Fishery Data Series No. 10-48

Disappearance Creek Chum Salmon Weir Study, 2009

by

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and

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

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

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

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

Measures (fisheries)	
fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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Month Year

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ABSTRACT

In 2009, we conducted the second year of a project to monitor the escapement of fall chum salmon at Disappearance Creek. From 20 August to 29 October, we enumerated the adult salmon escapement through a weir and conducted a secondary mark-recapture estimate of the total spawning population. We estimated the average weekly stream life and collected biological information to estimate the age, length, and sex composition of chum salmon in Disappearance Creek. We also collected otoliths from chum salmon carcasses to estimate the proportion of stray hatchery chum salmon in the escapement. The chum salmon weir count was 55,436 and the estimated number of fish upstream of the weir at start up was 50 chum salmon (=55,486). The mark-recapture study yielded a maximum likelihood Darroch estimate of approximately 61,500 chum salmon (SE=1,600; 95% CI=58,500–65,000) that was accepted as the best available estimate of total escapement to the system. The peak aerial survey estimate of 26,000 chum salmon occurred on 5 October 2009 and was 42% of the estimated total escapement of 61,500 chum salmon for a peak survey expansion factor of 2.37. Seasonal mean stream life, weighted by week, was estimated at 7.7 days, and decreased from 15.8 days in mid-to-late August to 6.7 days in mid-to-late October. The estimated age distribution of the chum salmon escapement was 39% age 0.2, 52% age 0.3, and 9% age 0.4. Approximately 1% of the 235 chum salmon sampled for otoliths in 2009 were thermal-marked fish that strayed from the Neets Bay and Nakat Inlet hatchery release sites in the Ketchikan area.

Key words: chum salmon, *Oncorhynchus keta*, Disappearance Creek, escapement, hatchery stray, mark-recapture, otolith, purse seine, Southeast Alaska, stream life, weir.

INTRODUCTION

For over three decades, the Alaska Department of Fish and Game (ADF&G) has managed a fall chum salmon purse seine fishery in Cholmondeley Sound, Prince of Wales Island, Southeast Alaska (Figure 1). Management of this fishery, conducted in September and early October, has changed little since the fishery's inception and has successfully provided commercial fisherman with a valuable opportunity to extend their fishing season beyond the end of the directed pink salmon purse seine season that ends in late August. Harvests of fall chum salmon in Cholmondeley Sound (District 102-40) averaged 42,000 fish in the 1970s and 1980s, but increased to an average of 122,000 fish a year from 1991 to 2004, including a peak catch of 359,000 chum salmon in 1998 (Eggers and Heinl 2008). Total catch, fishing time, and effort have decreased since the late 1990s and the most recent harvests have been very low: 3,000 in 2005, 10,500 in 2006, 389 in 2007, and 1,250 in 2008 (Table 1). Fishing time in Cholmondeley Sound historically extended into early October, but in the last six years the fishery has closed prior to October 1 due to poor catches. Commercial fishermen have voiced concerns to the ADF&G Ketchikan area management biologists about the reduced catch and the lack of adequate escapement and run timing information with which to manage this fishery.

In the 1980s and 1990s, management of the fall chum salmon fishery in Cholmondeley Sound was based on an informal escapement target of 30,000 chum salmon at Disappearance Creek (ADF&G Stream Number 102-40-043) and, since about 1985, peak aerial escapement survey counts of 10,000–15,000 fish in Lagoon Creek (ADF&G Stream Number 102-40-060; P. Doherty, retired Area Management Biologist, ADF&G, Ketchikan, personal communication). These escapement targets were established in the early days of state management and were based on the professional judgment of the area management staff rather than a critical examination of biological data; thus, the Cholmondeley Sound chum salmon escapement targets were not escapement goals as defined in the Policy for Statewide Escapement Goals (5 AAC 39.223).

The escapement at Disappearance Creek was measured at an adult counting weir operated nearly annually from 1961 to 1984. This weir was used to ensure that the 30,000 chum salmon escapement target was met and, starting in the mid-1970s, was used to facilitate the collection of broodstock for fall chum salmon enhancement efforts in the Ketchikan area. The weir was typically removed once the escapement target had been met and was not always operated continuously when it was in place (Heinl et al. 2004); thus, all of the weir counts during those years represent minimum estimates of escapement. Since 1985, aerial surveys have been used to monitor escapements to Disappearance and Lagoon creeks to ensure that escapement targets are met (Heinl et al. 2004). As management biologists observe chum salmon moving into the head waters of Cholmondeley Sound and into the spawning streams, fishing areas are expanded to target surplus chum salmon. Peak escapement survey estimates have ranged from 8,000 to 50,000 chum salmon in Disappearance Creek and 4,000 to 50,000 chum salmon in Lagoon Creek. Although our stock assessment methods for Cholmondeley Sound fall chum salmon do not allow an accounting of total runs for the two major contributing stocks, trends in escapement and commercial harvests indicate that runs had been stable since the early 1970s (Heinl et al. 2004, Heinl 2005).

ADF&G developed the first formal escapement goals for chum salmon in Southeast Alaska in 2008, including a sustainable escapement goal for Cholmondeley Sound fall chum salmon that was based on the "Bue and Hasbrouck"[1] approach of setting a goal between the 25^{th} and 75^{th} percentiles of historic escapement data (Eggers and Heinl 2008). The goal for Cholmondeley Sound is 30,000 to 48,000 index spawners, based on the combined annual peak survey estimates at Disappearance and Lagoon creeks. In order to determine if stray hatchery fish were contributing to our escapement estimates at Disappearance Creek, we collected otolith samples from chum salmon carcasses throughout the season in 2008 and 2009. Most chum salmon escapement goals in Southeast Alaska, including the Cholmondeley Sound fall chum salmon escapement goal, are based on peak aerial survey estimates (Eggers and Heinl 2008). If hatchery-produced chum salmon were straying into wild stock streams in Cholmondeley Sound, it is likely that peak aerial survey estimates and, therefore, trends in the escapement index series would have been affected by increased numbers of hatchery strays. Hatchery releases of fall chum salmon from Southern Southeast Regional Aquaculture Association's (SSRAA) Neets Bay and Nakat Inlet release sites in southern Southeast Alaska averaged approximately 25 million fry over the last decade. All of SSRAA's chum salmon releases have been 100% otolith marked since brood year 2002.

We conducted the first year of a project to monitor the escapement of fall chum salmon at Disappearance Creek in 2008 (Piston and Heinl 2010), and we conducted the second year of the proposed three-year project in 2009. From 20 August to 29 October, we enumerated the adult salmon escapement through a weir, by species, and conducted a secondary mark-recapture estimate of the total spawning population of adult chum salmon. The average weekly stream life was estimated and used in conjunction with the daily weir counts to estimate the number of live fish in the creek on any given day. The estimates of live fish in the creek were then compared to aerial survey estimates conducted during the season by Ketchikan area management biologists. In addition, we collected biological information to estimate the age, length, and sex composition of chum salmon in Disappearance Creek.

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[1] Bue, B. G., and J. J. Hasbrouck. *Unpublished*. Escapement goal review of salmon stocks of Upper Cook Inlet. Alaska Department of Fish and Game, Report to the Alaska Board of Fisheries, November 2001 (and February2002), Anchorage. Subsequently referred to as Bue and Hasbrouck (*Unpublished)*.

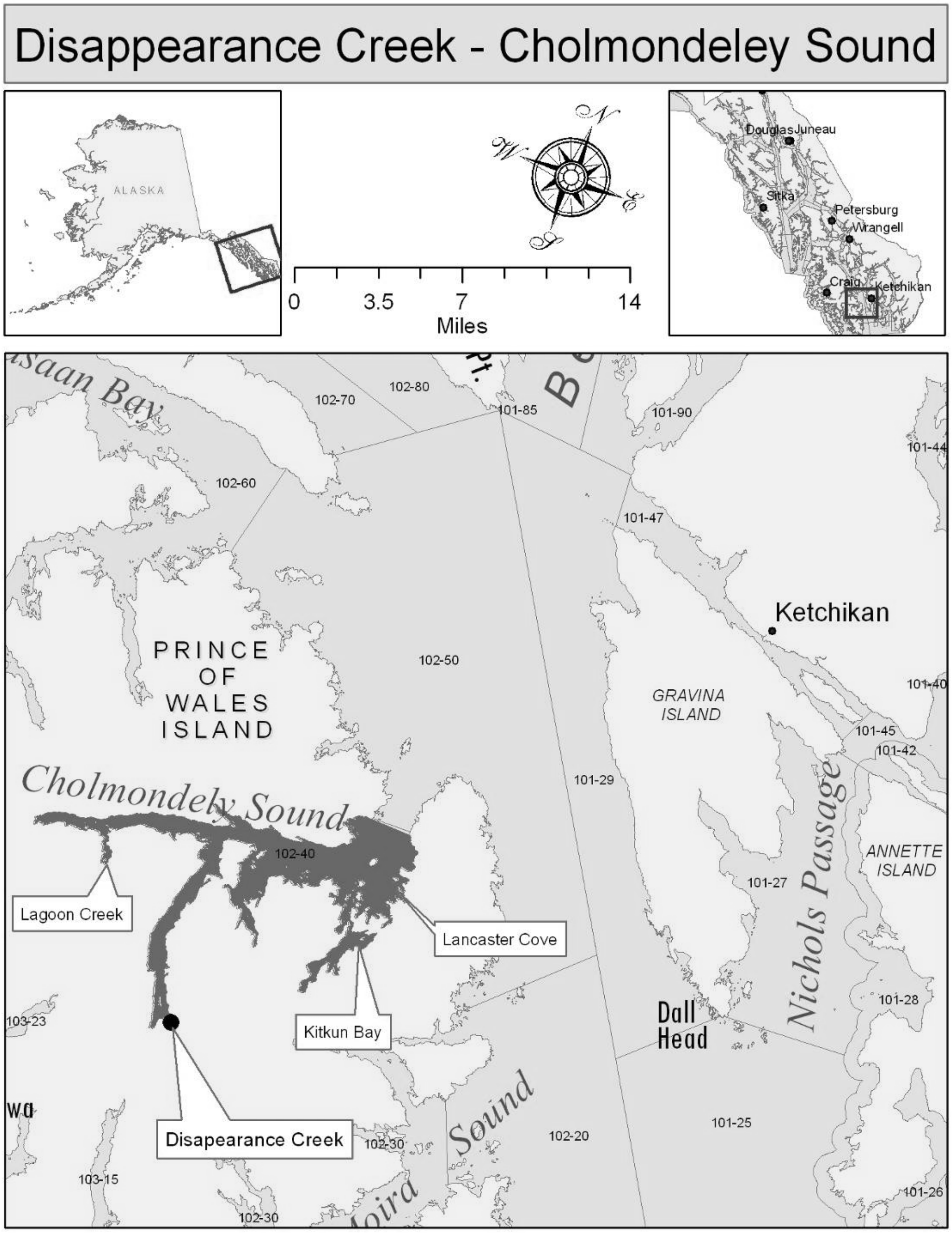

Figure 1.–The geographic location of Disappearance Creek, South Arm, Cholmondeley Sound, Prince of Wales Island, Southeast Alaska. Most of the chum salmon caught in the District 2 fall purse seine fishery are harvested in subdistrict 102-50, and inside Cholmondeley Sound in subdistrict 102-40.

