

2A98-13

BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES FOR 1997



by

Drew L. Crawford

and

Beverly A. Cross

Regional Information Report¹ No. 2A98-13

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

April 1998

¹Contribution 98-13 from the Anchorage regional office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate needs for up-to-date information, reports in this series may contain preliminary data.

BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES FOR 1997

by

Drew L. Crawford

and

Beverly A. Cross

Regional Information Report Draft¹ No. 2A98-13

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

April 1998

¹Contribution 98-13 from the Anchorage regional office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate needs for up-to-date information, reports in this series may contain preliminary data.

AUTHORS

Drew L. Crawford is a Region II Bristol Bay Research Biologist for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Road, Anchorage, AK 99518-1599.

Beverly A. Cross is Region II Bristol Bay Research Project Leader for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Road, Anchorage, AK 99518-1599.

ACKNOWLEDGMENTS

We wish to thank the following Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development personnel for contributing to the success of the Bristol Bay sockeye salmon smolt studies in 1997. Tom Kerns^a, Robert McFadden^c, Susan McNeil^{ad}, Dirk Middleton^a, Don Perrin^c, Dan Salmon^{cd}, Christopher Sheldon^b, Fred Tilly^{cd}, Clyde Vicary^{bd}, Fred West^b, and Don Woodruff^a collected smolt data. Cathy Tilly and Deborah Crouch aged all the smolt scales. Mark Reynolds and Branch River Air Service provided logistical support. Jim Miller and Dan Gray provided editorial reviews of this document. We also wish to thank hydroacoustics consultant, Al Menin, who provided technical assistance and expert advice to the 1997 smolt studies.

^a Egegik River Smolt Project

^b Ugashik River Smolt Project

^c Kvichak River Smolt Project

^d Lead crew member

PROJECT SPONSORSHIP

The Ugashik River smolt project was financed through cooperative agreements with the Lake and Peninsula Borough (COOP-97-077), Pilot Point City Council (COOP-97-078), and the State of Alaska, Department of Fish and Game, Division of Commercial Fisheries Management and Development.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	vii
LIST OF FIGURES	x
LIST OF APPENDICES	xi
ABSTRACT	xv
INTRODUCTION	1
METHODS	4
Hydroacoustic Equipment	4
Project Locations	5
Estimation of Smolt Numbers	5
Biomass Estimation	5
Estimation of River Velocities and Adjustment to Sonar Counts	6
Expansion of Biomass Estimates	6
Age, Weight, and Length Estimation	7
Estimation of Smolt Numbers	9
Vertical Distribution of Smolt Passage	10
Climatological Data Collection	10
RESULTS	10
Kvichak River	10
Egegik River	12
Ugashik River	13

TABLE OF CONTENTS (Continued)

	<u>Page</u>
DISCUSSION	15
Kvichak River	15
Egegik River	17
Ugashik River	18
LITERATURE CITED	21
TABLES	33
FIGURES	73
APPENDIX	93

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Sonar counts by smolt day and array at the sockeye salmon smolt counting site on Kvichak River, 1997	33
2. Sonar counts by hour and array at the sockeye salmon smolt counting site on Kvichak River, 1997.....	34
3. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Kvichak River, 1997	35
4. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Kvichak River, 1997	36
5. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Kvichak River, 1997	37
6. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Kvichak River, 1997	38
7. Depth of sockeye salmon smolt passage at Kvichak River sonar site, May 17 to June 8, 1997	39
8. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Kvichak River, 1997	40
9. Sonar counts by smolt day and array at the sockeye salmon smolt counting site on Egegik River, 1997	41
10. Sonar counts by hour and array at the sockeye salmon smolt counting site on Egegik River, 1997.....	42
11. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Egegik River, 1997	43
12. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Egegik River, 1997	44
13. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Egegik River, 1997	45
14. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Egegik River, 1997	46

LIST OF TABLES (Continued)

<u>Table</u>	<u>Page</u>
15. Depth of sockeye salmon smolt passage at Egegik River sonar site, May 19 to June 8, 1997	47
16. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Egegik River, 1997	48
17. Sonar counts by smolt day and array at the sockeye salmon smolt counting site on Ugashik River, 1997	49
18. Sonar counts by hour and array at the sockeye salmon smolt counting site on Ugashik River, 1997	50
19. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Ugashik River, 1997	51
20. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Ugashik River, 1997	52
21. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Ugashik River, 1997	53
22. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Ugashik River, 1997	54
23. Depth of sockeye salmon smolt passage at Ugashik River sonar site, May 10 to June 30, 1997	55
24. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Ugashik River, 1997	56
25. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Kvichak River, 1955-1997	57
26. Water temperatures at sockeye salmon smolt counting site, Kvichak River, 1963-1997	58
27. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1956-1995 brood years, Kvichak River	59

LIST OF TABLES (Continued)

<u>Table</u>	<u>Page</u>
28. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1952-1995 brood years, Kvichak River	60
29. Comparison of the age composition of outmigrating sockeye salmon smolt at Kvichak River with the freshwater age composition of their total adult returns by brood year, 1981-1990	61
30. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Egegik River, 1939-1997	62
31. Water temperatures at sockeye salmon smolt counting site, Egegik River, 1981-1997	63
32. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1978-1995 brood years, Egegik River	64
33. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1978-1995 brood years, Egegik River	65
34. Comparison of the age composition of outmigrating sockeye salmon smolt at Egegik River with the freshwater age composition of their total adult returns by brood year, 1981-1990	66
35. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Ugashik River, 1958-1997	67
36. Water temperatures at sockeye salmon smolt counting site, Ugashik River, 1983-1997 ...	68
37. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1979-1995 brood years, Ugashik River	69
38. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1979-1995 brood years, Ugashik River	70
39. 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, 1981-1988	71

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Bristol Bay Management Area with major rivers and locations of smolt counting projects, 1997	73
2. River bottom profile and sonar array placement at Kvichak River smolt sonar site, 1997	74
3. River bottom profile and sonar array placement at Egegik River smolt sonar site, 1997	75
4. River bottom profile and sonar array placement at Ugashik River smolt sonar site, 1997	76
5. Depth of smolt passage data summarized by hour, Kvichak River, May 17 to June 8, 1997	77
6. Depth of smolt passage data summarized by hour, Egegik River, May 19 to June 8, 1997	78
7. Depth of smolt passage data summarized by hour, Ugashik River, May 10 to June 12, 1997	79
8. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Kvichak River smolt project with the 1987-1996 mean	80
9. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Kvichak River smolt project with the 1987-1996 mean	81
10. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Kvichak River smolt project with the 1988-1996 mean	82
11. Comparison of the age composition of outmigrating sockeye salmon smolt at Kvichak River with the freshwater age composition of the total adult returns by brood year, 1981-1990.....	83
12. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Egegik River smolt project with the 1987-1996 mean.....	84
13. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Egegik River smolt project with the 1987-1996 mean.....	85

LIST OF FIGURES (Continued)

<u>Figure</u>	<u>Page</u>
14. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Egegik River smolt project with the 1988-1996 mean.....	86
15. Comparison of the age composition of outmigrating sockeye salmon smolt at Egegik River with the freshwater age composition of the total adult return by brood year, 1981-1990	87
16. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Ugashik River smolt project with the 1987-1996 mean.....	88
17. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Ugashik River smolt project with the 1987-1996 mean.....	89
18. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Ugashik River smolt project with the 1987-1996 mean.....	90
19. 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, 1981-1988.....	91

LIST OF APPENDICES

	<u>Page</u>
APPENDIX A: RIVER WIDTH AND DISTANCE BETWEEN ARRAYS AT SMOLT SONAR SITES	
A.1. River width and distance between arrays at Kvichak River smolt sonar site, 1989-1997	93
A.2. River width and distance between arrays at Egegik River smolt sonar site, 1989-1997	94
A.3. River width and distance between arrays at Ugashik River smolt sonar site, 1988-1997	95
APPENDIX B: WINTER ICE-COVER DATES FOR EAST-SIDE BRISTOL BAY LAKES	
B.1. Ice-cover dates for Lake Iliamna, 1970-1997	97

LIST OF APPENDICES (Continued)

	<u>Page</u>
APPENDIX B: WINTER ICE-COVER DATES FOR EAST-SIDE BRISTOL BAY LAKES	
(Continued)	
B.2. Ice-cover dates for Becharof Lake, 1970-1997	98
B.3. Ice-over dates for Upper and Lower Ugashik Lakes, 1970-1997	99
APPENDIX C: FYKE NET CATCH AT SMOLT SONAR SITES	
C.1. Kvichak River smolt fyke net catch log, 1997	101
C.2. Egegik River smolt fyke net catch log, 1997.....	105
C.3. Ugashik River smolt fyke net catch log, 1997	107
APPENDIX D: RIVER VELOCITIES AT SMOLT SONAR SITES	
D.1. Kvichak River water velocity at the center smolt sonar array, 1987-1997	109
D.2. Egegik River water velocity at the center smolt sonar array, 1984-1997	110
D.3. Ugashik River water velocity at the inshore smolt sonar array, 1983-1997	111
APPENDIX E: SMOLT ESTIMATE DATA BY OUTMIGRATION YEAR	
E.1. Total smolt outmigration estimates for Kvichak River by outmigration year, 1983-1997	113
E.2. Age composition of smolt outmigration estimates for Kvichak River by outmigration year, 1983-1997.....	114
E.3. Total smolt outmigration estimates for Egegik River by outmigration year, 1983-1997	115
E.4. Age composition of smolt outmigration estimates for Egegik River by outmigration year, 1983-1997.....	116
E.5. Total smolt outmigration estimates for Ugashik River by outmigration year, 1983-1997	117

LIST OF APPENDICES (Continued)

Page

APPENDIX E: SMOLT ESTIMATE DATA BY OUTMIGRATION YEAR (Continued)

E.6. Age composition of smolt outmigration estimates for Ugashik River by outmigration year, 1983-1997.....118

APPENDIX F: MEAN WATER TEMPERATURES AT SMOLT SONAR SITES

F.1. Comparison of Kvichak River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.....119

F.2. Comparison of Egegik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.....120

F.3. Comparison of Ugashik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.....121

APPENDIX G: CLIMATOLOGICAL FACTORS WHICH MAY HAVE EFFECTED THE FRESHWATER SURVIVAL OF 1997 SMOLT.....123

G.1. Average monthly air temperature for King Salmon, July 1967 to June 1997127

G.2. Comparison of monthly air temperature to the 30-year mean at King Salmon, July 1994 to June 1997128

G.3. Daily air temperatures (normals, means, and extremes) for King Salmon, October 1994 to April 1995129

G.4. Daily air temperatures (normals, means, and extremes) for King Salmon, October 1995 to April 1996130

G.5. Daily air temperatures (normals, means, and extremes) for King Salmon, October 1996 to April 1997131

G.6. Average monthly precipitation for King Salmon, July 1967 to June 1997132

G.7. Comparison of monthly precipitation to the 30-year mean at King Salmon, July 1994 to June 1997133

LIST OF APPENDICES (Continued)

Page

**APPENDIX G: CLIMATOLOGICAL FACTORS WHICH MAY HAVE EFFECTED THE
FRESHWATER SURVIVAL OF 1997 SMOLT (Continued)**

- G.8. Average monthly snowfall for King Salmon, July 1967 to June 1997.....134
- G.9. Comparison of monthly snowfall to the 30-year mean at King Salmon, July 1994 to
June 1997.....135

APPENDIX H: SMELT SPAWNING DATA

- H.1. Timing and duration of Boreal smelt spawning in King Salmon Creek (Naknek River
drainage), 1976-1997137

ABSTRACT

Numbers of sockeye salmon *Oncorhynchus nerka* smolt emigrating to sea from three rivers in Bristol Bay, Alaska, were estimated from sonar counts and age-weight-length samples from mid-May to mid-June in 1997. 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 were 363,397,663 from Kvichak River, 27,050,113 from Egegik River, and 15,519,783 from Ugashik River. Age-1. smolt, the progeny of 1995 spawners, predominated at Kvichak River (74%) and Ugashik River (92%). Age-2. smolt, the progeny of 1994 spawners, predominated at Egegik River (54%).

KEYWORDS: 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 includes all waters east of a line from Cape Newenham to Cape Menshikof (Figure 1) and supports the largest sockeye salmon *Oncorhynchus nerka* fishery in the world. From 1977 to 1996 the commercial catch in Bristol Bay averaged 25.1 million sockeye salmon (K.Weiland, ADF&G, King Salmon, personal communication). To effectively manage this fishery, managers need accurate abundance forecasts of returning sockeye salmon and precise estimates of optimum spawning escapement goals. Estimates of outmigrating smolt numbers are currently used as an index of production for adult salmon; this improves the accuracy of preseason forecasts and aids in setting goals for optimum numbers of spawners.

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 total smolt numbers. To improve estimates of smolt numbers, the department began experimenting with and using hydroacoustic (sonar) equipment.

Hydroacoustic equipment was used to estimate sockeye salmon smolt numbers on Kvichak River from 1971 through 1997; Wood River from 1975 to 1990; Naknek River from 1982 to 1986 and 1993 to 1994; Egegik River from 1982 through 1997; Ugashik River from 1983 to 1991 and 1993 to 1997; 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).

Hydroacoustic equipment developed by Bendix Corporation² was tested on Kvichak River in 1969 (McCurdy and Paulus 1972b; Paulus and Parker 1974). Further testing and modification of this prototype resulted in the construction of smolt counters for use on Wood (Krasnowski 1976, 1977) and Kvichak Rivers (Randall 1977) in 1975 and 1976. Hydroacoustic equipment for counting smolt was tested on Ugashik River from 1973 to 1975 (Schroeder 1974b, 1975; Sanders 1976). Smolt studies on Naknek, Egegik, Ugashik, and Nuyakuk Rivers were limited to occasional fyke net sampling to obtain age and size data from 1975 to 1982 (Huttunen 1980; Eggers 1984; Minard

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

1984). An experimental two-array sonar system similar to the one used on Kvichak River was tested on Egegik River during 1981 (Bue 1982). Smolt enumeration projects using modified counters began on Naknek and Egegik Rivers in 1982 (Huttunen 1984; Bue 1984) and on Ugashik and Nuyakuk Rivers in 1983 (Fried et al. 1987; Minard and Frederickson 1987).

Side-scanning sonar was used in 1985 and 1986 to determine the lateral distribution of smolt passing each of the respective sonar sites. Bue et al. (1988) reported that most smolt passing the Kvichak River sonar site stayed within a 68-m corridor that began 6.4 m from the left bank³ (total river width = 100 m). Smolt passing the Egegik River sonar primarily used a 73-m corridor beginning 12.2 m from the left bank (total river width = 104 m). Ugashik River smolt used a 21-m corridor which began 7.0 m from the left bank (total river width = 43 m). Side-scanning sonar was not an effective tool for collecting lateral smolt distribution data on Wood River (Cross et al. 1990; Woolington et al. 1990, 1991). Therefore, lateral smolt distribution was assumed to be a function of river width and depth, measured and recorded when tidal influence was minimal. Based on those measurements, Wood River smolt were assumed to migrate within a 94-m corridor which began 3.3 m from the left bank.

Due to budget cuts, the monitoring of smolt migrations was discontinued on Naknek River in 1986 (Bue et al. 1988), on Togiak River in 1988 (Woolington et al. 1990), on Nuyakuk River in 1989 (Woolington et al. 1991), and on Wood River in 1990 (Crawford et al. 1992).

In 1990 a single narrow-beam, side-looking sonar unit was used from May 29 to 31 to determine the lateral limits of smolt distribution at the Kvichak River sonar site (Huttunen and Skvorc 1991); most smolt migrated between 40 and 100 m offshore from the right bank. The total river width at the site was 136 m.

The results of the 1990 study were encouraging, so in 1991 it was expanded to evaluate the feasibility of using side-looking sonar to enumerate outmigrating Kvichak River sockeye salmon smolt. Huttunen and Skvorc (1992) estimated, based on 81 h of horizontal-aspect echo-integration data collected June 2-14, that 44,972,864 smolt passed through the sonar site during the counting period. This compared well to an upward-looking sonar estimate of 43,525,980 smolt for the same hours of operation. The maximum single-beam listening range for the side-looking sonar varied from 118 m to 120 m, ensonifying 88%-90% of the total 134-m river cross section. In comparison, the three arrays of the historical upward-looking sonar ensonified roughly 7.5% of the river. The spacial distribution of smolt on a nightly basis were highly dynamic; side-looking estimates peaked at ranges from 64 m on June 12 to 118 m on June 7. Whereas the distribution of upward-looking estimates also varied between nights, the largest estimates were typically from the inshore array at 56 m from the right bank. No side-looking sonar smolt studies have been conducted since 1991 due to lack of funding.

³ In this report the location of projects and the placement of equipment are referenced to the right and left bank of the respective river as determined by facing downstream at the study site.

Due to budget cuts, the smolt migration on Ugashik River was not monitored in 1992 (Crawford and Cross 1992). However, approval of cooperative agreements between the City of Pilot Point and ADF&G in 1993; the Lake and Peninsula Borough and ADF&G in 1994; the City of Pilot Point, Lake and Peninsula Borough, and ADF&G in 1995; the Lake and Peninsula Borough, and ADF&G in 1996; and the City of Pilot Point, Lake and Peninsula Borough, and ADF&G in 1997 allowed for continued enumeration of sockeye salmon smolt with hydroacoustic equipment on Ugashik River. The Ugashik River smolt study was resumed to measure the freshwater production and the size and age structure of smolt from recent sockeye salmon spawning escapements. Also each of these organizations wanted a continuation of the historical Ugashik River sockeye salmon smolt data base that had been collected annually (except for 1992) since 1983.

In 1993, approval of a cooperative agreement between the National Park Service and the Alaska Department of Fish and Game (ADF&G) allowed for continued enumeration of sockeye salmon smolt with hydroacoustic equipment on Naknek River in 1993 and 1994. The primary impetus for resuming the Naknek River smolt study was to measure freshwater production from the record sockeye salmon escapement (3.6 million fish) that entered the Naknek River drainage to spawn during the 1991 commercial fishermen strike. This study was concluded in 1994 and was summarized in Crawford and Cross (1995b).

Upward-looking sonar studies were conducted on Kvichak, Egegik, and Ugashik Rivers in 1997 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 smolt sonar and sampling equipment; plus detailed instructions on data collection, recording, and reporting techniques see Crawford and Tilly (1995).

Hydroacoustic Equipment

Bendix Corporation constructed all hydroacoustic systems used to estimate smolt numbers in Bristol Bay river systems in 1997; all projects used 1982 or 1983 model smolt counters. Transducers used to transmit and receive sound pulses at each sonar site were housed in two-to-three 3.03-m long arrays set on the river bottom and connected by coaxial cable to a control unit located on shore. Three arrays were used at each sonar site except Ugashik River. Only two arrays were used at Ugashik River due to a narrow channel width. Each array had 10 upward-facing single-element International Transducer Corporation², Model 5095 transducers which operate at a frequency of 235 KHz and a half power beamwidth angle of 9°. Detected echoes from each transducer were accumulated in the smolt counter and a printer produced a hard copy of totaled counts by array at prescribed intervals which were summed and recorded hourly on a field data collection form. Each smolt counting system was powered by a single 12-volt battery recharged by a pair of 43 watt, 2.9 amp solar panels.

Hydroacoustic equipment to monitor smolt outmigrations was operated on Kvichak and Egegik, Rivers from mid-May to mid-June. In 1997, the Ugashik River smolt counter was started on May 8 to gauge early smolt passage and it operated through mid-June. The smolt outmigrations in Kvichak, Egegik, and Ugashik Rivers generally peak during late May or early June and drop off by mid-June. All arrays at each project site were removed from the water at the end of the field season.

All hydroacoustic systems used in 1997 were factory calibrated to record one count whenever 41.5 g of biomass passed through each transducer beam during a given period. Because most smolt 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 equipment was set to record counts to within 1-2 cm of the water surface to avoid counting debris or entrapped air.

Sources of false counts, e.g., boats, wind, rain, 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.

Site location and equipment changes that have been made over the years to improve our ability to enumerate annual sockeye salmon smolt outmigrations using sonar are summarized in Crawford and Cross (1996, 1997).

Project Locations

The Kvichak River counting site was located 6 km below the outlet of Lake Iliamna (Figure 1); it was moved to this location in 1989, approximately 1 km downstream from the site used during the previous 15 years (Woolington et al. 1991). The Kvichak River was 126 m wide at this site. Three transducer arrays referred to as *inshore*, *center*, and *offshore*, were anchored 62 m, 80 m, and 93 m from the right bank (Figure 2). Array placement was improved by using lateral smolt distribution data reported by Huttunen and Skvorc (1991, 1992).

The Egegik River counting site was located 4 km below the outlet of Becharof Lake (Figure 1); it has been operated at this location since 1982 (Eggers and Yuen 1984). Egegik River was 107 m wide at this site. The inshore, center, and offshore arrays were anchored 40 m, 55 m, and 67 m from the left bank (Figure 3).

The Ugashik River counting site was located 50 m below the outlet of Lower Ugashik Lake (Figure 1). Because this river-section is only 42 m wide, only two arrays have been used. The inshore and offshore arrays were anchored 27 m and 31 m from the right bank (Figure 4).

See Appendix A.1 through A.3 to see how the 1997 river widths and array placements compare to past years at each of these rivers.

Estimation of Smolt Numbers

The process of estimating smolt numbers was divided into three steps: (1) determining 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 continually monitored hydroacoustic equipment. The signal pulse rate of the smolt counter was set to correspond with the river velocity measured at a location referred to as the *velocity index*. In most instances, the velocity at one of the arrays was used as the velocity index. At Egegik River, a buoyed flow meter anchored downriver of the inshore array was used as the velocity index.

Estimation of River Velocities and Adjustments to Sonar Counts . River velocities at the Kvichak and Ugashik River sites were nearly constant; thus velocities were measured once a week with a Gurley², Model 622 flow meter and the counter was adjusted accordingly.

River velocities at the Egegik River site were influenced by tides, therefore river velocities were measured continuously by a Gurley, Model 625, flow meter anchored directly behind the velocity index array, and smolt counts were adjusted every 15-30 min to account for changes in river velocity. To account for differences in river velocities between the velocity index and the arrays (i), readings were taken over each array at specified intervals and velocity correction factors (vcf_i) were then calculated:

$$vcf_i = \frac{v_i}{v_{index}}, \quad 1$$

where

$$\begin{aligned} v_i &= \text{velocity over array } i, \text{ and} \\ v_{index} &= \text{velocity over the velocity index array.} \end{aligned}$$

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

$$ac_{i,z} = c_{i,z} (vcf_i), \quad 2$$

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 the section of river ($l_{i,z}$) monitored by array i on day z depended on array length (3.03 m), water depth over the array, and transducer signal beam width:

$$l_{i,z} = 3.03 + 2 \left(d_{i,z} \tan \frac{bw}{2} \right), \quad 3$$

where

$d_{i,z}$ = average water depth over array i on day z , and
 bw = transducer beam width in degrees (9° for all transducers).

Arrays were placed perpendicular to the river current; distances from each array to a reference point on one river bank were measured to the nearest foot (Appendix A.1, A.2, and A.3). Estimates of the inshore and offshore limits of smolt passage were made based on past studies with side-scanning hydroacoustic equipment (Bue et al. 1988; Huttunen and Skvorc 1991, 1992). However, due to the low water levels and slower river velocities at Kvichak River in 1997, the crew notice that the schools of smolt seemed to be passing further out from the inshore bank. Therefore the inshore limit dead zone (e.g., the shallow or slack water area of the river that extends outward from the right river bank where little or no smolt passage was recorded or observed) was extended from 40' to 60' (Appendix A.1). Distances were calculated between inshore limit of smolt passage to first array (D_1); first to second array (D_2); second to third array (D_3) at sites where three arrays were used; 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:

$$\hat{B}_z = \frac{1}{2} D_1 \left(\frac{ac_{1,z}}{l_{1,z}} \right) + \sum_{i=2}^{na} \left[\frac{1}{2} D_i \left(\frac{ac_{i-1,z}}{l_{i-1,z}} + \frac{ac_{i,z}}{l_{i,z}} \right) \right] + \frac{1}{2} D_{na+1} \left(\frac{ac_{na,z}}{l_{na,z}} \right), \quad 4$$

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 1997 smolt occurred in 1995 for age-1. smolt, 1994 for age-2. smolt, and 1993 for age-3. smolt.

Sample size goals for Kvichak, Egegik, and Ugashik Rivers were 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 was 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 all smolt collected each day: up to a maximum of 600 for length and weighing and sampling up to 100 of those smolt for age (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):

$$W_j = \alpha L_j^\beta \quad , \quad 5$$

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:

$$\hat{W} = \frac{\sum_{k=1}^m \left(\frac{\sum w_k}{n_k} \right)}{m} \quad , \quad 6$$

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

$$\hat{P}_j = \frac{\sum_{k=1}^m \left(\frac{n_{j,k}}{n_k} \right)}{m} , \quad 7$$

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 into estimates of smolt per count ($S\hat{P}C$):

$$S\hat{P}C = \frac{BPC}{\hat{W}} , \quad 8$$

where BPC = biomass (g) per count.

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

$$\hat{N}_z = \hat{B}_z (S\hat{P}C) . \quad 9$$

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

$$\hat{N}_{j,z} = \hat{N}_z (\hat{P}_j) . \quad 10$$

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

$$\hat{N}_{tot} = \sum \hat{N}_z , \quad 11$$

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

$$\hat{N}_{j,tot} = \sum \hat{N}_{j,z} . \quad 12$$

Vertical Distribution of Smolt Passage

Monitoring of vertical distribution of passing smolt schools was conducted with an oscilloscope during the 2 weeks of peak smolt passage. Vertical distribution of smolt was monitored for approximately 1 h during each 8-h shift. Observers recorded the top and bottom depth (in centimeters) of passing smolt schools and spread their hour of monitoring throughout their shift and among all arrays. The arrays that received the highest counts were monitored most.

Climatological Data Collection

Climatological data were recorded at each counting site. Observations of sky conditions and measurements of wind direction, wind velocity (km/h), daily precipitation (mm), air and water temperatures (°C) were recorded at 0800 and 2000 hours daily.

RESULTS

Kvichak River

A local pilot reported that Lake Iliamna was still ice-covered at Iliamna on April 30, however the honeycombed ice was deteriorating fast and expected to break up with the next strong wind (T. LaPort, Iliamna Air Taxi, personal communication). Following an overflight of Lake Iliamna on the evening of May 6, a commercial airline passenger reported that the lake was still ice covered (C. Vicary, ADF&G King Salmon, personal communication). Local residents reported that the ice began breaking up on Lake Iliamna over the next several days and the lake was ice-free at Igiugig by May 10 (D. Salmon, Igiugig resident, personal communication). Subsequent southerly and westerly winds blew the ice pack up the lake and warmer than usual temperatures melted it in place. The average reported break-up date for Lake Iliamna between 1971 and 1996 was May 14 (Appendix B.1). Therefore break-up was 6 d earlier than average in 1997.

ADF&G's Kvichak smolt personnel arrived in Igiugig on the morning of May 15; there was no ice in Lake Iliamna or the Kvichak River at that time. From May 15-16, the crew observed three instances of Arctic terns *Sterna paradisaea* catching smolt in Kvichak River. The smolt counter was activated at 1800 hours on May 17 and it immediately began registering smolt counts. The smolt passage rate during the first 18 h of sonar operation ranged from 3 smolt to 270 thousand smolt per hour for a daily total of 8.0 million smolt.

The first three fyke net sets fished between 1830 and 2200 hours on May 18 caught zero sockeye salmon smolt (Appendix C.1). The fourth fyke net set fished from 2205 to 2300 hours on May 18 caught 700 sockeye salmon smolt which indicated a relatively low abundance (CPUE=13) of smolt in the river. The age composition of the first fyke net catch was 17% age-1. and 83% age-2. smolt.

River velocity measurements over the center index array, which were used to adjust the sonar counter firing rate, ranged from 0.9 to 1.1 m/s (2.9 to 3.5 ft/sec). The average river velocity in 1997 was the lowest river velocity recorded at the Kvichak River sonar site in the last 10 years (Appendix D.1), however similar low flows were also observed in 1992 and 1996. Velocity correction factors (m/s) used for the three arrays were as follows:

Smolt Days	Inshore	Center	Offshore
May 17 - May 25	0.99	1.00	0.93
May 26 - June 02	0.98	1.00	0.91
June 03 - June 12	0.95	1.00	0.88
June 13	1.00	1.00	0.90

A total of 12,001,609 sonar counts were recorded at the Kvichak River counting site from May 17 to June 12, 1997 (Table 1). More counts were recorded over the offshore (39%) and inshore (34%) arrays than over the center (27%) array. Daily sonar counts were highest from May 18 to June 1 when 86% of the total counts were recorded. The peak daily sonar count of 1,449,153 occurred on May 22. Over the course of the entire sampling season, 63% of the total sonar counts were obtained between 2100 hours and 0600 hours (Table 2); the peak hourly passage rate of 229,472 sonar counts per hour occurred at 0200 hours on May 18.

Based on sonar counts an estimated 363,397,663 sockeye salmon smolt migrated from Kvichak River in 1997 (Table 3). Age-1. smolt (1995 brood year) comprised 74% of the total smolt estimate and they were the predominant age class from May 19 to June 12. Age-2. smolt (1994 brood year) comprised the largest percentage of the daily counts on May 17 and May 18. The highest daily smolt counts occurred on May 22. The smolt per count estimates based on mean smolt weights ranged from 3.3 to 5.5 with an average of 5.1 smolt per count (Table 4).

Age, weight, and length data were collected from 1,823 sockeye salmon smolt in 1997 (Table 5). All smolt sampled were age 1. or 2. Mean length was 88 mm for age-1. smolt and 105 mm for age-2. smolt. Mean weight was 6.8 g for age-1. smolt and 10.6 g for age-2. smolt. An additional 9,736 smolt were measured for length only (Table 6). The discriminating lengths calculated to differentiate age-1. from age-2. smolt were of 98.44 mm from May 18-19 and 97.99mm from May 20 to June 10.

One hundred three depth measurements were recorded for smolt schools passing over Kvichak River sonar arrays between May 17 and June 8 (Table 7). Schools passed at an average depth range of 32 cm to 156 cm below the surface. Average water depth over the sonar arrays ranged from 244

cm to 258 cm during the peak smolt passage. The difference in the depth of smolt passage by hour over each sonar array is shown in Figure 5.

River and weather conditions were recorded at the counting site from May 17 to June 13 (Table 8). The weather was excellent for counting smolt in 1997. There was no disabled time from lake ice flows in the Kvichak River or equipment problems. The smolt counter was disabled for only 3.2 h (<1%) of the 648 h it operated in 1997 due to heavy rain showers and wind on June 2, June 9, and June 12. Mean water temperature during the project was 8.1 °C (range 5.0 °C to 13.0 °C). Mean daily water temperature during the peak of the smolt migration on May 22 was 6.5 °C.

Egegik River

A sea surface temperature map generated from an infrared satellite photo showed that Becharof Lake was ice-free by April 19 (Page 1997). This is 3 d earlier than the 1975-1996 average reported break-up date for Becharof Lake of April 22 (Appendix B.2).

The Egegik River smolt crewmembers flew to the study site on the morning and afternoon of May 15. There was no ice in the lake or the river when the crew arrived and few observations of smolt or birds feeding on smolt were reported prior to the installation of the Egegik River smolt sonar counter on the afternoon of May 18. Activation of the sonar counter was delayed until 0600 hours on May 19 due to high SE winds. There were a few smolt passing during the first several days of operation, however the first daily sonar count greater than 100,000 did not occur until May 23.

The fyke net was installed and fished nightly from May 20-25, but few smolt ($n \leq 10$) were caught until after midnight on May 26 (Appendix C.2). From then on the fyke net routinely caught more than 100 smolt per set.

River velocities at the counting site ranged from 0.4 to 0.6 m/s (1.2 to 1.9 ft/sec). These river velocities were slightly higher than the low flows observed in 1996 (Appendix D.2), however the average river velocity in 1997 was still 22% less than the 1984-1996 average of 0.6 m/sec (2.1 ft/sec). In 1997, the smolt counter was calibrated according to the water velocities at an index buoy set downstream from the center array. Velocity correction factors (m/s) used for three arrays were:

Smolt Days	Index Buoy	Inshore	Center	Offshore
May 20 - May 24	1.00	0.99	1.33	1.28
May 25 - May 30	1.00	0.76	1.02	1.08
May 31 - Jun 06	1.00	0.80	1.01	1.01
Jun 07 - Jun 09	1.00	0.71	1.00	0.99

A total of 1,955,398 sonar counts were recorded at the Egegik River counting site from May 18 to June 9, 1997 (Table 9). Sonar counts were most numerous over the center array (42%) followed by the offshore (31%) and inshore (27%) arrays. Daily sonar counts were highest from May 23-31. Eighty-five percent of the total sonar count was recorded during this nine-day period. The peak daily sonar count of 353,904 occurred on May 29. Over the course of the season, the largest hourly sonar counts were recorded from 1500 hours to 1700 hours and 0200 hours to 0600 hours (Table 10); 57% of all smolt counts were obtained during these times.

An estimated 27,050,113 sockeye salmon smolt migrated from Egegik River in 1997 based on sonar counts (Table 11). Age-1. smolt (1995 brood year) comprised 45% of the total smolt estimate and they were the predominant age class from May 18-25, May 31 to June 1, and June 4-9. Age-2. smolt (1994 brood year) were the predominant age class from May 26-30 and June 2-3 and they comprised 54% of the total smolt estimate. Age-3. smolt composed less than 1% of the total smolt estimate. Mean weight of smolt varied from 9.9 to 13.3 g per smolt (Table 12), resulting in an average 3.6 smolt per count adjustment factor to expand sonar counts.

Age, weight, and length data were collected from 1,511 sockeye salmon smolt in 1997 (Table 13). Age-1., -2., and -3. smolt were sampled. Mean length was 103 mm for age-1. smolt, 117 mm for age-2. smolt, and 135 mm for age-3. smolt. Mean weight was 9.5 g for age-1. smolt, 13.4 g for age-2. smolt, and 18.4 g for age-3. smolt. An additional 6,915 smolt were measured for length only (Table 14). Age-1. smolt were separated from age-2. smolt using a discriminating length of 109.59 mm.

Ninety-eight depth measurements were recorded for smolt schools passing over Egegik River sonar arrays during peak smolt passages between May 19 and June 8 (Table 15). Most schools passed from 60 cm to 150 cm below the surface. Average water depth over the sonar arrays at this site ranged from 291 cm to 349 cm. The depth of smolt passage by hour for each array is shown in Figure 6.

River and weather conditions were recorded at the counting site from May 19 to June 10 (Table 16). The weather at the Egegik River sonar site was excellent for counting smolt in 1997. The smolt counter was disabled for less than one hour due to weather or river related events. Mean water temperature during the season was 7.9 °C (range 3.5 °C to 13.0 °C). Mean daily water temperature during the peak of the smolt outmigration on May 29 was 9.0 °C.

Ugashik River

Local pilots reported that Upper Ugashik Lake was totally ice-free by April 26 and Lower Ugashik Lakes was about 90% open by the same date with skim ice packed along the windward shore (C. Klutsch, ADF&G, King Salmon, personal communication). This is 4 d later than the 1976-1996 average reported break-up date of April 22 for these lakes (Appendix B.3). The owner of a private cabin located next to the Ugashik River Lodge, about 1.5 km downstream from the Ugashik River sonar site, reported the last remnants of winter ice from Lower Ugashik Lake flowed past his cabin

on May 3 (C. Vicary, ADF&G, Ugashik Smolt Project, personal communication). The same individual also reported and videotaped a large concentration of gulls and terns actively feeding on an unknown food source in the main channel of the Ugashik River and along the gravel bars above his cabin from May 4-6.

In 1997, the Ugashik River smolt sonar crew was deployed 10 d sooner than usual in order to evaluate the early passage of smolt. The first two Ugashik smolt crewmembers arrived at the study site on the afternoon of May 7 and the remaining crewmembers arrived the next morning. During the first afternoon and evening, the crew observed quite a few gulls and terns in the area, but there were no reports of them actively feeding on smolt (C. Vicary, ADF&G, Ugashik Smolt Project, personal communication). Over the next several days the number of birds diminished and they dispersed. Since there were no initial signs of smolt passing, for the first several days the sonar was used only to document the presence or absence of smolt. The sonar counter was activated and monitored from 2200-2400 hours on May 8 and 1200-2400 hours on May 9 and no smolt were counted. From 0001-0800 hours on May 10, the smolt counter was left on but unmanned. Upon inspection of their sonar tape printouts in the morning, the crew determined that the first smolt counts occurred between 0100 hours and 0200 hours on May 10. Therefore, the Ugashik smolt sonar counter was activated at 1200 hours on May 10 and manned full time thereafter. Smolt passage ranged from 30,000 to 40,000 cts/d during the first two days and then dropped well below this level for the next six days.

The first sockeye salmon smolt (n=200) were caught in the fyke net fished from 0101 hours to 0118 hours on May 11 (Appendix C.3).

River velocity measurements over the inshore index array ranged from 1.5 to 1.7 m/s (4.8 to 5.1 ft/sec). These river velocities were the fourth lowest recorded at the Ugashik River sonar site since 1983 (Appendix D.3). The average velocity in 1997 was 26% less than the 1983-1996 average of 1.9 m/sec (6.3 ft/sec). Velocity correction factors (m/s) used to adjust the sonar counter firing rate for the two arrays were as follows:

Smolt Days	Inshore	Offshore
May 05 - May 15	1.00	1.13
May 16 - May 18	1.00	1.08
May 19 - May 22	1.00	1.10
May 23 - May 28	1.00	1.12
May 29 - Jun 03	1.00	1.13
Jun 04 - Jun 12	1.00	1.13

A total of 1,544,027 sonar counts were recorded at the Ugashik River sonar counting site from May 10 to June 12, 1997 (Table 17). Most counts (78%) were recorded over the offshore array. Daily sonar counts were highest from May 23-28. Sixty-eight percent of the total counts were recorded during this six-day period. The peak daily sonar count of 416,036 occurred on May 24. Over the

entire sampling season, 90% of all smolt counts were recorded between 2200 hours and 0500 hours with peak passages occurring between 2400 hours and 0300 hours (Table 18).

Based on sonar counts an estimated 15,519,783 sockeye salmon smolt migrated from Ugashik River in 1997 (Table 19). Age-1. smolt (1995 brood year) comprised 92% of the total smolt estimate and they were the predominant age class throughout the sampling period. Age-2. smolt (1994 brood year) composed 8% of the total migration and they were most numerous on May 17, May 20, May 29, and May 30. Mean weights of smolt ranged from 7.3 to 10.0 g per smolt (Table 20), resulting in an average 5.1 smolt per count adjustment factor for expansion of sonar counts.

Age, weight, and length data were collected from 1,386 sockeye salmon smolt in 1997 (Table 21). Mean length was 92 mm for age-1. smolt and 109 mm for age-2. smolt. Mean weight was 7.9 g for age-1. smolt and 12.1 g for age-2. smolt. An additional 8,651 sockeye salmon smolt were sampled for length only (Table 22). A discriminating length of 104.8 mm was calculated to differentiate age-1. smolt from age-2. smolt at Ugashik River.

Thirty-three depth measurements were recorded for smolt schools passing over Ugashik River sonar arrays between May 10 and May 30 (Table 23). Schools passed at an average depth of 0 cm to 77 cm below the surface. Average water depth over the sonar arrays at this site ranged from 278 cm to 305 cm during the peak smolt passage. The depth of smolt passage by hour for each array shown in Figure 7.

River and weather conditions were recorded at the counting site from May 10 to June 13 (Table 24). The weather was generally good for enumerating sockeye salmon smolt emigrating from Upper and Lower Ugashik Lakes in 1997. SE 20-25 winds, waves, and snow prohibited 9 h of smolt counts on smolt day 5/11. Gusty SW 20-42 winds and rain interfered with 12 h of smolt counts on smolt day 5/14. High E 20-31, SE 25⁺-60, and ESE 20-40 winds and wave action caused a total of 19.5 h of disabled time on smolt days 5/17 and 5/18. Counts for 30 h of disable time were estimated by interpolation (Table 17). Average water temperature was 7.1°C (range 3.5 °C to 12.0 °C). The mean water temperature during the peak of the smolt outmigration -- May 24 -- was 6.5 °C.

DISCUSSION

Kvichak River

The 1997 smolt outmigration estimate of 363 million smolt is the second largest smolt outmigration estimate ever recorded at the Kvichak River sonar site (Appendix E.1 and E.2). Three out of the last four years have had smolt outmigrations greater than the 1983-1996 average of 152 million smolt. Four out of the last five smolt outmigrations have been composed primarily of age-1. smolt.

