	0	1	0

[a] Daylight hours unless indicated otherwise
[b] Twilight hours
[c] Hours of darkness





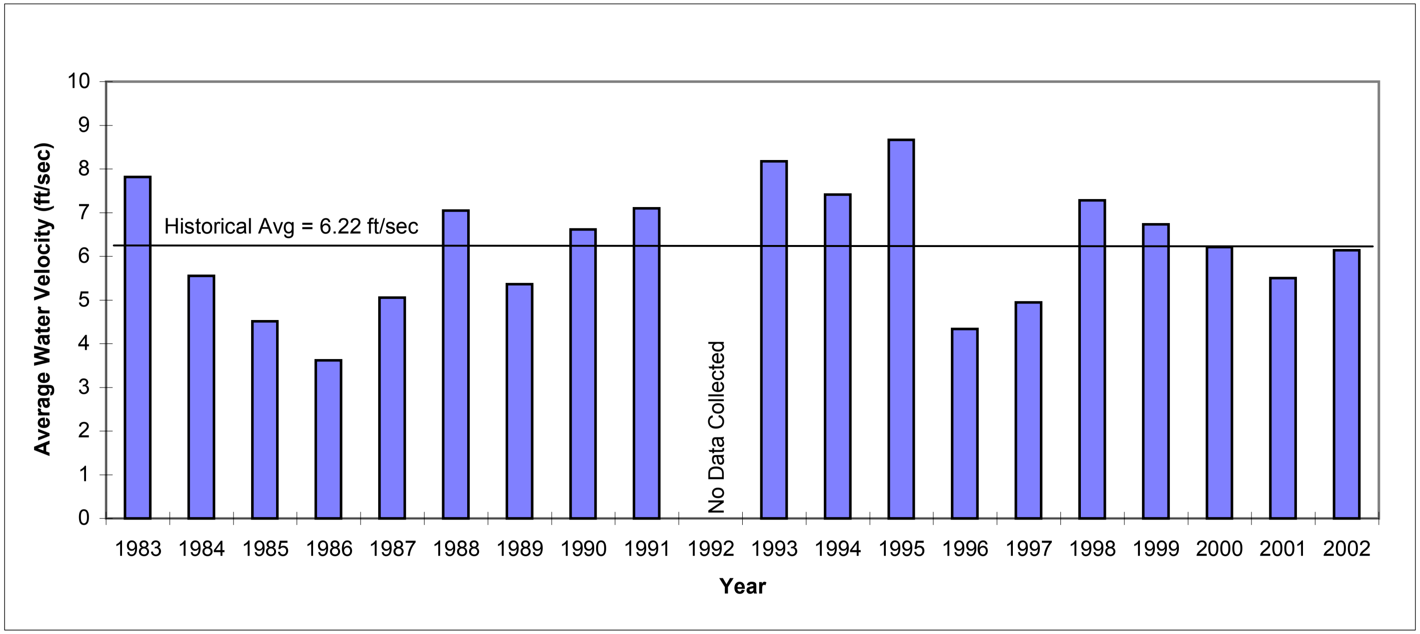
Appendix C.4. Estimated sockeye salmon smolt fyke net catch and time fished by smolt day and hour at Ugashik River, 2002.

APPENDIX D: RIVER VELOCITIES

Appendix D.1. Ugashik River water velocity at the inshore smolt sonar array, 1983-2002.

	Water Velocity (ft/sec)																				
Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	1983-2001 Average
5/05															4.99						4.99
5/06																					
5/07																					
5/08																					
5/09																					
5/10																					
5/11																					
5/12																					
5/13																					
5/14																					
5/15																					
5/16															5.13						5.13
5/17					5.17	7.15					7.84					6.30					6.62
5/18																					
5/19														3.91	5.01			6.12		5.81	5.01
5/20								6.23	5.78			7.60							5.38		6.25
5/21																					
5/22	8.00			3.16			4.13						9.48								6.19
5/23			4.10												4.86						4.48
5/24																6.49	6.12				6.31
5/25	7.63										8.34							6.12			7.36
5/26												7.78		4.52							6.15
5/27																			5.38		5.38
5/28		5.56						6.73	7.82				8.93							6.08	7.26
5/29															4.82						4.82
5/30							4.90														4.90
5/31				3.89												7.74	6.30	5.93			5.97
6/01											8.19										8.19
6/02							5.12					7.23		4.45							5.60
6/03																				6.19	
6/04			4.93				6.17	6.84					8.72		4.88				5.75		6.21
6/05									7.70												7.70
6/06																8.59					8.59
6/07																	6.91				6.91
6/08											8.34							6.67			7.51
6/09												7.04	7.53	4.47							6.35
6/10																				6.47	
6/11				3.80													7.60				5.70
6/12							6.51	6.67													6.59
6/13																					
6/14					4.94																4.94
6/15						6.95															6.95
Max	8.00	5.56	4.93	3.89	5.17	7.15	6.51	6.84	7.82		8.34	7.78	9.48	4.52	5.13	8.59	7.60	6.67	5.75	6.47	9.48
Avg	7.82	5.56	4.51	3.62	5.06	7.05	5.37	6.62	7.10		8.18	7.41	8.67	4.34	4.95	7.28	6.73	6.21	5.50	6.14	6.22
Min	7.63	5.56	4.10	3.16	4.94	6.95	4.13	6.23	5.78		7.84	7.04	7.53	3.91	4.82	6.30	6.12	5.93	5.38	5.81	3.16

[a] Project not conducted in 1992 because of a lack of funding. No data collected.

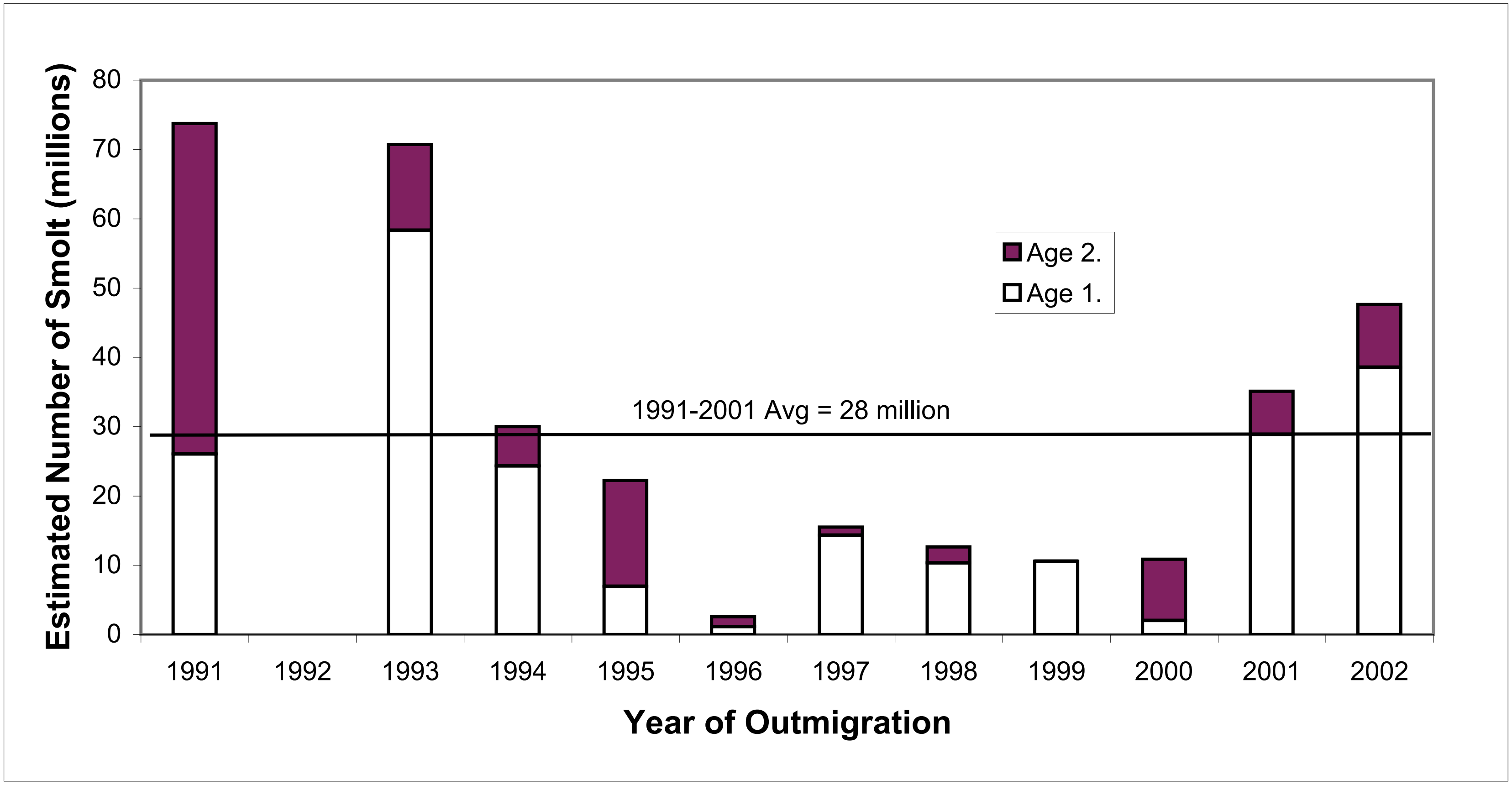


Appendix D.2. Average water velocity at Ugashik River smolt sonar inshore array, May 15 to June 15, 1983-2002.

APPENDIX E: SMOLT ESTIMATE DATA BY OUTMIGRATION YEAR

Appendix E.1. Total smolt outmigration estimates for Ugashik River by outmigration year, 1983-2002.

Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/21-6/16	27	5/26	6/01	6/13	6/07	5,355,409	44,033,811	
1984	5/22-6/16	26	5/24	6/01	6/08	6/01	26,771,956	158,174,626	
1985	5/22-6/17	27	5/24	6/05	6/11	6/04	5,498,113	34,101,390	Intermittent ice floes - 5/17-5/21
1986	5/21-6/13	24	5/30	6/02	6/10	5/30	9,142,549	53,076,253	
1987	5/17-6/13	28	5/21	6/03	6/06	6/03	4,944,521	26,947,225	
1988	5/17-6/13	28	5/28	6/06	6/10	6/07	55,816,902	215,968,015	
1989	5/22-6/15	25	5/25	5/31	6/09	5/25	22,376,115	126,298,122	
1990	5/20-6/13	25	5/26	5/30	6/07	5/29	13,459,723	53,627,347	Poor Weather - 199 h disabled time
1991	5/20-6/13	25	5/25	6/02	6/06	6/02	11,905,863	73,769,877	Poor Weather - 187 h disabled time
1992		0							
1993	5/17-6/11	26	5/26	5/30	6/06	5/26	12,360,357	70,747,074	Bad Weather - 264 h disabled time
1994	5/20-6/12	24	5/28	6/04	6/07	6/04	6,914,049	30,030,624	Excellent Weather - 44 h disabled time
1995	5/22-6/12	22	5/24	5/26	6/01	5/25	4,355,545	22,234,137	Excellent Weather - 21 h disabled time
1996	5/19-6/11	24	5/25	5/30	6/04	6/04	627,517	2,576,812	Fair Weather - 105 h disabled time
1997	5/10-6/12	34	5/18	5/24	5/30	5/24	4,065,127	15,519,783	Excellent Weather - 31 h disabled time
1998	5/17-6/12	27	5/27	6/05	6/11	6/05	2,058,183	12,624,441	Fair Weather - 148 h disabled time
1999	5/17-6/12	27	5/29	6/10	6/11	6/10	4,171,058	10,631,631	Intermittent to heavy ice floes - 5/18-5/23; good weather - 62 h disabled time
2000	5/19-6/11	24	5/25	5/31	6/05	6/01	1,908,369	10,880,559	Good Weather - 88 h disabled time
2001	5/20-6/12	24	5/29	6/03	6/07	6/02	6,018,400	35,123,888	Excellent Weather - 15 h disabled time
1991-01 Max		34	5/29	6/10	6/11	6/10	12,360,357	73,769,877	
1991-01 Avg		23	5/25	6/01	6/05	6/01	5,438,447	28,413,883	
1991-01 Min		0	5/18	5/24	5/30	5/24	627,517	2,576,812	
2002	5/19-6/12	25	5/26	5/31	6/04	5/31	7,903,931	47,627,642	Fair Weather - 115 h disabled time



Appendix E.2. Age composition of smolt outmigration estimates for Ugashik River by outmigration year, 1991-2002.

APPENDIX F: MEAN WATER TEMPERATURES

Appendix F.1. Comparison of Ugashik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-2002.

	Sonar Startup		Peak Smolt Passage	
Year	Smolt Day	Mean Water Temperature °C	Smolt Day	Mean Water Temperature °C
1984	22-May	4.5	1-Jun	6.5
1985	22-May	3.8	4-Jun	5.5
1986	21-May	3.0	30-May	5.3
1987	17-May	5.5	3-Jun	7.3
1988	17-May	6.0	7-Jun	8.3
1989	22-May	3.5	25-May	4.8
1990	20-May	3.0	29-May	6.8
1991	20-May	4.3	2-Jun	6.5
1992 [a]				
1993	17-May	6.0	26-May	7.5
1994	20-May	5.9	4-Jun	8.0
1995	22-May	4.5	25-May	5.3
1996	19-May	4.0	4-Jun	7.0
1997	10-May	6.0	24-May	6.5
1998	17-May	3.5	5-Jun	6.0
1999	21-May	1.0	10-Jun	5.0
2000	19-May	4.5	1-Jun	7.5
2001	20-May	4.5	6-Jun	5.0
Max		6.0		8.3
Avg		4.3		6.4
Min		1.0		4.8
2002	19-May	5.0	31-May	7.0

[a] Project not conducted. No data collected.

APPENDIX G. CLIMATOLOGICAL FACTORS THAT MAY HAVE AFFECTED THE FRESHWATER SURVIVAL OF 2002 SMOLT

The freshwater survival of sockeye salmon smolt from brood years 1998, 1999, and 2000 may have been affected by climatic factors outlined below; however, we have no direct information indicating the magnitude or direction of the effect.

	Juvenile sockeye salmon life stages by 12 month periods			
Brood Year	July 1998 to June 1999	July 1999 to June 2000	July 2000 to June 2001	July 2001 to June 2002
1998	Egg / alevin / Age 0. fry/smolt	Age 1. fry/smolt	Age 2. fry/smolt	Age 3. smolt
1999		Egg / alevin / Age 0. fry/smolt	Age 1. fry/smolt	Age 2.smolt
2000			Egg / alevin / Age 0. fry/smolt	Age 1. smolt

Air Temperature

According to air temperature data collected by the National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f) the overall annual temperatures for King Salmon and vicinity from July through June in 1998-1999 was -3.1 ^oF colder, in 1999-2000 was -1.6 ^oF colder, in 2000-2001 was 3.9 ^oF warmer, and in 2001-2002 was -0.3 ^oF colder than the 30-year mean (Appendix G.1).

Average monthly temperatures for the same time periods are shown in (Appendix G.2). Some colder months which may have adversely impacted salmon eggs, fry, and smolt in the Kvichak and Ugashik River drainages were December 1998 (7.4 ^oF below average); January, February, March, and December 1999 (7.4 ^oF, 6.1 ^oF, 12.3 ^oF, 11.0 ^oF, 15.4 ^oF below average); January 2000 (12.9 ^oF below average); and December 2001 (9.4 ^oF below average). Temperatures during the remaining months were near or above the 30-year mean, which should have been favorable for the development and survival of juvenile salmon. The spring and the fall of 2000, the winter of 2000/2001, and the spring of 2001 had very favorable temperatures for juvenile salmon.

Air temperatures during the winter of 1998-1999 were the coldest that the Bristol Bay area has experienced in the last 10-years. Between October 1998 and April 1999 there were 142 d with average daily air temperatures less than or equal to 32 ^oF and 45 d with average daily temperatures less than 0 ^oF (Appendix G.3). The winter of 1998-1999 had only 70 d with average daily air temperatures greater than 32 ^oF which may have slowed development of salmon eggs and fry from the 1998 brood year. Below normal temperatures predominated from late November to mid-December (18 d), late December to early January (10 d), mid-January to mid- February (22 d) and late February to mid-March (19d).

During the winter of 1999-2000, air temperatures from October through January were colder than 1998-1999, but the remainder of the winter was much warmer. Between October 1999 and April 2000 there were 137 d with average daily air temperatures less than or equal to 32 ^{o}F and 31 d with average daily temperatures less than 0 ^{o}F (Appendix G.4). The winter of 1999-2000 had 76 d with average daily air temperatures greater than 32 ^{o}F which may have benefited fry and smolt from the 1998 brood year as well as salmon eggs and fry from the 1999 brood year. Below normal temperatures predominated from late October to mid-January (67 d), late January to early February (5 d), and late March to early April (7d).

The winter of 2000-2001 was one of the warmest winters in the last 30-years. Air temperatures from November through February were all well above normal. Between October 2000 and April 2001 there were 119 d with average air temperatures above 32 ^{o}F, 93 d with average daily air temperatures less than or equal to 32 ^{o}F and 2 d with average daily temperatures less than 0 ^{o}F (Appendix G.5). These milder winter temperatures may have created more favorable rearing conditions for salmon eggs and fry from the 2000 brood year as well as smolt and fry from the 1998-1999 brood years.

The winter of 2001-2002 was one of the coolest winters in the last 10-years. Air temperatures from mid-October through mid-November were below normal and December was the coldest month of the winter. Between October 2001 and April 2002 there were only 48 d with average air temperatures above 32 ^{o}F, 114 d with average daily air temperatures less than or equal to 32 ^{o}F and 20 d with average daily temperatures less than 0 ^{o}F (Appendix G.6). These cooler temperatures may have slowed development and decreased survival of salmon eggs and fry from the 2001 brood year as well as smolt and fry from the 1998-2000 brood years.

Precipitation

Precipitation data collected by the National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f) for King Salmon and vicinity from July through June in 1998-1999, 1999-2000, 2000-2001, and 2001-2002 were 1.2 in more, 0.8 in less, 0.1 in more, and 0.9 in less than the 30-year mean annual precipitation of 19.2 in (Appendix G.7).

Average monthly precipitations during the 1998-1999 season fluctuated above and below the 30-year mean (Appendix G.8). The average monthly precipitations for August and October were 3.59 in and 3.96 in; 27% and 86% greater than the 30-year mean. This increased precipitation in the fall may have caused some flooding which could decrease freshwater survival of eggs from the 1998 brood year because of scouring and siltation of salmon redds. The months in which low precipitation may have impacted freshwater survival of sockeye salmon in east side Bristol Bay river systems were December through April. The precipitation for these months was 36%, 55%, 32%, 56%, and 33% less than the 30-year mean. It is unknown how this increase followed by decreases in precipitation may have effected the eggs, alevin, and age-0. fry (1998 brood year).

