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Stock Assessment and Restoration of the Afognak Lake Sockeye Salmon Run

Final Report for Study 03-047

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Abstract: The Afognak Lake sockeye salmon *Oncorhynchus nerka* runs were extremely weak in 2001 and 2002. Spawning escapement goals to the system were not achieved, and the Afognak Bay subsistence fishery was closed in 2002. In response to poor runs and concerns of the local subsistence users, the Alaska Department of Fish and Game conducted a one year feasibility study during 2003, through the Fisheries Resource Monitoring Program, to estimate smolt abundance and determine biological characteristics and the timing of the emigration.

A total of 82,970 sockeye salmon smolts were captured using a floating incline plane trap and then a Canadian fan trap operated from 12 May to 3 July 2003. Using mark-recapture techniques and a variation of the stratified Peterson estimator, we estimated that 564,793 sockeye salmon smolts (95% C.I. 374,814 - 754,772) emigrated from Afognak Lake in 2003. The emigration was composed of 373,513 age-1. and 191,279 age-2. smolts. Age-1. smolts had a mean weight of 4.1 g, mean length of 79.1 mm, and a mean condition factor of 0.82. Age-2. smolts had a mean weight of 4.2 g, a mean length of 81.4 mm, and a mean condition factor of 0.77. Age-2. smolts were most abundant during the first two weeks (12-25 May) of the emigration, whereas age-1. smolts were the predominant age class from 1 June to 3 July. Results demonstrated that mark-recapture techniques are a feasible method to estimate Afognak Lake sockeye salmon smolt abundance. Afognak Lake smolt age at emigration, size, and emigration timing in 2003 appear to be “typical” for this and other populations within this geographic region. Based on these data, lake rearing conditions have probably improved. Projected adult returns from the 2003 smolt emigration suggest that, beginning in 2005, runs should be larger than those experienced in 2001 and 2002.

Key words: Afognak Lake, Afognak Island, age, emigration, enumeration, escapement, Kodiak Island, *Oncorhynchus nerka*, smolt, sockeye salmon, subsistence harvest, trap.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

INTRODUCTION

Afognak Lake sockeye salmon *Oncorhynchus nerka* runs were weak in 2001 and 2002, and escapements failed to reach the sustainable escapement goal (SEG) range of 40,000 to 60,000 fish (Brennan 2001; Wadle 2001). As a result, the commercial salmon fishery in Afognak Bay was restricted in 2001 and closed throughout the 2002 season. Sport fishing was also restricted and on 13 June 2002, State and Federal managers closed subsistence fishing in Afognak Bay. The subsistence fishing closure, unprecedented in the Kodiak Management Area, remained in effect until 1 August, 2002, when subsistence salmon fishing was reopened to allow harvesting of pink *O. gorbuscha* and coho *O. kisutch* salmon.

The possibility of future subsistence closures in Afognak Bay was of great concern to local subsistence users and the Kodiak-Aleutian Islands Regional Advisory Council, Kodiak Fish and Game Advisory Committee, and Kodiak Tribal Council. They contended that continued closure of this system would not only make it more difficult for local residents to meet their subsistence needs but would also shift fishing pressure to the Buskin River and small sockeye salmon runs in Marmot Bay, Raspberry Straits and Ouzinkie Narrows. The Regional Advisory Council, Kodiak Advisory Committee, and Kodiak Tribal Council informed the Alaska Department of Fish and Game (ADF&G) and U.S. Fish and Wildlife Service (FWS) that the Afognak Lake sockeye salmon run failure constituted an emergency situation for their constituents. In response to this problem, the ADF&G received funding through the Office of Subsistence Management, Fisheries Resource Monitoring Program to assess the feasibility of estimating Afognak Lake sockeye salmon smolt production. This report provides the results of these efforts.

Objectives

The objectives of the project were to 1) estimate the number of sockeye salmon smolts by age emigrating from Afognak Lake in 2003; 2) determine the average weight, length, and condition factor of the smolts; and 3) estimate the timing by age class of the sockeye salmon smolt emigration from Afognak Lake in 2003.

Background

Afognak Lake has historically provided sockeye salmon for the largest subsistence fishery on Afognak Island and the second largest subsistence fishery in the Kodiak Archipelago. Local villagers from Port Lions and Ouzinkie, and Kodiak area residents harvest sockeye salmon returning to Afognak Lake (Figure 1). The subsistence fishery occurs entirely within the Alaska Maritime Wildlife Refuge. Subsistence harvests in Afognak Bay have ranged from 1,279 (2002) to 12,412 (1997) sockeye salmon from 1990 through 2002 (Table 1). Subsistence harvest effort has ranged from 120 (1998) to 376 (1996) participants during this time period.

The ADF&G has operated a salmon counting weir on the Afognak River annually since 1978 (Brodie 2001). Weir counts along with catch data (commercial, subsistence, and sport) have provided managers with an estimate of adult sockeye salmon production, but little information on juvenile production has been collected.

Freshwater production in sockeye salmon systems throughout Alaska has been evaluated by enumerating sockeye salmon smolts emigrating from lakes to the ocean, and by measuring primary and secondary production in the lakes in which they rear (Koenings et al. 1987). In the past, evaluation and monitoring projects on juvenile sockeye salmon production in Kodiak area systems have provided data for evaluating the possible effects of overescapement into Akalura, Frazer and Red Lakes (Kyle et al. 1988; Barrett et al. 1993a,b; Coggins 1997; Coggins and Sagalkin 1999; Sagalkin 1999). Smolt abundance estimates were also included as part of lake rehabilitation projects at Malina and Karluk Lakes (Kyle and Honnold 1991; Schrof and Honnold 2003). These studies estimated smolt abundance and size by age using trapping and mark-recapture techniques.

Currently, annual juvenile production data are collected from five sockeye salmon systems in the Kodiak archipelago and on the Alaska Peninsula (ADF&G 2003; Schrof and Honnold 2003). Recently, Sagalkin and Honnold (2003) assessed potential sources of error in the estimates generated from a smolt enumeration project employing mark-recapture methods. Sources of error were investigated relating to mortality caused by marking, handling, and trapping. Bias in the trapping system associated with smolt size and behavior were also examined. These sources of error were judged to be negligible.

Description of Study Area

The Afognak Lake system is located on the southeast side of Afognak Island approximately 50 km northwest of the city of Kodiak (Figure 1). Afognak Native Corporation owns the land surrounding the system, but most subsistence fishing occurs in Afognak Bay, which is part of the Alaska Maritime National Wildlife Refuge. Afognak Lake (58^o 07' N, 152^o 55' W) lies about 21 m above sea level, is 8.8 km long, up to 0.8 km wide at its widest point, and has a surface area of 5.3 km^2 (White et al. 1990; Schrof et al. 2000). The lake has a mean depth of 8.6 m, a maximum depth of 23.0 m, and a lake-water residence time of 0.4 years. Runoff from Afognak Lake flows in an easterly direction via the 3.2 km Afognak River, emptying into Afognak Bay

In addition to sockeye salmon, resident fish in the Afognak Lake drainage include pink salmon, coho salmon, rainbow trout (anadromous and non-anadromous) *O. mykiss*, Dolly Varden char *Salvelinus malma*, three spine stickleback *Gasterosteus aculeatus*, and freshwater sculpin *Cottus aleuticus* (White et al. 1990). Chinook *O. tshawytscha* and chum *O. keta* salmon have also been observed in the Afognak River on occasion, but do not represent viable populations (White et. al 1990).

