**Regional Operational Plan CF.1J.14-06**

# Operational Plan: Ford Arm Creek Coho Indicator Stock and Sockeye Escapement Monitoring

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**and**

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**June 2014**

**Alaska Department of Fish and Game** **Divisions of Sport Fish and Commercial Fisheries**

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| milliliter | mL |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| nautical mile | nmi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| degrees kelvin | K |
| hour | h |
| minute | min |
| second | s |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity (negative log of) | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| Alaska Administrative Code | AAC |
| all commonly accepted abbreviations | e.g., Mr., Mrs., AM, PM, etc. |
| all commonly accepted professional titles | e.g., Dr., Ph.D., R.N., etc. |
| at | @ |
| compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| copyright | © |
| corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| District of Columbia | D.C. |
| et alii (and others) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g. |
| Federal Information Code | FIC |
| id est (that is) | i.e. |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S.C. | United States Code |
| U.S. state | use two-letter abbreviations (e.g., AK, WA) |

**Mathematics, statistics**

| | |
|---|---|
| *all standard mathematical signs, symbols and abbreviations* | |
| alternate hypothesis | $H_A$ |
| base of natural logarithm | *e* |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, etc.) |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular ) | ° |
| degrees of freedom | df |
| expected value | *E* |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_{2,}$ etc. |
| minute (angular) | ' |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| variance | |
| population | Var |
| sample | var |

*REGIONAL OPERATIONAL PLAN CF.1J.14-06*

# OPERATIONAL PLAN: FORD ARM CREEK COHO INDICATOR STOCK AND SOCKEYE ESCAPEMENT MONITORING

by

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Alaska Department of Fish and Game
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June 2014

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## Signature Page

| | |
|---|---|
| Project Title: | *Ford Arm Creek Coho Indicator Stock and Sockeye Escapement Monitoring* |
| Project leader(s): | *Leon Shaul, Fishery Biologist III* |
| Division: | *Division of Commercial Fisheries, Region 1* |
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## Approval

| Title | Name | Signature | Date |
|---|---|---|---|
| Project Leader | Leon Shaul | Leon D. Shaul | 06-15-14 |
| Research Coordinator | Steve Heinl | Steven C. Heinl | 06-15-14 |

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# PURPOSE

This project provides stock assessment information on coho salmon (*Oncorhynchus kisutch*) at Ford Arm Lake, one of four long term Southeast Alaska coho salmon indicator stocks. Coho salmon presmolts are captured, sampled for age and length, adipose fin clipped, coded-wire-tagged, and released. Returning adults are enumerated and sampled for age, length, and sex, and the presence of coded wire tags. These data are used in combination with estimates of harvest of tagged fish by Alaska Department of Fish and Game catch sampling and Coded wire Tag Laboratory programs to estimate a variety of parameters for the stock. Long term indicator programs such as the Ford Arm project, conducted continuously since the 1980s, provide detailed information on population dynamics useful for establishing objective escapement goals and for managing commercial fisheries that target coho salmon.

# OBJECTIVES

1. Estimate the harvest rate in all marine fisheries for the Ford Arm Lake coho salmon stock such that the estimated coefficient of variation is 5% or less.
2. Determine the total coho salmon escapement using a weir count. In the event of a failure to enumerate all fish that pass the weir, obtain a Chapman mark-recapture estimate of the escapement such that the estimated coefficient of variation is 7% or less.
3. Estimate the total coho salmon return (fisheries and escapement) such that the estimated coefficient of variation is 7% or less.
4. Estimate the proportional distribution of the marine harvest of Ford Arm Lake coho salmon by gear type (troll, purse seine, drift gill net, and sport).
5. Estimate the area distribution of the marine harvest of Ford Arm Lake coho salmon by quadrant (troll harvest) and regulatory district (other gear types).
6. Estimate weekly proportions of the troll harvest of Ford Arm Lake coho salmon.
7. Estimate the total mid-July abundance of coho salmon presmolts such that the estimate has a coefficient of variation of 7% or less.
8. Estimate the age and sex compositions of the escapements to Ford Arm Lake from a sample of 650 coho salmon and 500 sockeye salmon.
9. Obtain a Chapman mark-recapture estimate of the total sockeye salmon escapement such that the estimated coefficient of variation is 10% or less.

# BACKGROUND

The coho salmon (*Oncorhynchus kisutch*) is an important species to commercial, sport and subsistence fisheries in Southeast Alaska. The total common property commercial harvest averaged 2.3 million coho salmon over the decade 2001–2010, of which an average 66% was harvested in troll fisheries (Shaul et al. 2011). The majority of the coho salmon harvested in Southeast Alaska originate in thousands of local streams, of which most are small producers about which little is known. Important contributions are also made by Canadian portions of three major transboundary rivers (Stikine, Taku and Alsek) and streams along the British Columbia coast. Thus, management of fisheries for coho salmon in Southeast Alaska is complicated by the scattered distribution of the resource and highly mixed stock nature of most of the fisheries. Effective management requires an understanding of the migratory characteristics, status, productivity, harvest rates, and contribution to the fisheries of stocks or groups of stocks.

The Alaska Department of Fish and Game (ADF&G) implemented marking programs in the 1970s to better understand and manage Southeast Alaska coho salmon stocks (Gray et al. 1978, Shaul et al. 1991). In the early 1980s, program emphasis shifted to long-term research on selected "indicator stocks" that represent a larger group of stocks (Shaul et al. 1986, Shaul 1994, Shaul and Crabtree 1998). Indicator stocks are marked as smolts or presmolts with coded-wire tags, which makes it possible to estimate smolt production and contribution to fisheries by systematically sampling fishery harvests and escapements. Four stocks have been studied continuously since the early 1980s: Ford Arm on the outer coast, Berners River and Auke Lake north of Juneau, and Hugh Smith Lake south of Ketchikan (Figure 1). In addition to the indicator stocks, a systematic escapement survey program was developed to assess coho salmon spawning abundance in individual streams and aggregates of index streams in Southeast Alaska (Shaul et al. 2011). These programs provide detailed information on population dynamics useful for establishing objective escapement goals and developing models to predict abundance (Clark et al. 1994; Shaul et al. 2009 and 2011), and provide for informed management of fisheries that target coho salmon. A biological escapement goal of 1,300–2,900 spawners was established for Ford Arm coho salmon by Clark et al. (1994) and remains unchanged following a recent review of the updated spawner-recruit data series.

This project covers ongoing stock assessment activities at Ford Arm Lake. Pre-smolt abundance, survival, adult return, catch, escapement, exploitation rate, and age composition are estimated annually. Located on the outer coast, the Ford Arm coho salmon stock has shown survival, abundance and exploitation patterns that differed substantially from inside indicator stocks. While exploitation of inside stocks has fallen sharply since the 1990s, Ford Arm Lake continues to be exploited at a moderate to high rate ranging from 49–82% (average 64%) during 2000–2012. It is highly available and important to hook and line fisheries on the outer coast, including the commercial troll fishery and the Sitka marine sport fishery, and is also harvested incidentally to pink salmon (*O. gorbuscha*) in the Khaz Bay purse seine fishery. The most recent summary of statistics on the Ford Arm coho salmon stock is published in the following report:

> Shaul, L., K. Crabtree, E. Jones, S. McCurdy and B. Elliott. 2011. Coho salmon stock status and escapement goals in Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 11-23, Anchorage.