Average monthly precipitations during the 1999-2000 season were less than the 30-year mean in 7 out of 12 months (Appendix G.8). The months in which precipitation probably did not impact the freshwater survival of sockeye salmon in east side Bristol Bay river systems were July through October, December through February, and June. The average monthly precipitations for the remaining 5 months were below the 30-year mean. Low water levels may have reduced access to and availability of suitable adult salmon spawning habitat and juvenile rearing habitat. Lower than usual precipitation in the spring may also have dewatered some smaller tributaries and prevented fry from entering rearing areas in the lakes.

Average monthly precipitations during the 2000-2001 season were greater than or equal to the 30-year mean in 6 out of 12 months (Appendix G.8). The months in which precipitation probably had the greatest impact upon freshwater survival of sockeye salmon in east side Bristol Bay river systems were July, November, February, and April. The average monthly precipitations for these months were 44%, 46%,156%, and 43% greater than the 30-year means. The increase in precipitation may have caused some flooding, although we have no direct information that significant flooding occurred.

Average monthly precipitations during the 2001-2002 season fluctuated above and below the 30-year mean (Appendix G.8). The average monthly precipitations for July, October, and January were 3.51 in, 3.61 in, and 2.40 in; 63%, 70%, and 123% greater than the 30-year mean. The increased precipitation mid-summer and in the fall may have caused some flooding which could decrease freshwater survival of eggs from the 2001 brood year because of scouring and siltation of salmon redds. The months in which low precipitation may have impacted freshwater survival of sockeye salmon in east side Bristol Bay river systems were September, November, December February, March, and May. The precipitation for these months was 40%, 91%, 38%, 33%, 81%, and 45% less than the 30-year mean. It is unknown how these increases followed by decreases in precipitation may have effected the eggs, alevin, and age-0. fry (2001 brood year).

Snowfall

Snowfall data collected for King Salmon and vicinity by the National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f) from July through June in 1998-1999, 1999-2000, 2000-2001, and 2001-2002 were 8.2 in more, 9.5 in more, 11.8 in less, and 15.4 in more than the 30-year mean annual snowfall of 46.4 in. (Appendix G.9).

Overall, snowfall during the winter of 1998-1999 season was above normal (Appendix G.10). The total monthly snowfalls for October, February, and April were 258%, 90%, and 154% respectively, above the 30-year mean. The warm spell that occurred in late October and early November melted most if not all of the October snow. Snowfalls in November, December, January, and March were below normal. It is unknown how the lack of insulating snow in the early half of the winter may have affected the incubating salmon eggs (1998 brood year) and rearing fry in east side Bristol Bay streams and lakes.

Average monthly snowfalls during the winter of 1999-2000 were above normal (Appendix G.10). The average monthly snowfalls during October and November were slightly less than normal, but were probably adequate to provide an insulating layer to protect developing salmon eggs and emerging fry (1999 brood year) from sharp changes in temperature. The insulating effects of the above average snowfall in December and January may have cancelled out the negative effects of the below normal temperatures (Appendix G.2).

During the winter of 2000-2001 the snowfall from October through January and the month of March were well below normal (Appendix G.10). Above average snowfalls did occur in February and April, however the insulating qualities of these later snowfalls and whether or not they provided any protection to developing eggs (2000 brood year) and rearing age-1. and -2. fry (1998 and 1999 brood years) from exposure to winter temperatures is unknown.

The winter of 2001-2002 is one of the snowiest winters in the King Salmon area in the last 10-years (Appendix G.10). Most of the snow came mid-winter; the monthly snowfalls from December through February were 50% above, 119% above, and 178% above normal. Snowfalls during the early and later months of the winter were well below normal. The insulating qualities of the heavy snowfalls may have protected developing eggs (2001 brood year) from exposure to severe temperatures.

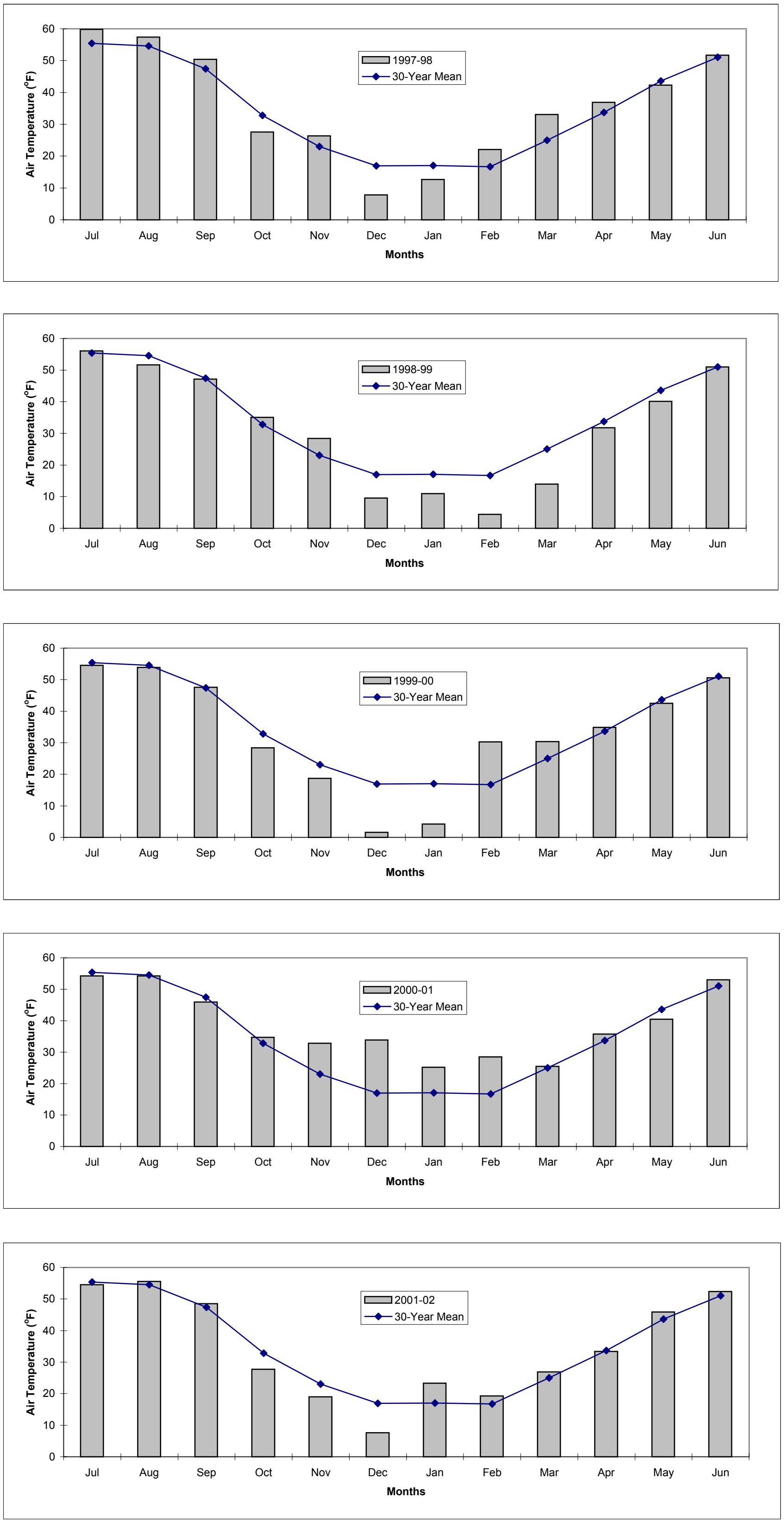
Appendix G.1. Average monthly air temperature for King Salmon, July 1972 to June 2002.

Smolt Year	Air Temperature (°F) [a]												
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Average Annual
1972-73	55.2	54.4	45.5	36.0	25.4	16.2	1.8	19.5	19.3	35.9	42.9	51.4	33.6
1973-74	55.6	54.6	47.2	34.1	24.7	17.9	9.5	0.4	23.2	35.6	45.5	51.2	33.3
1974-75	55.4	57.0	50.6	33.4	20.1	8.0	4.7	3.9	14.5	25.0	39.4	47.1	29.9
1975-76	54.7	53.6	47.1	32.4	12.7	10.2	12.3	7.3	15.3	29.5	39.5	46.9	30.1
1976-77	53.2	53.1	45.3	31.5	24.2	19.3	34.4	30.1	18.8	25.7	39.5	50.5	35.5
1977-78	54.3	56.8	47.0	31.7	14.1	10.6	28.6	24.8	25.6	37.5	45.2	49.5	35.5
1978-79	54.2	57.1	47.7	36.5	30.0	28.0	30.1	6.2	30.3	39.6	47.3	52.0	38.3
1979-80	57.8	56.0	50.0	39.4	29.4	4.5	9.0	20.7	27.6	36.4	41.7	48.9	35.1
1980-81	55.1	51.1	47.0	35.2	26.3	5.3	29.8	21.9	34.4	35.8	46.8	50.3	36.6
1981-82	55.1	54.8	44.9	33.2	23.4	13.3	17.0	12.8	23.9	25.5	40.3	48.9	32.8
1982-83	51.5	52.3	46.2	28.1	26.1	24.0	11.9	18.7	33.2	36.5	46.6	53.8	35.7
1983-84	57.4	54.1	45.5	28.8	30.1	27.2	17.4	-2.1	36.3	29.2	43.0	52.3	34.9
1984-85	53.7	53.5	48.0	30.1	22.5	24.7	32.6	10.6	22.6	20.8	39.9	47.4	33.9
1985-86	54.3	52.4	47.4	26.7	25.1	34.2	16.9	22.1	21.5	28.1	42.1	49.9	35.1
1986-87	53.7	52.2	48.8	36.1	26.3	30.6	21.1	24.3	29.8	32.3	42.8	49.3	37.3
1987-88	55.9	57.0	45.4	37.5	16.5	9.4	25.6	26.6	24.8	31.1	44.5	52.8	35.6
1988-89	56.8	53.5	45.8	30.9	13.9	20.8	-2.9	28.8	23.6	36.1	42.0	51.6	33.4
1989-90	56.3	57.1	51.7	36.7	18.1	19.5	16.8	-1.8	25.4	39.3	45.8	51.4	34.7
1990-91	56.0	55.9	47.5	31.5	17.3	20.4	17.5	14.2	25.7	36.4	44.5	50.4	34.8
1991-92	55.2	53.7	50.7	37.2	23.1	15.1	17.7	3.1	22.0	32.4	42.7	52.6	33.8
1992-93	55.6	53.9	41.0	31.7	23.5	19.2	15.0	22.7	31.1	41.0	48.3	53.1	36.3
1993-94	57.9	56.0	48.6	38.1	29.6	24.6	21.2	14.3	19.5	36.0	45.4	51.7	36.9
1994-95	55.7	55.9	48.6	29.9	19.3	14.3	19.5	23.1	17.4	40.3	46.4	53.2	35.3
1995-96	57.3	54.8	52.5	35.1	18.4	25.0	15.2	14.0	33.1	34.9	46.5	52.0	36.6
1996-97	55.3	52.9	43.6	29.4	25.6	6.3	12.8	30.3	20.8	37.7	47.8	54.0	34.7
1997-98	59.8	57.4	50.4	27.6	26.4	7.8	12.7	22.1	33.1	36.9	42.3	51.7	35.7
1998-99	56.1	51.7	47.2	35.1	28.4	9.6	11.0	4.4	14.0	31.8	40.1	51.0	31.7
1999-00	54.5	53.9	47.6	28.4	18.7	1.6	4.2	30.3	30.4	34.9	42.5	50.6	33.1
2000-01	54.2	54.2	45.9	34.7	32.8	33.9	25.2	28.5	25.5	35.8	40.5	53.0	38.7
2001-02	54.5	55.6	48.5	27.7	19.0	7.6	23.3	19.3	26.9	33.4	45.9	52.4	34.5
Max	59.8	57.4	52.5	39.4	32.8	34.2	34.4	30.3	36.3	41.0	48.3	54.0	38.7
30-Year Mean	55.4	54.6	47.4	32.8	23.0	17.0	17.1	16.7	25.0	33.7	43.6	51.0	34.8
Min	51.5	51.1	41.0	26.7	12.7	1.6	-2.9	-2.1	14.0	20.8	39.4	46.9	29.9

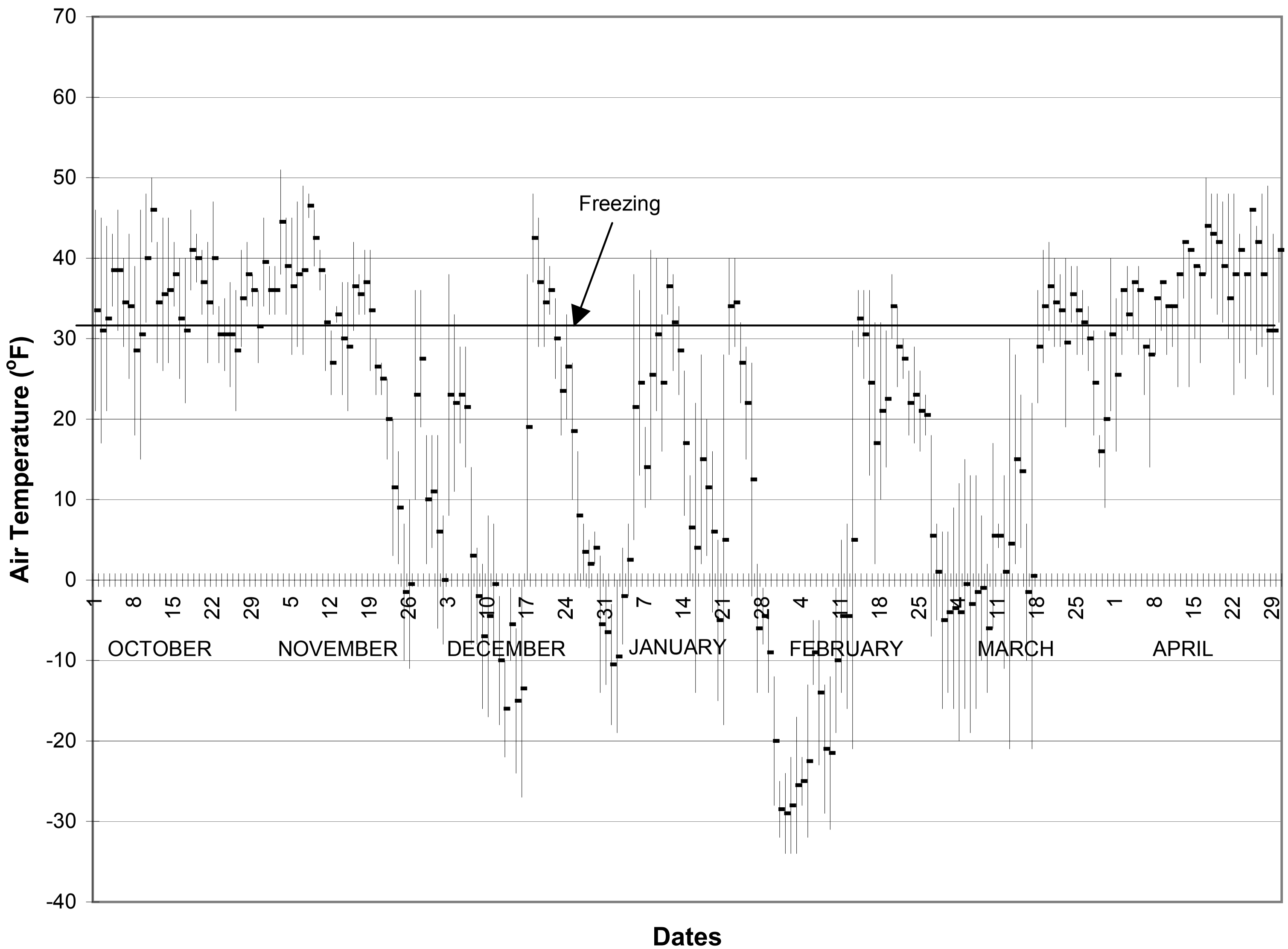
[a] Source - National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f)

1998-99	0.69	-2.85	-0.24	2.28	5.37	-7.37	-6.06	-12.30	-10.99	-1.91	-3.49	-0.03
1999-00	-0.91	-0.65	0.16	-4.42	-4.33	-15.37	-12.86	13.60	5.41	1.19	-1.09	-0.43
2000-01	-1.21	-0.35	-1.54	1.88	9.77	16.93	8.14	11.80	0.51	2.09	-3.09	1.97
2001-02	-0.91	1.05	1.06	-5.12	-4.03	-9.37	6.24	2.60	1.91	-0.31	2.31	1.37

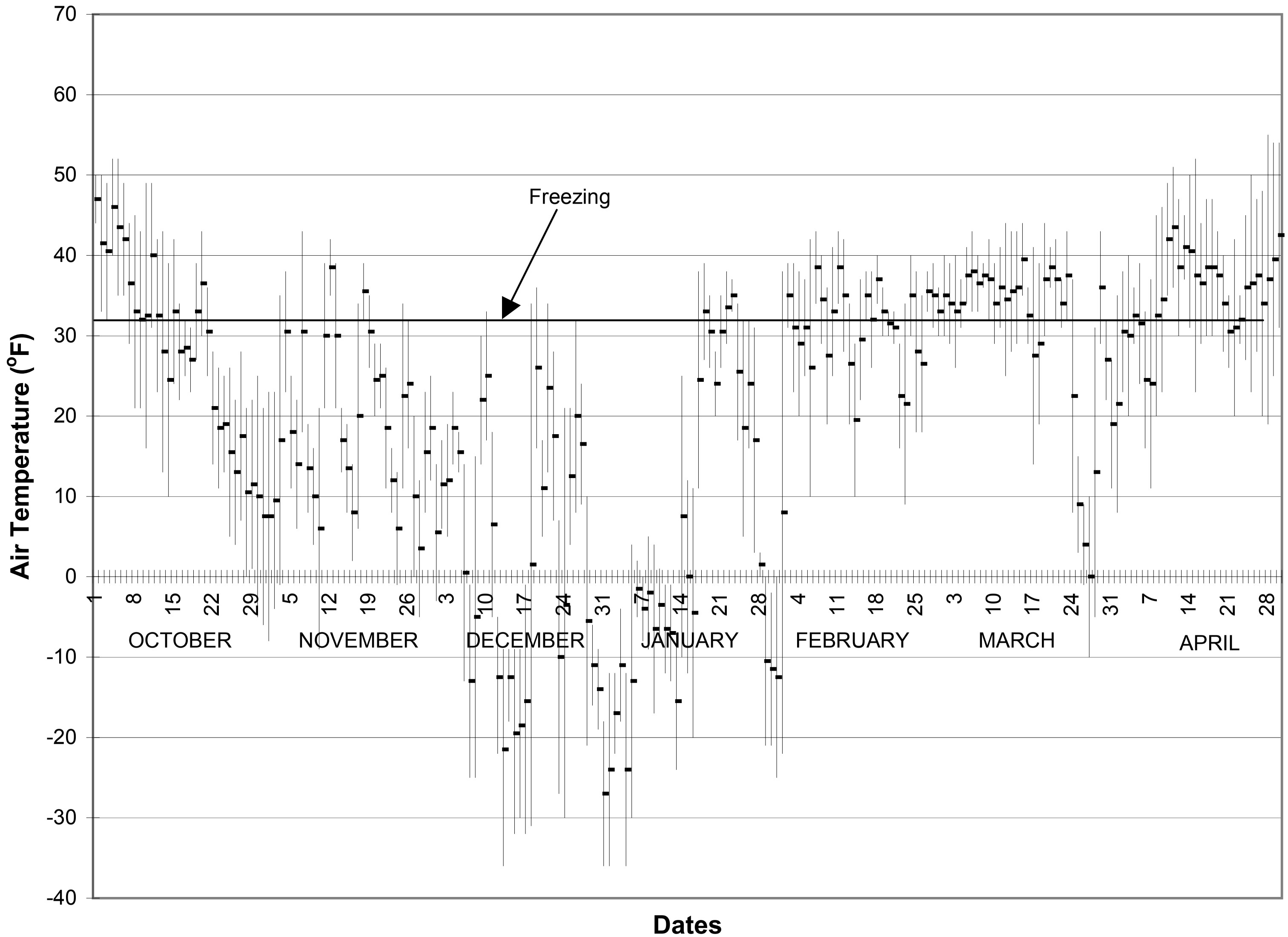
1998-99	0.01	-0.05	-0.01	0.07	0.23	-0.43	-0.36	-0.74	-0.44	-0.06	-0.08	0.00
1999-00	-0.02	-0.01	0.00	-0.13	-0.19	-0.91	-0.75	0.81	0.22	0.04	-0.03	-0.01
2000-01	-0.02	-0.01	-0.03	0.06	0.42	1.00	0.48	0.71	0.02	0.06	-0.07	0.04
2001-02	-0.02	0.02	0.02	-0.16	-0.18	-0.55	0.37	0.16	0.08	-0.01	0.05	0.03



