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Abundance and marine survival of coho salmon smolts from the Nome River, Alaska, 2006 through 2009

by:

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ABSTRACT

This report describes results from 2006 through 2009, of an ongoing study to assess the potential for establishing habitat-based escapement goals for coho salmon, *Oncorhychus kisutch*, in the Norton Sound region of Alaska. If the amount of available freshwater habitat can be used to predict smolt production, managers may be able to use smolt production to estimate the number of adult coho spawners needed to seed the freshwater habitat and produce the next generation of smolts. The number of adult spawners needed would form the basis for an escapement goal.

The primary goal of this study was to estimate the annual abundance of coho salmon smolts in the lower Nome River. Additionally, a coded wire tagging study was implemented to estimate marine survival of these smolts to adult escapement. Basic environmental variables, fish run timing, and fish biological characteristics were also recorded to assess correlations with smolt abundance and growth. Stray rates of tagged fish to the nearby Snake River were also estimated in 2008 and 2009.

The population estimates of coho salmon smolt decreased from 118,089 in 2006 to 81,116 in 2007 to 34,318 in 2008 and slightly increased in 2009 to 40,126. Smolt emigration timing peaked each year in mid June, and was composed mainly of age-2 fish. In 2006 and 2007, the smolt emigration peak was followed by an influx of age-0 and age-1 coho salmon, beginning in July. In 2008 and 2009, fewer age-0 and age-1 coho salmon were caught in the lower Nome River after the smolt outmigration peak. Whether the reduced catch of juvenile fish in 2008 and 2009 indicates a fluctuation in the population size, a behavioral change, or both, remains unclear. Observed smolt abundance numbers were near or below the lower bounds of the habitat-based model estimates.

Adult pink salmon, *O. gorbuscha*, escapements were strongly correlated (r^2=0.85) with mean body size of age-2 coho salmon smolts the next year. Mean body length of these coho salmon smolts was in turn positively correlated (r^2=0.97) with subsequent marine survival to adult escapement. There was no evidence of smolt population size affecting growth of age-2 coho salmon (r^2=0.01).

Key Words: abundance, coded-wire-tag, coho salmon, habitat-based production, marine survival, Nome River, Norton Sound, *Oncorhychus kisutch*, smolt.

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INTRODUCTION

Coho salmon were monitored in the Nome River from 2006 through 2009 to generate annual estimates of smolt abundance and marine survival and to collect basic biological information that could help explain variability in the smolt abundance and survival estimates. The abundance estimates continue a time series begun in 2004 and 2005, yielding a 6-year data set developed to determine if coho salmon smolt abundances were within the range predicted by habitat-based smolt production models. The marine survival estimates were used to apportion survival of juvenile coho salmon into freshwater and marine stages, for the habitat-based models, while providing the first estimates of coho salmon marine survival from the Norton Sound region of Alaska. Biological information such as fish community composition, smolt body condition and age structure may also help explain interannual trends, such as years in which marine survival is relatively high or low. This biological information can also be used as a baseline by which to compare population characteristics in future years. The years 2004 through 2009 may have been particularly useful because of high variation in the escapement of the parent year classes of coho salmon smolts, and high variation in the returns of adult pink salmon.

Habitat-based models have been developed throughout much of the coho salmon's range, and are usually based on a well-documented relationship between smolt production and the quantity and quality of available habitat for rearing (e.g., Nickelson 1998). At the regional level, large-scale indicators such as the lineal kilometers or area of habitat available to rearing juveniles is associated with smolt production (Bradford et al. 1997). At the local level (e.g., within a watershed), more specific features such as habitat type are useful predictors of smolt abundance (Sharma and Hilborn 2001). Nemeth et al. (2004; 2009b) developed two models based upon stream length to predict that the Nome River could produce from approximately 72,000 to 182,000 smolts per year; this range was based on the 95% confidence intervals from two different relationships between stream length and smolt production, demonstrated in other populations. One major goal of this study since 2004 has been to estimate the abundance of smolts annually to determine whether the observed abundances fall within the range predicted by the models.

An important reason to estimate the abundance of smolts is because of their strong influence on the eventual abundance of adult coho salmon (Bradford et al. 1997). Fishery managers have used smolt abundance estimates, and some assumptions about fecundity and smolt survival, to manage adult harvest and escapement goals in such a way as to allow enough spawning adult salmon to return to produce a given level of smolt production (Bocking and Peacock 2005). Smolt abundance is also used to predict the number of adults returning the following year, given assumptions about marine survival (Volkhardt et al. 2007). Shaul et al. (2007) estimated that smolt abundance explained nearly as much of the variation in adult returns as marine survival for a variety of coho populations in Washington, British Columbia, and southeast Alaska. Estimates of smolt abundance from the Nome River could possibly be used to calculate adult escapements needed to maintain the 6-year average abundance of smolts, and to predict years in which the subsequent adult run is likely to be large or small (based on relative abundance of the smolt cohort).

The variable that links smolt production to adult return is survival at sea. Estimates of marine survival are instrumental when attempting to project subsequent adult returns based upon smolt abundances. Although marine survival rates have been determined for populations outside of Norton Sound, survival is heavily influenced by geography (Shaul et al. 2007) and the applicability of these estimates to Norton Sound populations is questionable. Estimates from the Nome River provide the first empirical data useful to our study population, while also providing the best indicator data to date for nearby populations in Norton Sound. An estimate of marine survival was the second major goal of the study from 2006 through 2009.

Although smolt abundance is correlated with habitat quality and type, it can realistically be influenced by other variables such as climatic variability and density dependence. Favorable overwinter temperatures, for example, could increase egg or fry survival and lead to an increase in smolt abundance. A large increase in juvenile coho salmon prey populations could allow smolts to reach a larger size that may, in turn, affect marine survival. We monitored age and size structure of coho salmon smolts each year, as well as the relative abundance of other fish in the system, to determine if these variables could help explain variations in smolt abundance or survival. Collection of biological and ecological data was a third major goal of the work from 2006 through 2009.

Our initial studies in 2004 and 2005 showed that the age structure and run timing of juvenile coho salmon in the lower river could introduce uncertainty when evaluating actual smolt abundance against predicted smolt production from a habitat model (Williams et al. 2006). Although most smolts appear to migrate in a distinct pulse in June that is composed primarily of age-2 fish (fish that spent two winters in freshwater), there were a number of additional juvenile coho present at the mouth of the river in July and August. These late-season fish were younger than the peak-season smolts (e.g., mostly age-1), but some of them were of an equivalent size and potentially capable of smolting late in the summer. Adult returns indicate that some age-1 smolts migrate to sea, but not whether these fish smolted during the peak of the outmigration or came from a late seaward migration. This uncertainty could affect the total smolt population estimate by as much as 25% and hence our understanding of the relationship between actual smolt production and the production predicted by the habitat model. The final goal of the project from 2006 through 2009 was to determine whether these late season fish found at the river mouth should be added to the smolt total for each year.

In summary, the study objectives from 2006 through 2009 were to estimate annual smolt abundance from the entire river, to estimate the subsequent marine survival of these smolts, to monitor biological and ecological factors that could influence abundance and survival, and to assess whether juvenile coho salmon observed at the river mouth in July and August should be included as part of the total smolt production when comparing with the production predicted by the habitat model.

There are several reasons why the Nome River during the study period was particularly useful for addressing these objectives. First, the Alaska Department of Fish and Game monitors adult salmon returns to the Nome River annually, allowing us to examine the relationships between smolt abundance and adult returns. Second, such examinations are more useful when the data have high contrast, and this study covers a period of relatively high contrast years (based on criteria presented by Brannian et al. 2006) of adult coho salmon escapements, from 548 fish in 2003 (a record low) to 10,308 fish in 2006 (a record high). If adult run size affects subsequent smolt abundance, progeny from these escapements would be expected to differ in abundance. Conversely, if smolt abundance is influenced chiefly by habitat quantity, these contrasting escapements should result in little differences in smolt abundance. Third, one factor that could also affect coho salmon abundance and marine survival is the influx of nutrients provided by pink salmon, either in the form of pink salmon carcasses, eggs, or fry. Pink salmon abundances had high contrast during the study period (from over one million in 2004 to a low of 16,500 fish in 2009), increasing the ability to detect responses in juvenile coho salmon, such as larger body size in years when pink salmon fry are abundant than in years when pink salmon fry are scarce.

OBJECTIVES

1. Estimate coho salmon smolt abundance) in 2006—2009.
2. Tag coho salmon smolts with coded-wire tags in 2006—2008.
3. Examine returning adults for coded-wire tags in 2006—2009.
4. Estimate marine survival of coho salmon based upon the number of coded-wire tags identified.
5. Monitor environmental and biological factors that may influence smolt abundance or survival.
6. Assess whether juvenile coho salmon observed at the river mouth in July and August should be included as part of the total smolt production

All objectives of the project were met.

METHODS

The Nome River watershed is 4th order at 1:63,360 scale and is 51 km long, drains 420 km^2, and empties into Norton Sound 5 km east of the town of Nome (Figure 1). The outlet is narrow and high energy, with an estimated mean discharge of 6.5 m^3/s (Selkregg 1976, as reported by Webb and McLean 1991). The Nome River in its current state is essentially a non-estuarine system entering directly into Norton Sound, with only sporadic mixing of fresh and marine waters in the lower river (Nemeth et al. 2005).

Fish were sampled at the same two sites from 2006 through 2009 (Figure 1), which were the same sites used in 2005 and most of 2004 (Williams et al. 2006). Site 1 was located 1.5 km upstream from Norton Sound. Site 2 was located 0.5 km upstream from Norton Sound (about 200 m downstream of the road bridge over the Nome River).

Sampling gear

Site 1 was fished with a single fyke net set perpendicular to the water current. Wings extended out from either side of the trap mouth to help funnel fish into the trap; one wing was made of 1.27 cm stretched mesh netting and extended 15 m to shore at an upstream angle of approximately 45°. The other wing extended out into the thalweg of the river at a more acute angle; this wing was made of 1.27-cm Vexar©, measured 10.7 m long by 1.2 m high, and was supported by wood and rebar supports placed approximately every 1 m to provide resistance against the current. The fyke net trap had a mouth opening that measured 1.7 m by 1.8m and which was faced with 0.64 cm stretched mesh netting supported by a stainless steel frame (Christensen Net Works, Everson, WA).

A fyke net with paired cod ends was fished from the shoreline at Site 2, approximately 1.0 km downstream from Site 1. The cod ends consisted of traps of 1.27-cm stretched mesh netting, supported by stainless steel frames (1.7 m x 1.8 m). A lead net of 2.5-cm knotless nylon mesh was 2 m deep and ran 60 m to the shoreline when fully extended. A single 15 m wing extended from the outside edge of each cod-end frame, at an angle approximately 45° to the lead net. The entire assemblage was installed with the lead running perpendicular from shore, following the configuration described by Gallaway et al. (1991). The net was operated and checked as described for Site 1. Site 2 was fished at the same location with the same paired cod end fyke used in 2004 and 2005 (Williams et al. 2006). All sampling gear was operated for 24 hrs a day, 6 days per week from late May through either July (2008 and 2009) or into mid-August (2006 and 2007).

Water depth was recorded daily at Site 1 and water temperature was recorded continuously at Site 1 for the entire sampling season, using loggers from the Onset Computer Corporation (Pocasset, MA). Temperatures were measured daily using a hand held bulb thermometer as a backup measure.

Fish capture and biosampling

Sites 1 and 2 were checked twice daily, at approximately 12 hour intervals. At each check, fish were removed from the cod end traps and held in floating net pens for processing. All fish captured were identified and counted. The number of juvenile coho salmon captured was recorded and sub-samples were taken for length (fork length), weight (grams), and age analyses (scale samples). A random sample of 20 coho salmon was taken daily for length measurements, from each sampling station. Weight and scale samples were collected weekly from 30 coho salmon, targeted across size classes. All scales were sent to Birkenhead Scale Analysis (Lone Butte, B.C.) for aging. In 2008 and 2009, targets of 10 scale samples were collected for binned 5 mm length classes by week.

Catch per unit effort (CPUE) was calculated as the number of fish collected per 24 hours of fishing effort at a fyke net. Fish CPUE, age, length, and weight were used to analyze run timing, estimate age and length compositions, and evaluate fish body condition. Total catches of all species were used to calculate species diversity, richness, and evenness for the entire fish assemblage in the lower river (Pielou 1966; Elliott and Hewitt 1997).

Run timing and biological characteristics of juvenile coho salmon

Juvenile coho salmon run timing was reported using trends of CPUE over time, for all coho salmon combined, and for subsets of age and size. Age-length proportions were calculated weekly to account for changes in size-at-age and an expansion to the unaged population was done daily to account for changes in size structure in the migrating population. The proportions were calculated by separating scale-aged fish lengths into 5-cm increments and the proportion that were age-0, 1, 2 + were calculated for each size increment. The proportion of ages in each length group was then expanded to the larger random sample of fish from which length measurements (but not scales) were taken each day, and then further expanded to the rest of the unmeasured population caught in the net.

Travel times from Site 1 to Site 2 were modeled as a Poisson distribution. The lag time between the number of fish released and the number recaptured, as well as the recapture rate, were adjusted to minimize the sum of square differences between the number of recoveries observed and the number predicted based on the Poisson travel time model.

Relative weight (W_r) of juvenile coho salmon was used to provide a graphical index of body condition within a year or among length groups of fish. Relative weight is based upon a standard body condition, which is the expected weight of a fish in good condition at a given length and is generally composed of regional data from multiple stream systems (Wege and Anderson 1978). Because there was no pre-existing smolt weight-length standard available for Norton Sound, we used data from within the Nome River (all years and fish lengths combined) as the reference data set, and generated W_r from the pooled Nome River data.

The relative weight for a healthy fish was assigned a value of 100. Fish with relative weights ranging between 95 and 105 were considered to be in good condition. Fish with relative weights greater than 105 were considered to be in better condition, and fish below 95 were considered to be in poorer condition (Guy and Brown, 2007).
The W_r index is calculated as

$$W_r = (W/W_s) * 100,$$

Where W is individual fish weight and W_s is a length-specific standard weight predicted from a weight-length regression developed to represent the body form of the species.

Abundance estimates of juvenile coho salmon

Marking and statistical analysis

Population abundance estimates of juvenile coho salmon were calculated using a two-site mark-recapture method (Ricker 1975). Based on size-at-age from prior monitoring (Williams et al. 2006) only fish greater than 60 mm fork length received marks. Smaller fish were excluded due to greatly reduced observed travel between the sampling sites as well as 60 mm being the lower bounds of age-1 coho salmon. Temporary caudal fin marks were applied with toenail clippers and alternated weekly to allow for temporal stratification to account for changes in capture efficiency caused by fluctuations in river discharge or changes in fish behaviour. All coho salmon captured at Site 2 were checked for marks (i.e., the 2nd sampling event), absence or presence of which was subsequently recorded. Fish captured at Site 2 were given an additional temporary caudal mark, or had their adipose fin removed (in conjunction with coded wire tagging), to identify them as a prior capture. All recaptured fish were measured for length. Release and recapture groups were apportioned into appropriate size classes based on the site-specific daily length-frequency distributions of randomly measured fish from the corresponding sample. This apportionment into size classes allowed for examinations of size selectivity by the capture method at each location.
Notation for stated variables in the mark-recapture models were as follows:

n_1 = marks released in the first sample
n_2 = fish checked for marks in the second sample
m_2 = recaptures in the second sample
N = population abundance estimate

The Chapmanized Pooled Petersen estimate (PPE) was calculated as

$$N = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \quad (1)$$

The assumptions required for the mark-recapture estimate to be unbiased were as follows (Seber 1982):

1. Closed population (i.e., no mortality, emigration or recruitment between the marking and recapture sites),
2. Either the probability of capture was equal across all individuals at the time of capture (constant p_1), or marked fish mixed uniformly with unmarked fish before the recapture event, or the second sample was a simple random sample,
3. Trap efficiency was constant for the duration of the experiment
4. Marking did not affect catchability,
5. Marks were not lost,
6. All marks were recognized and reported.