A more detailed summary report specific to Ford Arm Creek for all species through 2009 is in the publication process:

> Shaul, L. D., K. F. Crabtree, K. C. Koolmo, K. M. Koolmo, J. V. Nichols, and H. J. Geiger. In Prep. Studies of coho salmon and other Oncorhynchus species at Ford Arm Creek, 1982–2009. Alaska Department of Fish and Game, Fishery Manuscript Series, Anchorage.

In addition to coho salmon, Ford Arm Lake also supports a sockeye salmon (*O. nerka*) run important to a local subsistence fishery. The sockeye salmon portion of the project is conducted in conjunction with coho salmon assessment. Mark-recapture estimates of escapement have been made and age-length-sex sampling conducted since 1983. Fish are seined, marked, and sampled for age-sex-length on beach spawning areas around the lake in late August and early September and recovery sampling is conducted on carcasses in the system that wash onto the weir.

Ford Arm Lake is also one of the primary systems in the region for which detailed habitat assessments have been being conducted to better define the relationship between habitat features and fish production and escapement needs. Further population monitoring and refinement of direct spawner-recruit goals for the coho and sockeye salmon populations will also contribute to the objectives of the habitat assessment project.

# METHODS

## OVERVIEW

Coho salmon presmolts are captured in baited minnow traps, adipose clipped, coded-wire-tagged and released. The majority of tagged juveniles return as adults 2 years after tagging while fewer than 10% return 3 years after tagging. Returning adults are enumerated and sampled for age, length, and sex and the presence of coded wire tags. A variety of parameters are estimated from data collected under this project. Marine commercial fishery sampling objectives for coded wire tags in Southeast Alaska have been established since 1982 at a minimum of 20% of the catch by area and week. Nearly the entire coho salmon escapement at the Ford Arm Lake weir is sampled for tags. Only a small percentage of the fish are unsampled, a few that may arrive before the weir is installed and those that remain behind the weir when it's removed for the season. The sockeye salmon escapement is estimated by capturing and marking fish in beach spawning areas around the lake and sampling carcasses that drift onto the weir.

### Sample Size

As many coho salmon presmolts as is reasonably practical will be captured and coded-wire-tagged at Ford Arm Lake during a 2-week period that begins during the last week of July. Although the objective is to tag up to 12,000 presmolts, if possible, that number has been reached only four times in 32 years because environmental conditions and abundance are usually not favorable enough to capture and mark that many fish in the allotted time. The catch rate of unmarked presmolts in minnow traps set throughout the Ford Arm system usually declines precipitously by the end of the 12-day tagging period, with most of the later catch comprised of fish that have already been marked and released. Potential tagging rates are limited by increasing incremental tagging costs and potential stress related mortality from repeatedly recapturing the same fish.

Over a 20-year period, the number tagged averaged 9,771 fish (range: 6,483–12,762). Numbers as low as 6,000–8,000 have proven adequate, depending on the survival rate to adulthood which has averaged 12.8% (range: 5.5–22.0%). At the average survival rate, even only 6,500 presmolts tagged would result in a return of 832 marked adults, which would produce about 100 random tag recoveries from the fisheries (at an exploitation rate of 60% and a catch sampling rate of 20%). The vast majority of the harvest of Ford Arm coho salmon occurs in the troll fishery in a single quadrant, and therefore, fishery stratification is very limited. Under even below-average survival and sampling rates, precision of objectives for all parameters will likely be met with 10,000 presmolts which would result in a marked rate of over 10% of the adult return.

Marking of adults at the weir and recapture sampling of spawners is essential to verify the performance of the weir and to estimate escapement when the integrity of the weir has been compromised. Marking and recovery sample sizes for adults returning to Ford Arm Lake were developed around a worst-case scenario that could occur in a year when the weir fails due to flooding at the peak of the run and when conditions for recovery sampling are difficult. Marking fish at the weir is relatively inexpensive, so every fish that is passed is marked. This makes it possible to quickly verify from a recovery sample of 60 to 100 fish whether or not a substantial number of fish have escaped past the weir uncounted. Recovery sampling effort can then be increased if necessary to achieve desired precision. Marking 70% of the escapement, with 30% escaping in flood events, and sampling only 83 spawners for marks would result in a coefficient of variation near the maximum target of 7%. The coefficient of variation for the 17 historical mark-recapture estimates has averaged 3.2% and has exceeded 7.0% only once (9.2% in 1983). Sampling will be discontinued if no unmarked fish are found in a sample of 60 spawners. If more are found, the goal will be increased to 100 or more to ensure the precision objective is met.

An age-sex-length sampling objective of 650 coho salmon was developed from information presented in Appendix A. The appendix lists the required sample size to achieve approximate 90% or 95% simultaneous confidence intervals with the absolute value of the difference between the estimate and the parameter controlled to 5% or less (See Angers 1989, and also see Thompson 1987, or Thompson et al. 1992). The sampling objective is established using the sample size for the 95% confidence intervals, assuming there to be three age classes, an infinite population size, and allowing for up to 20% unageable scale samples due to regeneration or other causes. A weekly and cumulative schedule for the number of samples is shown in Table 1. In the past, during years of large returns, samples based on a percentage of fish or a fixed number over the season tended to either over-sample the run substantially or sample the early part of the run more than the late part. When sampling occurs, samples are to be drawn randomly between adults (age .1) and jacks (age .0). The age composition estimate will be used primarily to assign returns to brood year for spawner-recruit analysis, based on adult spawners and returns. The total objective of 650 samples aims to achieve about 600 samples from adults (based on the 1994–2003 average of 92% adults and 8% jacks).

After the weir is installed, late migrating sockeye salmon that enter the trap will be marked with a dorsal fin clip and released upstream. Sockeye salmon will be seined in beach spawning areas around the lake and in the outlet and sampled for age-length-sex. Fish sampled in lakeshore areas will be marked with an adipose clip, those sampled in the outlet will be marked with an opercle punch. Sampling objectives are 250 marked beach spawners and as many spawners as can be practically caught and marked in the outlet. Sockeye salmon carcasses that drift out of the lake and onto the weir will be sampled for age-length-sex until a total sample of 500 fish from all sources is achieved. All carcasses that wash up on the weir will be sampled for marks, excluding those that are too decomposed for reliable determination. A Chapman mark-recapture estimate (Seber 1982) will be made based on the number of fish marked in lakeshore areas ($M$), total adipose-clipped and unmarked carcasses sampled at the weir ($C$), and the number of adipose-clipped carcasses in the sample ($R$). Based on an average run of about 3,000 sockeye salmon, the statistical objective of a coefficient of variation within 10% would be met with 250 adipose-clipped fish and a total recovery sample of 800 fish. During 1998–2012, the recovery sample averaged 898 fish (range: 152–3,701). Unfortunately, there is no control over the recovery sample which depends on flow through the system to deposit carcasses on the weir. The total escapement estimate will include the Chapman estimate plus the number of upstream migrants that were counted at the weir, the number of fish marked in the outlet area with an opercle punch, and any fish that remain below the weir.

