Fishery Data Series No. 11-09

Disappearance Creek Chum Salmon Weir Study, 2010

by

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and

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April 2011

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

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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)

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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DISAPPEARANCE CREEK CHUM SALMON WEIR STUDY, 2010

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ABSTRACT

In 2010, we conducted the third year of a project to monitor the escapement of fall chum salmon at Disappearance Creek. From 19 August to 19 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 61,990 and the estimated number of fish upstream of the weir at start up was 15 chum salmon (=62,005). The mark-recapture study yielded a maximum likelihood Darroch estimate of approximately 85,600 chum salmon (SE=2,020; 95% CI=81,600–89,600) that was accepted as the best available estimate of total escapement to the system. The peak aerial survey estimate of 45,000 chum salmon occurred on 30 September 2010 and was 53% of the estimated total escapement of 85,600 chum salmon for a peak survey expansion factor of 1.90. Seasonal mean stream life, weighted by week, was estimated at 8.1 days, and decreased from 14.6 days in mid-to-late August to approximately 7 days after mid-September. The estimated age distribution of the chum salmon escapement was 8.6% age 0.2, 87.5% age 0.3, and 3.9% age 0.4. Only one of the 239 chum salmon sampled for otoliths in 2010 was a potential thermal-marked hatchery fish.

Key words: chum salmon, *Oncorhynchus keta,* Disappearance Creek, Cholmondeley Sound, 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 fish in 2005, 10,500 in 2006, 389 in 2007, 1,250 in 2008, and no harvest in 2009 (Table 1). Fishing time in Cholmondeley Sound historically extended into early October, but in the last seven 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; Heinl et al. 2004). 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 broodstock collection 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 escapement estimates. 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 25th and 75th 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. 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. 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 from 2008 to 2010. 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 a three-year project to monitor the escapement of fall chum salmon at Disappearance Creek in 2008 (Piston and Heinl 2010a), 2009 (Piston and Heinl 2010b), and 2010. From 19 August to 19 October 2010, 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 February 2002), Anchorage. Subsequently referred to as Bue and Hasbrouck (*Unpublished*).

