Survey of Coho Salmon Runs on the Pacific Coast of the Alaska Peninsula and Becharof National Wildlife Refuges, 1994 with Estimates of Escapement for Two Small Streams in 1995 and 1996.

Alaska Fisheries Technical Report Number 63

by

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key words: salmon, aerial survey, residence time, escapement, area under the curve, Alaska Peninsula, Becharof, Refuge

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April 2003

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Abstract

The primary objectives of this study were to describe the run timing and to evaluate methods for estimating escapement of coho salmon (*Oncorhynchus kisutch*) in small streams located on the Pacific side of the Alaska Peninsula. In the fall and winter 1994, aerial counts of adult coho salmon were conducted on several streams located along the Pacific Coast of the Alaska Peninsula and Becharof National Wildlife refuges. In 1995 and 1996, efforts were focused to estimate escapement of coho salmon on Clear and Sandy creeks. Escapement estimates were also generated opportunistically for pink (*O. gorbuscha),* chum (*O. keta*), and sockeye salmon (*O. nerka*). We assessed the applicability of using carcass counts to index escapement by exploring the relationship between escapement estimates and cumulative carcass counts between years and between streams. Live fish counts were extrapolated to estimate escapement using the area-under-the-curve method. Observer efficiency and species-specific residence times were measured on Clear Creek in 1996, and resulting averages were used in escapement calculations for Sandy Creek in 1995 and 1996, and for Clear Creek in 1995.

Aerial survey counts of adult coho salmon in late September 1994 were highest for Yantarni (1,815), Nakalilok (1,790), Sandy (1,070), and Clear (655) creeks of the 22 streams surveyed. Eleven streams were resurveyed from the air on 1 December 1994. Counts of coho salmon were lower in December than in September for all 11 streams resurveyed, despite excellent survey conditions. Cumulative carcass counts were not significantly (r^2 = 0.44) related to escapement estimates as the difference between these values varied greatly between years and between streams. In areas with high densities of bears like the streams we studied on the Alaska Peninsula, methods that rely on carcass counts may not be reliable indices of escapement because of predation on dead and dying fish. Observer efficiency averaged 74% for 13 trials conducted on Clear Creek in 1996, and was dependent on lighting, wind, and turbidity. Residence times were estimated to be 13.8 d for coho, 8.7 d for pink, 7.9 d for chum, and 18.1 d for sockeye salmon. Escapement estimates on Clear Creek, calculated using the average residence times and counts corrected for observer efficiency, were relatively consistent between 1995 and 1996 for coho (4,068 and 3,118), sockeye (122 and 338), and pink salmon (4,239 and 5,041), but were higher in 1996 (3,851) than in 1995 (1,885) for chum salmon. Estimates of escapement on Sandy Creek were higher in 1995 than in 1996 for coho (4,057 and 2,205), pink (17,969 and 2,676), and chum salmon (1,867 and 780). We suggest that observer efficiency and residence times be assessed concurrently with foot surveys as both parameters may vary between surveys, among streams, and between years, thereby influencing escapement estimates generated using the area-under-the-curve method. The number of surveys necessary to estimate escapement may, however, be minimized by setting the survey interval equal to or slightly less than the expected residence time specific to that survey period, without a substantial loss of accuracy.

Introduction

The Pacific Coast of the Alaska Peninsula is a rugged, remote region, widely recognized for its abundant fisheries resources. Much of the area is under federal ownership (Figure 1), and is managed for its fish and wildlife resources and unique scenic value (U. S. Fish and Wildlife Service 1985). Low-volume, high-gradient streams are numerous along the Pacific side of the Peninsula, and many are used by chinook (*Oncorhynchus tschawytscha*), chum (*O. keta*), pink (*O. gorbuscha)*, sockeye (*O. nerka*), and coho (*O. kisutch*) salmon for spawning and rearing. Salmon returns to these small streams are typically less than on the larger rivers tributary to Bristol Bay located on the north side of the Alaska Peninsula (Figure 1). The numerous streams on the Pacific side, however, contribute to a collective abundance that is large enough to support commercial, subsistence, and sport fisheries.

The Pacific Coast of the Alaska Peninsula area is within the Chignik Management Area of the Alaska Department of Fish and Game (ADFG), Division of Commercial Fisheries. From 1987 to 1996, the average commercial harvest of salmon in the Chignik Management Area was estimated at over 3.1 million fish, with the catch composed of about 52% sockeye, 35% pink, 7% coho, 6% chum, and less than 1% chinook salmon (Owen et al. 2000). Adults returning to spawn in area streams are also harvested by local residents for subsistence. Subsistence harvest for the Chignik Management Area in 1997 was estimated at 19,023 salmon, with a catch composition of 71% sockeye, 14% coho, 11% pink, 4% chum, and less than 1% chinook salmon (Owen et al. 2000). Catch and harvest rates for guided and unguided sport fishing specific to the numerous small, often unnamed streams along the Pacific Coast of the Alaska Peninsula are not readily available.

Commercial and sport fisheries targeting salmon stocks in the Chignik Management Area are managed to achieve established biological escapement goals. Management decisions are based on estimates of escapement generated from a variety of methods, including in-season aerial surveys, counts from fish weirs, post-weir estimates based on the relationship between the commercial catch and counts before the weirs are pulled, and post-season scale pattern analyses (Owen et al. 2000). Aerial counts of adult salmon entering streams in the Chignik Management Area, when available, are often extrapolated to estimate escapement using the area-under-the-curve method (Owen et al. 2000). This method requires an estimate of the duration that the salmon remain in freshwater before they spawn and die, referred to as residence time or stream life. Residence times of the various salmon species that spawn in streams on the Pacific side of the Alaska Peninsula, however, are not well defined. Managers must instead use residence times derived from streams in other regions (Thompson and Owen 1992), which may reduce the accuracy of escapement estimates since residence times often vary among streams and between years (Bocking et al. 1988; Perrin and Irvine 1990). Variability in residence times can be caused by numerous factors: including run timing (Neilson and Geen 1981), sex ratios, fish density, morphological features (van den Berghe and Gross 1986), and stream flow (Fukushima and Smoker 1997). Errors in escapement estimates may be further compounded by inaccuracies in aerial counts, resulting from poor weather, high water, turbidity, and incomplete temporal and spatial coverage of the run (Bevan 1961; Cousens et al. 1982; Hill 1997).

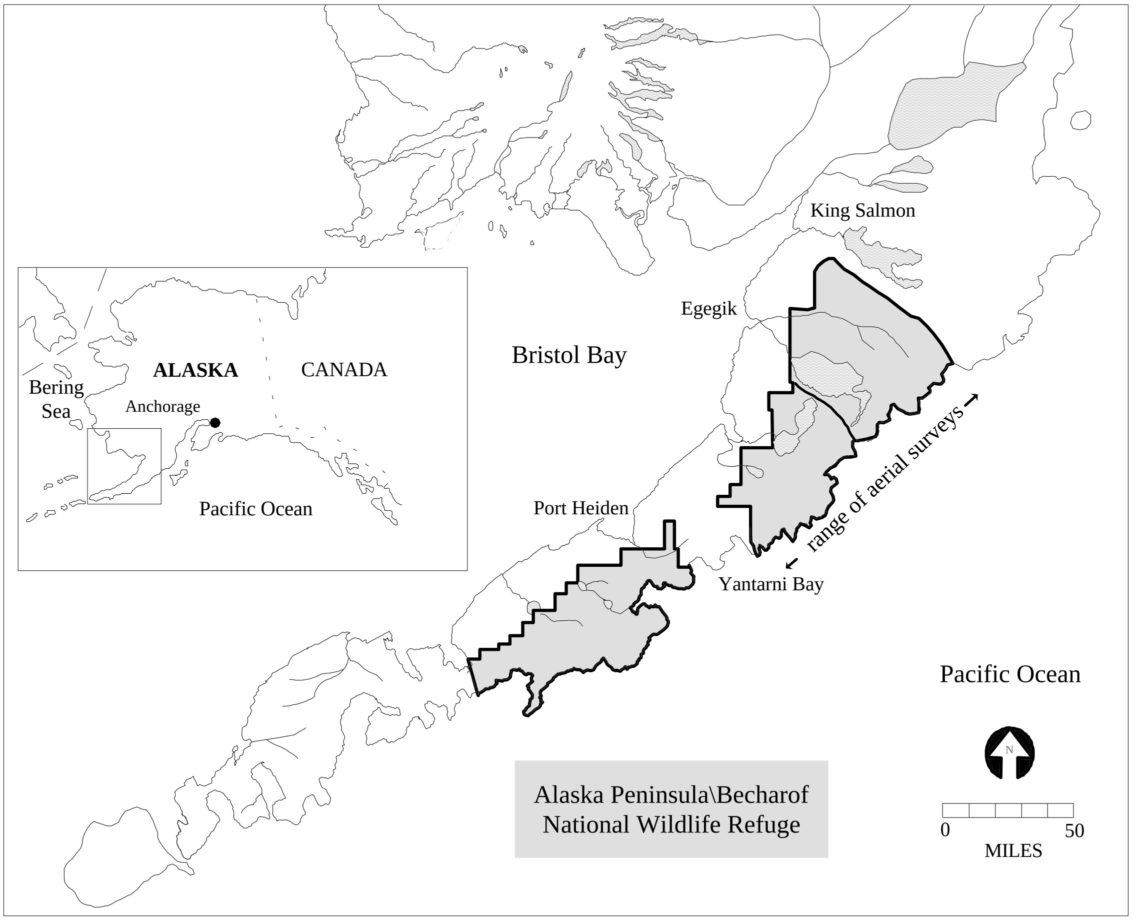

Figure 1. General location of streams surveyed along the Pacific Coast of the Alaska Peninsula from 1994 to 1996.

Commercial harvest of coho salmon in the Chignik Management Area has increased steadily since 1960 (Owen et al. 2000). This increase in fishing pressure intensifies the need for fisheries managers to obtain annual escapement estimates of coho salmon. Often, however, escapement data are lacking as coho salmon spawn late in the year when poor weather and budget constraints make it logistically and financially difficult to count fish in the numerous small streams scattered across such a broad geographic area (Owen and Sarafin 1999; Owen et al. 2000). Despite the lack of information on coho salmon escapement in the region, harvests of coho salmon by subsistence and sport anglers may also be increasing. The estimated annual subsistence harvest of all salmon species in the Chignik Management Area averaged just over 9,000 fish (6% or 540 coho salmon) from 1976 to 1993, but increased to an average of about 16,700 fish (16% or 2,672 coho salmon) from 1993 to 1997 (Owen et al. 2000). In addition, certain stocks may be more vulnerable to exploitation than others, as angling pressure is often concentrated in areas that can be accessed by road or small boat from local villages such as Ivanof Bay, Perryville, Chignik, Chignik Lake, and Chignik Lagoon, or by small aircraft landing on beaches, gravel bars, and sand blows.

This study was conducted to better describe the distribution, run timing, abundance, and stream life of coho salmon in selected streams, and to evaluate methods for monitoring escapement of adult coho salmon in small streams located along the Pacific Coast of the Alaska Peninsula. In 1994, we conducted aerial surveys and captured fish to document relative abundance and the length and age distribution of coho salmon stocks in various streams bordering the Pacific Coast of the Peninsula. Based on these preliminary data, we selected two streams, Clear and Sandy creeks, that were studied in detail in 1995 and 1996. Specific objectives of the project were to: 1) describe the age, sex, and length composition of sample catches of coho salmon on several streams along the Pacific Coast of the Alaska Peninsula, 2) estimate residence time and efficiency of visually counting coho salmon in Clear Creek, 3) estimate total escapement of coho salmon in Clear and Sandy creeks, 4) evaluate the potential for using replicate foot surveys and area-under-the-curve escapement methods to estimate escapement of coho salmon in other streams in the area, and 5) opportunistically collect information on the age, sex, and length compositions; residence times; and abundance of other salmon species in Clear and Sandy creeks.

Study Area

In 1994, we conducted aerial surveys of spawning coho salmon on several small streams located between Big Creek, south of Katmai National Park, and Yantarni Creek (Figure 1). Clear and Sandy creeks were studied in more detail in 1995 and 1996, and were selected based on their relatively small size, feasibility of access, and relative abundance of coho salmon observed during the aerial surveys conducted the previous year (Figure 2). Both streams are located within 5 km of a gravel airstrip built in the 1980's to provide access for oil exploration. The airstrip has since been used by commercial and private sport fishing and hunting parties. Both streams flow into Yantarni Bay on the Pacific Ocean, located southwest of Chiginagak volcano. We considered the streams representative of the numerous small drainages located along the Peninsula’s Pacific coastline.

Clear and Sandy creeks are second- to third-order streams, relatively short in length, and originate on steep slopes that drain into low-elevation marshes. Substrate varies from dense clay to gravel and cobble. Off-channel ponds and oxbows formed by beaver dams are common on both streams. In 1996, three beaver dams were present on Clear Creek that impeded upstream passage of adult salmon during low flows. Bank cover along the streams range from dense alder (*Alnus* sp.) to open tundra. Clear Creek is about 10 km long, but a waterfall located 6 km upstream from its mouth blocks upstream fish passage. Clear Creek flows into Camp Creek about 2 km upstream from Camp Creek’s confluence with the Pacific Ocean. Sandy Creek is a low-gradient stream that meanders through wetlands and tundra before emptying into the Pacific Ocean. The lower 0.5 km of Sandy Creek is tidally influenced. When this study began in 1994, Camp Creek was in the process of capturing the upper reach of the Sandy Creek watershed, about 7 km upstream from Sandy Creek’s confluence with the Pacific Ocean (Figure 2). By 1996, the upper reach of Sandy Creek had been diverted into Camp Creek, limiting flow in its lower reach to inputs from groundwater and small surface seeps.