In 1982–2012, the age composition of Ford Arm Lake sockeye salmon averaged 11% age 3, 37% age 4, 45% age 5, and 8% age 6. The age-sex-length sampling objective of 500 sockeye salmon was based on four significant age classes and an average run size of 3,300 fish. The appropriate sample of about 445 fish (Appendix A) was increased to 500 to allow for about 10% unageable scale samples due to regeneration or other causes.

## Juvenile Coho Salmon Tagging

Wire-mesh minnow traps and other larger custom built traps baited with prepared salmon roe are used to capture age-1+ and older juveniles at Ford Arm Lake. As many fish as possible will be trapped and tagged during a 12-day period, with a minimum objective of 10,000 fish. The exact timing of this trip is flexible but usually occurs within the first two weeks of July. The bait used is salmon roe disinfected by an iodine solution and mixed with borax. Fifty traps will be set and checked up to four times daily at 2-hour intervals under normal water conditions. Up to 100 traps will be set and checked twice daily under cold water conditions (less than $11^{o}$ C) when fish are less active. Traps will be moved frequently to maintain the highest possible catch rates. Gray and Marriott (1986) and Magnus et al. (2006) described the minnow trapping method in detail. Juvenile coho salmon of 62 mm snout-fork length and larger will be removed for tagging while smaller fish and recaptured tagged fish will be released immediately. Juveniles are held in pens before tagging until a total of 1,000 to 4,000 are captured, but not for a period longer than three days.

Koerner (1977) and Magnus et al. (2006) provided field guides for the tagging process, which involves anesthetization, sorting fish into three size groups, removal of the adipose fin, and injecting a coded wire tag into the cartilage in the snout. After tagging, the fish will be released near the tagging operation. The released fish disperse rapidly throughout the available habitat.

The most productive locations and habitat types for trapping juveniles in the system have changed over time. The lake was a reliable producer of high catch rates for approximately the first decade, during which the shallows in the lower lake were full of tall aquatic plants. Then, over a period of a few years, the aquatic plant forest mostly disappeared and trapping became mediocre in the lake. During a subsequent period, the outlet stream almost all the way to saltwater remained teaming with juveniles and provided very productive trapping. Increasing nutrient input from an increasing trend in pink salmon escapements during 1982–1996 may have contributed to increasing juvenile abundance and catch rates in the outlet. However, following a year with significant flooding and streambed scouring, the outlet streambed became dished-out and many cut banks were eliminated, which substantially reduced trapping success. In recent years, a beaver pond complex developed at the upper end of Mouse Stream, a tributary at the head of the lake, and an increasing proportion of the catch in recent years has come from there. In 2012 it was deemed efficient to haul by hand the whole tagging operation ¼ mile up Mouse Stream to the pond to tag and release all the fish caught there. The tagging crew has recently also reported that catches in the outlet stream are showing improvement. The lake is still the first area to be targeted during the annual tagging trip, but continues to produce poorer catches compared with the 1980s. It now is only good for three or four days of trapping and then it is more productive to move on to the other habitats.

# COHO SALMON ADULT TAG RETURNS

## Tag Recovery from Fisheries

Marine fisheries in Southeast Alaska and northern British Columbia are sampled for coded wire tags. Commercial catch sampling for coded wire tagged coho salmon in Southeast Alaska is conducted by Alaska Department of Fish and Game (ADF&G) sampling personnel stationed at fish processors and buying stations located throughout the region. The minimum sampling objective is 20% of the catch by district, gear type, and statistical week. Samplers examine coho salmon for missing adipose fins during off-loading and sorting operations. Skippers of fishing vessels and tenders are interviewed to determine fishing districts. The heads of all adipose fin clipped fish are sent to the ADF&G Coded Wire Tag Laboratory in Juneau for tag extraction and reading. Geographic areas used in expanding random tag recoveries vary by fishery: tag recoveries from the drift gillnet fishery are expanded by district, tag recoveries from the purse seine fishery are expanded by seine areas which consist of one or more districts, and recoveries from the troll fishery are expanded by four quadrants which are aggregations of several districts (Table 2, Figure 2). Time strata used for expanding net recoveries are statistical weeks (Sunday through Saturday) while troll fishery samples are expanded over the total catch for open periods (between closures). Exceptions are that troll recoveries are expanded by statistical week and quadrant for analysis of migratory timing for analysis of harvest distribution. Randomly recovered tags are expanded by the inverse of the proportion of the catch that is sampled within area, gear type and weekly or period strata (Clark and Bernard 1987). An adjustment for lost samples is made by multiplying expansions by the inverse of one minus the proportion of heads and tags lost.

The ADF&G Division of Sport Fish conducts a creel census and survey of the Juneau, Sitka, Ketchikan, and Craig marine recreational fisheries. Tags recovered from random samples are expanded over biweekly strata that contain additional stratifications including weekdays vs. weekends, mornings vs. afternoons, and low use vs. heavy use docks (Suchanek and Bingham 1990).

Sampling of British Columbia coastal fisheries and reporting of coded wire tag recoveries is conducted by the Department of Fisheries and Oceans Canada.

## Coho Salmon Escapement Estimation and Sampling

An aluminum bipod picket weir, approximately 60 m long, has been operated at the outlet of Ford Arm Lake annually since 1982, except 1984. The weir has been operated from approximately 12 August through 23 October; however, during 2011–2013 mark-recovery samples indicated that an unusually large proportion of escapement into the lake occurred before the weir was installed. Therefore, beginning in 2014 the tagging and weir operations will be overlapped so that the weir can be installed by about 1 August. A substantial migration begins in late August and continues through early to mid-October with the peak typically occurring in mid-September. Total age-.1 adult escapement estimates during 1982–2012 averaged 3,296 fish (range: 1,546–7,109). Typically, 100–500 fish remain downstream when the weir is removed in late October. Thorough downstream surveys are conducted from 4 October until the weir is removed, whenever conditions are favorable. The migration from saltwater into the outlet stream diminishes to near zero in mid-October, while some fish begin spawning and dying. The subsequent weir count is subtracted from each survey count and the greatest difference between these numbers is recorded as the number of fish remaining downstream.

In 1982 and 1983, the weir became ineffective for periods due to water flowing over the top, and mark-recapture estimates were made in those years (Shaul et al. 1985, 1986). This problem was largely solved by installing a railing with a hardware cloth extension along the top of the weir to maintain a complete barrier in flood conditions. However, minor problems with the integrity of the weir have occasionally occurred in some recent years when bears have opened holes in the wire mesh or when the substrate has washed-out beneath the weir during critical high water periods. This has necessitated marking and recovery to estimate the escapement. Provision for a mark-recapture estimate is made every season in anticipation of potential problems with the weir. Frequently, one or two unmarked fish is found in a sample of 60 to 100 adults even in years when there was no obvious problem with the weir. These fish may have been early migrants that entered the lake before the weir was installed.