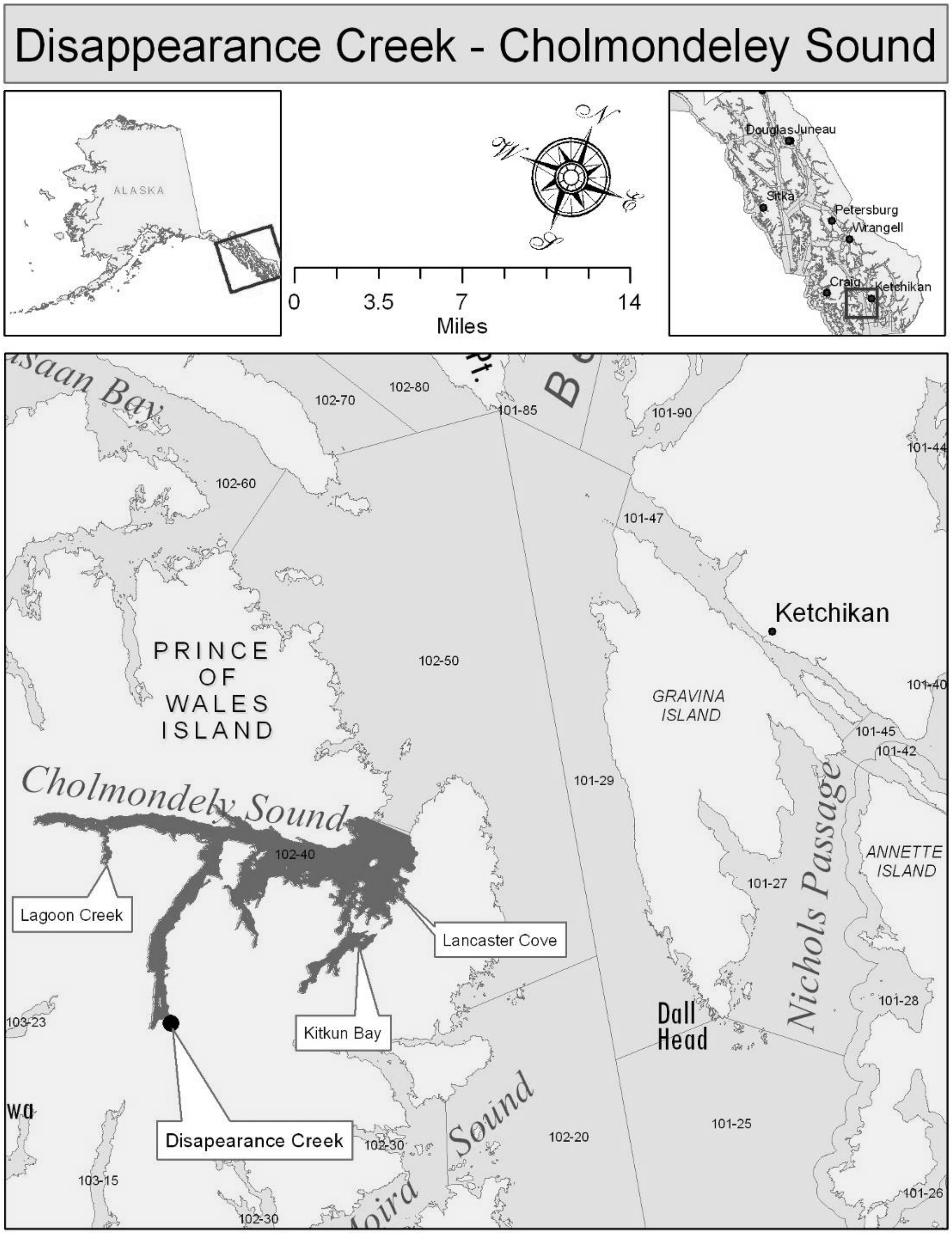

Figure 1.–The geographic location of Disappearance Creek, South Arm, Cholmondeley Sound, Prince of Wales Island, Southeast Alaska. Most of the chum salmon caught in the District 2 fall purse seine fishery are harvested in subdistrict 102-50, and inside Cholmondeley Sound in subdistrict 102-40.

Table 1.–Harvest of chum salmon by subdistrict in the District 2 fall purse seine fishery, 1971–2010.

	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									
2010		2,720		4,235	8,987		1,484	40	17,466
Average Proportion	1.6%	6.3%	0.4%	48.3%	37.9%	0.9%	4.3%	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 of this lake 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.