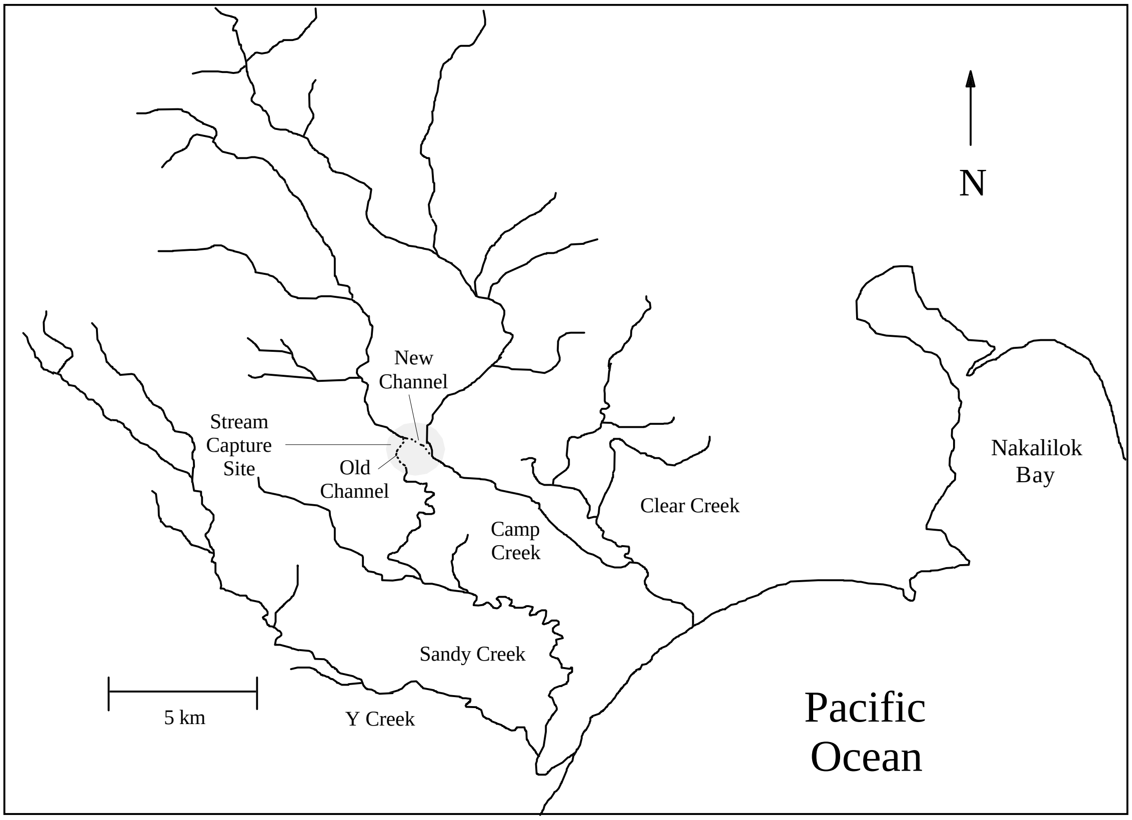

Figure 2. Relative locations of Y, Sandy, Camp, and Clear creeks.

Methods

Spawning surveys. In late September 1994, coho salmon were counted from the air on 22 streams scattered along the Pacific Coast of the Alaska Peninsula using a Bell 206 Jet Ranger helicopter. Eleven of the 22 streams were resurveyed on 1 December 1994 from a Cessna 206 airplane. Counts of adult salmon were recorded by species, and the geographic extent of the survey and presence of concentrations of Dolly Varden char (*Salvelinus malma*) were noted. Survey effectiveness was rated as poor, fair, good, or excellent based on turbidity, lighting, water surface turbulence, and flying conditions.

Between 10 August and 5 November 1995, we conducted 9 foot surveys on Clear Creek and 12 on Sandy Creek. Two observers counted salmon jointly as they walked upstream. Observers surveyed all waters accessible to adult salmon in the lower 7 km of Sandy Creek and lower 6 km of Clear Creek. Observers selected the route that maximized the visibility of salmon with respect to the angle of the sun, water clarity, and wind. Polarized glasses were worn to reduce water surface glare. When oxbows, side channels, and backwaters were encountered, one observer would remain stationary on the main channel to account for upstream and downstream migrant fish while the other observer counted fish in the off-channel habitats. Salmon carcasses were also counted and split with a machete to prevent them from being re-counted during subsequent surveys.

Between 8 August and 24 November 1996, we conducted 29 foot surveys on Clear Creek and 14 on Sandy Creek, using the same methods employed in 1995. In addition to counting adult salmon, we categorized lighting, wind generated surface turbulence, and water clarity encountered during the survey as either poor, fair, or good.

Salmon capture and tagging. Adult salmon were captured to collect age, sex, and length data using angling gear and a seine. In 1996, a partial fish weir was also used to capture fish on Clear Creek. The weir was located about 2 km upstream from the confluence of Clear Creek with Camp Creek and was constructed from plastic mesh netting and wood. The weir was operated from August until late October when it was damaged by high flows and brown bears (*Ursus arctos*). Although the weir spanned the entire channel, it was not fish-tight. Fish holding just downstream of the weir were captured daily using a seine and passed above the weir. Adult salmon holding downstream of the weir in deep pools were captured with angling gear. Subsamples of captured fish were tagged with streamer tags to measure observer efficiency and to estimate residence times. Fish were tagged by passing a needle threaded with surveyor's tape (flagging) through the skin, just ventral to the posterior end of the dorsal fin. Flagging was tied using a square knot, with about 7 cm of flagging left trailing behind the knot. The color and/or pattern of the flagging were varied between each of 13 separate marking events. We assumed that all tags were retained and were accurately identified on subsequent surveys. We did not capture fish less than 1 km upstream from the mouth of Clear Creek to minimize the probability of tagged fish drifting downstream out of the survey area.

Observer efficiency. We estimated observer efficiency on Clear Creek in 1996, as defined by the percentage of adult salmon counted by observers in relation to the actual number present (Bocking et al. 1988, Irvine et al. 1993). Observer efficiency was estimated on Clear Creek on 13 separate days between 13 August and 15 October. Observer efficiency was not quantified for Sandy Creek. Efficiency trials were conducted concurrently with foot surveys, on days that were representative of the range of wind, water clarity, and lighting conditions encountered by observers during the study. Observer efficiency was measured by marking a known number of salmon with highly visible streamer tags, allowing the marked fish to disperse for a minimum of three hours, and then counting newly-tagged fish during a foot survey conducted later that day. Observer efficiency was quantified independently for each of the thirteen trials, and was expressed as the probability of a tagged fish being counted during a foot survey conducted later that day, as shown by the equation:

$$O_i = \frac{r_i}{m_i}$$

where O_i equals the observer efficiency for trial i, r_i is the number of fish marked in the i^{th} trial that were counted in the subsequent foot survey, and m_i is the total number of fish marked for the i^{th} trial. Pink salmon were used in one trial, sockeye salmon in three trials, and coho salmon were used in the remaining nine trials. Although tag color and pattern varied between trials, tag size was kept constant. We assumed that tagged and untagged individuals had an equal probability of being counted, and did not differentiate observer efficiency by species or fish size. We also did not assess differences in efficiency between observers as the two surveyors conducted counts jointly.

Measured observer efficiencies were used to correct counts on Clear Creek in 1996 for the 13 surveys that occurred on days when efficiency was measured. We defined the relationship between measured observer efficiency and 1) numerical ratings (poor=1, fair=2, good=3) of lighting, wind, and turbidity; 2) the average and lowest of the three survey variables; and 3) stream discharge, using linear regression (Systat 1992). Observer efficiency was predicted for the remaining 16 surveys conducted on Clear Creek in 1996 using linear regression (Systat 1992), based on the relationship between the lowest of the three survey variables ratings for each of the 13 observer efficiency trials and the measured observer efficiency for that day. Counts of adult salmon taken on Sandy Creek in 1996 and on Clear and Sandy creeks in 1995 were corrected using the average of the 13 efficiency trials conducted on Clear Creek in 1996.

Residence time. We defined residence time as the average duration that individuals of a species spent alive in the stream. The residence times of coho, pink, chum, and sockeye salmon in Clear Creek were measured independently in 1996 by marking groups of fish with colored streamer tags at about 7- to 10-d intervals from mid August through September 18 and again on October 22. Tagged fish were counted on subsequent foot surveys, and counts were corrected for observer efficiency. Corrected counts of tagged fish were plotted against time to yield a tag depletion curve, with the intercept of the y axis representing the total number of tags (100%) deployed at the beginning of the test. The area under the tag curve was then divided by the original number of tags deployed to estimate a period-specific residence time (rt_p) (in days) for that time period as described by Irvine et al. (1992) and Irvine et al. (1993):

$$rt_p = \sum_{i=1}^{a} \left([C_i / O_i] \; t_i \right) / d$$

where a equals the number of surveys included in the trail, C_i is the count of tagged fish for the i^{th} survey, O_i equals observer efficiency for the i^{th} survey; t_i is the time elapsed between the i^{th} *and* i^{th} - 1 survey (in days); and d is the total number of tags deployed at the initiation of the trial. Coefficients of determination were calculated for each depletion curve to assess the fit of count data to a linear depletion model using linear regression (Systat 1992). We assessed the residence time of coho salmon in Clear Creek for three different time periods in 1996, corresponding to batches of tags deployed on 10 and 18 September and on 22 October. Tags were deployed to measure period-specific residence times of pink salmon on 14, 21, and 28 August and 4 September; on 8, 14, 21, and 28 August and 4 September for chum salmon; and on 14 and 21 August for sockeye salmon. An average of the period-specific residence times weighted by abundance (rt_w) was determined for the season for each species as shown by the equation:

$$rt_w = \sum_{i=1}^{a} \left([C_i / O_i] rt_p \right) / \sum_{i=1}^{a} C_i \; / O_i$$

where a equals the number of foot surveys conducted over the season, C_i is the count for the i^{th} survey, O_i equals the observer efficiency determined for the i^{th} survey, and rt_p is the residence time determined for the time period closest to the date of survey i.

Escapement Estimates. We calculated escapement of coho, pink, chum, and sockeye salmon in Clear and Sandy creeks in 1995 and 1996 by extrapolating foot survey counts using the area-under-the-curve method as described by Johnson and Barrett (1988), Irvine et al. (1993), and Jacobs and Nickelson (1998), as defined by the equation:

$$E = \sum_{i=1}^{a} \left([C_i / O_i] t_i \right) / rt$$

where E is the escapement estimate, a equals the number of survey periods, C_i is the count for the i^{th} survey, O_i is the observer efficiency for the i^{th} survey, t_i is the interval between adjacent surveys (in days); and rt is the residence time (in days) for the species counted. Six separate escapement estimates were generated for each species for each year, providing a range of estimates. Escapement estimates were calculated with three different residence times: period-specific residence times (rt_p) calculated from tag depletions tests conducted on Clear Creek in 1996, average weighted residence times determined on Clear Creek in 1996 (rt_w), and average residence times reported for a compilation of studies by Perrin and Irvine (1990). Each of the three types of residence times was used to estimate escapement using actual counts and counts corrected for observer efficiency, yielding a total of six escapement estimates for each species on each stream.

Model sensitivity. We explored the sensitivity of the area-under-the-curve model to varying survey intervals using data collected from Clear Creek in 1996. We used the escapement estimate calculated using counts corrected for observer efficiency independently for all 29 foot surveys and the average weighted residence time determined for Clear Creek in 1996 as a standard. This estimate was compared to estimates generated using actual counts and counts corrected for observer efficiency taken at about 1-, 2-, and 3- week intervals, and from corrected and uncorrected counts taken at intervals that approximated period-specific residence times, again using the average residence time determined for Clear Creek in 1996.

Length, age, and sex compositions. In late August through early October 1994, we attempted to collect length, age and sex data from coho salmon captured in Big, Camp, Chiginagak, Kialagvik, Nakalilok, Pier, Sandy, and Yantarni creeks using a seine and with angling gear. Incidental captures of Dolly Varden char were also sampled. About six scales were collected from the preferred area of each coho salmon captured, and ages were estimated by two experienced personnel using methods outlined by Jearld (1983). Disagreements were resolved by conference. Coho salmon were measured to the nearest mm from the middle of the eye, and Dolly Varden char from the tip of the snout to the fork of the caudal fin. Sex was determined by secondary physical characteristics, when possible. Length, age, and sex data from 1994 were typically collected over a period of a few days for each stream sampled. In 1995, coho salmon were sampled from Camp, Clear, and Y creeks and in 1996, from Clear and Sandy creeks. Length, sex, and age data were also collected from chum and pink salmon on Clear Creek in 1996. Collections from all salmon species in

1995 and 1996 were dispersed throughout the duration of the study. Dolly Varden char were measured and sexed in 1994 and 1995 but not aged, and were not sampled in 1996.

Stream Discharge. We monitored stream discharge on Clear Creek in 1996 by reading the water elevation on a staff gauge daily, and estimating flow periodically (Lyons 1988). Water velocity was measured with a Marsh-McBirney model 201 flow meter over a wide range of flows. Linear regression (Systat 1992) was used to define the correlation between the staff gauge height and discharge measurements, and the relationship between the two variables was used to convert stage height readings to discharge for days when discharge was not measured.

Results

Spawning surveys. Aerial counts of adult coho salmon conducted in late September 1994 were highest for Yantarni (1,815), Nakalilok (1,790), Sandy (1,070), and Clear (655) creeks of the 22 streams surveyed (Appendix A). Coho salmon were not observed on nine streams, and aerial counts ranged between 15 and 300 coho salmon for the other nine streams surveyed. Survey effectiveness was rated poor for four, fair for six, good for seven, and excellent for five of the 22 streams surveyed. Survey effectiveness was rated fair on Camp Creek and poor on Yantarni Creek on 22 September and both streams were re-surveyed on 26 September with survey effectiveness rated as good. Aerial counts of adult coho salmon conducted on 11 streams surveyed on 1 December 1994 were consistently lower than counts taken on the same streams in September, despite excellent survey conditions.

On 28 August 1995, one coho salmon was counted in Clear Creek during the first foot survey of the season (Figure 3, Appendix B). Subsequent counts of coho salmon peaked at 939 on 20 October, and decreased to 133 fish on the last survey of the year that occurred on 5 November. In 1996, coho salmon were first observed in Clear Creek on 6 September, and subsequent counts ranged from about 100 to 300 fish until late October when the count peaked at 1,160 fish. Twenty-five coho salmon were observed on 24 November, the last survey of 1996.

Coho salmon were first observed in Sandy Creek in 1995 in late August, and counts peaked in mid October at 1,471 fish (Figure 3, Appendix B). Two hundred and eighty-six coho salmon were counted on 2 November, the last survey of the season. In 1996, coho salmon counts on Sandy Creek were highest on 7 September (553 fish) and remained relatively constant through the end of October, ranging between about 200 to 500 fish for each survey. Counts of adult coho salmon decreased during November to a low of 20 fish on 23 November, the final survey of the year.

Nine hundred pink salmon were counted in Clear Creek during the first survey of the year on 28 August 1995 (Figure 4, Appendix B). Counts of pink salmon peaked at 1,300 fish on the following survey (11 September). In 1996, about 70 pink salmon were counted on the first survey of the season (8 August), which occurred 20 days earlier than the first survey conducted in 1995. Counts of pink salmon peaked (1,465 fish) on 2 September, 1996 at a level similar to that observed in 1995, but about nine days earlier than in 1995. The run of pink salmon ended by early October of 1995 and 1996.