These assumptions were addressed as follows:

Assumption 1 – closed population

There is recruitment within the system; therefore the population estimate is germane to the recapture site. We assumed no mortality due to the marking process and no appreciable natural mortality between the marking and recapture sites. Site 1 only sampled a portion of the river, and smolts outmigrating outside of the fyke net essentially entered the analysis as recruitment; thus, our population estimate was germane to the recapture site (Site 2) and not to the marking site. We also assumed that all fish migrating past Site 1 also migrated past Site 2 (i.e. no residualization), but tested for this by examining the recapture rates of different size and age classes.

Assumption 2 – equal probability of capture

To evaluate if p_2 varied significantly with fish size, the Kolmogorov-Smirnov two sample test (KS test; Conover 1980) was used. The length frequency distribution of all fish marked during the first event (n_1) was compared with that of marked fish recaptured during the second event (m_2). If the length distributions were significantly different (as indicated by a significant *D* statistic; the maximum absolute difference between the cumulative distributions), then we used the size grouping corresponding to this statistic as the cutpoint for stratification. That is, separate abundance estimates were given for all fish smaller than or equal to the cutpoint and all fish greater than the cutpoint. Using the location of the *D* statistic as the cutpoint ensures that the differences between the two length strata with respect to p_2 was maximized, and in so doing the most homogeneity within strata was also achieved.

Assumption 3 *– constant catchability*

Because of water fluctuation, the probability of capture at the marking site (p_1) was unlikely to be constant through time. Fluctuating water levels throughout the study period could also change the capture efficiency of the fyke net at the recovery site (p_2), and thus would not be constant for all individuals. Any observed changes in capture probabilities through time were addressed by stratifying the catches (see *Model Selection* below).

Assumptions 4, 5 & 6 *– marking did not affect catchability, mark loss and identification*

Fish marking and handling procedures were designed minimize behavioral effects and mortality levels. Fish were handled similarly at both Site 1 and Site 2. Short-term mortality was assessed at Site 2 by regularly holding marked fish overnight, and was found to be minimal; thus, we assumed minimal effects from the similar handling of fish at Site 1. On another study in Alaska, Nemeth et al. (2009a) found no difference in travel times of coho salmon smolts marked with temporary caudal fin marks versus more invasive pelvic fin clips.

All fish were handled and inspected individually at the recovery site to minimize any failure to recognize marks. The caudal fin notch is particularly recognizable because of its location at the end of the fish's body and the ability to see it from either above or below the fish. There is limited information in the literature that estimates tissue regeneration from such a clip, but we assumed the tissue did not regenerate in the relatively short time needed for smolts to travel from Site 1 downstream to Site 2 (average time subsequently estimated at less than 10 days in all years).

Model selection

Abundance estimates for coho salmon were calculated using the software SPAS (Arnason et al. 1996). One of two models fit with this software was chosen to provide a mark-recapture estimate. The two possible models were the PPE with Chapman's corrections (Seber 1982) and the partially stratified Petersen (i.e., the maximum likelihood Darroch model [Darroch 1961]). Schwarz and Taylor (1998) provide thorough descriptions of both models. If *Assumption 2* (i.e. equal probability of capture at Site 2) above was met then the PPE would be chosen, which pools all of the data from the entire sampling season. If *Assumption 2* was not met, then the Darroch model would be used to partially stratify the data into groups with similar capture probabilities.

Initial temporal strata were preset based on the dates fin clips were altered; however, further pooling to improve model fit could occur once recapture matrices were uploaded into SPAS. Any pooling of rows was guided by similar p_1 values estimated for each cell, and columns were pooled based on similar p_2 values across cells. The only pooling requirement was that the matrix either be square (number of tagging strata = number of recovery strata) or the number of recovery strata be greater than tagging strata in order for the estimate to be applicable to the recapture site (Schwarz and Taylor 1998). If a non significant Chi-square test resulted from any of the following three tests (α = 0.05), then the PPE model was chosen.

Mixing test

Tagging stratum	Recovered	Not seen again
S1	$m_{2,S1,.}$	$n_1 - m_{2,S1,.}$
S2	$m_{2,S2,.}$	$n_1 - m_{2,S2,.}$
S3	$m_{2,S3,.}$	$n_1 - m_{2,S3,.}$
S4	$m_{2,S4,.}$	$n_1 - m_{2,S4,.}$

Equal proportions test

	Recovery strata			
	R1	R2	R3	R4

Marked	$m_{2,.,R1}$	$m_{2,.,R2}$	$m_{2,.,R3}$	$m_{2,.,R4}$
Not marked	$u_{2,.,R1}$	$u_{2,.,R2}$	$u_{2,.,R3}$	$u_{2,.,R4}$

Equal movement test

Tagging stratum	Recovery strata R1	R2	R3	R4	Not seen again
S1	$m_{2,S1,R1}$	$m_{2,S1,R2}$	$m_{2,S1,R3}$	$m_{2,S1,R4}$	$n_1 - m_{2,S1,.}$
S2	$m_{2,S2,R1}$	$m_{2,S2,R2}$	$m_{2,S2,R3}$	$m_{2,S2,R4}$	$n_1 - m_{2,S2,.}$
S3	$m_{2,S3,R1}$	$m_{2,S3,R2}$	$m_{2,S3,R3}$	$m_{2,S3,R4}$	$n_1 - m_{2,S3,.}$
S4	$m_{2,S4,R1}$	$m_{2,S4,R2}$	$m_{2,S4,R3}$	$m_{2,S4,R4}$	$n_1 - m_{2,S4,.}$

Marine survival of coho salmon

Coded wire tagging

Coded wire tags were injected into juvenile coho salmon captured at Site 1 and Site 2 that were greater than 80 mm, for the entire study period in 2006, 2007 and 2008. Fish to be tagged were anesthetized with clove oil and their adipose fin was permanently removed. A full-length, sequentially-numbered coded wire tag (CWT) was injected into the snout of each fish, using a Northwest Marine Technologies® (NMT) Mark IV tag injector with the appropriate head molds. Tagged fish were then checked with a NMT quality control device to confirm the presence of a magnetized tag. Tagged fish were released at their capture point after recovering from anaesthesia. During each tagging event (day) up to 200 coho were kept overnight to evaluate tag retention and tagging mortality.

The number of CWT fish used for marine survival estimates was adjusted to reflect the number of fish that emigrated from the river and retained coded wire tags. After the removal of tagging mortalities, short term tag retention, T_h, was calculated as:

$$T_h = n_h / n_{th}$$

Where n_h = the number of marked fish detained on day h that retained tags during the holding period, and n_{th} = the number of marked fish detained on day h, corrected for tagging mortality (Carlon and Hasbrouck 1993). Tag retention estimates were pooled,

$$T_p = \sum_h T_h$$

to provide an overall estimate of tag retention, which was then multiplied by the total number of juvenile coho salmon tagged, to estimate the total number of viable tags released.

Determination of smolt group

From sampling in 2004 and 2005 (Williams et al. 2006), juvenile coho salmon were known to be present in the lower Nome River through the summer, from late May through August. The peak of the smolt run occurred in June, but fish of smolt age or size were caught through the month of August. It is possible that some, all, or none of these fish migrate to sea after the main smolt run peak in June, thereby adding uncertainty to whether a potentially large number of juvenile fish should be considered smolts or not. This uncertainty meant we did not know whether to include these fish as smolts for comparing to predictions from the habitat model, or when calculating marine survival. There were no prior studies from the area to help clarify this issue.

To determine a general cutoff date for classifying fish as smolts, juvenile coho salmon were examined in 2007, 2008, and 2009 to observe whether any of the fish tagged the prior year (because they were thought to be smolts) had overwintered in the Nome River instead of emigrating to sea. Such overwintering fish were identified by the absence of an adipose fin; when detected, these fish were sacrificed and their CWT was read to determine the date of tagging in the prior year. Tag dates were then classified as either during the peak of the run (fish tagged in June the prior year) or after the run peak (fish tagged in July and August the prior year). If both groups migrated to sea in equal proportions, there should be no difference in the proportion of them that recaptured as juveniles the following year (overwintered in the river). Such lack of difference would indicate that the fish from the later time period should be included in smolt abundance estimates; a greater holdover rate by the July/August group, conversely, would indicate that this group may not be able to be counted as smolts for the population estimate for a given year, and that smolt population estimates and marine survival data should be adjusted accordingly.

As a secondary way to examine evidence of overwintering differences between the June and the July/August groups of presumed smolts, juvenile fish were tagged with Passive Integrated Transponder (PIT) tags in 2007. Adult salmon recaptured in 2008 were then examined for PIT tags to see whether both groups of juveniles tagged in 2007 had contributed to the 2008 adult run at equal rates. In 2007, three-hundred PIT tags were placed into the body cavity of juvenile coho salmon migrating in both June and August, for a targeted total of 600 tags released. These tags each had a unique number that identified the tagging date. A lack of difference in tag return rate between the June and August tag groups would indicate that fish from the August group had smolted at the same rate as the June group; a lower tag rate by the August group would indicate that these fish had not emigrated in 2007, but had instead held over to smolt in 2008 and would return as adults in 2009. Smolts in 2008 were not examined for PIT tags placed in 2007 due to the considerable effort involved.

Adult salmon returns

Adult coho salmon returning to the Nome River in 2006 through 2009 were examined for adipose fin clips and scanned for CWTs (as well as PIT tags in 2008). Fish were examined just below and at the Nome River weir in August and September, using beach seines and the weir trap operated by the ADF&G. Fish captured at this site had migrated past the commercial, sport, and subsistence fisheries and were expected to successfully escape to the spawning grounds.

All adult coho salmon captured were examined for missing adipose fins, as evidence of a coded wire tag. Fish with no adipose fin were scanned with a tag reader to verify presence of a coded wire tag in the snout and/or a PIT tag. Each fish examined was given a caudal fin mark to prevent recounts. Coho salmon found with tags were sexed and measured from mid-eye to fork length (MEF). In 2008 and 2009, 40 adult coho salmon with coded wire tags were sacrificed and the coded wire tags removed to determine which portion of the smolt run in 2007 and 2008 these adults originated from.

Marine survival calculations

Marine survival was calculated using the proportion of CWT coho salmon that returned as adults each year (i.e., 2006, 2007, 2008, and 2009) and the number of CWT smolts released the prior year (i.e., 2005, 2006, 2007, and 2008; Baxter and Stephens 2005). The total number of tagged fish returning as adults each year was estimated by taking the CWT proportion of returning adults that were examined, and multiplying this proportion by the size of the entire run. This total run included escapement to the weir, plus estimated harvest in subsistence, recreational, and commercial fisheries. Marine survival was then calculated by dividing the estimated number of adults returning with CWTs by the number of smolts originally CWT marked. Survival was calculated both for smolt survival to total adult coho salmon return (escapement plus harvest) and for smolt survival to spawning ground escapement (upstream of the Nome River weir). Survival was also calculated for just the tags placed in the June group of juvenile fish.

Stray rates of coho salmon

In 2008 and 2009, adult coho salmon returning to the Snake River were also examined for coded wire tags to estimate the stray rate of smolts tagged in the Nome River. The Snake River is the closest river to the Nome River, and has a run of coho salmon similar in size. Snake River coho salmon were captured with beach seines at sites ranging from 8.1 miles (13 km) to 21 miles (33.8 km) upstream from the ocean, and examined for coded wire tags as described for the Nome River.

In 2008 and 2009, a message was also broadcast on local radio asking community members to save the heads of any coho salmon caught with missing adipose fins. These heads were returned to the NSEDC office in Nome, where opportunistic information on capture date and location was recorded.

RESULTS

Effort

Sampling effort was greatest in 2006 when sampling occurred from May 25 to Aug 25 (Table 1). Site 2 was installed on May 31 and removed on August 25; the net was operated for 73.8 of the 91 days in this range. This effort includes a temporary net fished near Site 2 from May 26 through May 31, at a position more protected from river ice, to capture early migrant fish. Site 1 was installed on June 1 and removed on August 12; the net was operated for 54 of the 72 days in this range. Sampling began earliest in 2007 with Site 2 installed on May 23. The sampling season did not run as late as in 2006 and Site 2 was removed on August 10 (Table 1); the net was operated for 59.3 of the 79 days in this range. Site 1 was installed on May 29 and removed on August 3 and fished for 21.5 of the possible 66 days during this range. Sampling duration was shortened in 2008, with Site 2 installed on May 29 and Site 1 on May 30 (Table 1); both sites were removed on July 31. Site 1 was operated for 43.4 of the 62 days available from May 30 to July 31, and Site 2 was operated for 50.3 of the 63 available days from May 29 to July 31. Sampling duration was the shortest in 2009; Site 2 installed on June 1 and Site 1 on June 15 (Table 1). Site 1 was operated for 37.6 of the 47 days available, and Site 2 was operated for 44.0 of the 63 available. A flood event early in the season precluded sampling.

Fish capture

The catch of fish was far greater in 2006 and 2007 than in the following years, both in total numbers and after adjusting for sampling effort. In 2006, threespine stickleback and juvenile coho salmon accounted for 90% of the catch; juvenile pink salmon were the only other species that accounted for more than 1% (Table 2). In 2007, the catch was more diverse and dominated by juvenile coho salmon, juvenile pink salmon, and threespine stickleback. Additionally, juvenile chum salmon and starry flounder each accounted for more than 1% of the total catch. In 2008, catches of threespine stickleback and juvenile pink salmon decreased by an order of magnitude, and catches of almost all fish species dropped at both sampling locations (Table 3); juvenile coho salmon and adult pink salmon dominated the catch. Catches of juvenile pink salmon and threespine stickleback increased in 2009 (Table 3), though the total number of fish caught at sites 1 and 2 were again low compared to catches in 2006 and 2007.

In 2006 a total of 125,373 fish were captured, of which 27,640 were juvenile coho salmon (Table 2). In 2007, a total of 145,531 fish were captured, of which 51,178 were juvenile coho salmon (Table 2). The significantly reduced catch in 2008 saw only 18,317 fish caught, of which 11,433 were juvenile coho salmon. Catches of juvenile coho salmon further declined in 2009 to 8,034. Although the numbers of fish caught changed substantially in 2008 and 2009, measures of species diversity were relatively similar each year (Table 4). A total of 22 species of fish, or species groups, were caught in all four years combined. Between 2006 and 2009 species diversity (Elliott and Hewitt 1997) ranged from 1.08 to 1.44 and species evenness (Pielou 1966) ranged from 0.36 to 0.48; Table 4).

Run timing and biological characteristics of juvenile coho salmon

2006

The catch per unit of effort of coho salmon was higher at Site 2 than at Site 1 during all weeks sampled (Figure 2). CPUE of both age-1 and age-2 coho salmon peaked in calendar week 25 (June 18-24: Figure 3). Coho salmon smolts migrated through the entire month of June, with the midpoint on June 21; 75% of the run migrated between June 12 and June 25 (Figure 4). Migration was somewhat associated with water levels, with catches of juvenile coho salmon increasing as water level declined (Figure 5). With higher catches generally associated with a lower water level. Water temperatures were not available in 2006, though catches in other years were associated with an increase in stream temperature (Figure 6).