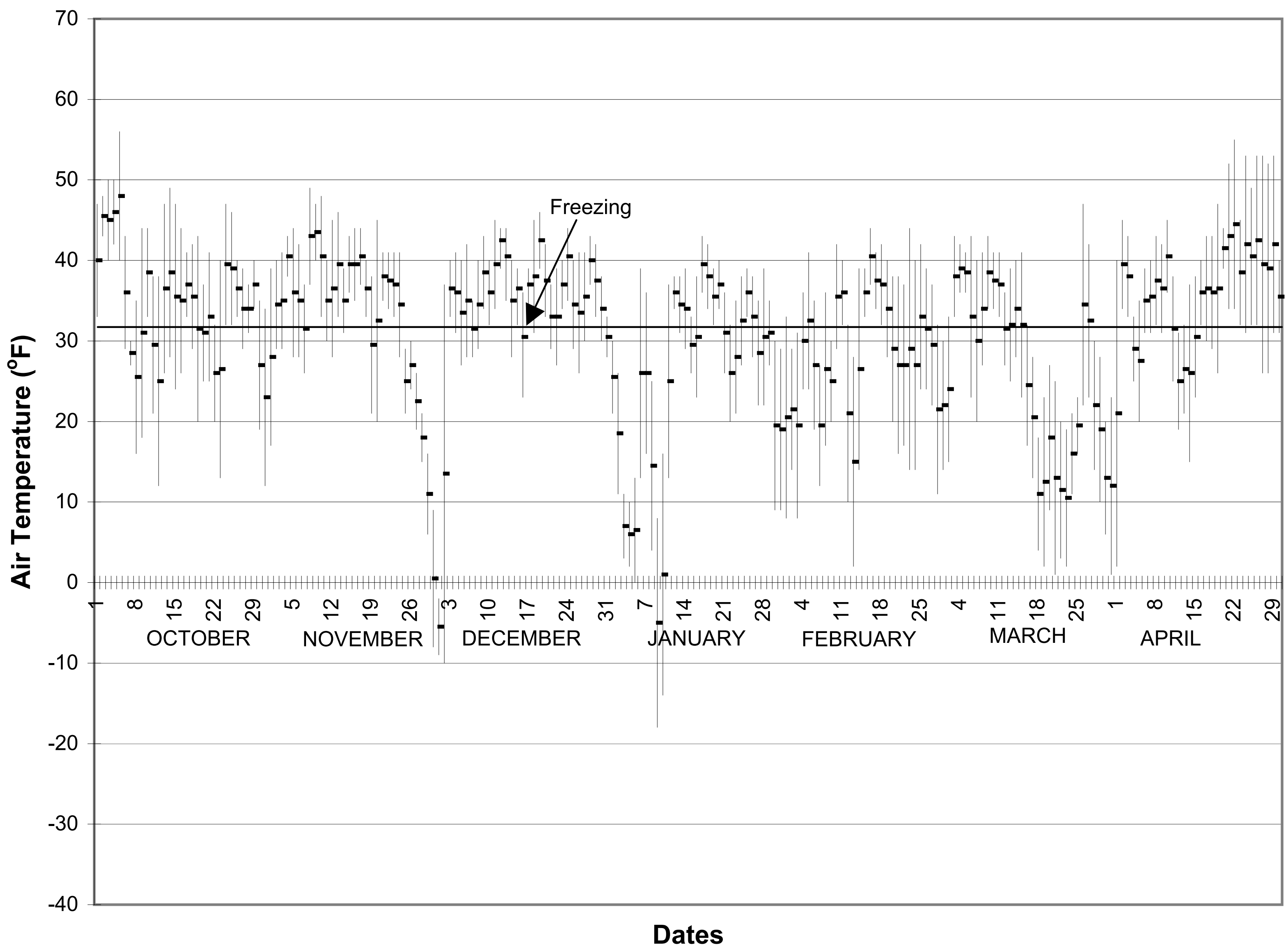
Appendix G.2. Comparison of monthly air temperature to the 30-year mean at King Salmon, July 1998 to June 2002.



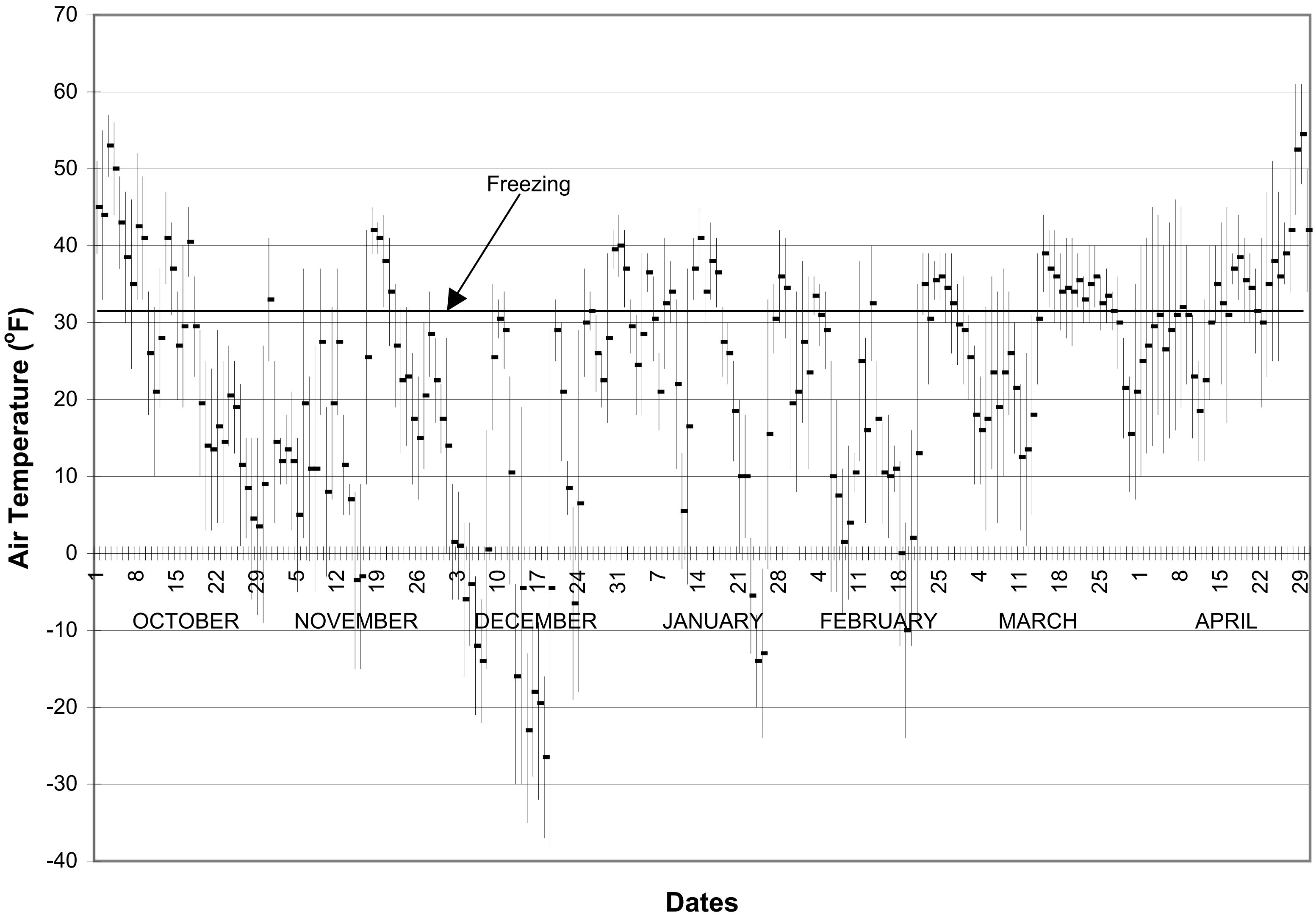
Appendix G.3. Daily air temperatures (normal, mean and extreme) for King Salmon, October 1998 to April 1999.



Appendix G.4. Daily air temperatures (normal, mean and extreme) for King Salmon, October 1999 to April 2000.



Appendix G.5. Daily air temperature (normal, mean and extreme) for King Salmon, October 2000 to April 2001.



Appendix G.6. Daily air temperatures (normal, mean and extreme) for King Salmon, October 2001 to April 2002.

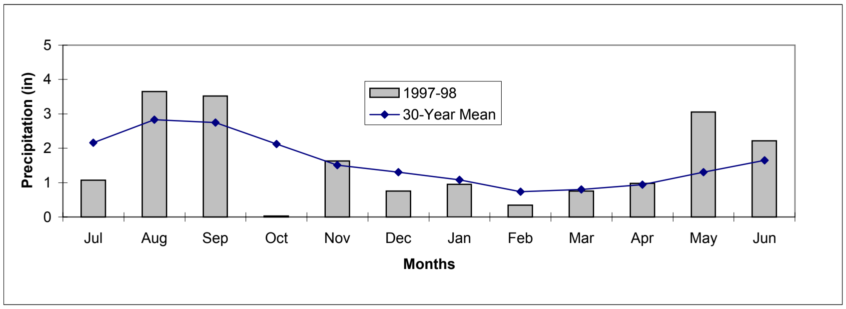
Appendix G.7. Average monthly precipitation for King Salmon, July 1972 to June 2002.

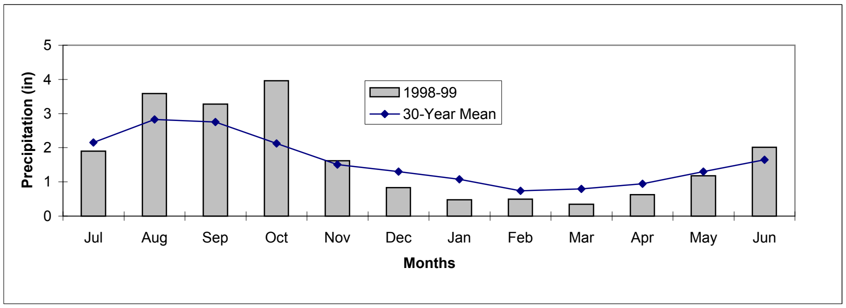
Smolt Year	Precipitation (in) [a] Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total Annual
1972-73	1.08	1.95	2.95	2.57	1.35	0.59	0.62	0.11	1.25	0.43	1.83	1.48	16.21
1973-74	2.43	3.80	1.41	1.52	0.97	1.10	0.86	0.55	1.27	1.18	0.57	2.40	18.06
1974-75	2.01	3.19	1.56	2.90	1.20	1.23	2.14	0.76	0.93	2.65	0.86	2.69	22.12
1975-76	0.74	1.05	3.90	2.10	0.46	1.38	1.24	0.97	0.78	0.58	1.47	1.34	16.01
1976-77	2.60	1.71	2.64	0.81	2.06	1.77	0.85	1.35	1.99	1.68	1.72	0.99	20.17
1977-78	1.60	3.16	2.58	3.29	0.58	1.04	0.70	0.28	0.26	0.58	0.98	2.81	17.86
1978-79	1.66	2.03	1.87	2.84	1.77	3.65	1.00	0.29	0.39	1.20	0.46	1.80	18.96
1979-80	2.24	2.50	0.91	2.71	2.89	1.09	1.46	0.83	1.51	0.42	1.61	2.19	20.36
1980-81	2.97	2.36	2.00	2.46	1.19	0.49	1.76	2.26	1.83	0.49	0.73	2.27	20.81
1981-82	2.17	3.93	1.82	1.59	1.31	0.59	1.48	0.15	1.37	1.20	1.55	3.04	20.20
1982-83	1.98	1.99	5.14	1.41	0.83	1.37	0.42	0.25	0.22	2.22	1.37	1.20	18.40
1983-84	1.53	2.33	2.36	2.82	0.98	0.48	1.17	0.55	0.44	0.43	1.08	1.59	15.76
1984-85	1.30	2.41	0.89	0.57	1.00	1.79	0.95	0.73	1.27	0.34	1.16	1.23	13.64
1985-86	1.31	3.24	2.64	2.29	3.35	1.58	1.33	0.19	0.24	0.98	1.01	0.93	19.09
1986-87	2.44	3.22	4.03	2.50	1.91	0.65	2.38	0.54	0.55	0.81	1.74	1.49	22.26
1987-88	1.94	2.73	2.99	2.47	2.75	1.07	0.56	0.75	0.74	1.02	2.95	1.11	21.08
1988-89	2.73	2.88	2.17	1.68	1.52	1.60	0.84	0.93	0.19	0.99	2.32	1.10	18.95
1989-90	3.04	3.15	5.90	2.86	1.58	1.31	1.44	1.61	1.71	0.89	1.52	1.22	26.23
1990-91	5.08	2.02	2.75	2.38	2.10	3.26	0.55	0.58	1.56	0.86	1.24	1.63	24.01
1991-92	1.02	1.79	2.10	1.99	1.34	1.26	0.79	0.92	1.40	0.19	0.74	2.53	16.07
1992-93	3.02	4.73	1.35	1.11	1.45	1.77	1.48	0.35	0.26	0.50	0.70	0.50	17.22
1993-94	1.01	3.21	4.53	1.98	3.00	2.15	1.35	1.22	0.91	1.35	1.74	1.71	24.16
1994-95	3.77	3.17	3.46	2.41	2.98	2.28	0.35	0.49	0.17	1.51	1.44	0.81	22.84
1995-96	2.27	4.73	2.74	1.46	0.13	0.14	0.70	0.75	0.38	0.87	0.84	2.41	17.42
1996-97	1.27	2.61	2.60	1.06	0.62	0.64	0.25	0.72	0.13	0.38	0.67	1.14	12.09
1997-98	1.07	3.65	3.52	0.03	1.63	0.75	0.95	0.34	0.75	0.98	3.05	2.22	18.94
1998-99	1.90	3.59	3.28	3.96	1.62	0.83	0.48	0.50	0.35	0.63	1.18	2.01	20.33
1999-00	1.91	3.07	3.46	2.22	0.31	1.63	0.95	0.73	0.32	0.63	1.18	1.99	18.40
2000-01	3.11	2.28	3.30	2.13	2.20	0.69	0.85	1.88	0.58	1.35	0.63	0.21	19.21
2001-02	3.51	2.37	1.64	3.61	0.14	0.80	2.40	0.49	0.15	0.99	0.71	1.46	18.27
Max	5.08	4.73	5.90	3.96	3.35	3.65	2.40	2.26	1.99	2.65	3.05	3.04	26.23
30-Year Mean	2.16	2.83	2.75	2.12	1.51	1.30	1.08	0.74	0.80	0.94	1.30	1.65	19.17
Min	0.74	1.05	0.89	0.03	0.13	0.14	0.25	0.11	0.13	0.19	0.46	0.21	12.09

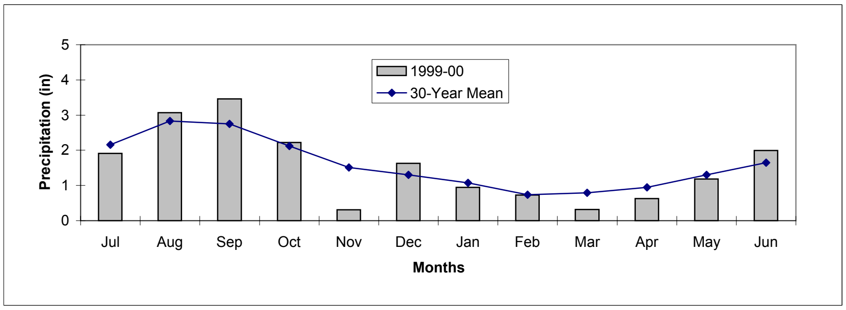
[a] Source - National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f)

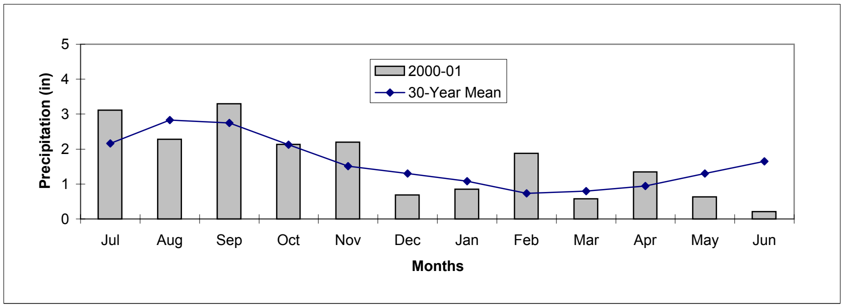
1998-99	-0.26	0.76	0.53	1.84	0.11	-0.47	-0.60	-0.24	-0.45	-0.31	-0.12	0.36
1999-00	-0.25	0.24	0.71	0.10	-1.20	0.33	-0.13	-0.01	-0.48	-0.31	-0.12	0.34
2000-01	0.95	-0.55	0.55	0.01	0.69	-0.61	-0.23	1.14	-0.22	0.41	-0.67	-1.44
2001-02	1.35	-0.46	-1.11	1.49	-1.37	-0.50	1.32	-0.25	-0.65	0.05	-0.59	-0.19

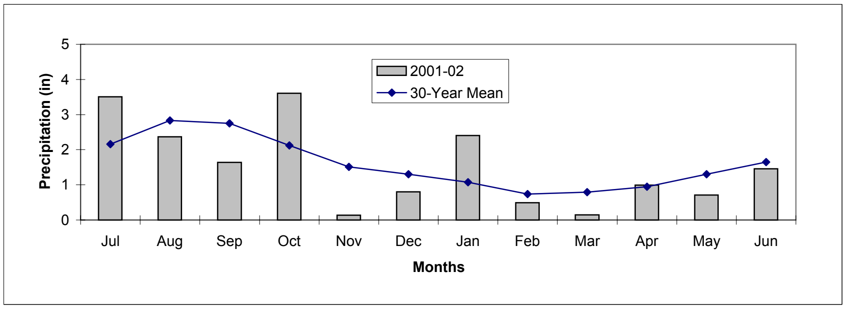
1998-99	-0.12	0.27	0.19	0.86	0.07	-0.36	-0.55	-0.32	-0.56	-0.33	-0.09	0.22
1999-00	-0.11	0.09	0.26	0.05	-0.79	0.25	-0.12	-0.01	-0.60	-0.33	-0.09	0.21
2000-01	0.44	-0.19	0.20	0.00	0.46	-0.47	-0.21	1.56	-0.27	0.43	-0.52	-0.87
2001-02	0.63	-0.16	-0.40	0.70	-0.91	-0.38	1.23	-0.33	-0.81	0.05	-0.45	-0.12











Appendix G.8. Comparison of monthly precipitation to the 30-year mean at King Salmon, July 1998 to June 2002.