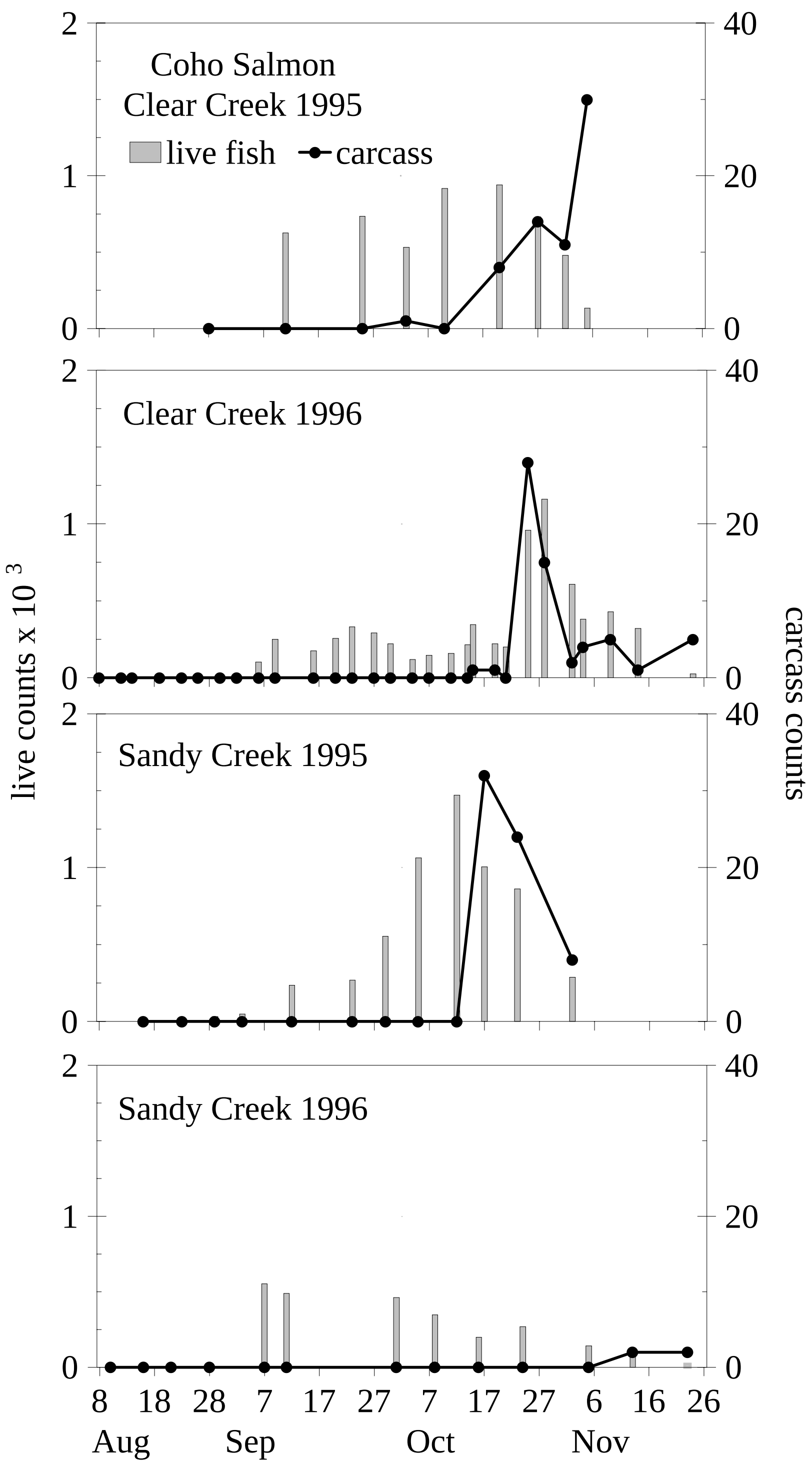

Figure 3. Counts of coho salmon taken during foot surveys conducted on Clear and Sandy creeks, 1995 and 1996.

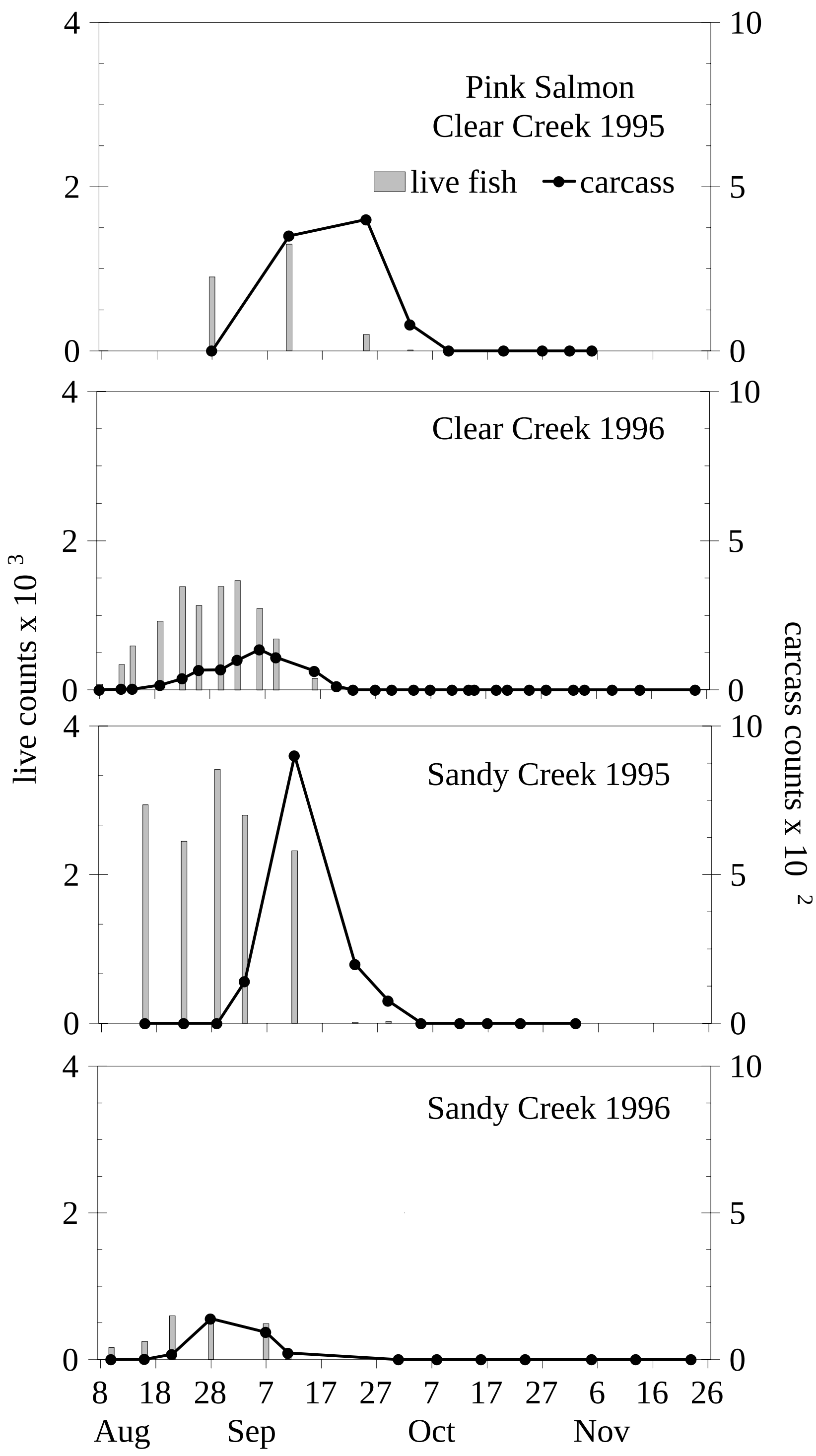

Figure 4. Counts of pink salmon taken during foot surveys conducted on Clear and Sandy creeks, 1995 and 1996.

In 1995, counts of pink salmon were relatively high (2,940 fish) for Sandy Creek on the first survey of the year conducted on 16 August (Figure 4, Appendix B). Subsequent counts peaked in late August at over 3,400 fish. In 1996, counts of pink salmon peaked on Sandy Creek in late August, but the peak was only about 20% of that measured in 1995. The run of pink salmon was over by early October in both 1995 and 1996, similar to what we observed on Clear Creek.

In 1995, the peak count of chum salmon (500 fish) on Clear Creek occurred on 28 August, the first foot survey of the year (Figure 5, Appendix B). Subsequent counts declined and were near zero by early October. In 1996, 69 chum salmon were counted on the first survey of Clear Creek, which occurred on 8 August. Counts gradually increased thereafter, and peaked at 1,026 fish on 23 August. Chum salmon counts on Clear Creek declined to less than 50 fish by the third week of September, 1996. The peak count of chum salmon in Clear Creek in 1996 was about two times greater than in 1995.

The first survey of 1995 on Sandy Creek was conducted on 16 August, and resulted in the highest count (660) of chum salmon for the season. Similar to what was observed on Clear Creek in 1995, subsequent counts of chum salmon declined and were near zero by 23 September. In 1996, chum salmon counts peaked at 209 fish on 21 August, the third survey of the season, and declined to less than 20 fish by mid September. The peak count of chum salmon in Sandy Creek in 1996 was about a one-third of the peak count for 1995.

Counts of sockeye salmon on Clear Creek were relatively low in 1995 (peak count 143) and in 1996 (peak count 35) (Figure 6, Appendix B). For both years, counts of sockeye salmon remained fairly constant from the initiation of surveys in August through the end of September, ranging between 0 to 35 fish in 1995 and 0 to 143 fish in 1996. Sockeye salmon were not observed in Clear Creek after about the third week of October of either year studied. No sockeye salmon were observed in Sandy Creek in 1995, and two were counted in Sandy Creek on 10 Aug and one on 21 August 1996. In addition to coho, pink, chum, and sockeye salmon, 1 chinook salmon was counted in Clear Creek on 19 August and on 2 September, and a spawning pair was observed on 23 August 1996.

Cumulative carcass counts of adult coho salmon accounted for about 1 to 2% of the escapement estimate generated from counts corrected for observer efficiency and the average residence time measured on Clear Creek in 1996. Cumulative carcass counts accounted for about 7 to 20% of the escapement estimate of pink salmon calculated using counts corrected for observer efficiency and the average residence time measured on Clear Creek in 1996, and 5 to 54% for chum, and from less than 1 to 13% for sockeye salmon. This variability was reflected in the lack of a significant relationship between escapement estimates and cumulative carcass counts of coho, pink, and chum salmon for both years and streams (r^2=0.44).

Salmon capture and tagging. Of the 762 salmon captured and tagged on Clear Creek in 1996, two died within hours of being released. We did not find any tagged carcasses of fish that had not spawned, and therefore assumed that tagging and handling mortality was negligible in subsequent calculations of observer efficiency and escapement.

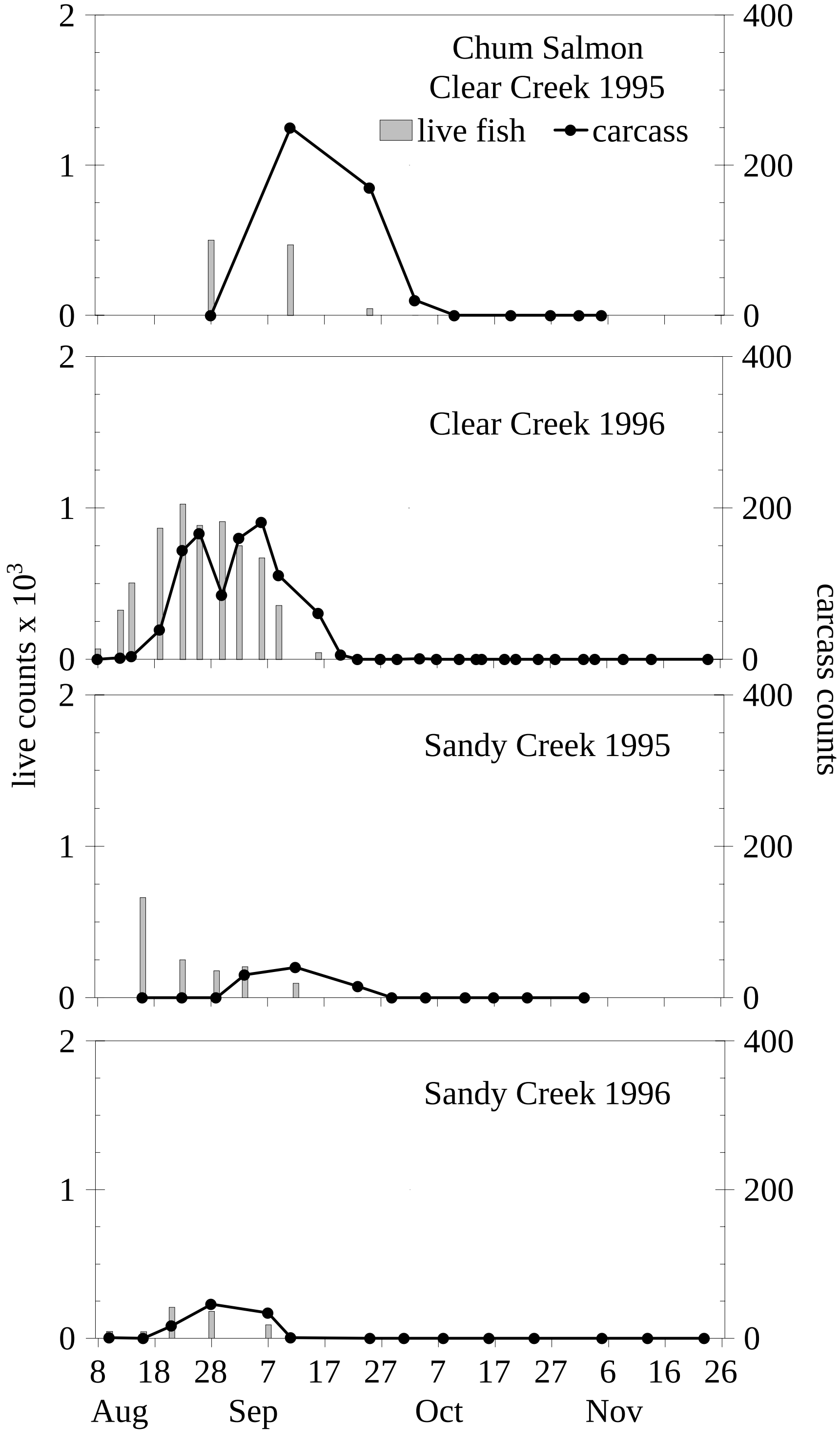

Figure 5. Counts of chum salmon taken during foot surveys conducted on Clear and Sandy creeks, 1995 and 1996.