All healthy coho salmon that pass through the weir will be captured in the trap, sampled for coded wire tags, and marked with a partial dorsal fin clip. The posterior three rays of the dorsal fin are sheared with wire cutters approximately 1 cm above the fish's back. In 1982 and 1983, fish were tagged with numbered floy tags (Shaul et al. 1985, 1986). However, data from those years indicated virtually complete intermixing of marked fish between tagging and recovery and, therefore, that a single stratum estimate (Chapman 1951) should be unbiased. In 1982, elapsed time between tagging at the weir and live recovery in the inlet streams ranged from 1 to 78 days (Shaul et al. 1985). Therefore, application of numbered tags was discontinued because of the expense and high rates of tag loss. The dorsal clip has been employed as the primary mark in more recent years because it is easier and less expensive to apply. It has virtually no loss rate on live samples, which account for nearly all recovery samples at Ford Arm Lake.

Recovery sampling will be initiated on approximately 10 October, after which passage at the weir is typically minimal. All fish that pass the weir after recovery sampling begins will be marked with a left opercular punch rather than a dorsal clip so that they can be distinguished if recaptured and excluded from the mark-recapture estimate. Recovery sampling is conducted using sport spinning gear and 1/4–3/8 ounce lures. Two rods are fished at locations around the lake. Fish that are captured will be marked with a right opercular punch and sampling will be conducted without replacement until 60 fish have been captured. If more than one fish without a dorsal clip or left opercular punch is captured in this sample, sampling will continue until a large enough sample is obtained such that the coefficient of variation for the escapement estimate is 7% or less.

If no fish are found to have passed the weir uncounted, the gross adult (age .1) escapement estimate will include the sum of the following: (1) total weir count including all weir mortalities and fish that are sacrificed for samples; (2) the greatest difference between a downstream survey count and the weir count after the survey was made; and (3) the sum of pre-spawning mortalities observed in downstream surveys. If fish are found to have passed the weir uncounted, the gross estimate will include the sum of the following: (1) Chapman estimate of the population above the weir when recovery sampling was initiated; (2) fish counted upstream and marked with a left opercular punch after recovery sampling was initiated; (3) upstream migrant mortalities that occur at the weir including fish that die in the trap or are killed there by bears and fish that are sacrificed as samples; (4) unspawned wash-ups on the weir (assumed to be handling mortalities and not included in the Chapman estimate); (5) the greatest difference between a downstream survey count and the weir count after the survey was made; and (6) the sum of pre-spawning mortalities observed in downstream surveys. Estimates of gross escapement are used in calculating total return, harvest rates and juvenile-adult survival rates. Net escapement is the gross escapement estimate minus pre-spawning mortalities that are human inflicted (trap mortalities, bear kills at the weir, coded wire tag samples, and unspawned wash-ups). Net escapement is used to estimate brood year escapement for stock-recruitment analysis.

The coho salmon escapement at Ford Arm Lake will be sampled for coded wire tags. All fish counted past the weir will be captured in the trap and examined for the presence of an adipose fin. Those that have clipped adipose fins will be examined with a coded-wire tag detecting wand to determine whether or not a tag is present. Adipose-clipped fish that do not register a positive signal will be sacrificed; the heads will be removed, labeled with a numbered cinch strap, the number recorded, and the heads sent to the ADF&G Coded Wire Tag Laboratory in Juneau for further verification. An individual record will be made of each fish that passes the weir including whether it is an adult (age .1) or jack (age .0); whether or not it has an adipose clip; and if clipped, whether or not it registers a positive signal by the detector. Age-length-sex samples will be recorded on the same form.

In odd years, Males under 405 mm mid-eye fork length should be classified as jacks while larger fish are classified as adults. In even years, when adults tend to be larger, males under 415 should be classified as jacks. These division points are based on the composite length distributions of age-.0 and age-.1 males for even and odd years during 2006–2013. The historical size distribution of all fish by ocean age (Figure 3) includes both sexes and earlier years when average adult size was substantially larger. When unusual growth conditions occur, as indicated by the size of coho salmon in the fisheries and in early samples at the weir, the classification size may be adjusted during the season based on available length-frequency and age data after consultation with project supervisors. A total of 650 age-length-sex samples will be taken from jacks and adults combined distributed throughout the run. A weekly and cumulative objective for the number of age-sex-length samples is shown in Table 2. If the number of fish obtained in the trap is insufficient to meet the weekly schedule, sampling should be increased in the subsequent week to attain the cumulative goal.

Each fish sampled for age, length, and sex will be anesthetized, placed in a padded measuring trough and measured to the nearest millimeter (mideye to fork length). Four scales will be taken from the left side of the fish approximately two rows above the lateral line along a diagonal downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (INPFC 1963). Scales are mounted on gum cards and impressions later made in cellulose acetate (Clutter and Whitesel 1956).

## Sockeye Salmon Escapement Estimation and Sampling

After the weir is installed, all migrating sockeye salmon that enter the trap will be marked with a dorsal fin clip and released upstream. During the period 15 August–15 September, sockeye salmon will be seined in beach spawning areas around the lake and in the outlet above the weir and sampled for age-length-sex. Fish sampled in lakeshore areas will be marked with an adipose clip, and those sampled in the outlet will be marked with an opercle punch. Sampling objectives are 250 marked beach spawners and as many spawners as can be practically caught and marked in the outlet. Sockeye salmon carcasses that drift out of the lake and onto the weir will be sampled for age-length-sex until a total sample of 500 fish from all sources is achieved using the same methods described for coho salmon. All carcasses that wash up on the weir will be sampled for marks, excluding those that are too decomposed for reliable determination. A Chapman mark-recapture estimate will be made based on the number of fish marked in lakeshore areas ($M$), total adipose-clipped and unmarked carcasses sampled at the weir ($C$), and the number of adipose-clipped carcasses in the sample ($R$). The total escapement estimate will include the Chapman estimate plus the number of upstream migrants that were counted at the weir, the number of fish marked in the outlet area with an opercle punch, and any fish that remain below the weir. Calculation of the Chapman estimate and 95% confidence bounds will be done using the same methods employed in estimating presmolt abundance (see Estimation of Presmolt Abundance, p. 10).

In addition, periodic counts of sockeye salmon in lakeshore spawning areas and in the outlet will be conducted during 15 August–15 September. The lakeshore counts will be conducted by slowly cruising by the spawning beds on the lake side, with one person counting using polarized fish counting glasses while the other drives the boat. The location and number of sockeye salmon spawners counted will be marked on a blank map of the lake. The surveys will be conducted with timing and frequency aimed at obtaining a peak count when the greatest number of sockeye salmon is available in spawning areas to be counted under good visibility conditions. The purpose of the survey counts is to produce a baseline of comparable survey counts and escapement estimates, so that estimates can be generated from survey counts in the event that a mark-recapture estimate is unavailable.