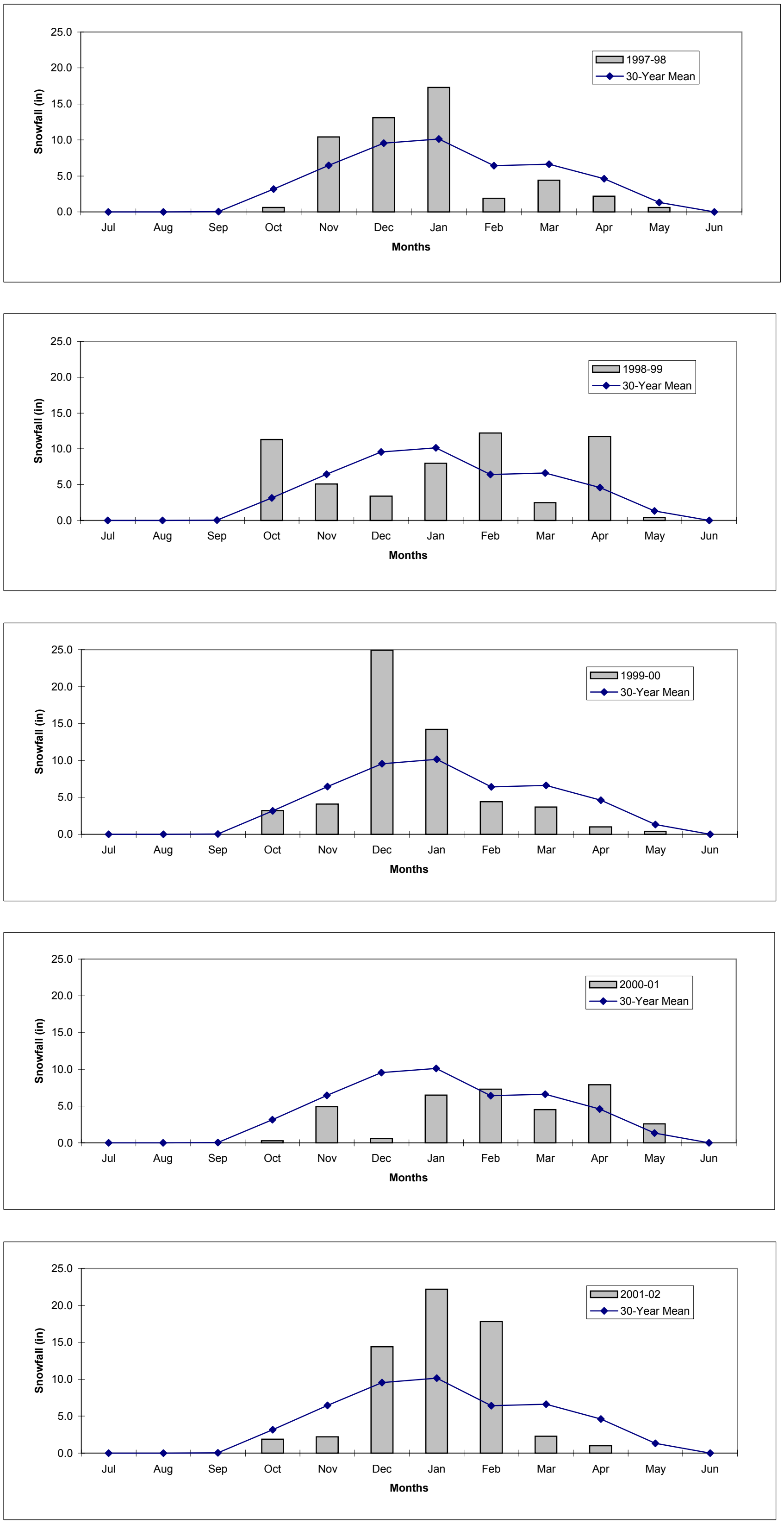
Appendix G.9. Average monthly snowfall for King Salmon, July 1972 to June 2002.

Smolt Year	Snowfall (in) [a b]												
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total Annual
1972-73	0.0	0.0	T	0.8	8.0	2.1	3.0	0.8	8.1	2.2	0.6	0.0	25.6
1973-74	0.0	0.0	T	2.0	2.1	12.7	11.9	5.3	4.6	5.1	T	0.0	43.7
1974-75	0.0	0.0	0.0	T	4.3	10.9	19.1	6.3	8.7	14.3	2.9	0.0	66.5
1975-76	0.0	0.0	0.0	0.8	3.9	13.9	12.0	3.2	6.7	6.2	3.2	0.0	49.9
1976-77	0.0	0.0	0.0	2.0	10.9	11.0	2.1	11.9	20.0	4.6	T	0.0	62.5
1977-78	0.0	0.0	T	4.3	5.3	4.5	3.9	3.7	2.2	0.6	T	0.0	24.5
1978-79	0.0	0.0	0.0	1.0	2.2	14.1	4.4	0.2	1.1	T	T	0.0	23.0
1979-80	0.0	0.0	0.0	T	8.5	9.7	11.5	11.1	9.0	T	0.8	0.0	50.6
1980-81	0.0	0.0	0.0	0.3	6.1	6.8	10.5	11.3	15.8	0.6	T	T	51.4
1981-82	0.0	0.0	0.5	0.3	4.8	5.9	5.7	T	8.3	8.3	T	0.0	33.8
1982-83	0.0	0.0	0.0	2.8	2.0	2.9	4.0	2.0	T	6.0	0.1	0.0	19.8
1983-84	0.0	0.0	T	9.9	2.3	2.8	8.4	5.5	T	4.0	0.3	0.0	33.2
1984-85	0.0	0.0	0.0	3.4	7.3	3.8	3.7	6.4	8.9	3.4	6.1	0.0	43.0
1985-86	0.0	0.0	0.0	2.5	9.3	3.6	13.5	1.8	2.5	9.8	1.3	0.0	44.3
1986-87	0.0	0.0	0.0	2.3	2.5	4.8	24.7	2.7	2.7	9.4	T	0.0	49.1
1987-88	0.0	0.0	T	0.1	13.2	8.9	3.3	10.1	9.4	4.4	1.2	0.0	50.6
1988-89	0.0	0.0	T	3.4	12.7	9.2	14.9	3.7	5.1	1.5	2.1	0.0	52.6
1989-90	0.0	0.0	T	0.4	12.3	12.4	14.9	20.3	13.5	3.4	0.2	0.0	77.4
1990-91	0.0	0.0	T	15.7	6.7	18.9	3.1	4.3	14.0	2.8	0.0	0.0	65.5
1991-92	0.0	0.0	0.0	T	9.0	9.4	7.2	8.6	8.7	0.5	T	T	43.4
1992-93	0.0	0.0	T	0.9	7.9	8.0	30.6	5.5	5.2	1.8	T	T	59.9
1993-94	0.0	0.0	0.1	2.0	5.1	28.4	11.0	3.2	7.7	5.6	0.2	0.1	63.4
1994-95	0.0	0.0	0.0	8.4	17.9	16.0	5.9	2.0	2.0	0.4	0.1	0.1	52.8
1995-96	0.0	0.0	0.0	2.1	2.4	1.5	2.9	7.3	1.7	5.7	1.9	0.3	25.8
1996-97	0.0	0.0	0.3	2.6	0.1	8.5	3.7	5.2	2.3	T	T	0.0	22.7
1997-98	0.0	0.0	0.0	0.6	10.4	13.1	17.3	1.9	4.4	2.2	0.6	0.0	50.5
1998-99	0.0	T	T	11.3	5.1	3.4	8.0	12.2	2.5	11.7	0.4	T	54.6
1999-00	0.0	0.0	0.0	3.2	4.1	24.9	14.2	4.4	3.7	1.0	0.4	0.0	55.9
2000-01	0.0	0.0	0.0	0.3	4.9	0.6	6.5	7.3	4.5	7.9	2.6	0.0	34.6
2001-02	0.0	0.0	0.0	1.9	2.2	14.4	22.2	17.8	2.3	1.0	T	T	61.8
Max	0.0	0.0	0.5	15.7	17.9	28.4	30.6	20.3	20.0	14.3	6.1	0.3	77.4
30-Year Mean	0.0	0.0	0.0	3.2	6.5	9.6	10.1	6.4	6.6	4.6	1.3	0.0	46.4
Min	0.0	0.0	0.0	0.1	0.1	0.6	2.1	0.2	1.1	0.4	0.0	0.0	19.8

[a] Source - National Weather Service (1998; 1999; 2000; 2001; 2002a,b,c,d,e,f)
[b] T = trace

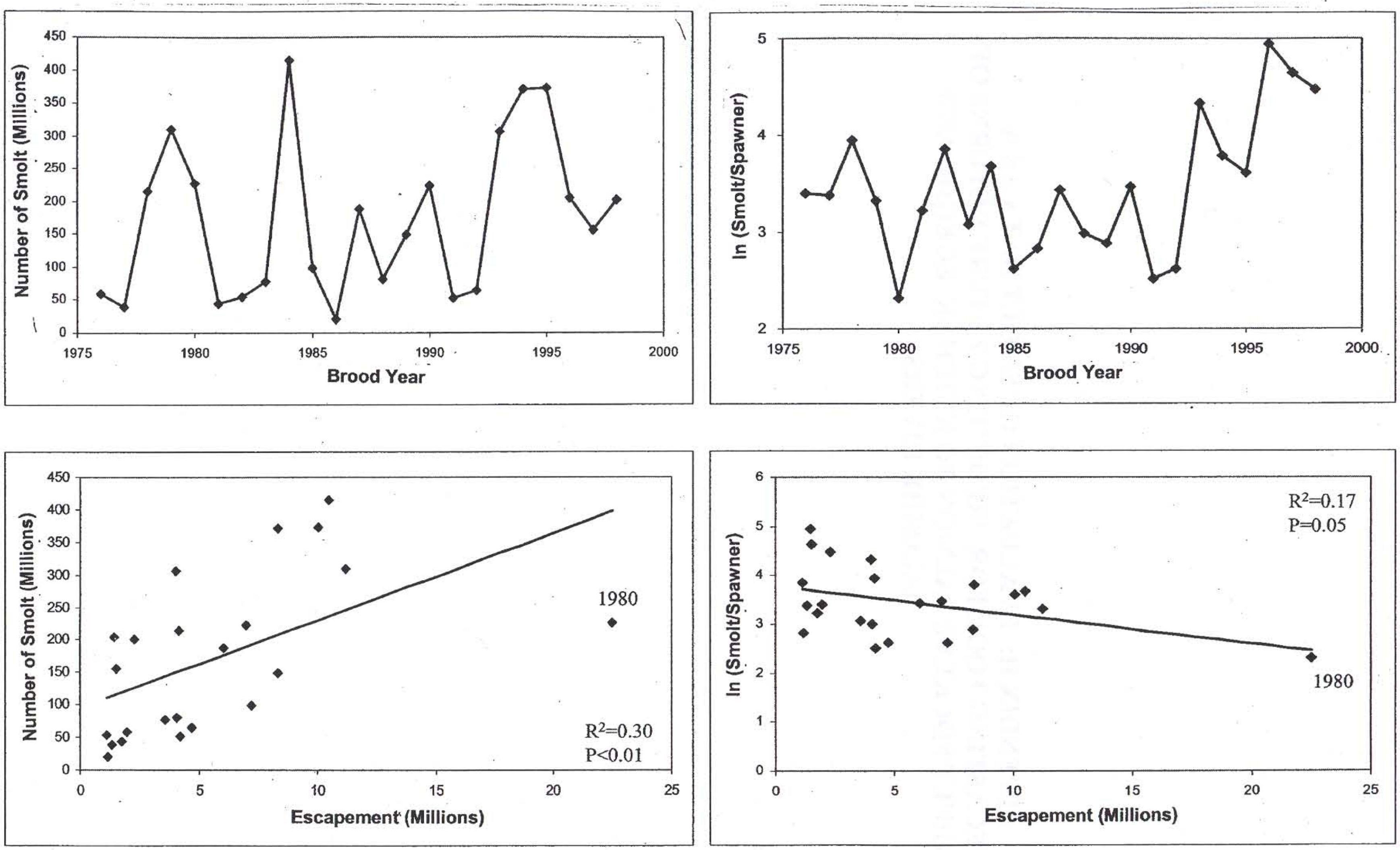
1998-99	0.00	T	T	8.14	-1.35	-6.17	-2.14	5.79	-4.13	7.09	-0.92	T
1999-00	0.00	0.00	-0.05	0.04	-2.35	15.33	4.06	-2.01	-2.93	-3.61	-0.92	-0.02
2000-01	0.00	0.00	-0.05	-2.86	-1.55	-8.97	-3.64	0.89	-2.13	3.29	1.28	-0.02
2001-02	0.00	0.00	-0.05	-1.26	-4.25	4.83	12.06	11.39	-4.33	-3.62	T	T

1998-99				2.58	-0.21	-0.64	-0.21	0.90	-0.62	1.54	-0.70	
1999-00			-1.00	0.01	-0.36	1.60	0.40	-0.31	-0.44	-0.78	-0.70	-1.00
2000-01			-1.00	-0.91	-0.24	-0.94	-0.36	0.14	-0.32	0.71	0.98	-1.00
2001-02			-1.00	-0.40	-0.66	0.50	1.19	1.78	-0.65	-0.79		

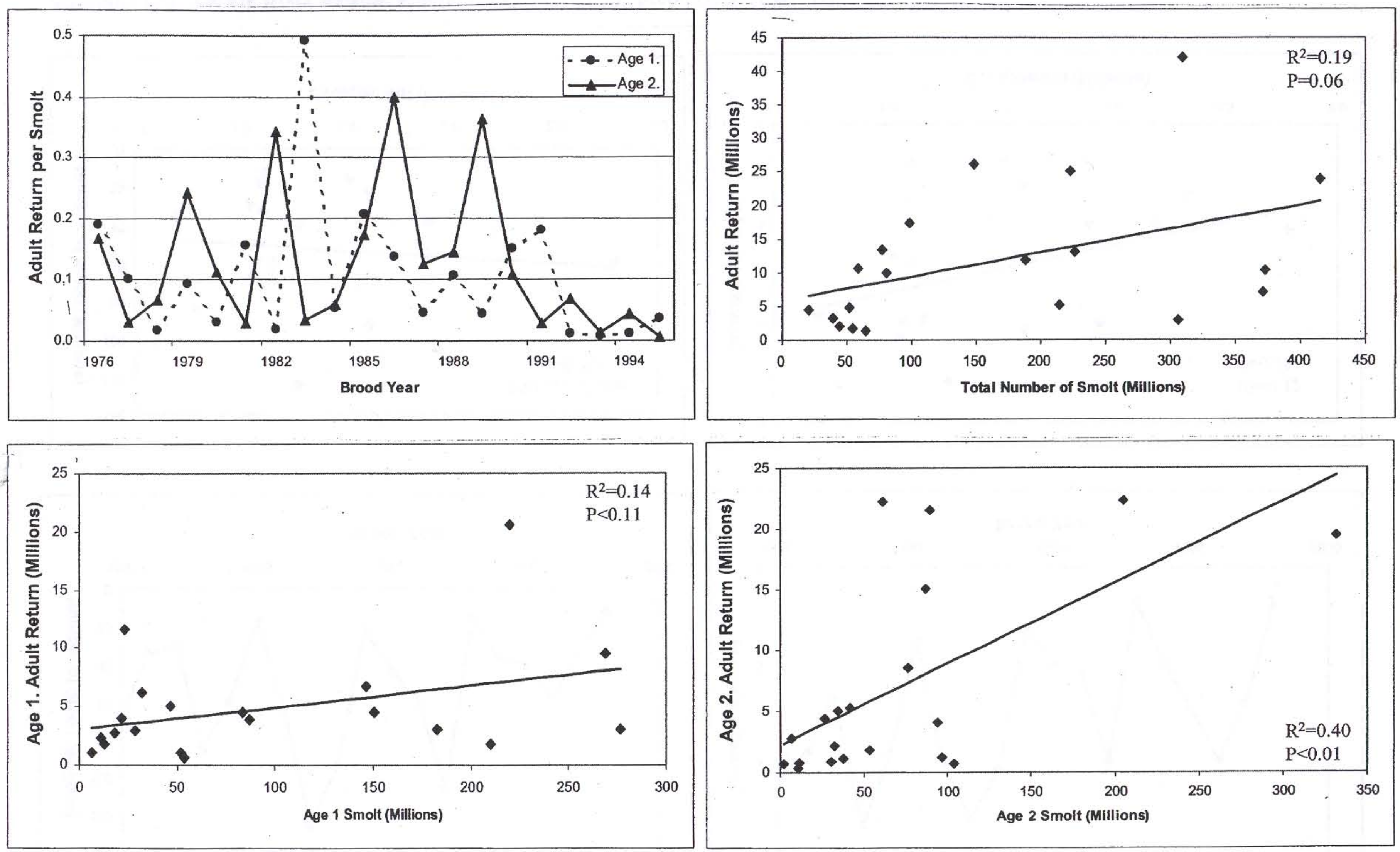


Appendix G.10. Comparison of monthly snowfall to the 30-year mean at King Salmon, July 1998 to June 2002.