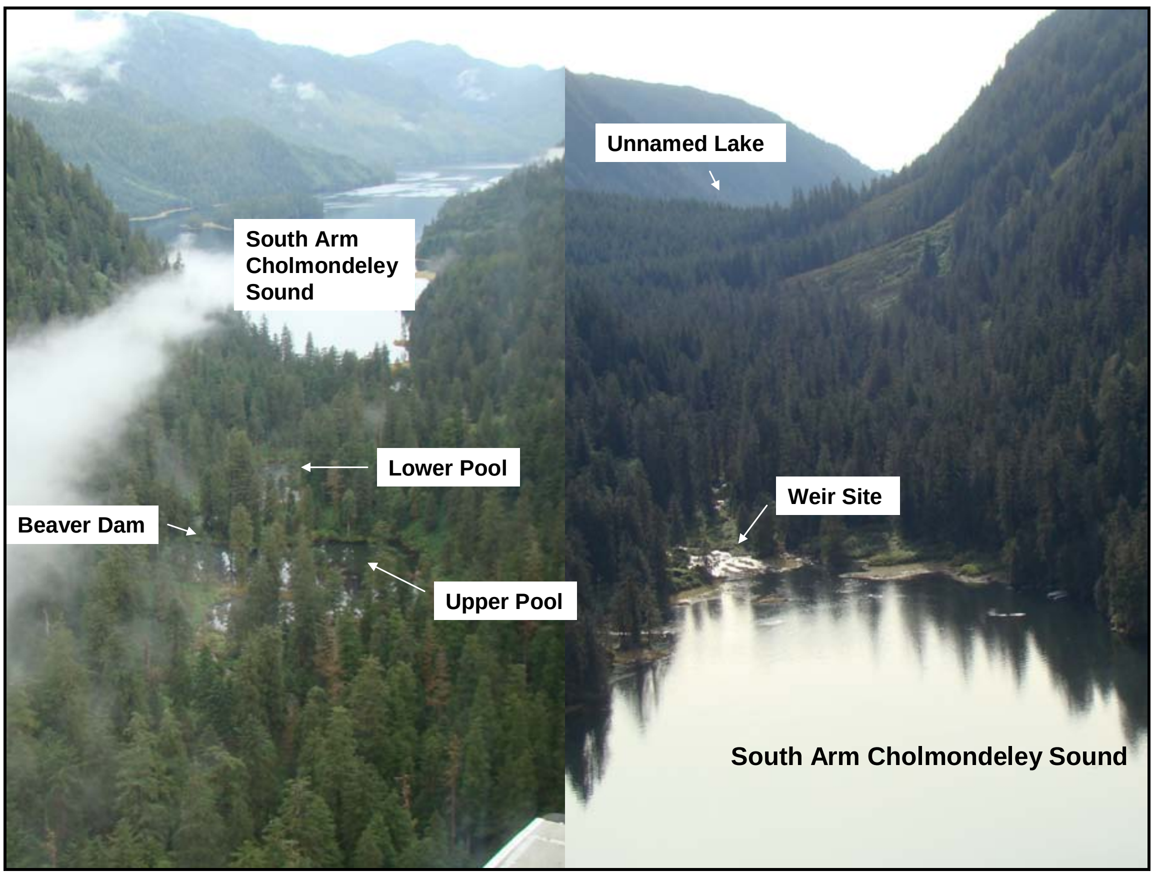

Figure 2.–Upstream (right) and downstream (left) views of the Disappearance Creek drainage. (©2008 ADF&G. Photos by Scott B. Walker)

Figure 3.–Aerial view of Disappearance Creek weir, 25 September 2008. (©2008 ADF&G. Photos 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 the photo.

METHODS

ADULT ESCAPEMENT

An adult salmon counting weir was operated at the mouth of Disappearance Creek, at the extreme upper reach of the intertidal zone (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. In 2008 and 2009, garden fencing supported with black iron pipe was attached to the west end of the weir to prevent fish from swimming around the weir during high water. A combination of thousands of salmon carcasses washing up against the fencing during high stream flows and black bears repeatedly damaging the fencing led us to consider alternatives. In 2010, we created sturdy tripods out of black iron pipe and lengths of aluminum channel and replaced the garden fencing with pickets. This modification greatly increased the stability of the extension between the west end of the weir structure and higher ground. 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 to enumerate 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 reduced this marking fraction to 2% when we switched marking strata on 11 September. 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, 19 August–10 September; left ventral fin clip, 11 September–1 October; and partial dorsal fin clip, 2 October–19 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 tail fork to the nearest 5 mm) were 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 stream life estimates 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, and the ends of the tags were tied with a single overhand knot (Pahlke and Bernard 1996). The tag numbers 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 waterproof 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. Since 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 total escapement 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 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 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 500 fish were passed through the weir on a given date and the stream life value 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 11th day. The estimates of live fish on specific dates included the daily weir counts for up to 15 preceding days early in the season and as few as seven 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 40 otoliths per week, with samples collected during the peak spawning period, 11 September–10 October. Otolith samples were processed, aged, and analyzed at the ADF&G Commercial Fisheries Mark, Tag, and Age Laboratory in Juneau.

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 35 (starting date 22 August) to week 40 (starting date 26 September; see Appendix B for ADF&G statistical weeks). On each survey, the number of live and dead chum salmon was estimated at the mouth of the creek, in the intertidal section of the creek below the weir, 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 to avoid biasing their aerial survey estimates.