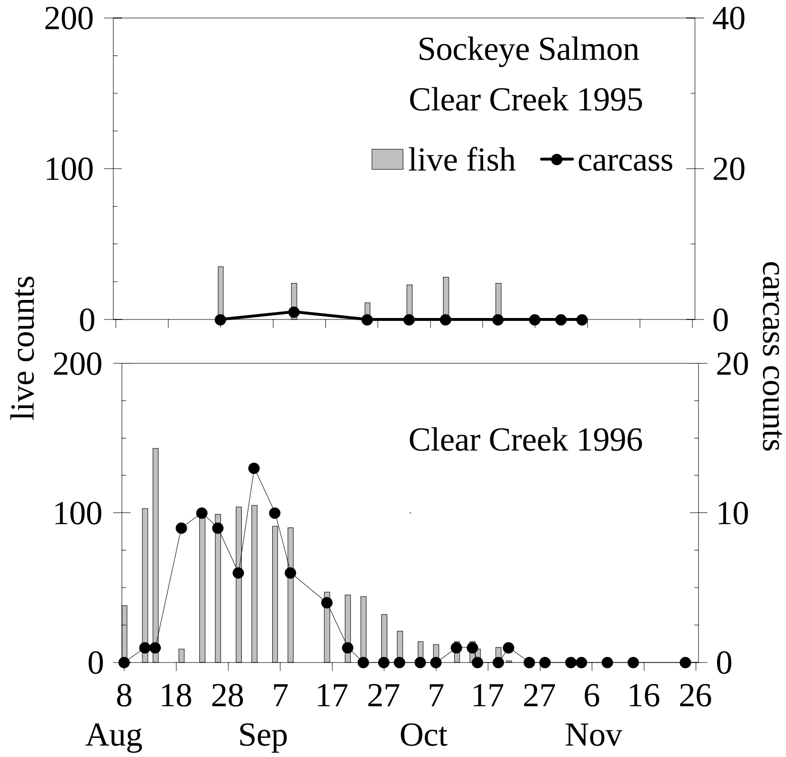

Figure 6. Counts of sockeye salmon taken during foot surveys conducted on Clear Creek, 1995 and 1996.

Observer efficiency. The average observer efficiency for the thirteen trials conducted on Clear Creek in 1996, expressed as a percentage of fish present that were counted during foot surveys, was 74%. Observer efficiency for individual trials ranged from 25% to 100% (Table 1). Light, turbidity, and wind conditions during the foot surveys associated with the 13 trials were mostly categorized as fair to good, with one poor rating for wind and four poor ratings for turbidity (Appendix C). There was little relation between lighting (r^2=0.19), turbidity (r^2=0.39), or wind (r^2=0.23) and observer efficiency measurements (Figure 7). A weak relationship was observed between stream discharge and observer efficiency (r^2 = 0.50) and a stronger relationship (r^2 = 0.77) existed between the average of the numerical ratings of the three survey condition variables and observer efficiency measurements. A significant relationship (r^2=0.86, P<0.01) did, however, exist between the lowest of the three survey condition factors and the measured observer efficiency (Figure 7), as described by the linear equation:

$$y = 32(x) + 5.6$$

where the independent variable *y* is the predicted observer efficiency and the dependent variable *x* equals the lowest value of the three survey condition variables for a survey day. Counts for Clear and Sandy creeks in 1995 and Sandy Creek in 1996 were corrected using the 74% average observer efficiency measured for Clear Creek in 1996.

Table 1. Date, sample size, and estimated observer efficiency for selected foot surveys conducted on Clear Creek in 1996, expressed as a percentage of the number of tagged fish released that were relocated during a foot survey conducted later that day.

Salmon species	Trial date	Number released	Number recovered	Observer efficiency (%)
pink	13 Aug	4	4	100
sockeye	14 Aug	9	9	100
	23 Aug	5	4	80
	29 Aug	2	2	100
coho	16 Sep	8	7	88
	20 Sep	19	19	100
	23 Sep	19	17	89
	27 Sep	20	17	85
	4 Oct	20	8	40
	7 Oct	20	5	25
	11 Oct	20	6	30
	14 Oct	20	11	55
	15 Oct	20	15	75

Residence time. Two groups of coho salmon (N=10 and 11 fish) were tagged in Clear Creek in September of 1996, soon after coho salmon were first observed during foot surveys. A group of 381 coho salmon was tagged in October during the peak of the run. Period-specific residence times for the first two tag groups were similar (43.1 and 37.3 d), but were about three times greater than the 13.7-d estimated residence time for the group tagged in October (Figure 8).

Four separate groups of pink salmon (N = 32, 43, 24, and 49 fish), four groups of chum salmon (N=34, 46, 42, and 78 fish), and two groups of sockeye salmon (N = 9 and 5) were tagged. Period-specific residence time estimates for pink salmon decreased as the run progressed, from 11.2 d and 11.9 d in mid- to late-August down to 7.4 d for fish tagged on 4 September (Figure 9). Similarly, period-specific estimates of residence time for chum salmon also decreased over time, from 8.5 d on 14 August down to 7.1 d on 4 September (Figure 10). Residence times of sockeye salmon were estimated to be 23.5 d for fish tagged on 14 August and 17.1 d for fish tagged on 21 August (Figure 11).

Escapement estimates. Estimates of coho salmon escapement in Clear Creek ranged from 2,151 to 4,925 fish in 1995 and from 1,745 to 3,747 fish in 1996 (Table 2). Estimates of coho salmon escapement in Sandy Creek ranged from 2,649 to 4,911 fish in 1995 and from 1,042 to 2,669 fish in 1996 (Table 2). Calculations using the 1996 period-specific residence times and actual counts resulted in the lowest escapement estimates. Estimates of escapement made using counts corrected for observer efficiency and the 11.4-d average residence time reported Perrin and Irvine (1990) resulted in the highest estimates.

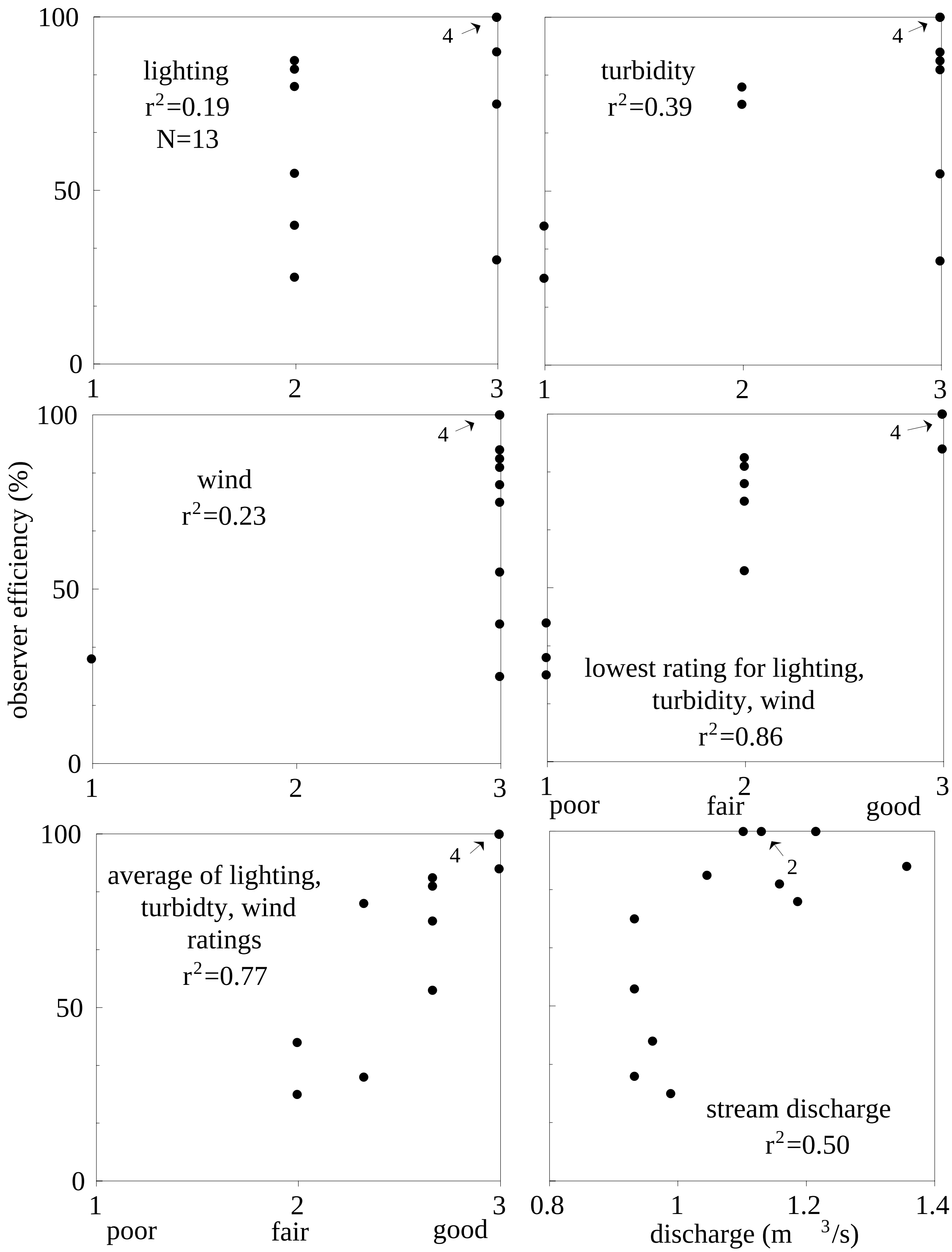

Figure 7. Scatter plots depicting the relationship between numerical ratings of survey condition variables and observer efficiency measured on Clear Creek in 1996.

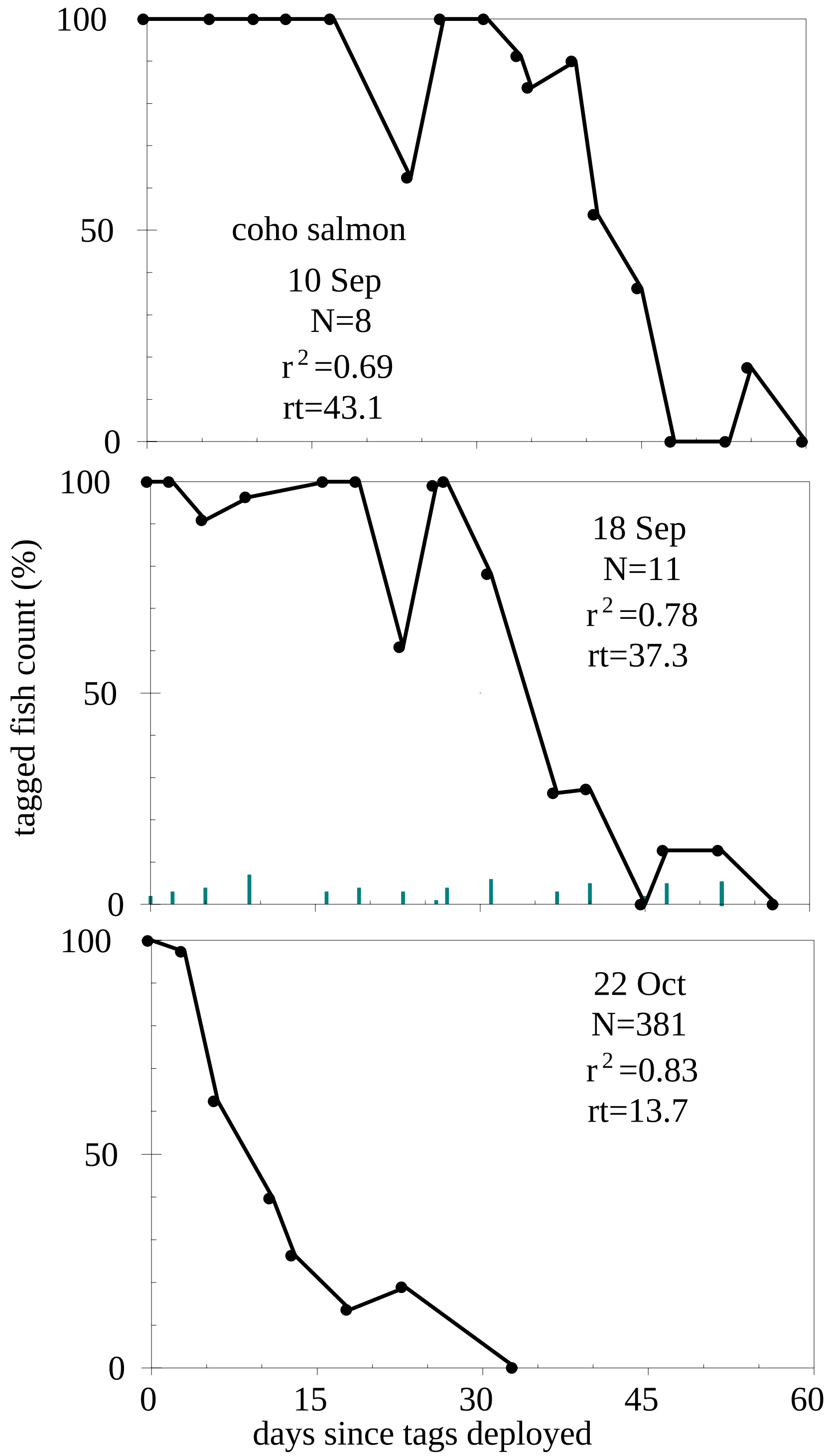

Figure 8. Proportion of coho salmon tagged on three different dates that were observed on subsequent foot surveys conducted on Clear Creek in 1996 (rt=residence time).