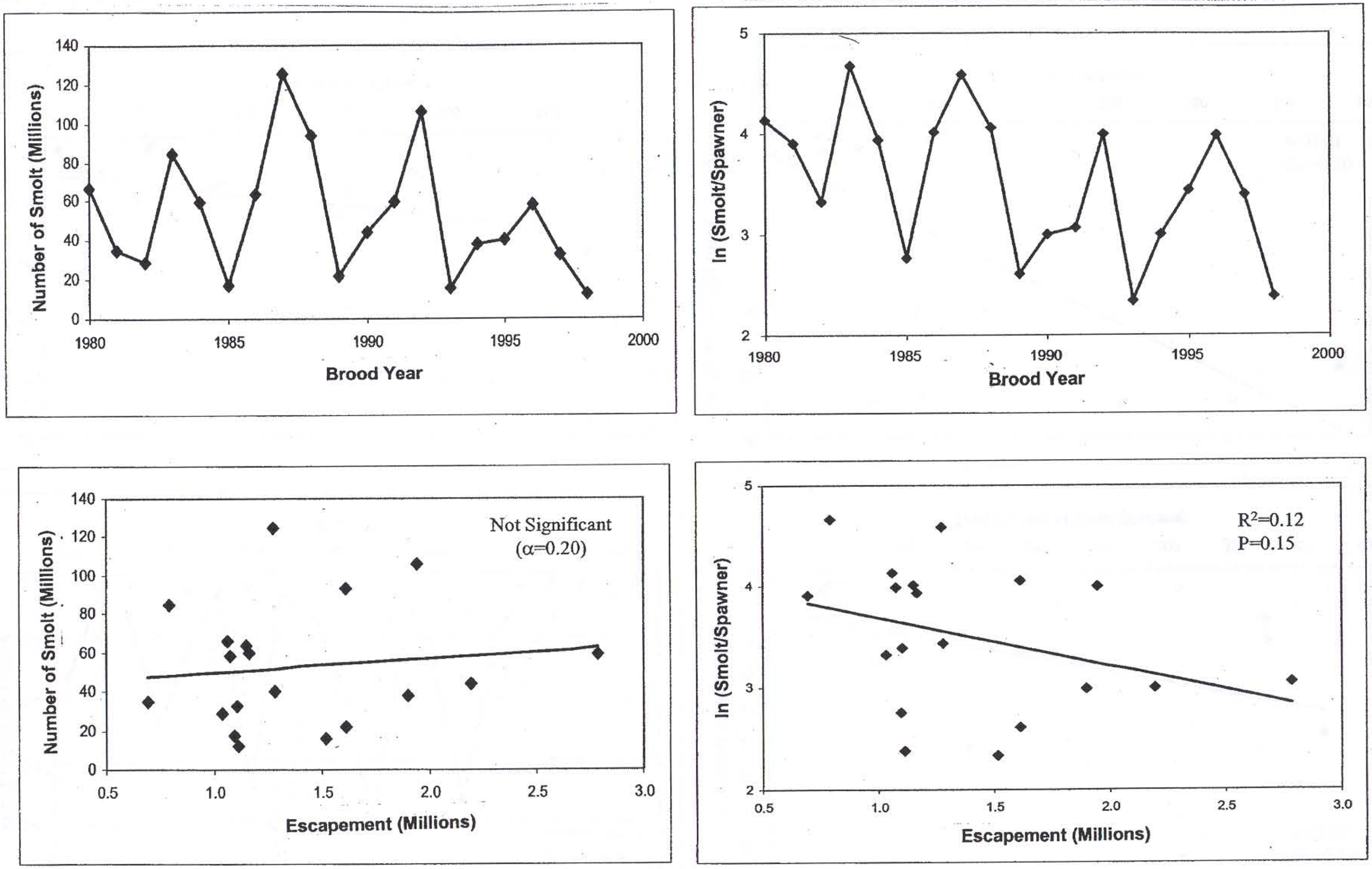
APPENDIX H: EVALUATION OF SMOLT DATA AS A FORECASTING TOOL FOR PREDICTING FUTURE RETURNS OF ADULT SOCKEYE SALMON TO KVICHAK, EGEGIK, AND UGASHIK RIVERS



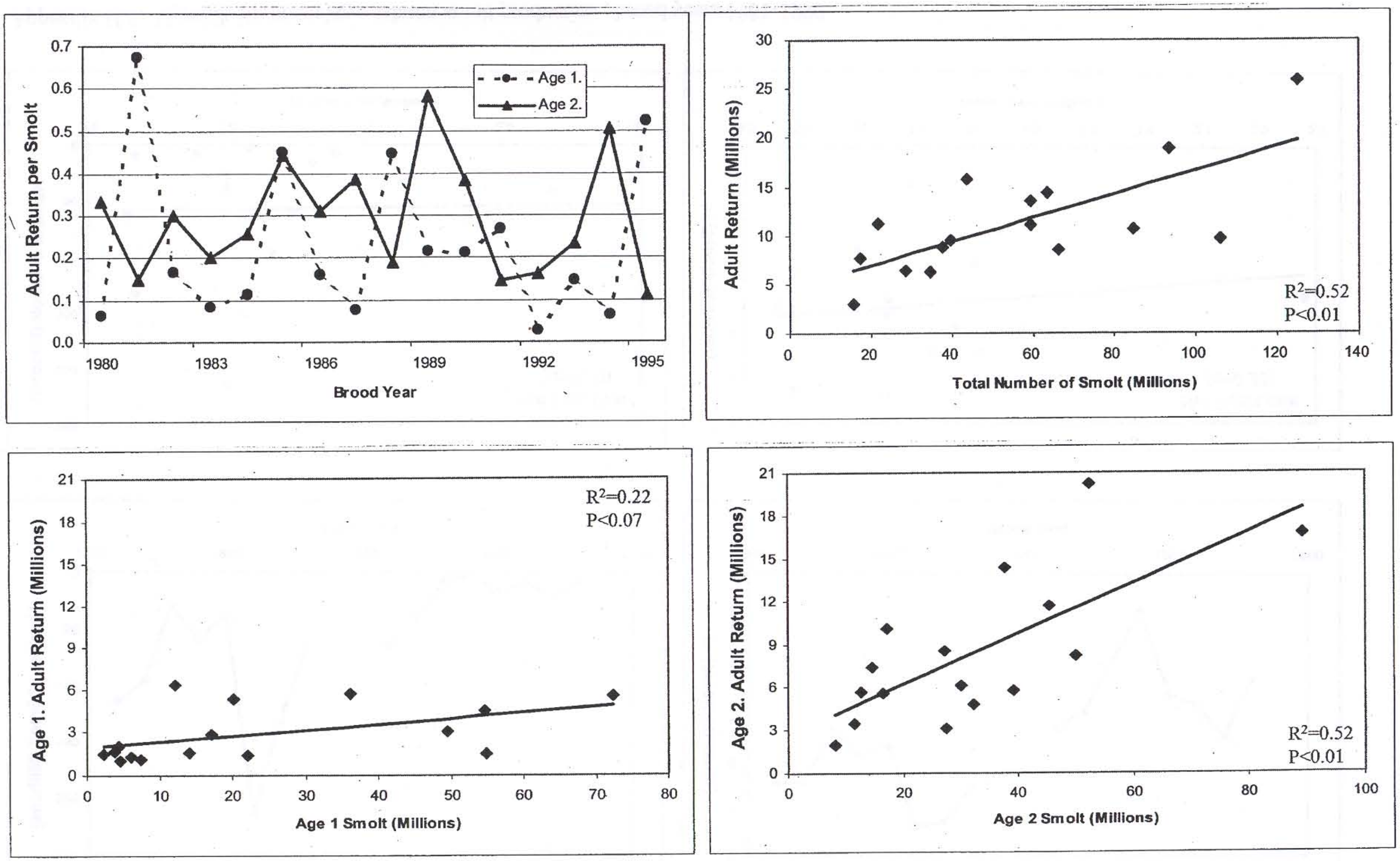
Appendix H.1. Kvichak River sockeye salmon smolt production , brood years 1976-1998.



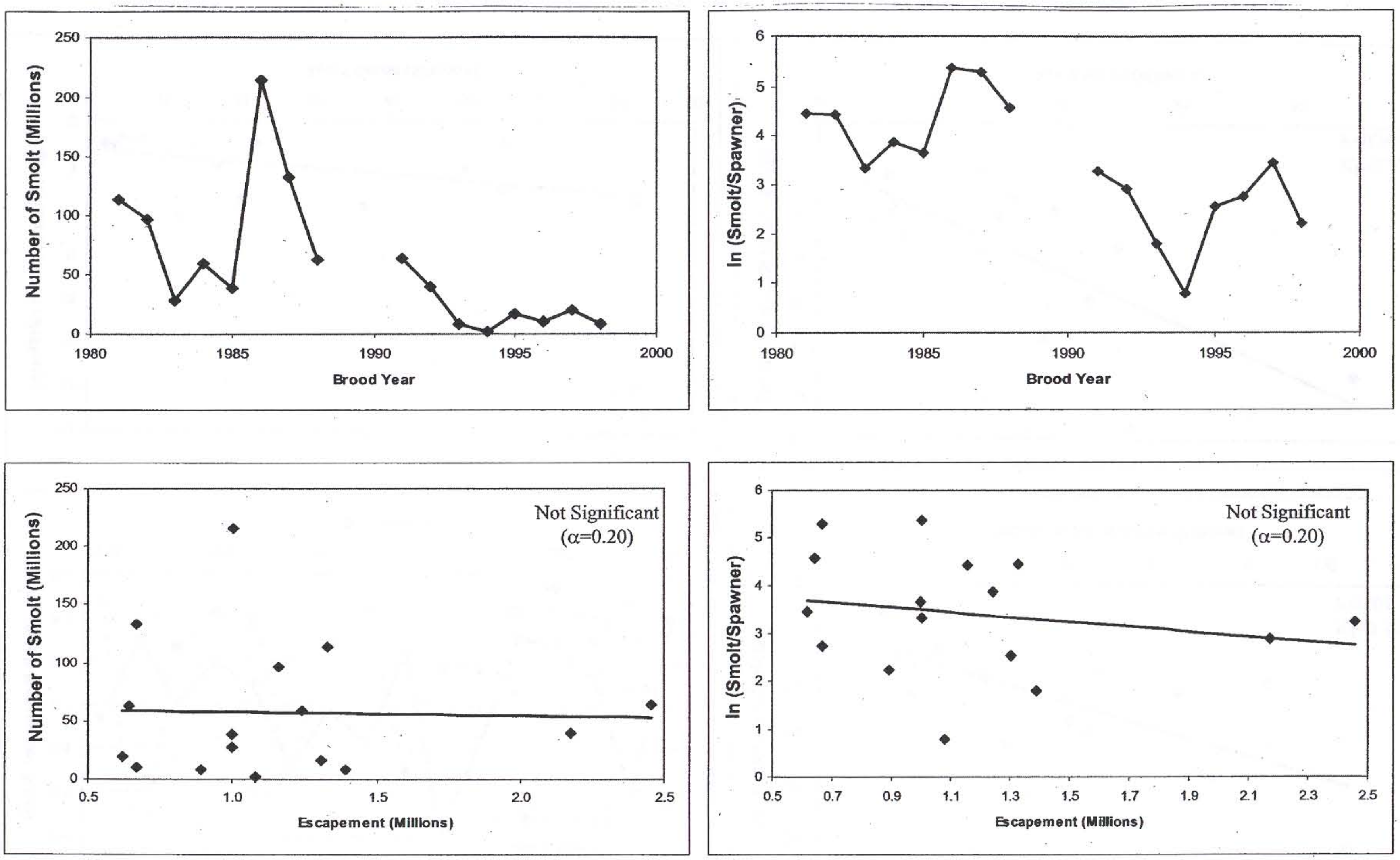
Appendix H.2. Marine survival of age-1. and –2. sockeye salmon smolt, Kvichak River, brood years 1976-1995.



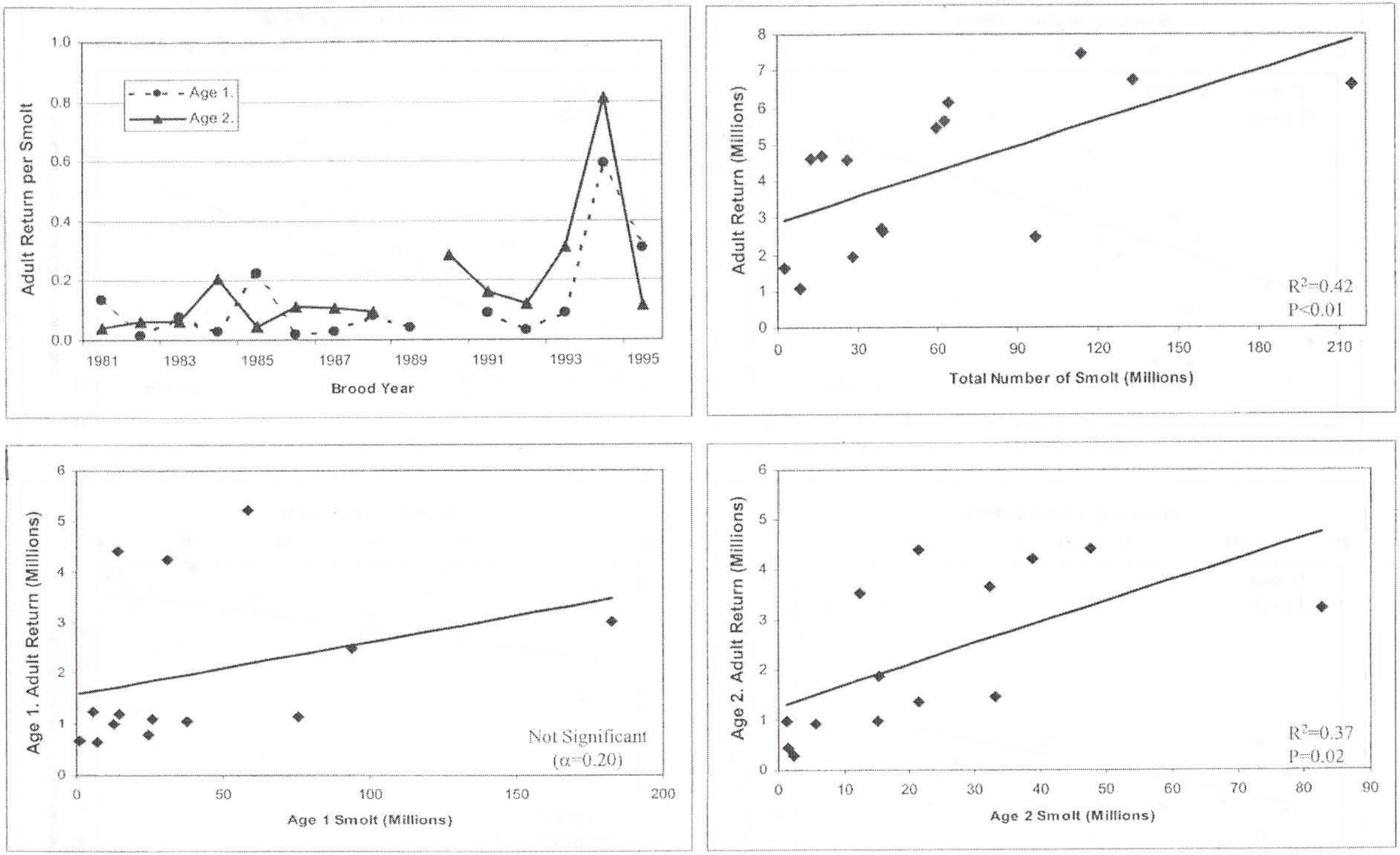
Appendix H.3. Egegik River sockeye salmon smolt production , brood years 1980-1998.



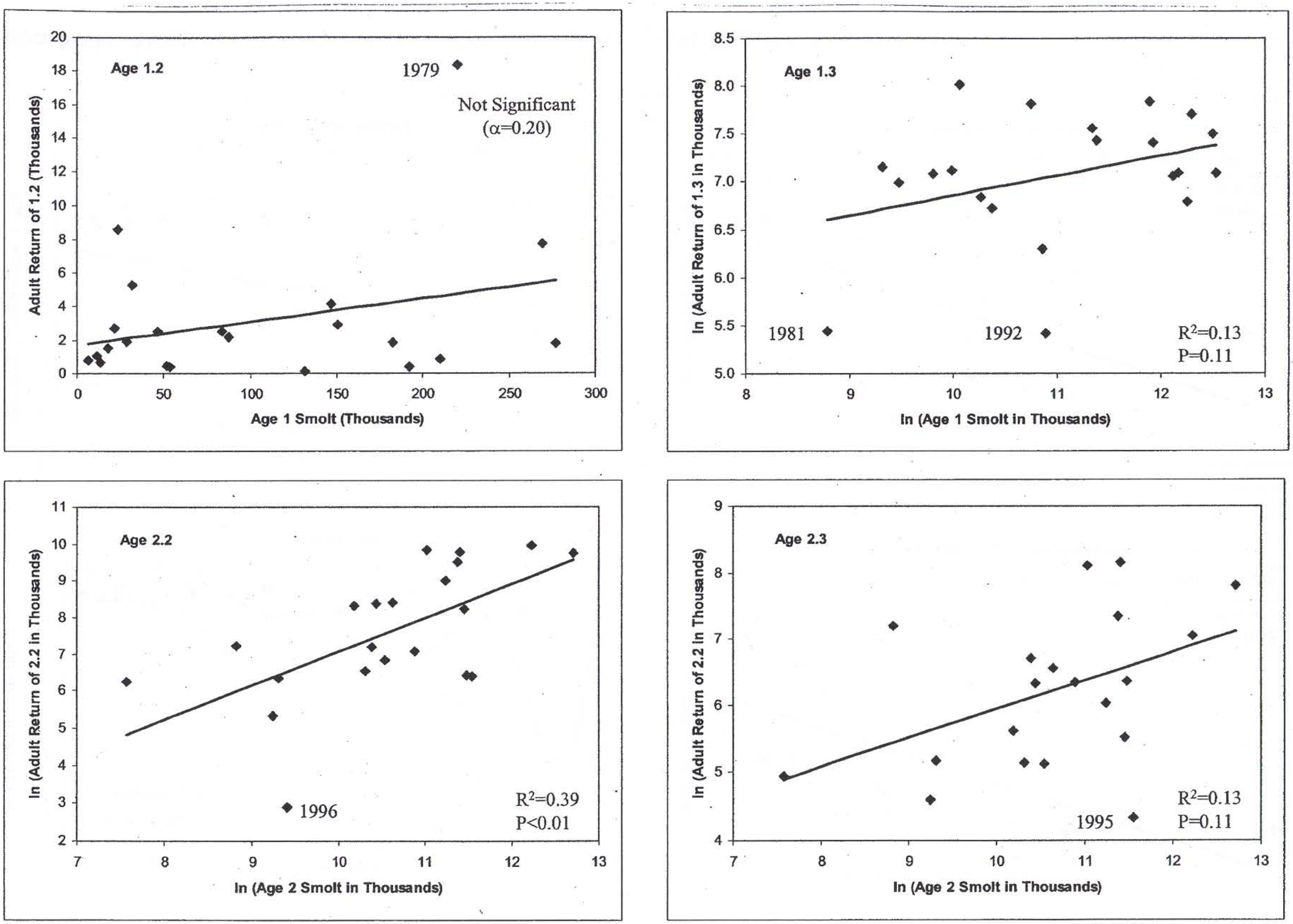
Appendix H.4. Marine survival of age-1. and -2. sockeye salmon smolt, Egegik River, brood years 1980-1995.