Table 1.–Harvest of chum salmon by sub-district in the District 2 fall purse seine fishery, 1971–2009.

	District 102 Subdistricts								
Year	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**	**-70**	**-80**	**Total**
1971	0	0	1,350	88	18,628	11,558	6,131	183	37,938
1972	3,415	4,155	0	66,230	4,457	0	293	284	78,834
1973	4,245	83,069	5,879	18,824	64,579				176,596
1974	0	6,434	4,025	155,857	1,799	0	0	0	168,115
1975	4,298	20,264	2,252	30,048	6,510				63,372
1976	6,530	5,253	0	50,872	28,386		8,286	1,040	100,367
1977	466	1,647	0	41,677	25,808	517			70,115
1978				15,434					15,434
1979	52	2,318		194	19,392		390		22,346
1980				1,983	5,666				7,649
1982	2,469			78,300	20,145				100,914
1983				35	13,346				13,381
1984		258		25,811	46,950				73,019
1985				15,071	29,009				44,080
1986				62,654	7,322				69,976
1987	4,221	5,917		37,213	62,556				109,907
1988	9,353	27,056	4,694	124,430	24,632				190,165
1989	699	3,322		48,739	3,069				55,829
1990	1,671	2,902		402	28,738				33,713
1991	0	11,274		99,543	74,364				185,181
1992	293	7,124		40,136	31,101	1,211	5,753		85,618
1993	6,865	8,954		81,414	107,626	2,555	2,252		209,666
1994	453			63,810	188,641		7,400		260,304
1995	4,891	13,043		105,342	60,135		12,583		195,994
1996		1,562		66,991	45,161		8,577		122,291
1997	2,535	370		153,833	105,238		3,645		265,621
1998	24,414	8,369		359,443	140,441		27,740		560,407
1999	187	1,397		215,214	23,563		2,411	2,050	244,822
2000		4,877		195,876	16,790		7,656		225,199
2001	6,233	6,622		127,258	51,902		26,218		218,233
2002		3,859		47,309	40,170		8,058		99,396
2003		4,819		93,200	34,727		8,792		141,538
2004		157		57,923	27,521	1,584	13,729		100,914
2005		2,242		2,850	6,078		1,629		12,799
2006	721	1,052		10,487	3,374		1,672		17,306
2007	1,001	531		389	11,611	110	4,979		18,621
2008		663		1,256	1,788		227		3,934
2009									
Average Proportion	1.7%	6.1%	0.4%	49.0%	37.6%	1.0%	4.2%	0.1%	100.0%

STUDY SITE

Disappearance Creek (ADF&G Stream Number 102-40-043) flows north into the head of the south arm of Cholmondeley Sound, 50 km west of Ketchikan, on Prince of Wales Island, Southeast Alaska (Figures 1 and 2). Approximately 1 km of the lower creek is accessible to salmon; the upper portion of the creek disappears underground, hence the name "Disappearance

Creek." A small (1.22 km long) lake is located in the upper creek valley, but the only obvious outlet stream flows south into Dickman Bay, Moira Sound. The area at the mouth of Disappearance Creek, and continuing for approximately 75 m upstream, is shallow, wide, and braided, with good spawning substrate (Figure 3). The creek then enters a narrow and fast reach for approximately 0.25 km before reaching the first of two large pools (Figure 2). Above the first major pool, the creek narrows again for approximately 25 m and becomes very swift, with a steep series of short rapids leading up to the second main pool. The creek emerges from the ground approximately 100 m above the upper spawning pool.

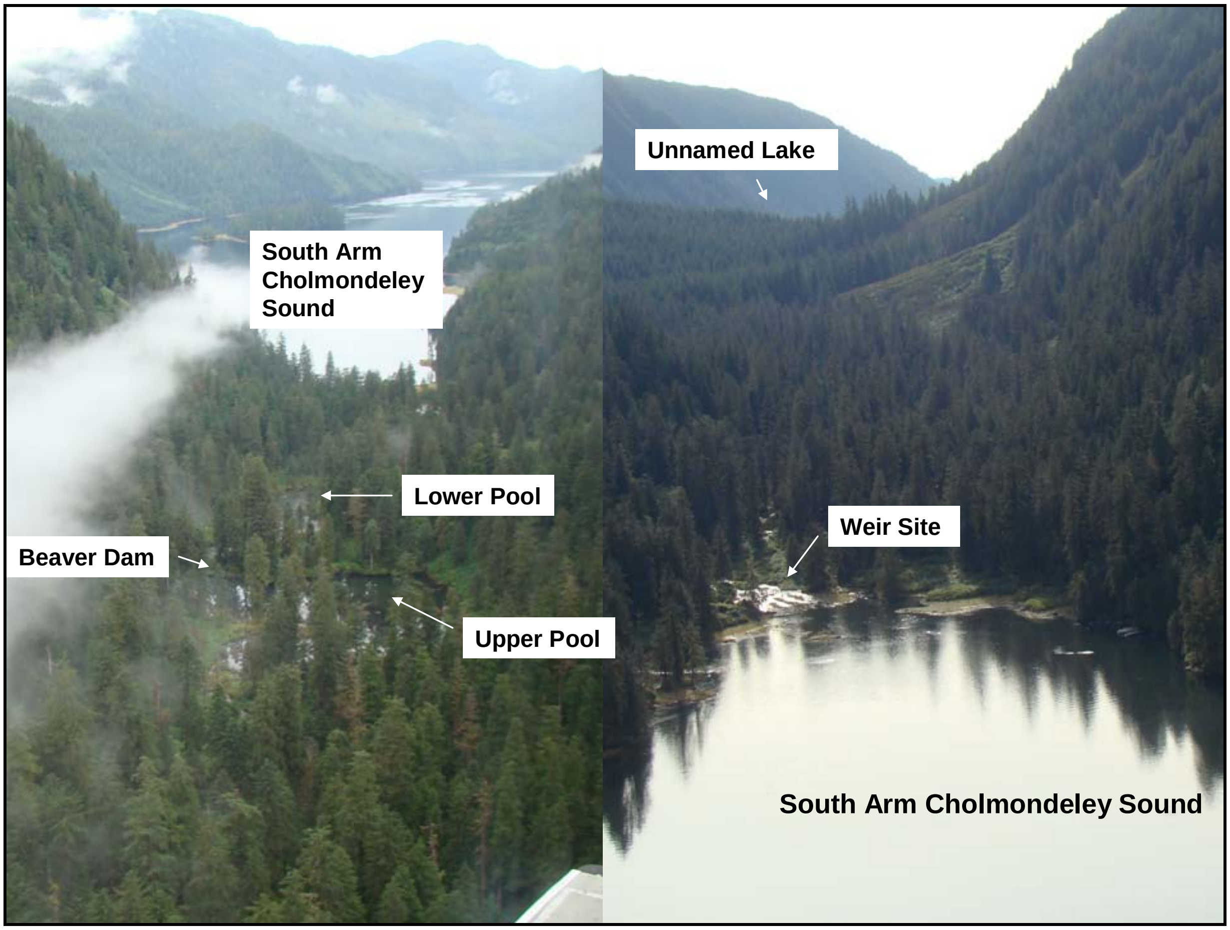

Figure 2.–Upstream (right) and downstream (left) views of the Disappearance Creek drainage (Photo by Scott B. Walker).

Figure 3.–Aerial view of Disappearance Creek weir, 25 September 2008 (Photo by Scott B. Walker). The stream flows from left to right, and the mouth of the creek is to the right of the photo. Note the old cabin at the bottom of the photo. Fencing on the west side of weir (side opposite cabin) is not visible in photo.

METHODS

ADULT ESCAPEMENT

An adult salmon counting weir was operated at the mouth of Disappearance Creek, at the extreme upper reach of the tidal flats (Figures 2 and 3). We employed a standard aluminum bi-pod, channel-and-picket weir design, with an upstream trap for enumerating and sampling salmon. We placed a 20 ft by 120 ft section of ground stabilization fabric across the stream and placed the weir on top of the cloth to reduce erosion behind the weir and reduce the likelihood of a wash out. Large tides (approximately 14 feet and larger) reached the base of the weir and raised the water level up to two feet at the weir. Garden fencing (3.5 ft tall) was attached to the west end of the weir and extended 50 feet to high ground over an area that was typically dry to keep fish from passing around the weir during high water. The fence was held up with black iron pipe pounded into the stream bottom every eight feet. The integrity of the weir structure was verified through daily inspection and a secondary mark-recapture study.

In order to minimize handling, most fish were passed above the weir by pulling one or two pickets at a counting station and enumerating them as they swam past. Fish that were marked for the mark-recapture study, or sampled for biological data, were enumerated at the weir trap and released upstream.

Mark Recapture

A two-sample mark-recapture study was conducted to estimate the total spawning population of chum salmon at Disappearance Creek. The mark-recapture estimate provided an important back-up to the weir count in the event that weir problems allowed fish to pass uncounted—the weir was operated during September and October, two of the wettest months of the year. Chum salmon were marked with a readily identifiable fin clip at the weir, starting at a rate of 1 in 20 (5%). We attempted to maintain this marking fraction throughout the season, but our marking rate fell below 5% on peak fish passage days. Fish that were to be marked were dip-netted from the trap, fin-clipped, sampled for scales when appropriate, and released upstream next to the trap to recover. We did not use anesthetic while sampling chum salmon at Disappearance Creek. Only healthy fish were marked with a fin-clip. Marking was stratified through time on the following schedule: right ventral fin clip, 16 August–10 September; left ventral fin clip, 11 September–1 October; and partial dorsal fin clip, 2 October–26 October. In addition, every marked fish had its adipose fin removed to ensure that marked fish were easily identifiable.

Foot surveys of the spawning grounds were conducted daily once salmon began spawning in the creek. All dead fish found during stream surveys were examined for fin clips and each fish was recorded as unmarked (no fin-clip) or marked (right ventral, left ventral, or dorsal fin clip). Dead fish that washed up on the weir were also examined for marks, although late in the season we occasionally pulled pickets and shoveled dead and dying fish downstream in an effort to keep high water and carcasses from washing out the weir structure. We cut the tails off all sampled carcasses in order to prevent double sampling.

We used Stratified Population Analysis System (SPAS) software (Arnason et al. 1996) to generate stratified mark-recapture estimates of the total spawning population of chum salmon. SPAS was designed for analysis of two-sample mark-recapture data where marks and recoveries take place over a number of strata. This program was based on work by Chapman and Junge (1956), Darroch (1961), Seber (1982), and Plante (1990). We used this software to compare maximum likelihood Darroch estimates and pooled-Petersen estimates, and to calculate their standard errors. This software also provided chi-square tests for goodness-of-fit based on the deviation of predicted values (fitted by the Darroch estimate) from the observed values, and chi-square tests of the validity of using fully pooled data (a test of complete mixing of marked fish between release and recovery strata, and a test of equal proportions of marked fish in the recovery strata). We chose to use full pooling of the data (i.e., the pooled-Petersen estimate) if the results of either of these tests was not significant ($p>0.05$). The manipulation of release and recovery strata in calculating estimates (the method used in SPAS) was presented and discussed at length by Schwarz and Taylor (1998). We manipulated strata only to yield non-negative estimates and to minimize the lack of fit between the estimated proportion of marks in the recovery strata and the observed proportion of marks in the recovery strata. We deemed the weir count of chum salmon to be "verified" if the count fell within the 95% confidence interval of the mark-recapture estimate. In the event of a flood, or other situations that allowed fish to escape past the weir uncounted, we decided prior to conducting the study that the mark-recapture estimate would be used as the official escapement estimate.