Stream Temperature Monitoring

Stream temperatures were monitored at three locations in Disappearance Creek, from 24 July 2009 to 14 October 2010, 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.

RESULTS

ADULT ESCAPEMENT

In 2010, the adult weir was fish-tight from 19 August to 19 October, and in that time we passed 61,990 chum salmon through the weir (Appendix C). We did not identify any direct handling mortality at the weir in 2010. The weir structure was fish-tight on the afternoon of 19 August; we conducted a foot survey of the stream the same day and estimated that there were approximately 15 chum salmon above the weir. The total weir count plus the estimated number of fish upstream of the weir at start up was approximately 62,005 chum salmon. We also passed 6,414 pink salmon between 20 August and 2 October, with a peak from late August through mid-September. The system does not appear to support a run of coho salmon and we observed only four fish the entire season.

The mid-point of the chum salmon run occurred on 27 September, which is near the long-term average from weir counts conducted between 1965 and 1984 (Figure 4). The 75th percentile of the escapement was reached seven days later on 4 October, and the run was nearly over by 6 October. Approximately 34,500 chum salmon were counted through the weir from 27 September to 6 October (additional fish passed uncounted due to high water on 5 and 6 October), accounting for approximately 55% of the total weir count. Very few fish were passed after the

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[2] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

first week of October and schools of chum salmon were no longer observed in the bay or within a mile of the creek mouth.

For most of August and September, weir operations proceeded smoothly and there were no apparent holes for fish to get through uncounted. However, starting on 23 September a series of storm systems produced frequent heavy rain for the rest of the season, leading to three flood events that overtopped the weir or caused water to flow through the woods and around parts of the weir. We measured approximately 102 cm of rain at the weir between 23 September and 19 October and the extreme high water resulted in fish passing around the weir uncounted on 24 September and 5 and 6 October.