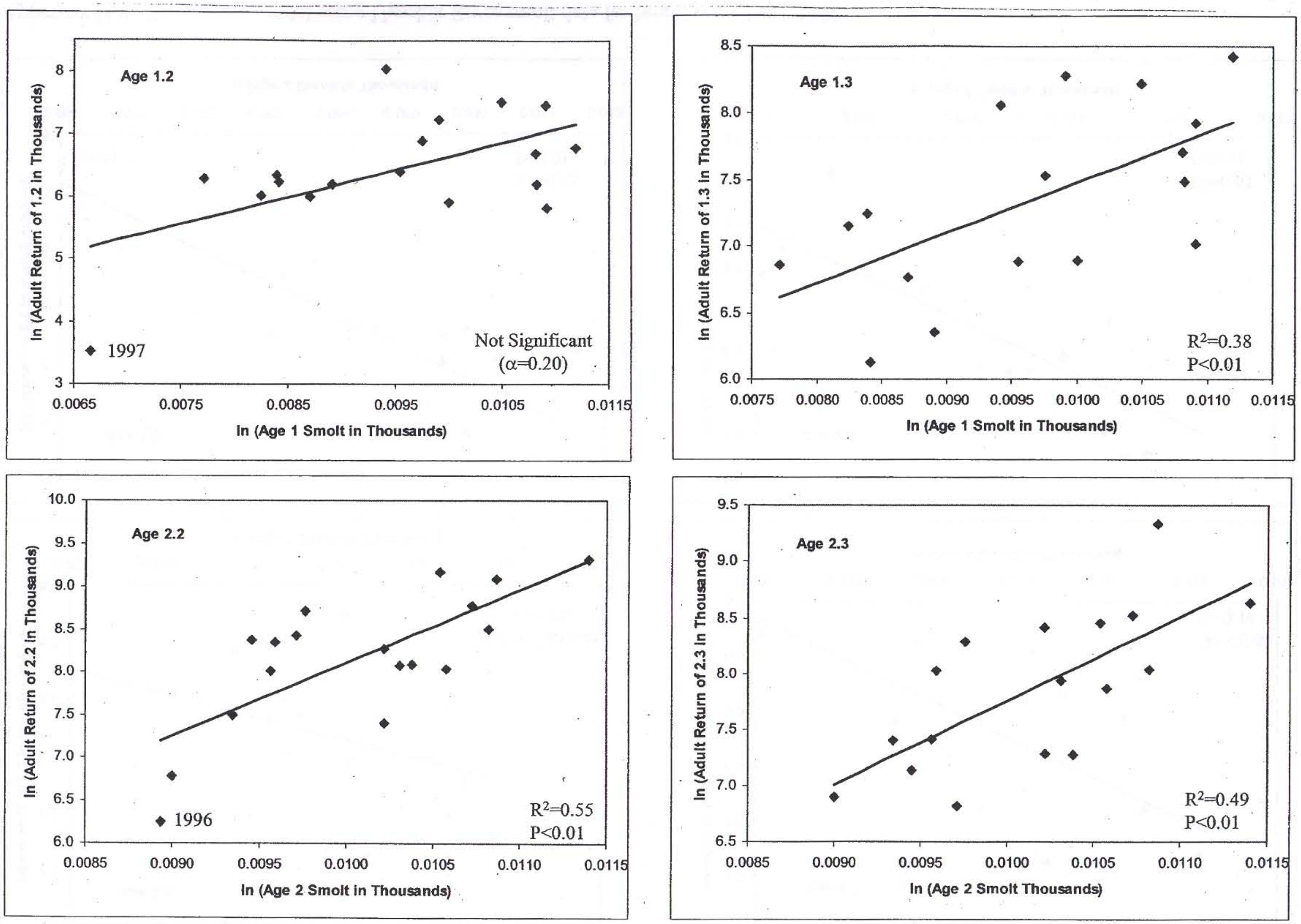
Appendix H.5. Ugashik River sockeye salmon smolt production , brood years 1981-1998.



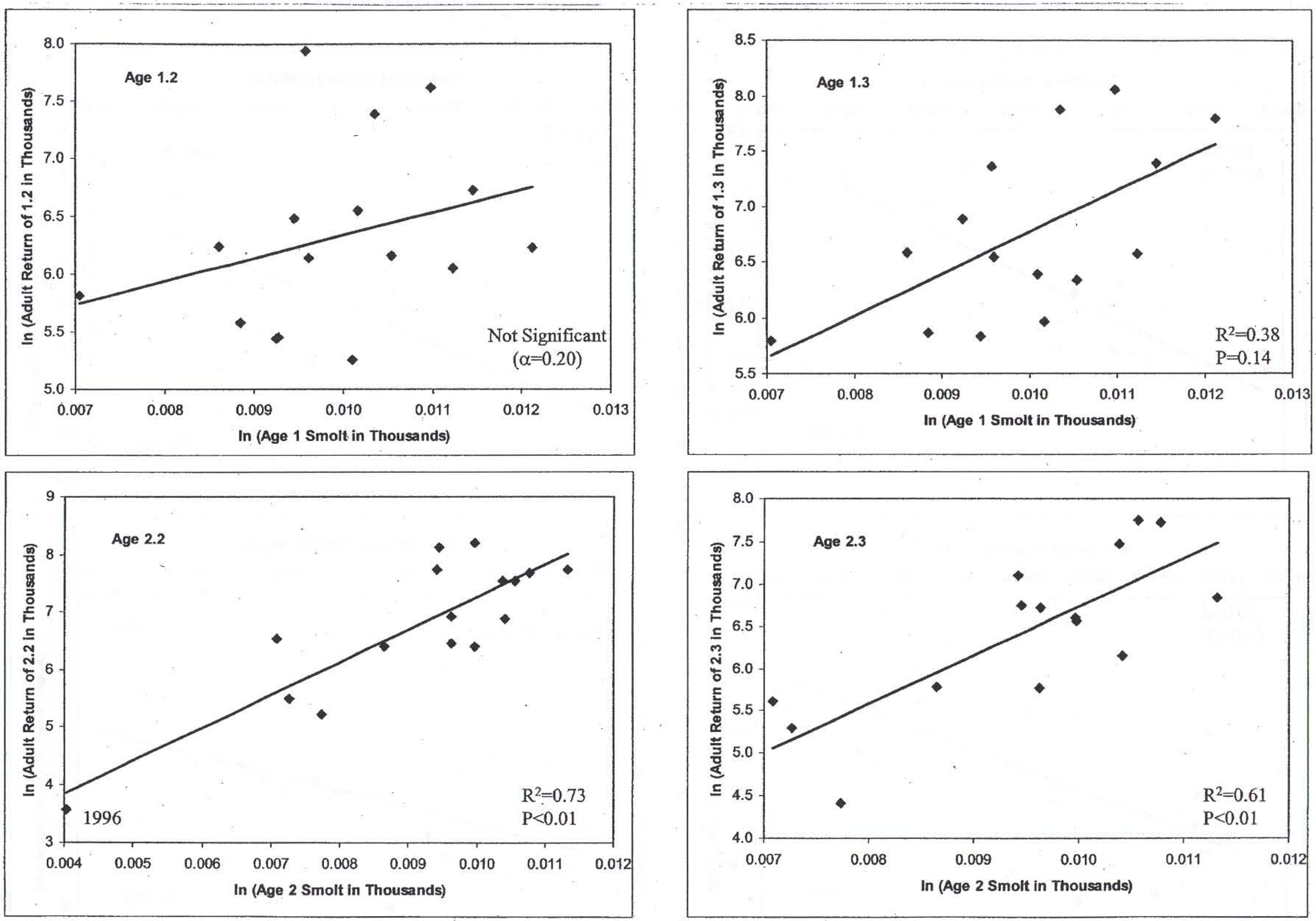
Appendix H.6. Marine survival of age-1. and -2. sockeye salmon smolt, Ugashik River, brood years 1981-1995.



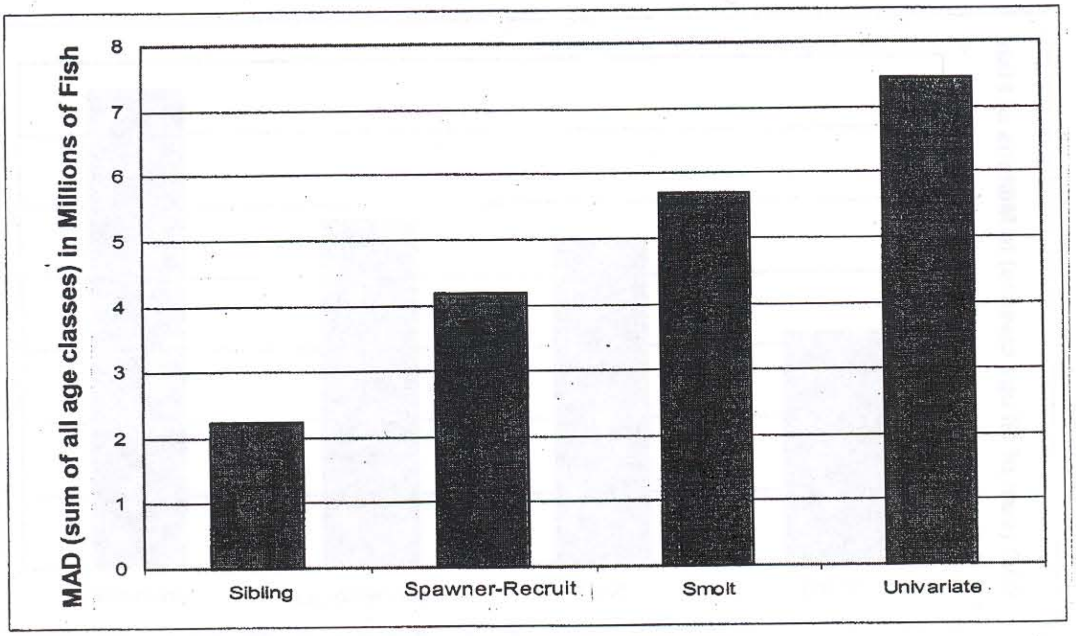
Appendix H.7. Forecasting model using Kvichak River smolt data for brood years 1976-1998.

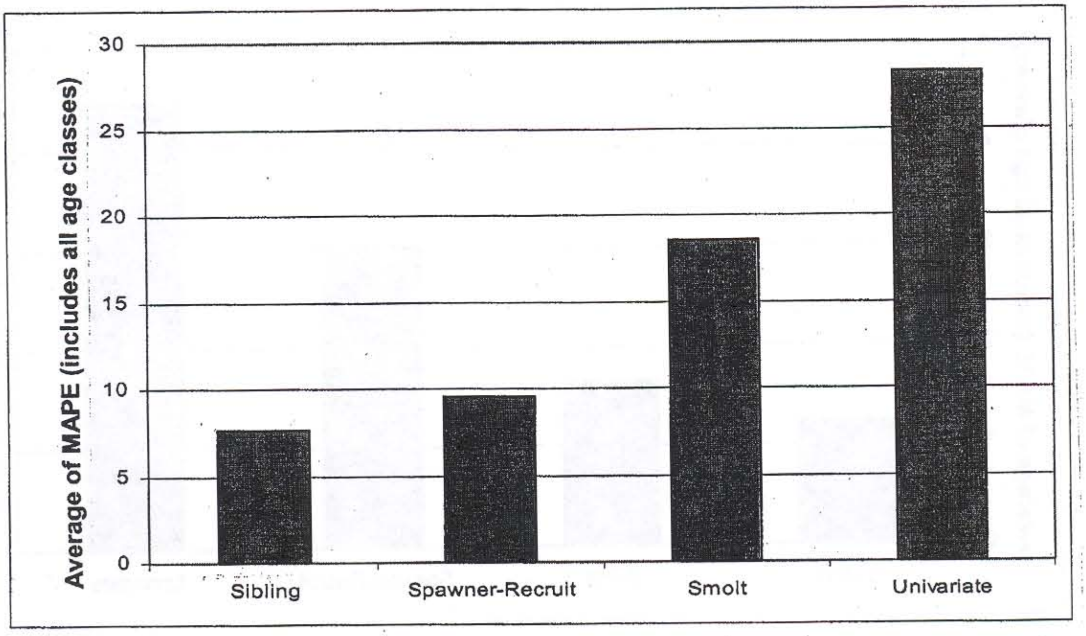


Appendix H.8. Forecasting model using Egegik River smolt data for brood years 1980-1998 .

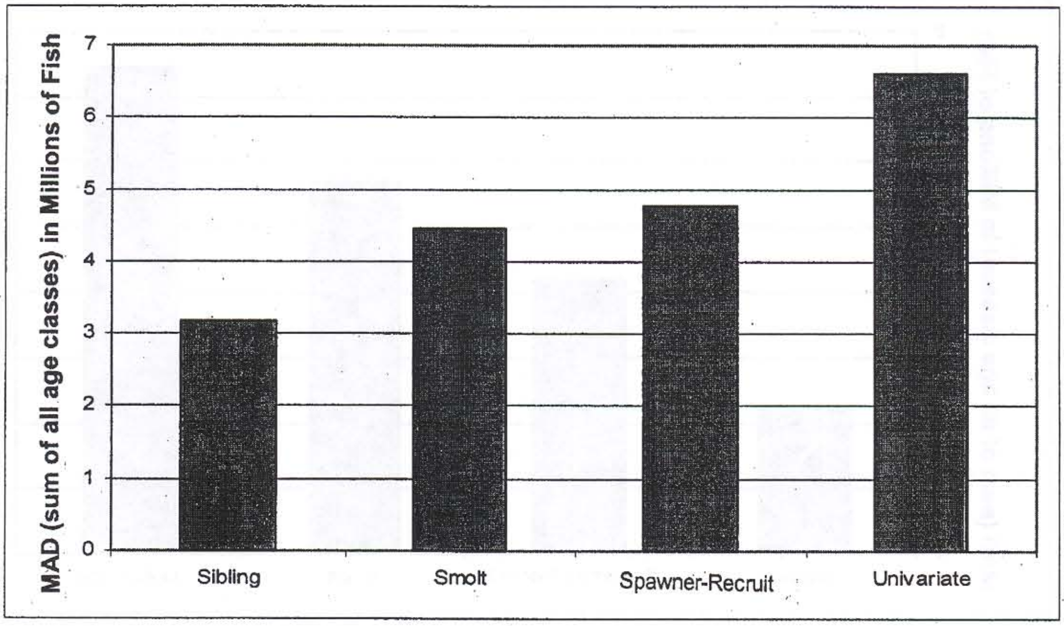


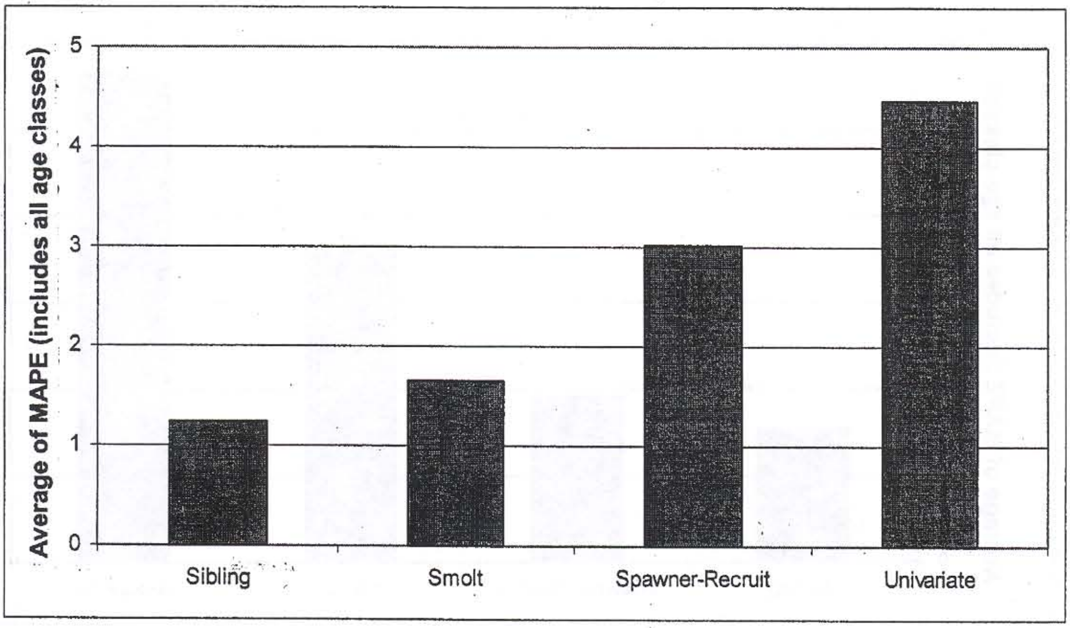
Appendix H.9. Forecasting model using Ugashik River smolt data for brood years 1981-1998.