Comparing the percent of the total adjusted sonar count by smolt day for 1997 with the 1987-1996 mean it appears that the timing of the peak count was 5 d early (Figure 8). A comparison of the cumulative percent of the total adjusted sonar count by smolt day for 1997 with the 1987-1996 mean shows that the timing for the front end (25%) of the smolt outmigration was 4 d early, the mid-point (50%) of the smolt outmigration was 5 d early, and the later portion (75%) of the smolt outmigration was 6 d early (Figure 9). Therefore an undetermined number of smolt probably passed the Kvichak smolt counting site before counting began.

During past outmigrations the proportion of age-2. smolt have been higher early in the season. Therefore, since break-up was 6 d early in 1997 and we have no smolt counts for the first 7-8 ice-free days of the open-water season, we will have to wait until the age-2.2 adults return to the Kvichak River in 1999 to find out whether the current estimate of age-2. smolt for the 1994 brood year is good or if the majority of age-2. smolt passed the sonar site prior to the start of the 1997 project.

The graph of the percent of the total adjusted sonar count by hour for 1997 is very similar to the graph of the 1986-1997 mean count per hour (Figure 10).

Age-1. smolt in 1997 were 1% longer and 16% heavier than the 1955-1996 mean (Table 25). Age-2. smolt were 2% shorter and 2% heavier than the 1955-1996 mean.

The mean water temperature in 1997 was 49% warmer (NSC) than the 1963-1996 mean of 5.9 °C (Table 26). The mean daily water temperature when the Kvichak sonar began this year was 0.9 °C warmer than the recent 12-year average of 4.6 °C (Appendix F.1). On May 22, the peak of the 1997 smolt passage, the mean daily water temperature was 0.6 °C warmer than the 1984-1996 mean. For other climatological factors which may have affected the freshwater survival of smolt that outmigrated in 1997 see Appendix G.

Approximately 76 smolt per spawner were produced from the 1993 brood year escapement of 4,025,166 sockeye salmon (Table 27). The 1993 smolt-per-spawner from Kvichak was 179% greater than the recent ten-year average; mean production from brood years 1984-1993 was 27.29 smolt per spawner. Marine survival (i.e. adult salmon returns per smolt) has averaged 14% for age-1. smolt and 18% for age-2. smolt for the 1981-1990 brood years (Table 28).

A comparison of the age composition of sockeye salmon smolt from the Kvichak River with the freshwater age composition of the total adult returns shows close comparison for brood years 1984, 1985, 1988, and 1990 (Figure 11). For example in brood year 1984, 20% of the smolt were estimated to be age-1. and 80% of the smolt were estimated to be age-2. Analysis of the freshwater age of the total adult return for the 1984 brood year showed 19% age-1. and 81% age-2. However, the freshwater age relationship between smolt and adults does not always hold true. In brood years 1981 and 1983, estimates of smolt age composition were significantly higher for age-1. smolt and lower for age-2. smolt than adult returns (Table 29). Similarly, in brood years 1982, 1986, 1987, and 1989, smolt age composition showed greater percentages of age-1. and smaller percentages of age-2. smolt than the age composition of the adult return.

If fyke nets catch 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, there is strong evidence that survival rates are higher for the larger age-2. smolt than for the smaller age-1. smolt (Table 28). 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 due to not counting the early or later portions of the outmigration.

Egegik River

The 1997 Egegik River smolt outmigration estimate was 52% less than the 1983-1996 average of 56.6 million smolt (Appendix E.3 and E.4). Three of the last five years have had smolt outmigrations greater than or equal to the 1983-1996 average, however the last two years have been well below average. Age-2. smolt have been the predominant age class outmigrating from the Egegik River in three of the last five years.

Comparing the percent of the total adjusted sonar count by smolt day for 1997 with the 1987-1996 mean, the timing of the peak count appeared to be 4 d later (Figure 12). A comparison of the cumulative percent of the total adjusted sonar count by smolt day for 1997 with the 1987-1996 mean shows the first half (50%) of the smolt outmigration was 2 d later and the later portion (75%) of the smolt outmigration was 1 d later than average (Figure 13).

The graph of the percent of the total adjusted sonar count by hour for 1997 differed somewhat from the 1988-1996 mean which peaked at 0300 hours (Figure 14). The 1997 plot was bi-modal with peak hourly counts occurring between 1500-1700 hours and 0200-0500 hours. This mid-to-late afternoon peak in smolt counts was the result of high hourly counts on smolt day 5/27, 5/29, and 5/31. Although this 1500-1700 hour increase in counts was more pronounced this year than in the past, we have also observed some increases in mid-to-late afternoon counts in 1988, 1992, and 1996.

Age-1. smolt in 1997 were the same length and weighed 2% less than the 1939-1996 mean (Table 30). Age-2. smolt were also the same length as the historical mean and weighed 6% less; age-3. smolt were 2% longer and weighed 9% less.

The mean water temperature in 1997 was 23% warmer than the 1981-1996 average of 6.4 °C (Table 31). The mean daily water temperature when the Egegik River sonar was activated was 0.9 °C cooler than the 1984-1996 average (Appendix F.2). During the peak of smolt passage on May 24, the mean daily water temperature was 3.3 °C warmer than the 1981-1996 average of 9.7 °C. Other climatological factors which may have affected the freshwater survival of 1997 smolt are discussed in Appendix G.

Total production from the 1993 spawning escapement of 1,517,000 sockeye salmon was 10.35 smolt per spawner (Table 32). The 1993 smolt-per-spawner from Egegik was below average; mean production for brood years 1984-1993 was 39.77 smolt per spawner. Average marine survival has been 26% for age-1. smolt for the 1981-1990 brood years and 32% for age-2. smolt for the 1981-1990 brood years (Table 33).

A comparison of the age composition of outmigrating sockeye salmon smolt at Egegik River with the freshwater age composition of the total adult returns shows similarities ($\pm 15\%$) for brood years 1982, 1984, 1985, 1988, 1989, and 1990 (Figure 15, Table 34). However, as we saw at Kvichak River, the smolt to adult freshwater age relationship does vary. In brood year 1981, smolt age composition showed a lower percentage of age-1. smolt and a higher percentage of age-2. smolt than the adult return. Conversely, during brood years 1983, 1986, and 1987 the smolt age compositions showed higher percentages of age-1. and lower percentages of age-2. smolt than the corresponding adult returns.

However, as we saw at the Kvichak River, this smolt to adult freshwater age relationship does vary. In brood year 1981, age composition from outmigrating smolt underestimated the age-1. component by 18% and overestimated the age-2. component of the total adult return by 17%. There were no reports of ice, weather, or equipment problems in outmigration year 1983 or 1984 that account for this greater degree of variability (Bue and Fried 1987; Bue 1986a).

Ugashik River

The 1997 smolt outmigration of 15.5 million smolt is the second lowest estimate recorded at the Ugashik River smolt sonar site (Appendix E.5 and E.6). Four out of the last five years have had smolt outmigrations smaller than the 1983-1996 average of 70.1 million smolt. Three of the last five years have had smolt outmigrations composed primarily of age-1. smolt.

Comparing the percent of the total adjusted sonar count by smolt day for 1997 with the 1987-1996 mean it appears that the timing of the peak counts was about 2 d to 6 d early (Figure 16). A comparison of the cumulative percent of the total adjusted sonar count by smolt day with the 1987-1996 mean shows that the timing for the front end (25%) of the smolt outmigration was 5 d early, the mid-point (50%) of the smolt outmigration was 8 d early, and the later portion (75%) of the smolt outmigration was 9 d early (Figure 17). Judging from the gentle slope at the front and back ends of the cumulative curve, it looked like the vast majority of outmigrating smolt passed the Ugashik River sonar site during the operating dates of the 1997 project. The graph of the percent of the total adjusted sonar count by hour for 1997 was very similar to the graph of the 1987-1996 mean count per hour (Figure 18).

The dominant age groups of adult sockeye salmon from the 1997 smolt outmigration will return in 1999 (ages 1.2 and 2.2 fish) and 2000 (ages 1.3 and 2.3 fish).

Age-1. smolt in 1997 were 1% longer and 14% heavier than the 1958-1996 mean (Table 35). Age-2. smolt were 3% shorter and equal in weight to the 1958-1996 mean.

The mean water temperature in 1997 was 18% warmer than the 1983-1996 mean of 6.0 °C (Table 36). The average daily water temperature when the sonar was activated this year was 5.0 °C which is 0.8 °C warmer than the 1984-1996 average (Appendix F.3). At the peak of the 1997 smolt passage on May 24 the mean daily water temperature was 6.5 °C , 0.5 °C warmer than the 1984-1996 average. See Appendix G for other climatological factors which may have affected the freshwater survival of smolt that outmigrated in 1997.

Total smolt production from the 1993 spawning escapement of 1,413,454 sockeye salmon was 8,390,955 smolt which equates to a smolt per spawner value of 5.94 (Table 37). Marine survival has averaged 7% for age-1. smolt for the 1981-1990 brood years and 11% for age-2. smolt for the 1981-1990 brood years (Table 38).

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 ($\pm 5\%$) for brood years 1983 and 1988 (Figure 19, Table 39).

In brood years 1981 and 1985, age composition estimates from outmigrating smolt showed lower percentages of age-1. smolt and higher percentages of age-2. smolt compared to returning adults.

In brood years, 1982, 1984, 1986, and 1987 smolt age composition data showed higher percentages of age-1. smolt and lower percentages of age-2. smolt compared to adult returns.

The observed feeding activity by gulls and terns in the main channel of the Ugashik River and along the gravel bars above the Ugashik River Lodge from May 4-6, 1997 may imply that significant numbers of smolt were migrating downstream prior to the installation of the sonar equipment. However, after viewing a local resident's videotape of the bird activity, I believe the birds were likely feeding on smelt rather than sockeye salmon smolt.

There are several reasons why I believe the bird were feeding on smelt rather than smolt. First, three species of smelt (e.g., pond smelt *Hypomesus olidus*, eulachon *Thaleichthys pacificus*, and rainbow smolt *Osmerus mordax*) have been identified and known to occur in the Bristol Bay area (Morrow 1980), and all three return to freshwater in the spring to spawn. Second, from 1987 to the present the peak passage times for smolt at the Ugashik River sonar site have always been during hours of darkness (Figure 18). Historically, 76% of all smolt counts at the sonar site have occurred between 2200 hours and 0400 hours, with peak passage occurring between 2400 hours and 0300 hours. The videotape showed a large number of birds actively feeding on a very abundant food source in broad daylight. Third, Ugashik River smolt crews have reported seeing schools of smelt swimming upstream past the sonar site (B. Cross, ADF&G, Bristol Bay Research Project Leader, personal communication). The crews have differentiated smelt from smolt by when and where the fish were observed. Smelt have typically been seen only during the first few days of the project in early May. They have also only been seen swimming upstream past the sonar site in thin narrow

schools traveling close to the river banks. No downstream movements of smelt have been documented. Smolt schools on the other hand, swim downstream and typically travel out in the main current. Smelt have not been seen at the sonar site every year, in fact no smelt have been reported at the Ugashik River sonar site from 1991-1997.

For comparison, smelt in King Salmon Creek in the Naknek River drainage typically spawn one-to-two weeks after the ice goes out, and the 1976-1997 average spawning dates have been April 30 to May 6 (Appendix H.1).

LITERATURE CITED

- Bergstrom, D.J., and H.J. Yuen. 1981. 1980 Kvichak River sockeye salmon smolt studies. Pages 1-15 *in* C.P. Meacham, editor. 1980 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 63, Juneau.
- Bill, D.L. 1975. 1974 Naknek River sockeye salmon smolt studies. Pages 14-23 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.
- Bill, D.L. 1976. 1975 Naknek River sockeye salmon smolt studies. Pages 10-19 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.
- Bill, D.L. 1977. 1976 Naknek River sockeye salmon smolt studies. Pages 14-23 *in* N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.
- Bucher, W. 1980. 1979 Wood River sockeye salmon smolt studies. Pages 12-33 *in* C.P. Meacham, editor. 1979 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 46, Juneau.
- Bucher, W. 1981. 1980 Wood River sockeye salmon smolt studies. Pages 16-33 *in* C.P. Meacham, editor. 1980 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 63, Juneau.
- Bucher, W. 1982. 1981 Wood River sockeye salmon smolt studies. Pages 28-48 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.
- Bucher, W. 1983. 1983 Wood River sockeye salmon smolt studies. Pages 72-96 *in* B.G. Bue, and S.M. Fried, editors. 1987. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.
- Bucher, W. 1984. 1982 Wood River sockeye salmon smolt studies. Pages 47-68 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

LITERATURE CITED (Continued)

- Bucher, W. 1986a. 1984 Wood River sockeye salmon smolt studies. Pages 56-78 *in* B.G. Bue, editor. 1984 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 182, Juneau.
- Bucher, W. 1986b. 1985 Wood River sockeye salmon smolt studies. Pages 67-91 *in* B.G. Bue, editor. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.
- Bucher, W. 1987. 1983 Wood River sockeye salmon smolt studies. Pages 72-98 *in* B.G. Bue, and S.M. Fried, editors. 1987. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.
- Bue, B.G. 1982. 1981 Egegik River sockeye salmon smolt studies. Pages 15-27 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.
- Bue, B.G. 1984. 1982 Egegik River sockeye salmon smolt studies. Pages 28-40 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.
- Bue, B.G. editor. 1986a. 1984 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 182, Juneau.
- Bue, B.G. editor. 1986b. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.
- Bue, B.G., and D.M. Eggers. 1989. An age-length key for sockeye salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2D89-5, Anchorage.
- Bue, B.G., and S.M. Fried. 1987. Bristol Bay sockeye salmon smolt studies for 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.
- Bue, B.G., D.L. Bill, W.A. Bucher, S.M. Fried, H.J. Yuen, and R.E. Minard. 1988. Bristol Bay sockeye salmon smolt studies for 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 88-15, Juneau.

LITERATURE CITED (Continued)

- Burgner, R.L. 1962. Studies of red salmon smolts from the Wood River Lakes, Alaska. Pages 251-314 *in* T.S.Y. Koo, editor. Studies of Alaska Red Salmon. University of Washington Publications in Fisheries, Seattle.
- Burgner, R.L., and S.Y. Koo. 1954. Results of the red salmon seaward migrant enumeration, Wood River Lakes, 1951-1953. University of Washington, Fisheries Research Institute, Circular 62, Seattle.
- Church, W. 1963. Red salmon smolts from the Wood River system, 1961. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 32, Juneau.
- Church, W., and M. Nelson. 1963. Abundance, size and age of red salmon smolts from the Wood River system, 1962. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 33, Juneau.
- Clark, J.H., and T.L. Robertson. 1980. 1978 Wood River sockeye salmon smolt studies. Pages 18-29 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.
- Cochran, W.G. 1977. Sampling Techniques. John Wiley and Sons, New York, New York.
- Crawford, D.L., and B.A. Cross. 1992. Bristol Bay sockeye salmon smolt studies for 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 92-20, Juneau.
- Crawford, D.L., and B.A. Cross. 1994a. Bristol Bay sockeye salmon smolt studies for 1992. Alaska Department of Fish and Game. Division of Commercial Fisheries Management and Development, Technical Fisheries Report 94-19, Juneau.
- Crawford, D.L., and B.A. Cross. 1994b. Bristol Bay sockeye salmon smolt studies for 1993. Alaska Department of Fish and Game. Division of Commercial Fisheries Management and Development, Regional Information Report 2A94-14, Anchorage.
- Crawford, D.L., and B.A. Cross. 1995a. Bristol Bay sockeye salmon smolt studies for 1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-12, Anchorage.
- Crawford, D.L., and B.A. Cross. 1995b. Naknek River sockeye salmon smolt studies 1993-1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-09, Anchorage.

LITERATURE CITED (Continued)

- Crawford, D.L., and B.A. Cross. 1996. Bristol Bay sockeye salmon smolt studies for 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A96-10, Anchorage.
- Crawford, D.L., and B.A. Cross. 1997. Bristol Bay sockeye salmon smolt studies for 1996. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A97-10, Anchorage.
- Crawford, D.L., and F.C. Tilly. 1995. Bristol Bay upward-looking sonar sockeye salmon smolt enumeration project instruction manual. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-14, Anchorage.
- Crawford, D.L., J.D. Woolington, and B.A. Cross. 1992. Bristol Bay sockeye salmon smolt studies for 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 91-2013, Juneau.
- Cross, B.A., B.L. Stratton, and B.G. Bue. 1990. Bristol Bay sockeye salmon smolt studies for 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 90-05, Juneau.
- Eggers, D.M. 1984. 1982 Ugashik River sockeye salmon smolt studies. Pages 41-46 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.
- Eggers, D.M., and H.J. Yuen, editors. 1984. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.
- Fried, S.M., H.J. Yuen, and B.G. Bue. 1987. 1983 Naknek, Egegik, and Ugashik rivers sockeye salmon smolt studies. Pages 36-71 *in* B.G. Bue, and S.M. Fried, editors. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.
- Goodman, L. 1965. On simultaneous confidence intervals from multinomial populations. *Technometrics*. 7:247-254.
- Huttunen, D.C. 1980. 1978 Bristol Bay special sockeye salmon smolt studies. Pages 30-34 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.

LITERATURE CITED (Continued)

- Huttunen, D.C. 1984. 1982 Naknek River sockeye salmon smolt studies. Pages 14-27 *in* D.G. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.
- Huttunen, D.C., and P.A. Skvorc II, 1991. Kvichak River side-looking sonar smolt investigations, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J91-04, Anchorage.
- Huttunen, D.C., and P.A. Skvorc II, 1992. Kvichak River side-looking sonar abundance estimation. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J92-07, Anchorage.
- Jaenicke, H.W. 1963. Ugashik River smolt studies: a preliminary report of the 1962 season. United States Department of the Interior, Bureau of Commercial Fisheries, Manuscript Report 63-5, Auke Bay, Alaska.
- Jaenicke, H.W. 1968. Sockeye salmon smolt investigations on the Ugashik River, Alaska, 1958-63. Master of Science Thesis, Humbolt State College, Humbolt, California.
- Kerns, O.E. 1961. Abundance and age of Kvichak River red salmon smolts. *Fishery Bulletin* 189(61):301-320.
- Krasnowski, P. 1975. 1974 Kvichak River sockeye salmon smolt studies. Pages 1-13 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.
- Krasnowski, P. 1976. 1975 Wood River sockeye salmon smolt studies. Pages 29-51 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.
- Krasnowski, P. 1977. 1976 Wood River sockeye salmon smolt studies. Pages 24-43 *in* N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.
- Marriott, R.A. 1965. 1963 Kvichak River red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 48, Juneau.

LITERATURE CITED (Continued)

- McCurdy, M.L., and R.D. Paulus. 1972a. 1971 Naknek River sockeye salmon smolt studies. Pages 29-34 *in* P.A. Russell, and M.L. McCurdy, editors. 1971 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 2, Juneau.
- McCurdy, M.L., and R.D. Paulus. 1972b. 1969 Kvichak River sockeye salmon smolt studies. Pages 1-34 *in* M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.
- McCurdy, M.L. 1974a. 1972 Naknek River sockeye salmon smolt studies. Pages 38-48 *in* K.P. Parker, editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.
- McCurdy, M.L. 1974b. 1973 Naknek River sockeye salmon smolt studies. Pages 23-32 *in* K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.
- Minard, R.E. 1984. 1982 Nushagak and Nuyakuk River sockeye salmon smolt studies. Pages 69-72 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.
- Minard, R.E., and J. Brandt. 1986. 1985 Nuyakuk River sockeye salmon smolt studies. Pages 92-106 *in* B.G. Bue, editor. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.
- Minard, R.E., and M. Frederickson. 1987. 1983 Nuyakuk River sockeye salmon smolt studies. Pages 97-110 *in* B.G. Bue, and S.M. Fried, editors. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage.
- National Weather Service. 1995. 1995 Local climatological data, annual summary with comparative data, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9787.

LITERATURE CITED (Continued)

- National Weather Service. 1996. 1996 Local climatological data, annual summary with comparative data, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-978.
- National Weather Service. 1997a. Local climatological data, monthly summary, January 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (1 of 12).
- National Weather Service. 1997b. Local climatological data, monthly summary, February 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (2 of 12).
- National Weather Service. 1997c. Local climatological data, monthly summary, March 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (3 of 12).
- National Weather Service. 1997d. Local climatological data, monthly summary, April 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (4 of 12).
- National Weather Service. 1997e. Local climatological data, monthly summary, May 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (5 of 12).
- National Weather Service. 1997f. Local climatological data, monthly summary, June 1997, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (6 of 12).
- Nelson, M.L. 1964. Abundance, size and age of red salmon smolts from the Wood River system, 1963. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 37, Juneau.
- Nelson, M.L. 1965a. Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1964. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 62, Juneau.
- Nelson, M.L. 1965b. Abundance, size and age of red salmon smolts from the Wood River system, 1964. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 54, Juneau.

LITERATURE CITED (Continued)

- Nelson, M.L. 1966a. Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1965. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 85, Juneau.
- Nelson, M.L. 1966b. Abundance, size and age of red salmon smolts from the Wood River Lakes system, 1965. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 76, Juneau.
- Nelson, M.L. 1969. 1967 Ugashik River red salmon smolt studies. Pages 26-32 in D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 134, Juneau.
- Nelson, M.L., and H.W. Jaenicke. 1965. Abundance, size and age of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1963. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 49, Juneau.
- Newcome, N. 1978. 1977 Wood River sockeye salmon studies. Pages 24-34 in H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau.
- Page, R. 1997. Sea surface temperature map of Cook Inlet and Bristol Bay for April 19, 1997 at 6:56 PM AST. National Weather Service Alaska Region, Marine Weather Images, Marine Ice and Sea Surface Images. http://www.alaska.net/~nwsar/html/ice/ice_marine.html
- Parker, K.P. 1974a. 1972 Kvichak River sockeye salmon smolt studies. Pages 1-37 in K.P. Parker editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.
- Parker, K.P. 1974b. 1973 Kvichak River sockeye salmon smolt studies. Pages 1-22 in K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.
- Paulus, R.D. 1972. 1969 Egegik River sockeye salmon smolt studies. Pages 62-65 in M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.
- Paulus, R., and M. McCurdy. 1969. 1968 Kvichak River sockeye salmon (*Oncorhynchus nerka*) smolt studies. Pages 1-45 in M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 138, Juneau.

LITERATURE CITED (Continued)

- Paulus, R.D., and M.L. McCurdy. 1972. 1970 Kvichak River sockeye salmon smolt studies. Pages 1-13 in P.A. Russell, editor. 1970 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 4, Juneau.
- Paulus, R., and K. Parker. 1974. Kvichak River sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 166, Juneau.
- Pella, J.J., and H.W. Jaenicke. 1978. Some observations on the biology and variations of populations of sockeye salmon of the Naknek and Ugashik Systems of Bristol Bay, Alaska. National Oceanic and Atmospheric Administration, Northwest Fisheries Center, Northwest and Alaska Fisheries Center Processed Report, Seattle, Washington.
- Pennoyer, S. 1966. 1965 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 83, Juneau.
- Pennoyer, S., and M.C. Seibel. 1965. 1964 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 58, Juneau.
- Pennoyer, S., and D.M. Stewart. 1967. 1966 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Pages 4-18 in D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 102, Juneau.
- Pennoyer, S., and D.M. Stewart. 1969. 1967 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Pages 4-17 in D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 134, Juneau.
- Randall, R.C. 1976. 1975 Kvichak River sockeye salmon smolt studies. Pages 1-9 in P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.
- Randall, R.C. 1977. 1976 Kvichak River sockeye salmon smolt studies. Pages 1-13 in N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.

LITERATURE CITED (Continued)

- Randall, R.C. 1978. 1977 Kvichak River sockeye salmon smolt studies. Pages 1-5 *in* H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau
- Rietze, H.L., and P.J. Spangler. 1958. Operation report for red salmon smolt studies on the Naknek and Egegik Rivers, 1957. United States Fish and Wildlife Service, Bureau of Commercial Fisheries, Western Alaska Salmon Investigations.
- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191, Ottawa, Canada.
- Robertson, A.D. 1967. Naknek River red salmon smolt study, 1966. Pages 34-40 *in* D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 102, Juneau.
- Russell, P.A. 1972. 1971 Kvichak River sockeye salmon smolt studies. Pages 1-28 *in* P.A. Russell, and M.L. McCurdy, editors. 1971 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 2, Juneau.
- Sanders, G.H. 1976. 1975 Ugashik River sockeye salmon smolt studies. Pages 20-28 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.
- Schroeder, T.R. 1972a. 1969 Ugashik River sockeye salmon smolt studies. Pages 35-45 *in* M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.
- Schroeder, T.R. 1972b. 1970 Ugashik River sockeye salmon smolt studies. Pages 14-23 *in* P.A. Russell, editor. 1970 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 4, Juneau.
- Schroeder, T.R. 1974a. 1972 Ugashik River sockeye salmon smolt studies. Pages 49-56 *in* K.P. Parker, editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.
- Schroeder, T.R. 1974b. 1973 Ugashik River sockeye salmon smolt studies. Pages 33-45 *in* K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.

LITERATURE CITED (Continued)

- Schroeder, T.R. 1975. 1974 Ugashik River sockeye salmon smolt studies. Pages 24-37 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.
- Siedelman, D.L. 1967. Abundance, size and age of red salmon smolts from the Wood River Lakes system, 1966. Pages 18-33 *in* D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 102, Juneau.
- Siedelman, D.L. 1969. Abundance, size and age of sockeye salmon smolt from the Ugashik Lakes system, 1968. Pages 46-61 *in* M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 138, Juneau.
- Van Valin, G.R. 1969a. Naknek River red salmon smolt study, 1967. Pages 33-43 *in* D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 134, Juneau.
- Van Valin, G.R. 1969b. Naknek River sockeye salmon smolt study, 1968. Pages 62-77 *in* M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 138, Juneau.
- Woolington, J.D., B.A. Cross, B.L. Stratton, and B.G. Bue. 1990. Bristol Bay sockeye salmon smolt studies for 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 90-16, Juneau.
- Woolington, J.D., B.A. Cross, and B.L. Stratton. 1991. Bristol Bay sockeye salmon smolt studies for 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 91-19, Juneau.
- Yuen, H.J. 1978. 1977 Naknek River sockeye salmon smolt studies. Pages 12-23 *in* H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau.
- Yuen, H.J. 1980a. 1978 Kvichak River sockeye salmon smolt studies. Pages 1-17 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.
- Yuen, H.J. 1980b. 1979 Kvichak River sockeye salmon smolt studies. Pages 1-12 *in* C.P. Meacham, editor. 1979 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 46, Juneau.

LITERATURE CITED (Continued)

Yuen, H.J., and M. Wise. 1982. 1981 Kvichak River sockeye salmon smolt studies. Pages 2-15 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.

Table 1. Sonar counts recorded by smolt day and array at the sockeye salmon smolt counting site on Kvichak River, 1997.

Smolt Day ^a	Sonar Count			
	Transducer Array			Total
	Inshore	Center	Offshore	
5/17 ^b	158,814	136,902	91,798	387,514
5/18	315,655	206,770	185,061	707,486
5/19	396,466	212,582	175,050	784,098
5/20	69,454	72,781	69,892	212,127
5/21	183,782	233,014	253,392	670,188
5/22 ^c	446,710	440,487	561,956	1,449,153
5/23	464,506	372,992	381,349	1,218,847
5/24	146,826	194,713	439,340	780,879
5/25	92,049	77,915	284,937	454,901
5/26	207,448	160,403	660,355	1,028,206
5/27	269,006	148,430	328,578	746,014
5/28	132,406	120,848	249,804	503,058
5/29	81,747	59,887	86,169	227,803
5/30	55,218	18,915	30,746	104,879
5/31	213,485	227,440	369,119	810,044
6/01	290,899	202,482	173,422	666,803
6/02 ^d	124,681	79,625	83,444	287,750
6/03	158,287	75,119	128,783	362,189
6/04	86,373	43,538	34,501	164,412
6/05	70,736	39,200	37,935	147,871
6/06	36,385	18,115	21,546	76,046
6/07 ^e	4,111	1,533	1,033	6,677
6/08 ^e	13,148	7,013	5,060	25,221
6/09 ^{d,e}	24,133	16,610	21,698	62,441
6/10 ^e	33,260	24,842	29,057	87,159
6/11 ^e	3,506	3,996	5,982	13,484
6/12 ^{d,e}	6,853	5,042	4,464	16,359
Total	4,085,944	3,201,194	4,714,471	12,001,609
Percent	34.0	26.7	39.3	

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

^b Sonar counter was activated at 1800 hours on May 17.

^c Peak daily smolt passage for 1997. Sonar counts suggest heavy smolt passage across all three arrays from 2100 hours on May 22 to 0200 hours on May 23. These same large smolt schools passed by the fyke net site virtually undetected. The crew believes the smolt were traveling close to the left cut bank when they passed the fyke net site.

^d Sonar counter disabled due to hard rain shower or high winds on these dates: 6/02 (0.4 h), 6/09 (1.5 h), and 6/12 (1.3 h)

^e Rainbow trout *Salmo gairdneri* sport fishing season opened at 0001 hours on June 8. Increased boat traffic from this smolt day forward accounted for 8.9 hours of disabled time. The smolt days with the highest disabled time were: 6/11 (2.6 h), 6/10 (2.1 h), and 6/12 (1.8 h). The times with the highest disabled time were: 1100 hours (1.6 h), 1400 hours (1.4 h), and 1600 hours (1.1 h).

Table 2. Sonar counts by hour and array at the sockeye salmon smolt counting site on Kvichak River, 1997.

Sonar Operating Period	Sonar Count						Hourly Percent	Cum Percent
	Hour	Transducer Array			Total			
		Inshore	Center	Offshore				
	1200	276,493	199,708	130,809	607,010	5.06	5.06	
	1300	185,854	121,851	145,687	453,392	3.78	8.84	
	1400	167,797	108,625	93,564	369,986	3.08	11.92	
	1500	146,268	99,884	103,686	349,838	2.91	14.83	
	1600	126,420	73,137	64,557	264,114	2.20	17.03	
	1700	136,447	99,017	86,707	322,171	2.68	19.72	
	1800	92,579	105,114	97,834	295,527	2.46	22.18	
	1900	84,790	61,904	55,005	201,699	1.68	23.86	
	2000	133,631	120,082	101,628	355,341	2.96	26.82	
Smolt Days 5/17 to 6/12	2100	183,219	169,935	195,696	548,850	4.57	31.40	
	2200	306,560	135,548	246,163	688,271	5.73	37.13	
	2300	325,376	85,421	217,560	628,357	5.24	42.37	
	2400	183,258	63,566	216,413	463,237	3.86	46.23	
	0100	192,049	240,394	381,589	814,032	6.78	53.01	
	0200	249,734	518,889	486,698	1,255,321	10.46	63.47	
	0300	272,769	241,500	360,932	875,201	7.29	70.76	
	0400	271,760	125,600	436,898	834,258	6.95	77.71	
	0500	241,476	157,579	457,872	856,927	7.14	84.85	
	0600	144,765	133,722	318,094	596,581	4.97	89.82	
	0700	70,328	69,814	136,070	276,212	2.30	92.12	
	0800	36,991	37,999	79,580	154,570	1.29	93.41	
	0900	40,102	53,820	91,264	185,186	1.54	94.95	
1000	86,661	74,691	92,879	254,231	2.12	97.07		
1100	130,617	103,394	117,286	351,297	2.93	100.00		
Total		4,085,944	3,201,194	4,714,471	12,001,609			

Table 3. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Kvichak River, 1997.

Smolt Day ^a	Age 1.			Age 2.			All Ages	
	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/17	1,333,536	16.6	1,333,536	6,714,361	83.4	6,714,361	8,047,897	8,047,897
5/18	2,494,819	16.6	3,828,355	12,561,424	83.4	19,275,785	15,056,243	23,104,140
5/19	18,562,489	72.7	22,390,844	6,970,508	27.3	26,246,293	25,532,997	48,637,137
5/20	4,510,157	72.6	26,901,001	1,697,904	27.4	27,944,197	6,208,061	54,845,198
5/21	13,769,607	72.6	40,670,608	5,183,740	27.4	33,127,937	18,953,347	73,798,545
5/22	34,815,163	77.8	75,485,771	9,963,181	22.2	43,091,118	44,778,344	118,576,889
5/23	31,703,078	79.4	107,188,849	8,220,203	20.6	51,311,321	39,923,281	158,500,170
5/24	18,308,247	79.9	125,497,096	4,605,704	20.1	55,917,025	22,913,951	181,414,121
5/25	8,944,364	70.1	134,441,460	3,818,712	29.9	59,735,737	12,763,076	194,177,197
5/26	20,688,460	71.4	155,129,920	8,307,279	28.6	68,043,016	28,995,739	223,172,936
5/27	19,999,143	81.3	175,129,063	4,590,975	18.7	72,633,991	24,590,118	247,763,054
5/28	11,650,903	77.7	186,779,966	3,347,684	22.3	75,981,675	14,998,587	262,761,641
5/29	6,195,784	82.7	192,975,750	1,292,473	17.3	77,274,148	7,488,257	270,249,898
5/30	3,173,815	82.7	196,149,565	662,074	17.3	77,936,222	3,835,889	274,085,787
5/31	20,763,063	82.7	216,912,628	4,331,284	17.3	82,267,506	25,094,347	299,180,134
6/01	19,247,946	84.2	236,160,574	3,611,847	15.8	85,879,353	22,859,793	322,039,927
6/02	7,993,003	81.4	244,153,577	1,820,383	18.6	87,699,736	9,813,386	331,853,313
6/03	9,265,170	79.3	253,418,747	2,419,998	20.7	90,119,734	11,685,168	343,538,481
6/04	4,404,017	79.3	257,822,764	1,150,298	20.7	91,270,032	5,554,315	349,092,796
6/05	4,195,652	82.1	262,018,416	913,520	17.9	92,183,552	5,109,172	354,201,968
6/06	2,161,053	82.1	264,179,469	470,526	17.9	92,654,078	2,631,579	356,833,547
6/07	177,365	77.9	264,356,834	50,288	22.1	92,704,366	227,653	357,061,200
6/08	633,745	77.9	264,990,579	179,687	22.1	92,884,053	813,432	357,874,632
6/09	1,526,753	78.9	266,517,332	408,540	21.1	93,292,593	1,935,293	359,809,925
6/10	2,120,495	78.9	268,637,827	567,418	21.1	93,860,011	2,687,913	362,497,838
6/11	303,890	78.9	268,941,717	81,317	21.1	93,941,328	385,207	362,883,045
6/12	405,982	78.9	269,347,699	108,636	21.1	94,049,964	514,618	363,397,663
	269,347,699	74.1		94,049,964	25.9		363,397,663	

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

Table 4. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolts, Kvichak River, 1997.

Smolt Day ^a	Mean Weight of Smolt (g)	Smolt per Count
5/17	12.4	3.3
5/18	12.4	3.3
5/19	8.4	4.9
5/20	8.4	4.9
5/21	8.4	4.9
5/22	7.9	5.3
5/23	7.8	5.3
5/24	7.7	5.4
5/25	8.3	5.0
5/26	8.1	5.1
5/27	7.6	5.4
5/28	7.9	5.3
5/29	7.6	5.5
5/30	7.6	5.5
5/31	7.6	5.5
6/01	7.6	5.5
6/02	7.6	5.4
6/03	7.9	5.2
6/04	7.9	5.2
6/05	7.5	5.5
6/06	7.5	5.5
6/07	8.3	5.0
6/08	8.3	5.0
6/09	8.0	5.2
6/10	8.0	5.2
6/11	8.0	5.2
6/12	8.0	5.2

^a Sample day began at 1159 hours and ended at 1159 hours the next calendar day.

Table 5. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Kvichak River, 1997.

Smolt Day ^a	Age 1.					Age 2.				
	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/18	89	8.6	7.8	2.18	24	113	15.1	14.0	5.74	80
5/19	88	11.7	6.9	3.36	86	105	9.2	11.5	2.48	15
5/20	87	8.2	7.0	4.04	34	104	10.4	11.2	3.45	3
5/21	89	11.0	7.7	3.13	81	105	8.3	11.4	2.72	21
5/22	87	9.2	6.7	2.49	75	101	9.3	10.4	2.79	10
5/23	87	11.8	6.2	2.40	84	103	14.5	9.8	3.09	18
5/24	87	12.5	6.5	3.23	94	104	10.5	10.3	2.54	7
5/25	89	12.4	7.0	2.45	49	104	7.1	10.3	2.35	18
5/26	87	12.5	6.1	2.61	72	107	12.0	10.7	3.20	29
5/27	87	13.1	6.8	4.03	93	104	10.3	10.9	3.19	8
5/28	88	16.6	6.6	3.81	85	106	13.7	10.6	2.50	16
5/29	89	11.4	7.9	2.86	46	101	2.3	11.4	1.46	4
5/31	88	10.4	6.2	3.03	94	105	12.7	10.4	2.87	7
6/01	86	12.2	7.2	2.81	92	102	5.5	10.6	1.69	3
6/02	87	11.3	6.7	3.20	95	101	4.8	9.4	1.12	6
6/03	87	6.3	6.6	1.61	31	103		9.8		1
6/04	90	9.4	7.1	2.06	34	105	4.2	10.8	0.97	6
6/05	87	11.8	6.3	2.77	60	106	9.9	9.6	1.98	5
6/06	89	9.4	6.2	1.95	53	106	5.0	10.0	1.18	7
6/08	91	12.4	7.1	2.77	91	104	14.1	10.4	3.77	8
6/09	92	10.6	6.2	2.96	66	107	11.2	9.7	2.76	13
6/10	92	9.9	6.6	2.83	92	107	9.0	10.4	1.93	7
Total Mean	88		6.8		1,531	105		10.6		292

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

Table 6. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Kvichak River, 1997.

Smolt Day ^b	Age 1. ^a				Age 2. ^a			
	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size
5/18	88	12.8	6.8	110	111	27.3	13.4	516
5/19	88	18.4	6.8	461	106	15.5	11.8	85
5/20	88	15.2	6.8	182	108	14.8	12.4	18
5/21	89	16.1	6.9	414	104	12.3	11.1	112
5/22	86	15.8	6.4	450	104	10.8	11.3	28
5/23	87	19.5	6.6	469	104	8.1	11.1	26
5/24	86	19.5	6.4	485	104	10.9	11.3	36
5/25	86	18.8	6.5	299	105	14.1	11.3	64
5/26	88	18.8	6.6	441	105	13.7	10.4	75
5/27	86	21.4	6.4	573	105	11.6	10.5	30
5/28	88	20.7	6.6	475	105	12.9	10.4	42
5/29	89	13.9	6.7	207	104	13.9	10.3	36
5/31	87	20.3	6.5	489	102	9.4	10.0	23
6/01	86	16.7	6.4	511	104	8.9	10.2	8
6/02	86	20.2	6.4	499	101	8.4	9.8	25
6/03	87	11.4	6.5	169	102		9.8	1
6/04	89	15.4	6.7	268	105	12.4	10.5	31
6/05	86	14.5	6.4	247	98		9.1	3
6/06	88	15.5	6.6	387	105	11.2	10.5	17
6/08	90	15.7	7.0	486	101	7.3	9.7	32
6/09	90	12.7	7.0	236	105	16.6	10.5	49
6/10	92	14.5	7.2	549	101	12.9	9.7	72
Total Mean	88		6.6	8,407	104		10.7	1,329

^a Length-weight parameters by age group and discriminating length used to separate ages from May 18 to May 19 were:

Age 1. $a = -9.3798$ $b = 2.5166$ $r^2 = 0.4455$ $n = 68$

Age 2. $a = -10.349$ $b = 2.7426$ $r^2 = 0.7258$ $n = 87$

Discriminating Length₁ = 98.44 mm

Length-weight parameters by age group and discriminating length used to separate ages from May 20 to June 10 were:

Age 1. $a = -6.5413$ $b = 1.8815$ $r^2 = 0.3087$ $n = 1,462$

Age 2. $a = -6.9068$ $b = 1.9873$ $r^2 = 0.5459$ $n = 204$

Discriminating Length₂ = 97.99 mm

^b Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 7. Depth of sockeye salmon smolt passage at Kvichak River sonar site, May 17 to June 8, 1997.

	Depth of Passage (cm)							
	Inshore Array ^a Smolt Schools		Center Array ^b Smolt Schools		Offshore Array ^c Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Minimum	0	40	0	20	0	20	0	20
Mean	29	146	30	159	38	163	32	156
Maximum	160	250	170	255	175	247	175	255
n	38	38	33	33	32	32	103	103

^a Average depth of inshore array on smolt day 5/22 was 249 cm.