METHODS

Trap Deployment and Assembly

A floating incline plane trap (Todd 1994) was installed on 12 May, approximately 32 m upstream from the confluence of the Afognak River and Afognak Bay. The incline plane trap was positioned in the middle of the river, where water velocity was sufficient to minimize fish avoidance. Although trapping conditions were adequate when this trap was installed, stream flow and water levels gradually dropped over the next two weeks. The low stream flow conditions decreased both the volume and velocity of water entering the trap, which allowed smolts to more easily avoid capture. Consequently, the floating trap was removed on 25 May and replaced with a Canadian fan trap (Ginetz 1977). This type of trap performs better under low stream flow conditions because it rests directly on the river bottom. A live box (1.2 m x 1.2 m x 0.5 m) was attached to the cod end of the trap and the entire trapping device was suspended by cable attached to a come-along and secured to an aluminum pipe frame to allow for adjustments based on water level fluctuations. Perforated (3.2 mm) aluminum sheeting (1.2 m x 2.4 m), supported by a rackmaster-type pipe frame, were placed at the entrance of the trap in a “V” configuration to divert smolts into the live box. The wings were lined with plastic sheeting during low water conditions to increase the volume and velocity of water entering the trap. Once smolt abundance declined and the number captured was less than 100 per day for three consecutive days, trapping ceased and the trapping device was removed from the river. Detailed methods for trap installation, operation, and maintenance are described in ADF&G (2003).

Smolt Enumeration

Smolts were captured in the trapping system and held in an attached live box until they were counted. During the evening (2200 to 0800 hours), the live box was checked every one to two hours depending on smolt abundance. During the day (0801 to 2159 hours), the live box was checked every three to four hours. Smolts were removed from the live box with a dip net, counted, and either released downstream of the trap or moved to an in-stream holding box for sampling. Species identification was made by visual examination of external characteristics (Pollard et al. 1997). All data, including mortalities, were entered on a reporting form each time the trap was checked.

Age, Weight, and Length Sampling

A total of 200 sockeye salmon smolts were sampled each statistical week to obtain age, weight, and length (AWL) data. To reach the weekly total, daily samples of 40 sockeye salmon smolts was collected for five days within each statistical week. Smolts were collected hourly during the night and held in the in-stream live box. The number of smolts collected each hour was proportional to emigration abundance. Forty smolts were randomly collected from those retained in the live box and sampled to obtain daily AWL data. After sampling, all smolts were released downstream from the trap. Sampling was discontinued when smolt abundance declined to levels where less than 100 sockeye salmon smolts were captured per day for two consecutive days.

Tricaine methanesulfonate (MS-222) was used to anesthetize smolts prior to sampling. Fork lengths (FL) were measured to the nearest 1 mm, and weights were recorded to the nearest 0.1 g. Scales were removed from the preferred area (INPFC 1963) and mounted on a microscope slide for age determination. After sampling, smolts were held in aerated water until they recovered from the anesthetic, and subsequently released downstream from the trap. Age was estimated from scales using a microfiche reader (EYECOM 3000) under 60X magnification, and recorded in European notation (Koo 1962).

Condition factor (Bagenal and Tesch 1978), a quantitative measure of "fatness," was determined for each smolt as:

$$K = \frac{W}{L^3}10^5 \qquad (1)$$

where,

K	=	the smolt condition factor;
W	=	weight in g;
L	=	FL in mm.

Trap Efficiency and Population Estimates

Mark-recapture experiments were performed to measure smolt trap efficiency. Sockeye salmon smolts were marked (dyed) and released once per week and also when changes were made to the trapping system. Based on smolt studies at Akalura Lake (Coggins and Sagalkin 1999; Sagalkin and Honnold 2003), we targeted a trap efficiency of between 15 to 20%. Using a relationship between the trap efficiency (%) and relative error (*r)* (Robson and Regier 1964; Carlsen et al. 1998), where *r* is 25%, we calculated a minimum of 300-500 marked smolts should be released to achieve the *r*. Smolts were held in a holding box until the desired number was obtained for the dye test. Smolts were captured and held up to two nights to achieve the desired number. When the desired number was collected, smolts were placed in an aerated 33-gallon water filled trashcan and transported, in a trailer pulled by an all terrain vehicle, to the release site approximately 1,240 m upstream. At this site, smolts were placed in a second holding box in the river to recover from transport. After a recovery period of 3 to 4 hours in the holding box, smolts were transferred, using a dip net, into a trashcan containing 2.5 g of Bismark Brown Y dye, and 20 gallons of continuously oxygenated water. Smolts were held in the dye solution for 30 minutes and then returned to the holding box to recover for a minimum of 1 hour.

Between 2100-2300 hours, dyed sockeye salmon smolts were counted and released across the width of the stream. Dyed smolts that displayed unusual behavior were not released. All marked smolt recaptured at the trap site were counted and assigned to a dye test period (hereafter referred to as a stratum).

Trap efficiency for each stratum (*h*) was calculated by dividing the total number of dyed smolt recaptured by the number of dyed smolt released within the stratum:

$$u = \frac{m_h}{M_h} \tag{2}$$

where,

u	=	exploitation rate of the smolt population;
M_h	=	number of marked smolts released in stratum *h;*
m_h	=	number of marked smolts recaptured in stratum *h*.

A modification of the stratified Peterson estimator (Carlson et al. 1998) was used to estimate the number of smolts emigrating within each stratum:

$$\hat{U}_h = \frac{u_h (M_h + 1)}{m_h + 1} \tag{3}$$

where,

U_h	=	total number of smolts in stratum *h*, minus observed mortality;
u_h	=	number of unmarked smolt recaptured in stratum *h;*

Variance of the exploitation rate estimate was calculated as:

$$v\left(\hat{U}_h\right) = \frac{(M_h + 1)(U_h + m_h + 1)(M_h - m_h)U_h}{(m_h + 1)^2 (m_h + 2)} \tag{4}$$

Smolt AWL samples for each stratum were used to estimate the number and size of smolt within each age class. The percentage for each age class was multiplied by the smolt estimate in each stratum to determine the emigration by age by stratum. The smolts in each age class in each stratum were then summed to provide a total estimate by age. The 2003 sockeye salmon smolt population estimate was the sum of individual stratum estimates.

RESULTS

Smolt Enumeration and Sampling

Smolt trapping was conducted a total of 53 days from 12 May to 3 July 2003. During this period, 82,970 sockeye salmon smolts were captured (Table 2). The greatest daily sockeye salmon smolt catch was obtained 6 June when 6,674 smolts were captured (Table 2, Figure 2). Large daily catches were also obtained 2 June (5,115), 5 June (5,836), and 12 June (5,689).

Age, Weight, and Length Sampling

Of the 1,416 sockeye salmon smolts sampled for AWL data, 1,414 smolts were assigned ages (Table 3). Age-2. smolts represented the greatest proportion of the population (79% or more) during the first two weeks (12-25 May) of the emigration, age-1. smolts (52.5%) and age-2. smolts (47.5%) were represented almost equally during the third week of the emigration (26-31 May), and age-1. smolts were the dominant age class (87% or more) for the remainder of the emigration (Figure 3).

Age-1. smolts sampled had a mean weight of 4.1 g (range - 3.1 g to 5.1 g), a mean length of 79.1 mm (range - 74.5 mm to 83.3 mm), and a mean condition factor of 0.82 (range - 0.72 to 0.88; Table 4). Age-2. smolts had a mean weight of 4.2 g (range - 3.8 g to 9.9 g), a mean length of 81.4 mm (range - 78.7 mm to 104.0 mm), and a mean condition factor of 0.77 (range - 0.77 to 0.88).

Trap Efficiency and Population Estimates

Seven mark-recapture experiments were conducted during the sockeye salmon smolt emigration period (Table 2). Trap efficiencies ranged from 2.1% for the first experiment (20 to 25 May) to 37.5% for the fourth experiment (8 to 10 June). Mean trap efficiency for all seven experiments was 19.9%.

The total number of sockeye salmon smolts emigrating from the Afognak Lake system in 2003 was estimated to be 564,793 (95% C.I. 374,814 - 754,772; Table 5). The emigration was composed of 373,513 age-1. (66.1%) and 191,279 age-2. (33.9%) smolts (Table 6).

DISCUSSION

Initial attempts to estimate smolt emigrations from Afognak Lake occurred in 1990 and 1991 (Schrof and Honnold 2003). Smolt estimates obtained for these years, using methods similar to those for 2003, were substantially lower (approximately 50,000 in 1990 and 197,000 in 1991) than the estimate obtained for 2003 (565,000). Assuming returns at the average age of adults sampled from spawning escapements during 1987 to 2002 (Appendix A), most adults resulting from the 1990 and 1991 smolt emigrations returned during 1992 to1994. Total runs during 1992 to1994 ranged from about 78,000 (1993) to 102,000 (1994) adult sockeye salmon (Table 1). Since smolt-to-adult survivals are often about 10% (Koenings et al. 1993) and sometimes reach 25-30% (Honnold 1997), it is apparent that smolt abundance in 1990 and 1991 was grossly underestimated.