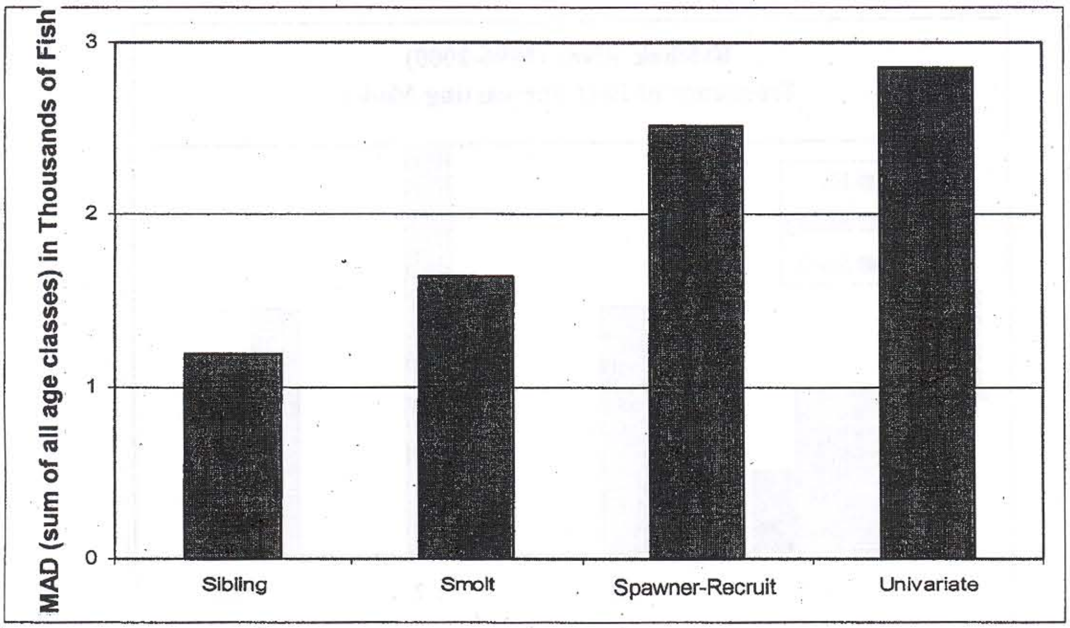


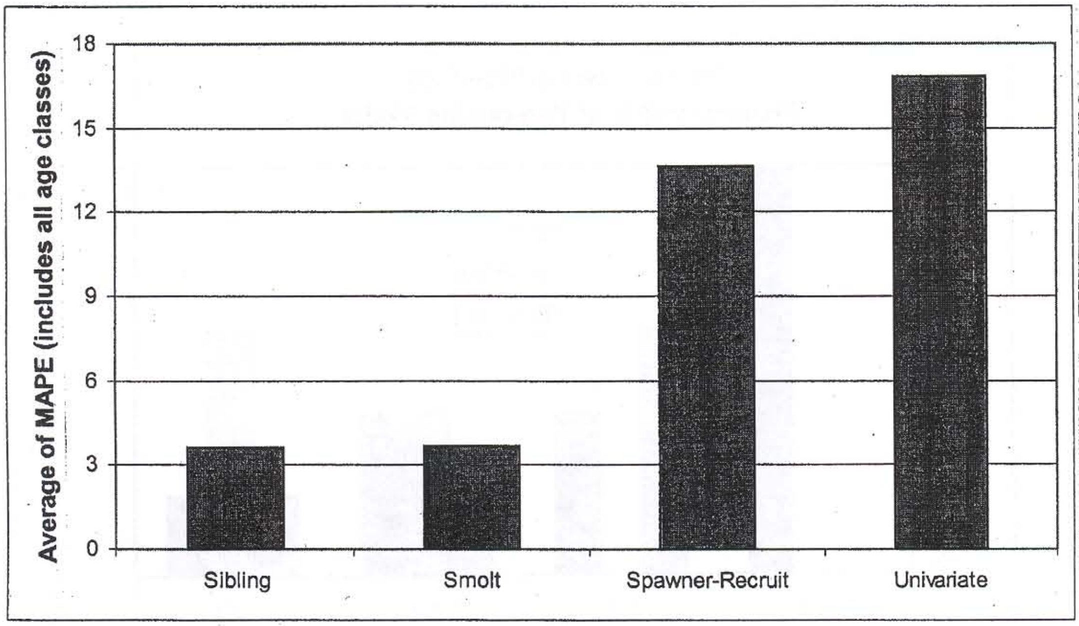
Appendix H.10. Comparison of various forecasting models for Kvichak River. Forecast model evaluation based on 1999-2001 hindcasts of Mean Absolute Deviation (MAD) and Mean Absolute Percent Error (MAPE). Smolt model accuracy based on sum of MAD and average MAPE by age class and year. Highlights: (a) Smolt model error (MAD) is 2.5 times greater than sibling model error. (b) Smolt model error (MAPE) is 2.4 times greater than sibling model error.



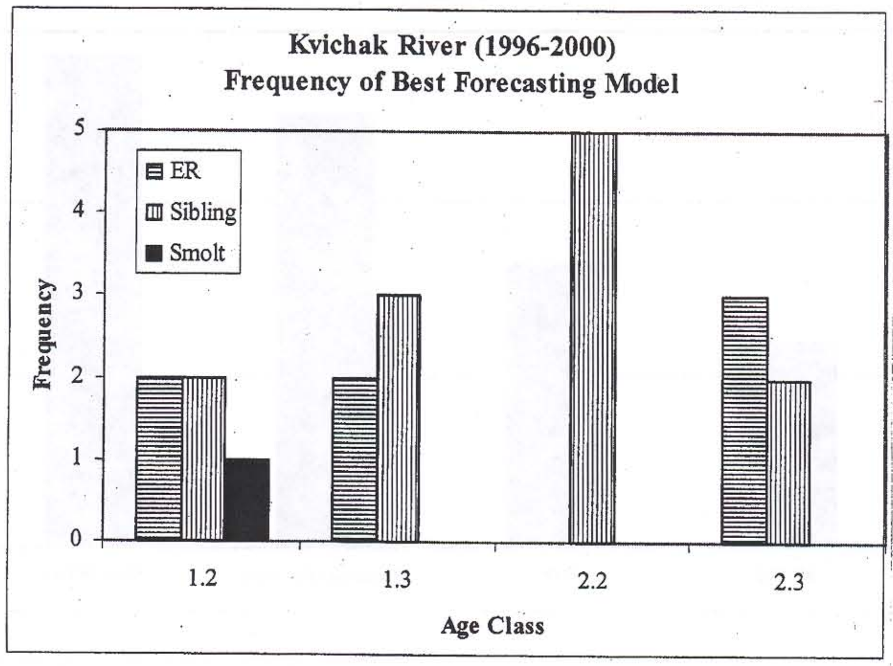


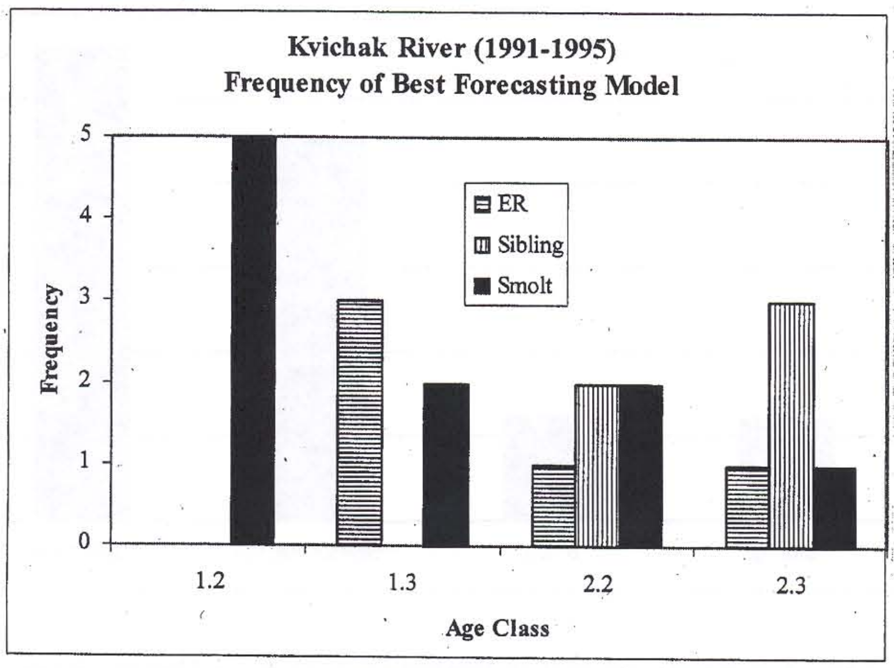
Appendix H.11. Comparison of various forecasting models for Egegik River. Forecast model evaluation based on 1999-2001 hindcasts of Mean Absolute Deviation (MAD) and Mean Absolute Percent Error (MAPE). Smolt model accuracy based on sum of MAD and average MAPE by age class and year. Highlights: (a) Smolt model error (MAD) is 1.4 times greater than sibling model error. (b) Smolt model error (MAPE) is 1.3 times greater than sibling model error.



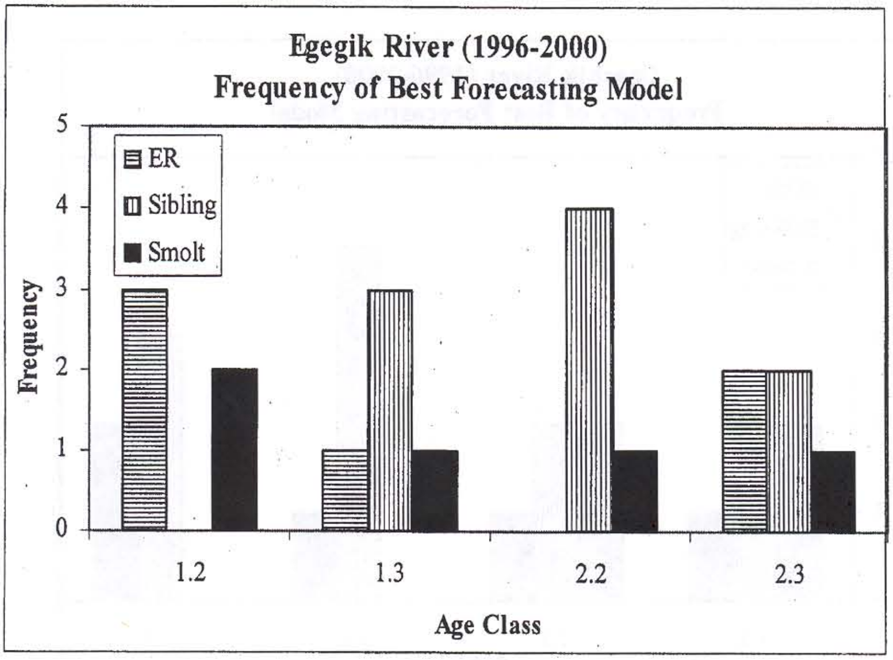


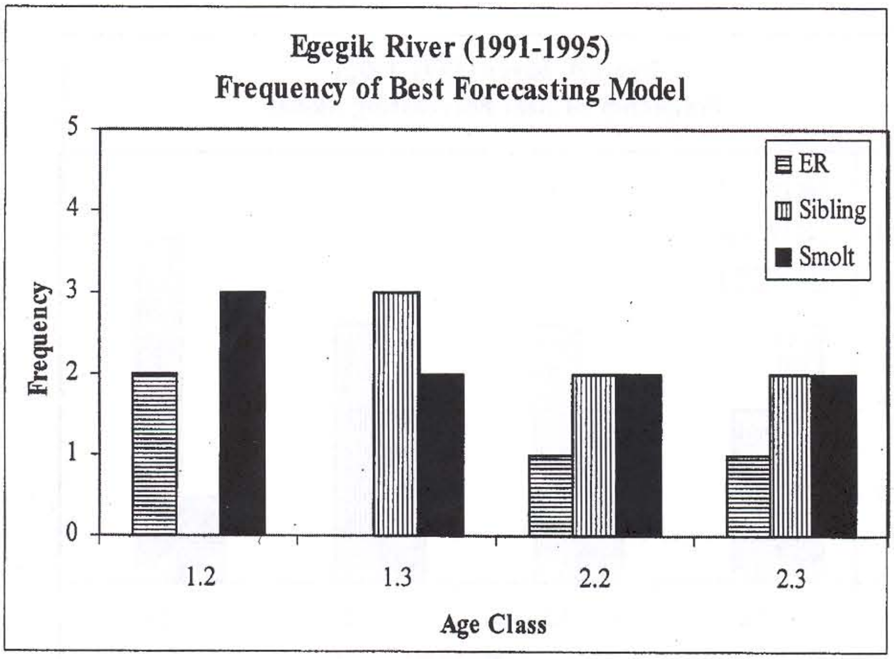
Appendix H.12. Comparison of various forecasting models for Ugashik River. Forecast model evaluation based on 1999-2001 hindcasts of Mean Absolute Deviation (MAD) and Mean Absolute Percent Error (MAPE). Smolt model accuracy based on sum of MAD and average MAPE by age class and year. Highlights: (a) Smolt model error (MAD) is 1.4 times greater than sibling model error. (b) Smolt model error (MAPE) is similar to the sibling model error.



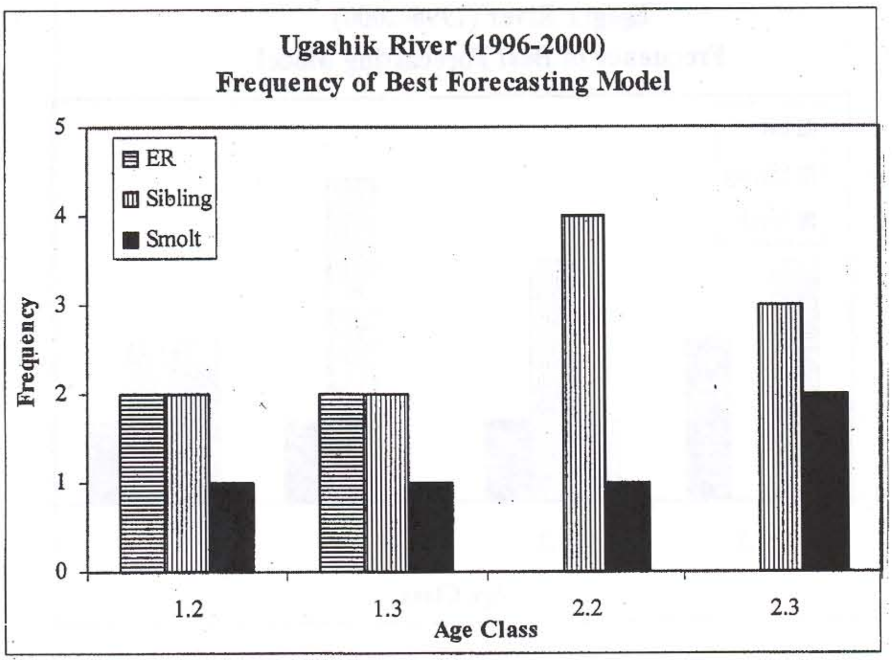


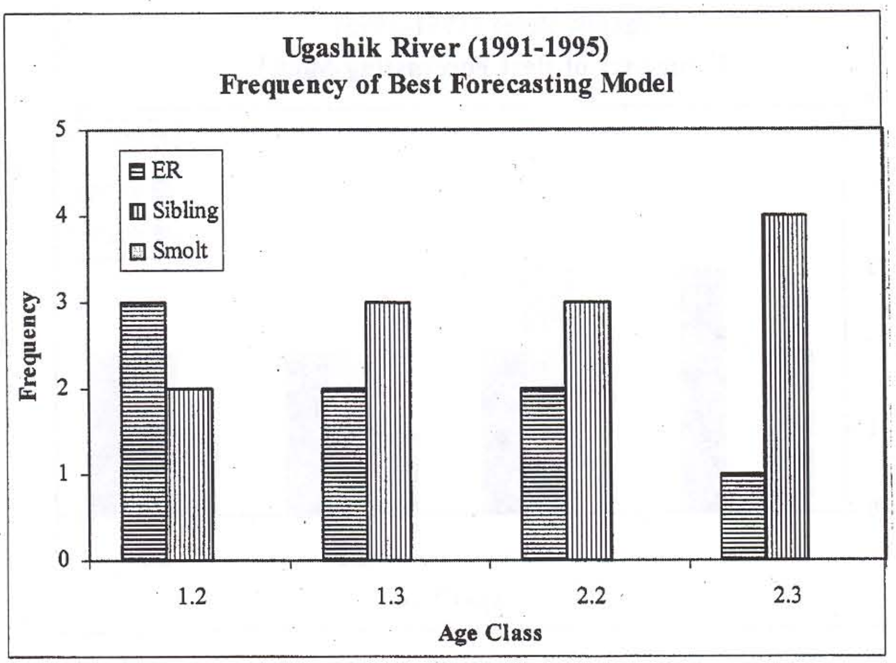
Appendix H.13. Comparison of which forecasting models (e.g., escapement-recruit, sibling, or smolt) forecasted closest to the actual returns for Kvichak River, 1991-2000. Note: without a time series approach, many smolt models were not significant using the traditional method, and were thus not forecasted for all years.



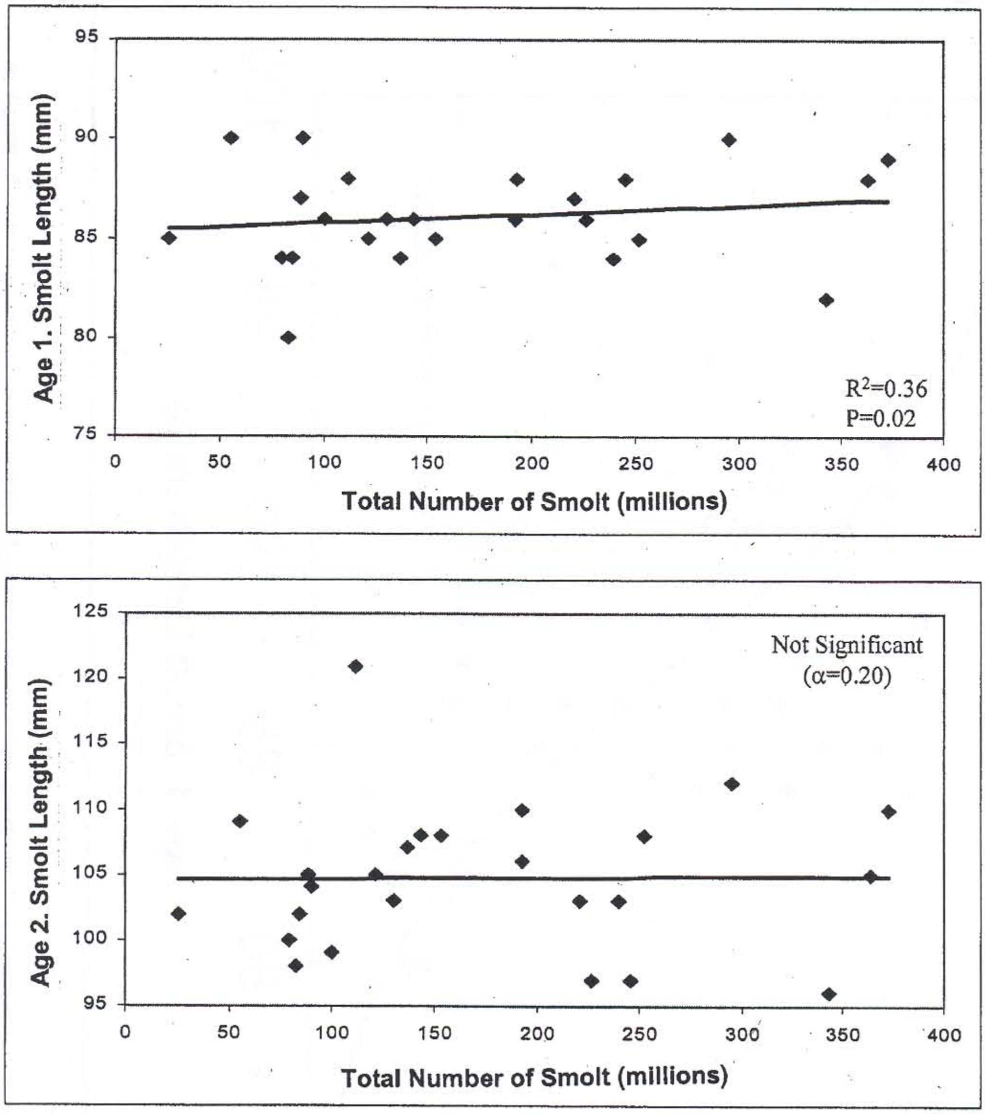


Appendix H.14. Comparison of which forecasting models (e.g., escapement-recruit, sibling, or smolt) forecasted closest to the actual returns for Egegik River, 1991-2000. Note: without a time series approach, many smolt models were not significant using the traditional method, and were thus not forecasted for all years.