^b Average depth of center array on smolt day 5/22 was 258 cm.

^c Average depth of offshore array on smolt day 5/22 was 244 cm.

Table 8. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Kvichak River, 1997.

Date	Cloud Cover ^a		Wind ^b Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Precipitation (mm)	Water Clarity ^c
	0800	2000	0800	2000	0800	2000	0800	2000		
5/17	-	1	-	W 24	-	10.0	-	5.5	0.00	clear
5/18	4	3	-	E 16	-	12.0	5.5	5.5	0.00	clear
5/19	4	2	0	SW 16	9.0	11.0	6.0	6.0	0.00	clear
5/20	4	4	0	0	5.0	9.0	6.0	6.0	6.35	clear
5/21	4	2	S 08	W 08-16	6.0	11.5	6.0	6.5	0.00	clear
5/22	4	2	S 08-16	W 08-16	6.0	14.0	6.0	7.0	0.00	clear
5/23	1	1	0	W 08	4.0	16.0	5.0	7.0	0.00	clear
5/24	1	1	0	E 08	6.0	17.0	5.0	7.0	0.00	clear
5/25	1	1	0	E 08-16	9.0	16.0	7.0	7.5	0.00	clear
5/26	1	1	0	S 08-16	11.0	16.0	8.0	7.5	0.00	clear
5/27	1	1	0	SE 08-16	9.0	16.0	8.0	10.0	0.00	clear
5/28	2	1	SW 08-16	E 08	9.0	20.0	7.5	11.0	0.00	clear
5/29	2	3	0	E 00-08	11.5	18.0	9.5	12.0	0.00	clear
5/30	4	3	S 16	SE 18-16	8.0	11.0	9.0	10.0	trace	clear
5/31	4	2	SW 08-16	NW 10-16	8.0	16.0	9.0	9.0	0.00	clear
6/01	1	3	SW 08-11	W 08-16	9.0	18.0	9.0	10.0	0.00	clear
6/02	3	2	SW 00-08	var. 00-08	9.0	19.0	8.5	11.0	0.00	clear
6/03	1	1	0	E 05-10	10.0	22.0	9.0	13.0	0.00	clear
6/04	2	4	0	E 00-08	10.5	11.0	9.0	11.0	0.00	clear
6/05	4	3	NE 08-19	NE 13-19	9.0	19.0	10.0	11.0	2.54	clear
6/06	3	3	0	E 03-10	5.0	18.5	10.0	11.0	0.00	clear
6/07	3	4	NW 08	E 11	9.0	18.0	10.0	11.0	2.54	clear
6/08	4	3	0	0	7.0	11.0	10.0	10.0	trace	clear
6/09	3	3	0	E 13	9.0	16.5	10.0	11.0	trace	clear
6/10	4	3	0	0	7.0	15.0	10.0	11.5	trace	clear
6/11	5	3	0	E 06	8.0	13.0	10.0	11.5	0.00	clear
6/12	4	3	0	NE 19	9.0	13.0	11.0	12.0	0.00	clear
6/13	4	-	E 05-11	-	8.0	-	11.0	-	trace	murky

^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 var. = variable winds

^c Water clarity at 0800 hours

Table 9. Sonar counts recorded by smolt day and array at the sockeye salmon smolt counting site on Egegik River, 1997.

Smolt Day ^a	Sonar Count			
	Transducer Array			Total
	Inshore	Center	Offshore	
5/18 ^b	342	277	43	662
5/19 ^c	2,773	11,740	1,502	16,015
5/20 ^d	5,154	7,927	3,433	16,514
5/21	78	4,658	42,235	46,971
5/22 ^e	19	496	1,702	2,217
5/23	3,190	9,931	87,274	100,395
5/24	21,440	22,569	23,786	67,795
5/25 ^{fg}	13,263	45,057	57,949	116,269
5/26 ^{h,i}	52,317	124,506	35,512	212,335
5/27	15,691	102,863	63,006	181,560
5/28	73,342	120,665	45,416	239,423
5/29	167,298	143,084	43,522	353,904
5/30	18,686	124,007	126,035	268,728
5/31	86,494	14,062	37,194	137,750
6/01	13,199	10,127	5,009	28,335
6/02	22,336	18,679	6,978	47,993
6/03	2,935	21,999	2,391	27,325
6/04	2,703	4,920	1,719	9,342
6/05	4,433	5,781	2,489	12,703
6/06	3,066	3,693	1,593	8,352
6/07	12,041	12,492	2,935	27,468
6/08	9,804	9,671	6,147	25,622
6/09	1,996	3,476	2,248	7,720
Total	532,600	822,680	600,118	1,955,398
Percent	27.2	42.1	30.7	

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

^b Sonar counter was activated at 0600 hours on May 19 (Smolt Day 5/18).

^c Smolt counter stopped counting at 2345 hours on May 19 (Smolt Day 5/19) due to a suspected bad connection on one of the depth setting dials. No counts obtained from 2345 hours on May 19 to 1400 hours on May 20 (15.25 hours) These counts were not able to be interpolated.

^d Replaced logic card and resumed counting at 1500 hours on May 20.

^e Al Menin shut down the smolt counter for testing, 1900-2000 hours on May 22. Low smolt numbers before, during, and after these tests.

^f Sonar counts interpolated for all three arrays for the following time periods due to solar panel overcharging the sonar counter during an extended period of sunny weather which may have damaged the logic board and caused it to undercount:

1300-2400 hours on May 25

0001-2400 hours on May 26

0001-0200 hours on May 27 (Smolt Day 5/26)

^g First major showing of smolt at the fyke net (Avg CPUE = 183) at 0100 hours on May 26.

^h Smolt passage increased at 2330 hours on May 26. The crew suspected that the sonar unit was undercounting. Replaced the logic card with the one from the spare Nakek counter and resumed counting.

ⁱ Peak fyke net catch for 1997 (Avg CPUE =450) occurred at 0100 hours on May 27.

Table 10. Sonar counts by hour and array at the sockeye salmon smolt counting site on Egegik River, 1997.

Sonar Operating Period	Sonar Count					Hourly Percent	Cum Percent
	Hour	Transducer Array			Total		
		Inshore	Center	Offshore			
	1200	6,363	13,859	24,910	45,132	2.31	2.31
	1300	12,000	16,694	5,652	34,346	1.76	4.06
	1400	29,233	21,826	5,716	56,775	2.90	6.97
	1500	48,267	39,313	27,960	115,540	5.91	12.88
	1600	29,908	93,363	86,987	210,258	10.75	23.63
	1700	40,837	46,967	38,289	126,093	6.45	30.08
	1800	36,110	15,222	22,290	73,622	3.77	33.84
	1900	22,043	4,193	34,108	60,344	3.09	36.93
	2000	30,333	8,091	22,550	60,974	3.12	40.05
Smolt Days 5/18 to 6/09	2100	65,382	3,773	12,170	81,325	4.16	44.21
	2200	35,220	14,050	19,145	68,415	3.50	47.71
	2300	14,025	19,502	49,877	83,404	4.27	51.97
	2400	1,997	9,782	12,340	24,119	1.23	53.20
	0100	1,813	24,847	13,936	40,596	2.08	55.28
	0200	4,694	89,570	27,821	122,085	6.24	61.52
	0300	12,286	126,206	9,360	147,852	7.56	69.08
	0400	47,747	83,396	9,459	140,602	7.19	76.28
	0500	14,016	81,474	65,795	161,285	8.25	84.52
	0600	36,174	46,123	7,109	89,406	4.57	89.10
	0700	20,450	19,770	13,529	53,749	2.75	91.84
	0800	14,579	15,094	15,407	45,080	2.31	94.15
	0900	1,041	8,925	37,807	47,773	2.44	96.59
	1000	1,197	5,314	15,760	22,271	1.14	97.73
	1100	6,885	15,326	22,141	44,352	2.27	100.00
Total		532,600	822,680	600,118	1,955,398		

Table 11. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Egegik River, 1997.

Smolt Day ^a	Age 1.			Age 2.			Age 3.			All Ages	
	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/18	5,824	48.9	5,824	5,708	48.0	5,708	371	3.1	371	11,903	11,903
5/19	136,420	48.9	142,244	133,716	48.0	139,424	8,698	3.1	9,069	278,834	290,737
5/20	140,603	48.9	282,847	137,816	48.0	277,240	8,965	3.1	18,034	287,384	578,121
5/21	375,609	48.9	658,456	368,163	48.0	645,403	23,950	3.1	41,984	767,722	1,345,843
5/22	17,821	48.9	676,277	17,468	48.0	662,871	1,136	3.1	43,120	36,425	1,382,268
5/23	805,449	48.9	1,481,726	789,482	48.0	1,452,353	51,359	3.1	94,479	1,646,290	3,028,558
5/24	571,146	48.9	2,052,872	559,824	48.0	2,012,177	36,418	3.1	130,897	1,167,388	4,195,946
5/25	763,329	48.9	2,816,201	748,197	48.0	2,760,374	48,673	3.1	179,570	1,560,199	5,756,145
5/26	899,995	34.1	3,716,196	1,735,761	65.7	4,496,135	7,136	0.3	186,706	2,642,892	8,399,037
5/27	950,532	40.8	4,666,728	1,368,095	58.7	5,864,230	12,822	0.5	199,528	2,331,449	10,730,486
5/28	671,860	23.8	5,338,588	2,151,081	76.2	8,015,311			199,528	2,822,941	13,553,427
5/29	2,290,732	46.9	7,629,320	2,590,436	53.1	10,605,747			199,528	4,881,168	18,434,595
5/30	1,880,280	49.4	9,509,600	1,922,875	50.6	12,528,622			199,528	3,803,155	22,237,750
5/31	1,165,941	56.3	10,675,541	901,209	43.5	13,429,831	2,690	0.1	202,218	2,069,840	24,307,590
6/01	275,325	64.6	10,950,866	150,677	35.4	13,580,508			202,218	426,002	24,733,592
6/02	309,493	47.2	11,260,359	346,769	52.8	13,927,277			202,218	656,262	25,389,854
6/03	113,862	33.8	11,374,221	223,408	66.2	14,150,685			202,218	337,270	25,727,124
6/04	65,260	50.6	11,439,481	63,713	49.4	14,214,398			202,218	128,973	25,856,097
6/05	89,861	50.6	11,529,342	87,730	49.4	14,302,128			202,218	177,591	26,033,688
6/06	77,912	62.9	11,607,254	45,994	37.1	14,348,122			202,218	123,906	26,157,594
6/07	244,748	62.9	11,852,002	144,482	37.1	14,492,604			202,218	389,230	26,546,824
6/08	280,761	72.6	12,132,763	106,228	27.4	14,598,832			202,218	386,989	26,933,813
6/09	84,376	72.6	12,217,139	31,924	27.4	14,630,756			202,218	116,300	27,050,113
	12,217,139	45.2		14,630,756	54.1		202,218	0.7		27,050,113	

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

Table 12. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Egegik River, 1997.

Smolt Day ^a	Mean Weight of Smolt (g)	Smolt per Count
5/18	11.7	3.5
5/19	11.7	3.5
5/20	11.7	3.5
5/21	11.7	3.5
5/22	11.7	3.5
5/23	11.7	3.5
5/24	11.7	3.5
5/25	11.7	3.5
5/26	12.6	3.3
5/27	12.1	3.4
5/28	13.3	3.1
5/29	11.5	3.6
5/30	11.0	3.8
5/31	10.9	3.8
6/01	10.6	3.9
6/02	11.7	3.6
6/03	12.4	3.4
6/04	11.3	3.7
6/05	11.3	3.7
6/06	10.7	3.9
6/07	10.7	3.9
6/08	9.9	4.2
6/09	9.9	4.2

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

Table 13. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Egegik River, 1997.

Smolt Day ^a	Age 1.					Age 2.					Age 3.				
	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
5/19	98	5.1	7.3	0.92	5	119	9.6	14.5	4.02	5					0
5/21					0	118		13.5		1					0
5/22	101	4.8	9.4	1.49	2	119		14.4		1					0
5/23	103	1.8	9.4	0.77	2					0	133		18.1		1
5/24	98	1.8	8.8	0.65	4	106		11.2		1					0
5/25	106	11.6	10.0	3.40	30	121	22.6	14.7	7.98	68	133		17.1		1
5/26	106	19.6	10.5	6.84	29	117	24.4	13.7	7.32	68	134	1.8	19.2	0.95	2
5/27	104	16.0	9.1	4.87	40	118	21.5	13.2	7.25	56	137	5.0	19.7	2.99	4
5/28	109	22.2	11.6	7.85	26	121	21.0	14.5	7.31	74					0
5/29	102	11.1	9.0	3.09	42	118	22.8	13.0	7.08	58					0
5/30	102	11.5	8.8	3.23	41	116	23.7	12.9	8.13	57					0
5/31	102	12.6	9.1	3.19	56	116	17.5	12.7	5.58	41	138		18.0		1
6/01	102	11.8	9.2	4.99	53	118	23.0	13.7	8.01	44					0
6/02	103	14.0	9.6	3.73	43	119	19.4	14.2	6.49	57					0
6/03	104	10.7	10.0	3.11	27	120	21.8	14.4	7.65	73					0
6/04	105	15.9	10.3	4.80	43	117	17.9	14.0	5.93	57					0
6/05	105	11.5	10.0	4.43	44	116	19.2	12.8	7.25	55					0
6/06	107	18.1	11.0	7.00	60	118	20.2	14.1	7.32	40					0
6/07	103	13.3	9.1	4.05	65	113	18.4	12.5	5.76	34					0
6/08	102	13.7	9.3	4.37	79	109	12.4	11.0	3.91	21					0
Total Mean	103		9.5		691	117		13.4		811	135		18.4		9

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

Table 14. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Egegik River, 1997.

Smolt Day ^b	Age 1. ^a				Age 2. ^a			
	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size
5/25	102	13.9	9.2	269	120	29.6	14.2	285
5/26	103	12.4	9.3	165	121	30.6	14.5	356
5/27	102	14.4	9.2	212	120	29.4	14.4	334
5/28	103	13.7	9.3	98	121	28.2	14.6	444
5/29	102	14.7	9.2	264	118	26.0	13.7	295
5/30	101	18.2	8.9	273	116	22.1	13.1	263
5/31	102	16.5	9.2	308	117	23.3	13.3	228
6/01	101	17.9	8.9	436	119	27.3	14.0	192
6/02	102	16.4	9.0	247	119	29.1	14.1	279
6/03	102	13.5	9.2	161	119	27.8	14.0	332
6/04	102	10.6	9.2	81	117	17.9	13.5	73
6/05	104	13.9	9.6	271	116	22.1	13.0	247
6/06	102	10.1	9.2	44	118	14.4	13.5	34
6/07	102	15.9	9.1	399	115	19.2	12.8	147
6/08	101	13.8	9.0	142	114	11.4	12.5	36
Total Mean	102		9.2	3,370	118		13.7	3,545

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

Age 1. $a = -10.4515$ $b = 2.7354$ $r^2 = 0.6843$ $n = 691$

Age 2. $a = -10.5032$ $b = 2.7456$ $r^2 = 0.8465$ $n = 811$

Discriminating Length = 109.59 mm

^b Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 15. Depth of sockeye salmon smolt passage at Egegik River sonar site, May 19 to June 8, 1997.

	Depth of Passage (cm)							
	Inshore Array ^a Smolt Schools		Center Array ^b Smolt Schools		Offshore Array ^c Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Minimum	16	96	0	60	0	48	0	48
Mean	59	134	63	158	58	157	60	150
Maximum	120	187	144	240	170	260	170	260
n	31	31	39	39	28	28	98	98

^a Average depth of inshore array on smolt day 5/29 was 291 cm.

^b Average depth of center array on smolt day 5/29 was 340 cm.

^c Average depth of offshore array on smolt day 5/29 was 349 cm.

Table 16. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Egegik River, 1997.

Date	Cloud Cover ^a		Wind ^b Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Precipitation (mm)	Water Clarity ^c
	0800	2000	0800	2000	0800	2000	0800	2000		
5/19	4	3	SE 48	SE 40	-0.6	2.2	4.0	4.0	0.0	clear
5/20	4	4	SE 24	SE 32	5.0	3.3	4.2	5.0	0.0	clear
5/21	1	3	SE 08	W 08	4.4	5.6	3.5	4.0	0.0	clear
5/22	1	1	0	W 08	5.0	7.8	4.0	8.0	0.0	clear
5/23	1	1	0	0	5.0	8.9	4.5	8.0	0.0	clear
5/24	1	1	SE 24	SE 16	5.0	11.1	4.0	9.0	0.0	clear
5/25	1	1	N 03	SE 08	6.7	11.7	4.5	9.0	0.0	clear
5/26	1	1	0	SE 08	7.8	12.2	6.0	9.5	0.0	clear
5/27	1	3	0	SE 08	7.2	12.2	5.8	9.5	0.0	clear
5/28	4	2	0	SE 08	8.9	13.9	7.0	11.0	0.0	clear
5/29	1	3	0	SE 08	7.8	12.2	7.0	11.0	0.0	clear
5/30	1	2	0	W 08	6.1	13.9	7.5	10.0	0.0	clear
5/31	1	2	0	W 08	5.6	11.7	7.0	10.0	0.0	clear
6/01	5	1	0	W 08-16	6.1	13.3	7.0	10.0	0.0	clear
6/02	1	1	SE 03	W 08	6.1	12.2	7.0	11.0	0.0	clear
6/03	1	1	SSE 08	SE 24	7.2	11.1	7.0	11.0	0.0	clear
6/04	1	4	0	0	6.1	11.7	7.5	11.0	0.5	clear
6/05	1	4	SE 08	E 08-16	5.6	11.1	8.0	12.0	0.0	clear
6/06	3	3	0	WNW 08	10.0	11.7	8.0	13.0	1.0	clear
6/07	1	3	NE 16	ESE 32	8.9	11.7	8.0	12.0	0.0	clear
6/08	4	4	SE 08	0	6.7	10.6	8.0	11.5	0.0	clear
6/09	4	4	SE 08	ESE 16	7.2	-	8.0	11.5	0.0	clear
6/10	3	-	0	-	6.1	-	7.0	-	0.0	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 var. = variable winds

^c Water clarity at 0800 hours

Table 17. Sonar counts by smolt day and array at the sockeye salmon smolt counting site on Ugashik River, 1997.

Smolt Day ^a	Sonar Count		
	Transducer Array		Total
	Inshore	Offshore	
5/10 ^c	4,770	28,872	33,642
5/11	4,747	35,885	40,632
5/12	997	1,734	2,731
5/13	1,945	11,575	13,520
5/14 ^d	1,023	1,656	2,679
5/15	977	7,020	7,997
5/16	2,648	10,985	13,633
5/17 ^d	3,758	18,745	22,503
5/18 ^d	5,696	28,151	33,847
5/19	9,406	47,602	57,008
5/20	7,061	35,223	42,284
5/21	8,443	25,100	33,543
5/22	6,550	38,850	45,400
5/23	38,971	83,065	122,036
5/24	81,741	334,295	416,036
5/25	32,392	151,206	183,598
5/26	18,140	67,131	85,271
5/27	4,537	33,719	38,256
5/28	61,800	99,011	160,811
5/29	7,556	18,620	26,176
5/30	8,221	47,963	56,184
5/31	619	3,825	4,444
6/01	681	2,174	2,855
6/02	2,528	5,230	7,758
6/03	4,465	4,570	9,035
6/04	3,264	8,950	12,214
6/05	3,117	2,764	5,881
6/06	3,569	6,962	10,531
6/07	4,148	8,874	13,022
6/08	2,449	6,160	8,609
6/09	3,100	7,577	10,677
6/10	2,567	7,874	10,441
6/11	490	3,805	4,295
6/12	723	5,755	6,478
Total	343,099	1,200,928	1,544,027
Percent	22.2	77.8	

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

^b Preliminary smolt counting to document the presence or absence of smolt:

2200-2400 hours on May 8, no smolt counted

1200-2400 hours on May 9, no smolt counted

0000-0800 hours on May 10, unmanned, first smolt counts detected between 0100-0200 hours

^c The sonar counter was activated at 1200 hours on May 10 and manned full-time thereafter.

^d Sonar counts interpolated for one or more arrays on the following hours and dates:

1200-2300 hours on May 14 due to high SW winds

0900-1100 hours on May 17 due to gusting E winds

1200-2400 and 0100-0800 hours on May 18 due to high E winds

Table 18. Sonar counts by hour and array at the sockeye salmon smolt counting site on Ugashik River, 1997.

Sonar Operating Period	Sonar Count					Hourly Percent	Cum Percent
	Hour	Transducer Array		Total			
		Inshore	Offshore				
	1200	4,824	4,443	9,267	0.60	0.60	
	1300	5,469	6,594	12,063	0.78	1.38	
	1400	4,538	6,649	11,187	0.72	2.11	
	1500	4,481	9,845	14,326	0.93	3.03	
	1600	6,169	6,483	12,652	0.82	3.85	
	1700	4,770	4,987	9,757	0.63	4.49	
	1800	4,204	4,014	8,218	0.53	5.02	
	1900	4,971	4,999	9,970	0.65	5.66	
	2000	12,053	8,244	20,297	1.31	6.98	
Smolt	2100	14,690	14,659	29,349	1.90	8.88	
Days	2200	24,240	24,663	48,903	3.17	12.05	
5/10	2300	21,361	77,207	98,568	6.38	18.43	
thru	2400	33,300	309,667	342,967	22.21	40.64	
6/12	0100	50,973	320,070	371,043	24.03	64.67	
	0200	43,407	123,856	167,263	10.83	75.51	
	0300	53,288	140,455	193,743	12.55	88.05	
	0400	25,883	98,112	123,995	8.03	96.08	
	0500	12,993	23,193	36,186	2.34	98.43	
	0600	419	841	1,260	0.08	98.51	
	0700	1,395	1,865	3,260	0.21	98.72	
	0800	2,772	1,813	4,585	0.30	99.02	
	0900	1,176	811	1,987	0.13	99.15	
	1000	1,761	2,184	3,945	0.26	99.40	
	1100	3,962	5,274	9,236	0.60	100.00	
Total		343,099	1,200,928	1,544,027			

Table 19. Daily number of sockeye salmon emigrating seaward estimated with hydroacoustic equipment, Ugashik River, 1997.

Smolt Day ^a	Age 1.			Age 2.			All Ages	
	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/10	295,074	93.3	295,074	21,223	6.7	21,223	316,297	316,297
5/11	353,427	93.3	648,501	25,420	6.7	46,643	378,847	695,144
5/12	26,444	91.5	674,945	2,459	8.5	49,102	28,903	724,047
5/13	115,210	91.5	790,155	10,716	8.5	59,818	125,926	849,973
5/14	24,085	89.5	814,240	2,837	10.5	62,655	26,922	876,895
5/15	61,681	89.5	875,921	7,267	10.5	69,922	68,948	945,843
5/16	106,344	89.5	982,265	12,529	10.5	82,451	118,873	1,064,716
5/17	120,250	70.4	1,102,515	50,463	29.6	132,914	170,713	1,235,429
5/18	281,594	90.5	1,384,109	29,456	9.5	162,370	311,050	1,546,479
5/19	481,946	90.5	1,866,055	50,414	9.5	212,784	532,360	2,078,839
5/20	288,750	80.2	2,154,805	71,152	19.8	283,936	359,902	2,438,741
5/21	316,219	94.8	2,471,024	17,486	5.2	301,422	333,705	2,772,446
5/22	347,603	87.6	2,818,627	49,385	12.4	350,807	396,988	3,169,434
5/23	1,075,414	89.0	3,894,041	133,323	11.0	484,130	1,208,737	4,378,171
5/24	3,815,122	93.9	7,709,163	250,005	6.1	734,135	4,065,127	8,443,298
5/25	1,792,708	95.1	9,501,871	92,963	4.9	827,098	1,885,671	10,328,969
5/26	915,149	96.7	10,417,020	31,524	3.3	858,622	946,673	11,275,642
5/27	371,255	95.3	10,788,275	18,432	4.7	877,054	389,687	11,665,329
5/28	1,764,142	92.1	12,552,417	151,113	7.9	1,028,167	1,915,255	13,580,584
5/29	236,273	86.1	12,788,690	38,048	13.9	1,066,215	274,321	13,854,905
5/30	465,690	86.1	13,254,380	74,992	13.9	1,141,207	540,682	14,395,587
5/31	41,710	95.5	13,296,090	1,979	4.5	1,143,186	43,689	14,439,276
6/01	28,425	95.5	13,324,515	1,348	4.5	1,144,534	29,773	14,469,049
6/02	81,170	95.5	13,405,685	3,851	4.5	1,148,385	85,021	14,554,070
6/03	103,332	95.5	13,509,017	4,903	4.5	1,153,288	108,235	14,662,305
6/04	124,180	95.5	13,633,197	5,892	4.5	1,159,180	130,072	14,792,377
6/05	63,107	92.3	13,696,304	5,301	7.7	1,164,481	68,408	14,860,785
6/06	102,601	92.3	13,798,905	8,619	7.7	1,173,100	111,220	14,972,005
6/07	125,635	92.3	13,924,540	10,554	7.7	1,183,654	136,189	15,108,194
6/08	86,567	95.5	14,011,107	4,069	4.5	1,187,723	90,636	15,198,830
6/09	107,547	96.2	14,118,654	4,259	3.8	1,191,982	111,806	15,310,636
6/10	102,892	96.2	14,221,546	4,075	3.8	1,196,057	106,967	15,417,603
6/11	39,164	96.2	14,260,710	1,551	3.8	1,197,608	40,715	15,458,318
6/12	59,124	96.2	14,319,834	2,341	3.8	1,199,949	61,465	15,519,783
	14,319,834	92.3		1,199,949	7.7		15,519,783	

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

Table 20. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Ugashik River, 1997.

Smolt Day ^a	Mean Weight of Smolt (g)	Smolt per Count
5/10	8.3	5.0
5/11	8.3	5.0
5/12	8.4	5.0
5/13	8.4	5.0
5/14	8.9	4.7
5/15	8.9	4.7
5/16	8.9	4.7
5/17	10.0	4.1
5/18	8.3	5.0
5/19	8.3	5.0
5/20	9.1	4.6
5/21	8.2	5.1
5/22	8.9	4.7
5/23	8.6	4.8
5/24	8.2	5.1
5/25	7.7	5.4
5/26	7.3	5.7
5/27	7.5	5.5
5/28	7.5	5.6
5/29	8.1	5.1
5/30	8.1	5.1
5/31	7.9	5.3
6/01	7.9	5.3
6/02	7.9	5.3
6/03	7.9	5.3
6/04	7.9	5.3
6/05	8.3	5.0
6/06	8.3	5.0
6/07	8.3	5.0
6/08	8.1	5.1
6/09	8.1	5.1
6/10	8.1	5.1
6/11	8.1	5.1
6/12	8.1	5.1

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

Table 21. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Ugashik River, 1997.

Smolt Day ^a	Age 1.					Age 2.				
	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/10	97	13.4	8.1	3.06	49	113		12.6		1
5/11	92	15.1	7.7	3.17	37	96	7.1	8.1	1.84	2
5/13	92	14.4	7.7	3.82	42	110	10.5	12.3	2.98	8
5/16	96	8.5	8.8	2.51	43	107	7.3	11.4	2.41	15
5/17	98	9.7	9.5	2.50	32	113	10.2	13.7	4.58	28
5/19	89	24.4	8.0	5.38	52	110	8.1	12.9	2.23	6
5/20	94	17.2	8.2	4.29	83	111	14.4	13.0	5.40	17
5/21	92	16.7	8.0	3.74	45	109	4.2	11.8	1.42	4
5/22	95	14.2	8.6	3.02	85	115	9.1	13.8	3.04	15
5/23	93	15.1	8.2	3.36	88	111	10.0	12.6	3.36	11
5/24	92	18.0	7.7	4.18	91	108	9.0	11.8	2.11	9
5/25	90	16.8	7.3	4.60	94	110	7.9	11.3	1.76	6
5/26	89	16.5	7.2	3.45	94	115	5.4	13.8	1.49	5
5/27	87	19.9	6.8	4.15	46	104	11.7	11.1	1.60	4
5/28	87	18.0	6.5	3.66	91	113	11.9	12.7	3.15	8
5/30	89	11.5	6.9	2.60	44	105	4.9	11.5	1.48	6
6/04	92	10.5	7.7	3.03	43	115	5.9	12.7	0.24	2
6/06	91	8.1	7.6	2.40	36	106	10.1	11.7	2.29	4
6/07	94	10.9	8.4	2.88	48	109	4.8	12.8	0.59	2
6/08	93	9.2	8.1	2.25	48	110	0.6	10.6	0.48	2
6/10	94	8.7	8.3	2.55	37	109	6.1	11.2	0.66	3
Total Mean	92		7.9		1,228	109		12.1		158

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

Table 22. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Ugashik River, 1997.

Smolt Day ^b	Age 1. ^a				Age 2. ^a			
	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size
5/10	94	20.4	8.2	249	113	13.9	13.2	31
5/11	92	21.3	7.8	273	110	9.1	12.3	11
5/13	93	26.5	7.9	392	112	12.8	12.9	33
5/16	96	15.8	8.5	331	111	13.1	12.7	30
5/17	97	14.5	8.8	240	112	13.9	13.1	127
5/18	96	12.6	8.6	90	113	6.8	13.3	10
5/19	90	38.8	7.4	346	112	11.9	12.9	37
5/20	94	23.3	8.1	341	113	15.5	13.1	116
5/21	93	25.1	7.9	344	110	6.3	12.4	14
5/22	94	24.9	8.2	455	113	15.3	13.3	65
5/23	93	25.3	8.0	476	113	12.5	13.2	61
5/24	92	30.2	7.9	516	111	9.8	12.6	28
5/25	90	30.8	7.3	532	111	9.6	12.7	21
5/26	87	32.2	6.8	505	110	8.0	12.5	10
5/27	89	24.7	7.0	344	109	6.8	12.2	11
5/28	88	32.4	6.9	468	111	8.9	12.6	39
5/30	89	21.4	7.2	316	110	9.3	12.4	56
6/04	91	19.7	7.5	378	108	6.0	12.0	13
6/06	92	17.0	7.6	286	112	10.1	12.8	13
6/07	93	19.0	8.0	346	112	12.2	13.0	39
6/08	92	19.1	7.8	367	108	5.1	11.9	13
6/10	92	16.0	7.8	274	108	7.6	12.0	4
Total Mean	92		7.8	7,869	111		12.7	782

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

Age 1. $a = -9.5689$ $b = 2.5647$ $r^2 = 0.78$ $n = 1,228$

Age 2. $a = -8.3962$ $b = 2.3192$ $r^2 = 0.68$ $n = 158$

Discriminating Length = 104.8 mm

^b Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 23. Depth of sockeye salmon smolt passage at Ugashik River sonar site, May 10 to May 30, 1997.

	Depth of Passage (cm)					
	Inshore Array ^a Smolt Schools		Offshore Array ^b Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom
Minimum	0	20	0	27	0	24
Mean	0	66	0	88	0	77
Maximum	0	110	0	135	0	123
n	11	11	22	22	33	33

^a Average depth of inshore array on smolt day 5/24 was 278 cm.

^b Average depth of offshore array on smolt day 5/24 was 305 cm.

Table 24. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Ugashik River, 1997.

Date	Cloud Cover ^a		Wind ^b Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Precipitation (mm)	Water Clarity ^c
	0800	2000	0800	2000	0800	2000	0800	2000		
5/10	4	3	SW 06	SE 21	3.3	6.7	5.0	6.0	0.8	clear
5/11	4	4	0	SE 40	4.4	6.7	6.0	6.0	0.0	clear
5/12	4	4	SW 19	W 24	1.7	4.4	6.0	6.0	0.5	clear
5/13	4	4	SW 11	SE 16	-3.3	6.7	4.5	6.0	0.0	clear
5/14	4	4	SW 16	SW 40 +	4.4	4.4	5.0	4.0	1.3	clear
5/15	4	4	SW 19	SE 19	3.3	6.7	3.5	4.0	0.0	clear
5/16	3	3	0	SE 16	5.6	9.4	5.0	5.0	0.0	clear
5/17	3	3	-	E 08	5.6	7.8	5.0	5.0	0.0	clear
5/18	4	4	ESE 23	SE 80	6.1	6.1	5.0	6.0	0.0	clear
5/19	3	3	ESE 32	SE 19	7.2	8.9	5.0	5.5	0.0	murky
5/20	4	3	ESE 24	NE 16	5.6	7.8	5.0	5.0	1.3	lt brown
5/21	5	4	E 11	NW 23	4.4	11.1	5.0	5.0	0.0	clear
5/22	4	1	SW 16	W 14	5.6	10.0	5.0	6.0	0.0	clear
5/23	1	1	-	NE 08	3.3	20.0	5.0	6.0	0.0	clear
5/24	1	1	0	SE 32	8.3	11.1	6.0	7.0	0.0	clear
5/25	1	1	0	SE 24	7.2	13.3	6.0	7.0	0.0	clear
5/26	1	1	NE 16	SE 24	10.0	12.2	8.0	8.0	0.0	clear
5/27	1	1	0	ENE 24	11.1	17.2	9.0	10.0	0.0	clear
5/28	4	3	0	ESE 19	8.9	11.1	9.0	8.0	1.3	clear
5/29	3	2	NE 08	E 19	8.9	11.1	9.0	10.0	0.0	clear
5/30	1	2	SE 08	WNW 19	7.2	13.3	9.0	9.0	0.0	clear
5/31	2	2	SW 16	WNW 23	7.8	10.0	6.0	6.0	0.0	clear
6/01	5	1	SW 14	WNW 16	5.0	15.0	6.0	6.0	0.0	clear
6/02	1	1	SW 14	WNW 16	7.2	14.4	6.0	6.0	0.0	clear
6/03	2	1	NW 19	ESE 19	10.0	12.8	6.0	8.0	0.0	clear
6/04	2	4	0	ESE 08	8.9	12.2	7.0	8.0	0.5	clear
6/05	3	3	E 16	ESE 18	8.9	10.0	8.0	8.0	0.0	clear
6/06	3	3	NE 08	0	8.9	14.4	9.0	11.0	0.0	clear
6/07	1	-	NE 21	-	8.9	-	10.0	-	-	clear
6/08	4	4	0	0	8.3	11.7	10.0	-	0.3	clear
6/09	4	3	0	ESE 08	8.3	11.7	10.0	10.0	trace	clear
6/10	1	2	SE 10	ESE 16	7.2	13.3	10.0	12.0	0.0	clear
6/11	2	4	NE 08	E 19	9.4	10.0	11.0	11.5	trace	clear
6/12	4	4	NE 14	E 29-32	10.6	10.6	11.0	11.0	trace	clear
6/13	3	-	0	-	8.9	-	9.0	-	-	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 var. = variable winds

^c Water clarity at 0800 hours

Table 25. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Kvichak River, 1955-1997.

Year of Migration	Brood Year	Age 1.			Age 2.			Age 3.			Total Estimate ^a		
		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)
1955	1953	7	89	—	1952	93	—	—	1951	0	—	—	260,068
1956	1954	39	92	—	1953	61	116	—	1952	0	—	—	77,660
1957	1955	72	96	7.3	1954	28	120	14.4	1953	0	—	—	30,907
1958	1956	98	84	4.6	1955	2	114	—	1954	0	—	—	3,333,953
1959	1957	3	80	—	1956	97	99	7.6	1955	0	—	—	2,863,876
1960	1958	10	91	6.3	1957	90	108	10.3	1956	0	—	—	614,003
1961	1959	72	92	6.8	1958	28	117	13.1	1957	0	—	—	36,164
1962	1960	94	82	4.3	1959	6	110	9.9	1958	0	—	—	1,203,000
1963	1961	3	83	4.8	1960	97	98	7.5	1959	0	—	—	4,229,431
1964	1962	22	87	5.2	1961	78	108	9.8	1960	0	—	—	2,061,586
1965	1963	4	90	6.8	1962	96	109	11.3	1961	0	—	—	1,812,555
1966	1964	92	94	7.4	1963	8	114	12.6	1962	0	—	—	275,761
1967	1965	93	86	5.9	1964	7	118	14.2	1963	0	—	—	3,088,742
1968	1966	11	88	5.5	1965	89	104	9.2	1964	0	—	—	6,123,683
1969	1967	52	92	5.7	1966	48	109	10.6	1965	0	—	—	1,135,344
1970	1968	38	91	6.0	1967	62	110	11.0	1966	0	—	—	483,638
1971	1969	93	90	5.8	1968	7	111	11.1	1967	0	—	—	91,682,813
1972	1970	1	80	4.2	1969	99	106	10.0	1968	0	—	—	54,623,559
1973	1971	3	86	5.1	1970	97	97	8.3	1969	0	—	—	196,966,331
1974	1972	9	96	8.3	1971	79	111	13.1	1970	12	124	17.5	27,082,626
1975	1973	63	98	8.4	1972	37	122	16.4	1971	0	—	—	15,632,531
1976	1974	97	88	5.8	1973	3	121	14.2	1972	0	—	—	111,388,180
1977	1975	38	86	5.5	1974	62	106	10.1	1973	0	—	—	192,578,099
1978	1976	12	88	6.0	1975	88	97	7.8	1974	0	—	—	245,591,014
1979	1977	51	90	6.0	1976	49	109	10.3	1975	0	—	—	55,181,540
1980	1978	94	88	5.9	1977	6	110	10.7	1976	0	—	—	192,853,007
1981	1979	89	85	5.4	1978	11	108	10.2	1977	0	—	—	252,222,769
1982	1980	58	84	5.1	1979	39	103	9.1	1978	0	—	—	239,721,729
1983	1981	8	80	4.9	1980	92	98	8.5	1979	0	—	—	82,793,899
1984	1982	58	90	6.8	1981	42	104	10.0	1980	0	—	—	89,489,975
1985	1983	92	85	5.3	1982	8	102	9.2	1981	0	—	—	25,527,851
1986	1984	61	84	5.5	1983	39	107	10.4	1982	<1	102	9.1	136,733,218
1987	1985	3	82	4.5	1984	97	96	7.0	1983	<1	97	8.5	342,686,918
1988	1986	13	86	5.6	1985	87	99	8.3	1984	<1	107	9.8	100,173,692
1989	1987	95	85	5.5	1986	5	108	10.8	1985	<1	105	9.5	153,464,216
1990	1988	53	87	6.1	1987	47	105	10.5	1986	0	—	—	88,004,103
1991	1989	72	85	5.5	1988	28	105	9.9	1987	0	—	—	121,454,182
1992	1990	23	84	5.6	1989	77	100	9.3	1988	0	—	—	79,490,008
1993	1991	10	86	6.0	1990	90	97	8.2	1989	0	—	—	226,407,888
1994	1992	64	84	5.7	1991	36	102	9.5	1990	0	—	—	83,845,472
1995	1993	95	87	6.2	1992	5	103	9.8	1991	0	—	—	220,892,127
1996	1994	74	89	6.5	1993	26	110	11.3	1992	0	—	—	373,166,532
Mean			87	5.8			107	10.4			107	10.9	
1997	1995	74	88	6.8	1994	26	105	10.6	1993	0	—	—	363,397,663
% Difference from Mean			1	16			-2	2					

^a Estimates of smolt numbers from 1955 to 1970 based on fyke net catches; estimates of smolt numbers from 1971 to 1997 based on hydroacoustic techniques.

Table 26. Water temperatures at sockeye salmon smolt counting site, Kvichak River, 1963-1997.