The low population estimates in 1990 and 1991 were likely due to poor trap placement and water conditions, which probably allowed many smolts to avoid capture (G. Watchers, Alaska Department of Fish and Game, Kodiak, personal communication). Unlike 1990 and 1991, in 2003 the trap was operated in a more mid-stream position to increase water level and flow into the trap. Additionally, replacement of the incline plane trap with a Canadian fan trap substantially increased daily smolt catches and improved trap efficiency from 2.1% to over 20% for most dye test periods (Table 2). These results indicated that a Canadian fan trap was the appropriate trapping device for conditions in the Afognak River. We feel that the use of this trap will allow us to obtain accurate smolt abundance estimates for this system.

The 2003 smolt estimate seems reasonable based on the expected number of smolts that would have been produced by the 2000 and 2001 escapements. Assuming a 50:50 sex ratio, a fecundity of 2,500 eggs per female (Roelofs 1964), and an average potential egg deposition to emergent fry survival of 7% (average of Drucker 1970 and Koenings and Kyle 1997), approximately 4.8 million spring fry should have resulted from the escapement of 54,000 adults in 2000. Assuming a 21% spring fry-to-smolt survival (Koenings and Kyle 1997) would have resulted in production of about 1 million smolts. Similarly, approximately 2.1 million spring fry and 400 thousand smolts would have resulted from the escapement of 24,000 adults in 2001. Apportioning these smolt estimates by average age (66% age-1. and 33% age-2.) would have resulted in migrations of 264 thousand age-1. smolts (brood year 2001) and 330 thousand age-2. smolts (brood year 2000) in 2003. Thus, approximately 594 thousand smolts would have been expected to migrate from the system in 2003. This is very similar to our 2003 mark-recapture estimate of 565 thousand smolt.

The 2003 emigration was dominated by age-1. smolts (66%) with a smaller component of age-2. smolts (34%). This trend was also seen in the 1990 and 1991 emigrations, although age-1. smolts were even more predominant than in 2003. However, the 1990 and 1991 estimates were likely biased toward smaller, younger fish due to the less than optimal trap placement, which enabled the larger, older smolts to avoid the trap (Sagalkin and Honnold 2003). The continued preponderance of age-1. smolts in 2003 is encouraging, as larger emigrations of younger fish typically indicate favorable freshwater conditions or that rearing numbers are not exceeding the carrying capacity of the system; the extension of freshwater residence in sockeye salmon suggests decreased lake productivity or that the carrying capacity of the system is being taxed (Barnaby 1944; Krokhin 1957; Burgner 1964; Foerster 1968; Koenings et al. 1993). When the juvenile population begins to exceed the rearing capacity of a system, they generally must spend two or more years in freshwater before growing large enough to transform into smolt. An example of this is the recent decline in sockeye salmon productivity documented for Ayakulik River on Kodiak Island. The proportion of adult freshwater age-1. sockeye salmon returning to this system has declined since 1985, while the proportion of freshwater age-2. adults has increased (Foster and Witteveen 2003; Witteveen et al *in press*). Moreover, as the proportion of freshwater age-1. sockeye salmon in the run has declined, overall run size has also declined. While most smolts emigrating from Afognak Lake were age-1. in 2003, a third of the emigration was composed of age-2. smolts, which may imply less than optimal freshwater rearing conditions. However, since the average proportion of age-1. adults in escapements (1987 to 2002 was 66%; Appendix A) is similar to the proportion of age-1. smolts emigrating in 2003, the 2003 smolt emigration may indicate a return to more typical rearing conditions for this system. Conversely, the adults that returned during 2000 to 2002 may have experienced poorer freshwater rearing conditions since the average proportion of age-1. adults in these escapement was only 31%.

Another indication of improved Afognak Lake system productivity is the magnitude of the smolt emigration in 2003 and its potential for increased adult returns. Koenings et al. (1993) examined smolt to adult survival for sockeye salmon lakes throughout the northern Pacific Ocean region and found a latitude-dependent relation in which average survival from Alaska lake systems was 12%. This was the same smolt to adult survival value recently found for Frazer Lake sockeye salmon (Sagalkin *in press*). Afognak Lake sockeye salmon smolt to adult survival is likely lower than that for Frazer Lake since Afognak Lake smolts are smaller than those from Frazer Lake. If about 10% of Afognak Lake smolt emigrating from the system in 2003 survive to return as adults, a total of approximately 56,500 adult may return. If these returns occur at average observed ages of escapements, approximately 6,700 adults could return in 2004, 19,600 in 2005, and 29,700 in 2006. This suggests that beginning in 2005 runs may exceed the magnitude of those experienced in 2001 and 2002.

Age, weight, and length data for the 2003 smolt migration also suggest Afognak Lake rearing conditions were reasonably good (Table 4). Mean size and condition of age-1. smolts in 2003 (n=1,031;4.1 g, 79.1 mm,0.82 K) were greater than those determined from smolt samples in 1990 (n=544; 2.5 g, 69 mm, 0.76 K), 1991 (n=1,895; 3.1 g , 72.9 mm, 0.78 K) or in three more recent years (1992, 1993, 1995) with smaller sample sizes (n=>200<400; 2.7 g-3.8 g, 69 mm-77 mm, 0.78 K-0.82 K) (Appendix B; Schrof and Honnold 2003). Although historical smolt data may not be representative of the emigrations each year due to trapping bias, the improved growth and condition of smolt in 2003 implies that rearing conditions have improved. Age-2. smolt trends were similar to those for age-1. smolts.

Afognak Lake smolt emigration timing in 2003 was similar to that observed for other systems on Afognak Island. For example, peak smolt emigrations from the Malina Lakes system mainly occurred from 24 May to 6 June (1992, 1997-2001; Appendix C), while Little Kitoi Lake smolt counts were greatest from 23 May to 13 June (1995-2001; Appendix D). Daily smolt trap catches were fairly constant throughout the emigrations from Afognak Lake in 1990 and 1991, except for increased daily counts on 24 and 25 May, when two-day total counts of 444 (1990) and 1,755

(1991) were obtained (Schrof and Honnold 2003). The 2003 emigration increased on 25 May and daily counts remained fairly constant until 19 June, when counts declined (Figure 2). Peak daily counts from the 2003 estimate occurred on 5 and 6 June. As has been documented for other systems (Barnaby 1944; Krogius and Krokhin 1948; Burgner 1962), older and larger smolts tended to migrate earlier from the Afognak Lake system.

CONCLUSIONS

1. A Canadian fan trap was found to be the appropriate smolt capture device for conditions in the Afognak River.

2. Mark-recapture techniques are a feasible method to estimate the number of sockeye salmon smolt emigrating from Afognak Lake.

3. Age, size, and emigration timing in 2003 suggest that this was a “typical” sockeye salmon population and that lake rearing conditions are improving or stabilizing.

4. Based on the 2003 smolt estimate, projected adult runs beginning in 2005 should exceed the magnitude of the runs in 2001 and 2002.

RECOMMENDATIONS

1. We have a high level of confidence in our ability to accurately estimate smolt abundance, age, and size for Afognak Lake system, and strongly feel the smolt project should be continued on an annual basis.

2. Project operations should be expanded to include measurements of primary and secondary production (limnology) that may affect smolt production in Afognak Lake. This will require increased funding.

3. To improve the precision of smolt estimates, assumptions on catchability of marked fish and delayed mortality of marked fish should be examined and tested.

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LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 2003. Salmon research operational plans for the Kodiak area, 2003. Alaska Dept. of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-31, Kodiak.

Bagenal, T.B., and F.W. Tesch. 1978. Age and growth. pp. 101-136 *in*: T. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3, third edition. Blackwell Scientific Publications. London.