## ANALYSIS OF COHO SALMON TAG RECOVERY DATA

We denote the proportion of fish in the escapement that was tagged as Θ. Let $s$ denote the number of fish in the escapement sampled for adipose clips, let $m_1$ denote the number of fish in sample that have adipose clips, let $m_2$ denote the number of adipose clips in the escapement sampled for tags, and finally, let $t$ denote number of adipose clipped fish in the escapement that are sampled for tags and are found to have tags. Then a reasonable estimate of Θ is given by

$$\hat{\Theta} = \left(\frac{m_1}{s}\right)\left(\frac{t}{m_2}\right). \qquad (1)$$

Let $E$ denote the total number of tagged fish in the escapement, which is estimated by multiplying the total escapement ($N$) by the estimated proportion tagged:

$$\hat{E} = N\hat{\Theta}. \qquad (2)$$

### Harvest by Gear Type and Escapement

Alaska troll fishery tag recoveries are expanded to total catch by quadrant (Table 2) and fishing period (time between fishery openings and closures). Recoveries from drift gillnet fisheries are expanded by district and statistical week, and purse seine fisheries by seine area and week (Table 1). Fishery contribution estimates for tagged fish are divided by the proportion tagged in escapement samples ($\hat{\Theta}$) to estimate total stock contributions $C_i$. Let $\hat{F}_i$ denote the estimated number of tagged fish harvested (expanded sum of random fishery recoveries) in fishery $i$, so that $C_i$ can be estimated with

$$\hat{C}_i = \frac{\hat{F}_i}{\hat{\Theta}_t}. \qquad (3)$$

Let the total run size be denoted by $X$, which is estimated by adding the sum of the estimated catch of the stock in all fisheries and escapement. In other words, our estimate of total run size is given by

$$\hat{X} = N + \sum_i \hat{C}_i \,. \qquad (4)$$

If $N$ is estimated, rather than based on a simple count, then $N$ needs to be replaced by its estimate in the above equation.

## Harvest Rates

The harvest rate ($H$) in fishery $i$ is estimated as follows:

$$\hat{H}_i = \frac{\hat{F}_i}{\sum \hat{F}_i + \hat{E}}. \quad (5)$$

The total harvest rate by all fisheries is estimated as follows:

$$\sum \hat{H}_i = \frac{\sum \hat{F}_i}{\sum \hat{F}_i + \hat{E}} \quad (6)$$

## Harvest Distribution

To estimate the harvest distribution (percent by area and gear type) of Ford Arm Lake coho salmon, expanded tag recoveries in each fishery ($F_i$) are divided by the sum of expanded fishery recoveries in all fisheries. Tag recoveries from the Alaska troll fishery are expanded by quadrant and fishing period while recoveries from drift gillnet fisheries are expanded by district and statistical week (Table 1). Recoveries from purse seine fisheries are expanded by seine area and week.

## Migratory Timing

The migratory timing in troll fishing districts is estimated from the distribution of the harvest of tagged fish by week. Troll fishery tag recoveries are expanded to total catch by quadrant and week. The weekly proportion of the total troll catch is estimated. Expanded weekly recoveries are divided by the sum of expanded recoveries from throughout the season to estimate weekly proportions of total catch. These estimates are based on the dates of landing of tagged fish at fishing ports. Since the average trip length for a troll vessel is 4–6 days, the average time of capture of landed fish probably occurs 2–3 days previously.

## Survival Rates

Survival rates are estimated for tagged juvenile coho salmon from the time of tagging in mid-July until returning adults enter the fisheries. It is assumed that all marked adults returning to the system had been tagged there as juveniles and that there is no incidence of naturally missing adipose fins. Therefore, all adipose clipped fish that do not contain tags are assumed to have shed their tags. A total of $T_1$ juveniles are tagged 2 years before returning as adults. A sample of adipose clipped fish ($m_2$) is drawn from the escapement and sampled for coded wire tags, of which $t$ fish are found to be tagged. The survival rate ($S$) from the time of tagging as presmolts to the adult stage (age .1) is estimated as follows:

$$\hat{S} = \frac{(\sum \hat{F}_i + \hat{E})(\frac{m_2}{t})}{T_1}. \quad (7)$$

Typically, 90% or more of recoveries from juvenile tag groups have been recovered in a single return year, while virtually all tagged smolts have returned in a single year. Tag retention is assumed to be the same in fish from a single return year because it is impossible to determine when adipose clipped fish without tags were marked. Potential bias occurs in the estimates to the extent that different tag retention rates occur in releases from different years.

## Estimation of Presmolt Abundance

The abundance of coho salmon presmolts is estimated using Chapman's modification of Petersen's estimator for closed populations (Seber 1982, p. 60). A sample of presmolts was marked and a sample of adults returning 2 years later is inspected for marks. During the period between marking and recovery, the population is open to mortality but is assumed closed to recruitment. The abundance of presmolts ($N_S$) is estimated as follows:

$$\hat{N}_S = \frac{(M+1)(C+1)}{(R+1)} - 1, \tag{8}$$

where $M$ is the number of presmolts marked and released in a year and $R$ is the number of adipose clip marks in a sample of $C$ returning adult spawners inspected for marks.

In this equation, $R$ is the random variable, and $C$ and $M$ are assumed to be constants. In mark-recapture sampling, $R$ follows a hyper geometric distribution by definition, which can be approximated with the Poisson distribution (Thompson 1992). By simplifying the Chapman mark-recapture equation, we have

$$\frac{1}{\hat{N}_S} \approx \frac{R}{C\,M}. \tag{9}$$

In the Poisson approximation for $R$, the mean and variance are the same, so that the variance (var), standard error (SE), and coefficient of variation (CV) of $\frac{1}{\hat{N}}$ are calculated as follows:

$$\text{var}(\frac{1}{\hat{N}_S}) \approx \frac{R}{(C\,M)^2}, \tag{10}$$

$$\text{SE}(\frac{1}{\hat{N}_S}) = \frac{\sqrt{R}}{C\,M}, \text{ and} \tag{11}$$

$$\text{CV}(\frac{1}{\hat{N}_S}) = \frac{1}{\sqrt{R}} \cdot 100. \tag{12}$$

If the numbers of mark-recoveries are moderate or large, the Chapman estimate should meet the criteria outlined above. The distribution for $R$ can then be approximated with the normal distribution. Under these circumstances, we will assume $\frac{1}{\hat{N}_S}$ is approximately normally distributed, and we will generate 95% confidence intervals for $\frac{1}{N_S}$ as

$$\frac{1}{\hat{N}_S} \pm 1.96 \cdot \text{SE}(\frac{1}{\hat{N}_S}). \tag{13}$$

Finally, 95% confidence intervals for $N_S$ were generated by inverting the confidence intervals for $\frac{1}{N_S}$.

The adult return sometimes includes a small proportion that had been tagged 3 years prior to their return as adults, having remained in freshwater an additional year after tagging. Also, in one year a fish classified as an adult (568 mm) was recovered from the troll fishery 1 year after tagging, indicating it had likely smolted the summer it was tagged. In those cases, the combined sample of fishery recoveries of tagged adults returning to Ford Arm Creek is used to apportion the number of tagged adults passing the weir to estimate *R* attributable a particular presmolt year. When recoveries from tagging in the prior year occurred, a substitute estimate of *R* for equation (1) was generated by multiplying the number of adipose clips in the escapement sample by the proportion of tags recovered in the inriver sample that were tagged 2 years prior to adulthood ($T_{(i\text{-}2)}$) compared with adult recoveries from tags implanted 1 or 3 years prior to adulthood ($T_{(i\text{-}1)}$ or $T_{(i\text{-}3)}$):

$$\hat{R} = R\left(\frac{T_{(i-2)}}{T_{(i-1)} + T_{(i-2)} + T_{(i-3)}}\right) \tag{14}$$

*M* represents the number of adipose clipped fish released without an adjustment for estimated tag loss at the time of release. Tag loss was estimated based on the proportion of fish in the escapement that registered no signal with the field detector and were found not to contain a tag upon further examination at the tag lab under an inherent assumption of no natural incidence of adipose clips. Tag loss was assumed to be equal among all tagged groups.