Year	Sample Period	Water Temperature (°C)		
		Minimum	Mean	Maximum
1963	May 16 - June 14	2.2	5.5	8.9
1964	May 18 - June 14	0.0	2.6	5.6
1965	May 17 - June 11	0.0	4.4	8.9
1966	May 16 - June 26	0.0	4.7	11.1
1967	May 17 - June 20	1.1	6.9	9.4
1968	May 12 - June 12	3.3	5.4	8.3
1969	May 16 - June 18	0.3	3.9	7.8
1970	May 13 - June 07	2.8	6.8	11.1
1971	May 17 - June 20	1.1	2.4	3.3
1972	May 18 - June 18	0.6	2.9	5.0
1973	May 15 - June 14	2.9	4.9	8.9
1974	May 13 - June 09	3.0	6.2	8.0
1975	May 17 - June 15	2.0	3.8	8.0
1976	May 18 - June 19	2.0	3.9	9.5
1977	May 17 - June 14	3.0	6.4	9.5
1978	May 19 - June 09	5.0	7.6	11.0
1979	June 01 - June 10	8.0	8.6	10.0
1980	May 16 - June 18	1.5	5.5	9.0
1981	May 15 - June 09	7.0	8.2	10.0
1982	May 14 - June 15	2.5	4.9	8.5
1983	May 19 - June 14	5.2	7.9	10.5
1984	May 19 - June 11	5.5	7.9	10.0
1985	May 23 - June 20	2.0	4.6	7.0
1986	May 18 - June 12	1.0	4.6	7.0
1987	May 21 - June 13	4.5	6.7	9.0
1988	May 17 - June 17	3.0	7.1	11.0
1989	May 19 - June 16	3.0	5.8	8.8
1990	May 22 - June 15	3.5	7.3	9.5
1991	May 23 - June 17	1.0	4.8	8.5
1992	May 22 - June 14	5.0	7.8	10.0
1993	May 19 - June 12	4.0	6.6	11.0
1994	May 22 - June 16	1.5	6.1	11.0
1995	May 21 - June 14	4.0	8.1	12.5
1996	May 17 - June 13	5.0	8.1	13.0
Mean		2.8	5.9	9.1
1997	May 17 - June 13	5.0	8.8	13.0
% Difference from Mean		78.6	49.2	42.9

Table 27. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1956-1995 brood years, Kvichak River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced						Total	Per Spawner
		Age 1.	(%) ^a	Age 2.	(%) ^a	Age 3.	(%) ^a		
Estimates of smolt numbers based upon fyke net catches									
1956	9,443,318	3,267,274	54	2,777,960	46	0	6,045,234	0.64	
1957	2,842,810	85,916	13	552,603	87	0	638,519	0.22	
1958	534,785	61,400	86	10,126	14	0	71,526	0.13	
1959	680,000	26,038	27	72,180	73	0	98,218	0.14	
1960	14,630,000	1,130,820	22	4,116,093	78	0	5,246,913	0.36	
1961	3,705,849	113,338	7	1,603,464	93	0	1,716,802	0.46	
1962	2,580,884	458,122	21	1,748,178	79	0	2,206,300	0.85	
1963	338,760	64,377	73	23,377	27	0	87,754	0.26	
1964	957,120	252,384	53	222,528	47	0	474,912	0.50	
1965	24,325,926	2,866,214	34	5,475,362	66	0	8,341,576	0.34	
1966	3,775,184	648,321	55	541,017	45	0	1,189,338	0.32	
1967	3,216,208	594,327	67	298,282	33	0	892,609	0.28	
1968	2,557,440	185,356							
Estimates of smolt numbers based upon hydroacoustic techniques									
1968				5,959,383		0	-	-	
1969	8,394,204	85,723,430	61	54,159,340	39	0	139,882,770	16.66	
1970	13,935,306	464,219	<1	191,842,930	98	2,918,768	195,225,917	14.01	
1971	2,387,392	5,123,400	19	21,423,246	81	0	26,546,646	11.12	
1972	1,009,962	2,740,610		-		-	-	-	
1973	226,554	-		3,031,287		0	-	-	
1974	4,433,844	108,356,892	49	114,269,848	51	0	222,626,740	50.21	
1975	13,140,450	78,308,251	27	213,364,470	73	0	291,672,721	22.20	
1976	1,965,282	32,226,544	55	26,423,348	45	0	58,649,892	29.84	
1977	1,341,144	28,758,191	73	10,410,467	27	0	39,168,658	29.21	
1978	4,149,288	182,442,540	85	32,294,536	15	0	214,737,076	51.75	
1979	11,218,434	219,928,232	71	89,300,703	29	0	309,228,935	27.56	
1980	22,505,268	150,421,026	66	76,244,773	34	0	226,665,799	10.07	
1981	1,754,358	6,549,125	15	37,595,987	85	0	44,145,112	25.16	
1982	1,134,840	51,893,988	96	1,937,408	4	2,065	53,833,461	47.44	
1983	3,569,982	23,590,443	31	53,260,693	69	123,975	76,975,111	21.56	
1984	10,490,670	83,470,460	20	331,384,545	80	43,135	414,898,140	39.55	
1985	7,211,046	11,178,398	11	87,004,194	89	30,345	98,212,937	13.62	
1986	1,179,322	13,126,363	66	6,830,717	34	0	19,957,080	16.92	
1987	6,065,880	146,603,154	78	41,434,534	22	0	188,037,688	31.00	
1988	4,065,216	46,569,569	58	34,266,421	42	0	80,835,990	19.88	
1989	8,317,500	87,187,761	59	61,317,308	41	0	148,505,069	17.85	
1990	6,970,020	18,172,700	8	204,626,879	92	0	222,799,579	31.97	
1991	4,222,788	21,781,009	42	30,207,268	58	0	51,988,277	12.31	
1992	4,725,864	53,638,204	83	11,034,144	17	0	64,672,348	13.68	
1993	4,025,166	209,857,983	69	96,434,554	31	0	306,292,537	76.09	
1994	8,337,840	276,731,978	75	94,049,964 ^b	25	^b	370,781,942 ^b	44.47 ^b	
1995	10,038,720	269,347,699				^b	^b	^b	
1984-1993 Max	10,490,670	209,857,983	83	331,384,545	92	43,135	414,898,140	76.09	
1984-1993 Avg	5,727,347	69,158,560	49	90,454,056	51	7,348	159,619,965	27.29	
1984-1993 Min	1,179,322	11,178,398	8	6,830,717	17	0	19,957,080	12.31	

^a Percent of total smolt production.

^b Incomplete returns from brood year escapements.

Table 28. Sockeye salmon spawning escapement, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1952-1995 brood years, Kvichak River.

Brood Year	Total Spawning Escapement	Age 1.			Age 2.		
		Number of Smolt	Adult ^a Returns	Adult Returns per Smolt	Number of Smolt	Adult ^a Returns	Adult Returns per Smolt
<u>Estimates of smolt numbers based upon fyke net catches.</u>							
1952	-	-	-	-	241,870	3,610,258	b
1953	-	18,198	152,165	b	47,373	424,627	b
1954	-	30,287	109,965	b	8,654	659,246	b
1955	-	22,253	351,240	b	66,679	1,132,813	b
1956	9,443,318	3,267,274	31,253,977	b	2,777,960	7,773,131	b
1957	2,842,810	85,916	488,844	b	552,603	3,591,552	b
1958	534,785	61,400	124,250	b	10,126	161,253	b
1959	680,000	26,038	328,287	b	72,180	217,593	b
1960	14,630,000	1,130,820	1,877,221	b	4,116,093	53,360,190	b
1961	3,705,849	113,338	524,416	b	1,603,464	2,971,816	b
1962	2,580,884	458,122	256,253	0.56	1,748,178	5,083,162	b
1963	338,760	64,377	98,571	b	23,377	1,008,242	b
1964	957,120	252,384	2,647,042	b	222,528	3,093,042	b
1965	24,325,926	2,866,214	10,349,415	b	5,475,362	34,671,692	b
1966	3,775,184	648,321	1,594,186	b	541,017	4,657,432	b
1967	3,216,208	594,327	621,690	b	298,282	900,307	b
1968	2,557,440	185,356	332,177	b	-	-	b
<u>Estimates of smolt numbers based upon hydroacoustic techniques</u>							
1968	2,557,440	-	-	-	5,959,383	209,138	0.04
1969	8,394,204	85,723,430	449,791	0.01	54,159,340	4,824,026	0.09
1970	13,935,306	464,219	56,778	0.12	191,842,930	15,351,498	0.08
1971	2,387,392	5,123,400	337,314	0.07	21,423,246	2,489,981	0.12
1972	1,009,962	2,740,610	436,837	0.16	-	1,504,435	b
1973	226,554	-	1,606,766	b	3,031,287	818,529	0.27
1974	4,433,844	108,326,892	8,353,542	0.08	114,269,848	17,796,617	0.16
1975	13,140,450	78,308,251	6,920,452	0.09	213,364,470	31,164,576	0.15
1976	1,965,282	32,226,544	6,132,390	0.19	26,423,348	4,431,284	0.17
1977	1,341,144	28,758,191	2,912,441	0.10	10,410,467	309,369	0.03
1978	4,149,288	182,442,540	2,991,655	0.02	32,294,536	2,151,024	0.07
1979	11,218,434	219,928,232	20,621,724	0.09	89,300,703	21,516,038	0.24
1980	22,505,268	150,421,026	4,534,253	0.03	76,244,773	8,508,770	0.11
1981	1,754,358	6,549,125	1,019,361	0.16	37,595,987	1,098,376	0.03
1982	1,134,840	51,893,988	995,144	0.02	1,937,408	663,241	0.34
1983	3,569,982	23,590,443	11,612,066	0.49	53,260,693	1,773,442	0.03
1984	10,490,670	83,470,460	4,455,429	0.05	331,384,545	19,478,848	0.06
1985	7,211,046	11,178,398	2,313,349	0.21	87,004,194	15,069,258	0.17
1986	1,179,322	13,126,363	1,791,108	0.14	6,830,717	2,722,727	0.40
1987	8,065,880	146,603,154	6,706,260	0.05	41,434,534	5,229,846	0.13
1988	4,065,216	46,569,569	4,982,204	0.11	34,266,421	4,961,033	0.14
1989	8,317,500	87,187,761	3,829,838	0.04	61,317,308	22,259,220	0.36
1990	6,970,020	18,172,700	2,740,515	0.15	204,626,879	22,351,542	0.11
1991	4,222,788	21,781,009	3,927,301	0.18	30,207,268	871,782 ^c	
1992	4,725,864	53,638,204	656,610 ^c		11,034,144	572,986 ^c	
1993	4,025,166	209,857,983	856,308 ^c		96,434,554	1,260 ^c	
1994	8,337,840	276,731,978	2,586 ^c		94,049,964		^c
1995	10,038,720	269,347,699					
1981-1990 Max	10,490,670	146,603,154	11,612,066	0.49	331,384,545	22,351,542	0.40
1981-1990 Avg	5,075,883	48,834,196	4,044,527	0.14	85,965,869	9,560,753	0.18
1981-1990 Min	1,134,840	6,549,125	995,144	0.02	1,937,408	663,241	0.03

^a Includes estimates of adult returns through 1997.

^b Insufficient smolt samples collected to perform this calculation.

^c Future adult returns will increase these values.

Table 29. Comparison of the age composition of outmigrating sockeye smolt at Kvichak River with the freshwater age composition of their total adult returns by brood year, 1981-1990.

Smolt Outmigration Year	Brood Years	Freshwater Age	Proportion of Total		Difference	Comments
			Smolt	Adult		
1983	1981	Age 1.	0.15	0.48	-0.33	Ice problems - (5/19-5/22), intermittent
	1980	Age 2.	-	-		
1984	1982	Age 1.	0.96	0.60	0.36	No ice problems noted.
	1981	Age 2.	0.85	0.52	0.33	
1985	1983	Age 1.	0.31	0.87	-0.56	Ice problems - 5/22-6/02, 6/06 intermittent, 6/3-6/5 continuous
	1982	Age 2.	0.04	0.40	-0.36	
1986	1984	Age 1.	0.20	0.19	0.01	No ice problems noted.
	1983	Age 2.	0.69	0.13	0.56	
1987	1985	Age 1.	0.11	0.13	-0.02	No ice problems noted.
	1984	Age 2.	0.80	0.81	-0.01	
1988	1986	Age 1.	0.66	0.40	0.26	No ice problems noted.
	1985	Age 2.	0.89	0.87	0.02	
1989	1987	Age 1.	0.78	0.56	0.22	No ice problems noted.
	1986	Age 2.	0.34	0.60	-0.26	
1990	1988	Age 1.	0.58	0.50	0.08	Ice problems prior to 5/21.
	1987	Age 2.	0.22	0.44	-0.22	
1991	1989	Age 1.	0.59	0.15	0.44	Ice problems - 5/22-5/26 intermittent, 5/27-5/29 continuous.
	1988	Age 2.	0.41	0.50	-0.09	
1992	1990	Age 1.	0.08	0.11	-0.03	Ice problems - 5/19-5/22 continuous, 5/24-5/26 and 5/31 intermittent.
	1989	Age 2.	0.41	0.85	-0.44	
1993	1991	Age 1.	-	-		No ice problems. River ice-free 10 d before sonar activated.
	1990	Age 2.	0.92	0.89	0.03	

Table 30. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Egegik River, 1939-1997.

Year of Migration	Age 1.				Age 2.				Age 3.				Total Estimate ^a
	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)	
1939	1937		96		1936		105		1935				
1956	1954		101		1953		116		1952		123		
1957	1955		107		1954		120		1953		130		
1959	1957		99		1956		116		1955		123		
1960	1958		106		1957		115		1956		140		
1969	1967		99		1966		119		1965		115		
1977	1975		110	11.3	1974		116	13.3	1973				
1978	1976		104	10.1	1975		122	15.4	1974		130	18.1	
1981	1979		105	9.1	1978		122	16.6	1977		128	19.1	
1982	1980	77	104	9.2	1979	23	130	17.1	1978	0	145	23.5	63,970,160
1983	1981	12	101	9.3	1980	88	116	13.6	1979	0			18,766,889
1984	1982	35	106	10.1	1981	65	112	12.2	1980	0	134	20.2	49,667,432
1985	1983	83	106	10.4	1982	17	123	16.8	1981	0	138	24.1	66,073,548
1986	1984	32	101	9.0	1983	68	122	15.7	1982	0	140	22.6	44,197,865
1987	1985	9	107	11.6	1984	91	114	14.1	1983	0	128	18.9	49,868,710
1988	1986	74	103	10.2	1985	26	117	14.3	1984	0	136	21.2	48,961,215
1989	1987	73	99	8.9	1986	27	119	15.4	1985	0	135	21.1	99,886,786
1990	1988	7	87	6.1	1987	93	105	10.5	1986	0			56,095,226
1991	1989	5	102	10.3	1988	95	118	15.6	1987	0	140	24.4	94,095,226
1992	1990	26	104	10.2	1989	73	112	12.4	1988	1	127	17.6	23,748,278
1993	1991	35	102	9.3	1990	65	112	12.2	1989	0	138	22.1	57,960,399
1994	1992	58	104	9.6	1991	42	118	13.7	1990	0	125	14.6	94,086,989
1995	1993	13	103	9.3	1992	87	112	11.6	1991	0	126	14.9	57,385,790
1996	1994	71	106	10.5	1993	26	124	16.1	1992	3	141	21.4	31,270,793
Mean			103	9.7			117	14.3			132	20.3	
1997	1995	45	103	9.5	1994	54	117	13.4	1993	1	135	18.4	27,050,113
% Difference from Mean			0	-2			0	-6			2	-9	

^a No estimate of smolt numbers for 1939-1981 fyke net catches; estimates of smolt of smolt numbers from 1982-1997 based on hydroacoustic techniques.

Table 31. Water temperature at sockeye salmon smolt counting site, Egegik River, 1981-1997.

Year	Sample Period	Water Temp (C°)		
		Minimum	Mean	Maximum
1981	May 15 - June 08	7.0	8.2	10.0
1982	May 15 - June 16	2.5	4.9	8.5
1983	May 18 - June 10	5.2	7.9	10.5
1984	May 17 - June 11	5.5	7.9	10.0
1985	May 17 - June 12	2.0	4.6	7.0
1986	May 19 - June 12	1.0	4.6	7.0
1987	May 18 - June 13	4.5	6.7	9.0
1988	May 19 - June 14	3.0	7.1	11.0
1989	May 21 - June 10	3.0	5.8	8.8
1990	May 20 - June 11	3.5	7.3	9.5
1991	May 21 - June 12	1.0	4.8	8.5
1992	May 21 - June 12	5.0	7.8	10.0
1993	May 18 - June 09	4.0	6.6	11.0
1994	May 21 - June 10	1.5	6.1	11.0
1995	May 21 - June 13	2.0	7.0	12.5
1996	May 19 - June 13	2.0	5.8	10.5
Mean		3.3	6.4	9.7
1997	May 19 - June 10	3.5	7.9	13.0
% Difference from Mean		6.1	23.4	34.0

Table 32. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1978-1995 brood years, Egegik River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced						Total	Per Spawner
		Age 1.	(% ^a)	Age 2.	(% ^a)	Age 3.	(% ^a)		
1978	895,698					225,522			
1979	1,032,042			14,287,075		0			
1980	1,060,860	49,457,563	75	16,524,563	25	197,429	0	66,179,555	62.38
1981	694,680	2,242,326	6	32,235,734	93	52,852	0	34,530,912	49.71
1982	1,034,628	17,234,269	60	11,434,848	40	564	0	28,669,681	27.71
1983	792,282	54,585,828	64	29,984,140	35	85,087	0	84,655,055	106.85 ^b
1984	1,165,345	14,016,441	24	45,386,536	76	80,931	0	59,483,908	51.04
1985	1,095,192	4,397,087	26	12,758,135	74	81,150	0	17,236,372	15.74
1986	1,151,750	36,122,149	57	27,347,612	43	0	0	63,469,761	55.11
1987	1,273,553	72,458,024	58	52,299,487	42	396,423	0	125,153,934	98.27 ^b
1988	1,612,745	3,795,739	4	89,162,038	96	361,128	0	93,318,905	57.86
1989	1,611,566	4,519,527	21	17,338,786	79	37,254	0	21,895,567	13.59
1990	2,191,582	6,048,364	14	37,719,609	86	19,196	0	43,787,169	19.98
1991	2,786,925	20,203,545	34	39,158,743	66	11,242	0	59,373,530	21.30
1992	1,945,632	54,909,050	52	49,962,265	47	1,067,697	1	105,939,012	54.45
1993	1,517,000	7,412,283	47	8,089,658	52	202,218	1	15,704,159	10.35
1994	1,897,977	22,113,438	60	14,630,756	40		^c	36,744,194 ^c	19.36 ^c
1995	1,266,692	12,217,139			^c		^c		^c
1984-1993 Max	2,786,925	72,458,024	58	89,162,038	96	1,067,697	1	125,153,934	98.27
1984-1993 Avg	1,635,129	22,388,221	34	37,922,287	66	225,724	0	60,536,232	39.77
1984-1993 Min	1,095,192	3,795,739	4	8,089,658	42	0	0	15,704,159	10.35

^a Percent of total smolt production

^b Smolt outmigration estimates for brood years with unusually high smolt per spawner ratios may be artificially low. During these years smolt may have passed undetected before, during, or after the operational dates of the smolt sonar.

^c Incomplete returns from brood year escapements.

Table 33. Sockeye salmon spawning escapement, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1978-1995 brood years, Egegik River.

Brood Year	Age 1.				Age 2.			Age 3.		
	Total Spawning Escapement	Number of Smolt	Adult Returns ^a	per Smolt	Number of Smolt	Adult Returns ^a	per Smolt	Number of Smolt	Adult Returns ^a	per Smolt
1978	895,698		908,379			8,264,740		225,522	33,395	0.15
1979	1,032,042		1,239,273		14,287,075	4,705,018	0.33	0	0	
1980	1,060,860	49,457,563	3,035,494	0.06	16,524,563	5,519,025	0.33	197,429	7,730	0.04
1981	694,680	2,242,326	1,508,516	0.67 ^b	32,235,734	4,785,803	0.15	52,852	16,119	0.30
1982	1,034,628	17,234,269	2,873,325	0.17	11,434,848	3,447,534	0.30	564	12,739	^c
1983	792,282	54,585,828	4,520,747	0.08	30,036,716	6,086,667	0.20	85,087	37,683	0.44 ^b
1984	1,165,345	14,160,585	1,597,084	0.11	45,386,536	11,665,474	0.26	80,931	256,616	^c
1985	1,095,192	4,397,087	1,980,826	0.45 ^b	12,758,135	5,652,082	0.44 ^b	81,150	25,976	0.32
1986	1,151,750	36,122,149	5,676,245	0.16	27,347,612	8,520,337	0.31	0	120,388	^c
1987	1,273,553	72,458,024	5,548,894	0.08	52,299,487	20,199,111	0.39	396,423	193,309	0.49 ^b
1988	1,612,745	3,795,739	1,695,748	0.45	89,162,038	16,775,951	0.19	361,128	412,775	^c
1989	1,611,566	4,519,527	974,486	0.22	17,338,786	10,076,582	0.58 ^b	37,245	201,466	^c
1990	2,191,582	6,048,364	1,273,444	0.21	37,719,609	14,413,565	0.38	19,196	51,024 ^d	^c
1991	2,786,925	20,203,545	5,385,263	0.27	39,158,743	5,749,393 ^d	0.15 ^d	11,242	21,520 ^d	
1992	1,945,632	54,909,050	1,457,373 ^d	0.03 ^d	49,962,265	5,057,236 ^d		1,067,697	2,276 ^d	
1993	1,517,000	7,412,283	500,992 ^d		8,089,658	30,698 ^d		202,218		
1994	1,897,977	22,113,438	7,654 ^d		14,630,756					
1995	1,266,692	12,217,139								
1981-1990 Max	2,191,582	72,458,024	5,676,245	0.67	89,162,038	20,199,111	0.58	396,423	412,775	0.49
1981-1990 Avg	1,262,332	21,556,390	2,764,932	0.26	35,571,950	10,162,311	0.32	111,458	132,810	0.39
1981-1990 Min	694,680	2,242,326	974,486	0.08	11,434,848	3,447,534	0.15	0	12,739	0.30

^a Includes estimates of adult returns through 1997.

^b Smolt outmigration estimates for brood years with unusually high adult return per smolt ratios may be artificially low. During these years smolt may have passed undetected before, during, or after the operational dates of the smolt sonar.

^c Insufficient Age 3. smolt sampled to perform this calculation.

^d Future adult returns will increase these values.

Table 34. Comparison of the age composition of outmigrating sockeye smolt at Egegik River with the freshwater age composition of their total adult returns by brood year, 1981-1990.

Smolt Outmigration Year	Brood Year	Freshwater Age	Proportion of Total		Difference	Comments
			Smolt	Adult		
1983	1981	Age 1.	0.06	0.24	-0.18	No ice problems noted.
	1980	Age 2.	-	-		
1984	1982	Age 1.	0.60	0.45	0.15	No ice problems noted.
	1981	Age 2.	0.93	0.76	0.17	
1985	1983	Age 1.	0.64	0.42	0.22	Ice present - 5/17-5/22 intermittent
	1982	Age 2.	0.40	0.54	-0.14	
1986	1984	Age 1.	0.24	0.12	0.12	Ice present - 5/19-5/25 intermittent
	1983	Age 2.	0.35	0.57	-0.22	
1987	1985	Age 1.	0.26	0.26	0.00	No ice problems noted.
	1984	Age 2.	0.76	0.86	-0.10	
1988	1986	Age 1.	0.57	0.40	0.17	No ice problems noted.
	1985	Age 2.	0.74	0.74	0	
1989	1987	Age 1.	0.58	0.21	0.37	No ice problems noted.
	1986	Age 2.	0.43	0.60	-0.17	
1990	1988	Age 1.	0.04	0.09	-0.05	Fair Weather - 118 h disabled time
	1987	Age 2.	0.42	0.78	-0.36	
1991	1989	Age 1.	0.21	0.09	0.12	Ice problems - 5/17-5/18 continuous.
	1988	Age 2.	0.96	0.89	0.07	
1992	1990	Age 1.	0.14	0.08	0.06	No ice problems noted.
	1989	Age 2.	0.79	0.90	-0.11	
1993	1991	Age 1.	-	-		No ice problems noted.
	1990	Age 2.	0.86	0.92	-0.06	

Table 35. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Ugashik River, 1958-1997.

Year of Migration	Age 1.				Age 2.				Age 3.				Total Estimate ^a
	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)	
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
Mean			91	6.9			112	12.1			128	17.9	
1997	1995	92	92	7.9	1994	8	109	12.1	1993	-	-	-	15,519,783
% Difference from Mean			1	14			-3	0					

^a No estimates of smolt numbers from 1958-1982 fyke net catches; estimates of smolt numbers from 1983-1991 and 1993-1996 based on hydroacoustic techniques.

^b Project not operated in 1992. No smolt data collected

Table 36. Water temperature at sockeye salmon smolt counting site, Ugashik River, 1983-1997.

Year	Sample Period	Water Temp (C°)		
		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
Mean		3.5	6.0	8.5
1997	May 10 - June 13	3.5	7.1	12.0
% Difference from Mean		0.0	18.3	41.2

^a Project not operated in 1992. No data collected.

Table 37. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by each age class, and number of smolt produced per spawner for 1979-1995 brood years, Ugashik River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced						Per Spawner
		Age 1.	(% ^a)	Age 2.	(% ^a)	Age 3.	(% ^a)	
1979	1,706,904					0		
1980	3,335,284			12,736,379		26,384		
1981	1,327,699	31,297,432	27	82,656,993	73	0	113,954,425	85.83
1982	1,185,551	75,491,249	78	21,407,762	22	0	96,899,011	81.73
1983	1,001,364	12,693,628	46	15,186,101	54	1,677	27,881,406	27.84
1984	1,270,318	37,890,152	64	21,483,727	36	9,598	59,383,477	46.75
1985	1,006,407	5,461,821	14	33,238,739	86	0	38,700,560	38.45
1986	1,015,582	182,719,678	85	32,278,743	15	0	214,998,421	211.70
1987	686,894	94,019,379	71	38,789,387	29	0	132,808,766	193.35
1988	654,412	14,837,960	24	47,713,086	76	- ^b	62,551,046 ^c	95.58 ^c
1989	1,713,287	26,056,791		- ^b		0	^c	^c
1990	749,478	- ^b		12,415,518		0	^c	^c
1991	2,482,016	58,331,556	91	5,725,543	9	0	64,057,099	25.81
1992	2,194,927	24,305,081	61	15,272,807	39	0	39,577,888	18.03
1993	1,413,454	6,961,330	83	1,429,625 ^d	17	0	8,390,955	5.94
1994	1,095,068	1,147,187 ^d		1,199,949		^c	2,347,136 ^c	2.14 ^c
1995	1,321,108	14,319,834		^c		^c	^c	^c
1984-1993 Max	2,482,016	182,719,678	91	47,713,086	86	9,598	214,998,421	211.70
1984-1993 Avg	1,318,678	50,064,861	62	23,149,686	38	1,066	77,558,527	79.45
1984-1993 Min	654,412	5,461,821	14	1,429,625	9	0	8,390,955	5.94

^a Percent of total smolt production.

^b 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.

^c Incomplete returns from brood year escapements.

^d Need adult returns through 1999 to validate this smolt estimate.

Table 38. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1979-1995 brood year Ugashik River.

Brood Year	Total Spawning Escapement	Age 1.			Age 2.			Age 3.		
		Number of Smolt	Adult Returns ^a	Adult Returns per Smolt	Number of Smolt	Adult Returns ^a	Adult Returns per Smolt	Number of Smolt	Adult Returns ^a	Adult Returns per Smolt
1979	1,700,904		3,960,210			2,045,642		0		^b
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	^b
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	^b
1984	1,241,418	37,890,152	1,052,692	0.03	21,483,727	4,399,295	0.20	9,598	6,732	^b
1985	998,232	5,461,821	1,233,686	0.23	33,238,739	1,454,422	0.04	0	0	
1986	1,001,493	182,719,678	3,001,968	0.02	32,278,743	3,639,400	0.11	0	4,459	^b
1987	668,964	94,019,379	2,478,649	0.03	38,789,387	4,215,483	0.11	0	34,612	^b
1988	642,972	14,837,960	1,193,721	0.08	47,713,086	4,426,031	0.09	^c	29,819	^b
1989	1,681,302	26,056,791	1,104,400	0.04	^c	^b		0	9,880	^b
1990	749,478	^c	1,057,589	^b	12,415,518	3,535,731	0.28 ^d	0	1,733 ^d	
1991	2,482,016	58,331,556	5,221,704	0.09 ^d	5,725,543	920,413 ^d		0	0 ^d	
1992	2,194,927	24,305,081	783,806 ^d		15,272,807	1,006,425 ^d		0	0 ^d	
1993	1,413,454	6,961,330	260,020 ^d		1,429,625 ^e	6,539 ^d		0		
1994	1,095,068	1,147,187 ^e	11,351 ^d		1,199,949					
1995	1,321,108	14,319,834								
1981-1990 Max	1,681,302	182,719,678	4,241,375	0.23	82,656,993	4,426,031	0.28	9,598	34,612	^b
1981-1990 Avg	1,046,876	53,385,343	1,750,615	0.07	33,907,784	3,063,797	0.11	1,253	8,987	^b
1981-1990 Min	642,972	5,461,821	995,579	0.02	12,415,518	957,765	0.04	0	0	^b

^a Includes estimates of adult returns through 1997.

^b Insufficient smolt data to complete this calculation.

^c 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.

^d Future adult returns will increase these values.

^e Need adult returns through 1999 to validate this smolt estimate.

Table 39. Comparison of the age composition of outmigrating sockeye smolt at Ugashik River with the freshwater age composition of their total adult returns by brood year, 1981-1988.

Smolt Outmigration Year	Brood Year	Freshwater Age	Proportion of Total		Difference	Comments
			Smolt	Adult		
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	Project not conducted due to lack of funding. Therefore no data for brood year 1989 Age 2. or brood year 1990 Age 1. smolt					

^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.

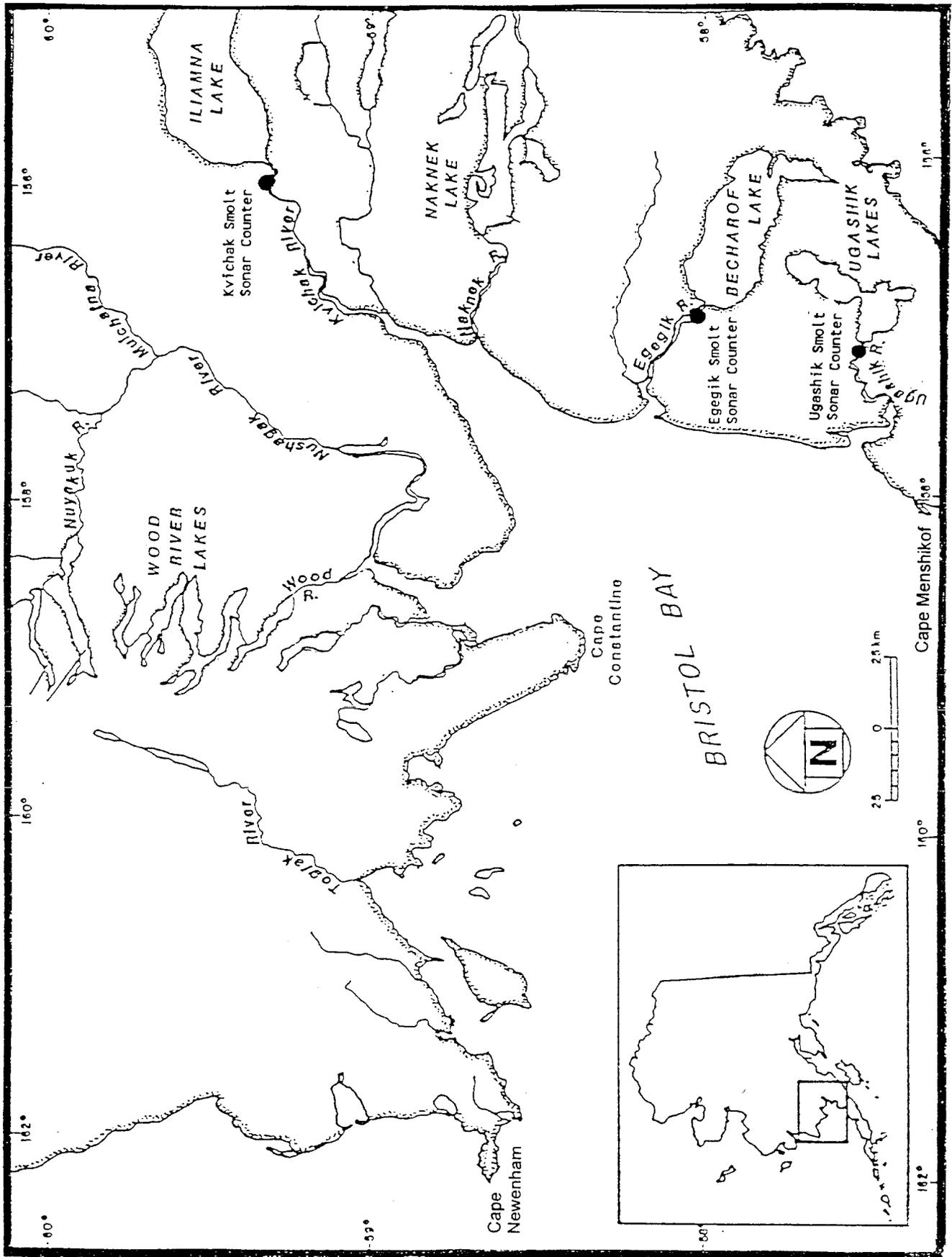


Figure 1. Bristol Bay Management Area with major rivers and locations of smolt counting projects, 1997.

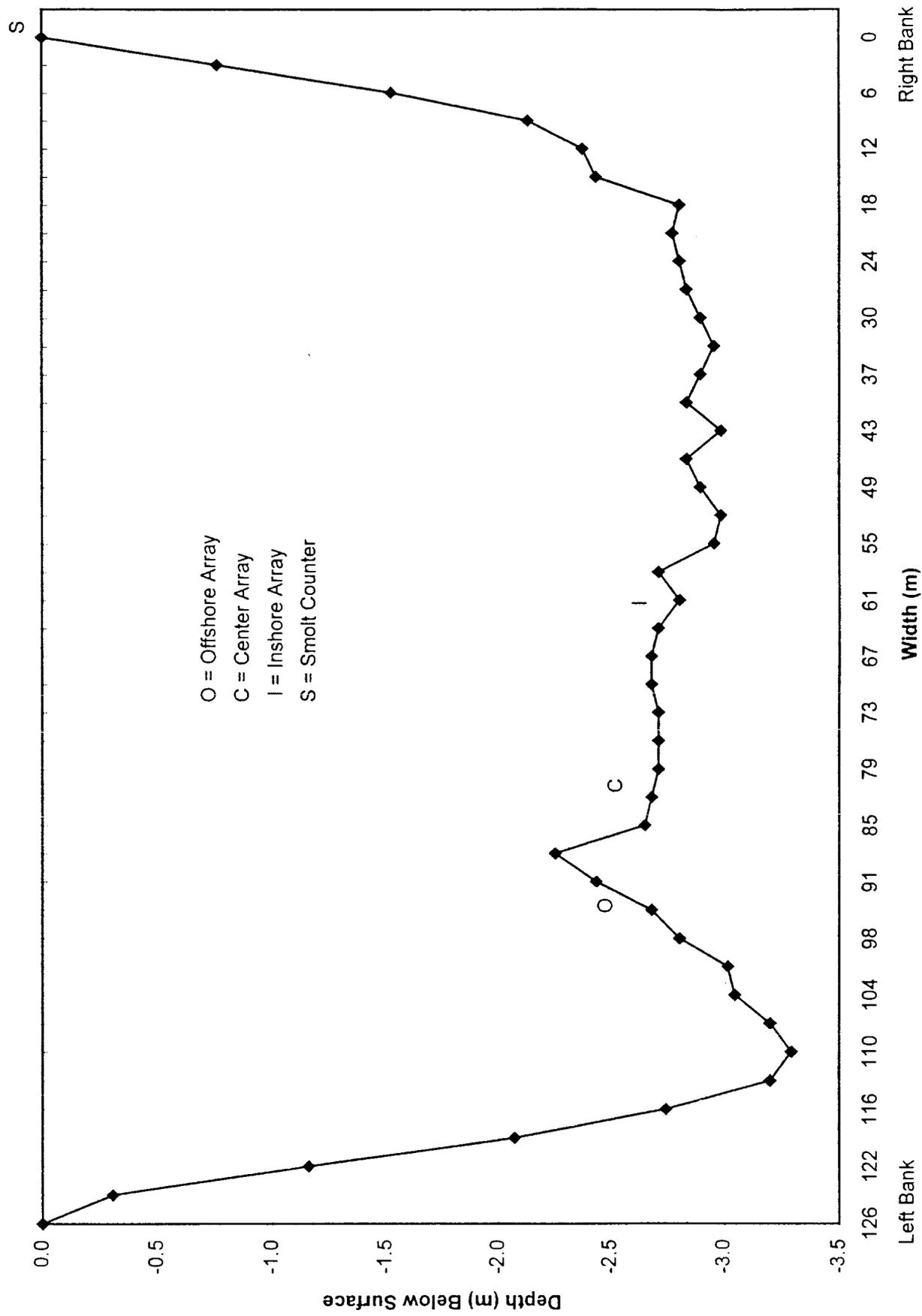


Figure 2. River bottom profile and sonar array placement at Kvichak River smolt sonar site, 1997.

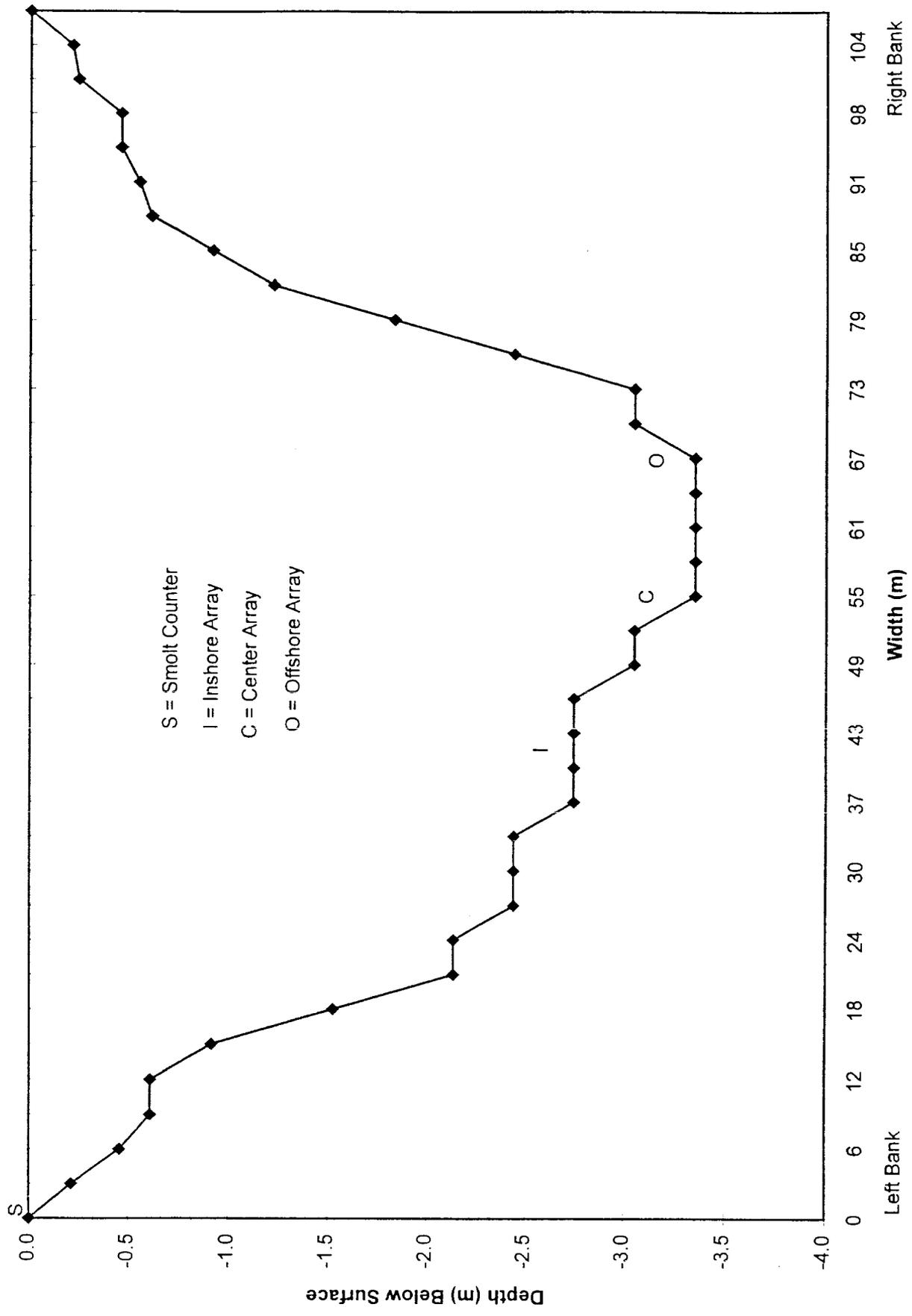


Figure 3. River bottom profile and sonar array placement at Egegik River smolt sonar site, 1997.