Adult Length, Sex, and Scale Sampling

The age composition of chum salmon at Disappearance Creek was determined from a minimum of 600 scale samples collected from live fish at the weir. The sample size was chosen based on work by Thompson (1992) for calculating a sample size for estimating several proportions simultaneously. A sample of 510 fish was determined to be the sample size needed to ensure that the estimated proportions of each of the three age classes of chum salmon returning to Disappearance Creek would be within 5% of the true value 95% of the time. We increased our sampling goal to ensure we met the sample size target even if 15% of our scale samples were unreadable. We began the season by taking scale samples at a rate of 1 in 20 (5%), and adjusted our sampling rate inseason to ensure that we reached our goal of 600 scale samples. The sex and length (mid-eye-to-fork to the nearest 5 mm) was recorded for each fish sampled. One scale was taken from the preferred area (INPFC 1963), mounted on a gum card, and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon-aging laboratory in Douglas, Alaska. The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex, weighted by week, were calculated using standard methods (Cochran 1977; see Appendix A).

Stream Life

Weekly estimates of stream life were used in conjunction with daily weir counts to estimate the number of live chum salmon present in the creek on a given day. In order to estimate stream life, we tagged chum salmon with numbered spaghetti tags at a rate of 30 fish per day throughout the length of the season. The 30-cm tags were sewn into the bony, posterior base of the dorsal fin, using a 15-cm metal needle; the ends of the tag were tied with a single overhand knot (Pahlke and Bernard 1996). The tag number and date of release were recorded onto sampling forms. We walked the stream on a daily basis to look for spaghetti-tagged carcasses in order to increase the precision of our stream life estimates. The tag number and date of all spaghetti-tagged fish recovered during carcass surveys was recorded into Rite-in-the-Rain© notebooks in the field and transferred to sampling forms.

The average stream life of chum salmon was calculated as the weighted average of the number of days between marking and recovery for all spaghetti-tagged fish that were recovered. Because stream life may be strongly tied to time of entry, and because the entry rate will be strongly tied to time, a non-weighted average stream life of all tagged fish will give far too much weight to the observed stream lives of fish near the beginning and end of the runs, when stream-life times are likely to be the most non-typical (Quinn and Gates 1997). Therefore, we weighted the weekly stream life value by the proportion of the number of fish that entered the system in that week.

We also used un-weighted weekly estimates of stream life to estimate the number of live chum salmon present in the creek on a daily basis. By applying the stream life estimate obtained for fish passing in a particular week to the daily weir counts, we were able to carry daily weir counts forward in time by the appropriate stream life value. We then added together live chum salmon estimates from a series of passage dates to approximate the number of live salmon in the creek for each day of the season. For example, if we passed 500 fish through the weir on a given date and the stream life for the corresponding week was 10 days, those fish would be added to our daily live chum salmon estimates for 10 days following the date of passage and then would drop out on the 11^{th} day. The estimates of live fish on specific dates include the daily weir counts for up to 17 preceding days early in the season and as few as six preceding days late in the season when stream life was shorter. These estimates were useful for comparisons with aerial survey counts.

Otolith Sampling

We collected otolith samples from chum salmon carcasses to determine if stray hatchery chum salmon were present in the creek and to determine what proportion of the total escapement was represented by hatchery fish. We collected two trays (192 otoliths) of otoliths, with samples collected through the peak of the run. Otolith samples were processed, aged, and analyzed at the ADF&G Commercial Fisheries Tag Otolith Laboratory, Juneau. We estimated the proportions (and standard errors) of wild and stray hatchery chum salmon in the escapement using standard methods (Cochran 1977).

Stream Surveys

Aerial surveys of Disappearance Creek were conducted by the Ketchikan area management biologists once a week through most of the run, from statistical week 36 (starting date 30 August, Appendix B) to week 41 (starting date 4 October). On each survey, the number of live and dead chum salmon was estimated at the mouth of the creek, the intertidal section of the creek, and through the length of the creek. The entire length of the stream was covered on each survey and results were entered into the ADF&G Integrated Fisheries Database at the end of the field season. The daily fish counts through the weir were not shared with management biologists during the season in order to avoid biasing their aerial survey estimates.

Stream Temperature Monitoring

Stream temperatures were monitored at three locations in Disappearance Creek, from 18 September 2008 to 3 June 2009, using StowAway Tidbit™ Temperature Loggers (Onset Computer Corp.[2]). In addition, one thermograph was used to record air temperatures near camp through the same time period. The thermographs were set to take readings every four hours beginning at 0300 hours each day. Temperature loggers were anchored to black iron pipes pounded into the stream substrate and were set at the surface of the stream bed. The loggers were located in the creek as follows: one was placed in the lower creek approximately 50 feet above the weir, one was located approximately half way between the lower spawning pool and the weir, and one was located in the lower spawning pool. After downloading the loggers to a laptop computer the thermographs were reset in same locations on 22 July 2009 to collect temperature information through the winter of 2009–2010.

RESULTS

ADULT ESCAPEMENT

In 2009, the adult weir was fish-tight from 20 August to 26 October, and we passed 55,436 chum salmon through the weir (Appendix C). We did not identify any direct handling mortality at the weir in 2009. The weir structure was fish-tight in the afternoon of 20 August. We conducted a foot survey of the stream the following morning and estimated that there were approximately 50 chum salmon above the weir. The total weir count plus the estimated number of fish upstream of the weir at start up was approximately 55,500 chum salmon. We also passed 1,826 pink salmon

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[2] Reference to trade names does not imply endorsement by Alaska Department of Fish and Game.

between 21 August and 2 October, with the peak occurring from the late August through mid-September. The system does not appear to support a run of coho salmon and we observed only 11 fish the entire season.

By mid-September, tremendous numbers of chum salmon were schooled up within a mile of the mouth of Disappearance Creek and fish passage through the weir increased considerably. The first large pulse of fish passed through the weir on 16 September when over 3,000 chum salmon moved upstream; the same date as our first large pulse in 2008 (Piston and Heinl 2010). The mid-point of the run occurred on 7 October, which is approximately a week later than the long-term average from weir counts conducted between 1965 and 1984 (Figure 4). The 75th percentile of the escapement was reached four days later on 11 October, and a total of 20,854 chum salmon passed through the weir during the seven-day period 7–13 October, accounting for approximately 38% of the total weir count. Fish passage remained strong through the third week in October before tapering off. At the time of weir removal on 27 October we no longer observed schools of chum salmon in the bay or within a mile of the creek mouth.

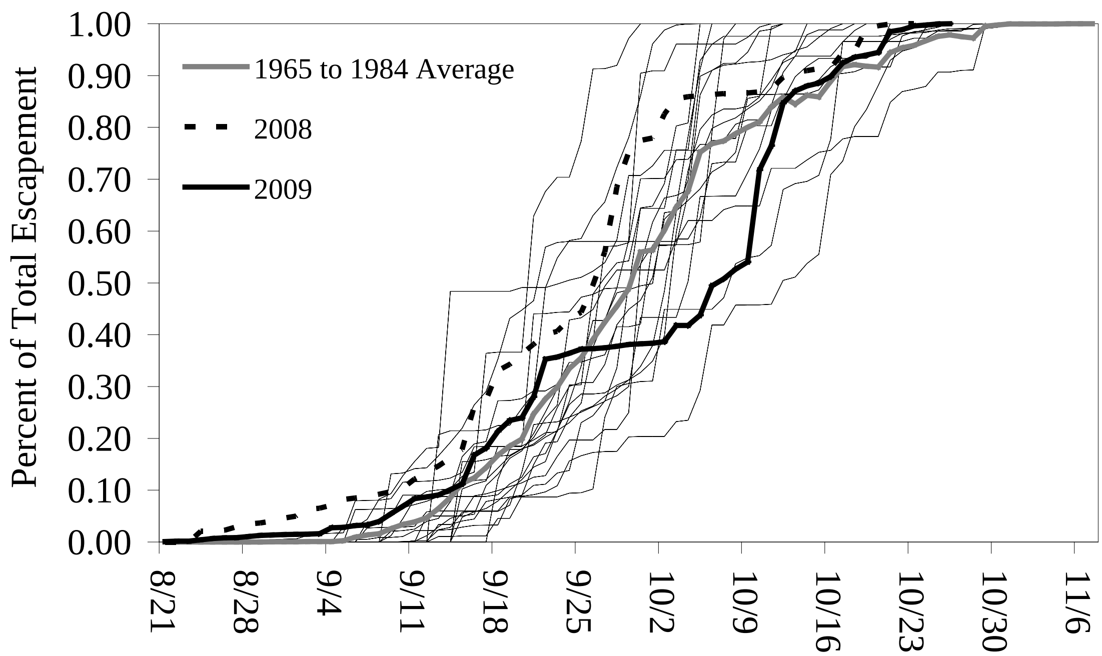

Figure 4.–Chum salmon run-timing at Disappearance Creek, 1965–1984, 2008, and 2009. In many years prior to 2008, the weir was not installed until the second week of September.

For most of the season, operation of the weir proceeded smoothly and there were no apparent holes for fish to get through uncounted. The ground cloth we used helped keep substrate from washing out beneath the bipods and helped keep the main weir fish-tight through the season, but we did have some problems with the fencing on the extreme ends of the creek. In normal water flow the fencing at the extreme ends of the weir is either out of the water, or in very shallow, slack water. We measured approximately 20 inches of rain at the weir between 15 and 27 October and the combination of high water, carcass buildup, and bears damaging the fencing at night resulted in several opportunities for fish to pass around the weir uncounted, and led to the slightly higher estimate we obtained from our mark-recapture study (see below).

Mark Recapture

In 2009, a total of 2,423 chum salmon were marked with different fin clips over three marking strata (Appendix C); 192 chum salmon were marked with a right ventral clip from 20 August to 10 September, 780 fish were marked with a left ventral clip from 11 September to 1 October, and 1,451 chum salmon were marked with a partial dorsal fin clip from 2 October to 27 October. Recapture sampling on the spawning grounds was conducted over the course of the entire spawning season, from 29 August to 29 October (Table 2). We sampled carcasses throughout the entire length of the creek nearly daily, including large numbers of carcasses that washed up on the weir structure. A total of 23,523 fish were sampled for fin clips, of which 920 were marked (Table 2). Thus, approximately 38% of the fish released with marks were eventually recovered as carcasses.