The largest coho salmon were caught at the peak of the run (Figure 7). After the peak of the run, coho salmon body size decreased. The mean body length of age-2 was lower in 2006 than in prior years (Figure 8), with a significantly different standard error. As in 2004 and 2005, age-1 and -2 coho salmon were the primary catch in June, whereas age-0 and-1 fish were the primary catch in July (Figure 2). Age 2 coho salmon were caught in low numbers from July 2 through July 29, and not thereafter. Age-1 coho salmon CPUE declined in the week of July 16 and remained low through the end of sampling on August 25. Age-0 coho salmon were caught only after the week of July 30, and were present through August 25 (Figure 2). Overall, coho salmon in each age class were smaller in 2006 than in 2005 and similar to fish sizes in 2004 (Figure 8). Body condition indices were similar between Site 1 and Site 2 (Figure 9) and relative weight increased steadily from May through July, and plateaued in August.

2007

Coho salmon CPUE was higher at Site 2 than Site 1, except for the weeks of June 11 and June 18 (Figure 2). Coho salmon CPUE peaked at Site 1 at 924.3 fish/d in the week of June 18, Site 2 CPUE peaked at 520.5 fish/d during the third week of July (Figure 2). Smolts migrated from late May through the month of June, with the midpoint on June 15; 75% of the run migrated between May 31 and June 21 (Figure 4). Migration was less associated with water levels than had been observed in prior years; there was a large catch early in the sampling season and consistently high CPUEs throughout the season (Figure 5). The large catch in May occurred during low water temperatures (Figure 6). The largest coho salmon tended to be caught at the peak of the run (Figure 7) in June, when the fish were primarily age-2 and -3. After the peak of the run, coho body size decreased as a younger (Figure 3) and smaller mostly age-0 and -1 salmon cohorts moved into the area, similar to the trends observed in prior years (Williams et al. 2006). Relative weight was higher than in 2006 for the month of June *Wr,* continued increasing into July, though the difference between the years was reduced over time (Figure 9).

Catches of age-0 and -1 coho salmon in 2007 were dissimilar to trends observed in 2006. In 2007, age-1 fish catches increased in the week of June 18 and remained at this level through August 10. Age-0 fish were present in the system as early as the week of May 28 and were caught in substantial numbers beginning in early July, a full three weeks before their first detection in 2006 (Figure 2). Mean body lengths of age-2 fish were larger in 2007 than in 2006, but mean body lengths of age-1 and age-0 fish were smaller (Figure 8).

2008

Coho salmon CPUE was higher at Site 2 than Site 1 (Figure 2) and peaked at both sites in the middle of June at 221.7 fish/d at Site 1 and 443.0 fish/d at Site 2. Smolts migrated through the entire month of June, with the midpoint on June 19; 75% of the run migrated between June 14 and June 26 (Figure 4). The general trend of coho salmon catches increasing as water levels declined was observed again in 2008 (Figure 5). The largest coho salmon tended to be caught during at the peak of the smolt run (Figure 7) in June. Unlike in previous years, the smaller, younger cohort of juvenile salmon did not move into the lower river after the smolt run ended (Figure 3).

Coho salmon captured in June and early July were primarily age-2+; the few fish captured later in July were mostly age-1, and very few age-0 fish were captured (Figure 3). Mean body length declined from 2007 to 2008 for age-2 fish, but increased for age-0 and -1 (Figure 8). Body condition was most similar to 2006 with low initial body condition recorded, which increased as the season progressed (Figure 9).

2009

Coho salmon CPUE was higher at Site 2 than Site 1for all weeks sampled (Figure 2). Coho salmon CPUE peaked at Site 1 at 76.6 fish/d in the week of June 25, Site 2 CPUE peaked at 180.8 fish/d during the same week (Figure 2). Smolts migrated from early-June until mid-July, with the midpoint on June 24; 75% of the run migrated between June 10 and June 29 (Figure 4). Water levels were extremely high in late May and early June, which precluded sampling the river, after the water level dropped catch trends were similar to those observed in 2008 (Figure 5). The largest coho salmon tended to be caught at the peak of the run (Figure 7) in June, when the fish were primarily age-2 and -3. After the peak of the run, coho body size decreased as a younger (Figure 2) and smaller, mostly age-0 salmon cohort moved into the area, similar to the trends observed in prior years (Williams et al. 2006). Relative weight trends were similar to those observed in 2008 (Figure 9).

Catches of age-0 and -1 coho salmon in 2009 had a different pattern from 2006 and 2007, with few age-0 and age-1 fish captured, which was more similar to 2008 catches. Age-0 fish were present in the system as early as the week of May 18 though were not caught in substantial numbers for the entire sampling season (Figure 2). Mean body lengths of age-2 fish were slightly larger in 2009 than in 2008, though mean body lengths of age-1 and age-0 fish were slightly smaller (Figure 8).

Abundance estimates of juvenile coho salmon

In all years, there was a run of coho salmon that peaked in June and consisted primarily of age-2 fish, with some age-1 fish that were larger than 80 mm. This peak was followed by catches of mixed sizes of fish that were primarily age-0 and -1 that continued through the end of sampling (the end of July or into August). Each year, this latter group included fish that were larger than 80 mm and some silvery appearances that resembled fish undergoing the smolting process; unlike those caught in June, these fish were almost always age-1 and rarely age-2.

In all years, fish in the size class from 60 to 80 mm were more abundant at Site 1 (the upstream site) than at Site 2, were recaptured at much lower rates at Site 2 than fish larger than 80 mm, and had fewer visual signs of smolting (parr marks, coloration, etc.). Based upon these observations, fish in the 60 through 80 mm size class were removed from all smolt population estimates. To account for the relative abundance of these smaller size classes, indices of abundance were calculated at Site 2 for age cohorts. These indices were based upon the total catch per unit effort for the month of June each year. Juvenile coho salmon travel times between sites 1 and 2 were modeled to be on the order of 1-10 days.

2006

For fish greater than 80 mm in 2006, the mixing, equal proportions, and equal movement chi-square tests were all significant at the 0.05 level (Appendix A). As such, the Darroch analysis was used in favor of the PPE to estimate smolt abundance. There was no significant evidence that size selective sampling occurred between the sampling events (Appendix B) so one group was analyzed that contained all coho salmon greater than 80 mm in length.

The peak period of coho salmon smolt migration was from June 1 to July 2; fish considered smolts were generally greater than 80 mm in length, had a silvery appearance, and had few or faded parr marks; postseason scale analysis indicated these fish were primarily age-2+ coho at Site 2 (Figure 3). The population estimate for this time period was 118,089 with a 95% confidence interval of 102,806 to 133,294 fish (Table 5). This estimate was based on 2,741 marked fish released from Site 1, 19,301 fish examined for marks at Site 2, and 414 (15.1% of the marks released) fish recaptured at Site 2 (Appendix C).

After July 2, another 124 coho salmon that were larger than 80 mm (and mainly age-1 fish) were marked at Site 1; of the 2,109 examined at Site 2, 89 (71.8% of the marked fish released) were recaptures. If these fish were included as smolts, they would have resulting in a revised smolt population estimate of 118,868 (108,931 – 128,754). Note that the population estimate essentially remained the same from the smolt estimate from the reduced time period. This is due to the nature of the change in percent of recaptures between the time periods, whereby the increase in the number of recaptures with relatively few fish examined does not significantly add to the population estimate. The index of CPUE at Site 2 from May 28 through July 31 was 0.0 for Age-0 fish and 130.6 for age-1 fish (Table 6).

2007

For fish larger than 80 mm in 2007, there was significant size selective sampling during the second sampling event (Appendix B) so this size class was broken into two groups, from 80 to 103 mm and >103 mm in length. There was also incomplete mixing of marked fish captured by time period, for both size groups (Appendix A). As such, the Darroch analysis was used in favor of the PPE for the smolt estimates. Population estimates were calculated for each length group separately and then summed.

The period of peak coho salmon smolt migration was from May 30 through July 1, using the same criteria for smolt classification as in 2006. Fish during this time were generally ages-2+ (Figure 3). The smolt population estimate for this time period was 81,116 with a 95% confidence interval of 71,196 to 91,036 smolts (Table 5). The estimate was based on 2,793 marked fish released from Site 1, 13,652 fish examined for marks at Site 2, and 645 recaptures (23.1% of the marked fish released) at Site 2 (Appendix C).

After July 1, another 472 coho salmon that were larger than 80 mm (mainly age-1 fish) were marked at Site 1; of the 3,847 subsequently examined at Site 2, 393 (83.3% of the marked releases) were recaptures. If these fish were smolts, they would have revised the total smolt population estimate to 102,714 (87,120-118,307). Compared to 2006, the index of juvenile salmon CPUE in 2007 was much higher for age-0 coho salmon (75.8 fish/d), but lower for age-1 (114 fish/d; Table 6).

2008

The period of peak coho salmon smolt migration was from May 31 through June 28, using the same criteria for smolt classification as in prior years. Fish during this time were generally age-2+ (Figure 3). There was significant size selective sampling during the second sampling event in 2008 (Appendix B) therefore coho salmon were seperated into two groups, from 80 to 97 mm and >97 mm in length. There was also incomplete mixing of marked fish captured by time period, so the Darroch analysis was used in favor of the PPE for the smolt abundance estimate (Appendix A).

The smolt population estimate for the peak migration time period was 34,318 with a 95% confidence interval of 31,176 to 37,460 smolts (Table 5). The estimate was based on 1,548 marked fish released from Site 1, 8,963 fish examined for marks at Site 2, and 411 recaptures (26.5% of marked fish released) at Site 2 (Appendix C).

After June 28, another 100 coho salmon that were larger than 80 mm (mainly age-1 fish) were marked at Site 1; of the 714 subsequently examined at Site 2, 40 (40.0% of the marked releases) were recaptures. If these fish were smolts, they would have resulted in a total smolt population estimate of 34,098 (30,814 – 37,382). Very few age-0 coho salmon were captured during the seasonal index with a CPUE of 0.1, and the age-1 CPUE declined dramatically from 2007 to 12.5 (Table 6).

2009

The period of peak coho salmon smolt migration was from June 16 through July 4, using the same criteria for smolt classification as in prior years. Fish during this time were generally age-2 + (Figure 2). There was significant size selective sampling during the second sampling event in 2009 (Appendix B), however a cutpoint at 99 would produce a sample size of smaller fish that was inadequate for a population estimate. Therefore coho salmon abundance was calculated as one group bounded by the lower and upper lengths sampled (80 – 138 mm). The Chi-square test for complete mixing was not significant; therefore the PPE was used to calculate abundance (Appendix A).

The smolt population estimate for the peak migration time period was 40,126 with a 95% confidence interval of 32,648 to 47,605 smolts (Table 5). The estimate was based on 755 marked fish released from Site 1, 5,088 fish examined for marks at Site 2, and 93 recaptures (12.3% of marked fish released) at Site 2 (Appendix C).

After July 4, another 12 coho salmon that were larger than 80 mm were marked at Site 1; of the 504 subsequently examined at Site 2, 4 (33.3% of the marked releases) were recaptures. If these fish were smolts, they would have resulted in a total smolt population estimate of 41,865 (33,497 – 50,234). Very few age-0 coho salmon were captured during the seasonal index with a CPUE of 0.3, and the age-1 CPUE slightly increased from 2008s 12.5 to 38.4 (Table 6).

Determination of smolt group

Juvenile coho salmon tagged in 2007 during the peak of the run (on or before June 25) accounted for all 62 of the CWTs recovered from adults returning in 2008 (Figure 10). Juvenile coho salmon tagged after the run peak in 2007, after June 25, account for 21 of the 23 juveniles found to have overwintered in the river from 2007 to 2008 (Figure 10). Similarly, juvenile coho salmon tagged after the run peak in 2006 accounted for all eight of the juveniles found to have overwintered in the river from 2006 to 2007.

PIT tags were implanted in 309 juvenile coho salmon in June of 2007. These 309 fish had an average length of 106 mm (SD = 12.7). An additional 237 juvenile coho were tagged in August when the fish were smaller (average length = 82 with a SD = 10.0). A total of 3 adults with PIT tags were recovered in 2008; these fish were tagged during the peak part of the run (June) in 2007.

Marine survival of coho salmon

Coded wire tagging

In 2006, coded wire tags were injected in 17,633 coho salmon, all between May 28 and August 25. No coded wire tags were placed between July 3 and July 10 due to problems with the tagging unit. A total of 2,908 coho were kept overnight, spread among 18 nights, during the peak of the run. Of these coho, 69 died (presumably due to tagging-associated handling) and 80 shed their tags. After accounting for unequal weighting among the 18 retention groups, and removing the tag mortalities and correcting for tag loss, the final number of coho smolts released with CWTs was 17,057 in 2006 (Appendix D).

In 2007, coded wire tags were implanted in 19,958 coho salmon from May 29 through July 26. A total of 5,136 coho salmon were kept overnight, spread among 49 nights during the peak of the run. Of these coho salmon, 371 died and 58 shed their tags. After removing tag mortalities, correcting for tag loss, and accounting for unequal weighting among the 49 retention groups, an estimated 19,110 coho smolts were released with CWTs in 2007 (Appendix D).

In 2008, coded wire tags were injected into 7,309 coho salmon from June 16 to July 30. One hundred and thirty-two mortalities were recorded for the 2,865 fish held overnight, with 354 shed tags. Accounting for tag loss and overnight mortality a total of 6,551 coded wire tagged coho salmon smolts were released in 2008 (Appendix B). Tagging began later than in 2006 and 2007 due to a combination of a late start to the run, and the desire to look for smolts with adipose fin clips that had overwintered from 2007 before adding in newly-clipped fish to the population.

Adult returns and marine survival estimate

Marine survival of smolts from 2005 to 2006 was estimated at 11.8% for coho salmon returning to the mouth of the Nome River watershed and 8.1% to the spawning grounds upstream of the weir (Table 7). An estimated 9,255 coho salmon smolts that emigrated in 2005 had been tagged with coded wire tags (Williams et al. 2006). In 2006, an estimated 15,123 adult coho salmon returned to the Nome River: 8,308 were counted at the weir (Kent 2007), an additional 2,000 were estimated to have migrated past the weir uncounted, 2,047 were harvested below the weir in the subsistence fishery (J. Menard, ADF&G, personal communication), and an additional 2,768 were harvested in a recreational fishery (Jennings et al. 2010) that was almost entirely below the weir (S. Kent, ADF&G, personal communication). Seine crews examined adult coho salmon for coded wire tags from August 11, 2006 and August 21, 2006 at sites immediately downstream from the weir. Of the 1,311 adult coho captured with beach seines below the Nome River weir, 95 (7.2%) had coded wire tags. Expanding this proportion to the entire run of 15,123 adult coho salmon resulted in an estimate of 1,096 tagged adult coho salmon returning to the river; expanding it to the 10,308 adult coho estimated to have escaped past the weir resulted in an estimate of 747 tagged adult coho salmon migrating past the weir.

Marine survival of coho salmon smolts from 2006 to 2007 was estimated at 2.4% for coho salmon returning to mouth of the Nome River watershed and 1.7% to the spawning grounds upstream of the weir. As described above, an estimated 17,057 coho salmon smolts that emigrated in 2006 had been tagged with coded wire tags (Table 6). In 2007, an estimated 3,446 adult coho salmon returned to the Nome River: 2,437 counted at the weir (Menard and Kent 2007), 205 harvested below the weir in the subsistence fishery (J. Menard, ADF&G, personal communication), and 804 harvested below the weir in the recreational fishery (B. Scanlon, ADF&G, personal communication). Seine crews examined adult coho salmon for coded wire tags on 14 dates from August 10, 2007 through September 12, 2007, immediately downstream from the weir. Of the 723 adult coho salmon captured with beach seines, 85 (11.8%) had coded wire tags. Expanding this proportion to the entire run of 3,446 adult coho salmon resulted in an estimate of 405 tagged adult coho salmon returning to the river; expanding it to the 2,437 adult coho salmon estimated to have escaped past the weir resulted in an estimate of 286 tagged fish escaping past the weir.