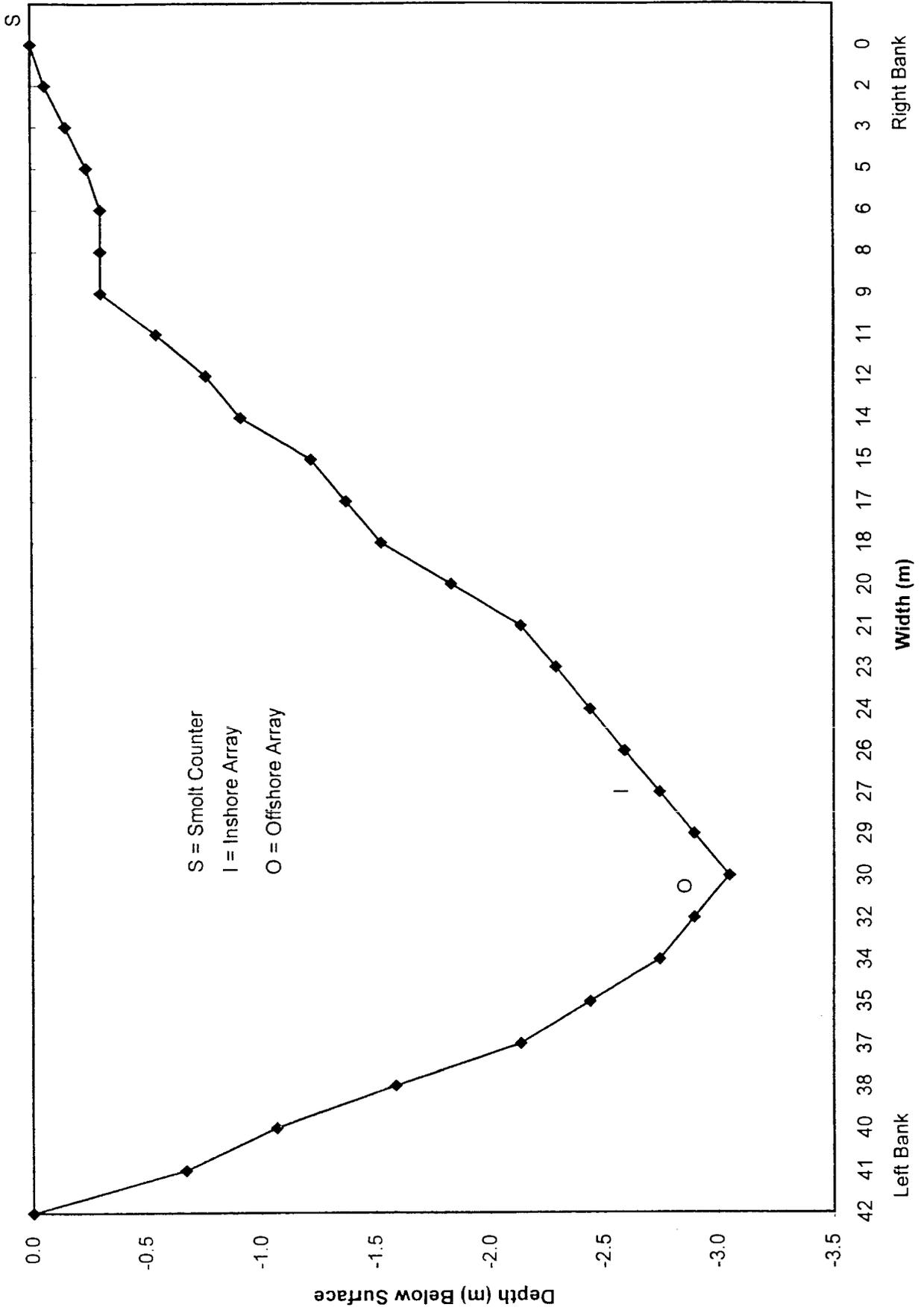


Figure 4. River bottom profile and sonar array placement at Ugashik River smolt sonar site, 1997.

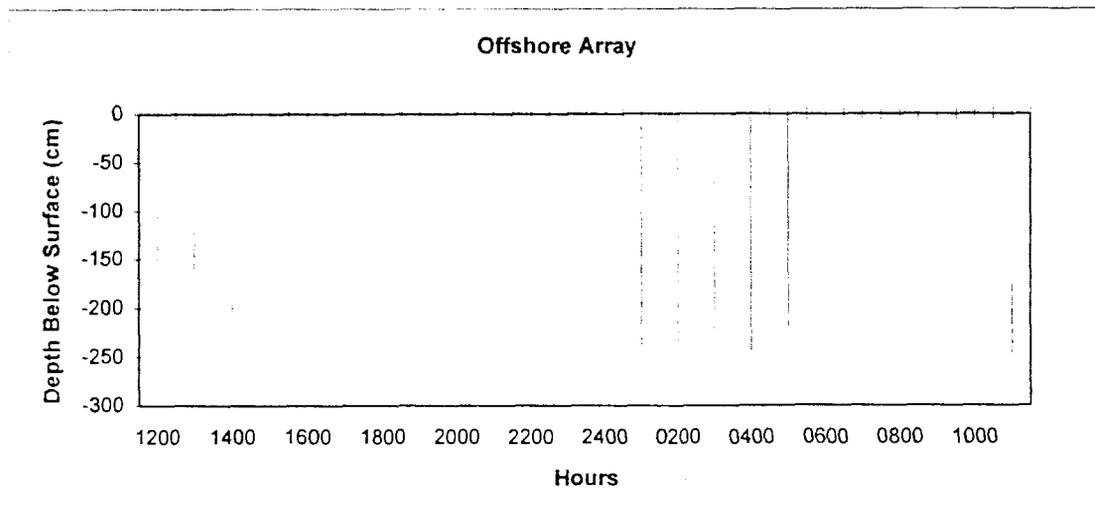
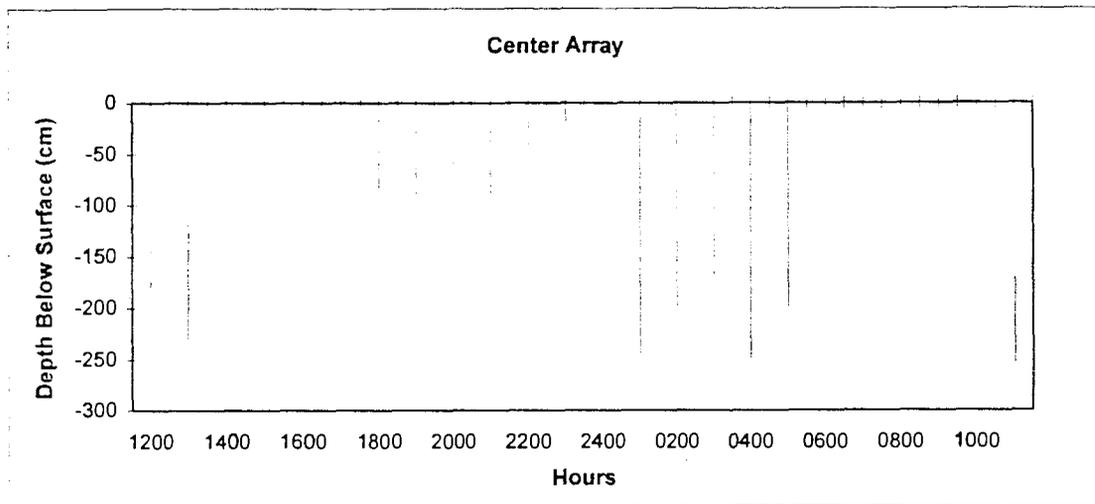
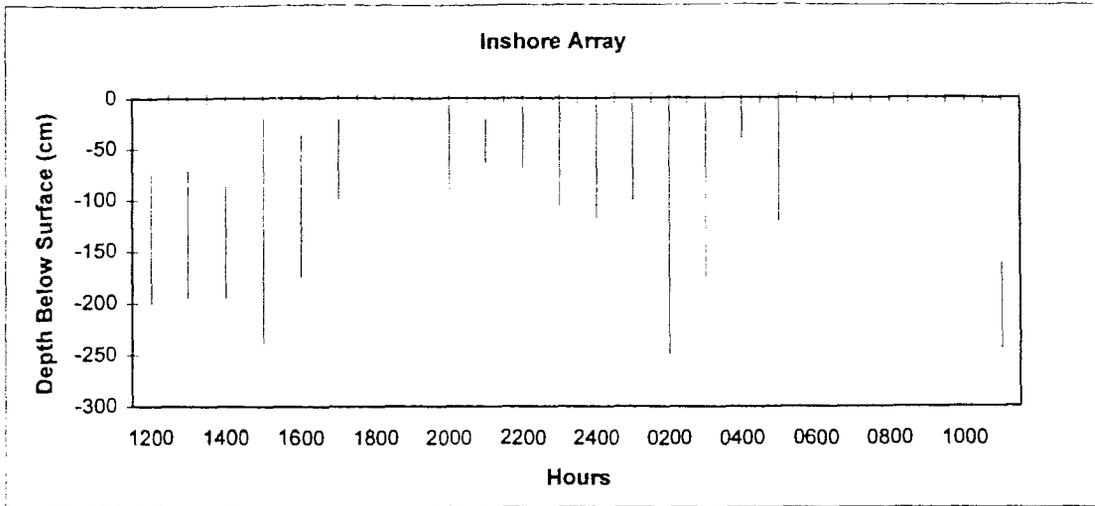


Figure 5. Depth of smolt passage data summarized by hour, Kvichak River, May 17 to June 8, 1997.

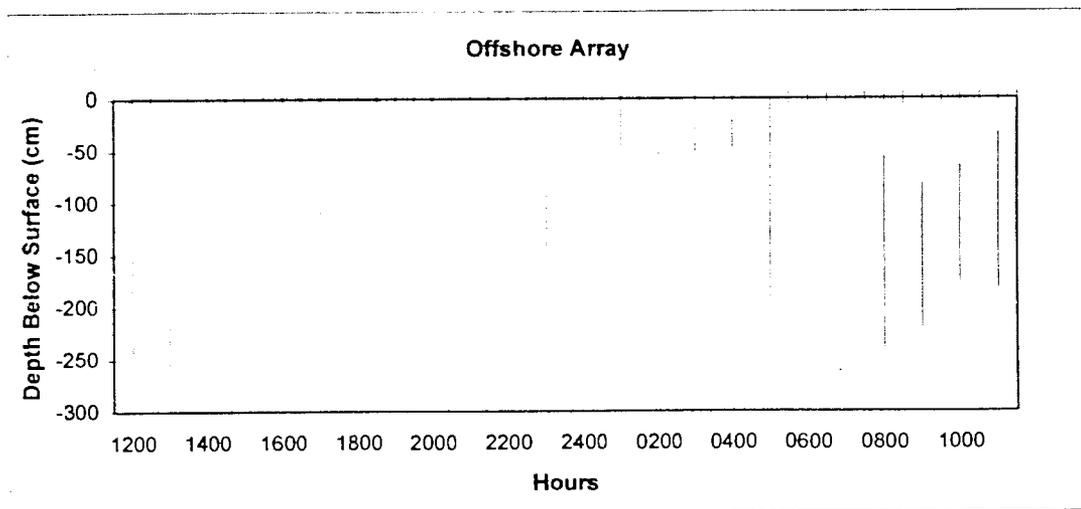
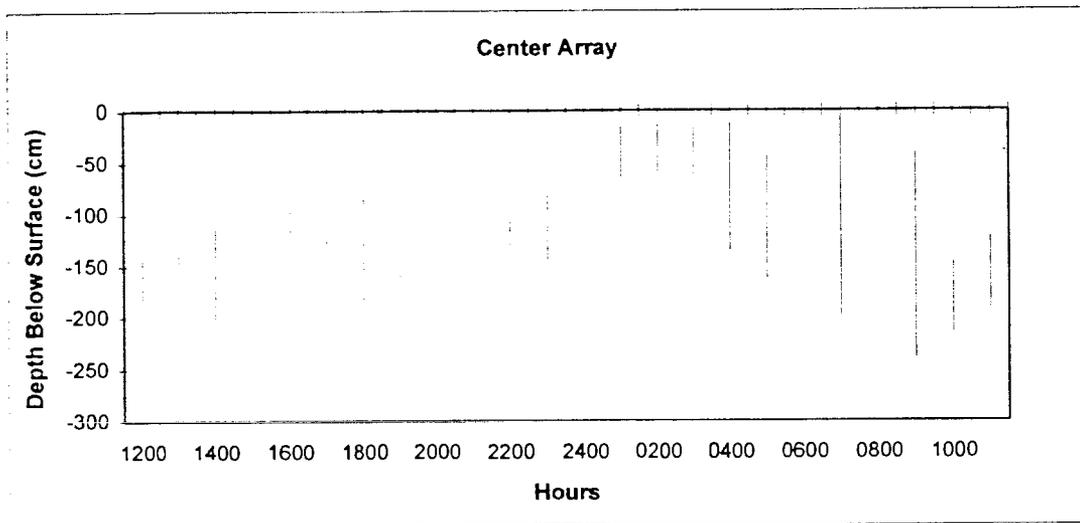
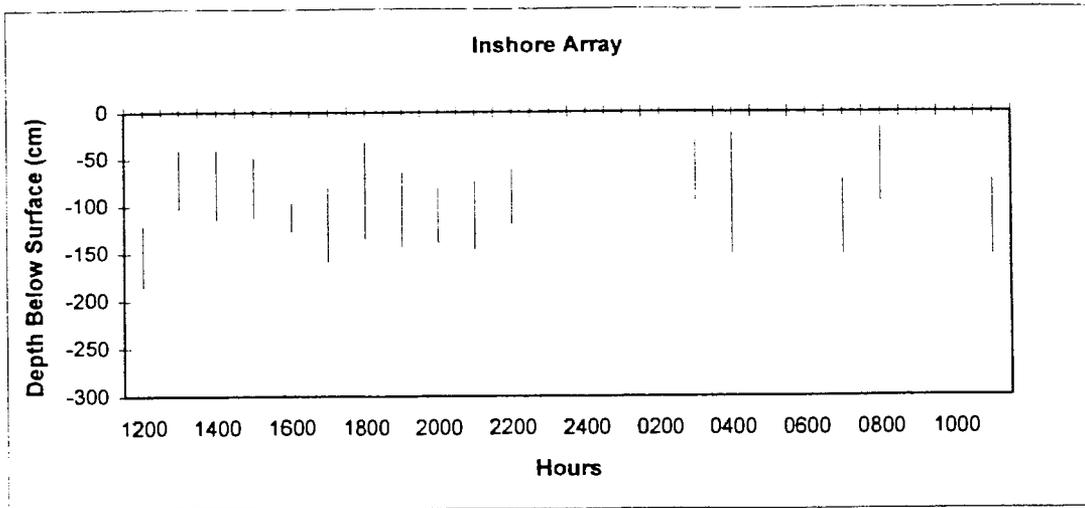


Figure 6. Depth of smolt passage data summarized by hour, Egegik River, May 19 to June 8, 1997.

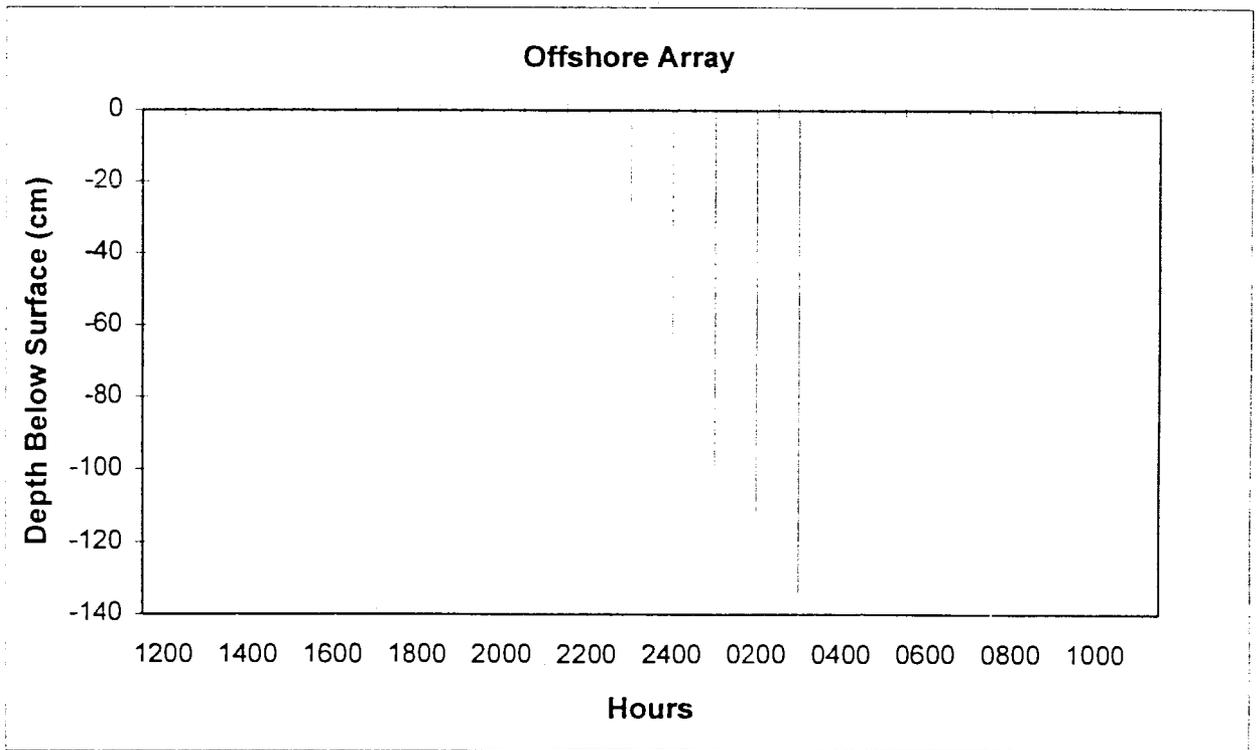
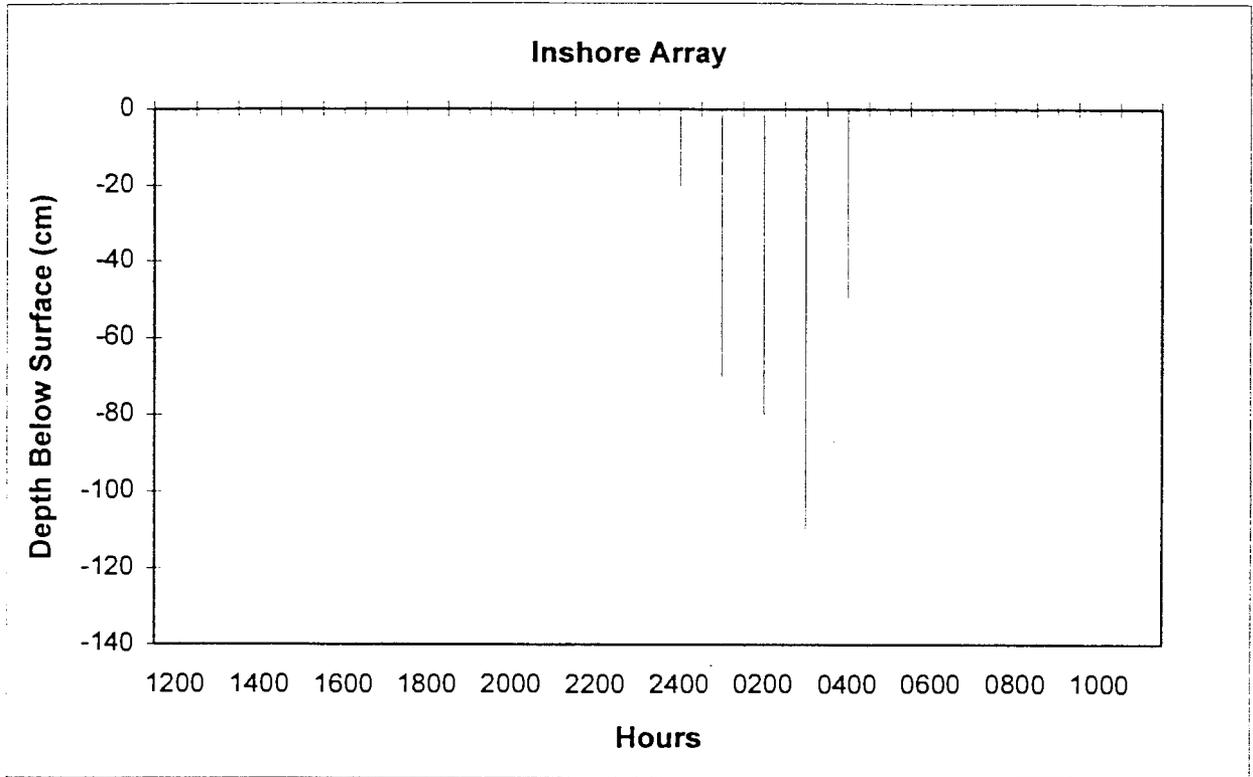


Figure 7. Depth of smolt passage data summarized by hour, Ugashik River, May 10 to June 12, 1997.

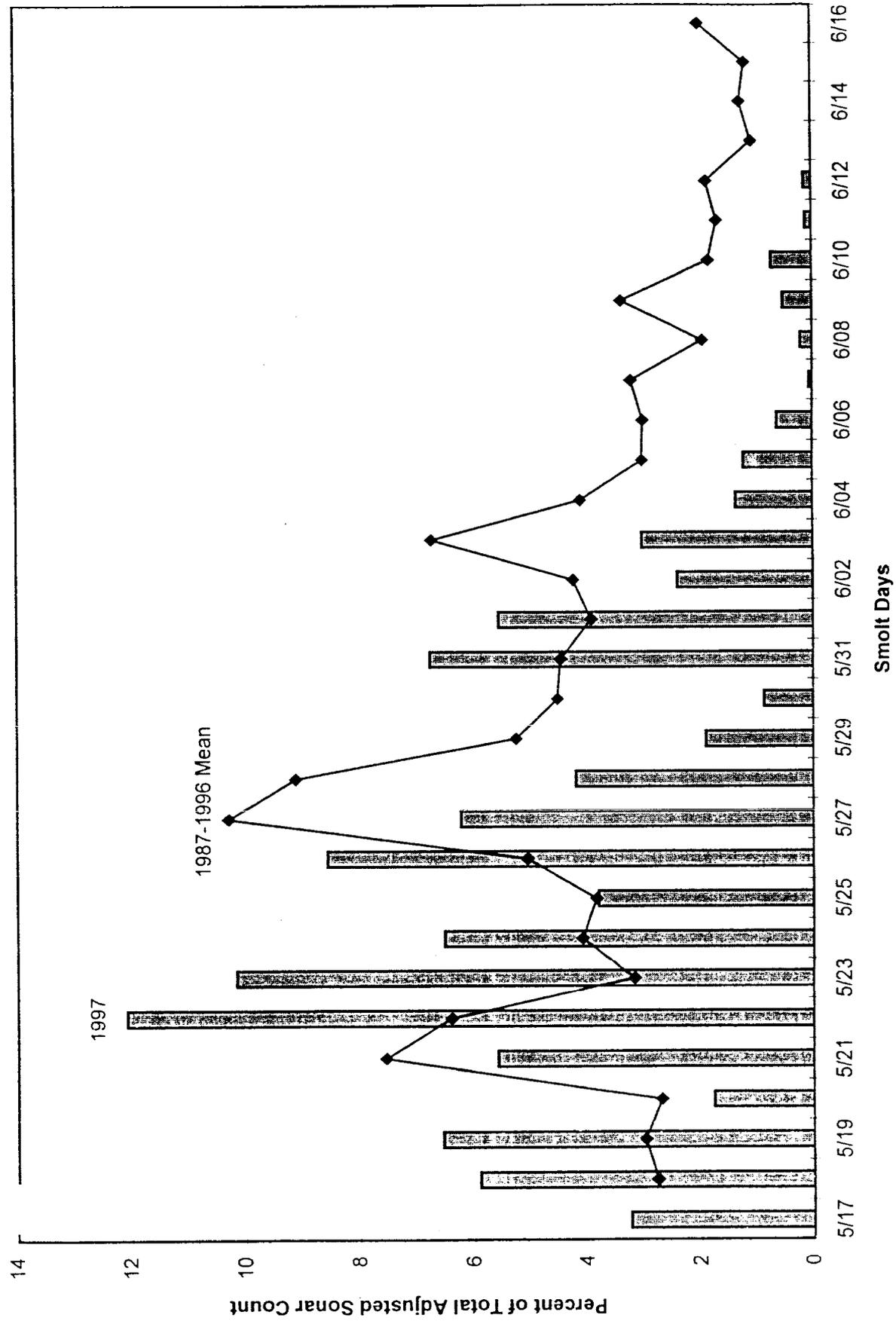


Figure 8. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Kvichak River smolt project with the 1987-1996 mean.

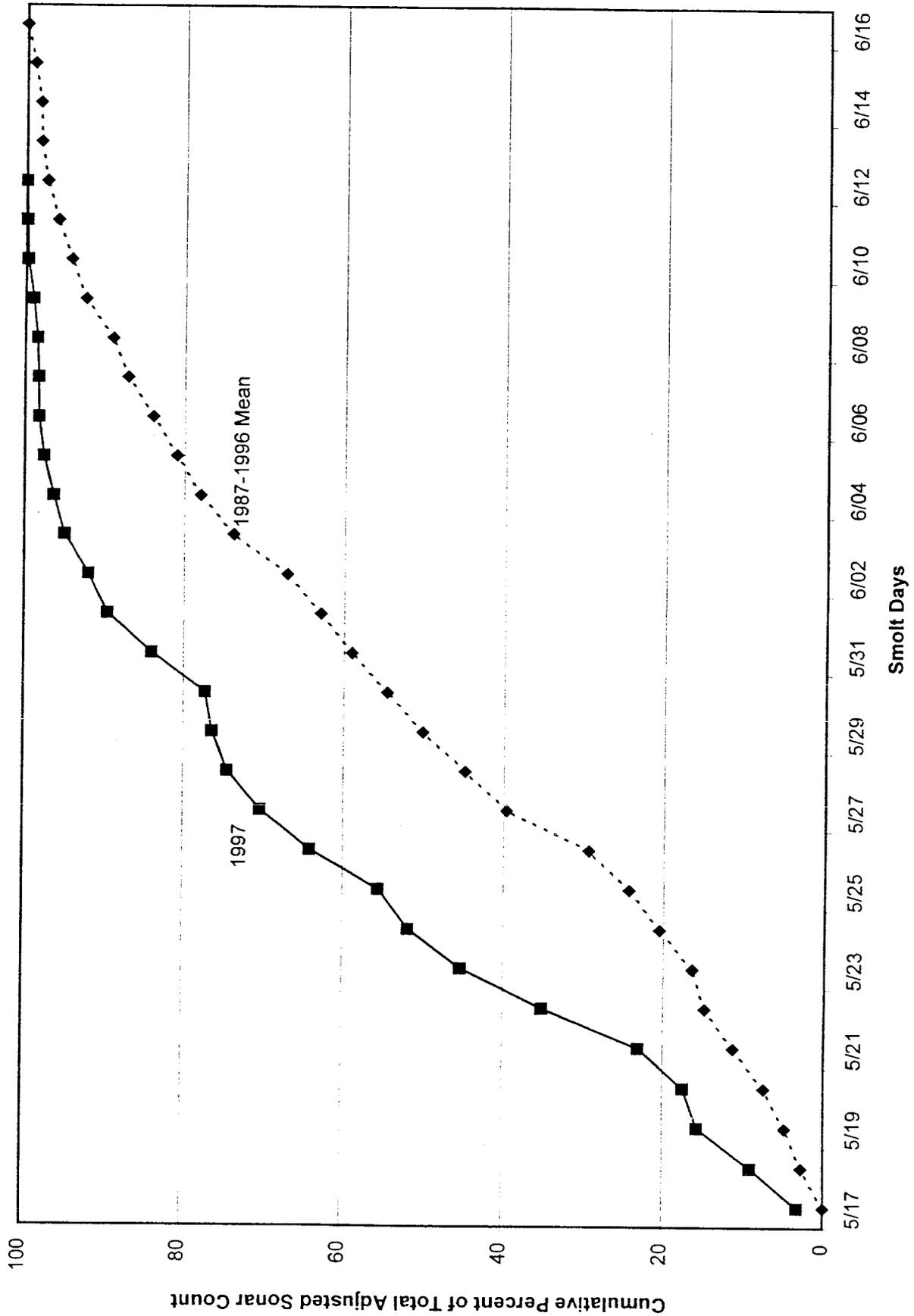


Figure 9. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Kvichak River smolt project with the 1987-1996 mean.

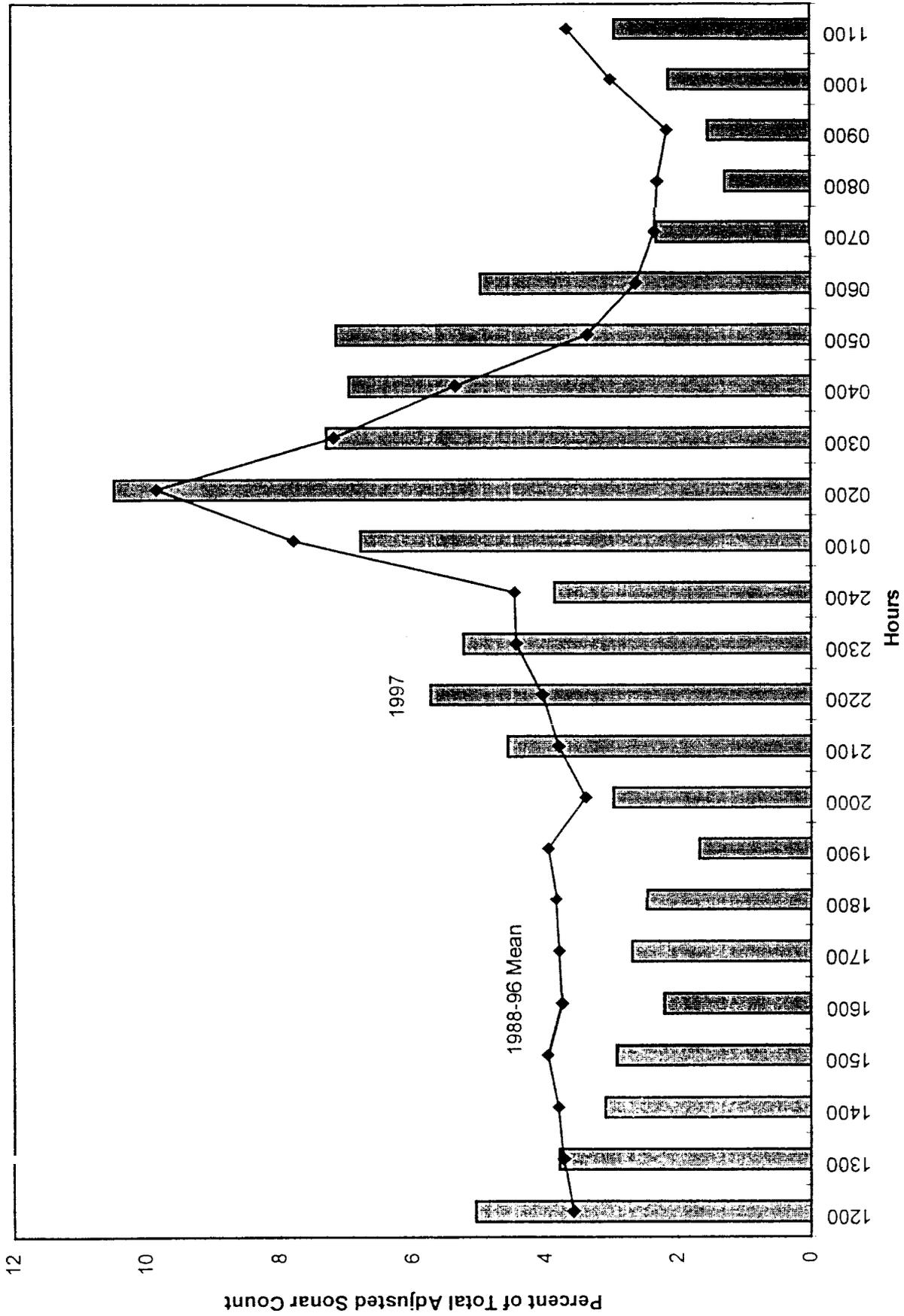


Figure 10. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Kvichak River smolt project with the 1988-1996 mean.

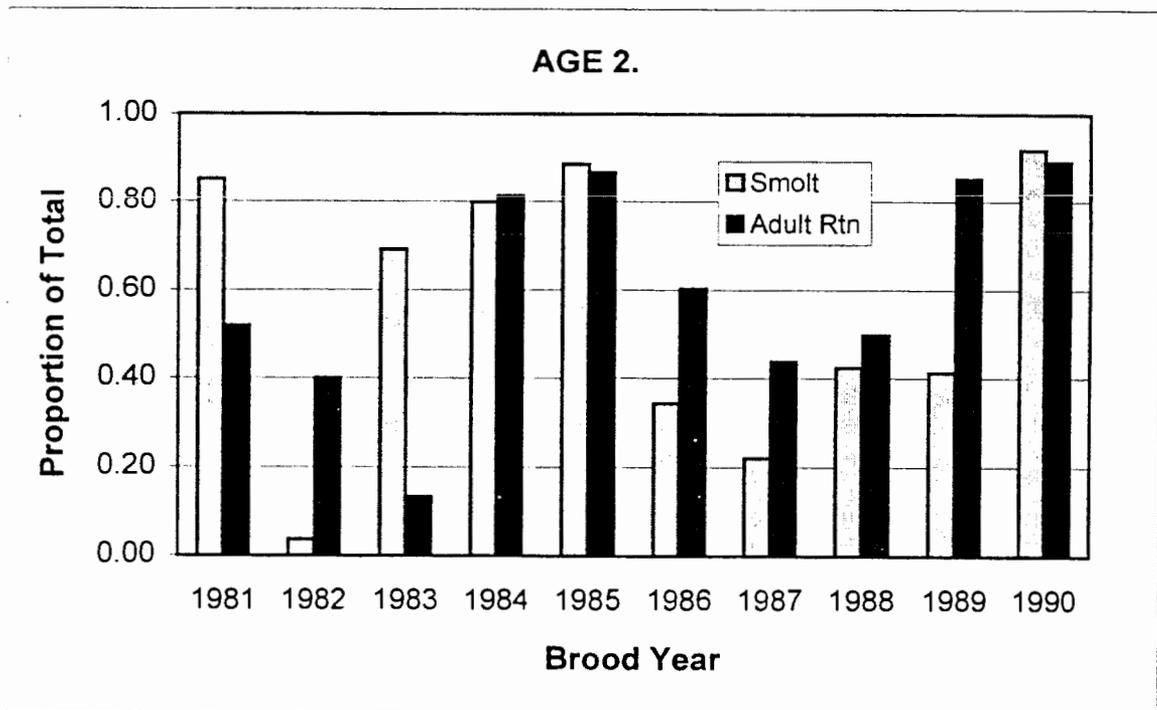
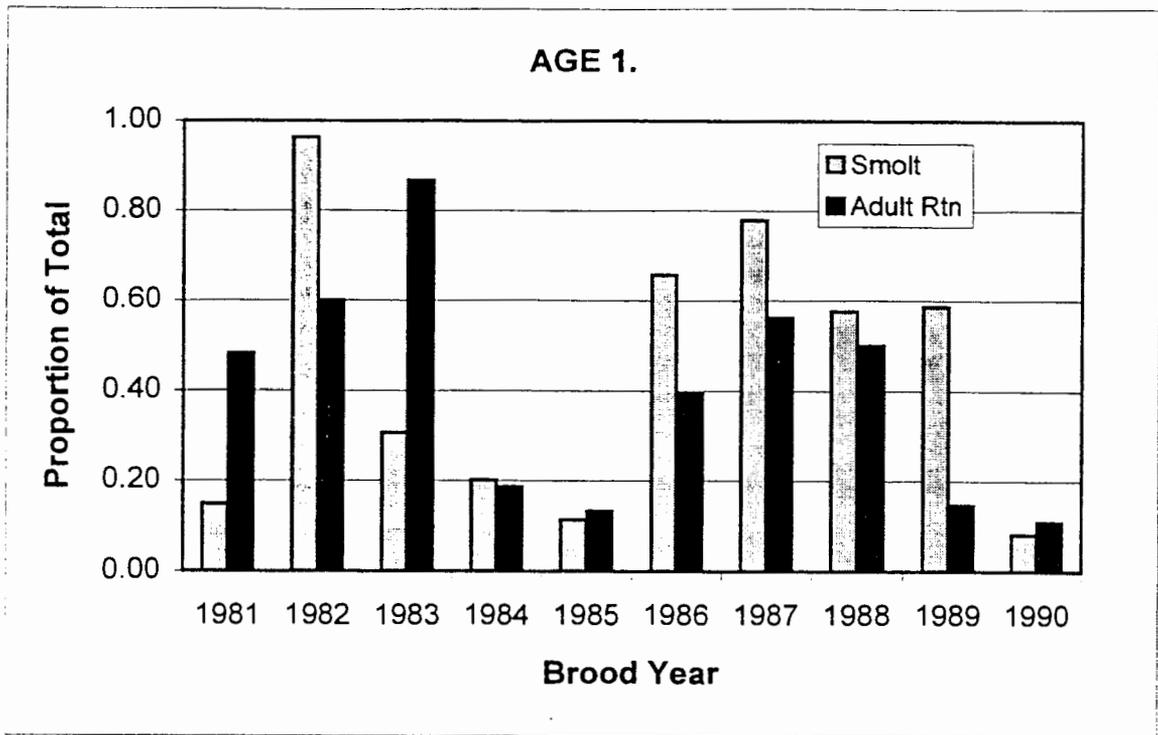


Figure 11. Comparison of the age composition of outmigrating sockeye salmon smolt at Kvichak River with the freshwater age composition of the total adult returns by brood year, 1981-1990.

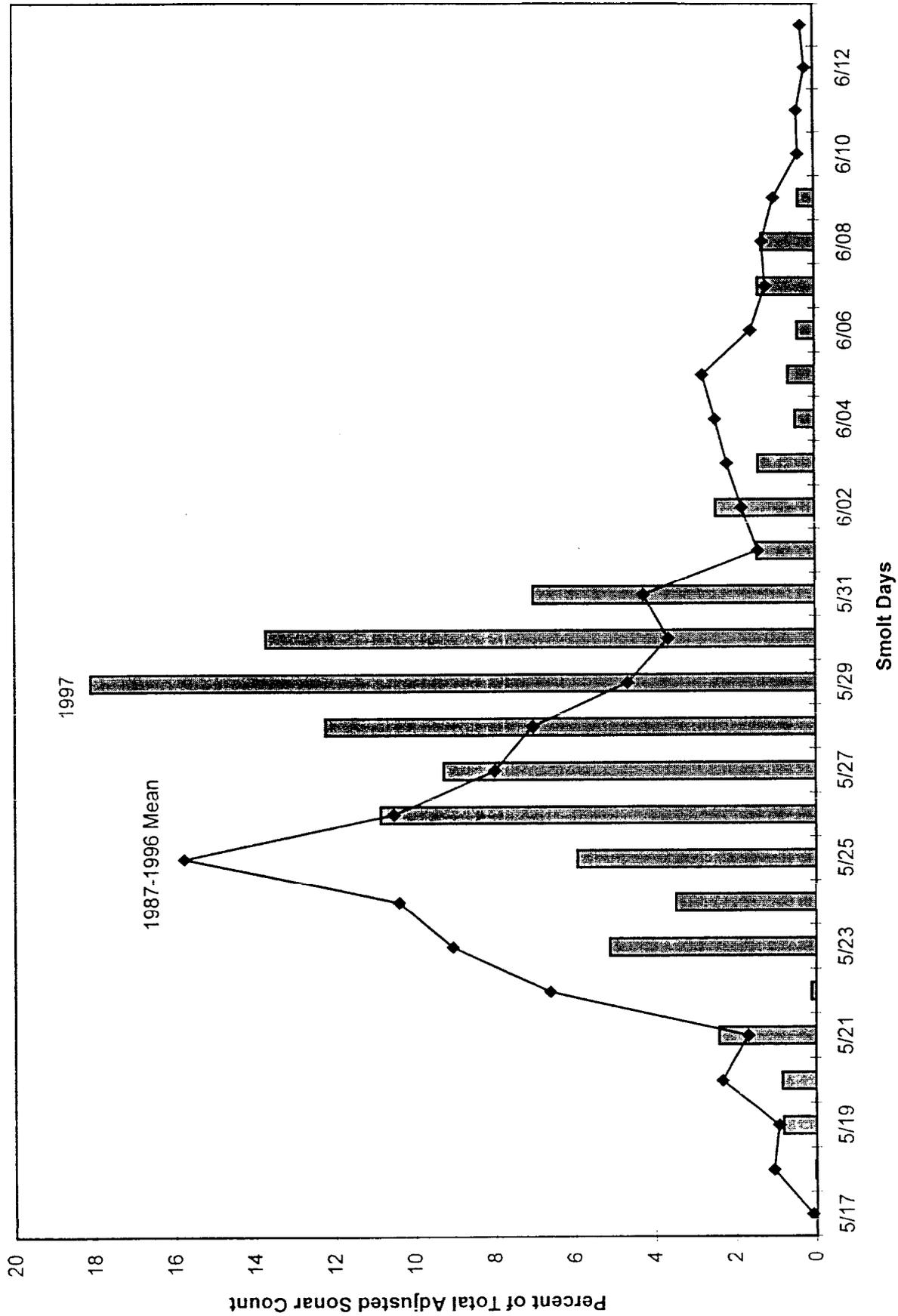


Figure 12. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Egegik River smolt project with the 1987-1996 mean.