Release and recovery strata were pooled over various combinations and entered into the SPAS program for analysis. We manipulated strata only to yield non-negative estimates and to minimize the lack of fit between the estimated proportion of marks in the recovery strata and the observed proportion of marks in the recovery strata. We then experimented with various poolings of the recovery strata, and looked for the best fit of the predicted values to the observed values. We obtained the best fit using three release and four recovery strata (Table 3). Release strata were (1) right ventral release period, (2) left ventral period, and (3) dorsal release period. Recovery strata were (1) 29 August–18 September, (2) 19–27 September, (3) 28 September–7 October, and (4) 8–29 October. Using these poolings, we generated a maximum likelihood Darroch estimate of 61,500 chum salmon (SE=1,600; 95% CI 58,500–65,000). The chi-square test of fit of the predicted values to the observed values was 2.24 (1 df, $P=0.13$). The pooled-Peterson estimate was 62,000 (SE=1,550); however, results of the chi-square tests of complete mixing and equal proportions of marks were both highly significant ($P<0.01$), which indicated that full pooling may not have been appropriate. Therefore, we used the Darroch estimate (61,500) as the mark-recapture estimate for 2009. The combined total of the weir count and the pre-weir foot survey was 55,486, which fell below the 95% confidence interval of the mark-recapture estimate.

Adult Length, Sex, and Scale Sampling

In 2009, a total of 955 chum salmon were sampled for age, sex, and length. The age composition, based on the scale samples, was 39% age-0.2, 52% age-0.3, and 9% age-0.4 fish (Table 4). Two additional samples were identified as age-0.5 fish, but this age group accounted for less than 0.5% of the total escapement, or approximately 60 fish. The mean weighted lengths by age class for males were 575 mm (age 0.2), 633 mm (age 0.3), and 648 mm (age 0.4; Table 5). For females the mean lengths by age class were 589 mm (age 0.2), 633 mm (age 0.3), and 648 mm (age 0.4).

Table 2.–Daily number of marked fish recovered by release strata and total number of carcasses sampled for marks at Disappearance Creek, 2009.

Date	Number of Marked Fish			Number Unmarked	Total Number Sampled
	Left Ventral	Right Ventral	Dorsal		
29-Aug	0	0	0	1	1
2-Sep	0	1	0	6	7
4-Sep	0	0	0	2	2
5-Sep	0	0	0	5	5
6-Sep	0	0	0	8	8
7-Sep	0	0	0	5	5
8-Sep	0	0	0	3	3
9-Sep	0	1	0	33	34
10-Sep	0	0	0	9	9
11-Sep	0	3	0	40	43
12-Sep	0	0	0	12	12
13-Sep	0	3	0	59	62
14-Sep	0	2	0	67	69
15-Sep	0	5	0	93	98
16-Sep	0	7	0	119	126
17-Sep	0	0	0	42	42
18-Sep	0	5	0	70	75
19-Sep	1	2	0	49	52
20-Sep	2	21	0	553	576
21-Sep	4	7	0	141	152
22-Sep	5	7	0	165	177
23-Sep	17	16	0	847	880
24-Sep	6	3	0	174	183
25-Sep	8	6	0	272	286
26-Sep	5	1	0	213	219
27-Sep	46	13	0	1,758	1,817
28-Sep	4	0	0	155	159
29-Sep	4	0	0	141	145
30-Sep	3	0	0	150	153
1-Oct	57	2	0	1,231	1,290
2-Oct	2	0	0	106	108
3-Oct	6	0	0	89	95
4-Oct	57	0	3	1,138	1,198
5-Oct	7	0	0	57	64
6-Oct	26	0	2	337	365
7-Oct	7	1	2	194	204
8-Oct	14	0	9	438	461
9-Oct	0	0	5	53	58
10-Oct	0	0	13	104	117
11-Oct	1	0	29	652	682
12-Oct	0	0	12	184	196
13-Oct	0	0	14	286	300
14-Oct	0	0	68	1,461	1,529
15-Oct	0	0	18	291	309
16-Oct	0	0	23	473	496
17-Oct	0	0	11	605	616
18-Oct	0	0	20	574	594
19-Oct	0	0	19	721	740
20-Oct	0	0	137	4,488	4,625
21-Oct	0	0	20	670	690
22-Oct	0	0	6	341	347
23-Oct	0	0	39	876	915
24-Oct	0	0	26	482	508
25-Oct	0	0	5	203	208
26-Oct	0	0	16	532	548
27-Oct	0	0	6	130	136
28-Oct	0	0	11	318	329
29-Oct	0	0	18	377	395
Total	282	106	532	22,603	23,523

Table 3.–Number of chum salmon released, by marking period, and number of fish sampled and number of marked fish recovered by recovery period, at Disappearance Creek in 2009.

Release Strata	Number Tags Released	*Recovery Strata* 29 Aug–18-Sep	18-Sep –27-Sep	27-Sep–7-Oct	7-Oct –29-Oct	Total
20 Aug–10 Sep	192	27	76	*3*	0	106
11 Sep–1 Oct	780	0	94	*173*	15	282
2 Oct–27 Oct	1,451	0	0	*7*	525	532
Number unmarked		574	4,172	*3,598*	14,259	22,603
Total number sampled		601	4,342	*3,781*	14,799	23,523

Stream Life

From 21 August to 26 October 2009, we released a total of 1,826 spaghetti-tagged chum salmon upstream of the weir. Between 2 September and 29 October 2009, we recovered 319 chum salmon carcasses with intact spaghetti tags. We conducted carcass surveys of the entire stream nearly daily throughout the season, so carcasses were generally examined within 24 hours of a fish's death. Stream life was longest for chum salmon entering the stream early in the season and declined through the run (Table 6). The seasonal mean stream life, weighted by week, was 7.7 days.

Aerial Stream Surveys

Aerial surveys of Disappearance were conducted by Ketchikan area management biologists from late August to early October in 2009. Daily weir counts were not shared with the management biologists during the course of the season in order to avoid biasing their aerial survey estimates. A total of five surveys were conducted by two different biologists, with surveys occurring on the following dates: 5 and 31 August, 11 and 29 September, and 5 October (Figure 5; Table 7). An additional survey was attempted on 18 September, but was cancelled due to high winds, rain, and fog in the creek valley. Estimates of the number of fish alive in the stream on a given day were calculated using daily weir counts and weekly stream life, and these estimates were used to compare directly to aerial survey estimates (Table 8).

The peak aerial survey estimate of 26,000 chum salmon occurred on 5 October 2009 and included 16,000 chum salmon in saltwater off the mouth of the creek, 2,000 in the intertidal, 3,000 live fish in the stream, and 5,000 dead fish in the stream. A multiplier of 2.37 would convert the peak aerial survey count to the estimated total escapement of chum salmon (61,500) at Disappearance Creek in 2009.

Table 4.–Age composition of the 2009 chum salmon escapement at Disappearance Creek based on scale samples, weighted by statistical week.

		Age Class				
Stat Week	**Parameter**	**0.2**	**0.3**	**0.4**	**0.5**	**Total**
34-35	Sample Size	6	14	6		26
	Esc. Age Class	150	351	150		651
	Proportion	23%	54%	23%		
	SE of %	8%	10%	8%		
36	Sample Size	14	20	8		42
	Esc. Age Class	293	419	168		880
	Proportion	33%	48%	19%		
	SE of %	7%	8%	6%		
37	Sample Size	57	59	21		137
	Esc. Age Class	1,347	1,394	496		3,238
	Proportion	42%	43%	15%		
	SE of %	4%	4%	3%		
38	Sample Size	68	114	23		205
	Esc. Age Class	2,718	4,557	919		8,195
	Proportion	33%	56%	11%		
	SE of %	3%	3%	2%		
39	Sample Size	89	111	22	1	223
	Esc. Age Class	3,064	3,821	757	34	7,677
	Proportion	40%	50%	10%	0%	
	SE of %	3%	3%	2%	0%	
40	Sample Size	59	45	8	1	113
	Esc. Age Class	1,297	990	176	22	2,485
	Proportion	53%	40%	7%	1%	
	SE of %	5%	5%	2%	1%	
41	Sample Size	34	37	7		78
	Esc. Age Class	7,255	7,895	1,494		16,643
	Proportion	44%	47%	9%		
	SE of %	6%	6%	3%		
42	Sample Size	29	36	2		67
	Esc. Age Class	4,963	6,161	342		11,467
	Proportion	43%	54%	3%		
	SE of %	6%	6%	2%		
43–44	Sample Size	11	49	4		64
	Esc. Age Class	722	3,216	263		4,200
	Proportion	17%	77%	6%		
	SE of %	5%	5%	3%		
Total	Escapement by Age Class	21,810	28,804	4,765	56	55,436
	SE of Number	534	648	60	0	
	Proportion by Age Class	39%	52%	9%	0%	
	SE of %	1.0%	1.2%	0.1%	0.0%	
	Sample Size	367	485	101	2	955

Table 5.–Weighted lengths in millimeters of chum salmon at Disappearance Creek by sex and age class, 2009.

		Age Class		
Sex	**Parameter**	**0.2**	**0.3**	**0.4**
Male	Number	253	305	59
	Mean Length	575	633	648
	Standard Error	2.7	2.9	5.3
	Maximum	660	745	720
	Minimum	485	550	560
Female	Number	114	180	41
	Mean Length	589	633	648
	Standard Error	3.7	3.4	5.6
	Maximum	655	715	770
	Minimum	515	560	570

Table 6.–Weekly and seasonal mean stream life (in days) of chum salmon at Disappearance Creek, 2009.

Statistical Week	Percent of Escapement	Mean Stream Life	Standard Deviation	Tags Recovered
34–35	0.01	15.8	4.3	18
36	0.02	13.2	4.3	32
37	0.06	11.4	3.0	24
38	0.15	10.1	3.3	39
39	0.14	9.6	2.3	42
40	0.04	6.7	2.4	51
41	0.30	6.8	2.6	46
42	0.21	6.9	1.6	55
43–44	0.08	6.7	2.0	12
Seasonal Weighted Stream Life		7.7		319

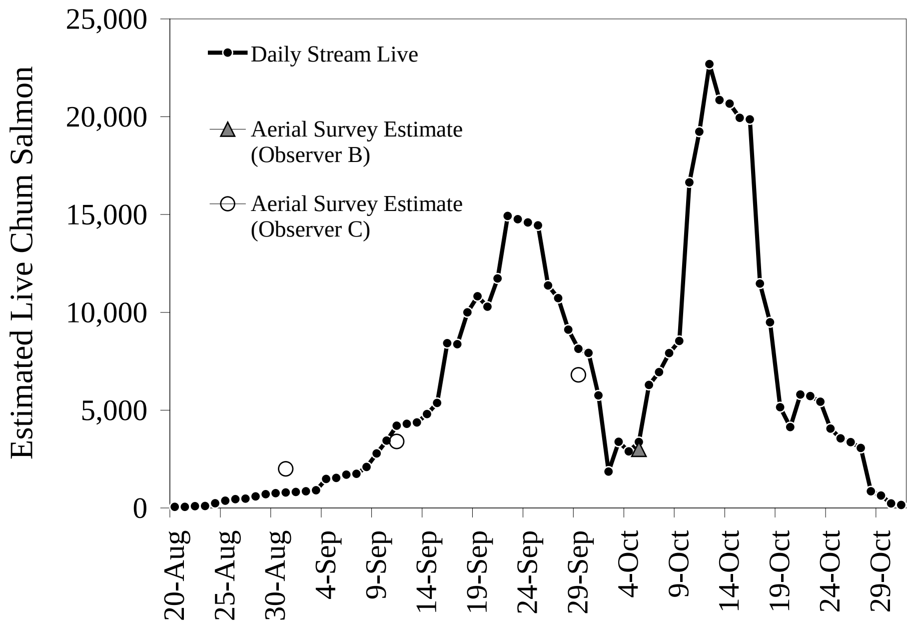

Figure 5.–Daily estimates of live chum salmon in Disappearance Creek in 2009, based on daily weir counts and mean weekly stream life estimates. Aerial survey estimates by two Ketchikan area management biologists are shown in comparison to the daily live estimates.