## Variances

The variances for the estimated parameters are based on methods and equations given in Clark and Bernard (1987), Goodman (1960), and Cochran (1977, p. 154). Most of the variances are approximations, based on product or ratio estimators. For example,

$$Var(\hat{\Theta}_t) = \frac{m_1(m_2-1)(s-1)\hat{\Theta}^2}{m_2(m_1-1)s} + \frac{m_1\hat{\Theta}}{m_2 s} - \hat{\Theta}^2 \text{, and} \tag{15}$$

$$Var(t) = \frac{m_2(m_2-1)s(s-1)\Theta^2}{m_1(m_1-1)s} + \frac{m_2 s\Theta}{m_2} - \Theta. \tag{16}$$

For the escapement, if there is a complete count of fish, then the variance of the estimate of *N* is 0 and *N* is a constant. If *N* is estimated by a Chapman estimate, then an estimated sample variance of *N* is given in Ricker (1975, p. 78). However, if *N* is estimated with an aerial or foot count (possibly expanded to account for unseen fish) there is no analytic means to obtain an estimated sampling variance for the estimate of *N*. A rough guess will be imputed using best professional judgment. The bounds about the escapement estimate are those that the project leader is comfortable with saying that he/she is 95% sure that the true escapement is within these bounds. This interval is then divided by 3.92 (i.e., 2 × 1.96), and squared to get a guess at the variance of the estimate of *N*. For example, if the escapement estimate is 7,000 coho salmon, and the project leader is sure (at least 95% sure) that the true escapement between 6,000 and 8,000 fish, then the estimated variance for the population size will assumed to be approximately $(2{,}000/3.92)^2$ or 260,000. Either way, an estimate of the variance of *N* is needed to estimate the variance of *E*:

$$Var(\hat{E}) = \hat{N}^2 Var(\hat{\Theta}) + \hat{\Theta}^2 Var(\hat{N}) - Var(\hat{N}) Var(\hat{\Theta}), \qquad (17)$$

based on the assumption that estimation of the escapement and tagging proportion are two independent processes.

If we assume that the estimate of Θ is very close to the true value of Θ (i.e., the variance is small, and there is no bias), the variance of $C_i$ can be approximated by

$$Var(C_i) = \frac{\hat{F}_i^2}{\hat{\Theta}^2} \left( \frac{Var(\hat{F}_i)}{\hat{F}_i^2} + \frac{Var(\hat{\Theta})}{\hat{\Theta}^2} \right). \qquad (18)$$

The variance of the $F_i$ can be estimated following formulas in Clark and Bernard (1987). The variance of the total run size is estimated as the sum of the component variances. The estimated variance of harvest rate is approximated by

$$Var(\hat{H}_i) \approx [\frac{\hat{F}_i}{\sum \hat{F}_i + \hat{E}}]^2 [\frac{Var(\hat{F}_i)}{\hat{F}_i} + \frac{\sum Var(\hat{F}_i) + \hat{E}}{(\sum \hat{F}_i + \hat{E}_i)^2} - \frac{2Var(\hat{F}_i)}{\hat{F}_i (\sum \hat{F}_i + \hat{E})}], \qquad (19)$$

and the variance of the sum of $H_i$ over all catch strata is estimated with

$$Var(\sum \hat{H}_i) = [\frac{(E \sum \hat{F}_i)^2}{(\sum \hat{F}_i + \hat{E})^4}][\frac{Var(\hat{E})}{\hat{E}^2} + \frac{\sum Var(\hat{F}_i)}{\sum \hat{F}_i^2}]. \qquad (20)$$

Because the estimates of $R_1$ and $H_1$ are equivalent, the estimated variance of $R_1$ is the same as the variance of $H_1$. The estimated variances of $R_\mathrm{i}$ will be calculated analogous to the variances of the estimate of $H_i$.

The estimated variance of the estimate of $S$ is

$$Var(\hat{S}) = \hat{S}^2 [\frac{Var(t)}{t^2} + \frac{\sum Var(\hat{F}_i) + Var(\hat{E})}{(\sum \hat{F}_i + \hat{E})^2}]. \qquad (21)$$

This variance is not quite correct (there is a covariance term in there, which is probably relatively small), but will be used until the equations can be rearranged to remove the covariance.

## SCHEDULE AND DELIVERABLES

| Date | Personnel | Activity |
|---|---|---|
| 7/1–7/25 | Kent Crabtree | Final project preparation and supply purchasing (groceries and fuel) for tagging. |
| 7/28–8/12 | Wayne Lonn<br>Matt Hemenway<br>Amy Hemenway<br>FWT III | Capture and coded-wire-tag juvenile coho salmon at Ford Arm Lake. Install the Ford Arm Lake Weir; begin enumerating, sampling and marking salmon. |
| 8/15–9/15 | Matt Hemenway<br>Amy Hemenway | Seine, sample and mark sockeye salmon and obtain survey counts in beach spawning areas and the outlet at Ford Arm Lake. |
| 10/1–10/24 | Matt Hemenway<br>Amy Hemenway | Conduct coho salmon escapement counts in the outlet stream below the weir. |
| 10/24–25 | Matt Hemenway<br>Amy Hemenway | Remove weir, pack up camp and store gear. |
| 11/1–2/15 | Kent Crabtree<br>Molly Kemp | Age scale samples; enter and summarize data; repair, maintain and store field gear; prepare equipment, plan logistics. |
| 2/15–6/30 | Leon Shaul<br>Kent Crabtree | Analyze tag recovery data; write operational plans; technical reporting; prepare equipment, plan logistics and purchase supplies for tagging and weir operations. |
| 1/1–12/31 | Leon Shaul<br>Kent Crabtree | Report on project results; Present analysis and results in written reports and orally at meetings of scientists, interested public groups (such as fishing organizations), and management entities including the Board of Fisheries, Pacific Salmon Commission, Federal Subsistence Regional Advisory Council. |

## RESPONSIBILITIES

Duties are assigned in the schedule provided above. Positions that are presently unfilled are referenced by position title only.