Barnaby, J. T. 1944. Fluctuations in abundance of red salmon *Oncorhynchus nerka* (Walbaum) in Karluk Lake, Alaska. U.S. Fish Wildlife Service Fishery Bulletin 39: 235-295. Technical Bulletin Number 154. Department of Natural Resources, Madison.

Barrett, B.M., P.A. Nelson, and C.O. Swanton. 1993a. Sockeye salmon *Oncorhynchus nerka* smolt investigations at Red, Akalura, and Upper Station Lakes conducted in response to the 1989 M/V Exxon Valdez Oil Spill, 1990-1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K93-1, Kodiak.

Barrett, B.M., C.O. Swanton and P.A. Nelson. 1993b. Sockeye Salmon Smolt Abundance, Timing, and Growth Characteristics for Red, Akalura, Upper Station, and Frazer Lakes, 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K93-32, Kodiak.

Brennan, K. 2001. Kodiak Management Area commercial salmon annual management report, 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-62, Kodiak.

Brodie, J.R. 2001. Kodiak Management Area salmon escapement cumulative counts for fish-weirs, 1991-2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-9, Kodiak.

Burgner, R. L. 1962. Studies of red salmon smolts from the Wood River Lakes, Alaska, p 247-314 In: T.S.Y. Koo (ed.) Studies of Alaska Red Salmon. University of Washington Publications in Fisheries. New Series 1.

Burgner, R. L. 1964. Factors influencing production of sockeye salmon (Oncorhynchus nerka) in lakes of southwestern Alaska. Int. Ver. Theor. Angew. Limnol. Verh. 15:504-513.

Carlson, S.R., L.G. Coggins Jr., C.O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fisheries Research Bulletin 5:88-102.

Coggins Jr., L.G. 1997. Summary Data from the 1996 Sockeye Salmon Smolt Investigations at Red, Akalura, and Frazer Lakes. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K97-50, Kodiak.

Coggins Jr., L.G. and N.H. Sagalkin. 1999. Akalura Lake sockeye salmon restoration. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K99-64, Kodiak.

Drucker, B. 1970. Red salmon studies at Karluk Lake, 1968. U.S. Bureau of Commercial Fisheries, Auke Bay Biological Laboratory Administrative Report 55p.

Foerster, R. E. 1968. The Sockeye Salmon, *Oncorhynchus nerka*. Bulletin of the Fisheries Research Board of Canada. 162:422 p.

Foster, M.B. and M.J. Witteveen. 2003. Kodiak Management Area salmon escapement and catch sampling results, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-43, Kodiak.

Ginetz, R.M.J. 1977. A review of the Babine Lake development project 1961-1976. Environment Canada. Fish and Marine Services Technical Report Service Number Pac-T-77-6, 192 p.

Honnold, S.G. and S.T. Schrof. 2001. A summary of salmon enhancement and restoration in the Kodiak Management Area through 2001: a report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-65, Kodiak.

Honnold, S.G. 1997. The results of sockeye salmon *Oncorhynchus nerka* stocking into Spiridon Lake on the Kodiak National Wildlife Refuge: juvenile and adult production, commercial harvest, and ecosystem effects, 1987-1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K97-47, Kodiak.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, British Columbia.

Koenings, J.P., and G.B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fishery Research Bulletin 4(2): 120-135.

Koenings, J.P., H. Geiger, and J. Hasbrouck. 1993. Smolt-to-adult survival patterns of sockeye salmon: effects of length and latitude after entering sea. Canadian Journal of Fisheries and Aquatic Sciences 50:600-611.

Koenings, J.P., J.A. Edmundson, G.B. Kyle, and J.M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series 71, Juneau.

Koo, T.S.Y. 1962 Age designation in salmon. Pages 37-48 in T.S.Y. Koo, editor. Studies of Alaska red salmon. University of Washington Publications in Fisheries, New Series, Volume I, Seattle.

Krokhin, E. M. 1957. Determination of the daily food ration of young sockeye and three-spined stickleback by the respiration method. Izvestiia TINRO, 44: 97-110. [FRB Translation No. 209].

Krogius, F.V. and E.M. Krokhin. 1948. On the production of young sockeye salmon (Oncorhynchus nerka Walb.). Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 28:3-27. (Translation from Russian; Fisheries Research Board of Canada Translation Series 109).

Kyle, G.B. and S.G. Honnold. 1991. Limnological and fisheries evaluation of sockeye salmon production *Oncorhynchus nerka* in Malina Lakes for fisheries development. Alaska Department of Fish and Game, Regional Information Report 110, Kodiak.

Kyle, G.B., J.P. Koenings, and B.M. Barrett. 1988. Density-dependent, trophic level responses to an introduced run of sockeye salmon (*Oncorhynchus nerka*) at Frazer Lake, Kodiak Island, Alaska. Canadian Journal Fisheries and Aquatic Sciences. 45:1-12.

Pollard, W.R., C.F. Hartman, C. Groot, and P. Edgell. 1997. Field Identification of Coastal Juvenile Salmonids. Harbour Publishing. Maderia Park, British Cloumbia, Canada. 31p.

Robson, D.S., and H.A. Regier. 1964. Sample size in Peterson mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

Roelofs, E.W. 1964. Further studies of the Afognak Lake system. Alaska Department of Fish and Game. Informational Leaflet No. 41. 18 p.

Sagalkin, N. H. *In press*. A sockeye salmon escapement goal evaluation for Frazer Lake. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-xx, Kodiak.

Sagalkin, N. 1999. Frazer Lake fish pass sockeye salmon smolt and adult research, 1997 and 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K99-59, Kodiak.

LITERATURE CITED (Continued)

Sagalkin, N.H. and S.G. Honnold. 2003. Evaluation of sockeye salmon smolt population estimate bias from single-site mark recapture experiments. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report 4K03-40, Kodiak.

Schrof, S.T. and S.G. Honnold. 2003. Salmon enhancement, rehabilitation, evaluation, and monitoring efforts conducted in the Kodiak management area through 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-41, Kodiak.

Schrof, S.T., S.G. Honnold, C.J. Hicks and J.A. Wadle. 2000. A summary of salmon enhancement, rehabilitation, evaluation, and monitoring efforts conducted in the Kodiak management area through 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K00-57, Kodiak.

Todd, G.L. 1994. A lightweight inclined-plane trap for sampling smolt in rivers. Alaska Department of Fish and Game. Alaska Fishery Research Bulletin 1(2):179-186.

Wadle, J.A. 2001. Kodiak management area commercial salmon annual management report, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-40, Kodiak.

White, L. E., G. B. Kyle, S. G. Honnold, and J. P. Koenings. 1990. Limnological and fisheries assessment of sockeye salmon (*Oncorhynchus nerka)* production in Afognak Lake. Alaska Department of Fish and Game. FRED Division Report 103, Juneau.

Witteveen, M.J., M. B. Foster, N. S. Sagalkin, K. A. Bouwens, S. T., Schrof, and R. T. Baer. *In press*. Westward Region Salmon Reconstruction for the 2003 Season and Forecasting for the 2004 Season. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-xx, Kodiak.

Table 1. Afognak Lake sockeye salmon escapements, harvests, and total run estimates, 1990-2002.

		Harvest				
Year	Escapement	Commercial[a]	Subsistence[b]	Sport[c]	Total	Total Run
1990	90,666	22,149	4,469	524	27,142	117,808
1991	88,557	47,237	5,899	524	53,660	142,217
1992	77,260	2,196	4,638	600	7,434	84,694
1993	71,460	1,848	4,580	524	6,952	78,412
1994	80,570	17,362	3,329	524	21,215	101,785
1995	100,131	67,665	4,390	524	72,579	172,710
1996	101,718	106,141	11,023	258	117,422	219,140
1997	132,050	10,409	12,412	535	23,356	155,406
1998	66,869	26,060	4,690	718	31,468	98,337
1999	95,361	34,420	5,628	237	40,285	135,646
2000	54,064	14,124	7,572	364	22,060	76,124
2001	24,271	0	4,720	169	4,889	29,160
2002	19,520	0	1,279	41	1,320	20,840

[a] Statistical fishing section 252-34 (Afognak Bay).