Marine survival of coho salmon smolts from 2007 to 2008 was estimated at 5.9% to the Nome River weir. Survival to the entire watershed was 9.2% based upon final harvest statistics for adult coho salmon returning in 2008. As described above, an estimated 19,110 coho salmon smolts that emigrated in 2007 had been tagged with coded wire tags (Table 7). In 2008, 4,605 adult coho salmon were counted through the Nome River weir (another 390 were estimated to have passed outside of the weir), harvest levels were reported at 2,695 fish, and an estimated 5,220 returned to the weir on the Snake River (J. Menard, ADF&G, personal communication). Seine crews examined adult coho salmon for coded wire tags on 12 dates on the Nome River (August 8, 2008 through September 9, 2008) and ten dates on the Snake River (August 21, 2008 through September 15, 2008). The mark rate for coded wire tags was 22.8% (208 tagged fish out of 914 examined) for the Nome River and 1.2% (7 tagged fish out of 561 examined) for the Snake River. Expanding these proportions to the escapements to each weir resulted in an estimate of 1,137 tagged fish to the Nome River weir and 65 tagged fish to the Snake River weir, for a total of 1,202 tagged fish returning. Based on the release of 19,110 smolts with tags in 2007, this yielded a marine survival estimate of 5.9% to the weir on the Nome River in 2007, and a rate of 6.3% to the Nome and Snake rivers, combined.

Marine survival of smolts from 2008 to return as adults at the Nome River weir in 2009 was estimated at 3.0% (Table 7). At the time of publishing this report subsistence and sport harvest numbers were not available, though based upon prior year's numbers fishing mortality is roughly 30% for Nome River coho salmon. If we assume that 30% more fish returned to the river than were counted at the weir, then an estimated 1,756 adults returned which would yield a survival to the river of 3.9%.

Stray rates

In 2008 the stray rates of marked fish returning to the Snake River was estimated at 5.4%. Of the 19,110 smolts released from the Nome River in 2007, an estimated 65 (0.3%) returned to the Snake River as adults; these 65 adult coho salmon represented 5.4% (65 of 1,202) tagged adult coho salmon estimated to have returned to the two systems combined. Collecting 2009 Snake River escapement numbers at the weir was hampered by high water. An aerial survey identified 700 coho salmon in the system. However, a total of 74 coho were seined and examined and none had been previously tagged producing a 0% stray rate.

DISCUSSION

There was nearly a fourfold difference in smolt abundance estimates during this study, with the estimates ranging from 120,000 fish in 2006 to 34,000 fish in 2008. In comparison, the parent year escapements for the smolt populations sampled in the Nome River had a tenfold difference, ranging from 548 to 5,800. These interannual ranges (fourfold for smolts, tenfold for adults) are similar to the ranges observed in coho salmon in southcentral Alaska, the closest known populations for which abundance of smolts and adults has been estimated in multiple years (Lafferty et al. 2007).

Coho salmon catch composition in the lower Nome River followed a pattern whereby a peak in emigration in early/mid June (primarily of age-2 smolt but inclusive of some larger age-1 fish) was immediately followed by a shift to smaller, younger fish. Recruitment of age-0 coho salmon generally occurred in July. Smolt emigration began before the ice was completely out of the river, but did not peak until the water level had fallen each year and water temperature had risen. The catches on the start date each year appear to be early on the rising limb of the emigration curve, and peak emigration appeared to have been captured. 2009 was an exception to this as flood level waters precluded operating sampling gear for the first two weeks of June.

Smolt abundance estimates were generated from a 5-week period each year that appeared to cover the entire smolt outmigration and was centered on the month of June. Although juvenile coho salmon >80 mm long continued to be captured after this 5-week period, tagging tests performed in 2006, 2007, and 2008 suggest that the majority of these fish do not contribute to the smolt run and instead remain to overwinter and migrate to sea the following year.

In 2006 and 2007, no coho salmon tagged after June 25th were recaptured the following year as adults (Figure 10), providing evidence that these fish remained overwinter and migrated the next year. Supporting this, all adults returning in 2007 and 2008 had been tagged as smolts before June 25th the prior year (the adult sample was limited to adults retained for tag reading; n = 62). Based on this tag presence in smolts and adults captured the following year, age-1 fish present in the river after the run peak do not appear to migrate in fall in great numbers, but instead overwinter, and therefore should not be counted toward total smolt production in their age-1 year. It is also possible that juvenile fish tagged after June 25 may migrate to sea that year, but do not survive or are not available for sampling for unidentified reasons. The value of the mark-recapture and abundance indices for these fish thus lies in the ability to compare relative differences among years, and to include as a factor affecting the abundance of age-2 coho salmon the following year.

Limiting the smolt population to those fish emigrating before June 25 reduced the estimated number of potential smolts tagged, and thus caused a minor increase in the marine survival estimates in 2007 and 2008. Prior to June 25, a total of 14,013 tags (compared to a total of 17,057) were released in 2006; this would increase the marine survival estimate to the Nome River weir from 1.7% to 2.0%. Prior to June 25, the number of tags released in 2007 would be reduced to 17,002 (compared to a total of 19,110), which would increase the marine survival estimate from 5.9% to 6.7%. This number would realistically be reduced slightly after factoring in smolts tagged after June 25 the prior year that survived to emigrate in 2007. Tagged releases in 2008 would drop to 4,792 which would result in a marine survival to escapement of 4.1% in 2009.

During the peak of the outmigration, juvenile coho salmon had a larger body size in 2007 than in 2006, 2008, and 2009. Body size at ocean entry is known to correlate with marine survival in some salmon populations, and preliminary data from the Nome River support this. Although marine survival of smolts emigrating in 2004 was not calculated, these smolts had relatively large body size and resulted in above-average adult escapements the following year. For the years with coded wire tag marine survival estimates strong correlations (r^2=0.97) were observed between age-2 juvenile coho salmon average length subsequent marine survival to escapement the following year. The largest smolts were caught in 2005 which subsequently had the highest marine survival. However, there is no evident density-dependence between age-2 coho salmon mean length and smolt abundance (r^2=0.01). The large smolt population in 2006 had a slightly smaller average body length and a relatively low marine survival. This smolt run resulted in an adult escapement of 2,437 fish in 2007, below the 2001-2008 average return of 3,736. The smolt population estimate in 2007 was 32% lower than in 2006, but these smolts had a larger body size and a higher marine survival, producing an above-average escapement in 2008 of 4,995 fish. The smolt population in 2008 was smaller and had a shorter average body length; the marine survival of these fish was 3.0%. If adult returns are affected by smolt abundance and body size, we would expect a moderate return of adult coho salmon in 2010 unless conditions at sea are anomalous from prior years.

Adult pink salmon escapement was highly variable during the years of this study, leading to questions of how pink salmon escapements might affect juvenile coho salmon. Our objective was not originally to test for an effect of pink salmon on coho salmon, but an informal consideration of possible interactions yields some interesting results. We found that the body size of age-2 coho salmon varied with the abundance of the adult pink salmon escapement in the prior year. There was a strong positive correlation (r^2=0.85) between age-2 juvenile coho salmon average length and pink salmon escapement the prior year

In 2004, over a million pink salmon returned to the river and age-2 smolt in 2005 were the largest (in body size) observed (Williams et al. 2006). In 2005, pink salmon escapement dropped by 75% and the body size of age-2 smolts decreased in 2006. In 2006, pink salmon escapement increased, and body size of age-2 coho smolts increased in 2007. Finally, in 2007 pink salmon escapement fell by an order of magnitude and the body size of age-2 smolts in 2008 decreased, however the large pink salmon escapement in 2008 was not accompanied by a strong increase in smolt size in 2009 (Figure 8). In short, years with large pink salmon escapements were followed by years with larger sized coho salmon smolts and years with small pink salmon escapements were followed by coho salmon smolts with smaller body sizes.

Though based upon a limited dataset, this pattern provides for a conceptual linkage between adult pink salmon escapement, the body size of coho salmon smolts the following year, and the smolt survival to escapement the next year (two years after the pink salmon run). A number of questions not examined with this study are raised by this linkage. For example, are smolts larger the year after a large pink salmon escapement because of late season growth that same year as pre-smolts (either from directly feeding on decomposing pink salmon carcasses, or from increased invertebrate production), or because the smolts migrating the next year are able to feed on pink salmon fry?

From 2004 through 2006, annual changes in body size were consistent for each age class of juvenile coho salmon; all three age classes increased or decreased in body size from one year to the next (Figure 8). This relationship decoupled in 2007, when age-2 fish had increased growth but age-0 and age-1 fish had decreased growth compared to the prior year. In 2008, the age-0 and age-1 cohorts increased in length, but the age-2 cohort decreased. Overall, it appears that age-2 growth has stayed consistently correlated with the increase or decrease in pink salmon returns in 2004 through 2009 (Figure 8), while the trends are inconsistent for the younger ages. Notably, the smolt run in 2007 had an earlier start and midpoint than in other years; these fish were migrating to sea during temperatures that were approximately 2 degrees colder than smolts in other years, and the greatest total number of juvenile coho salmon (51,178) was captured in this year. The winter of 2006-2007 was marked by low water levels, thick ice, cold temperatures and a shallow snow pack, which could contribute to reduced available overwintering habitat. It is plausible that a harsh winter could effectively reduce available overwintering habitat and inhibit invertebrate prey production, and may push fish, particularly less competitive younger fish, out of the upper river.

The index of abundance of age-0 and age-1 coho salmon was uncharacteristically low in 2008 and only slightly rebounded when compared to the years 2004 through 2007. Two consecutive years of reduced abundance estimates likely indicates an actual

REFERENCES

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106:vi+37p.

Baxter, B. E. and C. Y. Stephens. 2005. Adult and juvenile coho salmon enumeration and coded-wire tag recovery analysis for Zolzap Creek, BC, 2004. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2730. Fisheries and Ocean Canada, Prince Rupert, B. C.

Bocking, R. C. and D. Peacock. 2005. Habitat-based production goals for coho salmon in Fisheries and Oceans statistical area 3. LGL environmental research associates, Sidney, British Columbia. Final report for Pacific Scientific Advisory Review Committee, Department of Fisheries and Oceans, Canada.

Bradford, M. J., Taylor, G. C., and Allan, J. A. 1997. Empirical review of coho salmon smolt abundance and the prediction of smolt production at the regional level. Transactions of the American Fisheries Society 126: 49-64.

Brannian, L. K., M. J. Evenson. and J. R. Hilsinger. 2006. Escapement goal recommendations for select Arctic-Yukon-Kuskokwim region salmon stocks, 2007. Fishery Manuscript No. 06-07, Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries. Anchorage, Alaska.

Carlon, J. A., and J. J. Hasbrouck. 1993. Marking juvenile coho salmon in the Kenai River with coded, microwire tags. Alaska Department of Fish and Game. Anchorage Alaska, Fishery Data Series No. 92-52.

Conover, W. J. 1980. Practical nonparametric statistics, *second edition*. New York: John Wiley & Sons.

Darroch, J. N. 1961. The two sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Elliott, K. J., and D. Hewitt. 1997. Forest species diversity in upper elevation hardwood forests in the southern Appalachian Mountains. Castanea 62:32-42.

Gallaway, B. J., W. J. Gazey, J. M. Colonell, A. W. Niedorada, and C. J. Herlugson. 1991. The Endicott development project – preliminary assessment of the impacts from the first major offshore oil development in the Alaskan Arctic. Pages 42-80 in C. S. Brenner and R. W. Middleton, Eds. Fisheries and oil development on the continental shelf. American Fisheries Society Symposium 11:22-25. Bethesda, Maryland.

Guy, C. S. and M. L. Brown, editors. 2007. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Jennings, G. B., K. Sundet and A. E. Bingham. 2010. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10-02, Anchorage.

Lafferty, R., R. Massengill, D. Bosch, and J. J. Hasbrouck. 2007. Stock status of coho salmon in upper Cook Inlet: report to the Alaska Board of Fisheries, January 2005. Fishery Manuscript No. 07-01. Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries, Anchorage, Alaska.

Menard, J., and S. Kent. 2007. 2007 Norton Sound season summary. Memorandum to D. Bergstrom, ADF&G, 1 October 2007. Alaska Department of Fish and Game, Anchorage, Alaska.

Nemeth, M. J., B. Bocking, and S. Kinneen. 2004. Freshwater habitat as a predictor of coho salmon smolt production in two Norton Sound rivers: an initial study to support the development of habitat-based escapement goals. Annual report prepared for the Norton Sound Fishery Disaster Relief Fund by LGL Alaska Research Associates and Norton Sound Economic Development Corporation, Anchorage, Alaska.

Nemeth, M. J., B. Williams, B. H. Haley, and S. Kinneen. 2005. An ecological comparison of juvenile chum salmon from two watersheds in Norton Sound, Alaska: migration, diet, estuarine habitat, and fish community assemblage. Unpublished report for the Norton Sound Disaster Relief Fund by LGL Alaska Research Associates and Norton Sound Economic Development Corporation, LGL Alaska Research Associates, Anchorage, Alaska.

Nemeth, M. J., B. C. Williams, A. M. Baker, C. C. Kaplan, M. R. Link, S. W. Raborn, and J. T. Priest. 2009a. Movement and abundance of freshwater fish in the Chuit River drainage, Alaska, May through September 2008. Final report prepared by LGL Alaska Research Associates, Inc., Anchorage, Alaska for PacRim Coal, L. P.

Nemeth, M. J., B. C. Williams, R. C. Bocking, and S. N. Kinneen. 2009b. Freshwater habitat and coho salmon production in two rivers: an initial study to support the development of habitat-based escapement goals in Norton Sound, Alaska. *In* Krueger, C. C, and Zimmerman, C. E., editors. 2009. Pacific Salmon: Ecology and Management of Western Alaska's Populations. American Fisheries Society Symposium 70, Bethesda, Maryland.

Nickelson, T. E. 1998. A habitat-based assessment of coho salmon production potential and spawner escapement needs for Oregon coastal streams. Information Report No. 98-4. Oregon Dept. Fish and Wildlife, Portland, Oregon.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of Fisheries Research Board of Canada, Bulletin 191.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, *second edition*. Griffin and Company, Ltd. London.

Selkregg, L. L. 1976. Alaska regional profiles, Northwest region. University of Alaska, Arctic Environmental Information and Data Center, Anchorage, Alaska.

Schwarz, C. J. and C. G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhychus gorbuscha*) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences. 55:281-296.

Sharma, R. and Hilborn, R. 2001. Empirical relationships between watershed characteristics and coho salmon (Oncorhynchus kisutch) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58: 1453-1463.

Shaul, L., L. Weitkamp, K. Simpson, and J. Sawada. 2007. Trends in abundance and size of coho salmon in the Pacific Rim. North Pacific Anadromous Fish Commission Bulletin 4:93-104.

Webb, J. F. and R. F. McLean. 1991. An investigation of coho salmon rearing habitat in selected tributaries of the Nome River. Unpublished report, Alaska Department of Fish and Game, Fairbanks, Alaska.

Wege, G. J. and R. O. Anderson. 1978. Relative weight (Wr): a new index of condition for largemouth bass. Pages 79-91 in G. Novinger and J. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, Maryland.

Williams, B., M. Nemeth, S. Kinneen, and B. Bocking. 2006. Abundance of juvenile coho salmon in the Nome River, Alaska. Unpublished report prepared for the Norton Sound Disaster Relief Fund by LGL Alaska Research Associates, Inc. and Norton Sound Economic Development Corporation. 31 p. + appendix.