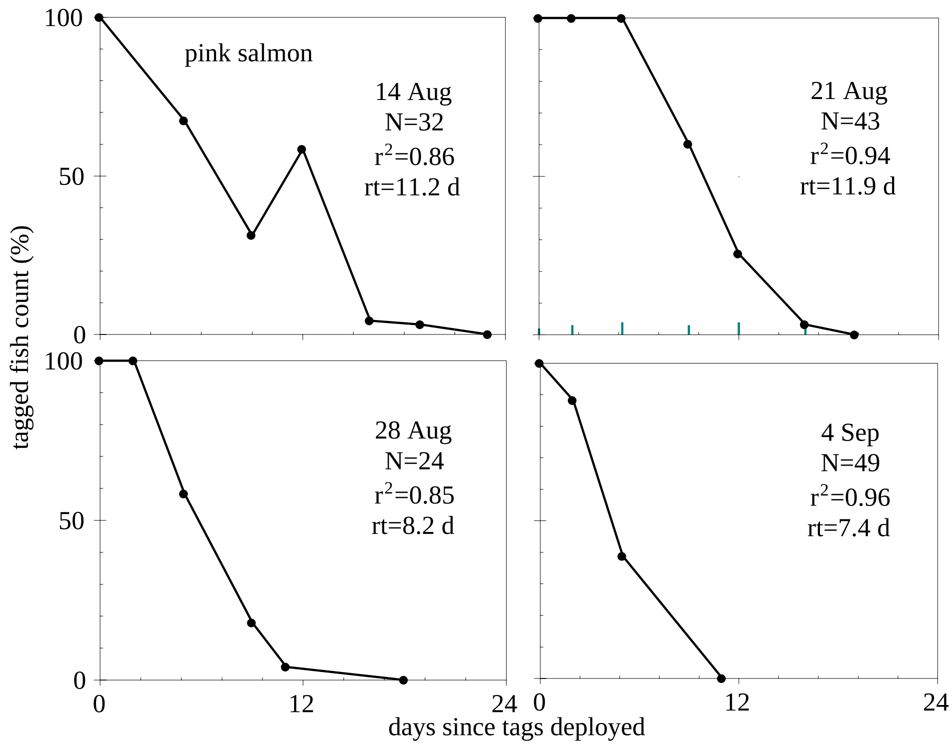

Figure 9. Proportion of pink salmon tagged on four different dates that were observed on subsequent foot surveys conducted on Clear Creek in 1996 (rt=residence time).

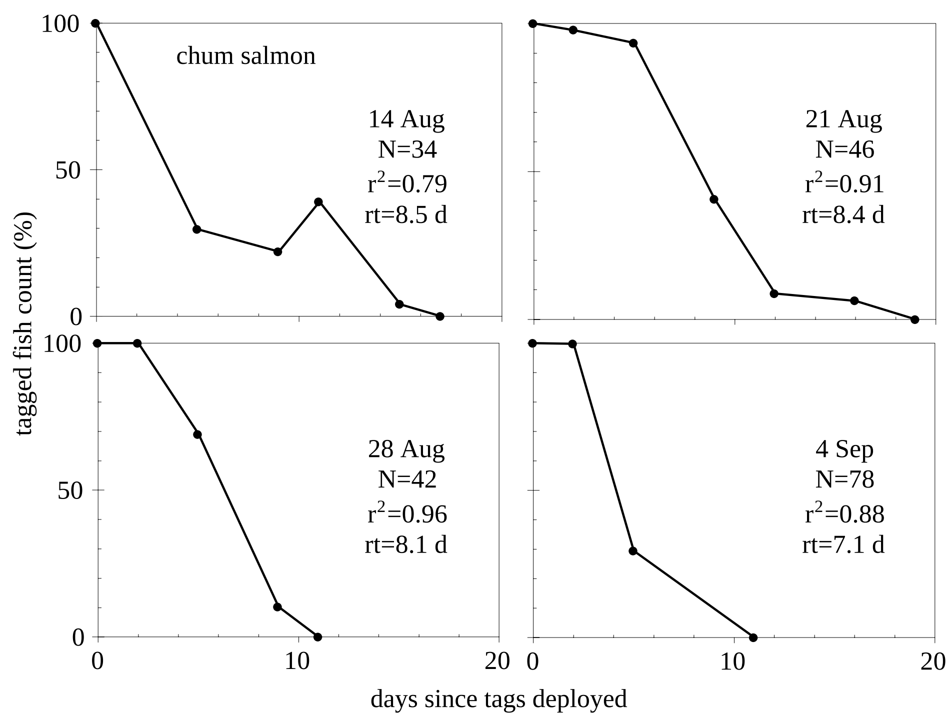

Figure 10. Proportion of chum salmon tagged on four different dates that were observed on subsequent foot surveys conducted on Clear Creek in 1996 (rt=residence time).

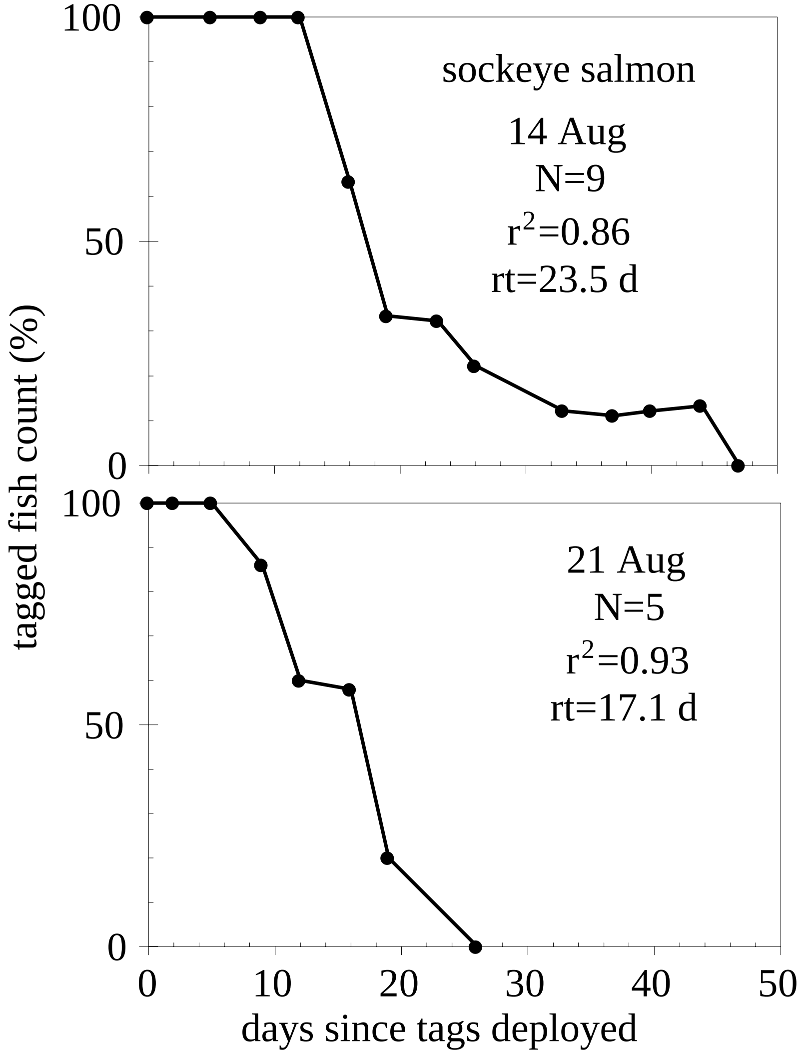

Figure 11. Proportion of sockeye salmon tagged on two different dates that were observed on subsequent foot surveys conducted on Clear Creek in 1996 (rt=residence time).

Table 2. Estimated escapement of coho, pink, chum, and sockeye salmon in Clear and Sandy creeks in 1995 and 1996. Estimates were calculated using the area-under-the-curve method with residence times (rt) derived from tag depletion tests conducted on Clear Creek in 1996, and from a compilation of similar studies summarized by Perrin and Irvine (1990).

Species	Stream	Year	Escapement estimates uncorrected for observer efficiency			Escapement estimates corrected for observer efficiency		
			Period-specific rt from 1996[a]	1996 ave. rt[b]	rt from literature[c]	Period-specific rt from 1996[a]	1996 ave. rt[b]	rt from literature[c]
sockeye	Clear	1995	95	90	124	129	122	167
		1996	268	281	385	328	338	464
chum	Clear	1995	1,481	1,395	926	2,002	1,885	1,251
		1996	3,086	3,078	2,043	3,844	3,851	2,557
	Sandy	1995	1,359	1,382	917	1,836	1,867	1,239
		1996	565	577	383	763	780	518
pink	Clear	1995	3,591	3,137	1,578	4,852	4,239	2,132
		1996	4,109	4,107	2,065	5,011	5,041	2,535
	Sandy	1995	13,147	13,297	6,687	17,766	17,969	5,296
		1996	1,893	1,980	996	2,558	2,676	1,346
coho	Clear	1995	2,151	3,011	3,644	2,906	4,068	4,925
		1996	1,745	2,052	2,484	2,752	3,118	3,747
	Sandy	1995	2,649	3,002	3,634	3,579	4,057	4,911
		1996	1,042	1,631	1,975	1,409	2,205	2,669

[a] Range of residence times measured on Clear Creek 1996: 23.5 to 17.1 d for sockeye, 8.5 to 7.1 d for chum, 11.2 to 7.4 d for pink, and from 43.1 to 13.7 d for coho salmon.

[b] Average residence times from Clear Creek 1996: 18.1 d for sockeye, 7.9 d for chum, 8.7 d for pink, and 13.8 for coho salmon.

[c] Average residence times from the literature: 13.2 d for sockeye, 11.9 d for chum, 17.3 d for pink, and 11.4 d for coho salmon.

Estimates of pink salmon escapement in Clear Creek to ranged from 1,578 to 4,852 fish in 1995 and from 2,065 to 5,041 fish in 1996 (Table 2). Estimates of escapement of pink salmon in Sandy Creek ranged from 5,296 to 17,969 fish in 1995 and from 996 to 2,676 fish in 1996. Escapement estimates were lowest when the 17.3-d average residence time reported by Perrin and Irvine (1990) and actual counts were used. Estimates of pink salmon escapement made using the 1996 period-specific residence time were similar to those generated with the 1996 average residence time, and yielded the highest estimates of escapement when used with counts corrected for observer efficiency.

Escapement estimates of chum salmon in Clear Creek ranged from 926 to 2,002 fish in 1995 and from 2,043 to 3,851 fish in 1996 (Table 2). Escapement estimates of chum salmon in Sandy Creek ranged from 917 to 1,867 fish in 1995 and from 383 to 780 fish in 1996. Estimates of escapement were consistently higher when period-specific or average weighted residence times were used than for estimates produced using the 11.9-d residence time reported by Perrin and Irvine (1990). Escapement estimates made using the 1996 period-specific residence time were similar to those generated with the 1996 average residence time.

Escapement estimates of sockeye salmon in Clear Creek ranged from 90 to 167 fish in 1995 and from 268 to 464 fish in 1996 (Table 2). Escapement estimates were higher when estimated using the 13.2-d residence time reported by Perrin and Irvine (1990), than for estimates produced using the average or period-specific residence time established for Clear Creek in 1996. Escapement of sockeye salmon in Sandy Creek was not estimated because none were observed during foot surveys in 1995 and only three individuals were counted in 1996.

Model sensitivity. Estimates of coho salmon escapement on Clear Creek in 1996 progressively decreased as we increased the interval between surveys from an average of about 4 d to 1-, 2-, and 3-week periods, and the decrease was consistent for estimates made using either actual counts or counts corrected for observer efficiency (Table 3, Appendix D). Estimates made using actual counts were, at a minimum, 34% less than the estimate made using all 29 surveys and counts corrected for observer efficiency. An estimate produced using counts corrected for observer efficiency from 11 surveys selected at about 1-week intervals was about 9% less than the estimate made using corrected counts from all 29 surveys. The estimate was 37% less when the survey interval was extended to 3 weeks, which incorporated five surveys total. Estimates made using five foot surveys selected at intervals that approximated period-specific residence times and counts corrected for observer efficiency were within 1% of the estimate generated using corrected counts from all 29 surveys.

Length, age, and sex compositions. Of the 131 coho salmon sampled from Chiginagak Creek in early September 1994, 60% were male, 30% were female, and the sex could not be determined for the remaining 10% (Appendix E). Age 1.1 males comprised the highest proportion of the catch (37%), followed by age 2.1 males (20%). Lengths ranged from 457 to 705 mm, and averaged 620 mm for the 131 fish sampled.

On 24 September 1994, 62 coho salmon were sampled from Nakalilok Creek. Males comprised 65% and females 28% of the total catch (Appendix E). The sex could not be determined from 7% (4 fish) of the catch. Age 1.1 males were the most abundant age group

Table 3. Estimates of coho salmon escapement on Clear Creek in 1996, calculated using actual counts and counts corrected for observer efficiency, and varying survey intervals. The estimate of 3,118 fish was used as the standard for comparison with other estimates.

Survey interval	Number of surveys	Uncorrected for observer efficiency		Corrected for observer efficiency	
		escapement estimate	% difference	escapement estimate	% difference
all surveys	22	2,052	- 34	3,118	0
1-wk intervals	11	1,887	- 40	2,846	- 9
2-wk intervals	7	1,500	- 52	2,478	- 21
3-wk intervals	5	1,446	- 54	1,975	- 37
interval set at residence time	5	1,956	- 37	3,129	+> 1

captured (35%), followed by age 2.1 males (24%). Mid-eye-to-fork lengths ranged from 355 to 711 mm, and averaged 616 mm for the 62 coho salmon captured. Few coho salmon were captured from the other six streams sampled in 1994, with samples sizes ranging from 1 to 22 fish.

Dolly Varden char were captured in three of the eight streams sampled in September 1994, with the largest sample size (84 fish) collected from Pier Creek (Appendix E). About 43% of the char captured from Pier Creek were females, 31% were males, and the sex could not be determined visually from the remaining 26%. Fork lengths ranged from 267 to 546 mm and averaged 416 mm. Sample sizes were low in the other two streams where char were captured (6 fish, Chiginagak Creek, 35 fish, Camp Creek). The sex could not be readily determined from the majority of these fish.

In August and September 1995, we sampled 342 coho salmon from Camp Creek, ranging in size from 413 to 718 mm and averaging 604 mm (Appendix E). About 46% of the fish captured were females and 54% were males. Age 2.1 males (30%) and females (23%) were the dominant age groups, followed by age 1.1 males (12%) and females (10%). During the same time period, 195 coho salmon were sampled from Sandy Creek. Mid-eye-to-fork lengths ranged from 451 to 673 mm and averaged 605 mm (Appendix E). Females comprised about 44% and males 56% of the total catch. The age composition was similar to that observed on Camp Creek, with age 2.1 males (31%) and females (26%) and age 1.1 males (14%) and females (14%) most prevalent in the catch. In addition, 21 coho salmon were sampled from Clear Creek, 42 Dolly Varden char were sampled on Camp Creek and 1 was captured on Chiginagak Creek, and 12 coho salmon were sampled from Y Creek in 1995.

In 1996, we sampled 141 coho, 152 pink, and 206 chum salmon from Clear Creek, with collections dispersed from August through November. Coho salmon ranged in length from 319 to 680 mm, averaged 602 mm, and were predominately age 2.1 male (50%) and female (29%) (Appendix E). Overall, about 35% of the coho salmon sampled from Clear Creek in 1996 were female and 65% were male. Age 2.1 males accounted for 50% and 2.1 females

29% of the overall catch. Of the 152 pink salmon sampled from Clear Creek in 1996, about 32% were female and 68% were male (Appendix E). Mid-eye-to-fork length of chum salmon captured in Clear Creek in 1996 averaged 641 mm and ranged from 344to 780 mm. Males accounted for 64%, and females 36% of the catch. Chum salmon were not aged. Only 14 adult coho salmon were sampled from Sandy Creek, which occurred in late October 1996.