[b] Data from ADF&G subsistence catch database.

[c] Data from ADF&G Sport Fish Division statewide harvest survey (SWHS) for 1992, 1996-2002; SWHS data for other years did not have enough respondents to provide reliable estimates. Four years with reliable data were averaged and entered for years with no data.

Table 2. Sockeye salmon smolt counts, number of samples collected, mark-recapture counts, and trap efficiency ratios from trapping at Afognak River, 2003.

	Catch		Dye Test Period	AWL Sample	Number Marked	Marked Recoveries		Trap Efficiency
Date	Daily	Cumulative	Cumulative	Cumulative	Releases	Daily	Cumulative	(%)
12-May	49	49						
13-May	22	71						
14-May	14	85						
15-May	37	122		34				
16-May	377	499		74				
17-May	138	637		114				
18-May	421	1,058						
19-May	329	1,387	1,387	154				
20-May	271	1,658		194	239	0	0	
21-May	129	1,787		234		3	3	
22-May	223	2,010		274		2	5	
23-May	657	2,667		314		0	5	
24-May	55	2,722				0	5	
25-May	1,577	4,299	2,912	354		0	5	2.1%
26-May	1,984	6,283		394	706	1	1	
27-May	902	7,185		434		37	38	
28-May	1,607	8,792		474		58	96	
29-May	1,942	10,734		514		32	128	
30-May	1,632	12,366				17	145	
31-May	3,899	16,265	11,966			16	161	22.8%
1-Jun	2,597	18,862		554	638	9	9	
2-Jun	5,115	23,977		576		75	84	
3-Jun	4,592	28,569		616		28	112	
4-Jun	2,369	30,938		656		8	120	
5-Jun	5,836	36,774		696		9	129	
6-Jun	6,674	43,448		736		4	133	
7-Jun	4,175	47,623	31,358			0	133	20.8%
8-Jun	3,142	50,765		776	686	49	49	
9-Jun	4,297	55,062		816		155	204	
10-Jun	3,714	58,776	11,153	856		53	257	37.5%
11-Jun	3,476	62,252		896	679	49	49	
12-Jun	5,689	67,941		936		51	100	
13-Jun	2,063	70,004				2	102	
14-Jun	2,297	72,301				1	103	
15-Jun	2,813	75,114		976		0	103	
16-Jun	1,170	76,284		1,016		0	103	
17-Jun	635	76,919		1,056		0	103	
18-Jun	553	77,472	18,696	1,056		0	103	15.2%

-Continued-

Table 2. (page 2 of 2)

Date	Catch Daily	Catch Cumulative	Dye Test Period Cumulative	AWL Sample Cumulative	Number Marked Releases	Marked Recoveries Daily	Marked Recoveries Cumulative	Trap Efficiency (%)
19-Jun	3,095	80,567		1,096	506	4	4	
20-Jun	404	80,971		1,136		40	44	
21-Jun	194	81,165		1,136		19	63	
22-Jun	238	81,403		1,176		12	75	
23-Jun	211	81,614		1,216		3	78	
24-Jun	338	81,952		1,256		1	79	
25-Jun	128	82,080				0	79	
26-Jun	154	82,234	4,762			0	79	15.6%
27-Jun	208	82,442		1,296	218	1	1	
28-Jun	176	82,618		1,336		8	9	
29-Jun	198	82,816		1,376		6	15	
30-Jun	71	82,887		1,416		2	17	
1-Jul	59	82,946				0	17	
2-Jul	23	82,969				0	17	
3-Jul	1	82,970	736			0	17	7.8%
					Average Trap Efficiency =			19.9%

Table 3. Estimated age composition of Afognak Lake sockeye salmon smolt sampled in each dye test period, 2003.

Stratum	Dye Test Period	Number Sampled		Age 1	Age 2	Age 3	Total
1	(5/12 - 5/19)	153	Numbers	12	141	0	153
			Percent	7.8	92.2	0.0	100.0
2	(5/20 - 5/25)	200	Numbers	33	127	0	160
			Percent	20.6	79.4	0.0	100.0
3	(5/26 - 5/31)	160	Numbers	84	76	0	160
			Percent	52.5	47.5	0.0	100.0
4	(6/1 - 6/7)	221	Numbers	192	29	0	221
			Percent	86.9	13.1	0.0	100.0
5	(6/8 - 6/10)	120	Numbers	115	5	0	120
			Percent	95.8	4.2	0.0	100.0
6	(6/11 - 6/18)	200	Numbers	197	3	0	200
			Percent	98.5	1.5	0.0	100.0
7	(6/19 - 6/26)	200	Numbers	199	1	0	200
			Percent	99.5	0.5	0.0	100.0
8	(6/27 - 7/3)	160	Numbers	199	1	0	200
			Percent	99.5	0.5	0.0	100.0
Total		1,414					

Table 4. Mean weight, length, and condition factor of Afognak Lake sockeye salmon smolt samples by age and statistical week, 2003.

			Weight (g)		Length (mm)		Condition (K)	
Age	Statistical Week	Sample Size	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
1	20	3	3.2	0.35	76.0	2.08	0.72	0.023
1	21	26	3.1	0.08	74.5	0.63	0.75	0.008
1	22	100	3.2	0.04	75.0	0.28	0.75	0.005
1	23	192	3.5	0.03	76.3	0.21	0.78	0.003
1	24	193	3.8	0.03	78.0	0.19	0.80	0.003
1	25	199	4.3	0.03	80.0	0.18	0.83	0.003
1	26	159	4.8	0.05	81.7	0.25	0.87	0.004
1	27	159	5.1	0.05	83.3	0.26	0.88	0.004
Total		1,031	4.1	0.03	79.1	0.12	0.82	0.002
2	20	30	4.0	0.11	80.2	0.71	0.77	0.012
2	21	214	4.2	0.05	81.6	0.28	0.77	0.004
2	22	100	4.2	0.08	81.2	0.48	0.77	0.006
2	23	29	4.2	0.12	81.3	0.70	0.77	0.009
2	24	7	3.8	0.17	78.7	1.27	0.78	0.013
2	25	1	3.9	0.00	79.0	0.00	0.79	0.000
2	26	1	4.7	0.00	83.0	0.00	0.82	0.000
2	27	1	9.9	0.00	104.0	0.00	0.88	0.000
Total		383	4.2	0.04	81.4	0.23	0.77	0.003

Table 5. Population estimate of the sockeye salmon smolt emigration from Afognak Lake, 2003.

Stratum (h)	Beginning Date	Ending Date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Estimate (U_h)	Variance var (U_h)	95% Confidence Interval lower	upper
1	5/12	5/19	1,387	239	5	55,480	4.31E+08	14,809	96,151
2	5/20	5/25	2,912	239	5	116,480	1.89E+09	31,188	201,772
3	5/26	5/31	11,966	706	161	52,222	1.31E+07	45,136	59,308
4	6/1	6/7	31,358	638	133	149,536	1.31E+08	127,063	172,008
5	6/8	6/10	11,153	686	257	29,698	2.18E+06	26,807	32,589
6	6/11	6/18	18,696	679	103	122,243	1.21E+08	100,663	143,823
7	6/19	6/26	4,762	506	79	30,179	9.63E+06	24,097	36,261
8	6/27	7/3	736	218	17	8,955	3.97E+06	5,050	12,859
Total						564,793	2.61E+09	374,814	754,772
						SE=	51,047		

Table 6. The Afognak Lake sockeye salmon smolt emigration estimate based on percents by age class and dye test period, 2003.