Table 7.–Aerial survey estimates of chum salmon at Disappearance Creek in 2009.

Date	Area Surveyed	Mouth	Intertidal	Stream Live	Dead	Total	Observer
5-Aug	Intertidal, Mouth, and Bay	0	0	0	0	0	B
31-Aug	Complete survey	0	0	2,000	0	2,000	C
11-Sep	Complete survey	7,000	500	3,400	750	11,650	C
18-Sep	Intertidal, Mouth, and Bay	—Cancelled due to wind, rain , and fog in stream valley—					B
29-Sep	Complete survey	6,000	0	6,800	1,000	13,800	C
5-Oct	Complete survey	16,000	2,000	3,000	5,000	26,000	B

Mark-Recapture Estimate	Peak Survey	Peak Survey to Total Escapement Multiplier
61,500	26,000	2.37

Table 8.–Comparison of aerial survey counts of live chum salmon above the Disappearance Creek weir compared to the estimated number of live chum salmon above the weir in 2009. The estimated number of live chum salmon present in the creek at the time of the survey was calculated by applying the average weekly chum salmon stream life to the daily counts of chum salmon through the weir.

	Survey Date				
Type of Estimate	5-Aug	31-Aug	11-Sep	29-Sep	5-Oct
Live Chum Salmon from Weir Count and Stream Life	0	791	4,201	8,132	3,366
Observer B Aerial Survey	0				3,000
Observer C Aerial Survey		2,000	3,400	6,800	
Relative Bias		153%	-19%	-16%	-11%

Otolith Sampling

We collected otoliths on a weekly basis beginning in statistical week 37 (6–12 September) and ending in week 42 (11–17 October). All of the otolith samples were collected from carcasses, and we distributed the sampling throughout the length of the creek. The nearest hatchery release site to Disappearance Creek is SSRAA's remote release site at Kendrick Bay, approximately 75 km away by water. All the chum salmon released at Kendrick Bay are summer chum, so we would have expected to see strays from this release site early in the season if they were present in any numbers at Disappearance Creek. The nearest releases of fall chum salmon occur at SSRAA's Neets Bay and Nakat Inlet release sites, approximately 90 km and 158 km from Disappearance Creek, respectively. (SSRAA's fall broodstock was originally taken at Disappearance and Lagoon creeks, in Cholmondeley Sound.) We recovered three otolith-marked fish in our sample of 235 fish; one Nakat Inlet brood year 2004 fall chum salmon, one Neets Bay brood year 2004 fall chum salmon, and one Neet's Bay 2003 summer chum salmon (Table 9). The overall sample proportion of stray hatchery fish was 1.3%, but when weighted by the weekly chum salmon counts at the weir the estimated proportion dropped to less than 1%. More than 60% of the total chum salmon escapement passed through the weir in weeks 40–44 when no otolith-marked fish were detected in our samples (Table 9).

Table 9.–Weekly otolith sampling results from the 2009 fall chum escapement at Disappearance Creek.

	Sampling Results from Disappearance Creek			
Statistical Week	**Total Sampled**	**Unmarked**	**Marked**	**% Hatchery Strays**
37	36	35	1	3%
38	51	50	1	2%
39	42	41	1	2%
40	34	34	0	0%
41	36	36	0	0%
42	36	36	0	0%
Total	235	232	3	<1%

Stream Temperature Monitoring

Stream temperatures were monitored at three locations in Disappearance Creek, from 18 September 2008 to 3 June 2009. Daily mean stream temperatures in the lower spawning pool were very stable through the monitoring period and varied from a high of 7.7 ºC on 2 October 2008 to a low of 3.8 ºC on 12 March 2009 (Table 10). Monthly mean temperatures ranged from a high of 7.3 ºC in October 2008 to a low of 4.3 ºC in April 2009, a variation of only 3 degrees between months (Table 10). Temperatures at the two locations closer to the mouth of the stream showed similar stability, with a slightly greater range from the monthly mean low to the monthly mean high temperature, probably a result of increasing distance from groundwater sources farther upstream. The highest daily mean temperature reading was 7.9 ºC near the weir on 2 October 2008 and the lowest daily mean temperature was 3.5 ºC on 25 February 2009, also near the weir site. The difference between the maximum daily mean temperature and the minimum daily mean temperature at the weir was only 4.4 ºC and was less than 4.0 ºC at the other two monitoring stations (Table 10).

Table 10.–Daily mean air and water temperatures (ºC) at Disappearance Creek, 18 September 2008 through 3 June 2009.

Month	Daily Mean Air Temperature	Daily Mean Water Temperature at Weir	Daily Mean Water Temperature Above First Rapids	Daily Mean Water Temperature in Lower Spawning Pool
September	9.8	7.3	7.3	7.2
October	6.4	7.3	7.3	7.3
November	4.2	6.5	6.5	6.5
December	-1.0	5.2	5.4	5.6
January	-0.3	4.8	5.0	5.1
February	-1.1	4.1	4.3	4.4
March	0.3	4.1	4.2	4.4
April	3.6	4.3	4.3	4.3
May–early June	8.4	4.4	4.3	4.3
Overall Mean	3.0	5.2	5.2	5.3
Maximum	14.8	7.9	7.6	7.7
Minimum	-7.9	3.5	3.7	3.8
Range	22.7	4.4	3.9	3.9

DISCUSSION

The point estimate from the mark-recapture study was 61,500 in 2009, which was slightly higher than the 2008 estimated escapement of 55,000 chum salmon. The mark-recapture estimate was approximately 6,000 fish higher than the weir count and our pre-season foot survey estimate combined (55,500). There were very few fish present in the creek at the start of the project, so underestimating the number of fish present at the time of weir installation was not a contributing factor to the discrepancy between the weir count and mark-recapture estimate. Despite the overall stability of the main body of the weir in 2009, breeches occurred on at least two occasions along the extreme edges of the creek where fencing was used to block fish in areas that were exposed to flow only during very high water or extreme high tide conditions. Early in the season we experienced problems with bears collapsing and creating holes in the fencing at the edge of the creek during the night. Normally this was not an issue because the water level was too low for fish to pass through the fenced area, even with a temporary opening; however, it is possible that a few fish passed through holes in the fencing at night during extreme high tides. We attempted to stabilize and reinforce the fenced area by overlapping another row of fencing and clamping aluminum pickets across the top of the fence to secure it firmly to the black iron pipe fence posts. This modification stabilized the fencing and reduced problems associated with bear activity. Despite these precautions, portions of the fence were overtopped by water on at least two occasions in October when the water level was extremely high at the weir due to a combination of heavy rainfall, carcass buildup, and high tides.

In 2009, the weir structure was set on a ground cloth, which was spread over the stream substrate and weighted down with rocks. The substrate at the weir site is composed primarily of medium to small cobbles, with some areas of large gravel. In 2008, the weir was set directly on the substrate and on two occasions scouring under one or more bipods during high water events allowed fish to pass through the weir uncounted (Piston and Heinl 2010). In both 2008 and 2009, clearing the weir of carcasses was a constant battle once chum salmon began dying in large numbers. The addition of the ground cloth in 2009 kept the main body of the weir stable and fish-tight throughout the season despite extremely heavy rainfall through much of October (21.5 inches through the 26th) and tremendous numbers of carcasses that washed up against the weir. Although we initially believed that the relatively large substrate size near the weir would keep scouring to a minimum, our experience in 2008 and 2009 has shown that, if possible, a ground cloth should be used in all weir installations that are not directly on bedrock.

Unlike in 2008, when most of the fish spawned below the upper pool due to blockage by a beaver dam, chum salmon had complete access to all available spawning habitat in 2009 and large numbers of fish spawned in the upper pool. When we arrived at Disappearance Creek in mid-August, we found that the upstream passage of chum salmon into the main spawning pools was blocked by several large beaver dams located at the outlet of the lower spawning pool, the middle of the lower spawning pool, and at the outlet of the upper spawning pool. This was a large increase in dam building activity compared to what we observed in 2008 (Piston and Heinl 2010). We completely removed the two dams in the lower spawning pool during the first week of the project and beavers did not attempt to rebuild the dams. We also breeched the dam at the outlet of the upper spawning pool on both edges of the creek, and after the first few weeks the beavers stopped trying to rebuild the sides of the dam. It is not clear what made the beavers stop trying to repair the breeches we made, because in 2008 they repaired the dam continuously throughout the season. It is possible that the higher rainfall in 2009 made it more difficult for beavers to maintain the dam, leading to an abandonment of the task. In September 2009, we measured 32 inches of rainfall at the weir site, compared to only 9 inches for the same month in 2008. The total escapements of chum salmon were similar in 2008 and 2009, which may give us some future insight into the effects of reduced spawning habitat availability and the associated increase in spawner density in the lower creek in 2008.

There were no hatchery fish detected in a sample of 156 chum salmon in 2008 (Piston and Heinl 2010) and in 2009 there were only three hatchery fish detected in a sample of 235 fish. The extremely low incidence of hatchery strays in our samples indicates that hatchery production of fall-run chum salmon in southern Southeast Alaska has had little effect on the department's ability to monitor fall chum salmon escapements to Cholmondeley Sound. In 2008, ADF&G began a three-year study to sample chum salmon index streams throughout the region for hatchery strays. Preliminary results from the first two years of sampling indicates that the proportion of hatchery fish in wild stock streams is typically low in systems that are located >50 km from the nearest release site, therefore, we would not expect to see high proportions of stray hatchery fall chum salmon in Cholmondeley Sound under current levels and locations of hatchery fall chum salmon releases.

The combined peak aerial survey estimates for Disappearance and Lagoon creeks (39,000 chum salmon) was within the Cholmondeley Sound fall chum salmon sustainable escapement goal of 30,000 to 48,000 index spawners (Figure 6). Although the total chum salmon escapement of 61,500 fish to Disappearance Creek was larger than the 2008 escapement of 55,000, the peak aerial survey estimate in 2009 was 9,500 fish less than the 2008 estimate. The associated peak survey expansion factor was 2.37 in 2009, versus an expansion factor of 1.55 in 2008. The timing of the peak aerial survey at Disappearance Creek in 2009 was too early to capture the peak of fish abundance in the stream; approximately 70% of the fish counted were in the intertidal area and off the mouth of the stream milling in saltwater. In comparison, approximately 48% of the fish counted in the 2008 peak survey were in the intertidal area or off the creek mouth in saltwater. It is possible that the difficulty in counting densely schooled fish in saltwater resulted in a higher degree of underestimation in 2009 than would have occurred had the survey been conducted a week later when fish numbers in the creek reached a peak (Figure 5). Many of the fish that were schooled at the mouth of the creek at the time of the October 5th peak survey entered the creek shortly after the survey and approximately 25,000 chum salmon were passed through the weir from 6 to 15 October. Disappearance Creek has exceptionally clear water and spawning chum salmon are generally well distributed and visible to counters. In their studies with pink salmon in Southeast Alaska, Dangel and Jones (1988) and Jones et al. (1998) found that the relative bias of aerial survey estimates becomes increasingly negative as fish abundance and density increase. In light of these observations, it is possible that the lower peak survey estimate in 2009 was at least partially due to the higher proportion of fish off the mouth of the creek at the time of the survey.