Stream discharge. Measurements of stream discharge taken on Clear Creek in 1996 were highly correlated (r^2=0.97) to stream elevations read off a staff gauge (N=6), allowing us to predict instantaneous discharge for days when discharge was not measured and staff gauge readings were available (Figure 12). Base flows were predominant throughout August, September, and October of 1996, ranging for the most part, between about 0.9 to 1.2 m^3/sec. Discharge increased to over 6 m^3/sec in mid-November.

Discussion

Aerial surveys conducted on 22 different streams in 1994 provided limited data on escapement of coho salmon. Information gained from the surveys was, however, crucial for identifying potential sites for subsequent and more-detailed study. Site selection was based on streams that 1) support sizable runs of coho salmon, 2) are in close proximately to one another so more than one stream could be monitored from a single base camp, 3) are relatively clear to allow counts to be conducted visually from the ground, and 4) are accessible by fixed-winged aircraft as needed to establish and operate a field camp. The airstrip at Yantarni Bay was selected as a suitable base camp for work conducted in 1995 and 1996 as it is accessible by air and provides access by foot to both Clear and Sandy creeks. While these two streams did not have the highest peak counts of the different streams surveyed by air in 1994, densities of adult coho salmon in Clear and Sandy creeks were high given the relative small size of these drainages.

Extreme winds, rain, and overcast skies, common to the Pacific Coast of the Alaska Peninsula, were prevalent during this study. Scheduled foot surveys often had to be postponed, sometimes for several consecutive days, because weather and stream conditions made it difficult to count fish. Effective survey conditions decreased as the season progressed, primarily because rains and increased turbidity became more frequent and intense. The accuracy of counts benefited from having a field crew camped at the remote study site, because observers were able to conduct foot surveys on days that had the best conditions with regard to wind, turbidity, and lighting, rather than following a less-flexible schedule regulated by the availability of flights and safe flying conditions.

The probability of a fish being counted on foot surveys on Clear Creek in 1996 was dependent on the lowest numerical rating of the three survey condition variables we categorized. For example, observer efficiency was low when winds and associated water-surface turbulence was high, even though the stream was running clear and the lighting was good. The relationship between the lowest numerical rating of the three survey condition variables and measured observer efficiency allowed us to apply efficiency corrections independently for each foot survey based on the conditions present during the survey. Adjusting counts using a correction factor based on the conditions encountered during a given survey was supported by the wide range of efficiency values (25 to 100%) we

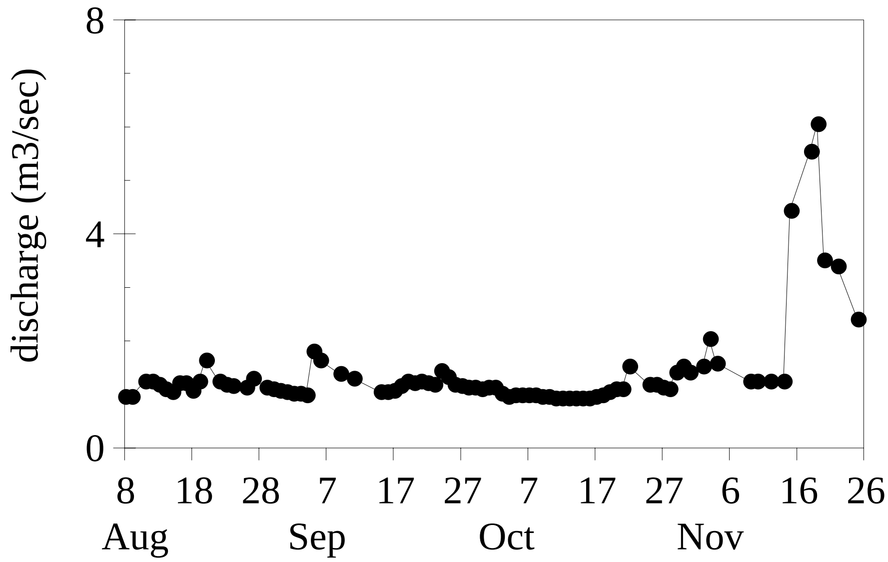

Figure 12. Instantaneous discharge measured on Clear Creek in 1996.

observed on the thirteen efficiency trials conducted on Clear Creek in 1996. For example, on 14 November 1996, 321 coho salmon were counted on Clear Creek. We predicted observer efficiency to be 38% on that day, resulting in a corrected count of 844 fish. If however, the 74% average observer efficiency determined from the 1996 season on Clear Creek were used, the corrected count would equal 404 fish, a decrease of over 400 coho salmon for that survey. Based on these observations, we believe that correcting observer efficiency independently for each survey, as was done for Clear Creek in 1996, improved the accuracy of our corrected counts over the use of uncorrected counts or counts corrected using an average efficiency for the entire season.

Applying a correction factor for observer efficiency can have a pronounced effect on estimates of escapement, especially for foot surveys conducted when observer efficiency is low, counts are high, and residence time is short (Figure 13). The average observer efficiency (74%) used to correct salmon counts from Clear and Sandy creeks in 1995 and Sandy Creek in 1996, was similar to that estimated for other streams (Solazzi 1984; Johnston et al. 1987). However, correcting counts with an average correction factor may be in error when applied to other streams or even different years on the same stream, and may have biased some of our estimates of escapement. Error in assessing observer efficiency will lead to error in estimating the area under the curve and error in the resulting escapement estimate (Hill 1997). If the average observer efficiency is higher than the true efficiency, escapement will be underestimated. Conversely, if the average observer efficiency is underestimated, the area-under-the-curve method will overestimate the true escapement (Bocking et al. 1988). Similarly, estimates of escapement made using actual counts may be in error if efficiency is not 100%, or when a fixed correction factor is used that is based on a relationship between survey conditions and efficiency for a different-sized stream in a geographically different area. Based on our observations, as well as the findings of other studies (Bocking et al. 1988; Solazzi 1984; Irvine et al. 1993), observer efficiency should be quantified on each stream for each year and applied independently for each foot survey as was done on Clear Creek in 1996. Measuring the condition variables present during each survey rather than

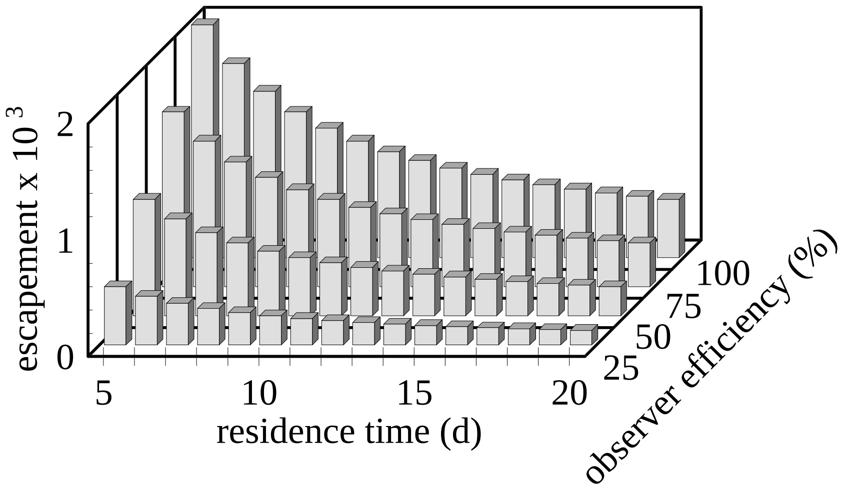

Figure 13. Influence of varying residence time and observer efficiency on estimates of escapement of a hypothetical run of 2,000 fish, calculated using the area-under-the curve model.

subjectively categorizing them as poor, fair, or good as we did in this study, could potentially improve the accuracy of the efficiency correction.

Chum and pink salmon spawned in lower reaches of Clear and Sandy creeks that were accessible throughout the course of the study, and residence times were relatively short. Coho salmon primarily spawned in the upper reaches of the two streams, but were prevented from accessing these areas by migration barriers (beaver dams in Clear Creek, dry channel in Sandy Creek below the stream capture site) until flows increased in October. With the advent of frequent rains accompanied by higher flows, coho salmon were observed spawning in the upper reaches of both streams and correspondingly, our estimates of residence time decreased. It is unclear whether pink and chum salmon would have spawned in the upper reaches had they been accessible.

The extended residence time estimated for coho salmon in Clear Creek in 1996 may have been related to inaccessibility to preferred spawning grounds. Coho salmon were first counted in Clear Creek on 6 September, one day after the instantaneous discharge increased from about 1.2 to 1.8 m^3/sec (Figures 3 and 12). Low flows, however, prevented these early-run fish from migrating over the beaver dams located in the lower reach of the stream. Coho salmon were observed holding in the lower reach of Clear Creek for an extended time during the early segment of the run when flows were low, as reflected in the relatively lengthy residence times (43.1 and 37.3 d) for test groups of fish marked on 10 (N=8) and 18 September (N=11)(Figure 10). Coho salmon counts peaked in late October 1996, the day after a rain event that increased flow to 1.5 m^3/sec, following 26 consecutive days of base flow. With the advent of rains and higher flow, coho salmon were observed passing over the beaver dams in Clear Creek without holding in the lower reach which coincided with a shorter (13.7 d) residence time for the test group of coho salmon (N=381) marked on 22 October.

The average residence times of coho, pink, chum, and sockeye salmon in Clear Creek in 1996 were within the range of values observed on streams in the Pacific Northwest (Table 4) and Alaska (Perrin and Irvine 1990). The 43.1 d and 37.3 d period-specific residence times of coho salmon tagged in September exceeded the maximum of 15.1 d for 22 separate studies summarized by Perrin and Irvine (1990), and 12 d for the Gechiak River in southwest Alaska reported by Minard (1986). Perrin and Irvine (1990) did, however, cite three studies where the residence time of coho salmon exceeded their reported maximum, but considered the values anomalous because they included extended periods of holding before the fish moved to the spawning grounds. To compensate for long periods of holding that results in high residence times and extends the duration of study, researchers often limit the survey area to spawning grounds and calculate a spawning ground residence time (Perrin and Irvine 1990; Bocking et al. 1988). Because we did not know the location of spawning areas and the objective of our study was to estimate escapement for the entire stream population, we defined residence time as the duration adult salmon were alive in the stream. It is important to note, however, that although some coho salmon entered Clear Creek in September 1996, the majority of the run occurred after flow increased, spawning grounds were accessible, and residence time had decreased. The extended residence times for the two test groups of coho salmon tagged in September had little effect on the average residence time for the season, since it was weighted based on escapement, and escapement was low in September.

Estimates of the average residence time of chum (7.9 d) and pink salmon (8.7 d) in Clear Creek in 1996 were considerably less than the 15- or 21-d residence times commonly used by ADFG for calculating escapement indices for the Chignik (Owen et al. 2000) and South Peninsula segments of the Alaska Peninsula (Campbell et al. 1999) Management areas.

Escapement estimates for Clear Creek in 1996, generated using uncorrected counts with average residence times for the season, were 48% and 42% higher for chum and pink salmon than estimates calculated using 15 d as the residence time, and 62% and 59% higher than estimates made using 21 d as the residence time. It is also important to realize that the relationship between residence time and escapement is not linear (Figure 13). For example, a decrease in residence time from 15 to 14 d results in a 7% increase in an escapement estimate, as compared to a 14% increase in escapement when residence time drops from 7 to 6 d. Managers need to recognize the sensitivity of the area-under-the-curve model to changes in residence time because residence times for salmon can vary substantially among streams (Perrin and Irvine 1990) as well as between years on the same stream (Bocking et al. 1988; van den Berghe and Gross 1986).

Coefficients of determination for the thirteen depletion curves ranged from 0.69 to 0.96, indicating a relatively good fit of tagged fish counts to a linear depletion line. Counts of tagged fish, however, were not expected to decline linearly. The mortality rate should be low or zero for fish that just entered the stream and high for spawners that have been in the stream for several days. The fit of count data to a depletion line may have been improved if a non-linear model had been used, or if the data points for the first two or three days after tags were deployed were omitted. Linear regression analyses did, however, provide a quick and effective way to assess the variability of tagged-fish counts over time. The regression analyses had no effect on estimates of residence time because they were calculated using the area-under-the-tag-curve method, instead of estimated based on the x-intercept of the linear depletion line.

Table 4. A comparison of average and range of residence times (rt) of salmon in streams in the Pacific Northwest as summarized by Perrin and Irvine (1990), with estimates for salmon in Clear Creek in 1996.

Salmon	Perrin and Irvine (1990)			Clear Creek, 1996		
species	average rt (d)	range rt(d)	number of studies	residence time (d)	range rt (d)	number of test periods
sockeye	13.2	7.0-26.5	23	18.1	17.1-23.5	2
chum	11.9	4.0-21.2	54	7.9	7.1-8.5	4
pink	17.3	4.6-40.5	36	8.7	7.4-11.9	4
coho	11.4	3.0-15.1	22	13.8	43.1-13.7	3

Carcass counts did not accurately reflect the number of deceased salmon in the streams we studied, even when survey intervals were short (Appendix B). We attribute the low carcass counts to the consumption of dead and dying fish by brown bears. Parts of salmon carcasses were abundant up to 0.5 km from the streams we studied, and pieces of streamer tags were found in bear scat up to 5 km from Clear Creek where tags were deployed. The frequent removal of carcasses from the streams by bears resulted in large and highly variable differences between cumulative carcass counts and escapement estimates. Ruggerone et al. (2000) reported similar variability in the relationship between escapement and predation rates on sockeye salmon by brown bears in Hansen Creek, a relatively small stream in the Wood River lake system near Bristol Bay, Alaska. They observed salmon predation rates by bears in excess of 90% of the run in a low escapement year (about 500 fish), with the rate decreasing to below 20% when runs were greater than about 7,000 fish. In areas with high densities of bears like the streams we studied on the Alaska Peninsula, escapement index methods that rely on carcass counts are inappropriate.

Estimates of coho salmon escapement were slightly higher in 1995 than in 1996 on Clear Creek and about two times greater in 1995 than 1996 on Sandy Creek. Owens et al. (2000) reported a similar decrease in the commercial catch of coho salmon in the Chignik Management Area from 1995 to 1996, although commercial catch statistics may not reflect escapement for the area. The decrease in escapement estimates for coho salmon in Sandy Creek between 1995 and 1996 was similar to that observed for chum and pink salmon and is, in part, likely due to the capture of its upper reach by Camp Creek.