Stratum	Dye Test Period	Age 1.	Age 2.	Age 3.	Total
1	(5/12-5/19)	4,351	51,129	0	55,480
2	(5/20-5/25)	24,024	92,456	0	116,480
3	(5/26-5/31)	27,417	24,805	0	52,222
4	(6/1-6/7)	129,913	19,622	0	149,536
5	(6/8-6/10)	28,461	1,237	0	29,698
6	(6/11-6/18)	120,409	1,834	0	122,243
7	(6/19-6/26)	30,028	151	0	30,179
8	(6/27-7/3)	8,910	45	0	8,955
		373,513	191,279	0	564,793
		66.1%	33.9%	0.0%	100.0%

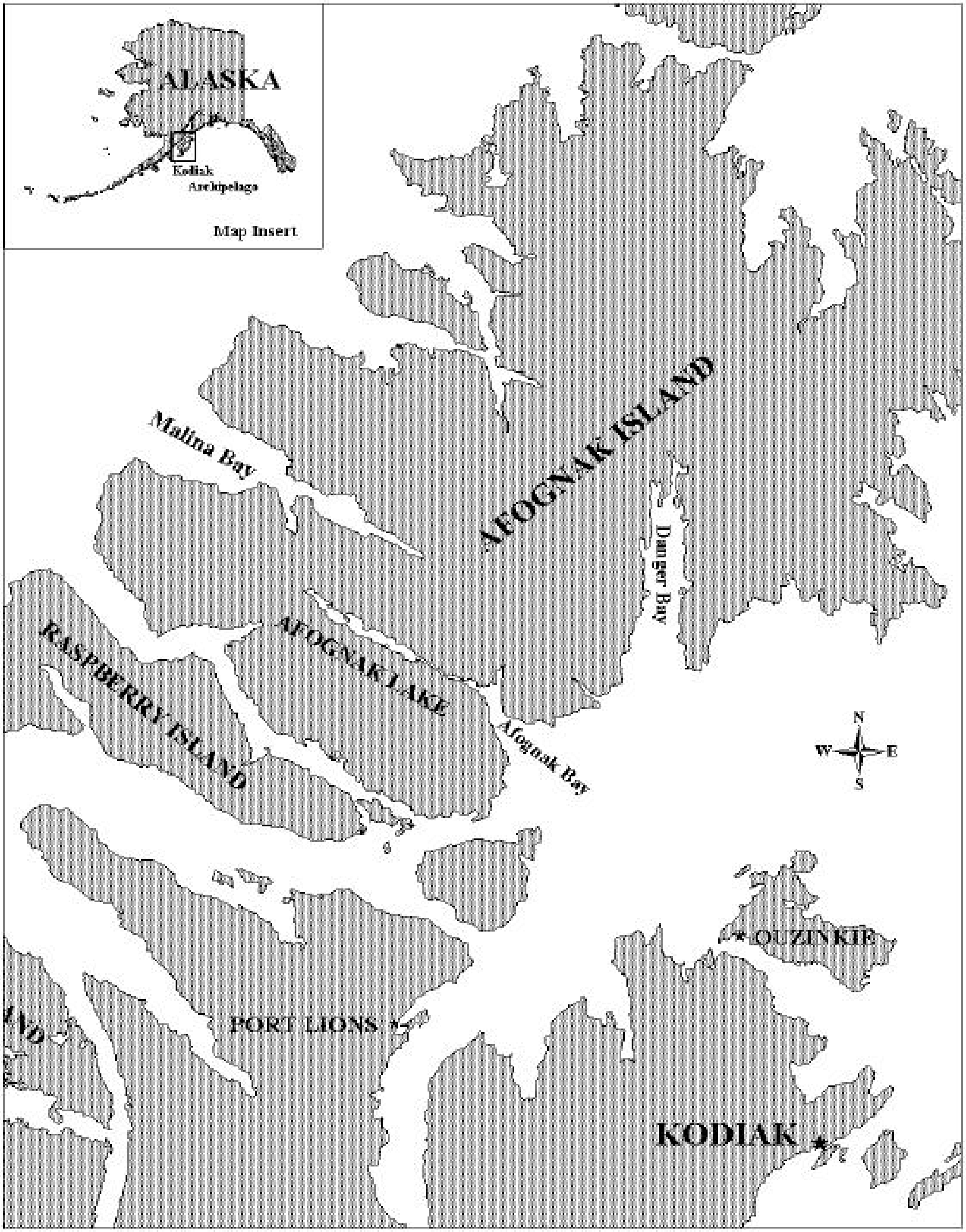


Figure 1. This map displays the locations of Kodiak City, and the villages of Port Lions, and Ouzinkie and their proximity to the Afognak Lake drainage on Afognak Island.

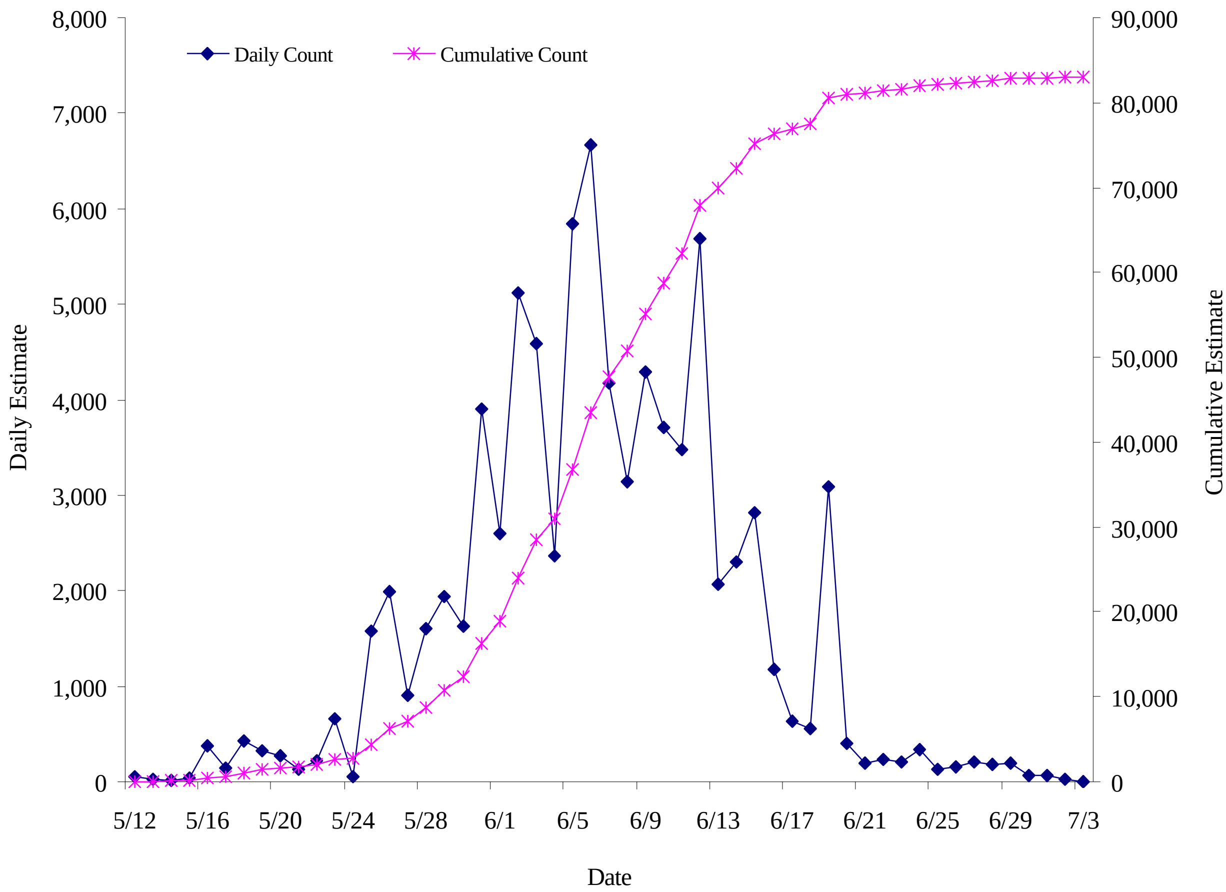


Figure 2. Daily and cumulative sockeye salmon smolt trap catch estimates by day from 12 May to 3 July in the Afognak River, 2003.