The estimated seasonal mean stream life, weighted by week, was very similar between 2008 and 2009—8.4 days in 2008 versus 7.7 days in 2009. In both years, stream life followed a similar seasonal pattern of a gradual reduction in stream life as the season progressed, with the stream life for fish entering in the final weeks of the season dropping to approximately half that of early arriving fish (Table 6; Piston and Heinl 2010). This same pattern of declining stream life through the season has also been noted at other summer chum salmon systems in southern Southeast Alaska (Heinl et al. 2000; ADF&G Traitors Creek *unpublished data*) and with other species elsewhere in Southeast Alaska and the Pacific Northwest (e.g., Dangel and Jones 1988, English et al. 1992). The age composition of the chum salmon escapement in 2009 was highlighted by a strong showing of age-0.2 fish. An estimated 39% of the total escapement of 61,500 fish was age 0.2, compared to 15% age-0.2 fish in 2008 (Table 4; Piston and Heinl 2010). The larger number and proportion of age-0.2 fish in 2009 was likely a reflection of the strong brood year escapement in 2006 as measured by the peak aerial survey estimate for that year (Figure 6). Age-0.2 fish returning in 2008 were the product of an escapement in 2005 that was well below the Cholmondeley Sound fall chum salmon escapement goal (Figure 6). In both years the dominant age class was age-0.3 fish, which accounted for 71% of the escapement in 2008 and 52% of the escapement in 2009.

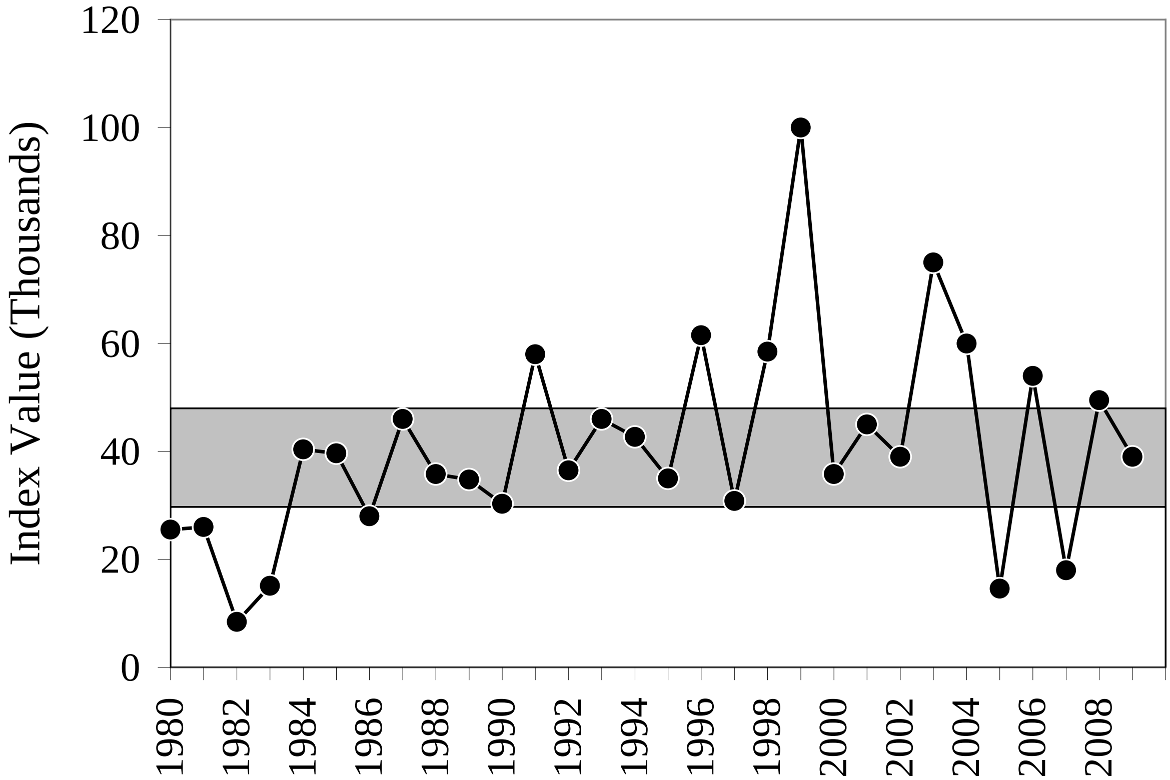

Figure 6.–Cholmondeley Sound fall chum salmon escapement index, 1980–2009. The index is based on the peak aerial survey estimates for Disappearance and Lagoon creeks combined.

Although the Cholmondeley Sound escapement goal has been met or exceeded in eight of the last 10 years, fishery openings and associated harvests within Cholmondeley Sound have sharply declined over the past decade and there was no fishery conducted within the Sound in 2009 (Figure 7, Table 1). The fishery has been managed conservatively in recent years due to escapements falling below the Cholmondeley Sound escapement goal range in 2005 and 2007 and concerns about escapements to some of the smaller streams in the Sound. The very small harvests of fall chum salmon in recent years suggests that total runs to streams in Cholmondeley

Sound were probably well below the levels of the 1990s and early 2000s, when the catch in the Cholmondeley Sound fishery was at a peak. The harvest inside Cholmondeley Sound averaged less than 5,000 chum salmon from 2005 to 2008, and there was no harvest in 2009. In contrast, the average chum salmon harvest inside of Cholmondeley Sound was approximately 140,000 fish from 1995 to 2004. Despite excellent escapements to Disappearance and Lagoon creeks in 2006, 2008, and 2009, there did not appear to be large harvestable surpluses of fish in the Sound and more aggressive fishery openings would likely have resulted in relatively low harvests compared to the 1995 to 2004 time period.

The amount of fishing time inside of Cholmondeley Sound is determined by management biologist's assessments of building escapements at the major spawning streams in the area and by the strength of catches in the last weeks of the pink salmon fishery and initial fall fishery openings. In years with low chum salmon abundance in Cholmondeley Sound, the number and length of fishery openings within the sound are dramatically reduced. Fisheries were more often conducted past early October in the 1970s to 1990s, compared to the recent period 2001–2009 (Figure 8). For example, fisheries were conducted past early October in 7 of 10 years in the 1970s, 4 of 10 years in the 1980s, and 10 of 10 years in the 1990s, but fisheries have not been conducted past early October since 2000 (Figure 8). The lack of fishing time past early October in recent years raised concern by some stakeholders in the fishery that the later part of the run was overharvested, causing an overall shift towards earlier run timing in the Cholmondeley Sound fall chum salmon stock.

Comparisons of the escapement run timing in 2008 and 2009 with historic run timing based on incomplete weir counts from 1965–1984 suggest that the run timing of chum salmon at Disappearance Creek was similar during the two time periods (Figure 4). Compared to the 1965–1984 weir counts, the 25th percentile of the run was reached five days earlier than average in 2008 and right at the long-term average in 2009. The apparent earlier arrival at the 25th percentile of the run in 2008 is almost certainly a reflection of the fact that in many of the historic years the weir was not installed until the second week of September, which delayed the arrival of the 25th percentile of fish passage through the weir. The 50th percentile of the run was reached three days before the 1965–1984 average in 2008 and seven days later than average in 2009. The 75th percentile of the run was reached six days earlier than average in 2008 and six days later than the long-term average in 2009. Although this is a rough assessment due to the fact that the weir was often not installed until the second week of September and was often removed prior to mid-October from 1965 to 1984, the idea that run timing has not changed substantially is also supported by the fact that from 1977 to 1979 the weir was operated into early November and very few fish were passed after the end of October: two fish in 1977 (1–2 November), 38 fish in 1978 (1–7 November), and 19 fish in 1979 (1–5 November). This is consistent with our observations during the past two seasons as fish passage through the weir and the presence of fish in saltwater quickly dropped at the end of October.

Despite the apparent decline in aggregate fall chum salmon run size to Cholmondeley Sound in recent years, peak aerial survey estimates to most streams in the Sound indicate that escapements have generally remained at, or above, levels found prior to the mid-1990s. For example, peak survey estimates at Lagoon Creek have declined since escapements reached high levels from the mid-1990s to the mid-2000s, but peak survey estimates since 2004 are still generally larger than those during the 1960–1990 time period (Figure 9). Again, there was very little harvest within Cholmondeley Sound during the past five seasons and escapements would almost certainly have been poor at Lagoon Creek if fishery managers had allowed more aggressive fishing since 2005. Peak aerial survey estimates at Disappearance Creek increased in the late 1980s and have remained at high levels over the past two decades, with the exception of very poor escapements in 2005 and 2007 (Figure 9). As with Lagoon Creek, escapements to Disappearance Creek over the past five years have benefitted from conservative management and would have certainly been much smaller if fishing effort in Cholmondeley Sound had remained at the level of the prior decade.