Volkhardt, G., P. Hanratty, D. Rawding, P. Topping, M. Ackley, C. Kinsel, K. Kiyohara, and L. Kishimoto. 2007. Wild Salmon forecasts for Puget Sound and Washington coastal systems. Washington Department of Fish and Wildlife, Science Division. Olympia, Washington.

Table 1. Nome River sampling effort by location for 2006 through 2009.

Year	Location	Date in	Date out	Effort (days)	Total possible effort (days)
2006	Site 1	1-Jun	12-Aug	54.0	72
	Site 2a	25-May	30-May	3.1	5
	Site 2	31-May	25-Aug	70.7	86
2007	Site 1	29-May	3-Aug	21.5	66
	Site 2	23-May	10-Aug	59.3	79
2008	Site 1	30-May	31-Jul	43.4	62
	Site 2	29-May	31-Jul	50.3	63
2009	Site 1	15-Jun	1-Aug	37.6	47
	Site 2	1-Jun	3-Aug	44.0	63

Table 2. Total and proportion of catch by species, 2006 through 2009. Data are for all sites combined on the Nome River. Catches reflect varying levels of effort, with sampling occurring between May 25 and August 25, 2006, between May 23 and August 10, 2007, between May 29 and July 31, 2008, and between June 1 and August 3, 2009.

	2006		2007		2008		2009	
Species	Total	%	Total	%	Total	%	Total	%
Alaska blackfish	5	0	6	0	5	0	5	0
Arctic flounder	36	0	60	0	29	0	23	0
Arctic grayling	2,422	2	1,027	1	114	1	89	0
Bering cisco	-	-	23	0	2	0	1	0
Burbot	1	0	1	0	-	-	1	0
Chinooksalmon j	5	0	7	0	41	0	-	-
Chum salmon a	9	0	1	0	-	-	-	-
Chum salmon j	118	0	5,117	4	502	3	112	1
Coho salmon j	37,640	30	51,178	35	11,433	62	8,034	38
Dolly Varden	1,788	1	1,454	1	1,464	8	710	3
Fourhorn sculpin	30	0	12	0	23	0	40	0
Least cisco	67	0	12	0	35	0	-	-
Ninespine stickleback	535	0	113	0	74	0	6	0
Pacific herring		-	-	-	1	0	-	-
Pacific lamprey	2	0	-	-	1	0	-	-
Pink salmon a	715	1	3	0	2,869	16	3	0
Pink salmon j	4,771	4	46,052	32	155	1	4,570	22
Rainbow smelt	8	0	10	0	1	0	3	0
Round whitefish	261	0	106	0	170	1	75	0
Saffron cod	7	0	13	0	6	0	-	-
Sculpin spp.	166	0	246	0	21	0	166	1
Sockeye salmon j	632	1	1,777	1	269	1	326	2
Starry flounder	1,262	1	3,196	2	309	2	712	3
Threespine stickelback	74,893	60	35,117	24	793	4	6,136	29
Total	125,373		145,531		18,317		21,012	

a = adult, j = juvenile

Table 3. Nome River fyke net catch by year and location. Catches reflect varying levels of effort, with sampling occurring between May 25 and August 25, 2006, between May 23 and August 10, 2007, between May 29 and July 31, 2008, and between June 1 and August 3, 2009.

	2006		2007		2008		2009	
Species	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Alaska blackfish	5	-	5	1	3	2	3	2
Arctic flounder	-	36	1	59	-	29	-	23
Arctic grayling	263	2,159	52	975	7	107	8	81
Bering cisco	-	-	-	23	-	2	-	1
Burbot	-	1	1	-	-	-	-	1
Chinooksalmon j	1	4	4	3	1	40	-	-
Chum salmon a	2	7	1	-	-	-	-	-
Chum salmon j	113	5	5,112	5	492	10	111	1
Coho salmon j	4,261	33,379	13,754	37,424	1,786	9,647	1,031	7,003
Dolly Varden	374	1,414	344	1,110	331	1,133	69	641
Fourhorn sculpin	5	25	4	8	1	22	16	24
Least cisco	-	67	-	12	-	35	-	-
Ninespine stickleback	441	94	70	43	50	24	5	1
Pacific herring	-	-	-	-	-	1	-	-
Pacific lamprey	1	1	-	-	-	1	-	-
Pink salmon a	31	684	1	2	14	2,855	-	3
Pink salmon j	4,745	26	45,621	431	151	4	4,549	21
Rainbow smelt	2	6	3	7	-	1	-	3
Round whitefish	5	256	24	82	7	163	-	75
Saffron cod	-	7	-	13	-	6	-	-
Sculpin spp.	115	51	213	33	17	4	159	7
Sockeye salmon j	300	332	1,668	109	225	44	147	179
Starry flounder	2	1,260	40	3,156	6	303	5	707
Threespine stickelback	14,931	59,962	10,146	24,971	24	769	300	5,836
Total	25,597	99,776	77,064	68,467	3,115	15,202	6,403	14,609

a = adult, j = juvenile

Table 4. Species richness, diversity and evenness for fyke nets at Site 1 and Site 2 in the Nome River from 2006 through 2009.

Sampling group	Richness (*S*)	Diversity (*H'*)	Hmax	Evenness (*J'*)
All years combined				
Site 1	17	1.35	2.83	0.48
Site 2	21	1.10	3.04	0.36
Both sites	21	1.40	3.04	0.46
2006				
Site 1	15	1.19	2.71	0.44
Site 2	18	0.96	2.89	0.33
Both sites	19	1.07	2.94	0.36
2007				
Site 1	16	1.19	2.77	0.43
Site 2	18	1.04	2.89	0.36
Both sites	19	1.43	2.94	0.49
2008				
Site 1	13	1.35	2.56	0.53
Site 2	20	1.20	3.00	0.40
Both sites	20	1.31	3.00	0.44
2009				
Site 1	12	1.02	2.48	0.41
Site 2	18	1.15	2.89	0.40
Both sites	18	1.49	2.89	0.52

Note: S = Species richness, *H'* = Shannon-Wiener index of diversity; *Hmax* = Maximum diversity; *J'* = Pielou's estimate of species evenness.

Table 5. Coho salmon smolt population estimates for the Nome River. Abundance was calculated using a Darroch or pooled Petersen estimator (PPE) for the time period of peak coho smolt migration, generally the month of June.

Year	Length Group (mm)	Estimate	95% confidence intervals Lower	Upper	Method
2006	80+	118,089	102,806	133,294	Darroch
2007	80-103	56,824	47,142	66,506	Darroch
	104+	24,292	22,131	26,453	Darroch
	sum	81,116	71,196	91,036	
2008	80-97	19,483	16,809	22,156	Darroch
	98+	14,835	13,185	16,486	Darroch
	sum	34,318	31,176	37,460	
2009	85-138	40,126	32,648	47,605	PPE

Table 6. Escapement of adult salmon and indices of juvenile coho salmon in successive years, by age class. Indices of juvenile abundance limited to June only to compare equally among years.

	Adult salmon escapement[a]				Juvenile coho salmon index (June only)[b]			
Year	Coho	Pink	Chum	Total		1 yr lag (age-0)	2 yr lag (age-1)	3 yr lag (age-2)
2001	2,418	3,138	2,859	8,415				
2002	3,418	35,057	1,720	40,195				
2003	548	11,402	1,957	13,907				
2004	2,283	1,051,146	3,903	1,057,332				
2005	5,848	285,759	5,584	297,191	1.9	1.9[b]	63.9	135.4
2006	10308[c]	578,555	5,677	594,540	0	0.0[b]	130.6	138.4
2007	2,437	24,395	7,034	33,866	75.8	75.8	113.8	116.1
2008	4995[d]	1,186,000	2,607	1,193,602	0.1	0.1	12.5	92.8
2009	1,370	16,490	1,565	19,425	0.3	0.3	38.4	113.7

[a] Adult salmon data for 2001 through 2007 from Soong et al. (2008); 2008-2009 data from J. Menard (Pers. Comm.)

[b] Juvenile salmon data from Williams et al. (2006) and from this report.

[c] Includes an estimated 2,000 adult coho uncounted past weir (J. Menard, Pers. Comm.)

[d] Includes an estimated 390 adult coho uncounted past weir (J. Menard, Pers. Comm.)

Table 7. Estimates of Nome River coho salmon marine survival for adult returns to the river and for escapement past the weir. Estimates are based upon the number of marked smolts released and the number of adults recaptured with tags.

Smolts		Adult returns (smolt year +1)					Returns to river		Weir escapement	
Cohort year	Tags Released	Returns to river[b]	Weir escapement	Examined for tags	Tags recovered	% with tags	Estimated tag returns	Marine survival	Estimated tag returns	Marine survival
2005	9,255	15,123	10,308	1,311	95	7.2%	1,096	11.8	747	8.1
2006	17,057	3,446	2,437	732	85	11.6%	400	2.3	283	1.7
2007[a]	19,110	7,690	4,995	914	208	22.8%	1750	9.2	1,137	5.9
Snake River			5,220	561	7	1.2%			65	0.3
2008	6,551	-	1,351	507	74	14.6%	-	-	197	3.0
Snake River			700	74	0	0.0%	-	-	-	-

[a] Weir escapement includes 390 coho salmon that were uncounted past the weir (J. Menard Pers. Comm.)

[b] Includes fish caught in the sport and subsistence fisheries as well as returns to the weir.

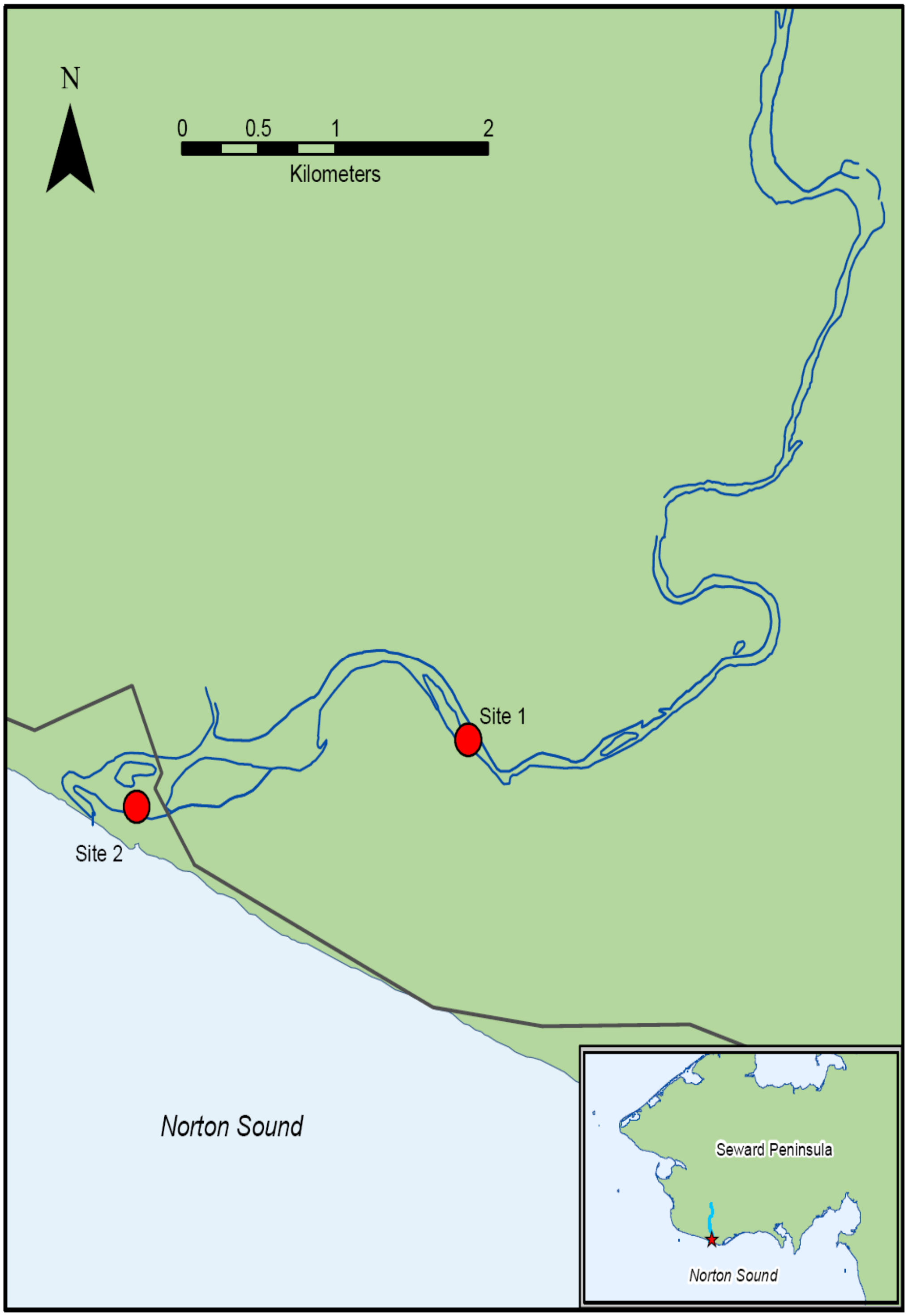

Figure 1. Sampling locations in the Nome River used in 2006 through 2009.

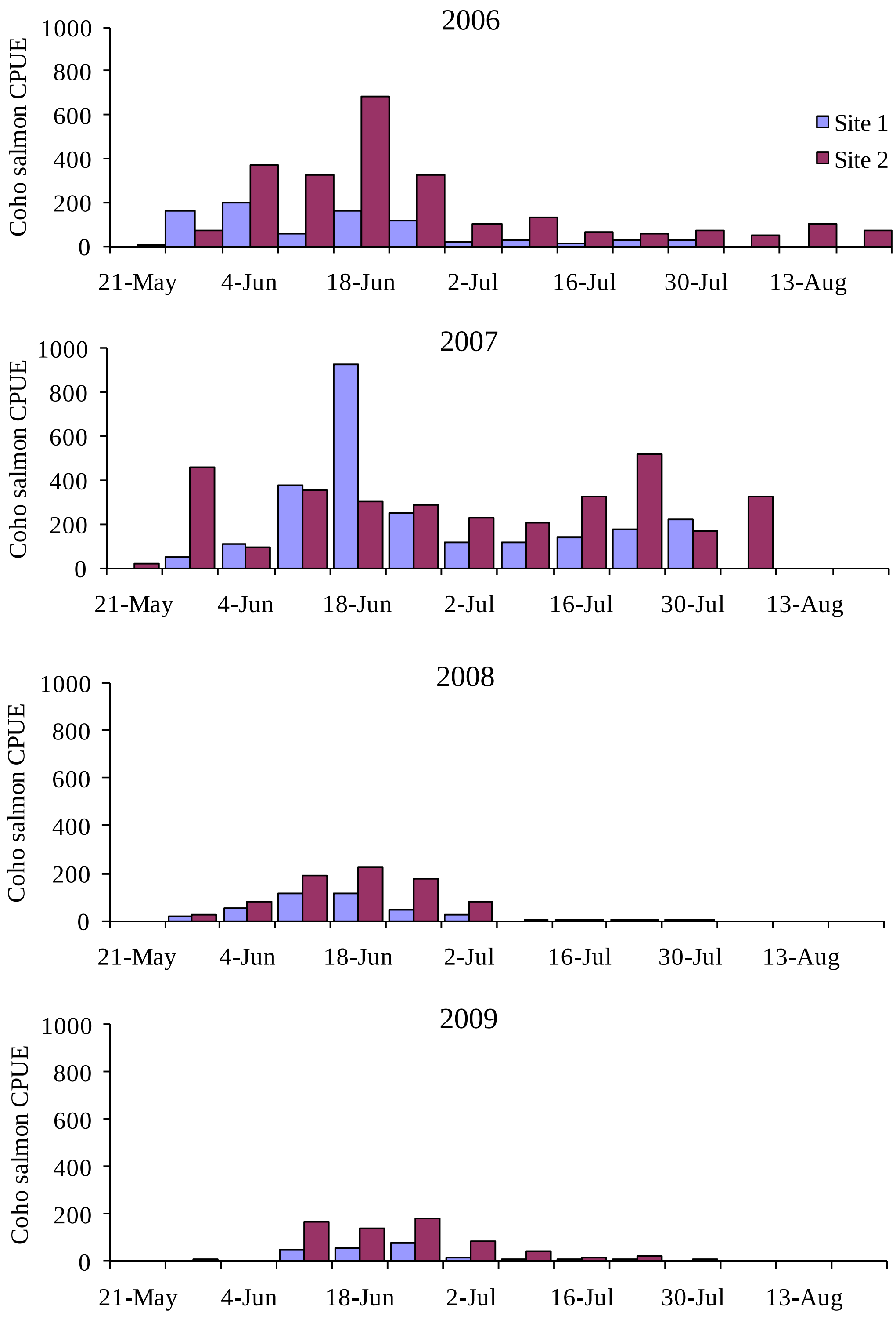

Figure 2. Juvenile coho salmon catch per unit effort (fish/week), by sampling location in the Nome River.