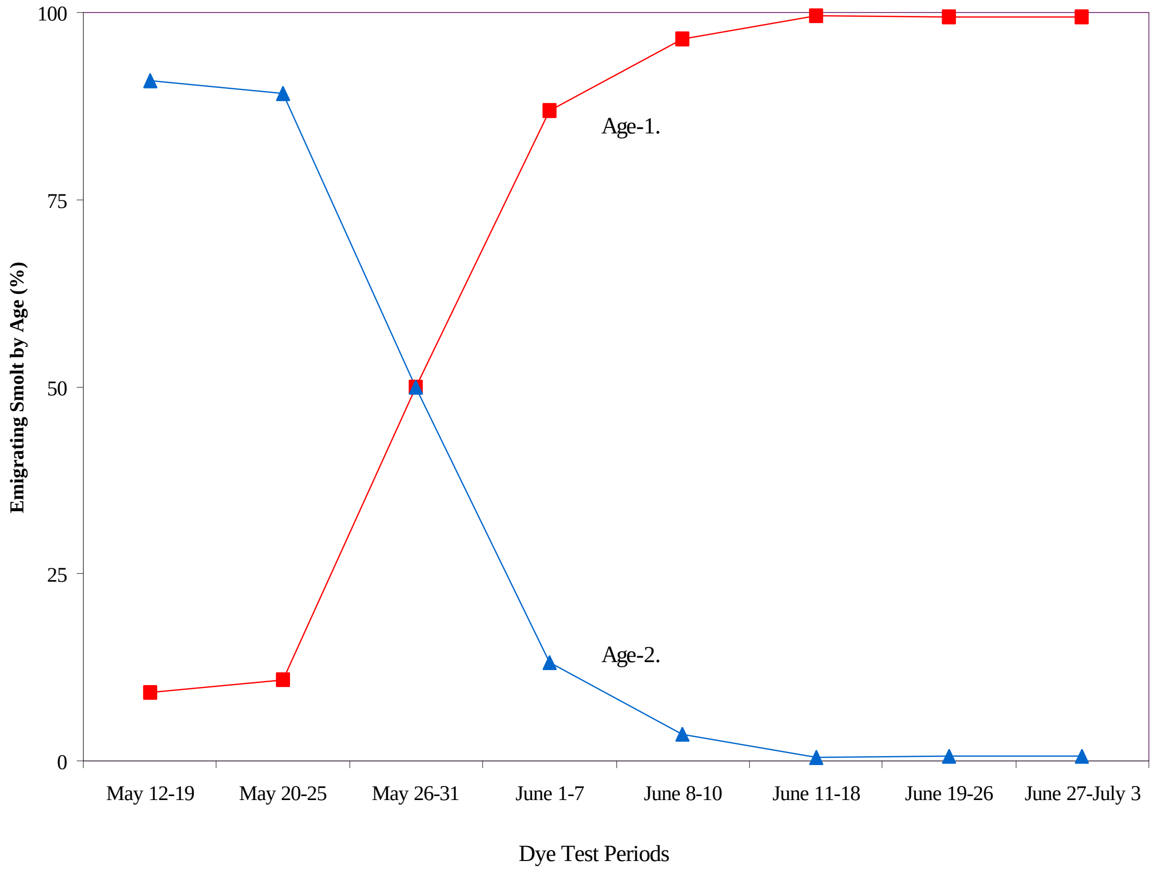


Figure 3. Afognak Lake sockeye salmon smolt emigration by age class and dye test period, 2003.

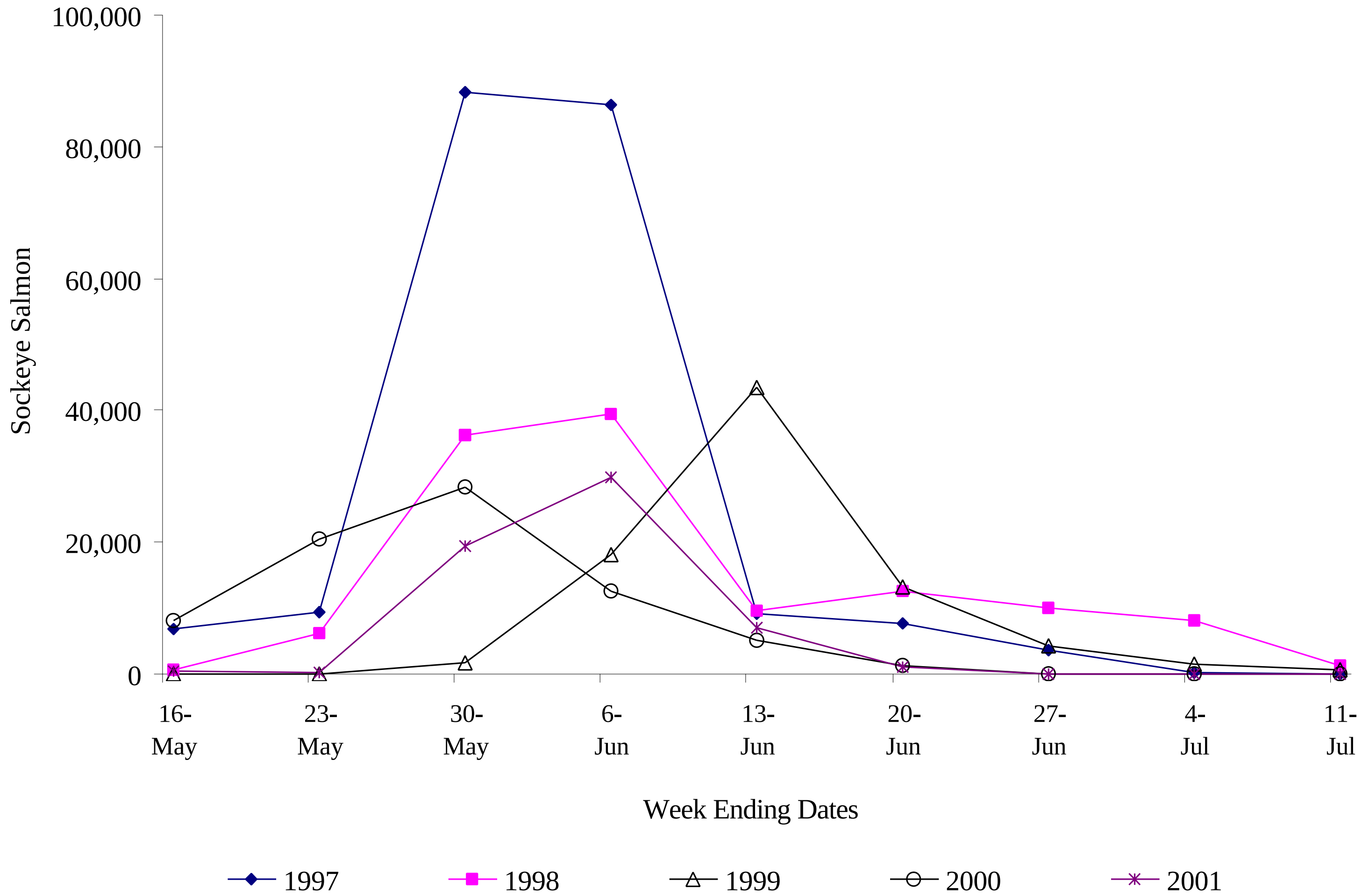
Appendix A. Estimated age composition of the Afognak Lake sockeye salmon escapement, 1987-2002.