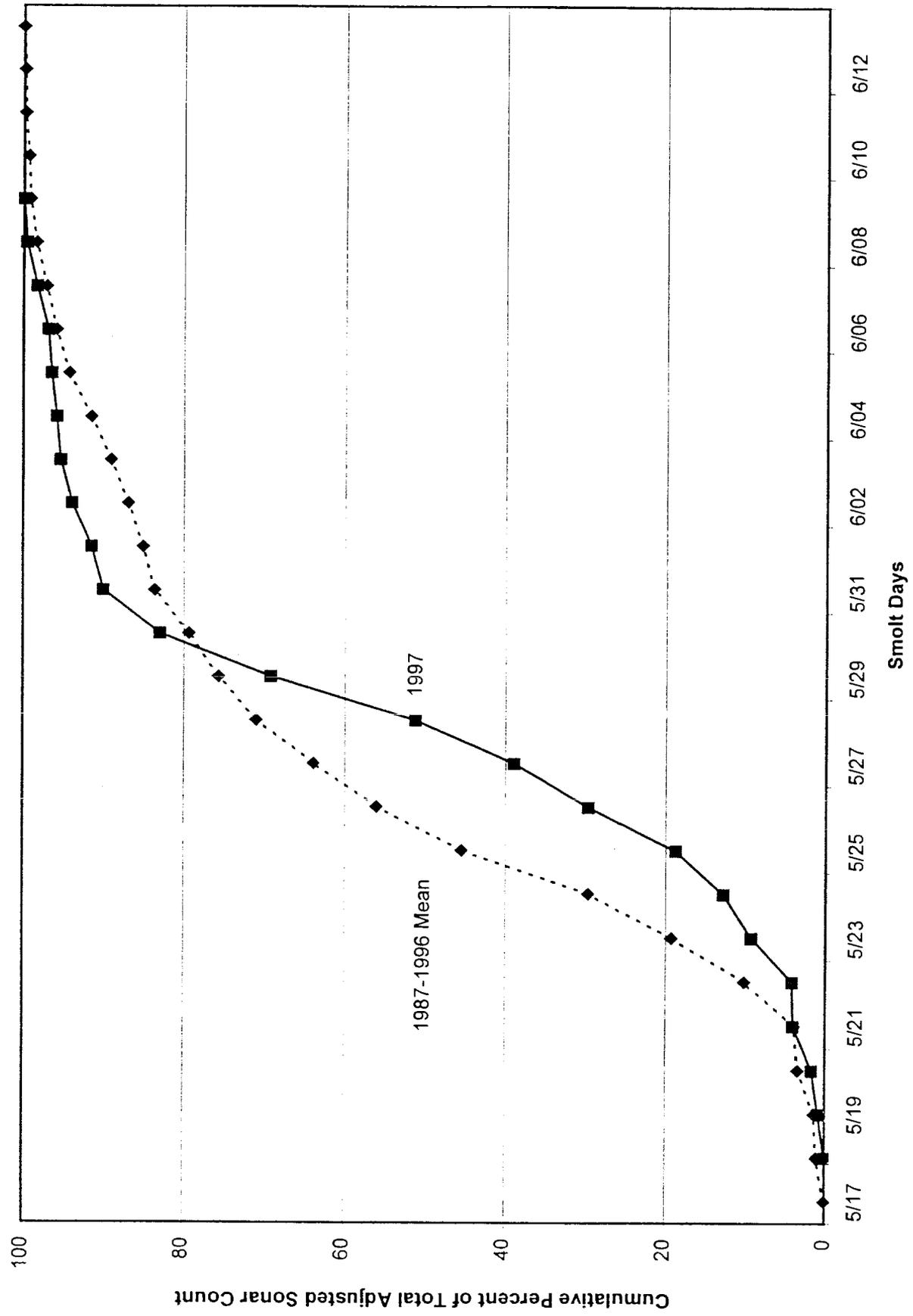


Figure 13. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Egegik River smolt project with the 1987-1996 mean.

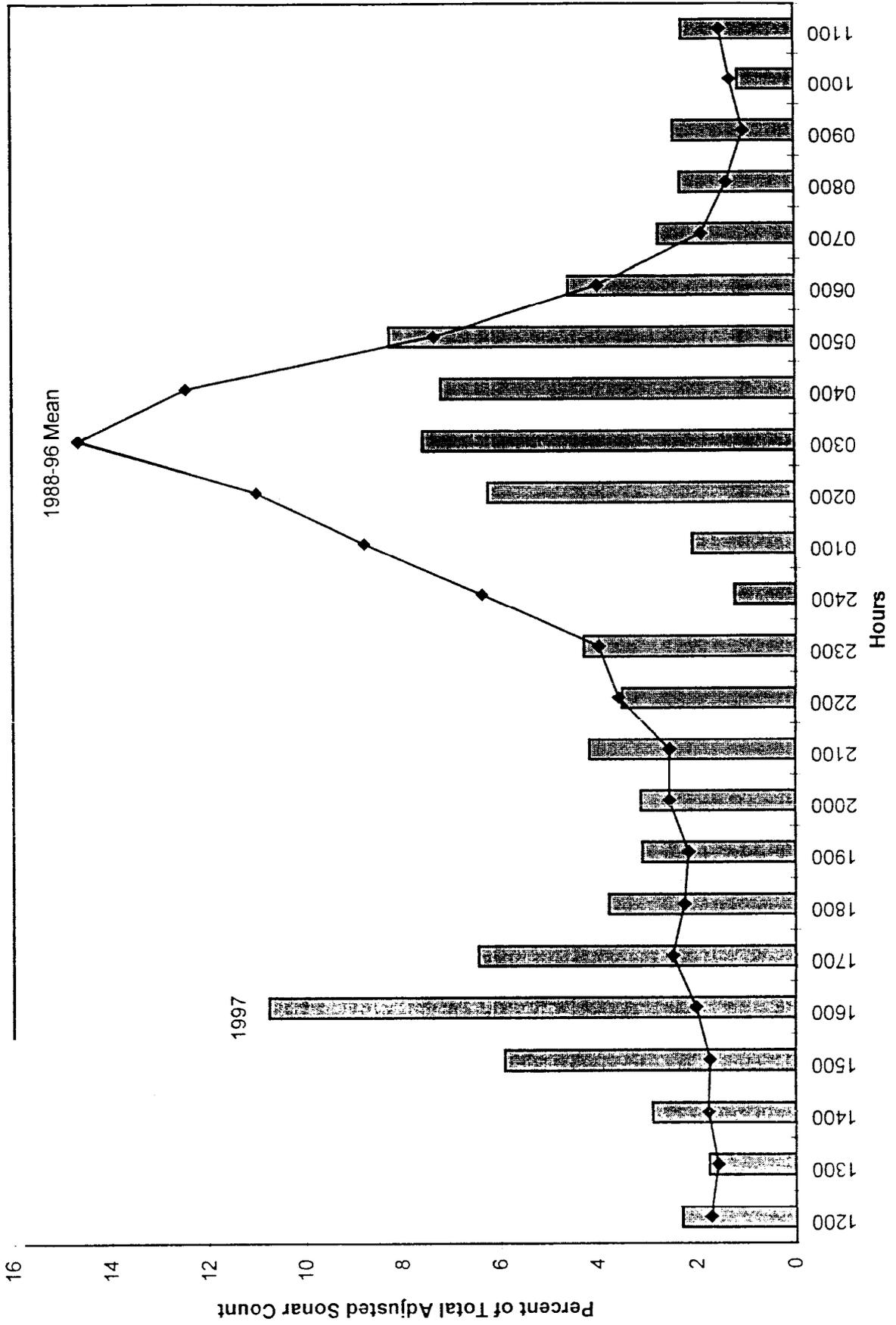


Figure 14. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Egegik River smolt project with the 1988-1996 mean.

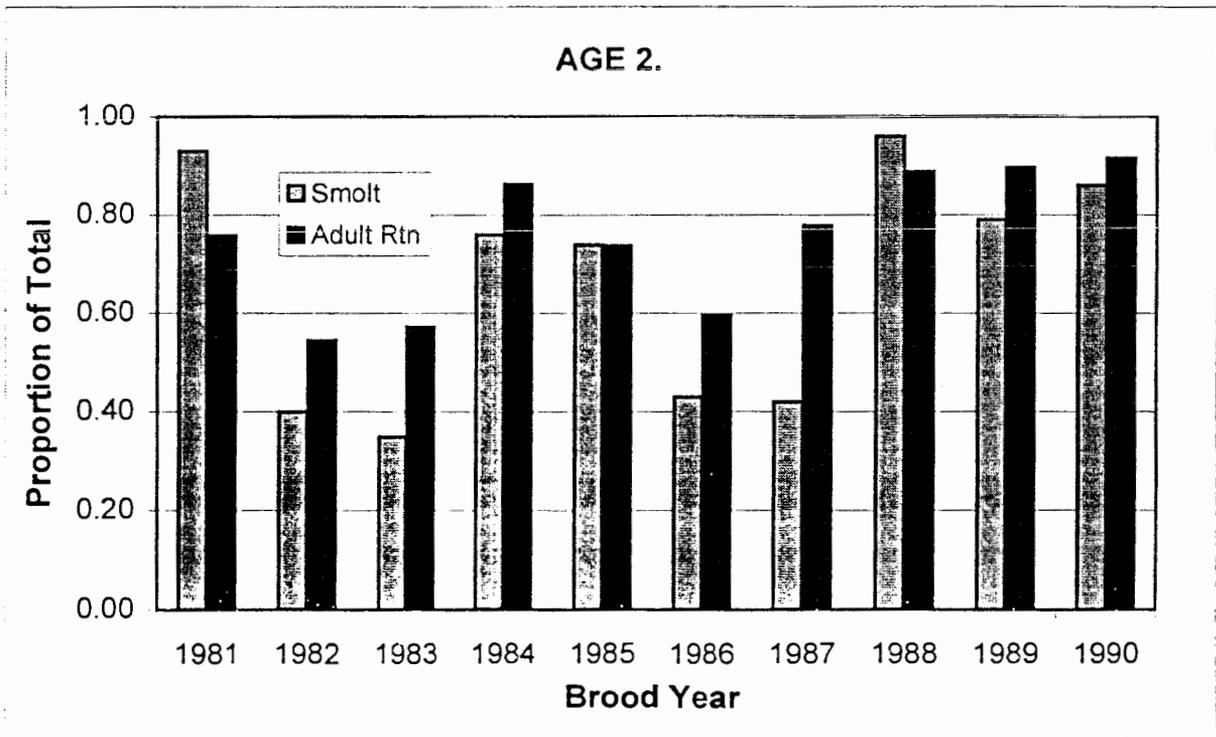
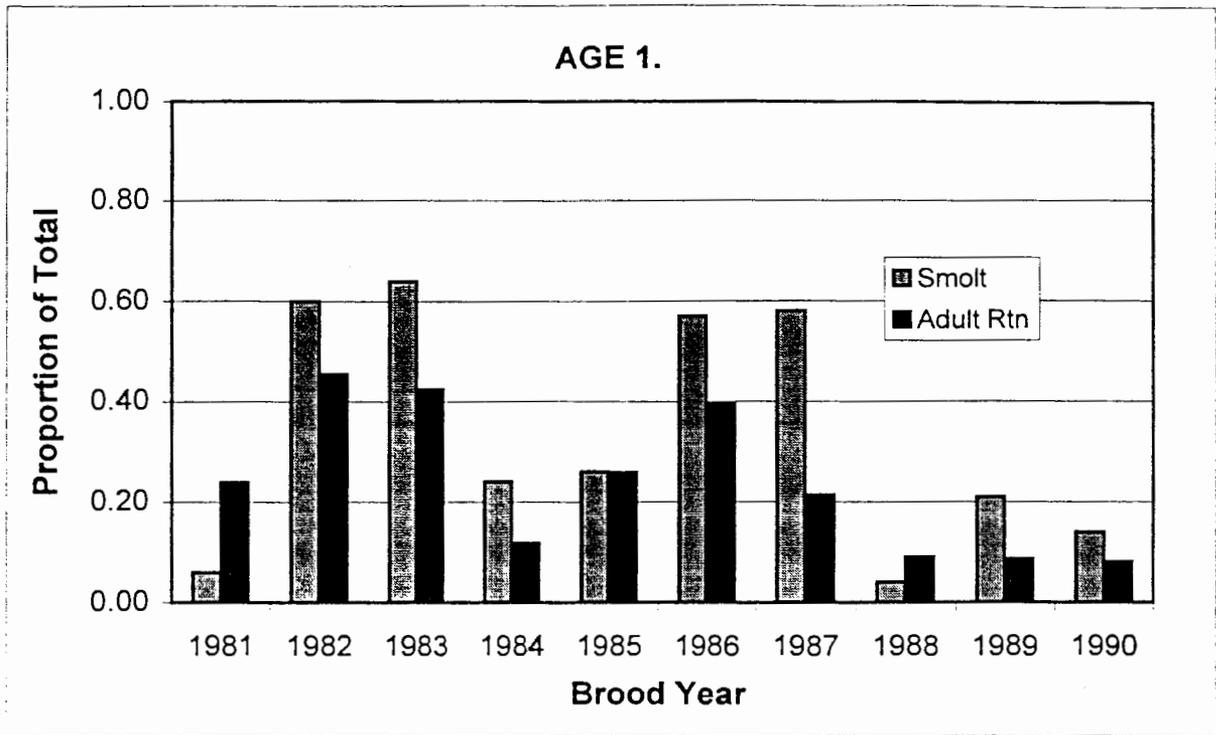


Figure 15. Comparison of the age composition of outmigrating sockeye salmon smolt at Egegik River with the freshwater age composition of the total adult returns by brood year, 1981-1990.

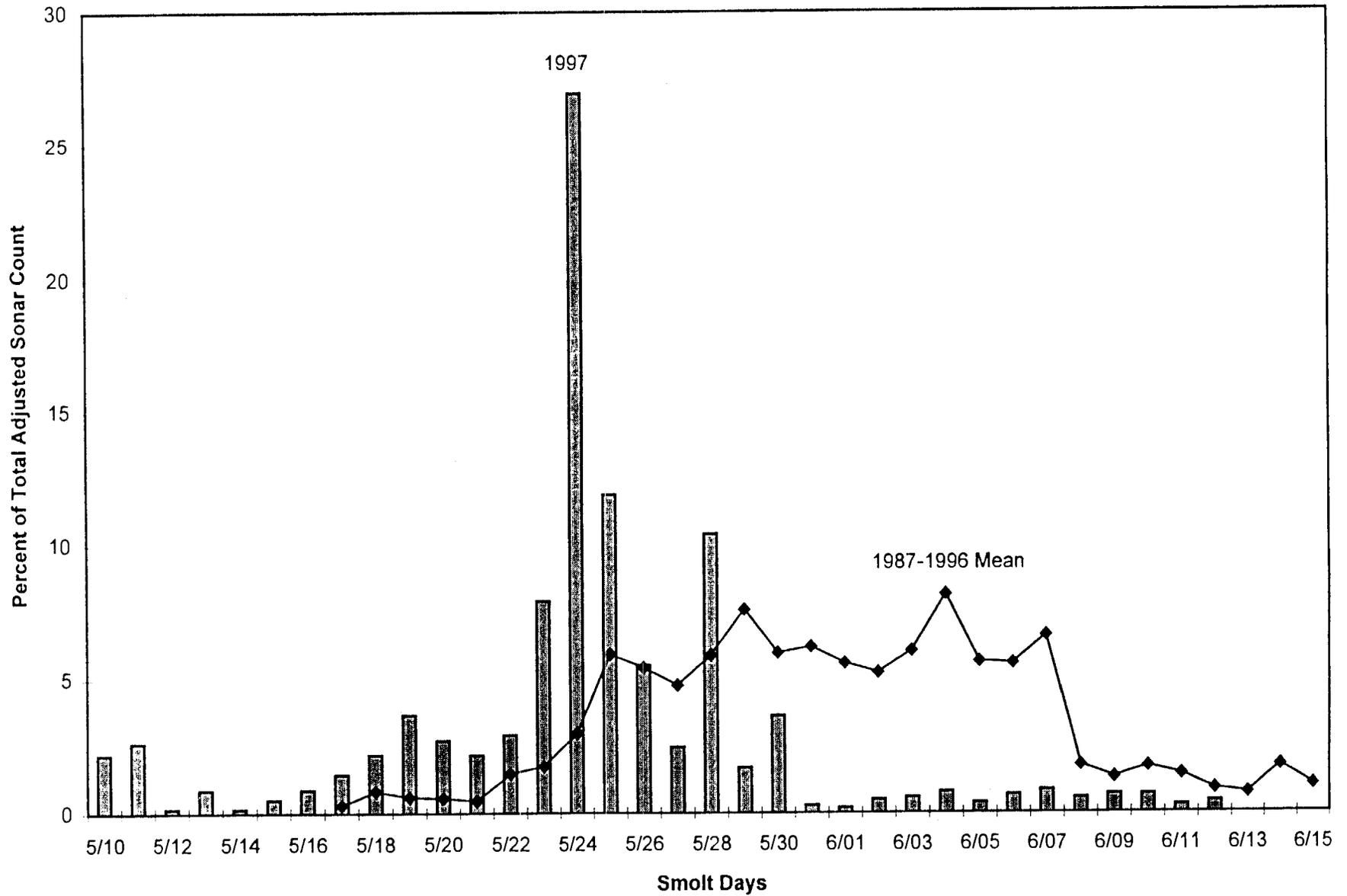


Figure 16. Comparison of the percent of the total adjusted sonar count by smolt day at the 1997 Ugashik River smolt project with the 1987-1996 mean.

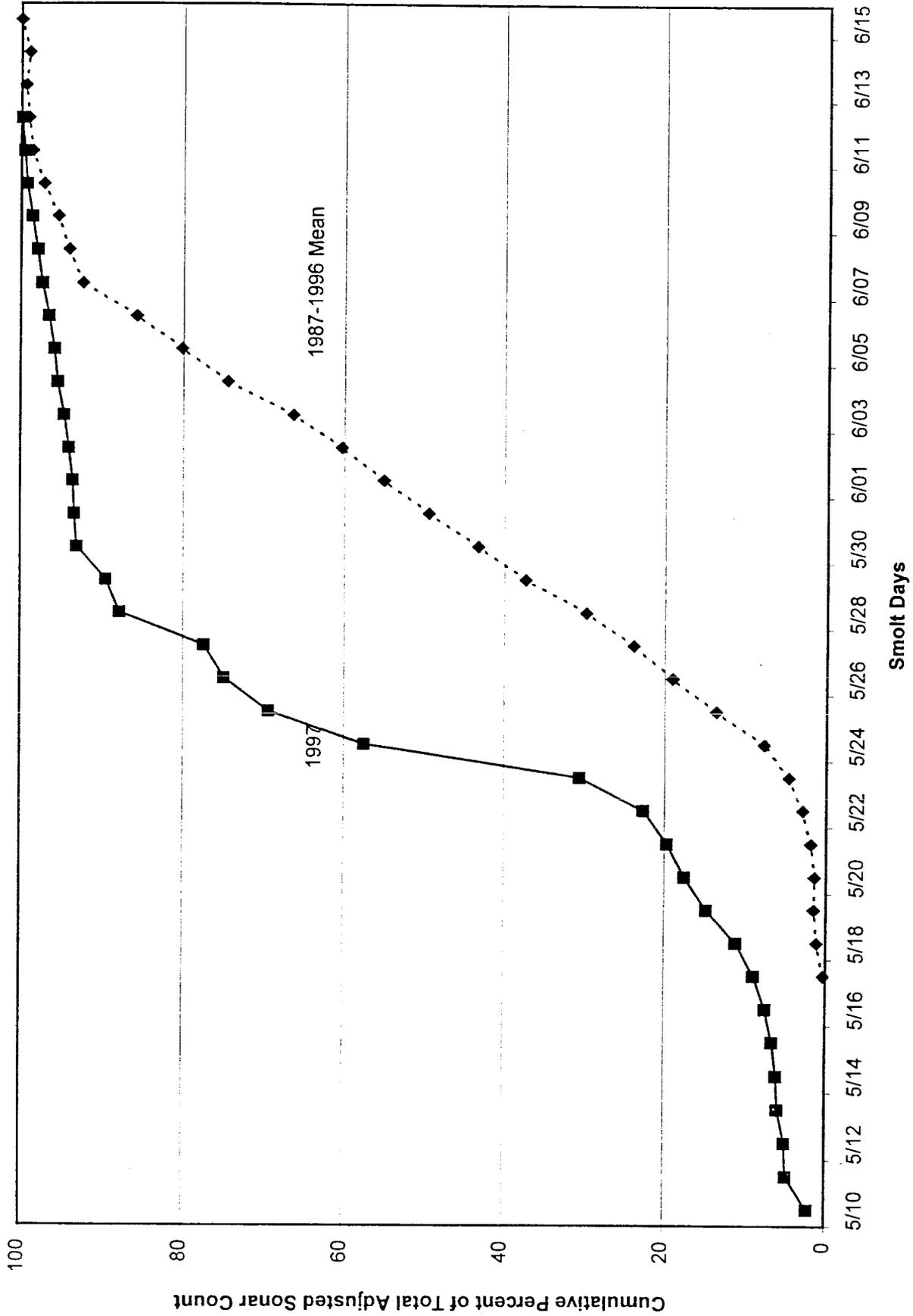


Figure 17. Comparison of the cumulative percent of the total adjusted sonar count by smolt day at the 1997 Ugashik River smolt project with the 1987-1996 mean.

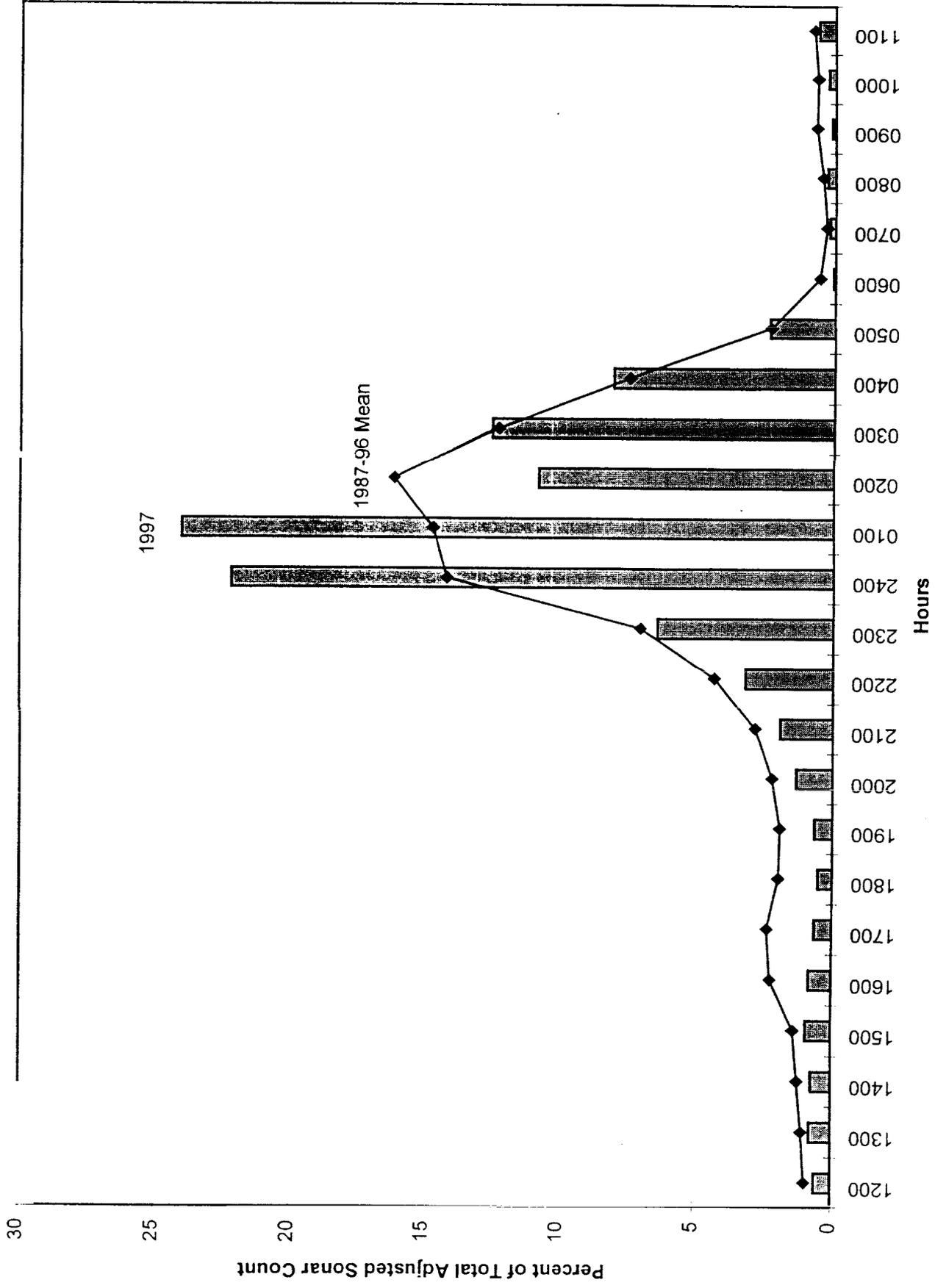


Figure 18. Comparison of the percent of the total adjusted sonar count by hour at the 1997 Ugashik River smolt project with the 1987-1996 mean.

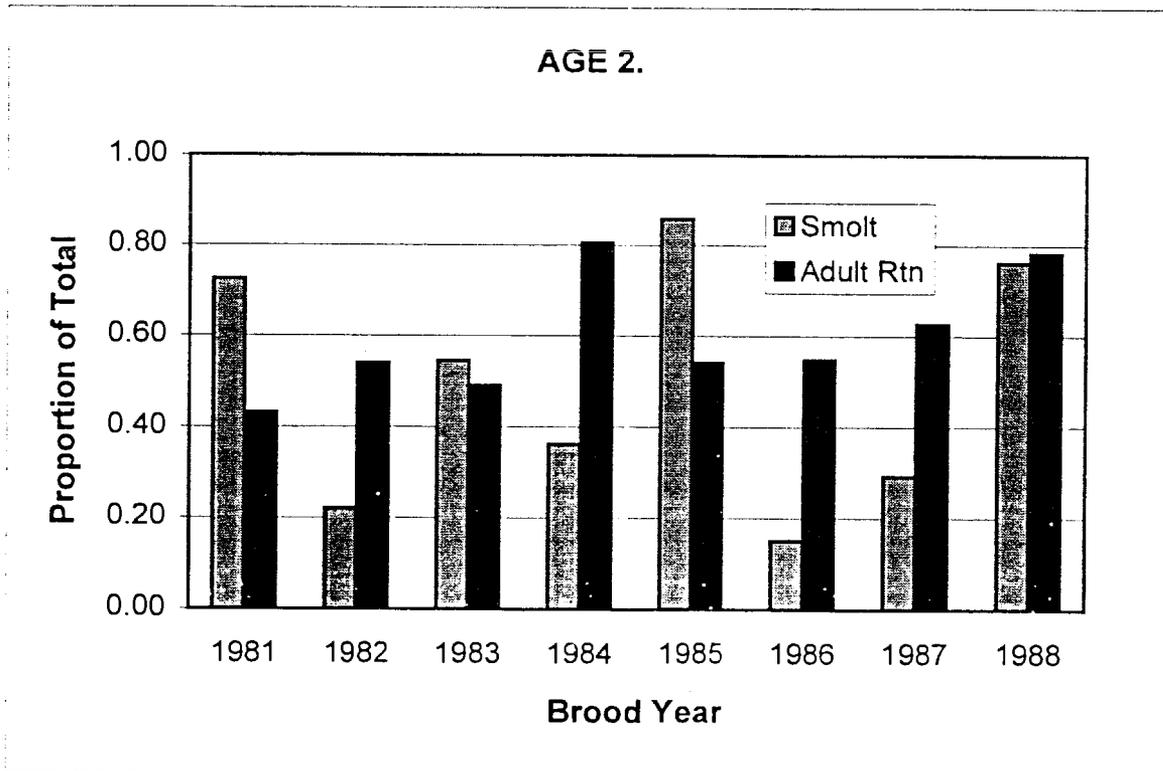
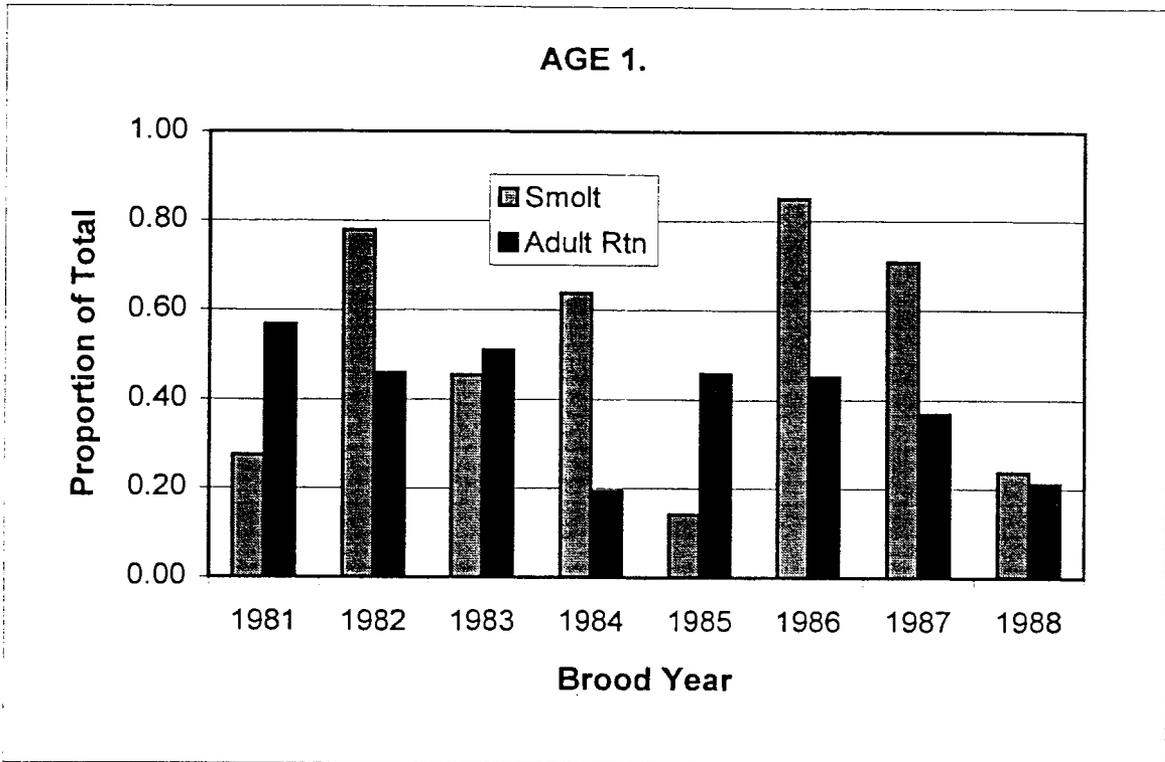


Figure 19. Comparison of the age composition of outmigrating sockeye salmon smolt at Ugashik River with the freshwater age composition of the total adult returns by brood year, 1981-1988.

Appendix A.1. River width and distance between arrays at the Kvichak River smolt sonar site^a, 1989-1997.

Year	Distance (ft)						
	Left Bank Shore	Offshore Limit Dead Zone	Offshore Array	Center Array	Inshore Array	Inshore Limit Dead Zone	Right Bank Shore
1989 ^b	404	389	237	180	75	40	0
1990	445	419 ^c	315	220	138	16 ^c	0
1991	439	413	318	255	185	16	0
1992	422	358	280	222	162	16	0
1993	410	380	304	230	170	40	0
1994	439	409	298	229	189	40	0
1995	442	410	328 ^d	236	200	40	0
1996	423	393	328	279 ^e	171	40	0
1997	415	385	305	262	205	60	0
1989-96 Max	445	419	328	279	200	40	0
1989-96 Avg	428	396	301	231	161	31	0
1989-96 Min	404	358	237	180	75	16	0

^a The Kvichak River smolt sonar site was located 6 km downstream from the outlet of Lake Iliamna from 1989-1997. The current site is 1 km downstream from the 1973-1988 smolt sonar site.

^b From 1989-1994 the cables for all sonar arrays were 330' long.

^c Source - Huttunen and Skvorc (1991)

^d Offshore array cables extended from 330' to 415' prior to the 1995 field season to improve array placement and safety during deployment.

^e Center array cables extended from 330' to 415' prior to the 1996 field season to improve array placement and safety during deployment.

Appendix A.2. River width and distance between arrays at the Egegik River smolt sonar site^a, 1989-1997.

Year	Distance (ft)						
	Left Bank Shore	Inshore Limit Dead Zone	Inshore Array	Center Array	Offshore Array	Offshore Limit Dead Zone	Right Bank Shore
1989	0	30	130	180	220	270	340
1990	0	30	130	180	220	270	340
1991	0	30	130	180	220	280	350
1992	0	70	140	180	240	330	360
1993	0	52	140	190	230	310	380
1994	0	40	130	180	220	296	366
1995	0	30	120	175	220	305	375
1996	0	40	130	180	220	293	367
1997	0	55	130	180	220	270	350
1989-96 Max	0	70	140	190	240	330	380
1989-96 Avg	0	40	131	181	224	294	360
1989-96 Min	0	30	120	175	220	270	340

^a The Egegik River smolt sonar site was located 4 km downstream from the outlet of Becharof Lake, 1982-1997.

Appendix A.3. River width and distance between arrays at the Ugashik River smolt sonar site^a, 1988-1997.

Year	Distance (ft)					Right Bank Shore
	Left Bank Shore	Offshore Limit Dead Zone	Offshore Array	Inshore Array	Inshore Limit Dead Zone	
1988	160		96	75		0
1989	140	110	91	75	40	0
1990	142	122	101	86	40	0
1991	140	120	99	85	40	0
1992 ^b						
1993	140	115	100	85	40	0
1994	140	120	105	89	40	0
1995	140	120	100	80	40	0
1996	135	115	100	85	35	0
1997	138	125	106	88	35	0
1989-96 Max	142	122	105	89	40	0
1989-96 Avg	140	117	99	84	39	0
1989-96 Min	135	110	91	75	35	0

^a The Ugashik River smolt sonar site was located 50 m downstream from the outlet of Lower Ugashik Lake, 1988-1997

^b Due to budget cuts, the smolt outmigration was not monitored on the Ugashik River in 1992.

Appendix B.1. Ice-cover dates for Lake Iliamna, 1970-1997.

Winter of	Freeze-up Date ^a		Break-up Date ^a		Total Days of Ice Cover	Comments ^a
	(dd-mmm)	Julian Day	(dd-mmm)	Julian Day		
1969-1970	1-Jan	1				
1970-1971	7-Jan	7	16-Jun	167	160	Long, cold winter.
1971-1972			5-Jun	157		
1972-1973			25-May	145		
1973-1974			21-May	141		
1974-1975	26-Dec	-5	4-Jun	155	160	
1975-1976			7-May	128		
1976-1977	4-Feb	35	2-May	122	87	Partially open 30-Mar
1977-1978			11-May	131		80% open 02-May
1978-1979			3-May	123		50% open 28-Apr
1979-1980			3-May	124		
1980-1981						
1981-1982	9-Jan	9	25-May	145	136	Started to reopen 10-Feb
1982-1983						
1983-1984						Still open 19-Dec
1984-1985	11-Feb	42	5-Jun	157	114	50% open 29-May
1985-1986	18-Jan	18	12-May	132	114	
1986-1987	13-Feb ^b	44	23-Mar	86	38	Still not frozen up by 13-Feb
1987-1988	26-Jan	26				Began re-opening 24-Feb; 75% open 01-Apr
1988-1989	13-Jan	13				50% open 20-Apr
1989-1990	9-Jan	9	22-May	142	133	
1990-1991	7-Jan	7				
1991-1992	27-Jan	27	4-May	125	98	
1992-1993	22-Jan	22	3-May	123	101	
1993-1994	16-Feb	47	5-May	125	78	Ice jammed along west shore; trickled out until 29-May
1994-1995	11-Jan ^b	11	22-May	142	131	Lake frozen briefly, 19-Dec, then reopened. Lake 95% open by 13-May
1995-1996	12-Jan	12	5-May	125	114	
1996-1997	23-Dec ^c	-9	8-May ^d	127	136	
1969-1996 Min	26-Dec		23-Mar		38	
1969-1996 Avg	19-Jan		14-May		114	
1969-1996 Max	16-Feb		16-Jun		160	

^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 later.

^c Mostly frozen 18-Dec, except several large holes.

^d Lake Iliamna was still ice covered on the evening of May 6. Subsequent southerly and westerly winds over the next several days caused the ice to break up, blew up the lake, and melt in place. By May 10 the lake was ice-free at Igiugig.

Appendix B.2. Ice-cover dates for Becharof Lake, 1970-1997.

Winter of	Freeze-up Date ^a		Break-up Date ^a		Total Days of Ice Cover	Comments ^a
	(dd-mmm)	Julian Day	(dd-mmm)	Julian Day		
1969-1970						
1970-1971						Long, cold winter.
1971-1972						
1972-1973						
1973-1974						
1974-1975						
1975-1976			6-Apr	97		
1976-1977			6-Apr	96		Island Arm still frozen. Main basin opened earlier.
1977-1978						
1978-1979						
1979-1980						
1980-1981			13-May	133		May have opened earlier.
1981-1982			20-May	140		Still open 15-Dec. May have opened earlier than 20-May.
1982-1983	18-Jan	18				50% open 31-Mar
1983-1984	16-Jan ^b	16	16-May	137		Still open 16-Jan
1984-1985	11-Feb	42	3-May	123	81	
1985-1986	26-Feb	57	27-Apr	117	60	Still open 30-Jan
1986-1987	12-Mar ^b	71				Still open 12-Mar
1987-1988	24-Mar ^b	84				Still open 24-Mar
1988-1989	17-Jan	17	27-Apr	117	100	
1989-1990	21-Feb	52	25-Apr	115	63	
1990-1991	4-Feb	35	1-Apr	91	56	
1991-1992	27-Jan	27	10-May	131	104	
1992-1993	23-Jan	23	31-Mar	90	67	
1993-1994	25-Feb	56	4-Apr	94	38	
1994-1995	24-Jan	24	28-Apr	118	94	Wind driven ice lense blocked lake outlet on 19-May & 20-May
1995-1996	8-Jan	8	28-Mar	87	80	
1996-1997	13-Dec ^c	-18	19-Apr ^d	109	127	
1975-1996 Min	8-Jan		28-Mar		38	
1975-1996 Avg	6-Feb		22-Apr		74	
1975-1996 Max	24-Mar		20-May		104	

^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 a small section of shoreline near Whale Mt and two small sections in the NW half of the lake.

^d In a 19-Apr satellite photo the lake appears to be completely ice free (1 oC), scatters patches of windblown ice remain along the NE & W end of lake.

Appendix B.3. Ice-cover dates for Upper and Lower Ugashik Lakes, 1970-1997.

Winter of	Freeze-up Date ^a		Break-up Date ^a		Total Days of Ice Cover	Comments ^a
	(dd-mmm)	Julian Day	(dd-mmm)	Julian Day		
1969-1970						
1970-1971						Long, cold winter.
1971-1972						
1972-1973						
1973-1974						
1974-1975						
1975-1976						
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	105	98	
1996-1997	13-Dec ^c	-18	26-Apr ^d	116	134	
1976-1996 Min	9-Dec		24-Mar		51	
1976-1996 Avg	27-Jan		22-Apr		86	
1976-1996 Max	12-Mar		14-May		113	

^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 May 4.