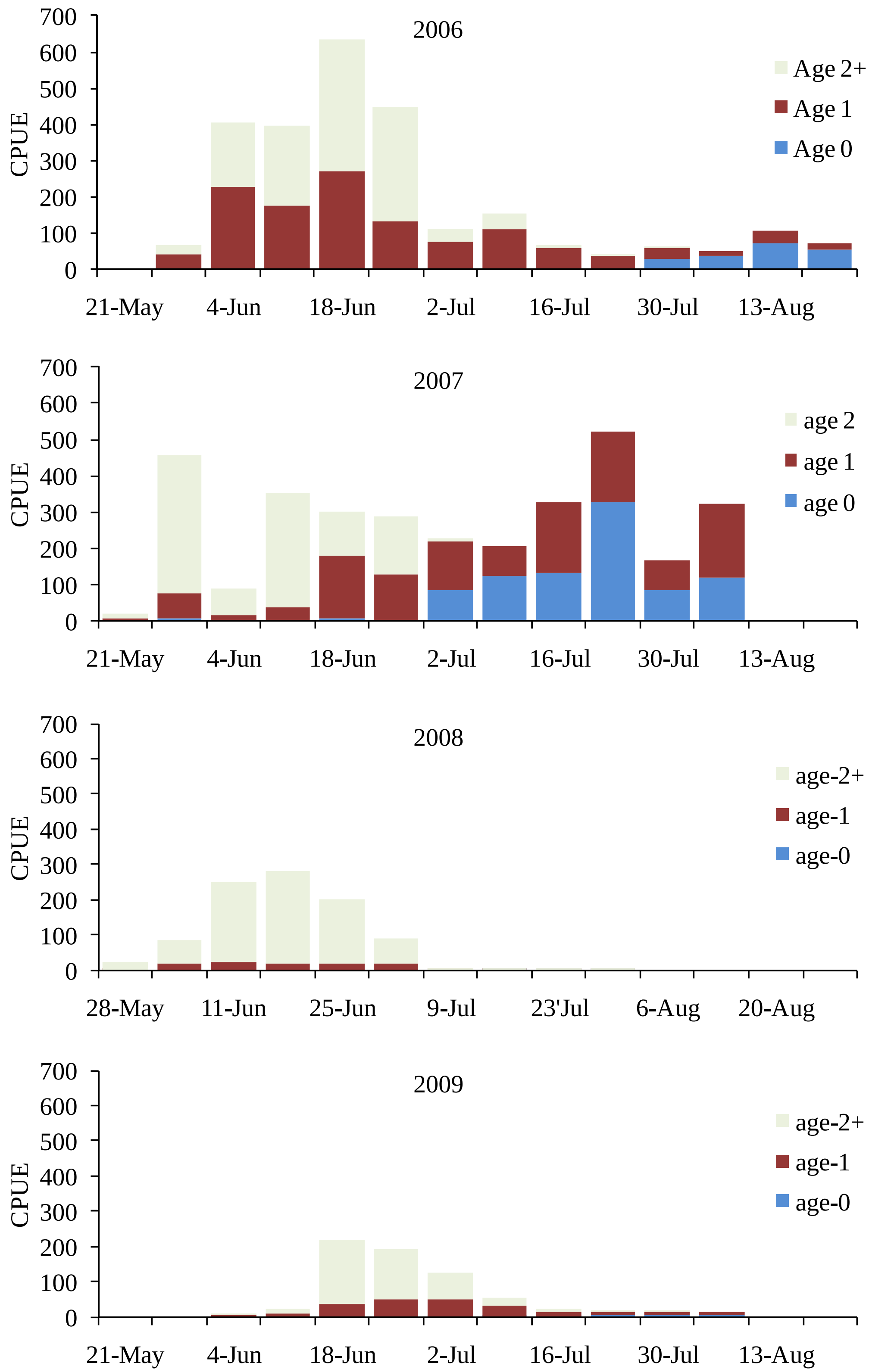

Figure 3. Weekly juvenile coho salmon catch per unit effort (fish/week) by age, for fish caught at Site 2 in the Nome River.

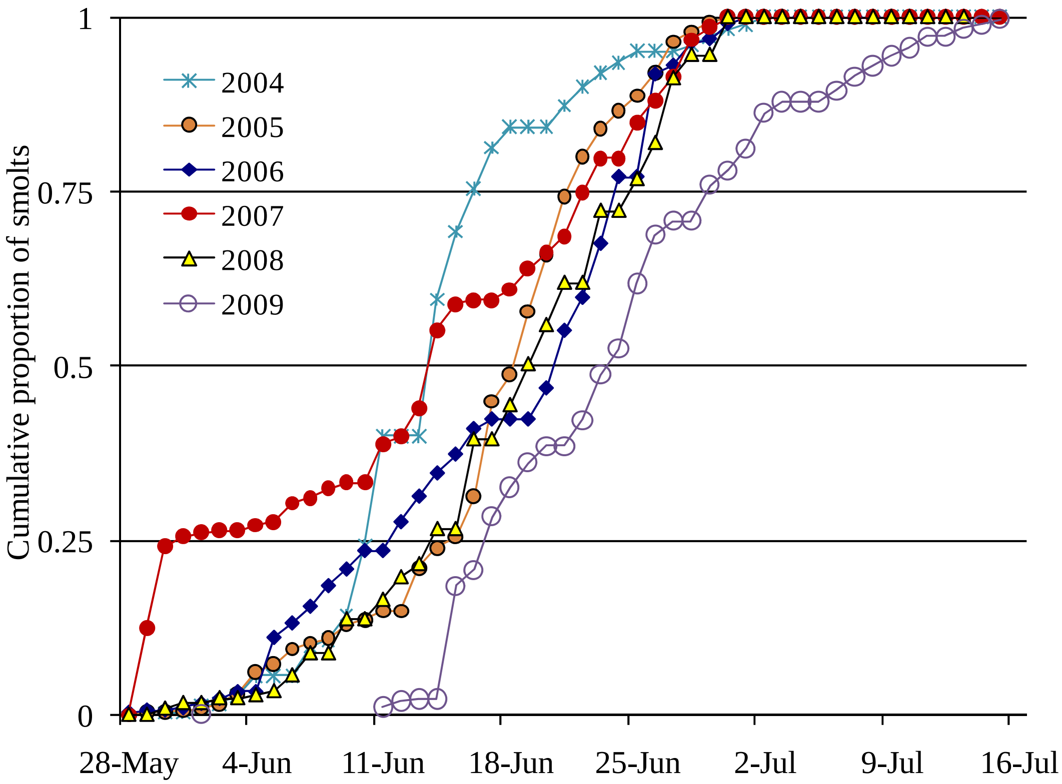

Figure 4. Coho salmon smolt (80mm+ and/or age-2) run timing in the Nome River, 2004 through 2009.

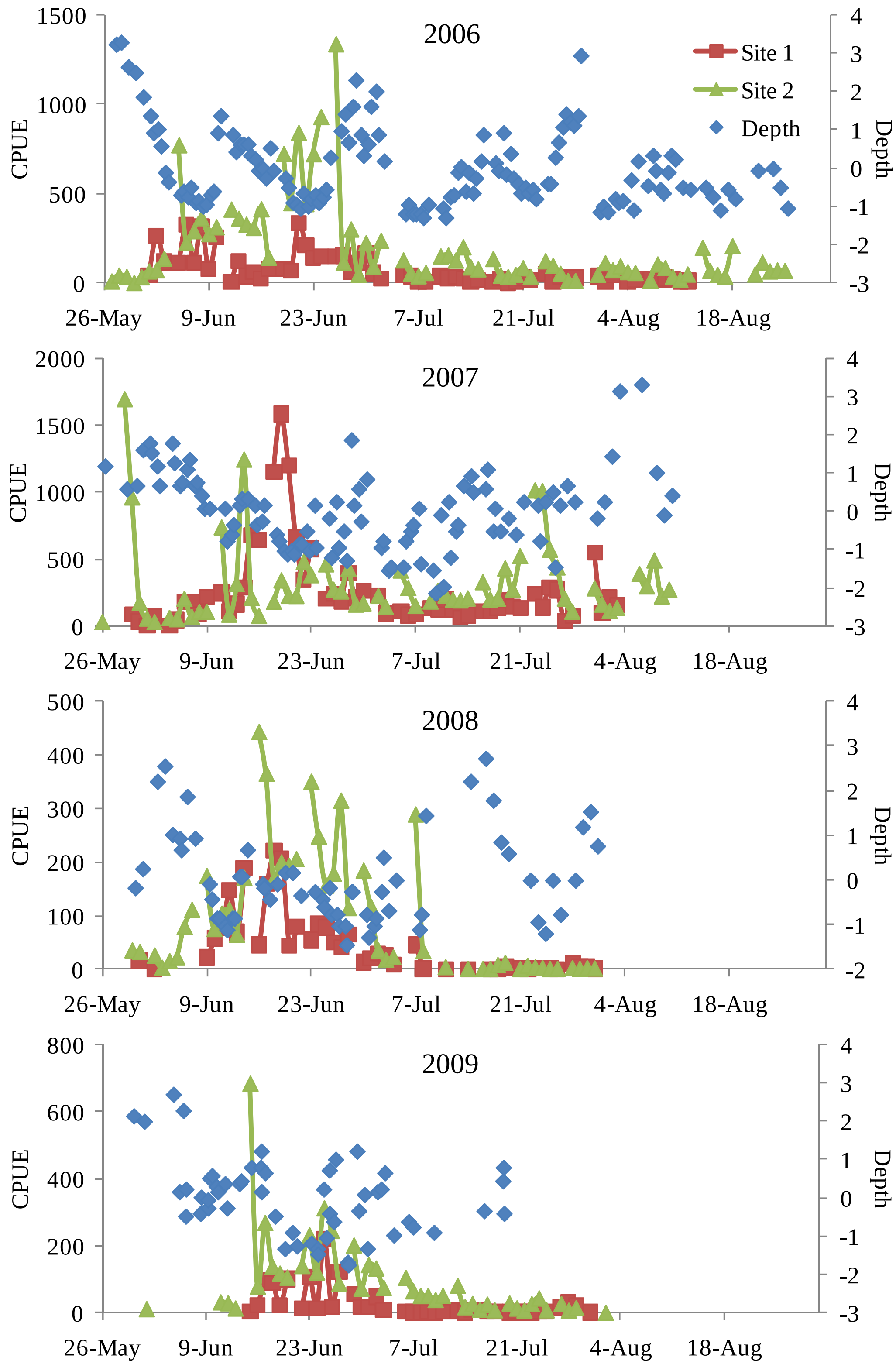

Figure 5. Juvenile coho salmon CPUE (fish/day) and standardized water depth for the Nome River, 2006 through 2009. Depth has been standardized with a Z-score transformation.

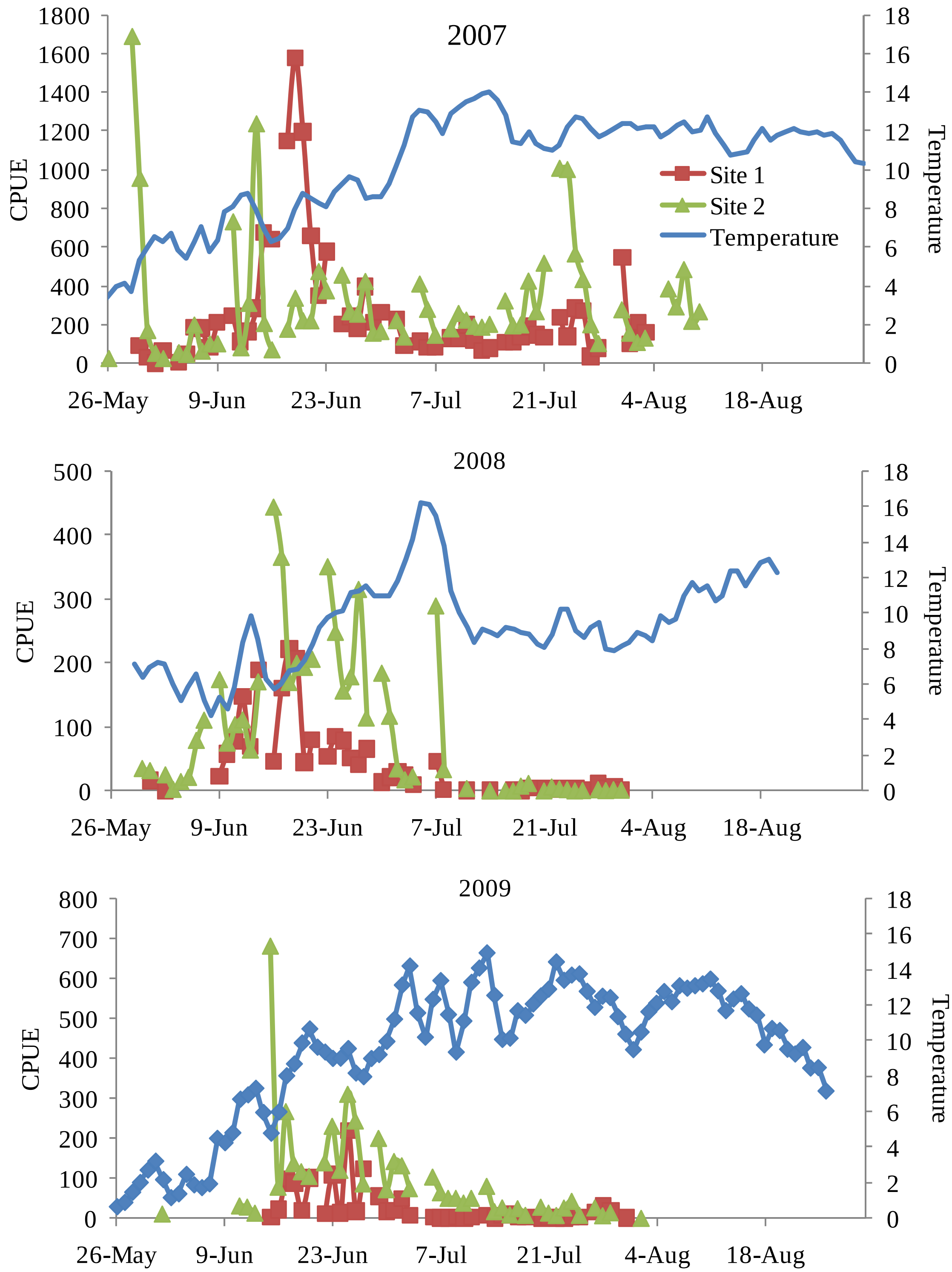

Figure 6. Juvenile coho salmon CPUE (fish/day) and water temperature for the Nome River, 2006 through 2009. Temperature is in degrees Celsius.