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# TABLES AND FIGURES

Table 1.–Weekly and cumulative age-sex-length sampling objective for adult and jack coho salmon, combined, at Ford Arm Lake.

| Time Period | Weekly Goal | Cumulative Goal |
|---|---|---|
| 10–23 August | 20 | 20 |
| 24–30 August | 70 | 90 |
| 31 August–6 September | 120 | 210 |
| 7–13 September | 120 | 330 |
| 14–20 September | 120 | 450 |
| 21–27 September | 90 | 540 |
| 28 September–4 October | 80 | 620 |
| 5–25 October | 30 | 650 |

Table 2.–Statistical areas of Southeast Alaska by seine areas and quadrants.

| Seine Area | Statistical Areas (Districts) | | | |
|---|---|---|---|---|
| SACO | 109 | 110 | | |
| SACI | 105 | 106 | 107 | |
| SASO | 103 | 104 | | |
| SASI | 101 | 102 | | |
| SA11 | 111 | | | |
| SA12 | 112 | | | |
| SA13 | 113 | | | |
| SA14 | 114 | | | |
| **Quadrant** | **Statistical Areas (Districts)** | | | |
| NW | 113 | 114 | 116 | 154 |
| | 156 | 157 | 181 | 183 |
| | 186 | 189 | 191 | |
| NE | 109 | 110 | 111 | 112 |
| | 115 | | | |
| SW | 103 | 104 | 150 | 152 |
| SE | 101 | 102 | 105 | 106 |
| | 107 | 108 | | |

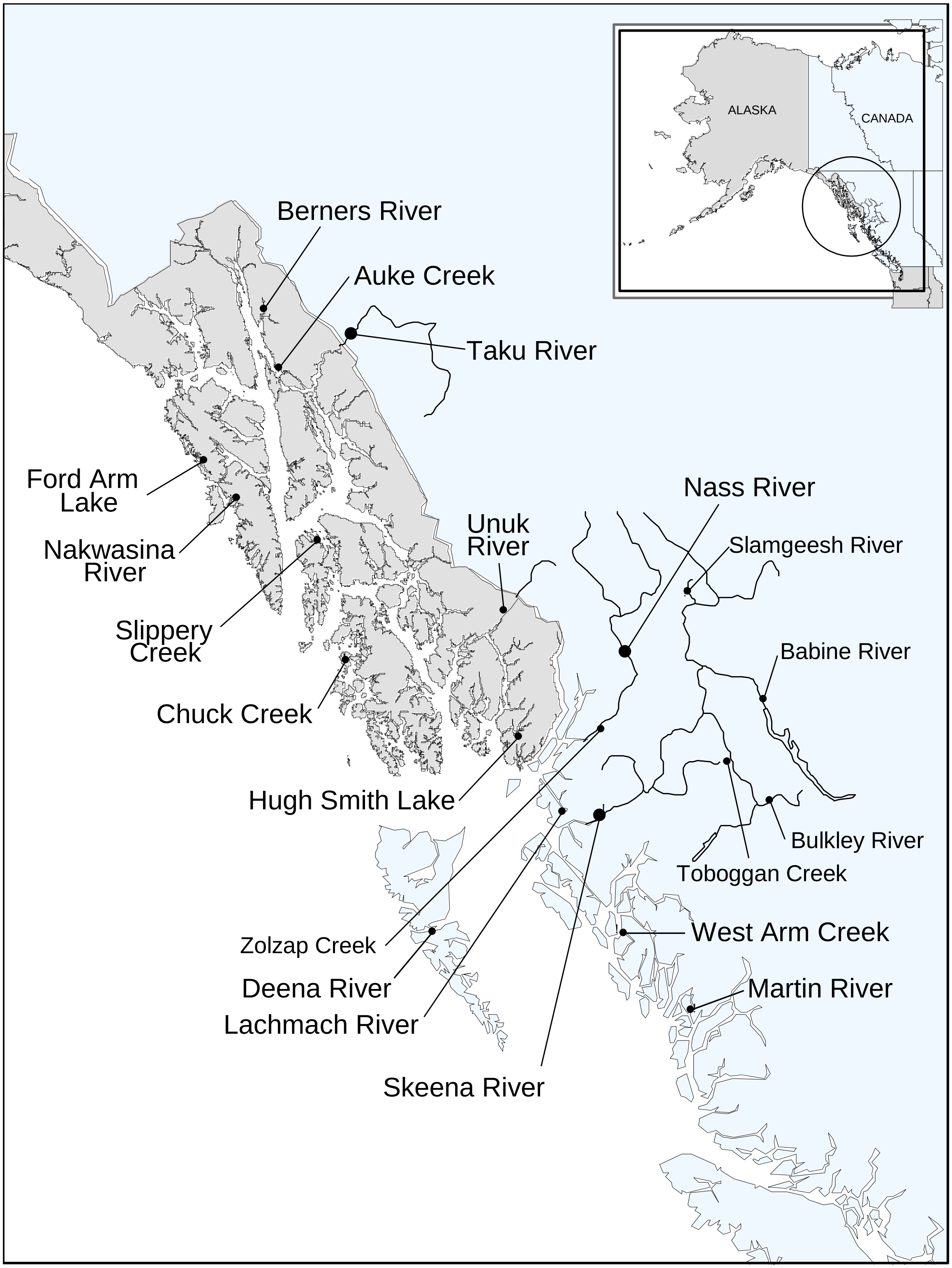


Figure 1.–Map of Southeast Alaska and northern British Columbia, showing the locations of long-term coho salmon stock assessment projects.