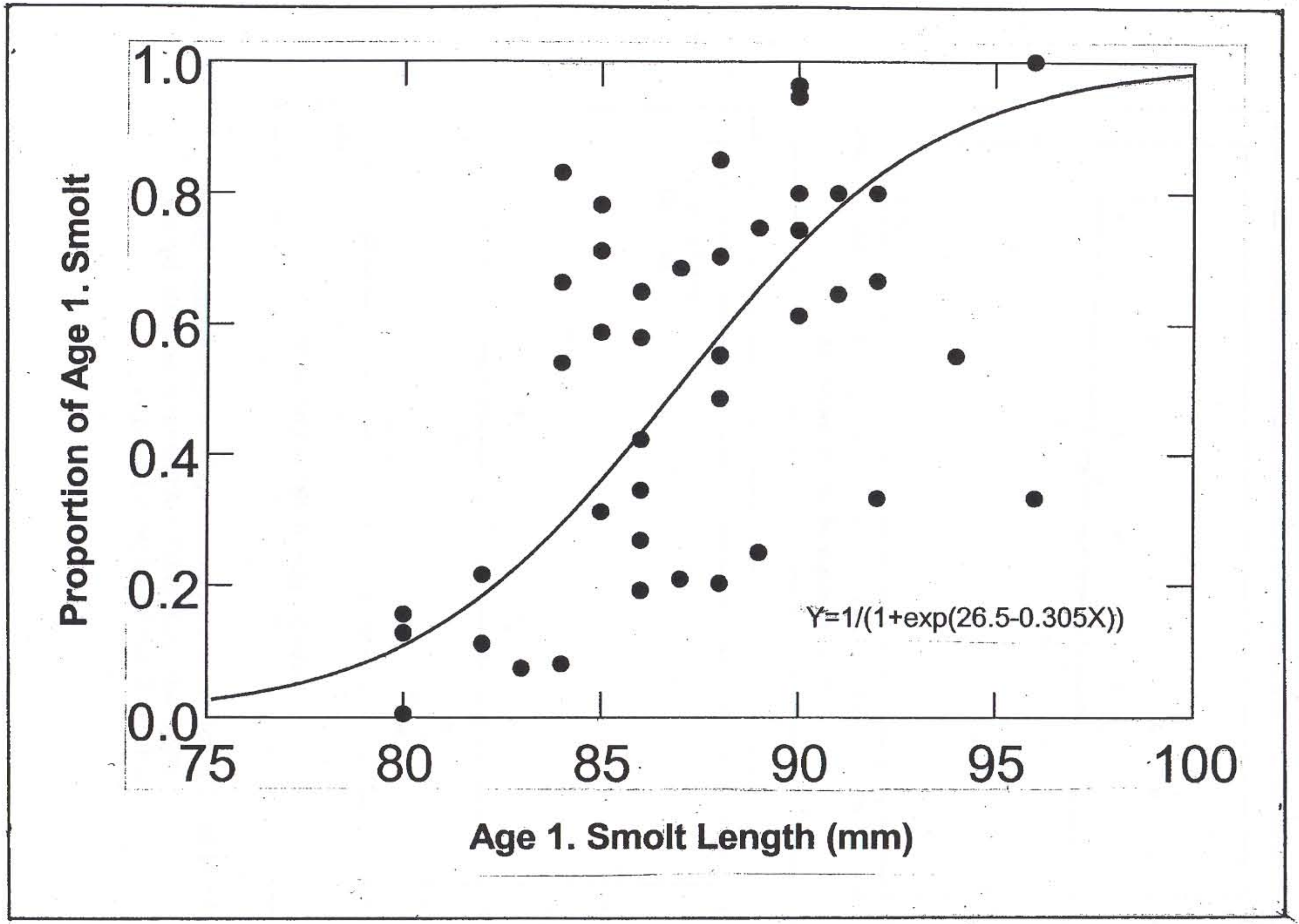




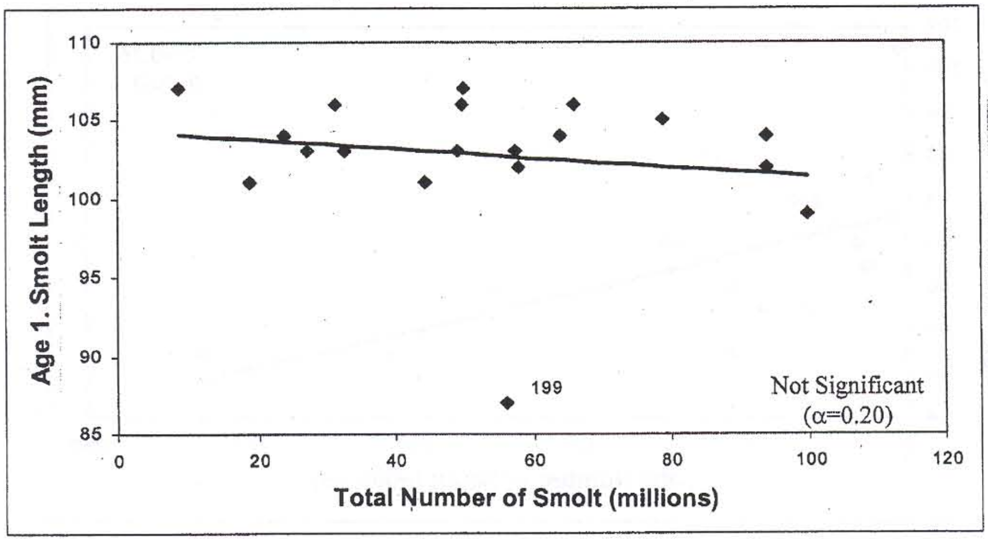
Appendix H.15. Comparison of which forecasting models (e.g., escapement-recruit, sibling, or smolt) forecasted closest to the actual returns for Ugashik River, 1991-2000. Note: without a time series approach, many smolt models were not significant using the traditional method, and were thus not forecasted for all years.

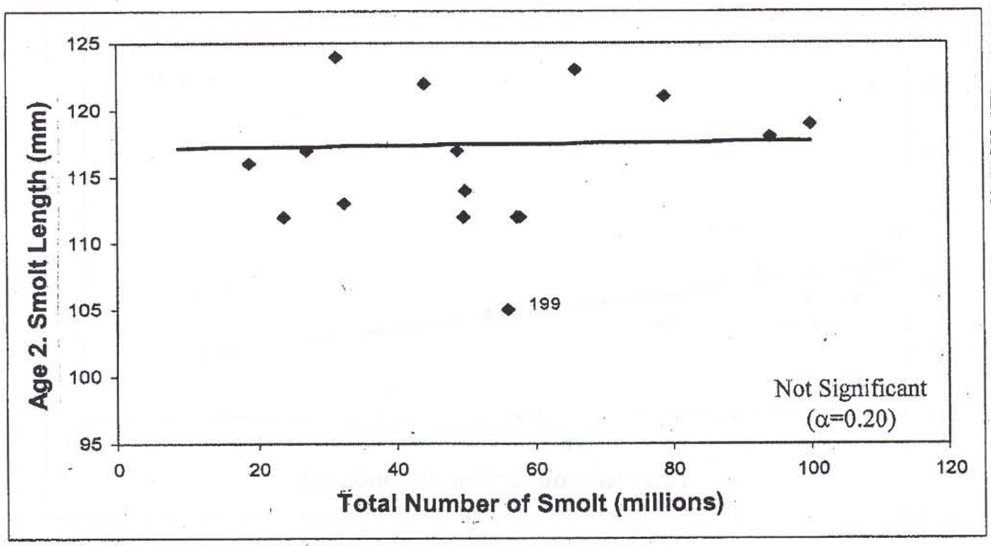


Appendix H.16. Plot of the average annual sockeye salmon smolt length versus the total smolt outmigration estimate by age, Kvichak River, brood years 1976-1998.

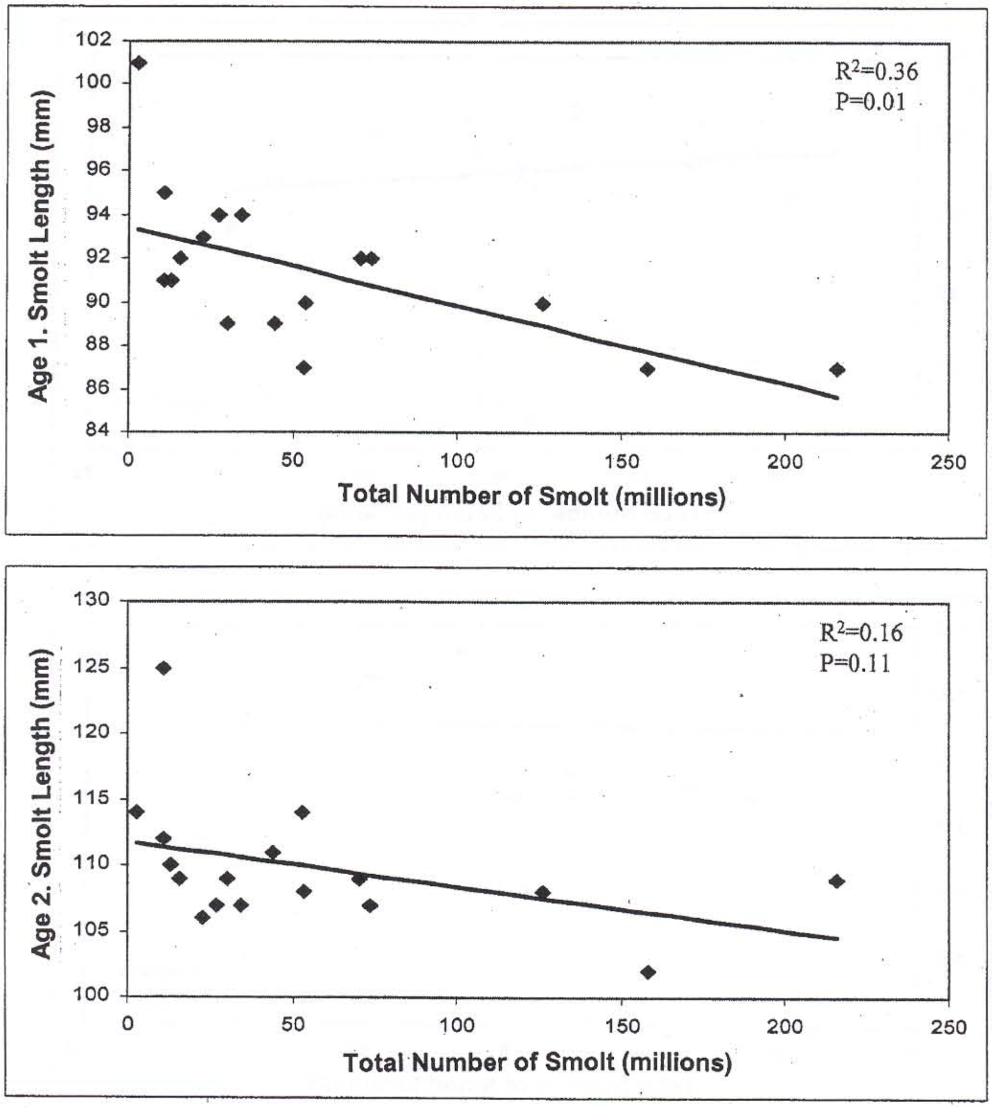


Appendix H.17. Plot of the average age-1. sockeye salmon smolt length versus the proportion of age-1. smolt in the total smolt outmigration, Kvichak River, brood years 1976-1998.



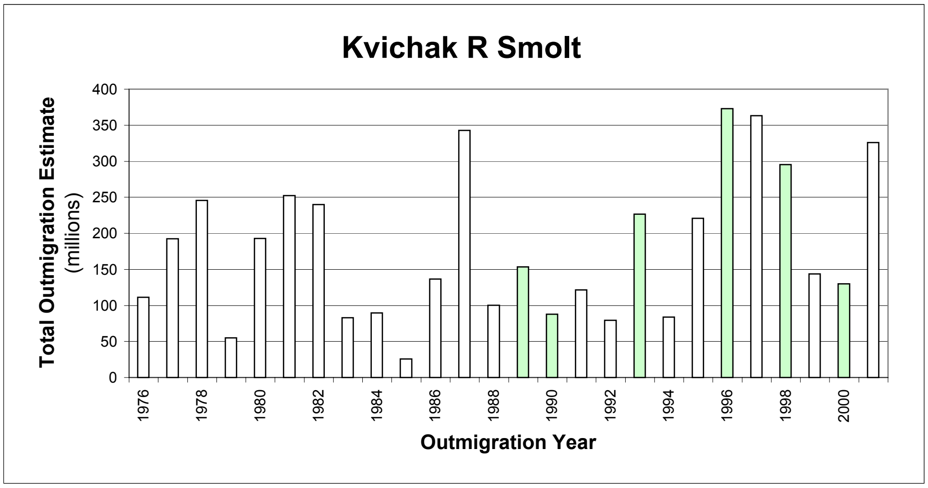


Appendix H.18. Plot of the average annual sockeye salmon smolt length versus the total smolt outmigration estimate by age, Egegik River, brood years 1980-1998.



Appendix H.19. Plot of the average annual sockeye salmon smolt length versus the total smolt outmigration estimate by age, Ugashik River, brood years 1981-1998.

APPENDIX I: LIST OF CHANGES AT KVICHAK RIVER SMOLT SONAR



Appendix I. List of major equipment and project changes at the Kvichak River smolt sonar,

Year	Changes
1976 to 1988	1976-1988 site - smolt sonar counter & arrays located on the Kvichak R, 5 km below the outlet of Lake Iliamna. Bendix, Model 1976 smolt counter - used 3 arrays with 7- upward-facing & 7-downstream-facing 118 kHz, 18° beam width tranducers on all array cables were 330' long, 1 count per 83.0 g of biomass
1989	Location Change - the smolt sonar site on the Kvichak R was relocated 6 km below the outlet of Lk Iliamna, ~1 km below the 1976-1988 The former site was deemed unusable due to changes in the river channel. The 1976-1988 site was located on an island and increased flows in side channels on both sides of the island had raised concerns that smolt were passing the sonar site undetected. Equipment Changes - the depth of the river at the new site was deeper than the 1976-1988 site, therefore the following smolt counting equipment changes were implemented: 1. The Bendix, Model 1982 smolt counter was set up and operated from the right bank of the river. This system used 3 arrays with 10 - upward-facing 235 kHz, 9° beam width transducers on each. All array cables were 330' long. 1 count per 41.5 g of biomass 2. The Bendix, Model 1976 smolt counter was modified in 1989 by Al Menin to operated in deeper water. It was then set up and operate from the left bank of the river. This system used 1 array with 7- upward-facing & 7-downstream-facing 118 kHz, 18° beam width trar The array cables were 330' long. 1 count per 83.0 g of biomass 1989 System Conclusions: Because the left bank smolt counter (Bendix, Model 1976) was not monitored continuously for false counts a the smolt outmigration estimate was not changed significantly by including the counts from the fourth array (14 transducers), only counts from the Bendix, Model 1982 system were used in the final estimate for Kvichak River in 1989.
1990	1989 site. Equipment Changes - In 1990, Bendix, Model 1976 smolt counting system was modified based on advise from former project leaders and Al Menin. 1. Al Menin modified the Bendix, Model 1976 smolt counter in 1990 to accommodate the following changes: 2. The offshore array cables were extended to 415' to help enumerate smolt in the deep, fast water near the left bank. To compensate for the additional 85' of cable on the offshore transducers, Al Menin installed 10 -150 Uh inductors in the center array components of the Bendix, Model 1976 smolt counter. 3. All downstream-facing transducers were disconnected and data was collected using only the 7 upward-facing transducers on each ar Bendix, Model 1976 smolt counter - used 3 modified arrays with 7 - upward-facing 118 kHz, 18° beam width tranducers on each, All downstream-facing transducers (n=7) were removed from each array. Offshore array cables extended to 415', inshore & center array cable length = 330'. 1 count per 83.0 g of biomass
1991	1989 site. No changes - same as 1990
1992	1989 site. No changes - same as 1990
1993	1989 site. Equipment Changes - 1. Had to switch from the Bendix Model 1976 to the Bendix Model 1982 smolt counter because of uncorrectable problems with the Benc Model 1976 smolt counter's Practical Automation, Inc., Model C4-265 moduprint printer. This unit can not be repaired or replaced. 2. Prior to the 1993 field season, Al Menin extended each of the offshore array cables on the Bendix, Model 1982 system (e.g., previou used at Nuyakuk R 1983-1989) from 330' to 415' and installed 10 - 150 Uh inductors in the offshore array components of the smolt count Bendix, Model 1982 smolt counter - used 3 arrays with 10 - upward-facing 235 kHz, 9° beam width transducers on each. Offshore array cable length = 415', inshore & center array cable length = 330'. 1 count per 41.5 g of biomass
1994	1989 site. No changes - same as 1993
1995	1989 site. No changes - same as 1993
1996	1989 site. Equipment Changes - 1. After the 1995 field season, Al Menin extended each of the center array cables on the Bendix, Model 1982 system from 330' to 415' The additional 85' of cable on the center array transducers allowed for easier deployment and better placement of the array in the river. 2. Al also installed 10 - 150 Uh inductors in the center array components of the smolt counter. Bendix, Model 1982 smolt counter - used 3 arrays with 10 - upward-facing 235 kHz, 9° beam width transducers on each, Offshore & center array cable length = 415', inshore array cable length = 330'. 1 count per 41.5 g of biomass
1997	1989 site. No changes - same as 1996
1998	1989 site. Equipment Changes - Al Menin installed a boat detector/inhibitor system that would disable the smolt counter for a preset period of time (~2 min) each time the system detected the outboard motor noise from a passing boat
1999	1989 site. No changes - same as 1998
2000	1989 site. Equipment Change - In order to provide a quick inseason comparison of Bendix smolt counter data with counts from other hydroacoustic systems, ADF&G contracted the Applied Physics Laboratory at the University of Washington during the winter of 1999/2000 to design and insert a comput interface into each of three smolt counters and write software to accept and store smolt count data on a computer. This new smolt coun system generated one file every hour with counts for each array in 1-second intervals. The new system operated independent of the nor smolt counter printer system which continued to print out counts on a paper tape at prescribed intervals every hour. This system was tes and used at Kvichak and Ugashik in 2000.
2001	1989 site. No changes - same as 2000