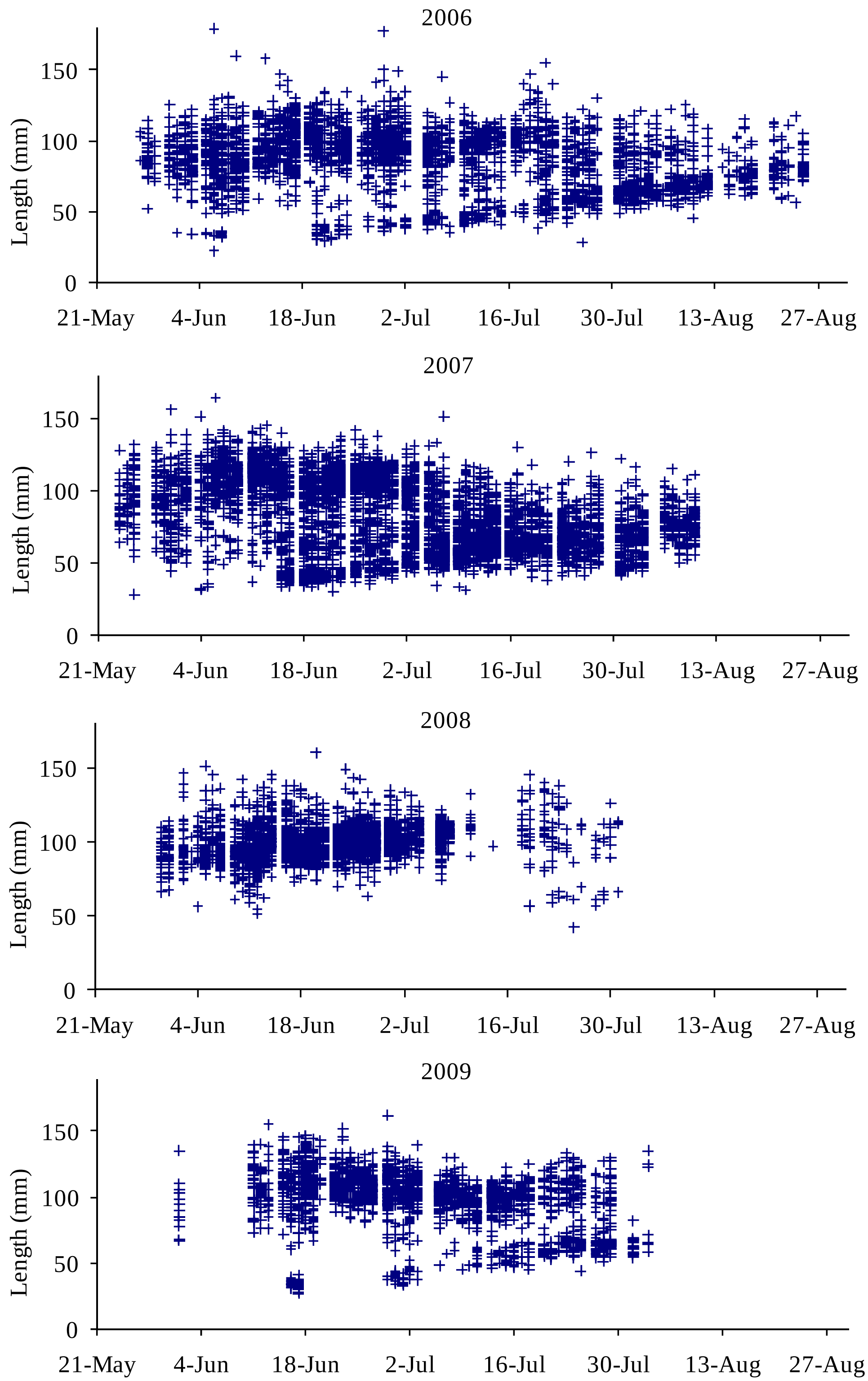

Figure 7. Juvenile coho salmon random lengths by date from the Nome River, 2006 through 2009.

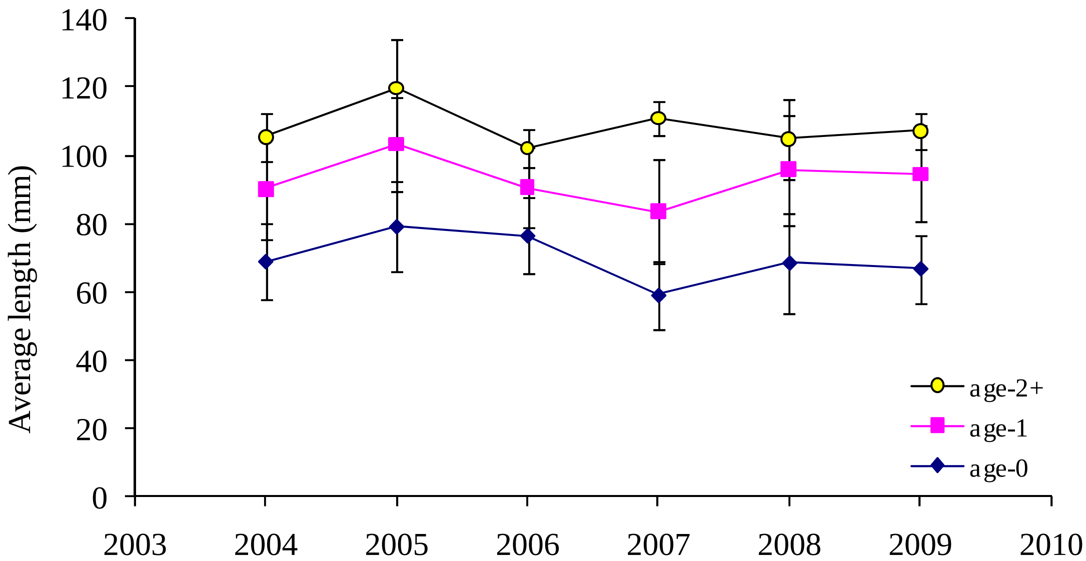

Figure 8. Nome River juvenile coho salmon average length by age and year. Error bars represent standard deviations

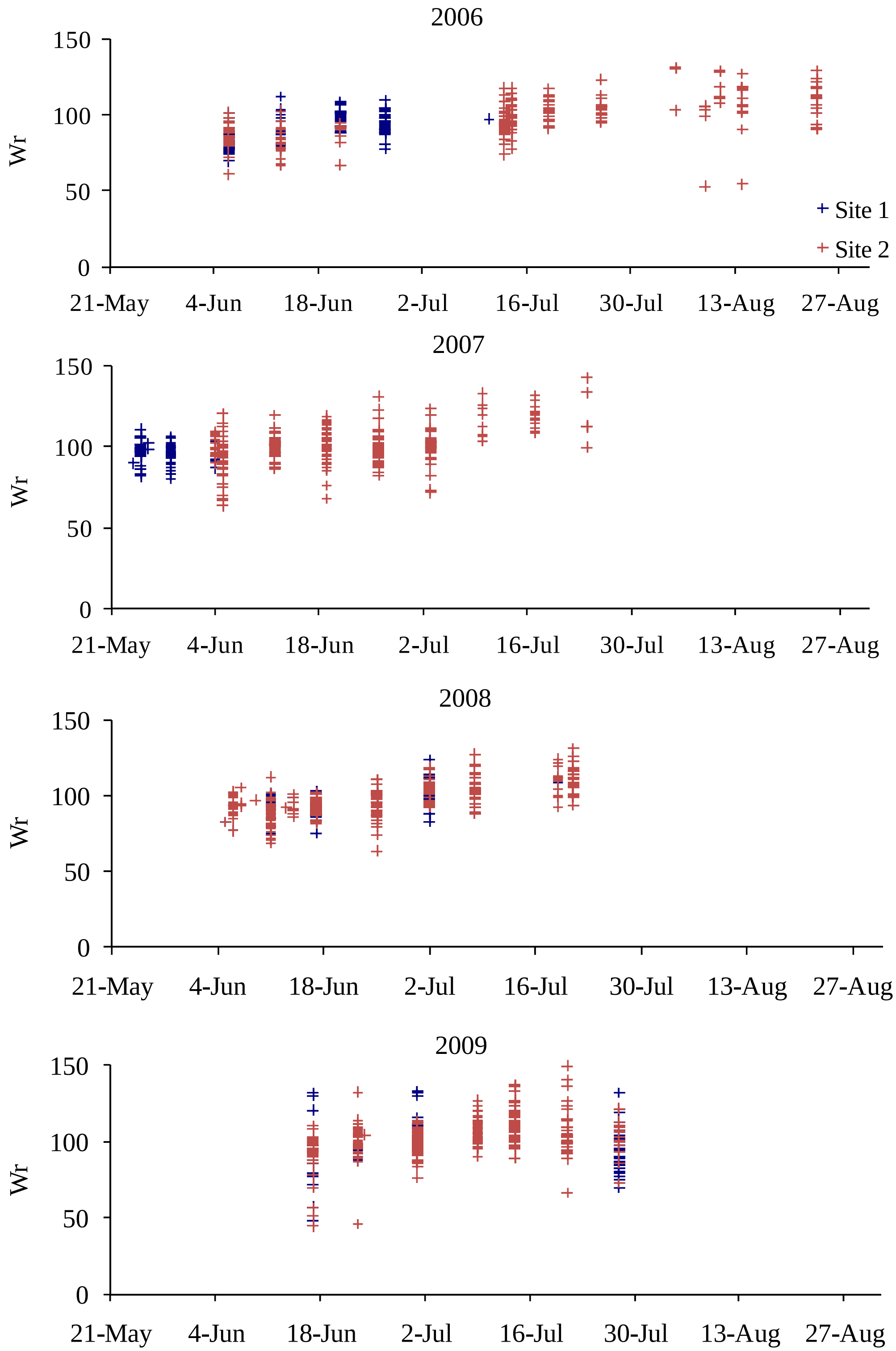

Figure 9. Juvenile coho salmon relative weight (*Wr*) by date. The *Wr* analysis was performed using data only from the Nome River.

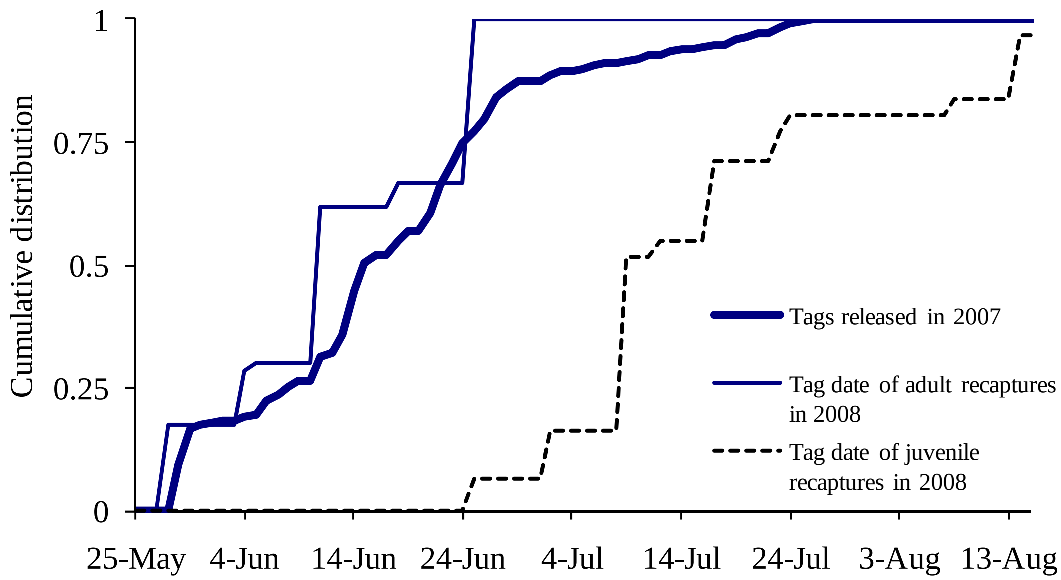

Figure 10. Evidence of overwintering based on tagging date for juvenile coho salmon released in the Nome River in 2007 and returning in 2008. Juvenile coho salmon tagged during the early and peak portions of the smolt outmigration (through June 25) returned the following year as adults. Juvenile coho salmon tagged after June 25 were capture the following year as juveniles, and had overwintered in the Nome River. No juveniles tagged after June 25 were recaptured as adults the following year.

DELIVERABLES

Deliverables include a progress report Williams, B.C., M.J. Nemeth, R.C. Bocking, C. Lean, and S. Kinneen. 2009. Abundance and marine survival of coho salmon smolts from the Nome River, Alaska, 2006-2008. Unpublished report prepared for the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative by LGL Alaska Research Associates, Inc. and Norton Sound Economic Development Corporation. 41 p. + appendices. A final report Williams, B. C., M. J. Nemeth, and C. Lean. 2010. Abundance and marine survival of coho salmon smolts from the Nome River, Alaska, 2006-2009. Report prepared for the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative by LGL Alaska Research Associates, Inc. and Norton Sound Economic Development Corporation. 52 p. A 2009 presentation at the AYKSSI meeting in Nome, Alaska. A 2010 presentation at the AYKSSI meeting. Anticipated presentation at an American Fisheries Society meeting, and an anticipated journal submission. Projects results are available in digital format from the authors as well as through the ARLIS library located on the University of Alaska Anchorage campus.

PROJECT DATA

Project data includes catch, effort, length, weight, and age information, is held in Microsoft Excel (2007) and Access file formats Inquiries for data should be directed to Ben Williams at LGL Alaska Research Associates, Inc., 1101 East 76th Ave, Suite B, Anchorage, Alaska 99518. E-mail bwilliams@lgl.com, phone 907-562-3339, fax 907-562-7223. The authors reserve first right to publish the data, and may restrict access to certain portions of the database until such publications can be completed.

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PRESS RELEASE

Coho salmon were monitored in the Nome River from 2006 through 2009 to generate annual estimates of smolt abundance and marine survival and to collect basic biological information that could help explain variability in the smolt abundance and survival estimates. The abundance estimates continue a time series begun in 2004 and 2005, yielding a 6-year data set developed to determine if coho salmon smolt abundances were within the range predicted by habitat-based smolt production models. The marine survival estimates were used to apportion survival of juvenile coho salmon into freshwater and marine stages, for the habitat-based models, while providing the first estimates of coho salmon marine survival from the Norton Sound region of Alaska. Biological information such as fish community composition, smolt body condition and age structure may also help explain interannual trends, such as years in which marine survival is relatively high or low. This biological information can also be used as a baseline by which to compare population characteristics in future years. The years 2004 through 2009 may have been particularly useful because of high variation in the escapement of the parent year classes of coho salmon smolts, and high variation in the returns of adult pink salmon. Results of this study have direct management implications in that a reason to estimate the abundance of smolts is because of their strong influence on the eventual abundance of adult coho salmon. Fishery managers have used smolt abundance estimates, and some assumptions about fecundity and smolt survival, to manage adult harvest and escapement goals in such a way as to allow enough spawning adult salmon to return to produce a given level of smolt production. The Norton Sound region has few coho salmon escapement goals established, by utilizing a habitat-based escapement model it may be possible to generate reliable escapement goals for systems that would otherwise have none.