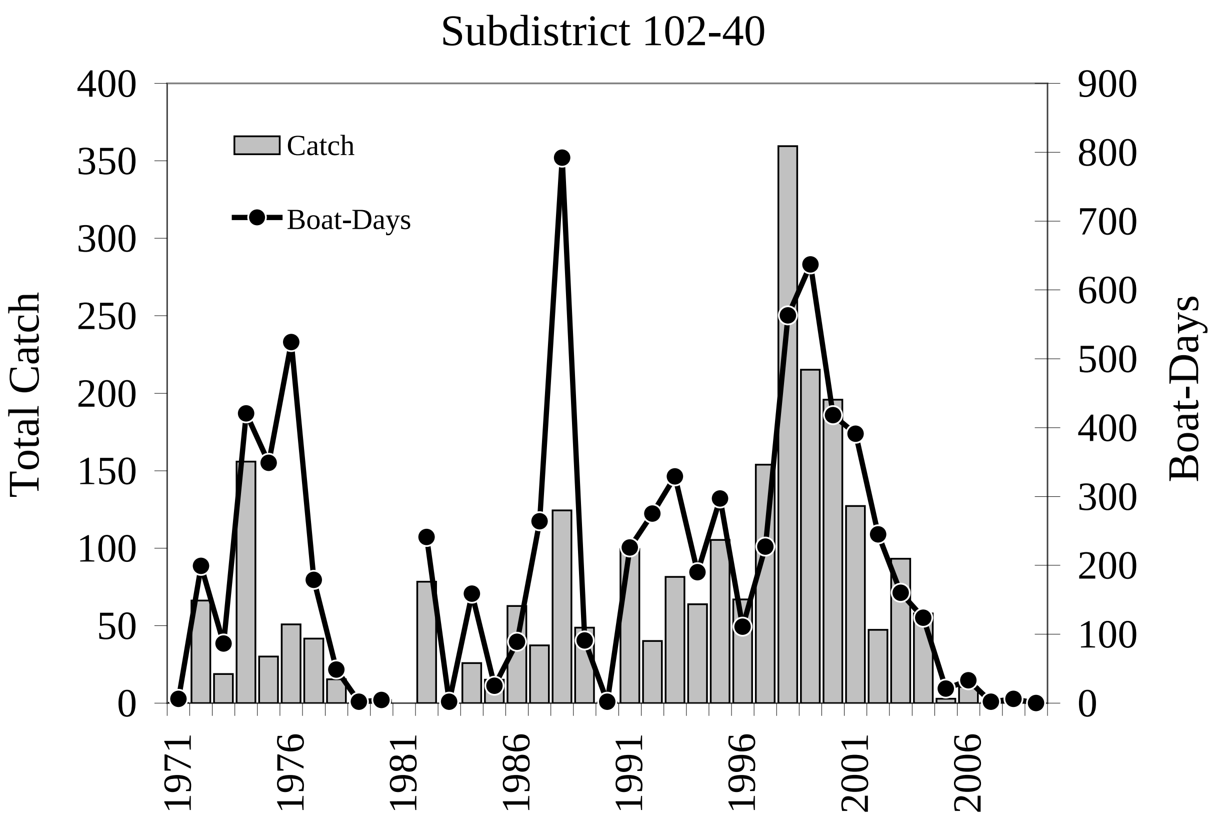

Figure 7.–Fishing effort and catch in the subdistrict 102-40 purse seine fishery inside Cholmondeley Sound, 1971–2009.

Most of the smaller chum salmon systems in Cholmondeley Sound have not been surveyed as regularly as Disappearance and Lagoon creeks, but long-term time series exist for several streams in areas where managers have expressed concerns with escapements in recent years. Lancaster Cove is located inside Cholmondeley Sound, approximately 9 km southeast from the opening into Clarence Strait (Figure 1). There are several small fall chum salmon streams located along several km of shoreline in this general area. Of two streams in Lancaster Cove that have been surveyed somewhat consistently since the late 1960s, one stream showed an increase in escapement in the mid-1980s and the other showed an erratic pattern with little long-term trend (Figure 10). For all of the small streams in Lancaster Cove, management biologists conducting aerial surveys in the area feel there has been an overall decline in chum salmon abundance during the past decade (Scott B. Walker, Area Management Biologist, ADF&G, Ketchikan; personal communication). There are also several fall chum salmon streams in Kitkun Bay, located inside Cholmondeley Sound, approximately 9 km southeast from the opening into Clarence Strait (Figure 1). The system with the longest and most consistent series of aerial and foot survey estimates in Kitkun Bay appears to have a fairly stable escapement history with a slight increase in recent years (Figure 11). Peak survey estimates are limited in most other areas of Cholmondeley Sound and do not provide a clear picture of trends in chum salmon abundance.

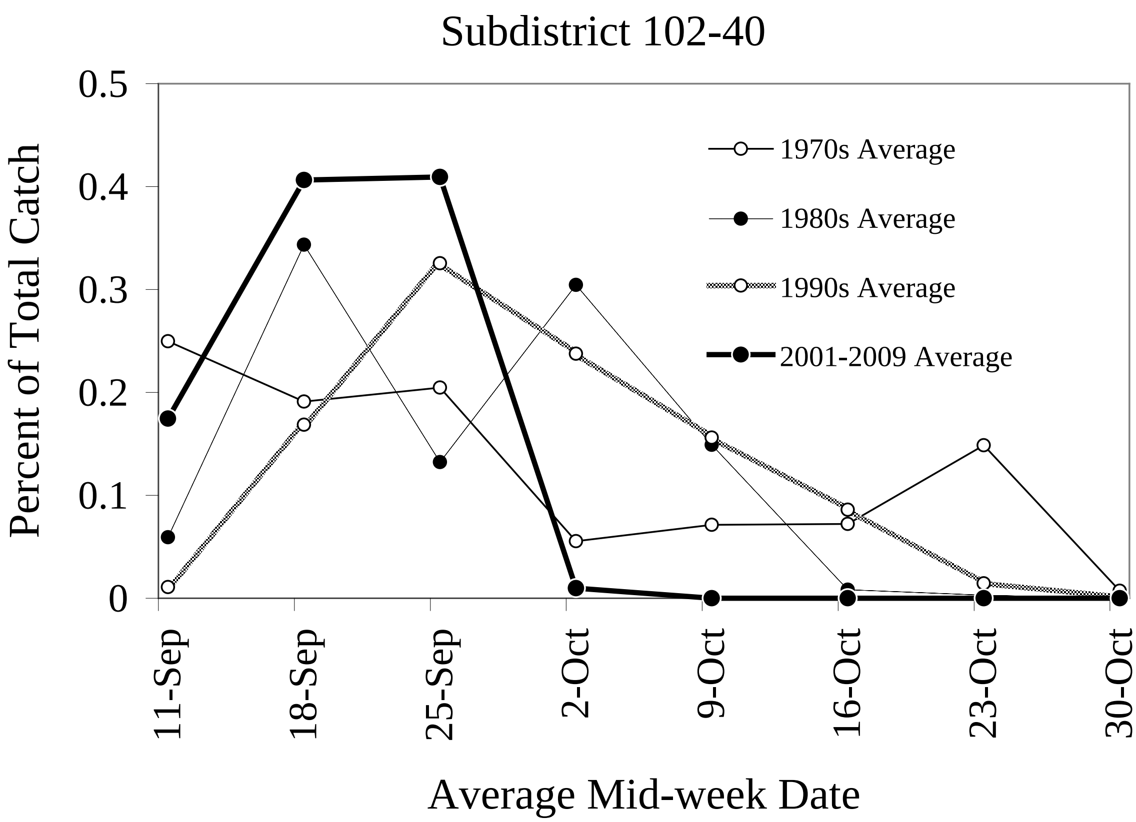

Figure 8.–Average weekly proportion of the total annual fall chum salmon catch in Cholmondeley Sound, subdistrict 102-40, by decade.

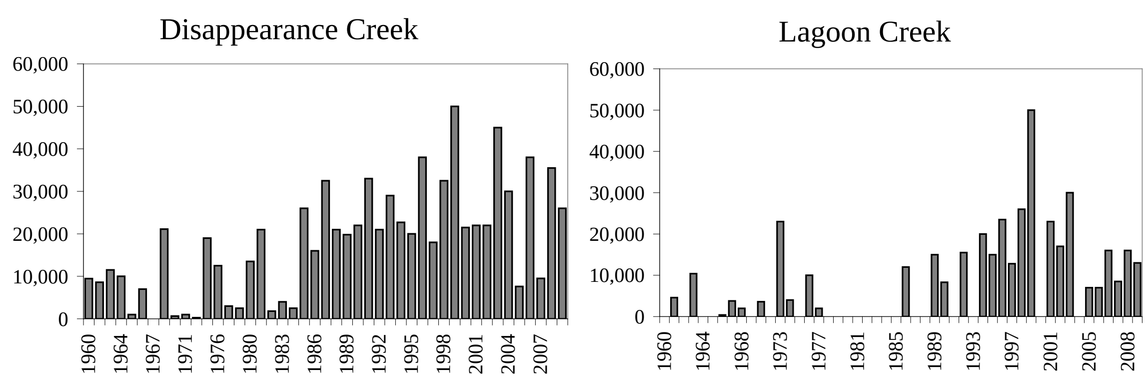

Figure 9.–Peak aerial survey estimates at Disappearance and Lagoon creeks, 1960–2009.

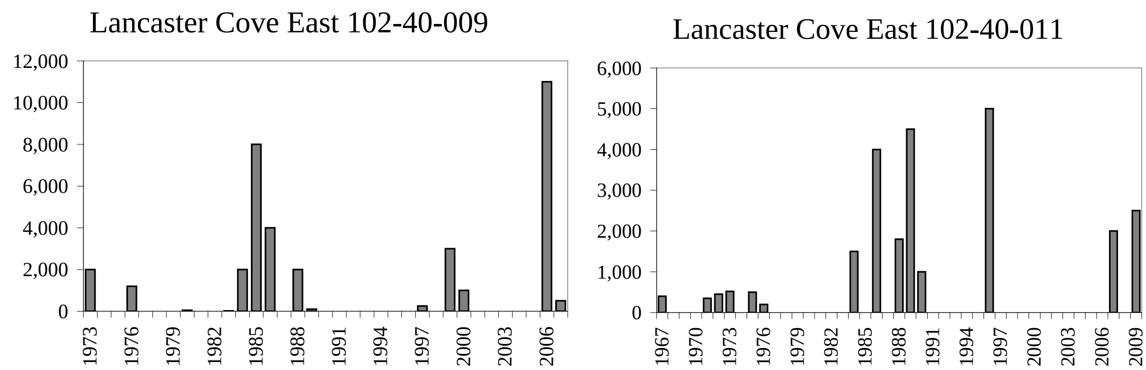

Figure 10.–Peak aerial and foot survey estimates at two streams in Lancaster Cove (ADF&G stream numbers 102-40-009 and 102-40-011), 1967–2009. Blank years indicate that no peak survey was obtained, rather than a complete lack of fish.

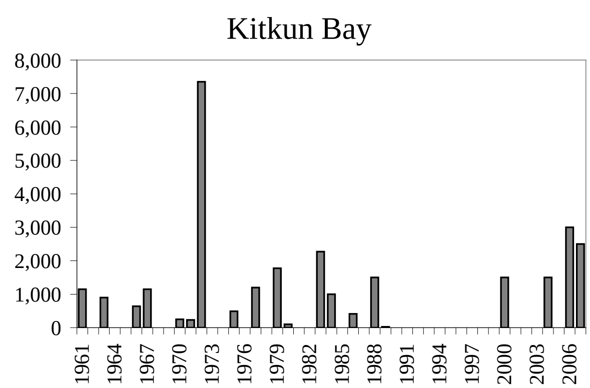

Figure 11.–Peak aerial and foot survey estimates at Kitkun Bay Creek (ADF&G stream number 102-40-017), 1960–2007. Blank years indicate that no peak survey was obtained, rather than a complete lack of fish.

Overall, escapements appear to have remained reasonably strong as a result of conservative management practices, but it appears that the very large runs that allowed for harvests in excess of 100,000 fall chum salmon in Cholmondeley Sound in many years during 1990s and early 2000s may have been the result of a period of high productivity and it may be unrealistic to expect runs of this size to continue indefinitely. The median harvest inside Cholmondeley Sound from 1971 to 2009 was approximately 50,000 chum salmon. From 1971 to 1990, however, the median fall chum salmon harvest was only 30,000 fish and harvests exceeded 100,000 fish in only two years. Fisheries occurred throughout the 1970s and 1980s, often with relatively high effort levels, despite total runs of chum salmon that were often much smaller than typical runs of the 1990s and early 2000s (Figure 7). In the past five years, fisheries managers have had to make decisions on fishery openings based on assessments of developing runs that are less than what they had come to expect during the 1990s and early 2000s. Maintaining consistent fishing opportunities in Cholmondeley Sound may require that fishery managers and fishermen be willing to accept catch rates and total harvests that are reduced compared to what they were accustomed to during the most recent period of very large harvests and escapements. Most importantly, however, fishery managers have to ensure that any fishery openings that occur in years of lower fall chum salmon abundance do not result in escapements below the established escapement goal range for Cholmondeley Sound and that smaller streams within the Sound maintain adequate escapements.