It is important to point out that our estimates of sockeye, chum, and pink salmon were derived from incomplete coverage of the runs. While count data are not available prior to the first surveys conducted in 1995 and 1996, an absence of carcasses on the first surveys indicates that fish that entered the streams prior to the first surveys may have still been alive and therefore counted and reflected in the overall escapement estimates (Appendix C). This is further supported by a review of the peak carcass counts for sockeye, chum, and pink salmon, which occurred about 2 to 4 weeks after the first surveys of each year were conducted.

The estimated escapement of sockeye salmon was relatively low in Clear Creek in 1995 and 1996 compared to abundance estimates for other species. This should be expected given the small size of the stream and the lack of lakes or ponds in the drainage suitable for rearing juvenile sockeye salmon (Table 2). Estimates of chum salmon escapement in Clear and Sandy creeks in 1995 were similar, but the lack of a measure of variability in escapement estimates did not allow us to compare them statistically. Estimated escapement of chum salmon was greater in 1996 than in 1995 on Clear Creek, but less in 1996 than in 1995 on Sandy Creek. Estimates of chum salmon escapement for the Chignik Management Area were similar between the two years (Owens et al. 2000). The decrease in chum salmon escapement on Sandy Creek between 1995 and 1996 was most likely a response to reduced flow and the decrease in available spawning habitat caused from its capture by neighboring Camp Creek in 1994. Fish returning to spawn in Sandy Creek may have also had difficulty locating their natal stream, since the headwaters of Sandy Creek now flow primarily into Camp Creek. It is also possible that estimates of escapement for Clear Creek were influenced by the stream capture because the upper reach of Sandy Creek is now a tributary to Camp Creek, only a short distance upstream of the confluence of Clear and Camp creeks.

Stream capture on Sandy Creek may have also accounted for the decrease in pink salmon from 1995 to 1996. Although pink salmon populations often fluctuate greatly from one year to the next, escapement estimates on nearby Clear Creek were similar in 1995 and 1996. The combined commercial catch and escapement estimates for pink salmon in the Chignik Management Area, however, decreased by more than 50% from 1995 to 1996 (Owens et al. 2000). The capture of the upper reach of Sandy Creek by Camp Creek also may have contributed to the magnitude of decrease in pink salmon escapement on Sandy Creek between the 2 years.

Recommendations

Estimating salmon escapement on streams located on the Pacific coast of the Alaska Peninsula is a challenging task. The remoteness and scattered distribution of streams in the area amplifies the necessary logistics and expense associated with conducting relatively routine monitoring efforts. This difficulty is elevated when coho salmon are targeted for study because runs may extend well into November when high winds, frequent rains, high flows, turbid discharge, and ice may limit the effectiveness of visual counts. Access to Clear and Sandy creeks provided by the primitive landing strip, coupled with the close proximity of the two drainages, makes the area a logical choice for future monitoring efforts. In addition, the two streams were considered representative of the numerous small, short drainages typical of the Pacific Coast of the Alaska Peninsula.

We discourage the use of any escapement methods that rely on carcass counts because of predation on dead and dying fish by brown bears. The area under the curve method, when used in conjunction with foot surveys corrected for observer efficiency and measured residence times, may be well suited for estimating salmon escapement in streams on the Pacific side of the Alaska Peninsula. It is, however, labor intensive and can be costly, especially given the remoteness of the area. To conserve effort, the survey interval could be extended to approximate the residence time specific for that survey interval without a substantial loss of accuracy in the estimate, but should not exceed about 10 d during the peak-spawning phase of the run. Increasing the survey interval beyond the 3-d average for Clear Creek in 1996 would allow a crew to sample more streams during a field season, which may provide an assessment of between-stream variability in determining general trends of escapement. Extending the survey interval beyond the period-specific residence time should be avoided, however, as the precision of escapement estimates rapidly declines when survey intervals exceed residence time (Hill 1997).

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Appendix A. Aerial counts of adult coho salmon from selected streams located along the Pacific Coast of the Alaska Peninsula in the fall and winter 1994. Streams are listed approximately from north to south.

Location	Date	ADF&G stream catalog #	Latitude longitude	Coho count	Water visibility	Aircraft	Comments
Big Creek	25-Sep-94	262-85-10010	N57° 28.45 W157° 12.50	95	fair	Jet Bell Ranger 206	surveyed from mouth to N57.31.11, W156.16.58, many Dolly Varden
	01-Dec-94			30	excellent	Cessna 206	river with 60% ice cover
Des Moines Creek	25-Sep-94	262-85-10020	N57° 25.67 W156° 18.57	0	poor	Jet Bell Ranger 206	surveyed from mouth to N57.28.41, W156.21.63
Des Moines Creek South Fork	25-Sep-94	262-85-10020-2005	N57° 25.97 W156° 19.25	15	fair	Jet Bell Ranger 206	surveyed from mouth to N57.26.71, W156.24.27
Pass Creek	25-Sep-94	262-85-10030	N57° 24.20 W156° 21.22	80	good	Jet Bell Ranger 206	surveyed from mouth to N57.25.44, W156.28.02
Short Creek	25-Sep-94	262-85-10040	N57° 22.30 W156° 24.51	0	good	Jet Bell Ranger 206	some Dolly Varden
Alai Creek	25-Sep-94	262-85-10070	N57° 18.75 W156° 32.38	0	good	Jet Bell Ranger 206	
Kialaguik Creek	25-Sep-94	262-85-10080	N57° 17.50 W156° 33.13	20	fair	Jet Bell Ranger 206	
	01-Dec-94			NA	NA	Cessna 206	100% ice cover
NW tributary of Kialagvik	25-Sep-94	262-85-10080-2003	N57° 17.17 W156° 33.95	80	good	Jet Bell Ranger 206	
	01-Dec-94			0	excellent	Cessna 206	river with 30% ice cover
Imuya Bay" Creek	25-Sep-94	262-85-10110	N57° 15.10 W156° 22.87	0	poor	Jet Bell Ranger 206	some Dolly Varden
	01-Dec-94			0	excellent	Cessna 206	river with 95% ice cover
Glacier Creek	25-Sep-94	272-96-10200	N57° 8.8 W156° 25.77	0	poor	Jet Bell Ranger 206	
Agripina River	25-Sep-94	272-96-10100	N57° 6.98 W156° 29.35	0	excellent	Jet Bell Ranger 206	surveyed from mouth to N57.08.34, W156.33.00; many Dolly Varden
Port Wrangell" Creek	25-Sep-94	272-92-10100	N57° 4.47 W156° 36.62	0	good	Jet Bell Ranger 206	surveyed from mouth to N57.08.13, W156.37.27
	01-Dec-94			0	excellent	Cessna 206	river with 70% ice cover; surveyed flying downstream, out of narrow box canyon

Appendix A (continued). Aerial counts of adult coho salmon from selected streams located along the Pacific Coast of the Alaska Peninsula in the fall and winter 1994. Streams are listed approximately from north to south.

Location	Date	ADF&G stream catalog #	Latitude longitude	Coho count	Water visibility	Aircraft	Comments
Chiginagak River	25-Sep-94	272-90-10400	N57° 2.52 W156° 45.80	250	fair	Jet Bell Ranger 206	Water clarity fair - poor survey supported by the # of fish sampled just prior to survey.
	01-Dec-94			10	excellent	Cessna 206	river with 70% ice cover
Nakalilok (main)	22-Sep-94	272-80-11000	N56° 58.3 W156° 55.28	1790	fair	Jet Bell Ranger 206	
	01-Dec-94			80	excellent	Cessna 206	river with 60% ice cover
Camp Creek (at Yantarni air strip)	22-Sep-94	272-80-10600	N56° 53.22 W157° 2.12	90	fair	Jet Bell Ranger 206	
	26-Sep-94			300	good	Jet Bell Ranger 206	surveyed from mouth to N56.58.09, W157.83.95 – resurvey from 22 Sep.
	01-Dec-94			30	excellent	Cessna 206	river with 60% ice cover
Clear Creek (trib. to Camp Creek)	22-Sep-94	272-80-10600-2006	N56° 55.10 W157° 1.48	655	good	Jet Bell Ranger 206	some coho observed upstream of main beaver dam
	01-Dec-94			40	excellent	Cessna 206	river with 20% ice cover
Sandy Creek	22-Sep-94	272-80-10500-2011	N56° 54.88 W157° 5.5	1070	excellent	Jet Bell Ranger 206	
	01-Dec-94			0	excellent	Cessna 206	river with 95% ice cover
"Y" Creek	22-Sep-94	272-80-10500-2008	N56° 54.73 W157° 4.32	0	excellent	Jet Bell Ranger 206	
Yantarni Creek	22-Sep-94	272-72-10170	N56° 51.43 W157° 11.3	120	poor	Jet Bell Ranger 206	
	26-Sep-94			1815	good	Jet Bell Ranger 206	surveyed from mouth to N56.56.62, W157.18.02 –resurvey from 9/22.
	01-Dec-94			0	excellent	Cessna 206	river with 60% ice cover
North Fork Yantarni Creek	22-Sep-94	272-72-10170-2003	N56° 51.67 W157° 11.18	65	good	Jet Bell Ranger 206	
Misery Creek	26-Sep-94	272-72-10170-2007	N56° 51.95 W157° 11.32	0	excellent	Jet Bell Ranger 206	
Home Creek	26-Sep-94	272-72-10170-2012	N56° 52.35 W157° 10.68	40	excellent	Jet Bell Ranger 206	coho are upstream of established beaver dam

Note: Flight on 1-Dec-94 took 3.5 hrs, round trip from King Salmon. Surveys conducted from altitude of 500 feet. Sun angle was low from the SE. Therefore, we flew upstream where terrain allowed to minimize glare for observer (on right side of aircraft).

Appendix B. Counts of live and dead adult salmon observed during foot surveys conducted on Clear and Sandy creeks in 1995 and 1996.

Stream	Year	Date	Coho salmon		Pink salmon		Chum salmon		Sockeye salmon	
			live	carcass	live	carcass	live	carcass	live	carcass
Clear	1995	28 Aug	1	0	900	0	500	0	35	0
		11 Sep	626	0	1,300	350	470	250	24	1
		25 Sep	735	0	200	400	45	170	11	0
		03 Oct	531	1	13	80	1	20	23	0
		10 Oct	918	0	2	0	2	0	28	0
		20 Oct	939	8	0	0	0	0	24	0
		27 Oct	730	14	0	0	0	0	0	0
		01 Nov	479	11	0	0	0	0	0	0
		05 Nov	133	30	0	0	0	0	0	0
Clear	1996	08 Aug	0	0	73	0	69	0	38	0
		12 Aug	0	0	339	3	325	2	103	1
		14 Aug	0	0	589	3	505	4	143	1
		19 Aug	0	0	921	16	866	39	9	9
		23 Aug	0	0	1,388	38	1,026	144	100	10
		26 Aug	0	0	1,128	66	885	166	99	9
		30 Aug	0	0	1,385	68	910	85	104	6
		02 Sep	0	0	1,465	100	750	160	105	13
		06 Sep	101	0	1,089	135	669	181	91	10
		09 Sep	250	0	685	109	356	111	90	6
		16 Sep	174	0	150	63	45	61	47	4
		20 Sep	255	0	59	12	14	6	45	1
		23 Sep	330	0	8	0	4	0	44	0
		27 Sep	292	0	13	0	2	0	32	0
		30 Sep	220	0	1	0	0	0	21	0
		04 Oct	119	0	0	0	0	1	14	0
		07 Oct	145	0	0	0	0	0	12	0
		11 Oct	159	0	0	0	0	0	14	1
		14 Oct	215	0	0	0	0	0	14	1
		15 Oct	346	1	0	0	0	0	9	0
		19 Oct	221	1	0	0	0	0	10	0
		21 Oct	199	0	0	0	0	0	1	1
		25 Oct	958	28	0	0	0	0	2	0
		28 Oct	1160	15	0	0	0	0	0	0
		02 Nov	607	2	0	0	0	0	0	0
		04 Nov	380	4	0	0	0	0	0	0
		09 Nov	428	5	0	0	0	0	0	0
		14 Nov	321	1	0	0	0	0	0	0
		24 Nov	25	5	0	0	0	0	0	0

Appendix B (continued). Counts of live and dead adult salmon observed during foot surveys conducted on Clear and Sandy creeks in 1995 and 1996.

Stream	Year	Date	Coho salmon		Pink salmon		Chum salmon		Sockeye salmon	
			live	carcass	live	carcass	live	carcass	live	carcass
Sandy	1995	16 Aug	0	0	2,940	0	660	0	0	0
		23 Aug	0	0	2,450	0	250	0	0	0
		29 Aug	31	0	3,415	0	178	0	0	0
		03 Sep	47	0	2,800	140	205	30	0	0
		12 Sep	235	0	2,320	900	95	40	0	0
		23 Sep	268	0	15	198	1	15	0	0
		29 Sep	553	0	26	75	3	0	0	0
		05 Oct	1063	0	2	0	0	0	0	0
		12 Oct	1471	0	0	0	0	0	0	0
		17 Oct	1005	32	0	0	0	0	0	0
		23 Oct	860	24	0	0	0	0	0	0
		02 Nov	286	8	0	0	0	0	0	0
Sandy	1996	10 Aug	0	0	164	0	47	1	2	0
		16 Aug	0	0	247	1	44	0	0	0
		21 Aug	0	0	598	18	209	17	1	0
		28 Aug	0	0	607	139	181	46	0	0
		07 Sep	553	0	490	93	91	34	0	0
		11 Sep	490	0	137	22	16	1	0	0
		01 Oct	462	0	0	0	0	0	0	0
		08 Oct	346	0	1	0	0	0	0	0
		16 Oct	199	0	0	0	0	0	0	0
		24 Oct	269	0	0	0	0	0	0	0
		05 Nov	142	0	0	0	0	0	0	0
		13 Nov	121	2	0	0	0	0	0	0
		23 Nov	20	2	0	0	0	0	0	0

Appendix C. Ratings for lighting, wind, and turbidity conditions experienced during foot surveys conducted on Clear Creek in 1996, categorized as good (3), fair (2), or poor (1).