APPENDICES

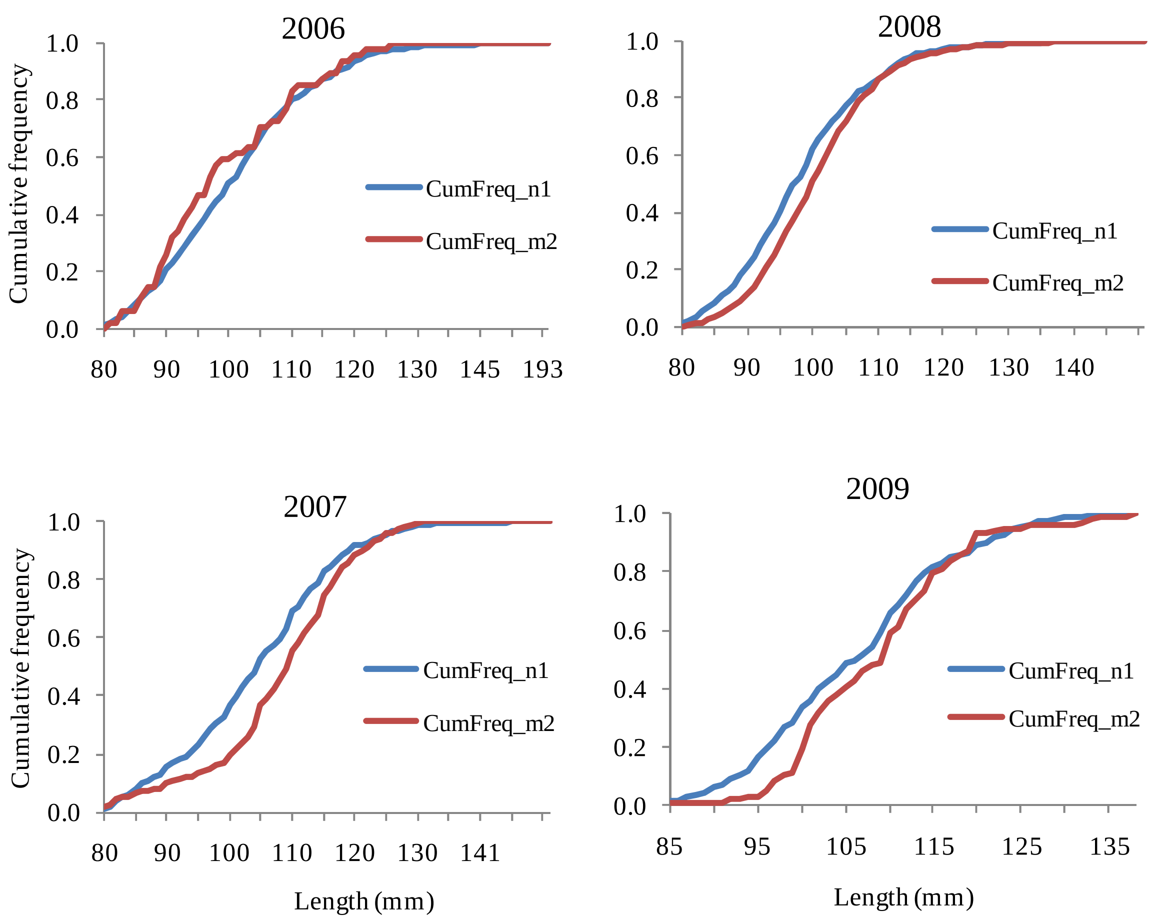
Appendix A. Chi-square test results from SPAS ouput, associated Darroch and pooled Petersen population estimates (PPE), and pooling used for the Darroch models by rows and columns. A non-significant Chi-square test allows for the use of the PPE.

			Chi-square tests						Population estimate				
Year	Length group (mm)	Sampling period	Complete mixing	DF	P	Equal proportions	DF	P	Method	Estimate	SE	Darroch model pooling	
2006	80+	Full season	29.14	4	<0.001	46.51	6	<0.001	Darroch	118,868	5,070	rows	1-2,3,4,5
									PPE	119,203	4,720	columns	1,2,3,4,5,6-7
		Peak smolt	57.18	4	<0.001	37.03	5	<0.001	Darroch	118,089	7,797	rows	1-2,3,4,5
									PPE	127,532	5,698	columns	1,2,3,4,5-6
2007	80-103	Full season	50.93	9	<0.001	103.27	10	<0.001	Darroch	77,091	7,877	rows	1-3,4,5,6-10
									PPE	74,373	5,077	columns	1-3,5,6-7,8-11
		Peak smolt	11.52	4	<0.001	94.54	5	<0.001	Darroch	56,824	4,940	rows	1-5
									PPE	56,398	4,859	columns	1-4,5-6
	103+	Full season	553.95	9	<0.001	81.12	10	<0.001	Darroch	25,623	1,117	rows	1-2,3,4-10
									PPE	25,780	883	columns	1-2,3,4,5,6-11
		Peak smolt	525.74	4	<0.001	60.03	5	<0.001	Darroch	24,292	1,103	rows	1-2,3,4-5
									PPE	24,426	837	columns	1-2,3,4,5-6

Appendix A. Chi-square test results from SPAS ouput, associated Darroch and pooled Petersen population estimates (PPE), and pooling used for the Darroch models by rows and columns. A non-significant Chi-square test allows for the use of the PPE.

			Chi-square tests						Population estimate				
Year	Length group (mm)	Sampling period	Complete mixing	DF	P	Equal proportions	DF	P	Method	Estimate	SE	Darroch model pooling	
2008	80-97	Full season	11.05	5	0.0500	N/A	5	N/A	Darroch	19,428	1,487	rows	1,2,3-6
									PPE	20,408	1,330	columns	1,2,3,4-6
		Peak smolt	9.53	2	0.0100	15.25	3	<0.001	Darroch	19,483	1,364	rows	1,2-3.
									PPE	19,640	1,304	columns	1,2,3-4
	98+	Full season	43.95	5	<0.001	11.43	5	0.0400	Darroch	15,591	830	rows	1,2,3,4-6
									PPE	15,437	725	columns	1,2,3,4,5-6
		Peak smolt	17.97	2	<0.001	16.06	3	<0.001	Darroch	14,835	842	rows	1,2-3
									PPE	14,502	737		
2009	85-138	Full season	95.29	6	<0.001	8.63	6	0.2000	PPE	41,403	3,764		
		Peak smolt	1.3	2	0.5200	7.46	3	0.0600	PPE	40,126	3,816		

Appendix B. Kolmogorov-Smirnov test for length bias between the marking site and the recapture site. All tests are at the a=0.05 level. If the D statistic is greater than the D_alpha statistic then the maximum absolute difference between the cumulative distributions is used as the cutpoint.



K-S test	Year	2006	2007	2008	2009
Results	D_alpha	0.2030	0.1133	0.0589	0.1609
	D	0.1306	0.2011	0.1280	0.1713
	Cutpoint	NA	103	97	99*

*Cutpoint not utilized as the sample size would be too low to generate a valid population estimate

Appendix C. Release-recapture data for Darroch and pooled Petersen population estimators.

Year	Length group	Release period	Number released	Recapture period 1	2	3	4	5	6
2006	All	1	307	13	14	0	0	0	0
		2	704	0	85	35	0	0	0
		3	309	0	0	42	26	0	0
		4	820	0	0	0	82	64	7
		5	601	0	0	0	0	46	0
		Number examined		358	3,657	3,404	6,326	4,196	1,360

Year	Length group	Release period	Number released	Recapture period 1	2	3	4	5	6
2007	80-103	1	75	0	1	0	0	0	0
		2	174	0	5	8	0	0	0
		3	189	0	0	8	16	0	0
		4	499	0	0	0	21	24	0
		5	274	0	0	0	0	25	9
		Number examined		1,230	371	1,184	1,445	792	468

Year	Length group	Release period	Number released	Recapture period 1	2	3	4	5	6
2007	104+	1	36	0	7	0	0	0	0
		2	424	0	46	59	0	0	0
		3	745	0	0	143	29	0	0
		4	166	0	0	0	82	105	0
		5	211	0	0	0	0	48	9
		Number examined		713	671	2,797	1,482	2,259	240

Year	Length group	Release period	Number released	Recapture period 1	2	3	4
2008	80-97	1	220	24	23	0	0
		2	494	0	64	21	0
		3	134	0	0	29	10
		Number examined		1,070	1,681	1,007	220

Appendix C. Release-recapture data for Darroch and pooled Petersen population estimators.

		Release period	Number released	Recapture period 1	2	3	4
2008	98+	1	232	40	15	0	0
		2	269	0	80	22	0
		3	199	0	0	70	13
		Number examined		914	2,146	1,409	516

		Release period	Number released	Recapture period 1	2	3	4	5	6	7
2009	85-138	1	191	15	6					
		2	460		43	13				
		3	103			10	6			
		4	3				1	3		
		5	3					1	0	
		6	2						0	0
		7	4							0
		Number examined		1,205	2,108	1,102	580	239	203	61

Appendix D.1. Coded wire tagging survival and tag retention for Nome River coho salmon 2006.

Date	# Tagged	# Kept Overnight	Overnight Mortality	Adjusted Survival	# Retained Tags	Tag Retention	Viable Tagged
28-May	22						21
29-May	28						27
31-May	51						49
1-Jun	173						168
2-Jun	340						330
3-Jun	417						404
5-Jun	1,358	260	0	1,358	250	0.96	1,306
6-Jun	617	202	0	617	193	0.96	590
7-Jun	480	203	0	480	199	0.98	471
8-Jun	761	200	0	761	198	0.99	753
9-Jun	475	200	1	474	197	0.99	467
10-Jun	562	200	0	562	198	0.99	556
12-Jun	588	200	1	587	199	1.00	584
13-Jun	783	200	0	783	187	0.94	732
14-Jun	617	200	0	617	200	1.00	617
15-Jun	601						583
16-Jun	715	200	0	715	199	1.00	711
17-Jun	324						314
19-Jun	8						8
23-Jun	290						281
24-Jun	1,747						1,694
26-Jun	1,904						1,845
27-Jun	126						122
28-Jun	658						638
29-Jun	175						170
30-Jun	588						570
1-Jul	227						220
2-Jul	337						327
11-Jul	131						127
12-Jul	215	226	15	200	224	0.99	198
13-Jul	370	200	20	350	180	0.90	315
14-Jul	144	92	4	140	88	0.96	134
15-Jul	88						85
17-Jul	214	115	15	199	115	1.00	199
18-Jul	57	48	4	53	44	0.92	49
19-Jul	61	20	4	57	20	1.00	57
20-Jul	69	48	1	68	47	0.98	67
21-Jul	94	94	4	90	90	0.96	86

Appendix D.1. Coded wire tagging survival and tag retention for Nome River coho salmon , 2006.

Date	# Tagged	# kept Overnight	Overnight Mortality	Adjusted Survival	# Retained Tags	Tag Retention	Viable Tagged
22-Jul	46						45
24-Jul	48						47
25-Jul	45						44
26-Jul	44						43
27-Jul	16						16
28-Jul	14						14
31-Jul	42						41
1-Aug	52						50
2-Aug	43						42
3-Aug	43						42
4-Aug	32						31
5-Aug	27						26
8-Aug	47						46
9-Aug	30						29
10-Aug	20						19
11-Aug	12						12
12-Aug	17						16
14-Aug	41						40
15-Aug	43						42
16-Aug	27						26
17-Aug	23						22
18-Aug	94						91
21-Aug	35						34
22-Aug	97						94
23-Aug	65						63
24-Aug	69						67
25-Aug	55						53
Sum	17,542	2,908	69	8,111	2,828	0.97	16,970

Appendix D.2. Coded wire tagging survival and tag retention for Nome River cohosalmon, 2007.

Date	# Tagged	# Kept Overnight	Overnight Mortality	Adjusted Survival	# Retained	Tag Retention	Viable Tagged
29-May	1,830	200	2	1,828	200	1.00	1,828
30-May	1,408	200	0	1,408	200	1.00	1,408
31-May	181	176	0	181	176	1.00	181
1-Jun	70	70	0	70	68	0.97	68
2-Jun	94	43	0	94	43	1.00	94
4-Jun	110	105	0	110	104	0.99	109
5-Jun	115	53	0	115	53	1.00	115
6-Jun	553	200	0	553	196	0.98	542
7-Jun	288	115	0	288	115	1.00	288
8-Jun	262	170	0	262	170	1.00	262
9-Jun	265	122	0	265	121	0.99	263
11-Jun	902	202	0	902	202	1.00	902
12-Jun	233	122	0	233	122	1.00	233
13-Jun	699	200	1	698	200	1.00	698
14-Jun	1,743	200	2	1,741	200	1.00	1,741
15-Jun	1,129	201	2	1,127	201	1.00	1,127
16-Jun	253			253			250
18-Jun	610	200	3	607	200	1.00	607
19-Jun	398			398			394
21-Jun	737	152	21	716	151	0.99	711
22-Jun	1,089	200	19	1,070	200	1.00	1,070
23-Jun	901			901			891
25-Jun	764	200	7	757	200	1.00	757
26-Jun	477			477			472
27-Jun	530	222	17	513	221	1.00	511
28-Jun	916	200	9	907	200	1.00	907
29-Jun	299			299			296
30-Jun	282			282			279
2-Jul	265	181	21	244	176	0.97	237
3-Jul	167			167			165
5-Jul	136	26	0	136	26	1.00	136
6-Jul	105	50	6	99	50	1.00	99
7-Jul	118			118			117
9-Jul	64	30	6	58	30	1.00	58
10-Jul	105	39	3	102	39	1.00	102
11-Jul	123	64	1	122	63	0.98	120
12-Jul	59	14	0	59	14	1.00	59
13-Jul	108	79	2	106	79	1.00	106

Appendix D.2. Coded wire tagging survival and tag retention for Nome River coho salmon, 2007.

Date	# Tagged	# Kept Overnight	Overnight Mortality	Adjusted Survival	# Retained	Tag Retention	Viable Tagged
14-Jul	72			72			71
16-Jul	128	90	44	84	90	1.00	84
17-Jul	110	85	40	70	82	0.96	68
18-Jul	52	53	0	52	53	1.00	52
19-Jul	231	207	8	223	201	0.97	217
20-Jul	116	108	4	112	100	0.93	104
21-Jul	158			158			156
23-Jul	258	179	22	236	179	1.00	236
24-Jul	207	200	74	133	177	0.89	118
25-Jul	180	132	47	133	130	0.98	131
26-Jul	58	46	10	48	46	1.00	48
Sum	19,958	5,136	371	19,587	5,078	0.99	19,110

Appendix D.3. Coded wire tagging survival and tag retention for Nome River coho salmon, 2008.

Date	# Tagged	# Kept Overnight	Overnight Mortality	Adjusted Survival	# Retained	Tag Retention	Viable Tagged
16-Jun	706	200	0	706	200	1.00	706
17-Jun	760	200	0	760	120	0.60	456
18-Jun	568	200	1	567	196	0.98	556
19-Jun	550	200	0	550	199	1.00	547
20-Jun	372	200	0	372	169	0.85	314
21-Jun	453			453			397
23-Jun	552	200	1	551	180	0.90	496
24-Jun	550	200	13	537	194	0.97	521
25-Jun	281	200	33	248	154	0.77	191
26-Jun	498	200	2	496	191	0.96	474
27-Jun	560	204	2	558	204	1.00	558
28-Jun	206	156		206			181
30-Jun	221	200	28	193	200	1.00	193
1-Jul	200	168	23	177	167	0.99	176
2-Jul	98	68	8	90	68	1.00	90
3-Jul	41	23	3	38	23	1.00	38
4-Jul	43			43			38
7-Jul	511	200	16	495	200	1.00	495
8-Jul	46	46	2	44	46	1.00	44
11-Jul	16			16			14
18-Jul	15			15			13
19-Jul	12			12			11
21-Jul	22			22			19
22-Jul	12			12			11
23-Jul	6			6			5
28-Jul	4			4			4
30-Jul	6			6			5
	7,309	2,865	132	7,177	2,511	0.88	6,551