Year	Sample Size		Ages 1.1	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2
1987	281	Numbers	1,695	9,797	284	9,609	1,131	0	0	3,863	0
		Percent	6.4	37.0	1.1	36.3	4.3	0.0	0.0	14.6	0.0
1988	933	Numbers	263	23,059	824	9,773	4,488	0	0	429	0
		Percent	0.7	59.1	2.1	25.1	11.5	0.0	0.0	1.1	0.0
1989	1,088	Numbers	13,288	13,404	3,135	35,165	16,314	0	0	7,519	0
		Percent	15.0	15.1	3.5	39.6	18.4	0.0	0.0	8.5	0.0
1990	1,053	Numbers	597	42,314	553	20,518	7,754	0	261	18,613	0
		Percent	0.7	46.7	0.6	22.6	8.6	0.0	0.3	20.5	0.0
1991	1,062	Numbers	295	13,054	196	67,805	3,101	0	0	4,106	0
		Percent	0.3	14.7	0.2	76.6	3.5	0.0	0.0	4.6	0.0
1992	1,025	Numbers	16,362	17,115	7,681	23,096	2,938	90	394	9,526	61
		Percent	21.2	22.2	9.9	29.9	3.8	0.1	0.5	12.3	0.0
1993	852	Numbers	11,837	7,634	12,318	21,667	8,818	53	0	8,965	163
		Percent	16.6	10.7	17.2	30.3	12.3	0.1	0.0	12.5	0.2
1994	840	Numbers	7,703	24,648	3,337	28,385	8,316	125	61	7,708	64
		Percent	9.6	30.6	4.1	35.2	10.3	0.2	0.1	9.6	0.1
1995	848	Numbers	2,281	21,788	837	56,367	10,773	0	149	7,776	0
		Percent	2.3	21.8	0.8	56.3	10.8	0.0	0.1	7.8	0.0
1996	1,119	Numbers	16,340	9,398	2,184	44,744	2,095	0	185	26,427	80
		Percent	16.0	9.2	2.1	44.0	2.1	0.0	0.2	26.0	0.1
1997	1,168	Numbers	5,234	29,004	7,330	47,888	2,351	0	41	14,840	0
		Percent	4.9	27.1	6.9	44.8	2.2	0.0	0.0	13.9	0.0
1998	1,240	Numbers	13,039	5,483	5,082	31,763	7,289	134	267	3,812	0
		Percent	19.5	8.2	7.6	47.5	10.9	0.2	0.4	5.7	0.0
1999[a]	1,195	Numbers	661	30,350	427	6,911	30,943	72	202	5,466	456
		Percent	0.9	40.2	0.6	9.1	41.0	0.1	0.3	7.2	0.6
2000	1,161	Numbers	887	1,276	171	8,302	3,084	0	0	37,238	1,753
		Percent	1.7	2.4	0.3	15.6	5.8	0.0	0.0	70.0	3.3
2001	790	Numbers	137	2,393	833	5,473	676	1,877	0	9,328	0
		Percent	0.7	11.4	4.0	26.2	3.2	9.0	0.0	44.6	0.0
2002	238	Numbers	20	215	683	6,871	4,626	176	0	976	5,934
		Percent	0.1	1.1	3.5	35.2	23.7	0.9	0.0	5.0	30.4
Average		Numbers	5,665	15,683	2,867	26,521	7,169	158	98	10,412	532
1987-2002		Percent	7.3	22.3	4.0	35.9	10.8	0.7	0.1	16.5	2.2

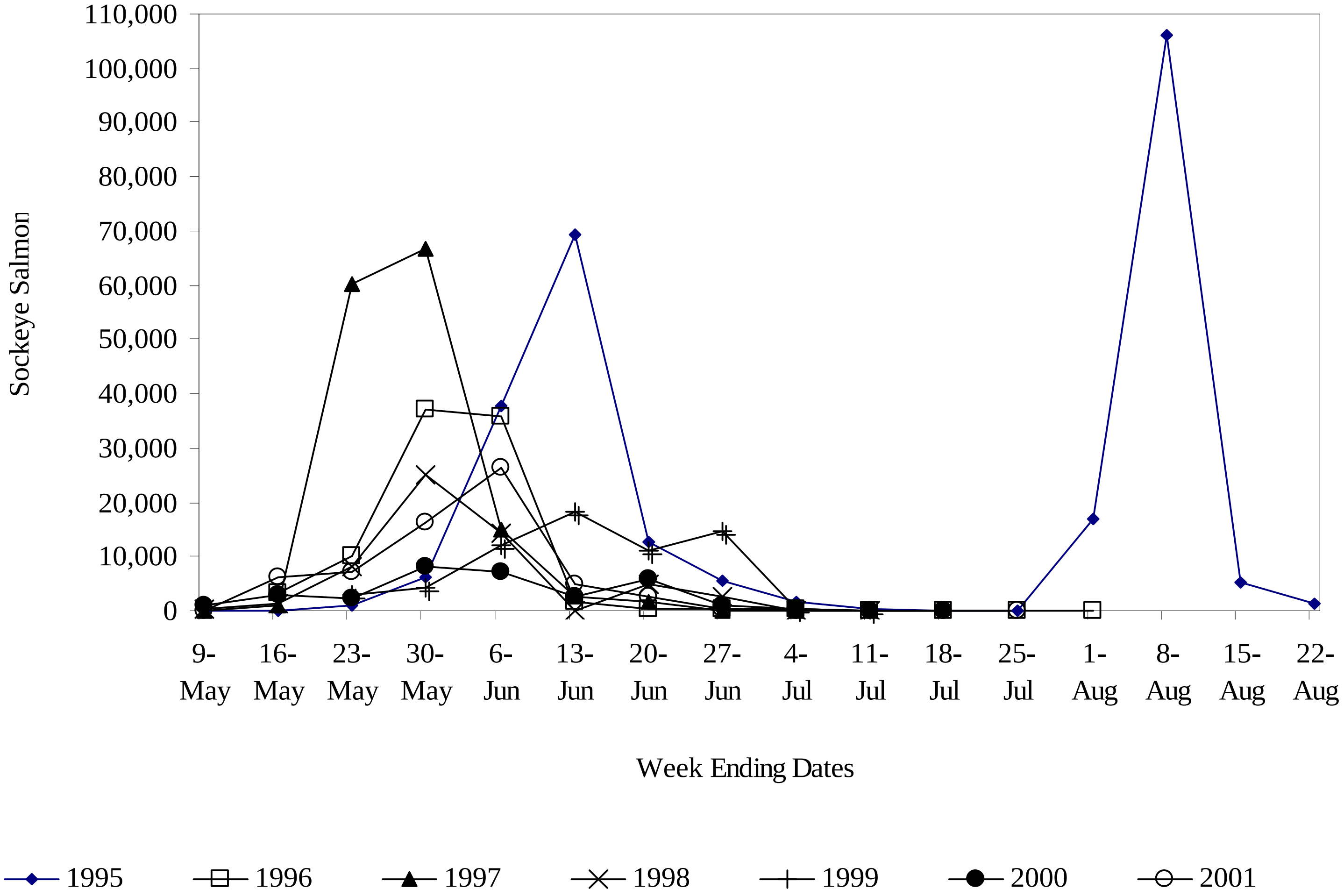
[a] In 1999, 72 (0.1%) sockeye salmon were aged 0.4.

Appendix B. Mean length, weight, and condition coefficient by age for sockeye salmon smolt sampled at Afognak Lake, 1987-2001.

		Age-1				Age-2			
Year	Sampling Period	n	Length (mm)	Weight (g)	Condition (K)	n	Length (mm)	Weight (g)	Condition (K)
1987	8-Jun	36	74.9	3.6	0.85	186	79.3	3.6	0.86
1988	15-Jun	202	77.9	4.1	0.90	0			
1989	15-Jun	208	76.8	4.1	0.91	2	78.0	5.2	1.10
1990	May23-June 24	544	68.8	2.5	0.76	21	77.3	3.4	0.73
1991	May 13-June 26	1,895	72.9	3.1	0.78	176	78.3	3.9	0.81
1992	June 7-20	268	77.0	3.8	0.82	37	76.9	3.8	0.83
1993	May 24-30	274	72.7	3.0	0.78	21	74.8	3.3	0.79
1994	May 17-23	138	72.0	3.0	0.81	142	84.3	4.7	0.79
1995	May 31-June 13	394	69.4	2.8	0.84	5	78.8	3.6	0.74
1996	June 5-11	54	80.9	4.6	0.87	339	81.6	4.8	0.88
1997	May 24-30	76	81.7	4.3	0.78	122	82.1	4.4	0.79
1998	May 24-30	116	66.4	2.6	0.82	46	88.0	6.6	0.90
1999	May 31-June 6	96	74.6	2.8	0.66	98	66.6	2.1	0.69
2000	May 31-June 13	84	81.5	4.9	0.89	100	85.3	5.6	0.89
2001	June 11-13	44	90.1	7	0.93	17	85.6	5.8	0.92



Appendix C. Sockeye salmon smolt emigration timing from Malina Lakes, 1997-2001.



Appendix D. Sockeye salmon smolt emigration timing from Little Kitoi Lake, 1995-2001.