Date	Condition ratings [a]			Lowest rating for survey	Discharge (m^3/sec)	Observer efficiency	Measured or predicted
	lighting	turbidity	wind				
08-Aug-96	3	3	3	3	0.96	100	predicted
12-Aug-96	2	2	3	2	1.33	70	predicted
13-Aug-96	3	3	3	3	1.27	100	measured
14-Aug-96	3	3	3	3	1.10	100	measured
19-Aug-96	2	2	2	2	1.25	70	predicted
23-Aug-96	2	2	3	2	1.19	80	measured
26-Aug-96	2	2	2	2	1.39	70	predicted
29-Aug-96	3	3	3	3	1.13	100	measured
30-Aug-96	2	3	3	2	1.10	70	predicted
02-Sep-96	3	3	3	3	1.02	100	predicted
06-Sep-96	2	3	3	2	1.64	70	predicted
09-Sep-96	3	3	3	3	1.39	100	predicted
16-Sep-96	2	3	3	2	1.05	88	measured
20-Sep-96	3	3	3	3	1.22	100	measured
23-Sep-96	3	3	3	3	1.36	90	measured
27-Sep-96	2	3	3	2	1.16	85	measured
30-Sep-96	2	3	3	2	1.10	70	predicted
04-Oct-96	2	1	3	1	0.96	40	measured
07-Oct-96	2	1	3	1	0.99	25	measured
11-Oct-96	3	3	1	1	0.93	30	measured
14-Oct-96	2	3	3	2	0.93	55	measured
15-Oct-96	3	2	3	2	0.93	75	measured
19-Oct-96	2	3	3	2	1.05	70	predicted
21-Oct-96	2	3	2	2	1.10	70	predicted
25-Oct-96	2	3	2	2	1.19	70	predicted
28-Oct-96	3	3	3	3	1.22	100	predicted
02-Nov-96	2	2	2	2	1.70	70	predicted
04-Nov-96	2	2	3	2	1.59	70	predicted
09-Nov-96	3	2	3	2	1.25	70	predicted
14-Nov-96	2	1	2	1	2.26	38	predicted
24-Nov-96	2	1	2	1	2.26	38	predicted

[a] condition ratings 1=poor, 2=fair, 3=good.

Appendix D. Area-under-the curve estimates of coho salmon escapement for Clear Creek in 1996, calculated using varying survey intervals (rt=residence time, 11.4 d average rt extracted from a compilation of studies summarized by Perrin and Irving 1990).

All Surveys

Clear Creek Coho salmon			Calculated using actual counts					Calculated using counts corrected for observer efficiency (measured or predicted for each survey)				
					Escapement estimates					Escapement estimates		
Survey date	Survey interval (days)	1996 period-specific rt	Actual count	Area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature (11.4 d)	Corrected count	Corrected area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature[b] (11.4 d)
08-Aug-96	4	43.1	0	0	0	0	0	0	0	0	0	0
12-Aug-96	3	43.1	0	0	0	0	0	0	0	0	0	0
14-Aug-96	5	43.1	0	0	0	0	0	0	0	0	0	0
19-Aug-96	4	43.1	0	0	0	0	0	0	0	0	0	0
23-Aug-96	3	43.1	0	0	0	0	0	0	0	0	0	0
26-Aug-96	4	43.1	0	0	0	0	0	0	0	0	0	0
30-Aug-96	3	43.1	0	0	0	0	0	0	0	0	0	0
02-Sep-96	4	43.1	0	0	0	0	0	0	0	0	0	0
06-Sep-96	3	43.1	101	303	7	22	27	144	432	10	31	38
09-Sep-96	7	37.3	250	1750	47	127	154	250	1750	47	127	154
16-Sep-96	4	37.3	174	696	19	50	61	198	792	21	57	69
20-Sep-96	3	37.3	255	765	21	55	67	255	765	21	55	67
23-Sep-96	4	37.3	330	1320	35	96	116	367	1467	39	106	129
27-Sep-96	3	37.3	292	876	23	63	77	344	1031	28	75	90
30-Sep-96	4	37.3	220	880	24	64	77	314	1256	34	91	110
04-Oct-96	3	37.3	119	357	10	26	31	298	893	24	65	78
07-Oct-96	4	13.7	145	580	42	42	51	580	2320	169	168	204
11-Oct-96	3	13.7	159	477	35	35	42	530	1590	116	115	139
14-Oct-96	1	13.7	215	215	16	16	19	391	391	29	28	34
15-Oct-96	4	13.7	346	1384	101	100	121	461	1845	135	134	162
19-Oct-96	2	13.7	221	442	32	32	39	316	632	46	46	55
21-Oct-96	4	13.7	199	796	58	58	70	284	1136	83	82	100
25-Oct-96	3	13.7	958	2874	210	208	252	1369	4107	300	298	360
28-Oct-96	5	13.7	1160	5800	423	420	509	1160	5800	423	420	509
02-Nov-96	2	13.7	607	1214	89	88	106	867	1734	127	126	152
04-Nov-96	5	13.7	380	1900	139	138	167	543	2715	198	197	238
09-Nov-96	5	13.7	428	2140	156	155	188	611	3055	223	221	268
14-Nov-96	10	13.7	321	3210	234	233	282	844	8440	616	612	740
24-Nov-96	13.7 [b]	13.7	25	343	25	25	30	64	877	64	64	77
totals				28322	1745	2052	2484		43027	2752	3118	3747

Appendix D (continued). Area-under-the curve estimates of coho salmon escapement for Clear Creek in 1996, calculated using varying survey intervals (rt=residence time, 11.4 d average rt extracted from a compilation of studies summarized by Perrin and Irving 1990).

One-Week Survey Intervals

Clear Creek Coho salmon			Calculated using actual counts					Calculated using counts corrected for observer efficiency (measured or predicted for each survey)				
					Escapement estimates					Escapement estimates		
Survey date	Survey interval (days)	1996 period-specific rt	Actual count	Area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature (11.4 d)	Corrected count	Corrected area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature[b] (11.4 d)
06-Sep-96	10	43.1	101	1010	23	73	89	144	1440	33	104	126
16-Sep-96	7	37.3	174	1218	33	88	107	198	1386	37	100	122
23-Sep-96	7	37.3	330	2310	62	167	203	367	2567	69	186	225
30-Sep-96	7	37.3	220	1540	41	112	135	314	2198	59	159	193
07-Oct-96	7	13.7	145	1015	74	74	89	580	4060	296	294	356
15-Oct-96	6	13.7	346	2076	152	150	182	461	2768	202	201	243
21-Oct-96	7	13.7	199	1393	102	101	122	284	1988	145	144	174
28-Oct-96	7	13.7	1160	8120	593	588	712	1160	8120	593	588	712
04-Nov-96	10	13.7	380	3800	277	275	333	543	5430	396	393	476
14-Nov-96	10	13.7	321	3210	234	233	282	844	8440	616	612	740
24-Nov-96	13.7 [b]	13.7	25	343	25	25	30	64	877	64	64	77
totals					1616	1887	2284			2511	2846	3445

Two-Week Survey Intervals

Clear Creek Coho salmon			Calculated using actual counts					Calculated using counts corrected for observer efficiency (measured or predicted for each survey)				
					Escapement estimates					Escapement estimates		
Survey date	Survey interval (days)	1996 period-specific rt	Actual count	Area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature (11.4 d)	Corrected count	Corrected area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature[b] (11.4 d)
06-Sep-96	14	43.1	101	1414	33	102	124	144	2016	47	146	177
20-Sep-96	14	37.3	255	3570	96	259	313	255	3570	96	259	313
04-Oct-96	15	37.3	119	1785	48	129	157	298	4463	120	323	391
19-Oct-96	14	13.7	221	3094	226	224	271	316	4424	323	321	388
02-Nov-96	12	13.7	607	7284	532	528	639	867	10404	759	754	913
14-Nov-96	10	13.7	321	3210	234	233	282	844	8440	616	612	740
24-Nov-96	13.7 [b]	13.7	25	343	25	25	30	64	877	64	64	77
totals					1193	1500	1816			2025	2478	2999

Appendix D (continued). Area-under-the curve estimates of coho salmon escapement for Clear Creek in 1996, calculated using varying survey intervals (rt=residence time, 11.4 d average rt extracted from a compilation of studies summarized by Perrin and Irving 1990).

Three-Week Survey Intervals

Clear Creek Coho salmon			Calculated using actual counts					Calculated using counts corrected for observer efficiency (measured or predicted for each survey)				
					Escapement estimates					Escapement estimates		
Survey date	Survey interval (days)	1996 period-specific rt	Actual count	Area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature (11.4 d)	Corrected count	Corrected area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature[b] (11.4 d)
06-Sep-96	21	43.1	101	2121	49	154	186	144	3024	70	219	265
27-Sep-96	22	37.3	292	6424	172	466	564	344	7557	203	548	663
19-Oct-96	21	13.7	221	4641	339	336	407	316	6636	484	481	582
09-Nov-96	15	13.7	428	6420	469	465	563	611	9165	669	664	804
24-Nov-96	13.7 [b]	13.7	25	343	25	25	30	64	877	64	64	77
totals					1054	1446	1750			1490	1975	2391

Survey Dates Selected Using the Period-Specific Residence Time as the Interval Between Survey Dates

Clear Creek Coho salmon			Calculated using actual counts					Calculated using counts corrected for observer efficiency (measured or predicted for each survey)				
					Escapement estimates					Escapement estimates		
Survey date	Survey interval (days)	1996 period-specific rt	Actual count	Area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature (11.4 d)	Corrected count	Corrected area under the curve	1996 period-specific rt	1996 average rt (13.8 d)	rt from literature[a] (11.4 d)
06-Sep-96	36	43.1	101	3636	84	263	319	144	5184	120	376	455
11-Oct-96	14	13.7	159	2226	162	161	195	530	7420	542	538	651
25-Oct-96	15	13.7	958	14370	1049	1041	1261	1369	20535	1499	1488	1801
09-Nov-96	15	13.7	428	6420	469	465	563	611	9165	669	664	804
24-Nov-96	13.7[b]	13.7	25	343	25	25	30	64	877	64	64	77
totals					1789	1956	2368			2894	3129	3788

[a] Average residence time derived from a compilation of studies conducted in the Pacific Northwest and Alaska, summarized by Perrin and Irvine (1990).
[b] Period-specific residence time used as the survey interval.

Appendix E. Average and standard deviation of lengths by age and sex, for fish captured in selected streams along the Pacific Coast of the Alaska Peninsula, 1994 to 1996.

Stream	Year	Species	Sex	Age	Average length	Standard deviation	Sample size	Percent
Big Creek	1994	coho salmon	female	1.1	611	42	3	23
			male	1.1	653	11	3	23
				2.1	593	64	6	46
				3.1	715		1	8
			overall		620	58	13	100
Camp Creek	1994	coho salmon	female	1.1	571	60	3	30
				2.1	635		1	10
			male	1.1	577	111	3	30
				2.1	656	29	3	30
			overall		605	73	10	100
		DollyVarden	unknown	-	422	42	22	63
			female	-	415	37	5	14
			male	-	482	59	8	23
			overall		434	52	35	100
	1995	coho salmon	female	-	580	69	17	5
				1.1	603	32	35	10
				2.1	621	35	78	23
				3.1	626	29	26	8
			male	-	568	55	26	8
				1.1	582	47	41	12
				2.1	611	47	105	31
				3.1	577	64	14	4
			overall		604	48	342	100
		Dolly Varden	unknown	-	375	7	2	5
			female	-	436	39	30	71
			male	-	475	37	10	24
			overall		443	43	42	100
Chiginagak Creek	1994	coho salmon	unknown	-	533		1	1
				1.1	618	52	9	7
				2.1	559	51	3	2
			female	-	600	57	3	2
				1.1	631	34	20	15
				2.1	622	28	17	13
			male	-	622	55	4	3
				1.1	611	54	48	37
				2.1	639	36	26	20
			overall		620	47	131	100
		Dolly Varden	unknown	-	470	98	6	100
	1995	Dolly Varden	unknown	-	381		1	100

Appendix E (continued). Average and standard deviation of lengths by age and sex, for fish captured in selected streams along the Pacific Coast of the Alaska Peninsula, 1994 to 1996.

Stream	Year	Species	Sex	Age	Average length	Standard deviation	Sample size	Percent
Clear Creek	1995	coho salmon	female	-	581	84	2	10
				2.1	638	25	6	29
				3.1	622		1	5
			male	-	580	77	3	14
				1.1	616		1	5
				2.1	603	80	8	38
			overall		609	62	21	100
	1996	coho salmon	female	1.1	618	29	9	6
				2.1	615	44	41	29
			male	1.1	573	43	18	13
				2.0	319		1	1
				2.1	602	57	71	51
			overall		602	57	140	100
		chum salmon	female	-	630	41	74	36
			male	-	647	45	132	64
			overall	-	641	44	206	100
		pink salmon	female	-	473	24	49	32
			male	-	483	32	103	68
			overall		480	30	152	100
Kialagvik Creek	1994	coho salmon	female	-	635		1	33
			male	-	595	113	2	66
			overall		608	83	3	99
Nakalilok Creek	1994	coho salmon	unknown	1.1	572	67	2	3
				2.0	355		1	2
				2.1	545		1	2
			female	1.1	619	21	8	13
				2.1	632	29	9	15
			male	-	672	45	2	3
				1.1	618	64	22	35
				2.1	622	49	15	24
				3.1	630	42	2	3
			overall		616	60	62	100
Pier Creek	1994	coho salmon	male	2.1	648		1	100
		Dolly Varden	unknown		395	100	22	26
			female		426	38	36	43
			male		420	45	26	31
			overall		416	62	84	100

Appendix E (continued). Average and standard deviation of lengths by age and sex, for fish captured in selected streams along the Pacific Coast of the Alaska Peninsula, 1994 to 1996.

Stream	Year	Species	Sex	Age	Average length	Standard deviation	Sample size	Percent
Sandy Creek	1994	coho salmon	male	1.1	626	16	5	50
				2.1	646	13	4	40
				3.1	665		1	10
			overall		638	19	10	100
	1995	coho salmon	female	-	586	52	6	3
				1.1	603	36	28	14
				2.1	621	45	50	26
				3.1	673		1	1
				4.0	451		1	1
			male	-	590	48	10	5
				1.1	590	58	28	14
				2.1	611	53	60	31
				3.0	425		1	1
				3.1	611	50	9	5
				4.0	445		1	1
			overall		605	53	195	100
Sandy Creek	1996	coho salmon	female	1.1	573	87	4	29
				2.1	661	26	2	14
			male	1.1	610	45	7	50
				2.1	560		1	7
			overall		603	61	14	100
Y Creek	1995	coho salmon	unknown	2.1	610		1	8
				3.1	560		1	8
			female	1.1	565	26	2	17
				2.1	597		1	8
			male	1.1	597		1	8
			male	2.1	628	23	4	33
				3.1	635	35	2	17
			overall		606	34	12	100
Yantarni Creek	1994	coho salmon	unknown	1.1	505		1	7
			female	1.1	615	33	6	46
			male	-	675		1	7
				1.1	610	69	1	7
				2.1	611	25	4	31
			overall		610	56	13	100