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APPENDICES

Appendix A.–Definitions and equations used in escapement sampling data analysis.

The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week, for smolt and adults, were calculated using equations from Cochran (1977; pages 52, 107–108, and 142–144).

Let,

h	=	index of the stratum (week),
j	=	index of the age class,
p_{hj}	=	proportion of the sample taken during stratum h that is age j,
n_h	=	number of fish sampled in week h, and
n_{hj}	=	number observed in class j, week h.

Then the age distribution was estimated for each week of the escapement in the usual manner:

$$\hat{p}_{hj} = n_{hj} / n_h \ . \qquad (1)$$

If N_h equals the number of fish in the escapement in week h, standard errors of the weekly age class proportions are calculated in the usual manner (Cochran 1977, page 52, equation 3.12):

$$SE(\hat{p}_{hj}) = \sqrt{\left[\frac{(\hat{p}_{hj})(1-\hat{p}_{hj})}{n_h - 1}\right][1 - n_h/N_h]}\ . \qquad (2)$$

The age distributions for the total escapement were estimated as a weighted sum (by stratum size) of the weekly proportions. That is,

$$\hat{p}_j = \sum_h p_{hj}(N_h/N), \qquad (3)$$

such that N equals the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107–108):

$$SE(\hat{p}_j) = \sqrt{\sum_j^h [SE(\hat{p}_{hj})]^2 (N_h/N)^2}\ . \qquad (4)$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142–144) for estimating means over subpopulations. That is, let i equal the index of the individual fish in the age-sex class j, and y_{hij} equal the length of the ith fish in class j, week h, so that,

$$\hat{\bar{Y}}_j = \frac{\sum_h (N_h/n_h) \sum_i y_{hij}}{\sum_h (N_h/n_h) n_{hj}}, \text{ and} \qquad (5)$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2} \sum_h \frac{N_h^2(1 - n_h/N_h)}{n_h(n_h - 1)} \left[\sum_i (y_{hij} - \bar{y}_{hj})^2 + n_{hj}\left(1 - \frac{n_{hj}}{n_h}\right)\left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2\right].$$

Appendix B.–Statistical week calendar for 2009.

Week	Start	End	Week	Start	End
1	1-Jan	3-Jan	28	5-Jul	11-Jul
2	4-Jan	10-Jan	29	12-Jul	18-Jul
3	11-Jan	17-Jan	30	19-Jul	25-Jul
4	18-Jan	24-Jan	31	26-Jul	1-Aug
5	25-Jan	31-Jan	32	2-Aug	8-Aug
6	1-Feb	7-Feb	33	9-Aug	15-Aug
7	8-Feb	14-Feb	34	16-Aug	22-Aug
8	15-Feb	21-Feb	35	23-Aug	29-Aug
9	22-Feb	28-Feb	36	30-Aug	5-Sep
10	1-Mar	7-Mar	37	6-Sep	12-Sep
11	8-Mar	14-Mar	38	13-Sep	19-Sep
12	15-Mar	21-Mar	39	20-Sep	26-Sep
13	22-Mar	28-Mar	40	27-Sep	3-Oct
14	29-Mar	4-Apr	41	4-Oct	10-Oct
15	5-Apr	11-Apr	42	11-Oct	17-Oct
16	12-Apr	18-Apr	43	18-Oct	24-Oct
17	19-Apr	25-Apr	44	25-Oct	31-Oct
18	26-Apr	2-May	45	1-Nov	7-Nov
19	3-May	9-May	46	8-Nov	14-Nov
20	10-May	16-May	47	15-Nov	21-Nov
21	17-May	23-May	48	22-Nov	28-Nov
22	24-May	30-May	49	29-Nov	5-Dec
23	31-May	6-Jun	50	6-Dec	12-Dec
24	7-Jun	13-Jun	51	13-Dec	19-Dec
25	14-Jun	20-Jun	52	20-Dec	26-Dec
26	21-Jun	27-Jun	53	27-Dec	31-Dec
27	28-Jun	4-Jul	–	–	–

Appendix C.–Daily chum salmon counts at the Disappearance Creek weir, 2009. Marks (fin clips) applied to chum salmon at the weir are right ventral (RV), left ventral (LV), and dorsal (D).

			Adults				Total Live Adults		Adult Mortalities		
			Number Marked		Number Not Marked						
Date	Stat Week	Mark	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Total Adults
20-Aug	34	RV	0	0	1	1	1	1	0	0	1
21-Aug	34	RV	1	1	3	4	4	5	0	0	5
22-Aug	34	RV	1	2	32	36	33	38	0	0	38
23-Aug	35	RV	1	3	11	47	12	50	0	0	50
24-Aug	35	RV	6	9	129	176	135	185	0	0	185
25-Aug	35	RV	6	15	127	303	133	318	0	0	318
26-Aug	35	RV	4	19	78	381	82	400	0	0	400
27-Aug	35	RV	1	20	22	403	23	423	0	0	423
28-Aug	35	RV	5	25	112	515	117	540	0	0	540
29-Aug	35	RV	5	30	106	621	111	651	0	0	651
30-Aug	36	RV	2	32	47	668	49	700	0	0	700
31-Aug	36	RV	2	34	39	707	41	741	0	0	741
1-Sep	36	RV	1	35	22	729	23	764	0	0	764
2-Sep	36	RV	1	36	37	766	38	802	0	0	802
3-Sep	36	RV	4	40	42	808	46	848	0	0	848
4-Sep	36	RV	30	70	598	1,406	628	1,476	0	0	1,476
5-Sep	36	RV	2	72	53	1,459	55	1,531	0	0	1,531
6-Sep	37	RV	10	82	165	1,624	175	1,706	0	0	1,706
7-Sep	37	RV	4	86	74	1,698	78	1,784	0	0	1,784
8-Sep	37	RV	20	106	339	2,037	359	2,143	0	0	2,143
9-Sep	37	RV	46	152	779	2,816	825	2,968	0	0	2,968
10-Sep	37	RV	40	192	754	3,570	794	3,762	0	0	3,762
11-Sep	37	LV	17	209	822	4,392	839	4,601	0	0	4,601
12-Sep	37	LV	7	216	161	4,553	168	4,769	0	0	4,769
13-Sep	38	LV	36	252	189	4,742	225	4,994	0	0	4,994
14-Sep	38	LV	38	290	526	5,268	564	5,558	0	0	5,558
15-Sep	38	LV	31	321	582	5,850	613	6,171	0	0	6,171
16-Sep	38	LV	80	401	3,015	8,865	3,095	9,266	0	0	9,266
17-Sep	38	LV	26	427	726	9,591	752	10,018	0	0	10,018
18-Sep	38	LV	42	469	1,723	11,314	1,765	11,783	0	0	11,783
19-Sep	38	LV	80	549	1,101	12,415	1,181	12,964	0	0	12,964
20-Sep	39	LV	33	582	252	12,667	285	13,249	0	0	13,249
21-Sep	39	LV	50	632	2,191	14,858	2,241	15,490	0	0	15,490
22-Sep	39	LV	162	794	3,878	18,736	4,040	19,530	0	0	19,530
23-Sep	39	LV	32	826	188	18,924	220	19,750	0	0	19,750
24-Sep	39	LV	32	858	372	19,296	404	20,154	0	0	20,154
25-Sep	39	LV	33	891	426	19,722	459	20,613	0	0	20,613
26-Sep	39	LV	6	897	22	19,744	28	20,641	0	0	20,641
27-Sep	40	LV	5	902	91	19,835	96	20,737	0	0	20,737
28-Sep	40	LV	30	932	132	19,967	162	20,899	0	0	20,899
29-Sep	40	LV	22	954	175	20,142	197	21,096	0	0	21,096
30-Sep	40	LV	18	972	61	20,203	79	21,175	0	0	21,175

–continued–

Appendix C.–Continued (page 2 of 2)

Date	Stat Week	Mark	Adults: Number Marked Daily	Adults: Number Marked Cum.	Adults: Number Not Marked Daily	Adults: Number Not Marked Cum.	Total Live Adults Daily	Total Live Adults Cum.	Adult Mortalities Daily	Adult Mortalities Cum.	Total Adults
1-Oct	40	D	12	984	54	20,257	66	21,241	0	0	21,241
2-Oct	40	D	10	994	137	20,394	147	21,388	0	0	21,388
3-Oct	40	D	92	1,086	1,646	22,040	1,738	23,126	0	0	23,126
4-Oct	41	D	5	1,091	12	22,052	17	23,143	0	0	23,143
5-Oct	41	D	7	1,098	1,087	23,139	1,094	24,237	0	0	24,237
6-Oct	41	D	95	1,193	3,051	26,190	3,146	27,383	0	0	27,383
7-Oct	41	D	108	1,301	624	26,814	732	28,115	0	0	28,115
8-Oct	41	D	200	1,501	835	27,649	1,035	29,150	0	0	29,150
9-Oct	41	D	18	1,519	754	28,403	772	29,922	0	0	29,922
10-Oct	41	D	225	1,744	9,622	38,025	9,847	39,769	0	0	39,769
11-Oct	42	D	109	1,853	2,495	40,520	2,604	42,373	0	0	42,373
12-Oct	42	D	125	1,978	4,432	44,952	4,557	46,930	0	0	46,930
13-Oct	42	D	50	2,028	1,257	46,209	1,307	48,237	0	0	48,237
14-Oct	42	D	30	2,058	517	46,726	547	48,784	0	0	48,784
15-Oct	42	D	20	2,078	286	47,012	306	49,090	0	0	49,090
16-Oct	42	D	60	2,138	630	47,642	690	49,780	0	0	49,780
17-Oct	42	D	80	2,218	1,376	49,018	1,456	51,236	0	0	51,236
18-Oct	43	D	50	2,268	572	49,590	622	51,858	0	0	51,858
19-Oct	43	D	10	2,278	206	49,796	216	52,074	0	0	52,074
20-Oct	43	D	10	2,288	287	50,083	297	52,371	0	0	52,371
21-Oct	43	D	100	2,388	2,112	52,195	2,212	54,583	0	0	54,583
22-Oct	43	D	11	2,399	216	52,411	227	54,810	0	0	54,810
23-Oct	43	D	15	2,414	381	52,792	396	55,206	0	0	55,206
24-Oct	43	D	3	2,417	81	52,873	84	55,290	0	0	55,290
25-Oct	44	D	5	2,422	116	52,989	121	55,411	0	0	55,411
26-Oct	44	D	1	2,423	24	53,013	25	55,436	0	0	55,436
27-Oct	44	D	0	2,423	0	53,013	0	55,436	0	0	55,436