Appendix C.1. Kvichak River smolt fyke net catch log, 1997.

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
5/18		1830	1940	70		0		0
		1945	2030	45		0		0
		2035	2200	85		0		0
	001	2205	2300	55		700		13
	002	2305	2400	55	310	1,000	1,700	18
5/19	003	0005	0100	55		500		9
	004	0105	0130	25		500		20
	005	0135	0200	25		1,000		40
	006	0300	0500	120		500		4
		1500	1630	30		0		0
		1635	1830	115		0		0
		2100	2155	55		0		0
	007	2200	2235	35		300		9
	008	2240	2300	20		200		10
009	2305	2400	55	535	1,000	4,000	18	
5/20	010	0005	0030	25		500		20
	011	0035	0130	55		1,000		18
	012	0135	0200	25		5,000		200
		1930	2030	60		0		0
		2035	2130	55		0		0
		2135	2230	55		0		0
		2235	2300	25		0		0
		2305	0100	115	415	0	6,500	0
5/21		0105	0155	50		0		0
	013	0200	0300	60		200		3
	014	0305	0500	115		30		0
		1630	1730	60		0		0
		1735	1930	115		0		0
		1935	2130	115		0		0
	015	2135	2215	40		200		5
	016	2220	2240	20		200		10
	017	2245	2300	15		250		17
018	2305	2400	55	645	200	1,080	4	
5/22	019	0005	0100	55		500		9
	020	0105	0200	55		1,000		18
	021	1200	1255	55		300		5
	022	1310	1340	30		450		15
	023	1350	1450	60		500		8
		1950	2100	70		0		0
		2105	2200	55		0		0
		2205	2300	55		0		0
	2305	2400	55	490	0	2,750	0	
5/23		0005	0100	55		0		0
		0105	0200	55		0		0
		0205	0400	115		0		0
		0405	0500	55		20		0
	024	0600	0715	75		1,000		13
	025	1100	1150	50		110		2
	026	1235	1245	10		200		20
	027	1300	1335	35		400		11
	028	1345	1415	30		200		7
	029	1830	1905	35		200		6
	030	1915	1935	20		300		15
	031	2130	2210	40	575	150	2,580	4

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b	
		Set	Pulled	per Set	per Day	per Set	per Day		
5/24	032	1400	1610	130		150		1	
	033	1615	1650	35		200		6	
	034	1700	0055	475	640	200	550	0	
5/25	035	0100	0200	60		250		4	
	036	0205	0300	55		2,000		36	
	037	0305	0400	55		1,000		18	
	038	1800	2015	135		200		1	
	039	2025	2125	60		500		8	
		2130	2230	60		5		0	
		2235	2400	85	510	0	3,955	0	
5/26		0005	0100	55		0		0	
		0105	0200	55		0		0	
		0205	0300	55		0		0	
	040	0305	0400	55		20		0	
		0405	0500	55		0		0	
		0505	0600	55		0		0	
	041	0605	0630	25		500		20	
	042	0635	0710	35		500		14	
		1500	2300	480		0		0	
			2305	0100	115	985	0	1,020	0
5/27		0105	0159	54		0		0	
	043	0200	0300	60		300		5	
	044	0305	0400	55		500		9	
	045	0405	0500	55		300		5	
	046	0505	0600	55		250		5	
	047	0605	0705	60		300		5	
	048	0710	0810	60		500		8	
	049	1230	1435	125		150		1	
	050	1440	1630	110		300		3	
	051	1640	1740	60		200		3	
	052	1745	0200	495	1,189	250	3,050	1	
	5/28	053	0205	0400	115		300		3
		054	0405	0600	115		350		3
055		1300	2235	575		100		0	
056		2240	2300	20		200		10	
057		2305	0030	85	910	150	1,100	2	
5/29	058	0035	0200	85		250		3	
	059	0205	0400	115		150		1	
	060	0405	0600	115		200		2	
	061	1200	1310	70		150		2	
	062	1315	1420	65		200		3	
		1800	2300	300		200		1	
			2305	0200	175	925	0	1,150	0
5/30		0205	0400	115		0		0	
		0405	0600	115		0		0	
		0605	0800	115		0		0	
		0805	1000	115		0		0	
		1500	1900	240	700	0	0	0	
5/31		1340	1415	35		0		0	
		1420	1755	215		0		0	
		1800	1900	60		0		0	
		1905	1955	50		0		0	
	064	2200	2300	60		150		3	
	065	2305	0200	175	595	250	400	1	

Appendix C.1. (p 3 of 4)

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
6/01	066	0205	0300	55		200		4
	067	0305	0400	55		300		5
	068	0405	0500	55		500		9
	069	0505	0600	55		500		9
	070	1310	1350	40		500		13
	071	1355	1430	35		500		14
	072	1435	1500	25		400		16
	073	1505	1535	30		200		7
	074	1540	1610	30		600		20
	075	1615	1635	20	400	200	3,900	10
6/02	076	1320	1615	180		200		1
	077	1620	1820	120		300		3
	078	1830	2030	120		150		1
	079	2035	2150	75		250		3
	080	2155	2245	50		300		6
	081	2250	2350	60	605	200	1,400	3
6/03		1300	1430	90		0		0
		1510	1800	170		0		0
		1730	1800	30		0		0
		1900	2045	105		0		0
		2050	2300	130		0		0
	082	2305	0100	115		150		1
	083	0105	0500	235	875	150	300	1
6/04		1310	1400	50		0		0
		1405	1440	35		0		0
	084	1445	1540	55		200		4
	085	1542	0630	48		36		1
		0635	1730	55		0		0
		1735	1900	85		0		0
		1905	2300	235		0		0
		2305	0300	235	798	0	236	0
6/05		0305	0500	115		0		0
		0505	0630	85		7		0
	086	0635	0900	145		150		1
		1200	1330	90		0		0
		1305	1600	175		0		0
		1605	1725	80		0		0
		1730	1940	130		0		0
	087	1945	2215	150		0		0
	2220	2350	90		25		0	
	2355	0100	65	1,125	0	182	0	
6/06		0105	0300	115		0		0
	088	0305	0500	115		200		2
	089	0505	0600	55		150		3
		1545	1645	60		0		0
		1650	1730	40		0		0
		1735	1820	45		0		0
	090	1825	2040	135		400		3
	091	2043	2240	117		400		3
	092	2242	2342	60		250		4
	093	2344	2400	16	758	51	1,451	3

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
6/07		0005	0830	505		40		0
		1200	1530	210		0		0
		1535	2310	455		7		0
		2315	0100	105		0		0
		0105	0200	55		0		0
		0205	0300	55		0		0
		0305	0500	115	1,500	0	47	0
6/08	094	2147	2330	103		130		1
	095	2335	2410	35	138	136	266	4
6/09	096	0015	0300	165		150		1
	097	0305	0500	115		150		1
	098	0505	0545	40		100		3
		1500	1555	55		0		0
	099	1740	1940	120		53		0
	100	1941	2145	124		150		1
	101	2146	2330	104		120		1
	102	2331	0500	329	1,052	42	765	0
6/10		0505	0830	205		6		0
		1630	1750	80		0		0
	103	1755	2015	140		250		2
	104	2016	2146	90		250		3
	105	2148	2330	102		400		4
	106	2332	2400	28	645	10,000	10,906	357
6/11	107	0001	0040	39		250		6
	108	0041	0115	34		500		15
		1515	1645	90		0		0
		1730	2005	155		0		0
		2010	2305	175		0		0
		2310	0100	110	603	0	750	0
6/12		0105	0200	55		3		0
		0205	0400	115		0		0
		0405	0500	55		0		0
		1530	1730	120		0		0
		1735	2115	220		0		0
		2120	2305	105		0		0
		2310	0900	590	1,260	3	6	0
Max					1,500	10,000	10,906	357
Avg					738	257	1,925	7
Min					138	0	0	0

^a Military time - 24 hour clock (hhmm).

^b CPUE = catch per unit effort

Appendix C.2. Egegik River smolt fyke net catch log, 1997.

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
5/20	1	0019	0131	72	72	10	10	0
5/21		0051	0136	45	45	0	0	0
5/22	2	0001	0147	106		1		0
	3	2348	0128	100	206	3	4	0
5/24	4	0049	0242	113	113	3	3	0
5/25	5	0104	0236	92	92	5	5	0
5/26	6	0029	0104	35		105		3
	7	0106	0116	10		155		16
	8	0119	0128	9		240		27
	9	0130	0131	1		400		400
	10	0141	0142	1		250		250
	11	0145	0146	1	57	400	1,550	400
5/27	12	0038	0039	1		500		500
	13	0046	0047	1		700		700
	14	0050	0051	1		400		400
	15	0053	0054	1		300		300
	16	0056	0057	1		300		300
	17	0100	0101	1	6	500	2,700	500
5/28	18	0026	0033	7		120		17
	19	0036	0037	1		120		120
	20	0039	0040	1		150		150
	21	0043	0044	1		400		400
	22	0046	0047	1		300		300
	23	0049	0050	1	12	200	1,290	200
5/29	24	0004	0051	47		100		2
	25	0054	0058	4		300		75
	26	0103	0104	1		300		300
	27	0105	0106	1		500		500
	28	0109	0110	1		120		120
	29	0111	0112	1	55	500	1,820	500
5/30	30	0029	0054	25		120		5
	31	0057	0100	3		200		67
	32	0102	0113	11		150		14
	33	0115	0119	4		200		50
	34	0121	0124	3		200		67
	35	0126	0131	5	51	110	980	22
5/31	36	0031	0051	20		130		7
	37	0052	0053	1		250		250
	38	0056	0101	5		110		22
	39	0103	0107	4		300		75
	40	0109	0110	1		400		400
	41	0112	0114	2	33	300	1,490	150

Appendix C.2. (p 2 of 2)

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
6/01	42	0031	0058	27		110		4
	43	0059	0105	6		125		21
	44	0107	0109	2		125		63
	45	0112	0113	1		175		175
	46	0115	0120	5		250		50
	47	0128	0132	4	45	200	985	50
	6/02	48	0042	0113	31		100	
49		0117	0118	1		160		160
50		0119	0124	5		60		12
51		0126	0128	2		150		75
52		0132	0133	1		130		130
53		0139	0140	1	41	150	750	150
6/03	54	0029	0116	47		150		3
	55	0117	0124	7		150		21
	56	0124	0128	4		150		38
	57	0129	0132	3		150		50
	58	0133	0136	3		110		37
	59	0137	0140	3	67	100	810	33
6/04	60	0051	0112	21		100		5
	61	0113	0117	4		110		28
	62	0118	0120	2		100		50
	63	0121	0124	3		110		37
	64	0126	0128	2		100		50
	65	0129	0131	2	34	100	620	50
6/05	66	0041	0123	42		110		3
	67	0124	0158	34		80		2
	68	0159	0216	17	93	60	250	4
6/06	69	0030	0056	26		120		5
	70	0057	0111	14		100		7
	71	0112	0133	21		100		5
	72	0134	0152	18		100		6
	73	0153	0202	9	88	40	460	4
6/07	74	0021	0141	80		100		1
	75	0142	0200	18	98	30	130	2
6/08	76	0030	0051	21		120		6
	77	0052	0102	10		110		11
	78	0103	0129	26		120		5
	79	0131	0200	29	86	100	450	3
6/09	80	0031	0106	35		100		3
	81	0107	0148	41		120		3
	82	0149	0200	11	87	40	260	4
Max				113	206	700	2,700	700
Avg				17	69	176	728	108
Min				1	6	0	0	0

^a Military time - 24 hour clock (hhmm).

^b CPUE = catch per unit effort

Appendix C.3. Ugashik River smolt fyke net catch log, 1997.

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
5/11	1	0101	0118	17		200		12
	2	0123	0131	8		200		25
	3	0136	0147	11		200		18
	4	2329	0001	32	68	103	703	3
5/12	5	0006	0021	15		100		7
	6	0026	0034	8	23	200	300	25
5/13	7	2318	2328	10		200		20
	8	2335	2340	5		111		22
	9	2351	0002	11	26	131	442	12
5/14	10	0007	0017	10	10	121	121	12
5/16	11	2342	2346	4		100		25
	12	2352	0004	12	16	200	300	17
5/17	13	0021	0030	9		108		12
	14	0035	0050	15	24	111	219	7
5/18	15	0016	0024	8		127		16
	16	0030	0033	3		150		50
	17	0038	0044	6		150		25
	18	0049	0056	7		200		29
	19	1900	1930	30	54	0	627	0
5/19	20	0052	0114	22	22	100	100	5
5/20	21	0022	0041	19		100		5
	22	0046	0104	18		103		6
	23	0109	0127	18		139		8
	24	0132	0148	16	71	115	457	7
5/21	25	0017	0021	4		300		75
	26	0026	0027	1		200		200
	27	0032	0033	1		200		200
	28	0046	0048	2		200		100
	29	0053	0054	1		200		200
	30	0100	0102	2	11	300	1400	150
5/22	31	0019	0021	2		102		51
	32	0027	0029	2		104		52
	33	0037	0042	5		100		20
	34	0047	0054	7	16	101	407	14
5/23	35	0022	0023	1		200		200
	36	0030	0033	3		200		67
	37	0040	0042	2		250		125
	38	0047	0049	2		500		250
	39	0106	0108	2		150		75
	40	0115	0117	2	12	250	1550	125
5/24	41	0011	0023	12		113		9
	42	0029	0040	11		200		18
	43	0046	0048	2		250		125
	44	0056	0058	2		300		150
	45	0106	0107	1		200		200
	46	0112	0114	2	30	250	1313	125

Date	Cod End No.	Time ^a		Total Time Fished (min)		Smolt Catch		CPUE ^b
		Set	Pulled	per Set	per Day	per Set	per Day	
5/25	47	0025	0026	1		150		150
	48	0040	0041	1		300		300
	49	0046	0047	1		200		200
	50	0052	0053	1		150		150
	51	0140	0141	1		1000		1000
	52	0146	0147	1	6	300	2100	300
5/26	53	0035	0037	2		500		250
	54	0044	0045	1		300		300
	55	0050	0051	1		300		300
	56	0126	0127	1		100		100
	57	0135	0136	1		150		150
	58	0142	0143	1	7	150	1500	150
5/27	59	0023	0026	3		200		67
	60	0031	0033	2		150		75
	61	0040	0041	1		400		400
	62	0050	0051	1		200		200
	63	0110	0111	1		200		200
	64	0116	0117	1	9	101	1251	101
5/28	65	0025	0027	2		150		75
	66	0039	0041	2		94		47
	67	0046	0049	3		101		34
	68	0125	0130	5	12	110	455	22
5/29	69	0023	0024	1		400		400
	70	0030	0031	1		700		700
	71	0040	0042	2		150		75
	72	0114	0115	1		300		300
	73	0124	0125	1		150		150
	74	0134	0135	1	7	300	2000	300
5/31	75	0125	0128	3		400		133
	76	0133	0134	1		150		150
	77	0139	0141	2		250		125
	78	0151	0154	3	9	119	919	40
6/05	79	0028	0032	4		300		75
	80	0038	0044	6		200		33
	81	0054	0104	10		102		10
	82	0137	0145	8	28	121	723	15
6/07	83	0030	0036	6		150		25
	84	0045	0048	3		200		67
	85	0113	0115	2	11	112	462	56
6/08	86	0027	0034	7		150		21
	87	0041	0044	3		123		41
	88	0052	0055	3		150		50
	89	0121	0126	5	18	101	524	20
6/09	90	0027	0030	3		150		50
	91	0037	0038	1		300		300
	92	0046	0047	1		150		150
	93	0114	0118	4	9	250	850	63
6/11	94	0037	0043	6		300		50
	95	0053	0056	3		113		38
	96	0132	0136	4	13	102	515	26
Max				32	71	1000	2100	1000
Avg				5	21	200	802	114
Min				1	6	0	100	0

^a Military time - 24 hour clock (hhmm).

^b CPUE = catch per unit effort

Appendix D.1. Kvichak River water velocity at the center smolt sonar array, 1987-1997.

Date	Water Velocity (ft/sec)											
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1988-1996 Average
5/16												
5/17											3.12	
5/18							4.20			3.52		3.86
5/19			3.96									3.96
5/20												
5/21	4.96								4.82			4.82
5/22		5.38		5.01	4.27							4.89
5/23				4.99		3.43		4.27				4.23
5/24												
5/25												
5/26											3.27	
5/27							4.35			3.63		3.99
5/28			3.95									3.95
5/29						3.53			4.72			4.13
5/30												
5/31		5.50										5.50
6/01					4.47							4.47
6/02				5.37								5.37
6/03											3.45	
6/04								4.33		3.59		3.96
6/05												
6/06												
6/07						3.89						3.89
6/08		5.80							4.88			5.34
6/09							4.59					4.59
6/10			4.27	5.44	4.69							4.80
6/11												
6/12												
6/13							4.61	4.35		3.67	3.53	4.21
6/14												
6/15									4.90			4.90
Max		5.80	4.27	5.44	4.69	3.89	4.61	4.35	4.90	3.67	3.53	5.80
Avg	4.96	5.56	4.06	5.20	4.48	3.62	4.44	4.32	4.83	3.60	3.34	4.46
Min		5.38	3.95	4.99	4.27	3.43	4.20	4.27	4.72	3.52	3.12	3.43

Appendix D.2. Egegik River water velocity at the center smolt sonar array, 1984-1997.

Date	Water Velocity (ft/sec)														1984-1996 Average
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	
5/16															
5/17				2.15						2.37					
5/18					2.63										
5/19							2.50								
5/20	1.89					2.00		2.00					1.50	1.80	
5/21		1.16	1.83							2.30	2.68				
5/22									1.58						
5/23															
5/24									1.70			2.62			
5/25					3.16								1.25	1.75	
5/26			1.53	2.14			2.68								
5/27											2.28				
5/28						2.09				2.30					
5/29								2.75							
5/30															
5/31									2.02				1.28	1.67	
6/01			1.76	2.30	2.90							2.75			
6/02							2.73				2.43				
6/03	1.82									2.30					
6/04						2.30									
6/05								2.85							
6/06		1.16													
6/07													0.90	1.72	
6/08												2.68			
6/09									1.98		2.25				
6/10			1.67	2.51	2.83										
6/11															
6/12												2.40			
6/13		1.32													
6/14															
6/15															
Max	1.89	1.32	1.83	2.51	3.16	2.30	2.73	2.85	2.02	2.37	2.68	2.75	1.50	1.80	3.16
Avg	1.86	1.21	1.70	2.28	2.88	2.13	2.64	2.53	1.82	2.32	2.41	2.61	1.23	1.74	2.12
Min	1.82	1.16	1.53	2.14	2.63	2.00	2.50	2.00	1.58	2.30	2.25	2.40	0.90	1.67	0.90

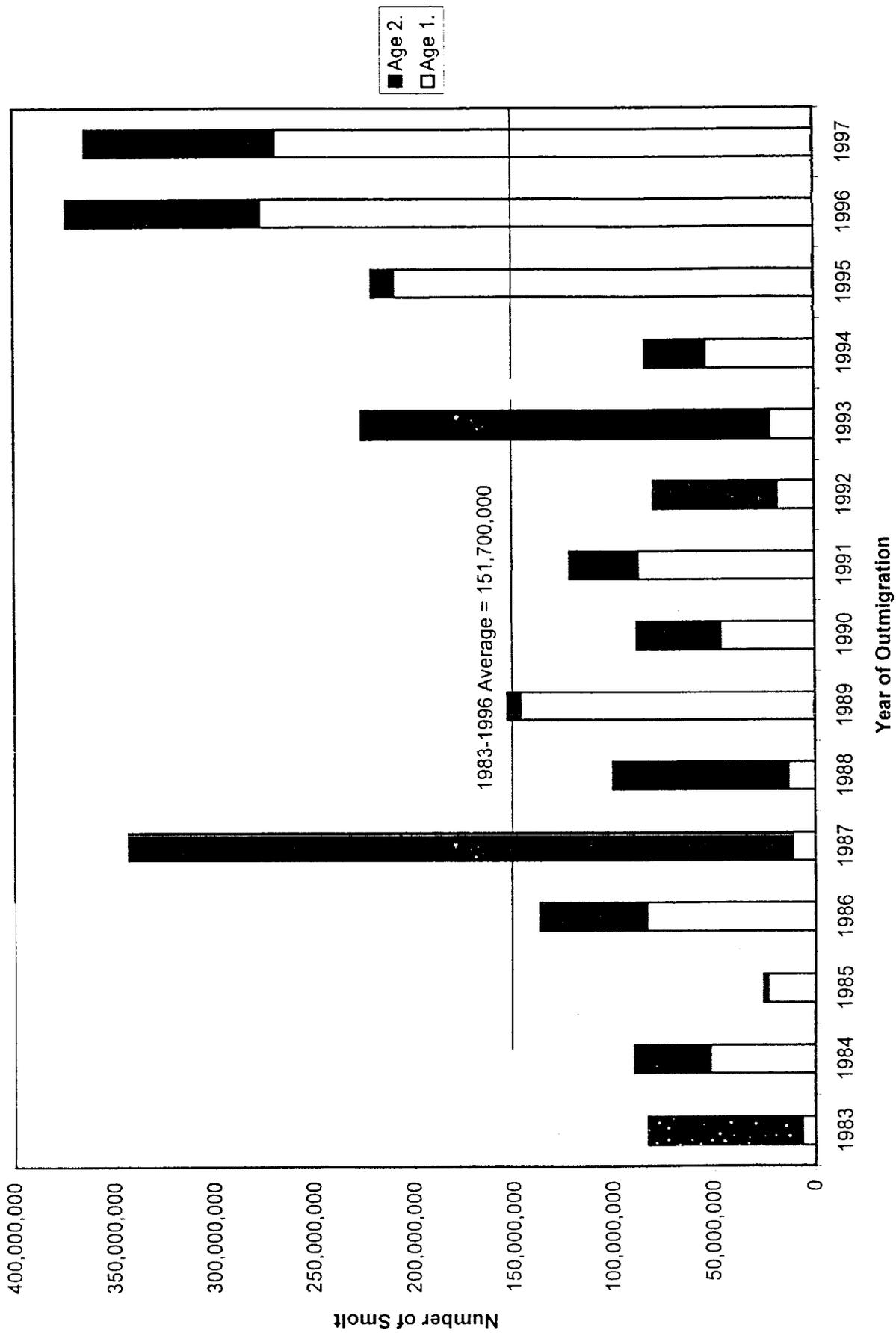
Appendix D.3. Ugashik River water velocity at the inshore smolt sonar array, 1983-1997.

Date	Water Velocity (ft/sec)															Average
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992 ^a	1993	1994	1995	1996	1997	
5/05															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		
5/17					5.17	7.15					7.84				6.72	
5/18																
5/19													3.91	5.01	3.91	
5/20								6.23	5.78			7.60			6.54	
5/21																
5/22	8.00			3.16				4.13					9.48		6.19	
5/23			4.10											4.86	4.10	
5/24																
5/25	7.63										8.34				7.99	
5/26												7.78		4.52	6.15	
5/27																
5/28		5.56						6.73	7.82				8.93		7.26	
5/29														4.82		
5/30								4.90							4.90	
5/31				3.89											3.89	
6/01											8.19				8.19	
6/02								5.12				7.23		4.45	5.60	
6/03																
6/04			4.93					6.17	6.84				8.72	4.88	6.66	
6/05									7.70						7.70	
6/06																
6/07																
6/08											8.34				8.34	
6/09												7.04	7.53	4.47	6.35	
6/10																
6/11				3.80											3.80	
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	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	6.25
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	3.16

^a Project not conducted in 1992 due to lack of funding. No data collected.

Appendix E.1. Total smolt outmigration estimates for Kvichak River by outmigration year, 1983-1997.

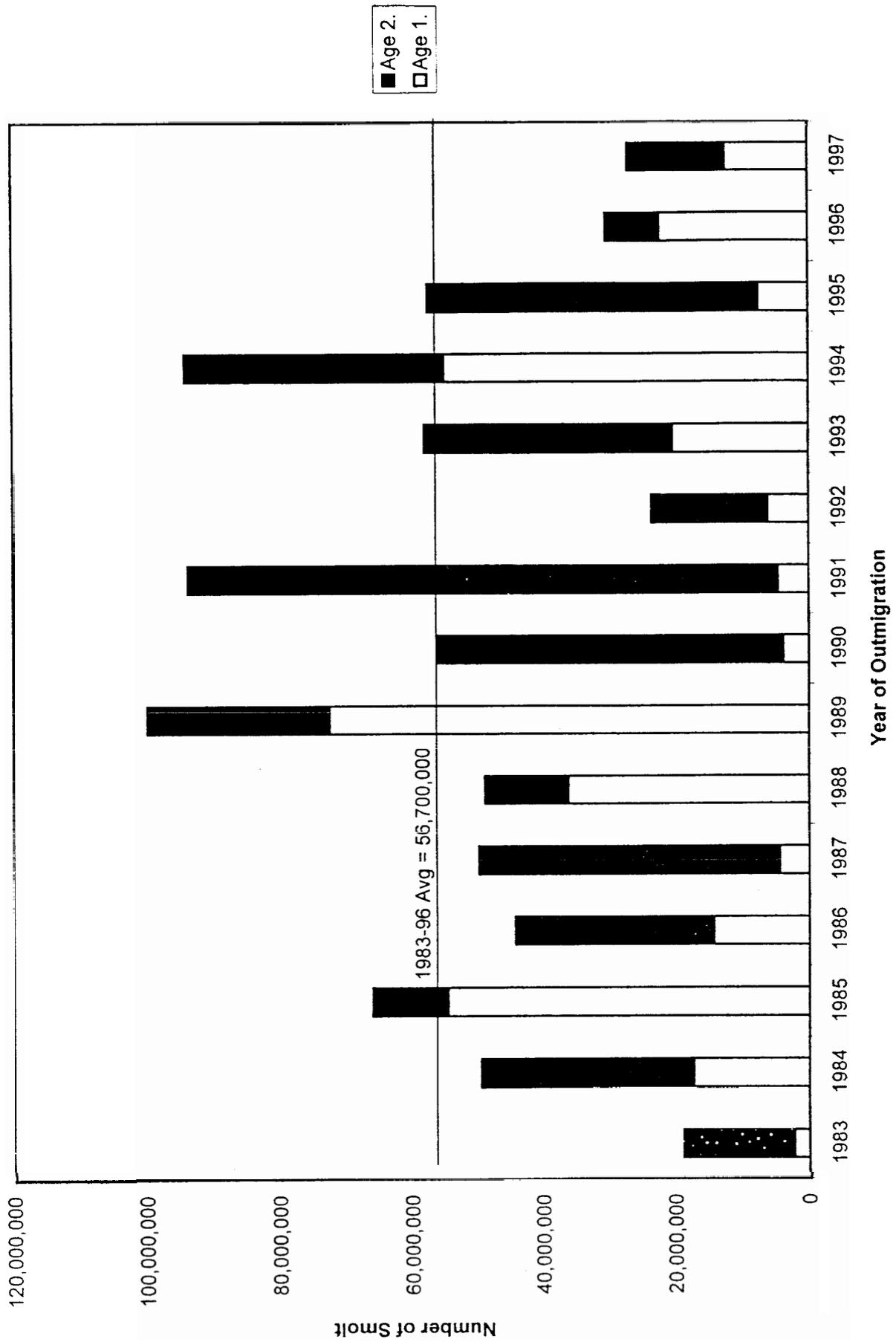
Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/19-6/13	26	5/23	5/26	6/05	5/24	14,258,463	82,793,899	Ice Problems - 5/19-5/22 intermittent
1984	5/18-6/10	24	5/21	5/27	6/05	5/27	13,184,162	89,489,975	
1985	5/22-6/19	29	6/06	6/10	6/17	6/09	6,059,204	25,527,851	Ice Problems - 5/22-6/02, 6/06 intermittent, 6/03-6/05 continuous
1986	5/21-6/12	23	5/28	6/05	6/06	6/06	58,591,781	136,733,218	
1987	5/21-6/13	24	5/24	5/28	6/09	5/28	45,657,674	342,686,918	
1988	5/22-6/16	26	5/23	6/01	6/13	6/01	15,490,767	100,173,692	
1989	5/19-6/15	28	5/29	6/03	6/10	6/03	26,318,761	153,464,216	New Site Location - 1 km downstream from 1974-1988 site
1990	5/21-6/14	25	5/22	5/25	6/10	5/27	11,721,914	88,004,103	Ice Problems - prior to 5/21
1991	5/22-6/16	26	5/30	5/28	6/10	6/04	19,885,424	121,454,182	Ice Problems - 5/22-5/26 intermittent, 5/27-5/29 continuous
1992	5/23-6/13	22	5/25	5/22	6/03	5/28	18,838,144	79,490,008	Ice Problems - 5/19-5/22 continuous, 5/24-5/26, 5/31 intermittent
1993	5/18-6/11	25	5/19	5/24	5/31	5/31	44,155,479	226,407,888	
1994	5/28-6/15	19	5/31	6/05	6/11	6/05	11,705,421	83,845,472	Ice Problems - 5/17-5/28 continuous
1995	5/21-6/13	24	5/21	5/25	6/03	5/22	40,060,740	220,892,127	Ice Problems - 5/17-5/21 continuous
1996	5/18-6/12	26	5/24	5/28	5/31	5/28	78,544,749	373,166,532	
1983-96 Max		29	6/06	6/10	6/17	6/09	78,544,749	373,166,532	
1983-96 Avg		25	5/25	5/29	6/07	5/30	28,890,906	151,723,577	
1983-96 Min		19	5/19	5/22	5/31	5/22	6,059,204	25,527,851	
1997	5/17-6/12	27	5/19	5/24	6/01	5/22	44,778,344	363,397,663	



Appendix E.2. Age composition of smolt outmigration estimates for Kvichak River by outmigration year, 1983-1997.

Appendix E.3. Total smolt outmigration estimates for Egegik River by outmigration year, 1983-1997.

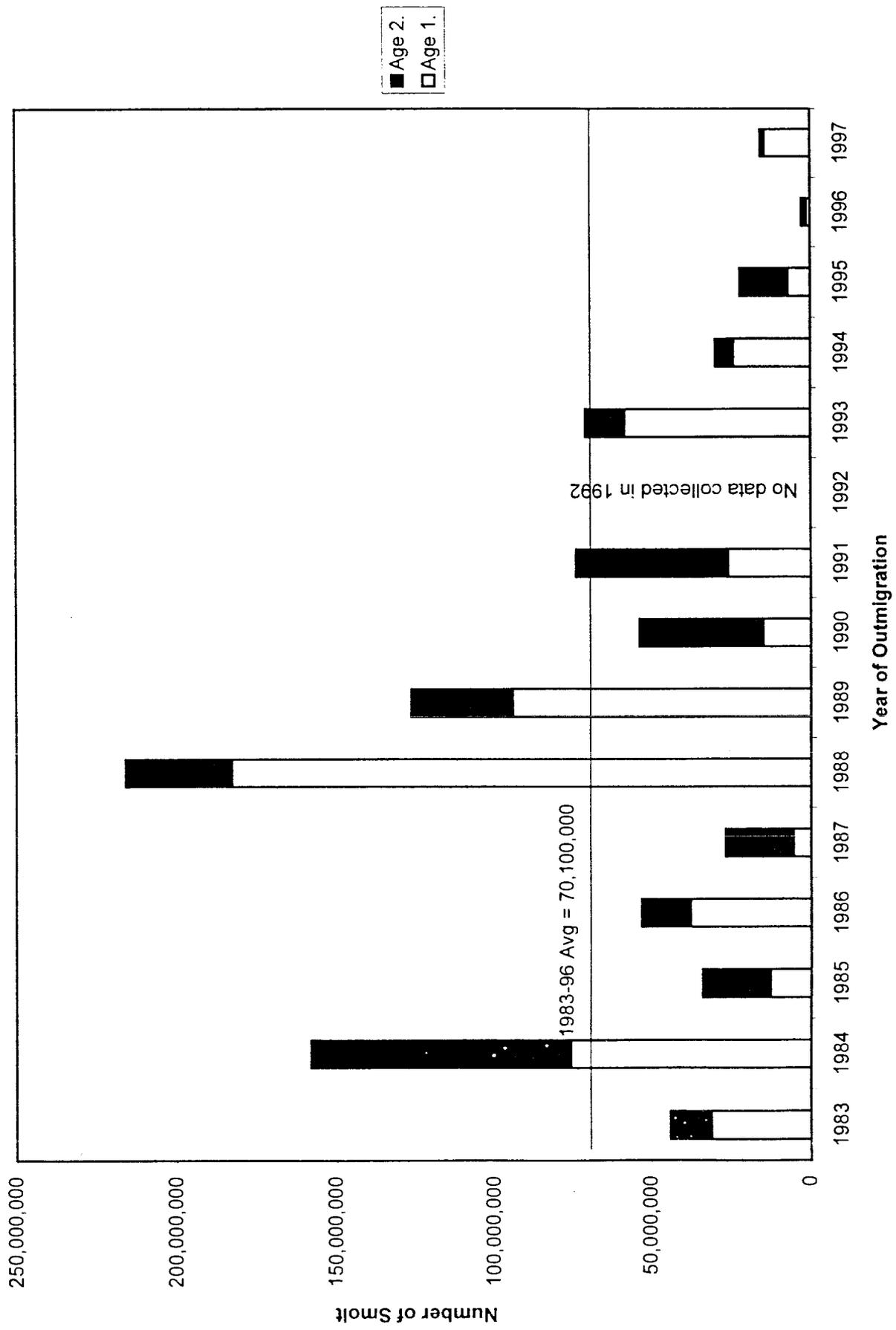
Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/17-6/10	25	5/21	5/27	5/31	5/29	5,377,393	18,766,889	
1984	5/19-6/10	23	5/26	5/26	5/30	5/26	23,006,014	49,667,432	
1985	5/19-6/11	24	5/27	5/29	6/01	5/27	24,392,451	66,073,548	Ice Present - 5/17-5/22 intermittent
1986	5/18-6/11	25	5/27	5/29	6/03	5/29	10,079,789	44,197,865	Ice Present - 5/19-5/25 intermittent
1987	5/19-6/13	26	5/21	5/24	6/08	5/22	9,088,350	49,868,710	
1988	5/18-6/13	27	5/23	5/26	6/05	5/24	9,963,520	48,961,215	
1989	5/20-6/09	21	5/25	5/27	5/31	5/27	21,494,695	99,886,786	
1990	5/19-6/11	24	5/23	5/25	5/29	5/25	17,366,276	56,095,226	Fair Weather - 118 h disabled time
1991	5/21-6/11	22	5/25	5/28	6/07	6/04	17,890,595	94,077,988	Ice Problems - 5/17-5/18 continuous
1992	5/22-6/11	21	5/26	5/27	6/02	5/26	7,935,493	23,748,278	
1993	5/17-6/08	23	5/20	5/24	5/27	5/25	11,674,298	57,960,399	
1994	5/21-6/09	20	5/24	5/31	6/05	5/31	14,215,785	94,086,989	
1995	5/21-6/12	23	5/22	5/23	5/29	5/23	19,428,442	57,385,790	Ice Problems - 5/19-5/21 continuous
1996	5/19-6/12	25	5/24	5/25	5/29	5/24	10,043,411	31,270,793	
1983-96 Max		27	5/27	5/31	6/08	6/04	24,392,451	99,886,786	
1983-96 Avg		24	5/23	5/26	6/01	5/26	14,425,465	56,574,851	
1983-96 Min		20	5/20	5/23	5/27	5/22	5,377,393	18,766,889	
1997	5/18-6/09	23	5/24	5/28	5/31	5/29	4,881,168	27,050,113	



Appendix E.4. Age composition of smolt outmigration estimates for Egegik River by outmigration year, 1983-1997.

Appendix E.5. Total smolt outmigration estimates for Ugashik River by outmigration year, 1983-1997.

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	Ice Present - 5/17-5/21 intermittent
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	Good 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
1983-96 Max		28	5/30	6/06	6/13	6/07	55,816,902	215,968,015	
1983-96 Avg		24	5/25	6/01	6/05	5/31	13,809,894	70,121,947	
1983-96 Min		0	5/21	5/26	5/06	5/25	627,517	2,576,812	
1997	5/10-6/12	34	5/18	5/24	5/30	5/24	4,065,127	15,519,783	Good/Excellent Weather - 31 h disabled tim



Appendix E.6. Age composition of smolt outmigration estimates for Ugashik River by outmigration year, 1983-1997.

Appendix F.1. Comparison of Kvichak River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.

Year	Sonar Startup		Peak Smolt Passage		
	Smolt Day	Mean Water Temperature °C	Smolt Day	Mean Water Temperature °C	
1984	18-May	5.5	^a	27-May	6.8
1985	22-May	3.8	^b	9-Jun	5.8
1986	21-May	4.5		6-Jun	7.0
1987	21-May	4.5		28-May	5.9
1988	22-May	3.8		1-Jun	5.7
1989	19-May	4.0		3-Jun	6.0
1990	21-May	3.5	^c	27-May	5.8
1991	22-May	2.0		4-Jun	4.8
1992	23-May	6.3		28-May	7.5
1993	18-May	4.5	^d	31-May	7.8
1994	28-May	4.0		5-Jun	6.0
1995	21-May	6.0		22-May	6.0
1996	18-May	7.0		28-May	7.5
Max		7.0			7.8
Avg		4.6			6.4
Min		2.0			4.8
1997	17-May	5.5		22-May	7.0

^a Water temperature recorded May 19, 1984.

^b Water temperature recorded May 23, 1985.

^c Water temperature recorded May 22, 1990.

^d Water temperature recorded May 19, 1993.

Appendix F.2. Comparison of Egegik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.

Year	Sonar Startup		Peak Smolt Passage	
	Smolt Day	Mean Water Temperature °C	Smolt Day	Mean Water Temperature °C
1984	19-May	7.0	26-May	7.5
1985	19-May	2.5	27-May	4.0
1986	18-May	3.0	29-May	4.7
1987	19-May	5.5	22-May	4.0
1988	18-May	4.9	24-May	5.8
1989	20-May	3.5	27-May	4.2
1990	19-May	3.5	25-May	3.8
1991	21-May	7.0	4-Jun	8.0
1992	22-May	7.0	26-May	6.8
1993	17-May	6.5	25-May	6.5
1994	21-May	4.0	31-May	5.8
1995	21-May	4.3	23-May	5.0
1996	19-May	4.8	24-May	5.3
Max		7.0		8.0
Avg		4.9		5.5
Min		2.5		3.8
1997	19-May	4.0	29-May	7.5

^a Water temperature recorded May 19, 1986.

^b Water temperature recorded May 19, 1988.

^c Water temperature recorded May 21, 1989.

^d Water temperature recorded May 20, 1990.

^e Water temperature recorded May 23, 1992.

^f Water temperature recorded May 18, 1993.

^g Water temperature recorded May 22, 1995.

Appendix F.3. Comparison of Ugashik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1997.

Year	Sonar Startup		Peak Smolt Passage	
	Smolt Day	Mean Water Temperature °C	Smolt Day	Mean Water Temperature °C
1984	22-May	4.8	1-Jun	6.5
1985	22-May	1.5	4-Jun	5.3
1986	21-May	4.0	30-May	5.0
1987	17-May	5.5	3-Jun	6.3
1988	17-May	3.5	7-Jun	7.3
1989	22-May	4.0	25-May	4.0
1990	20-May	3.0	29-May	6.3
1991	20-May	4.0	2-Jun	5.5
1992 ^a				
1993	17-May	6.0	26-May	7.0
1994	20-May	5.0	4-Jun	7.0
1995	22-May	4.5	25-May	5.0
1996	19-May	4.0	4-Jun	7.0
Max		6.0		7.3
Avg		4.2		6.0
Min		1.5		4.0
1997	10-May	5.0	24-May	6.5

^a Project not conducted. No data collected.

APPENDIX G. CLIMATOLOGICAL FACTORS AFFECTING FRESHWATER SURVIVAL

The freshwater survival of salmon eggs, fry, and smolt from the 1994 and 1995 brood years were probably affected by several climatic factors outlined below; however, we have no direct information indicating the magnitude or direction of the effect.

Air Temperature

According to air temperature data collected by the National Weather Service (1995; 1996; 1997a,b,c,d, e,f) the overall annual temperatures for King Salmon and vicinity from July through June in 1994-1995, 1995-1996, and 1996-1997 were 1.1 °F, 2.4 °F, and 0.5 °F warmer than the 30-year mean (Appendix G.1). Average monthly temperatures for the same time periods were also predominantly warmer than the 30-year mean (Appendix G.2). Some colder months which may have impacted salmon eggs, fry, and smolt in the Kvichak, Egegik, and Ugashik River drainage were October, November, and December 1994 (2.0 °F, 3.7°F, and 3.0 °F below average), March and November 1995 (6.3 °F and 4.6°F below average), February, October, and December 1996 (1.6 °F, 3.7°F, and 11.0 °F below average), and January and March 1997 (2.4°F and 2.9°F below average).