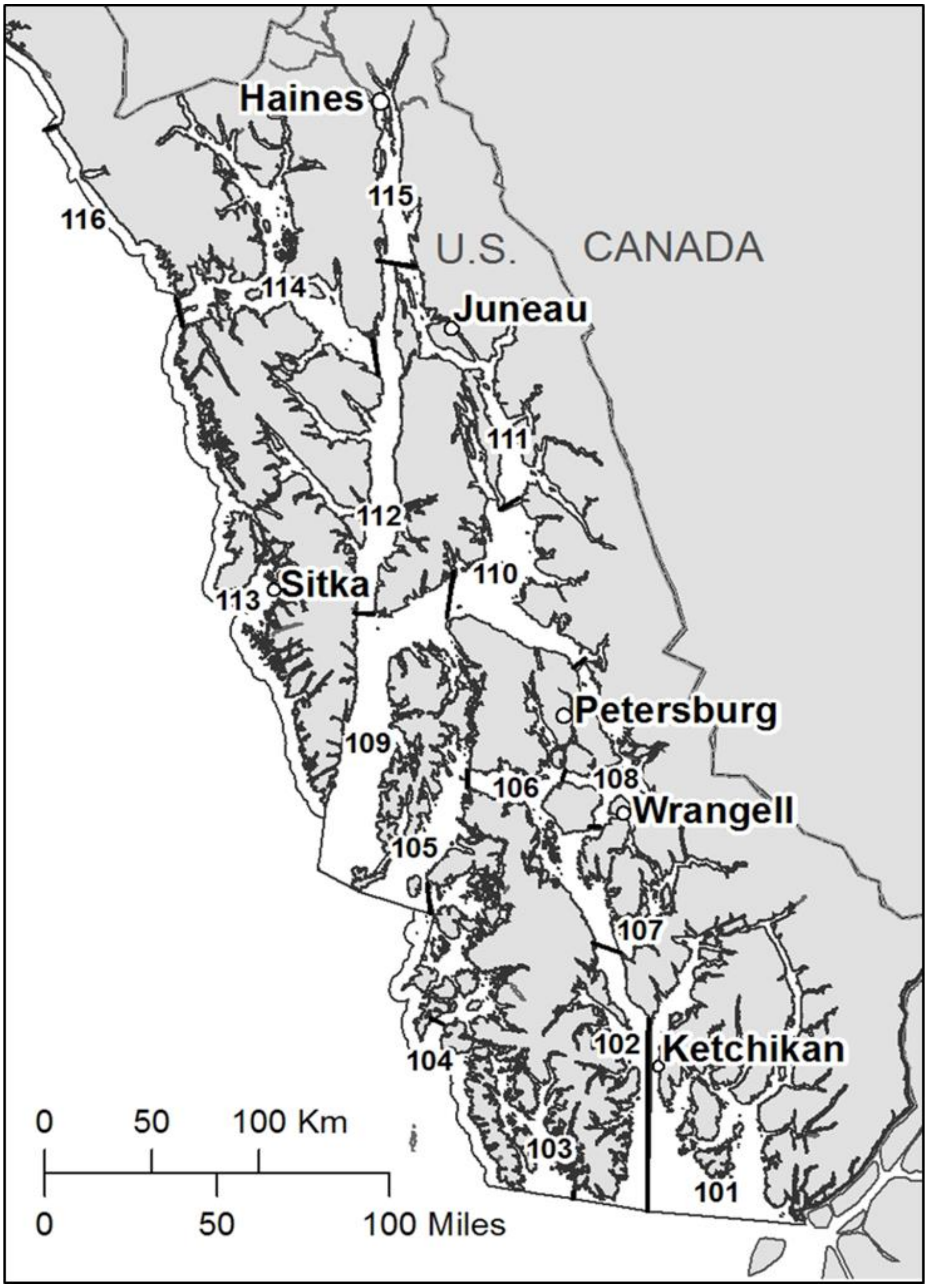


Figure 2.–Fishery management districts in Southeast Alaska.

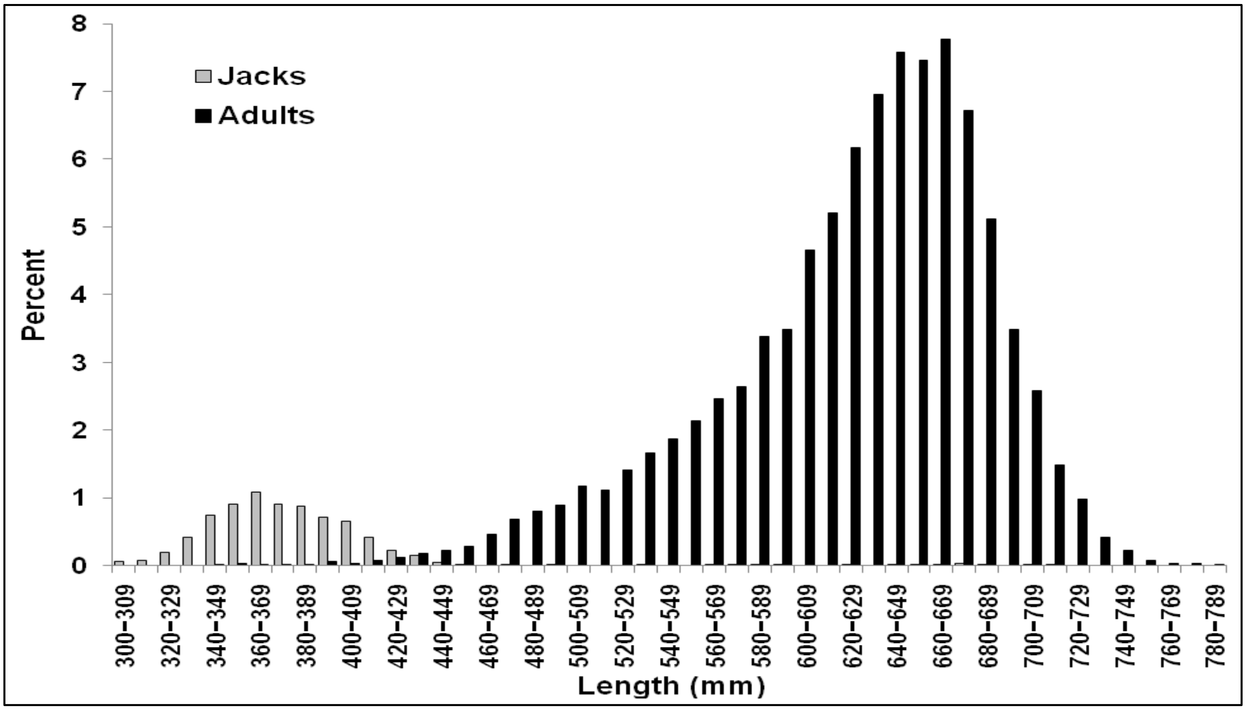


Figure 3.–Composite length-frequency distribution for adult and jack coho salmon based on matching aged scale samples at Ford Arm Lake, 1982–2009.

# APPENDIX

Appendix A.–Sample size required for approximate 90% or 95% simultaneous confidence intervals with the absolute value of the difference between the estimate and the parameter controlled to 5% or less.

| Population Size | Number of age classes | | | | | |
|---|---|---|---|---|---|---|
| | 90% Confidence | | | 95% Confidence | | |
| | 2 | 3 | 4+ | 2 | 3 | 4+ |
| 500 | 176 | 218 | 224 | 218 | 251 | 253 |
| 1000 | 214 | 278 | 288 | 278 | 335 | 338 |
| 1500 | 230 | 306 | 318 | 306 | 377 | 381 |
| 2000 | 239 | 323 | 336 | 323 | 402 | 407 |
| 2500 | 245 | 334 | 347 | 334 | 419 | 424 |
| 3000 | 249 | 341 | 356 | 341 | 431 | 436 |
| 3500 | 252 | 347 | 362 | 347 | 440 | 445 |
| 4000 | 254 | 351 | 366 | 351 | 447 | 452 |
| 4500 | 256 | 355 | 370 | 355 | 453 | 458 |
| 5000 | 257 | 357 | 373 | 357 | 457 | 463 |
| 6000 | 259 | 362 | 378 | 362 | 464 | 470 |
| 7000 | 261 | 365 | 381 | 365 | 469 | 475 |
| 8000 | 262 | 367 | 384 | 367 | 473 | 479 |
| 9000 | 263 | 369 | 386 | 369 | 476 | 483 |
| 10000 | 264 | 370 | 388 | 370 | 479 | 485 |
| 15000 | 266 | 375 | 393 | 375 | 487 | 493 |
| 20000 | 267 | 377 | 395 | 377 | 491 | 497 |
| 25000 | 268 | 379 | 397 | 379 | 493 | 500 |
| 30000 | 269 | 380 | 398 | 380 | 495 | 501 |
| 35000 | 269 | 380 | 398 | 380 | 496 | 503 |
| 40000 | 269 | 381 | 399 | 381 | 497 | 504 |
| 45000 | 269 | 381 | 399 | 381 | 497 | 504 |
| 50000 | 270 | 382 | 400 | 382 | 498 | 505 |
| 60000 | 270 | 382 | 400 | 382 | 499 | 506 |
| 70000 | 270 | 383 | 401 | 383 | 499 | 506 |
| 80000 | 270 | 383 | 401 | 383 | 500 | 507 |
| 90000 | 270 | 383 | 401 | 383 | 500 | 507 |
| 100000 | 270 | 383 | 401 | 383 | 500 | 507 |
| Infinite | 271 | 385 | 403 | 385 | 503 | 510 |