During the winter of 1994-1995 there were 139 d between October and April with average daily air temperatures less than or equal to 32 °F and 24 d with average daily temperatures less than 0 °F (Appendix G.3). During this same time period, there were 73 d with average daily air temperatures greater than 32 °F which would be favorable for the production of salmon eggs and fry for the 1994 brood year. Below normal temperatures which may have contributed to increased mortality of eggs were most prevalent in late November (8 d), early and mid December (14 d), late January (5 d), late February (6 d), and mid-to-late March (14 d).

The winter of 1995-1996 had milder air temperatures. Between October 1995 and April 1996, there were 127 d with average daily air temperatures less than or equal to 32 °F and 16 d with average daily temperatures less than 0 °F (Appendix G.4). This winter had 86 d with average daily air temperatures greater than 32 °F which would be favorable for the production of salmon eggs and fry for the 1995 brood year. Below normal temperatures which may have contributed to reduced freshwater survival of juvenile sockeye salmon occurred in late November to early December (14 d), mid-January (12 d), and in early and late February (13 d).

Air temperatures during the winter of 1996-1997 were colder than 1995-1996, but not as cold as 1994-1995. Between October 1996 and April 1997 there were 135 d with average daily air temperatures less than or equal to 0 °F and 20 d with average daily temperatures less than 0 °F (Appendix G.5). This cooler weather may have created less favorable rearing conditions for age-2. smolt from the 1994 brood year and age-1. smolt from the 1995 brood year. The winter of 1996-1997 had 77 d with average daily air temperatures greater than 32 °F which would be favorable for

the production of salmon eggs and fry for the 1996 brood year. Below normal temperatures predominated in late November (4 d), December (22 d), early and late January (11 d), and mid to late March (15 d).

Precipitation

Precipitation data collected by the National Weather Service (1996; 1997a,b,c,d,e,f) for King Salmon and vicinity indicate that the periods from July through June in 1994-1995, 1995-1996, and 1996-1997 differed from the 30-year mean annual precipitation of 19.4 in by +18%, -10%, and -37% (Appendix G.6).

Average monthly precipitations during the 1994-1995 season were greater than or equal to the 30-year mean in 8 out of 12 months (Appendix G.7). The month in which precipitation probably had the greatest impact upon freshwater survival of sockeye salmon in east side Bristol Bay river systems was July. The average monthly precipitation for July was 3.77 in, 69% greater than the 30-year mean. The increase in precipitation may have caused some flooding however we have no direct information that significant flooding occurred. If flooding did occur it would probably have more impact on the spawning success of adult salmon depositing egg for the 1995 brood year than the age-1. fry from the 1994 brood year rearing in east side Bristol Bay lakes.

Average monthly precipitation's during the 1995-1996 season were less than the 30-year mean in 8 out of 12 months (Appendix G.7). The months in which low precipitation may have had the greatest impacts upon freshwater survival of sockeye salmon in east side Bristol Bay river systems were August, October, November, December, and March. The average monthly precipitation for August was 4.73 in, 57% greater than the 30-year mean. The average monthly precipitation for October, November, December, and March were 1.46 in, 0.13 in, 0.14 in, and 0.38 in respectively. The precipitation for these months were 30%, 92%, 90%, and 60% less than their 30-year mean. It is unknown how this increase followed by decreases in precipitation may have effected the age-1. (1995 brood year) and -2. (1994 brood year) fry rearing in east side Bristol Bay lakes.

Average monthly precipitation's during the 1996-1997 season were less than the 30-year mean in 10 out of 12 months (Appendix G.7). The months in which precipitation probably did not impact the freshwater survival of sockeye salmon in east side Bristol Bay river systems were August, September, and February. The average monthly precipitation, for the remaining 9 months, were well below the 30-year mean. This suggests that access to and availability of suitable adult salmon spawning habitat and juvenile rearing habitat may have been reduced due to low water levels. Lower than usual precipitation in the spring may also have dewatered some smaller tributaries and prevented fry from entering rearing areas in the lakes.

Snowfall

Snowfall data collected for King Salmon and vicinity by the National Weather Service (1996; 1997a,b,c,d,e,f) indicate that the periods from July through June in 1994-1995, 1995-1996, and 1996-1997 differed from the 30-year mean annual precipitation of 46.2 in by +14%, -44%, and -51% (Appendix G.8).

During the winter of 1994-1995 most of the snow fell early with above normal snowfalls in October (8.4 in), November (17.9 in) and December (16.0 in) (Appendix G.9). The monthly snowfall for the remainder of the winter was below normal, however the insulating qualities of the early snowfall probably protected developing salmon eggs and emerging and rearing fry.

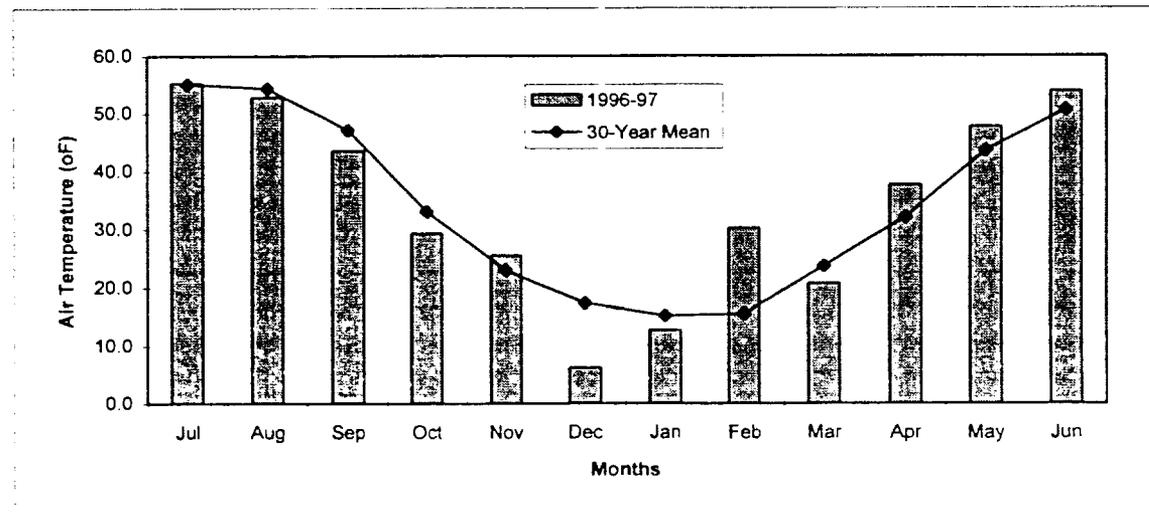
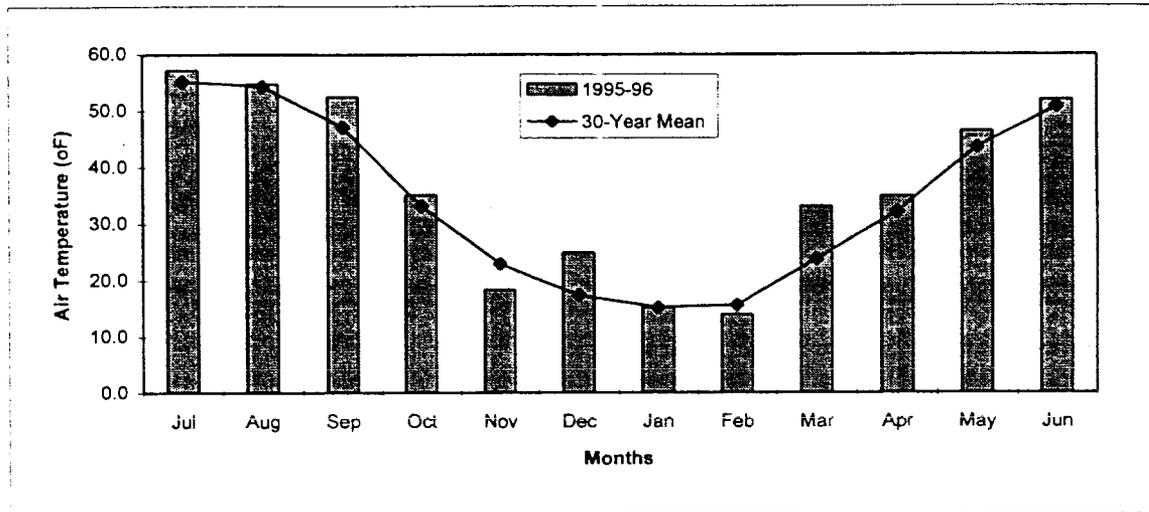
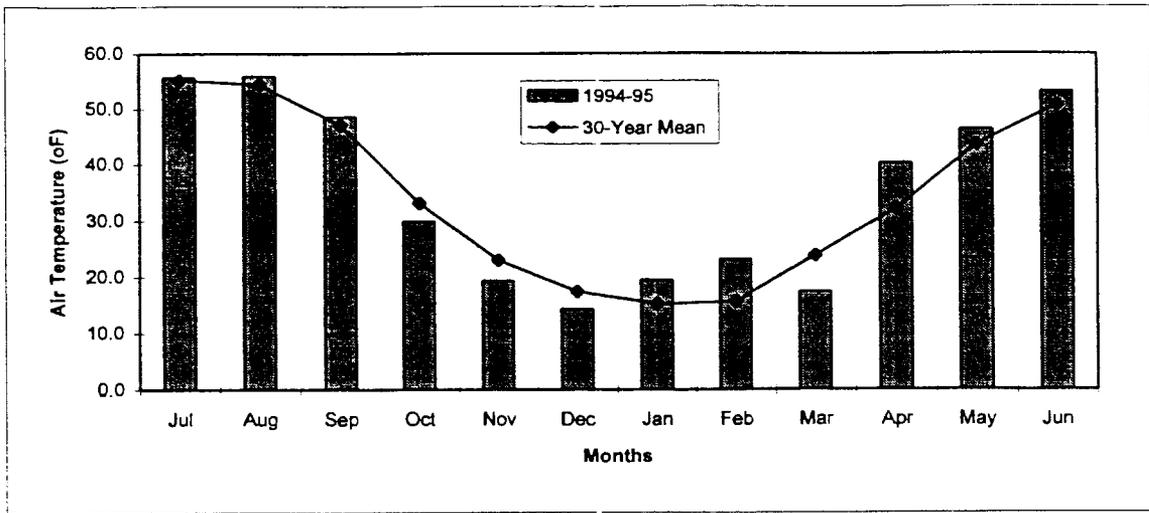
Snowfall during the winter of 1995-1996 season was sparse (Appendix G.9). The average monthly snowfall for October, November, December, January, and March, were -38%, -66%, -83%, -69%, and -76% respectively, below the 30-year mean. Snowfall in March, April, and May was normal. It is unknown how the lack of insulating snow in the early half of the winter may have affected the age-1. (1995 brood year) and -2. (1994 brood year) fry rearing in east side Bristol Bay lakes.

Average monthly snowfalls during the winter of 1996-1997 were also well below normal (Appendix G.9). The average monthly snowfall during October, December, and February were slightly less than normal, but would probably provide an excellent insulating layer which would help protect developing salmon eggs and emerging fry from sharp changes in temperature. Despite having little or no snowfall in November and well below average snowfall in January, March, and April, the negative effects caused by lack of insulating snow in these later months may have been canceled out by the average and above average air temperatures (Appendix G.2).

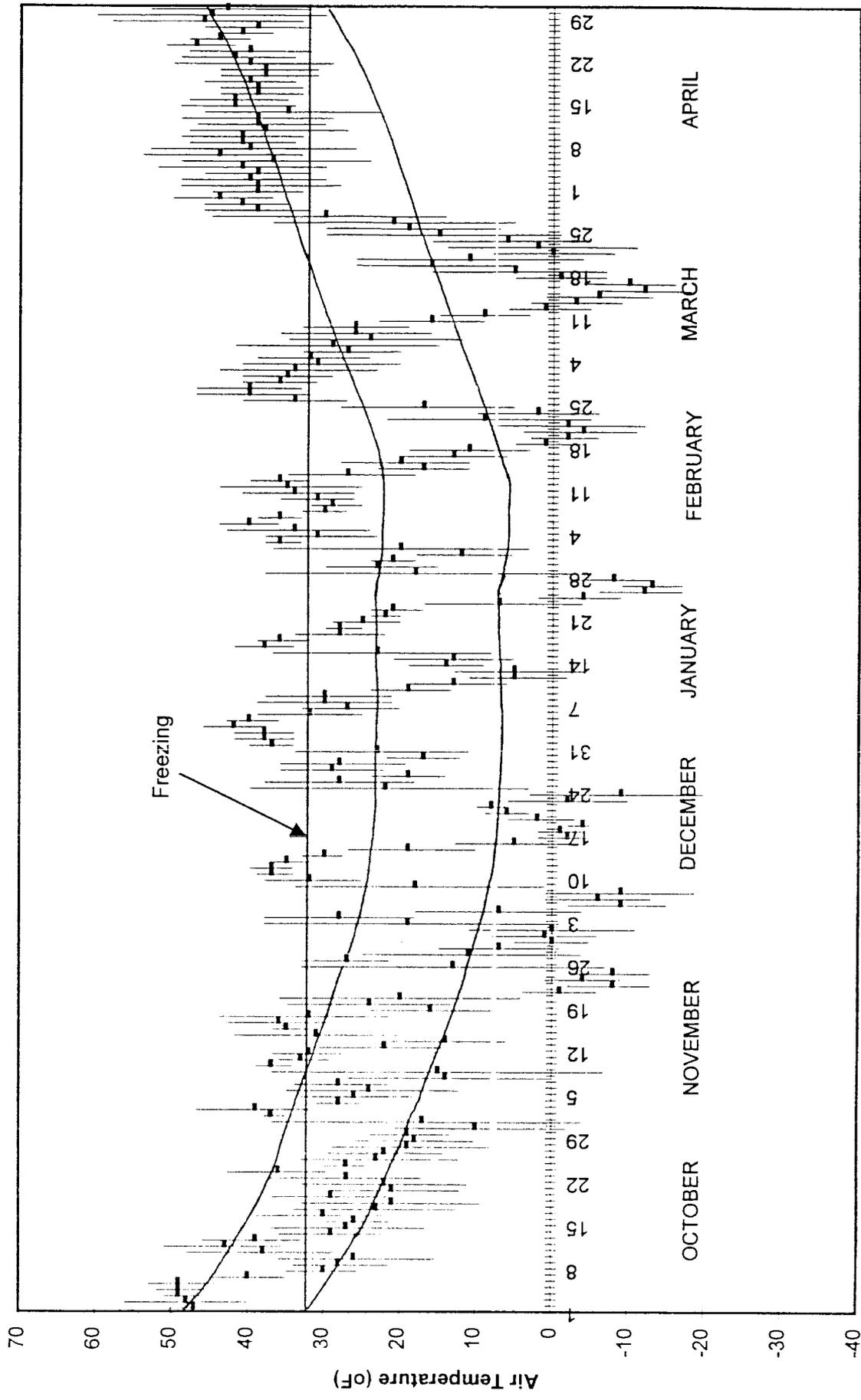
Appendix G.1. Average monthly air temperature for King Salmon, July 1967 to June 1997.

Smolt Year	Air Temperature (°F) ^a												Average Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
1967-68	54.6	54.6	46.3	30.0	29.3	12.0	10.0	12.8	25.5	30.1	43.8	50.7	33.3
1968-69	55.5	54.6	43.3	28.4	26.2	3.4	6.9	12.8	26.3	34.4	44.1	52.5	32.4
1969-70	54.3	50.9	48.1	38.8	17.0	26.2	-0.3	26.4	30.5	29.8	44.8	51.1	34.8
1970-71	52.7	51.7	44.8	29.3	29.3	11.6	-2.6	12.2	7.8	26.8	37.7	47.3	29.1
1971-72	54.5	54.9	46.8	34.3	21.6	18.6	6.7	6.2	1.8	2.1	40.9	46.6	27.9
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
Max	57.9	57.1	52.5	39.4	30.1	34.2	34.4	30.3	36.3	41.0	48.3	54.0	38.3
30-Year Mean	55.2	54.3	47.1	33.1	23.0	17.3	15.2	15.6	23.7	32.1	43.6	50.7	34.2
Min	51.5	50.9	41.0	26.7	12.7	3.4	-2.9	-2.1	1.8	2.1	37.7	46.6	27.9

^a Source - National Weather Service (1995; 1996; 1997a,b,c,d,e,f)

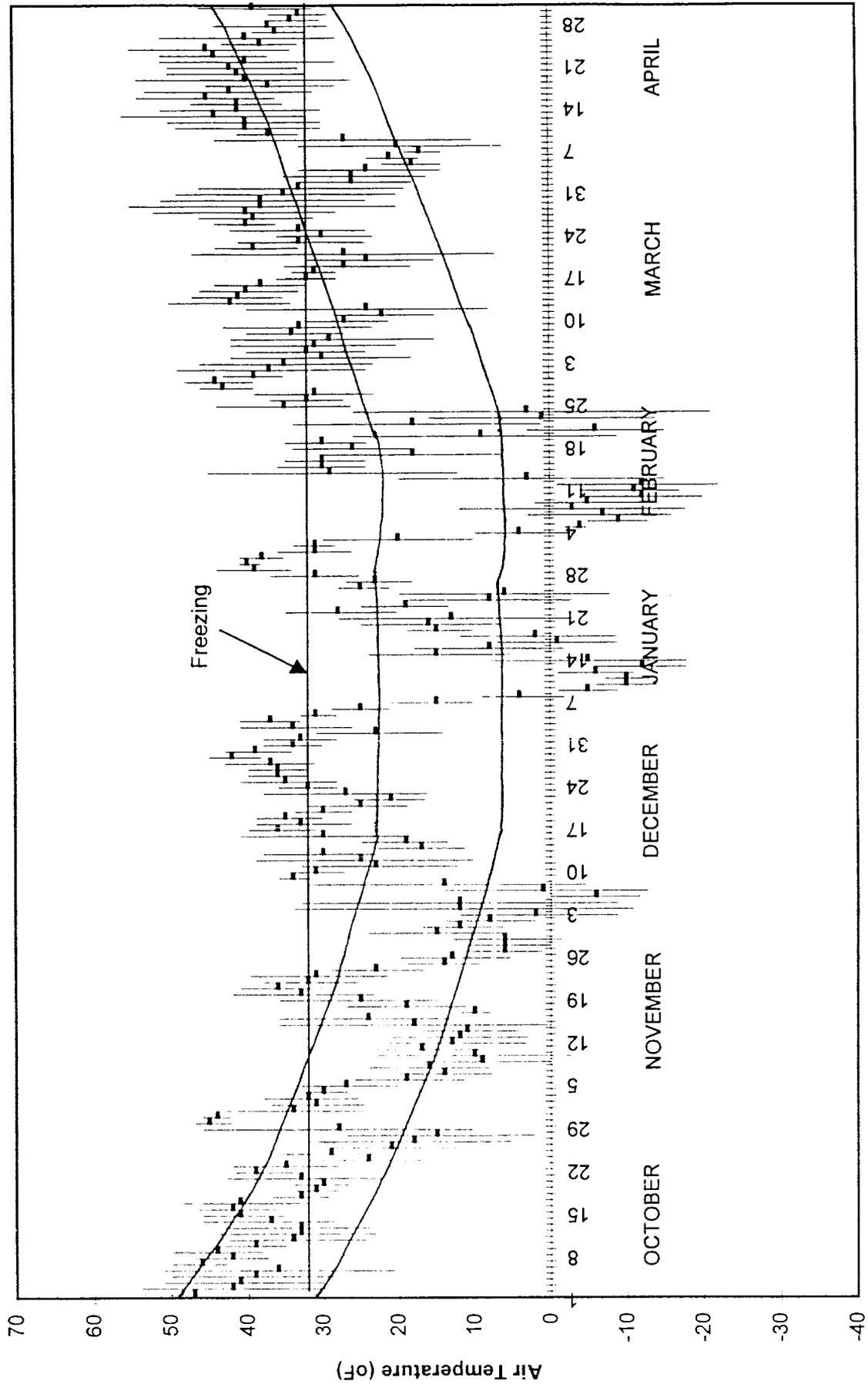


Appendix G.2. Comparison of monthly air temperature to the 30-year mean at King Salmon, July 1994 to June 1997.

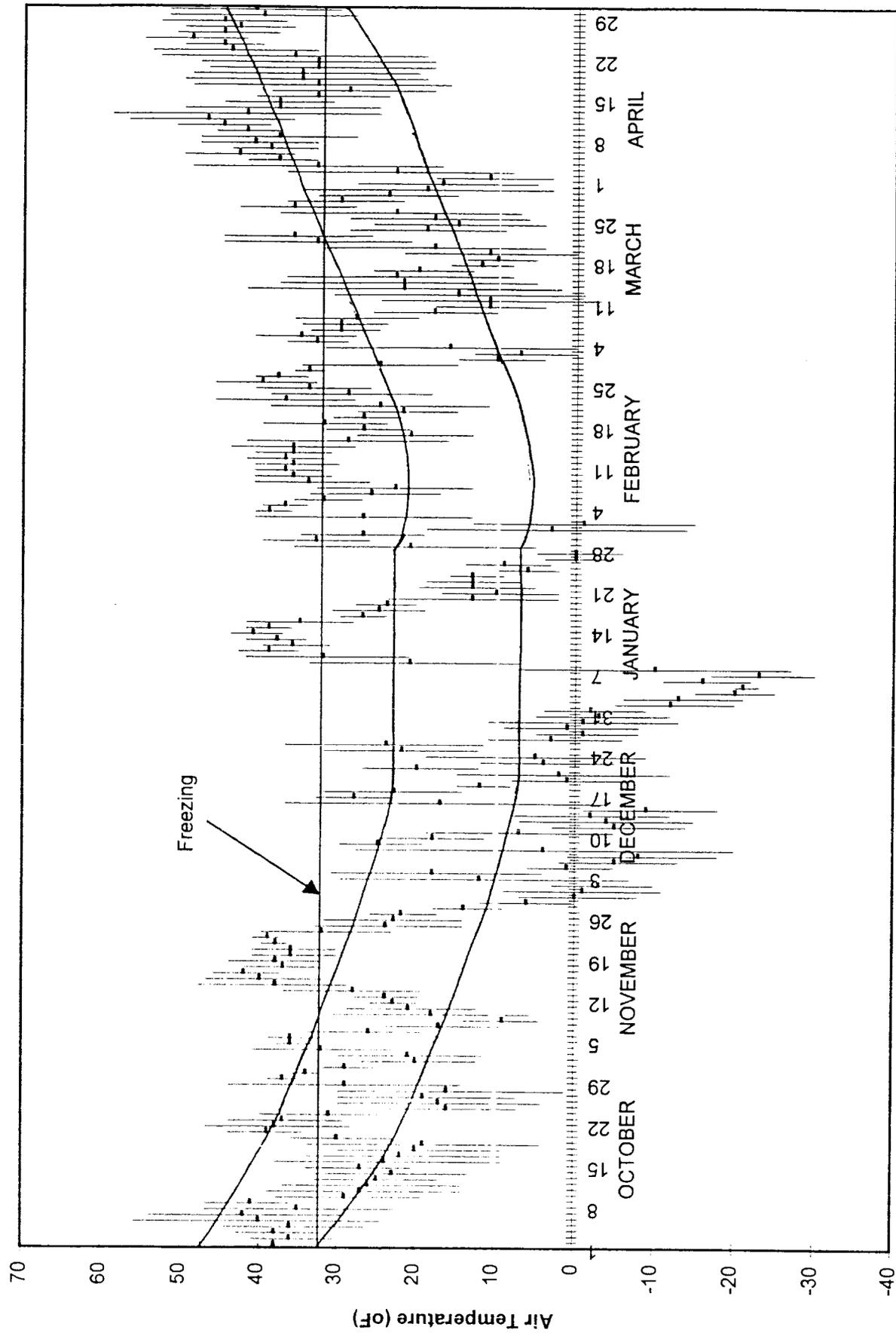


Dates

Appendix G.3. Daily air temperatures (normals, means and extremes) for King Salmon, October 1994 to April 1995.



Appendix G.4. Daily air temperatures (normals, means and extremes) for King Salmon, October 1995 to April 1996.

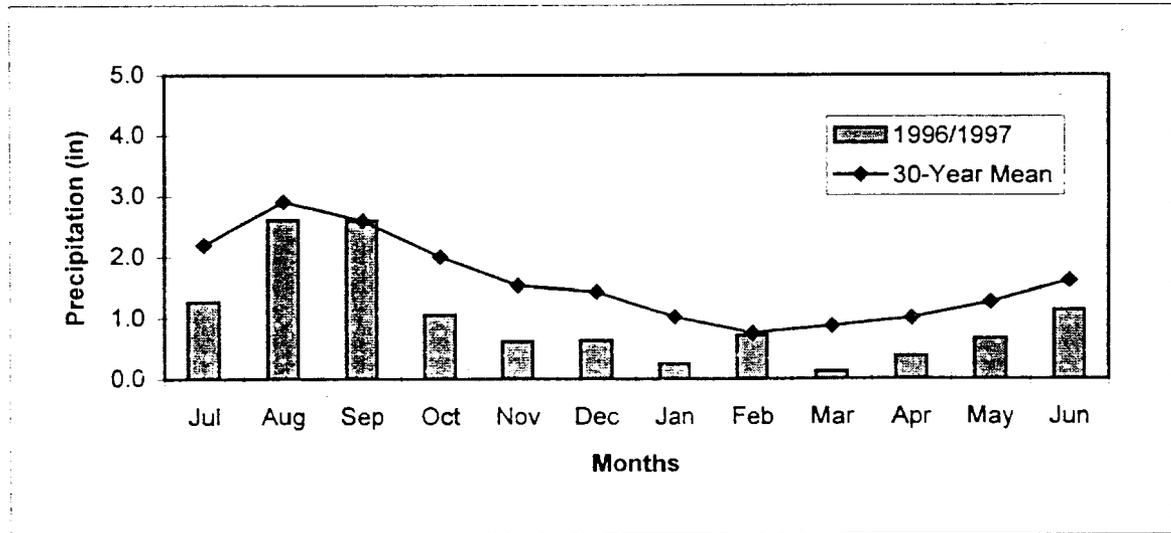
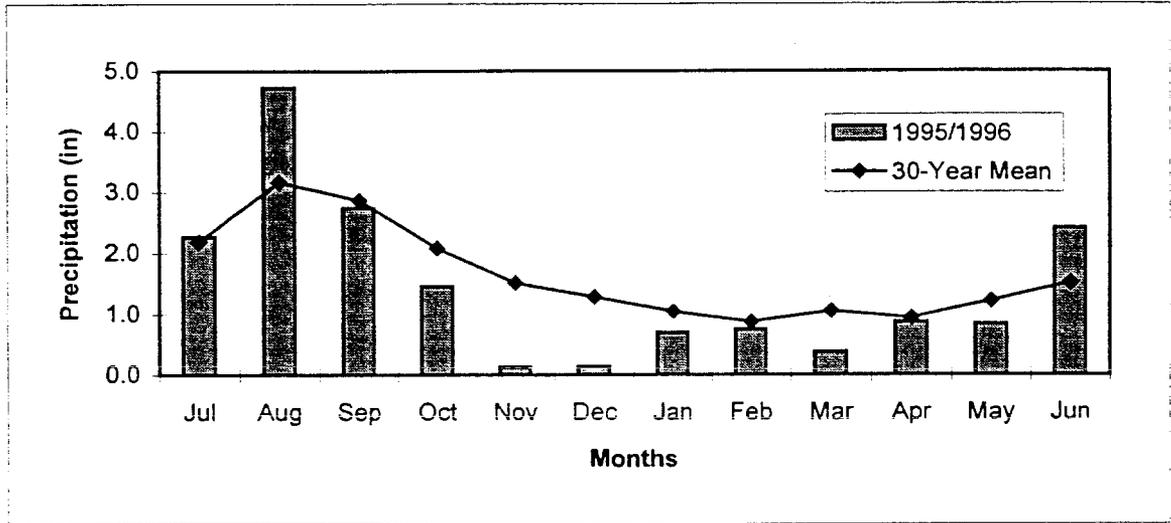
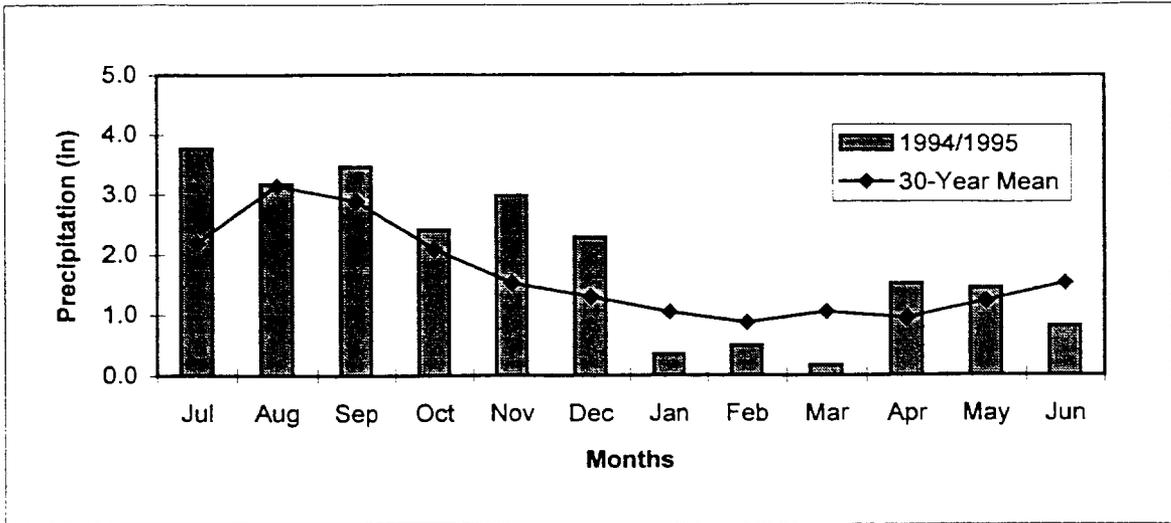


Appendix G.5. Daily air temperatures (normals, means and extremes) for King Salmon, October 1996 to April 1997.

Appendix G.6. Average monthly precipitation for King Salmon, July 1967 to June 1997.

Smolt Year	Precipitation (in) ^a												Total Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
1967-68	3.15	3.15	1.69	0.52	1.90	2.03	1.10	0.57	0.80	1.41	1.26	1.35	18.93
1968-69	1.14	2.20	2.70	0.51	0.91	1.25	0.65	1.94	1.19	0.30	0.79	0.56	14.14
1969-70	2.19	3.42	1.28	2.33	1.84	0.57	0.50	0.45	1.81	1.80	0.41	1.13	17.73
1970-71	2.87	4.31	1.59	2.24	0.79	1.33	0.45	1.62	0.27	0.84	1.43	1.48	19.22
1971-72	3.25	4.30	3.40	2.72	1.13	3.42	1.30	0.21	0.17	1.37	1.29	1.62	24.18
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
Max	5.08	4.73	5.90	3.29	3.35	3.65	2.38	2.26	1.99	2.65	2.95	3.04	26.23
30-Year Mean	2.19	2.91	2.60	2.00	1.53	1.43	1.02	0.76	0.87	1.00	1.27	1.61	19.38
Min	0.74	1.05	0.89	0.51	0.13	0.14	0.25	0.11	0.13	0.19	0.41	0.50	12.09

^a Source - National Weather Service (1995; 1996; 1997a,b,c,d,e,f)



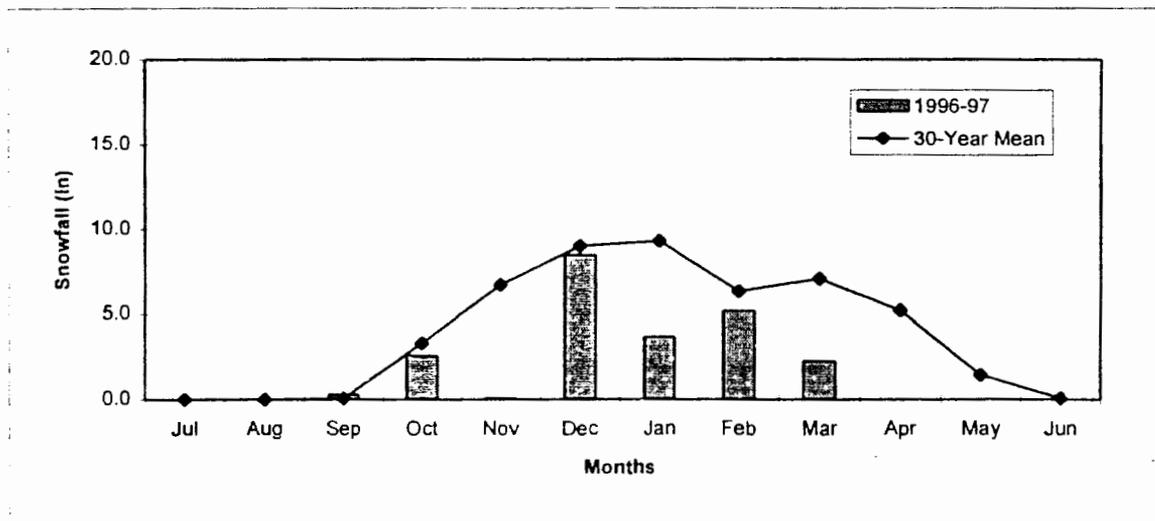
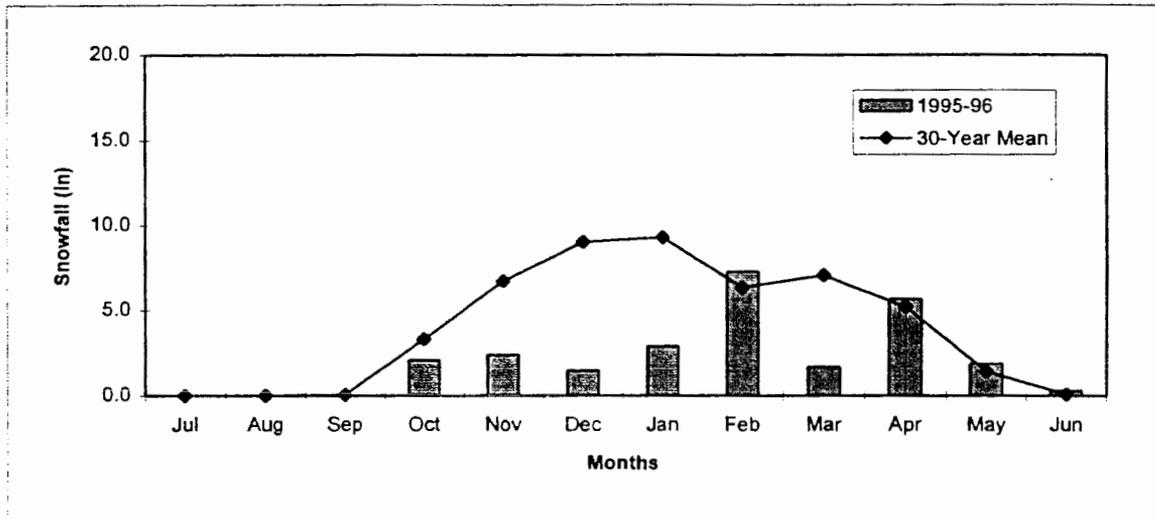
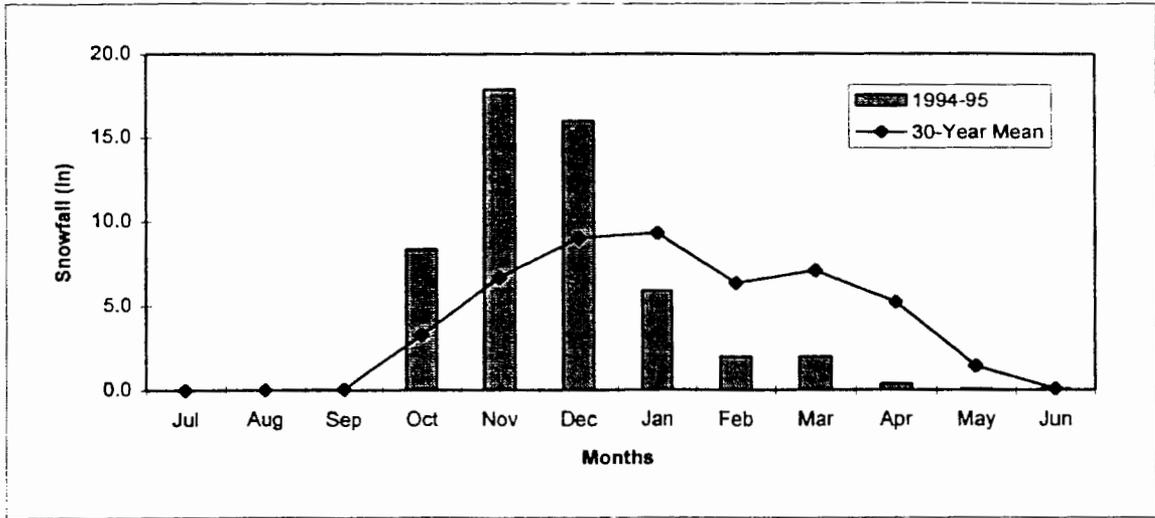
Appendix G.7. Comparison of monthly precipitation to the 30-year mean at King Salmon, July 1994 to June 1997.

Appendix G.8. Average monthly snowfall for King Salmon, July 1967 to June 1997.

Smolt Year	Snowfall (in) ^{a b}												Total Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
1967-68	0.0	0.0	0.0	1.2	4.1	3.5	9.3	5.3	7.5	16.0	2.2	0.0	49.1
1968-69	0.0	0.0	0.3	0.3	8.9	10.8	6.1	13.9	12.3	1.1	T	0.0	53.7
1969-70	0.0	0.0	0.0	T	16.1	1.5	11.1	4.6	6.4	5.5	T	0.0	45.2
1970-71	0.0	0.0	T	8.3	1.4	8.6	4.3	15.2	1.6	8.9	2.5	T	50.8
1971-72	0.0	0.0	0.0	7.9	3.9	15.1	11.7	2.1	1.9	8.7	0.1	1.3	52.7
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
Max	0.0	0.0	0.5	15.7	17.9	28.4	30.6	20.3	20.0	16.0	6.1	1.3	77.4
30-Year Mean	0.0	0.0	0.1	3.3	6.7	9.0	9.3	6.3	7.1	5.2	1.4	0.1	46.2
Min	0.0	0.0	0.0	0.1	0.1	1.5	2.1	0.2	1.1	0.4	0.0	0.0	19.8

^a Source - National Weather Service (1995; 1996; 1997a,b,c,d,e,f)

^b T = trace



Appendix G.9. Comparison of monthly snowfall to the 30-year mean at King Salmon, July 1994 to June 1997.

Appendix H.1. Timing and duration of Boreal smelt spawning in King Salmon Creek (Naknek River drainage), 1976-1997.

Year	Date of Break-up	Onset of Boreal Smelt Spawning	Day Julian	End of Boreal Smelt Spawning	Day Julian	Duration of Spawning (Days)	Remarks
1976	04/10	04/30	121				
1977	04/28						
1978							
1979							
1980	04/26						
1981							
1982							
1983							
1984	04/07						
1985	05/07						
1986	04/28	05/05	125				
1987	04/07						
1988	04/22						
1989	04/12	04/30	120				
1990	04/13	05/01	121				
1991	04/19						
1992	04/27	05/06	127	05/14	135	8	
1993	04/07	04/24	114	05/01	121	7	
1994	04/18	04/29	119	05/05	125	6	
1995	04/13	05/02	122	05/06	126	4	
1996	04/17	04/29	120	05/06	127	7	
1997	04/20	04/28	118	05/05	125	7	Stream temp = 44 °F at onset.
1976-1997 Min	04/07	04/24		05/01		4	
1976-1997 Avg	04/18	04/30		05/06		7	
1976-1997 Max	05/07	05/06		05/14		8	

Note: These observations were made by Richard Russell (ADF&G retired, King Salmon) from his house overlooking the creek...about 2 miles upstream from the King Salmon Creek mouth.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood, or disability. For information on alternative formats available for this and other department publications, contact the department ADA Coordinator at (voice) 907-465-4120, or (TDD) 907-465-3646. Any person who believes s/he has been discriminated against should write to: ADF&G, PO Box 25526, Juneau, AK 99802-5526; or O.E.O., U.S. Department of Interior, Washington, DC 20240.