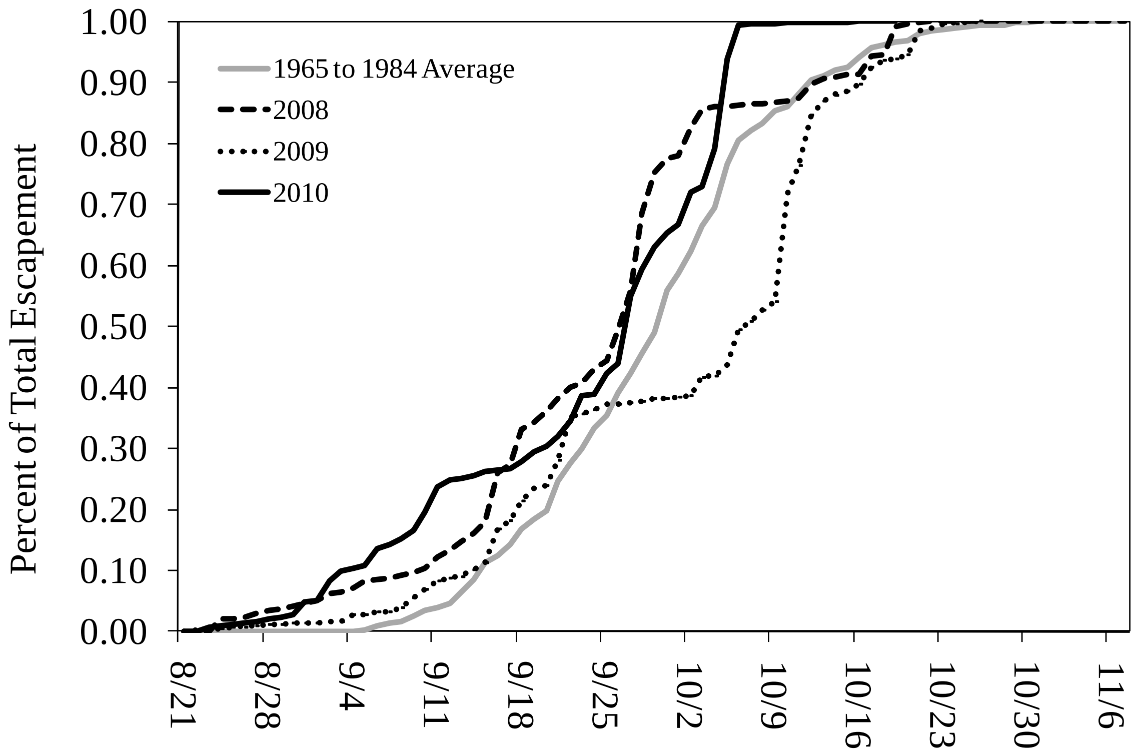

Figure 4.–Chum salmon run-timing at Disappearance Creek, 1965–1984, 2008, 2009, and 2010. In many years prior to 2008, the weir was not installed until the second week of September and was often removed prior to the end of the run.

Mark Recapture

In 2010, a total of 1,599 chum salmon were marked with fin clips over three marking strata (Appendix C): 600 chum salmon were marked with a right ventral clip from 19 August to 10 September, 587 fish were marked with a left ventral clip from 11 September to 1 October, and 412 chum salmon were marked with a partial dorsal fin clip from 2 October to 19 October. Recapture sampling on the spawning grounds was conducted over the course of the entire spawning season, from 29 August to 21 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 51,981 fish were sampled for fin clips, of which 1,062 were marked (Table 2). Thus, approximately 66% of the fish released with marks were eventually recovered as carcasses.

Table 2.–Daily number of marked fish recovered by release strata and total number of carcasses sampled for marks at Disappearance Creek, 2010.

	Number of Marked Fish			**Number**	**Total Number**
Date	**Right Ventral**	**Left Ventral**	**Dorsal**	**Unmarked**	**Sampled**
29-Aug	0	0	0	2	2
30-Aug	0	0	0	3	3
1-Sep	4	0	0	21	25
2-Sep	0	0	0	14	14
3-Sep	0	0	0	19	19
4-Sep	8	0	0	49	57
5-Sep	0	0	0	16	16
6-Sep	3	0	0	23	26
7-Sep	11	0	0	126	137
8-Sep	1	0	0	16	17
9-Sep	11	0	0	223	234
10-Sep	1	0	0	49	50
11-Sep	23	0	0	424	447
12-Sep	9	0	0	117	126
13-Sep	54	0	0	978	1032
14-Sep	50	0	0	986	1036
15-Sep	44	0	0	795	839
16-Sep	59	0	0	1111	1170
17-Sep	7	1	0	171	179
18-Sep	5	1	0	167	173
19-Sep	97	12	0	2776	2885
20-Sep	5	2	0	174	181
21-Sep	43	24	0	1910	1977
22-Sep	5	1	0	183	189
23-Sep	22	27	0	1324	1373
24-Sep	2	3	0	299	304
25-Sep	1	2	0	337	340
26-Sep	4	23	0	991	1018
27-Sep	1	9	0	510	520
28-Sep	2	6	0	462	470
29-Sep	12	23	0	2415	2450
30-Sep	0	4	0	752	756
1-Oct	2	25	0	2613	2640
2-Oct	0	10	0	851	861
3-Oct	0	17	2	3405	3424
4-Oct	0	12	0	858	870
5-Oct	0	14	1	1729	1744
6-Oct	0	27	2	1499	1528
7-Oct	0	71	13	6015	6099
8-Oct	0	11	6	1033	1050
9-Oct	0	25	19	2777	2821
10-Oct	0	12	13	813	838
11-Oct	0	2	11	1395	1408
12-Oct	0	6	21	1666	1693
13-Oct	0	4	31	2361	2396
14-Oct	0	2	30	1488	1520
15-Oct	0	7	22	2320	2349
16-Oct	0	3	10	1348	1361
17-Oct	0	0	1	361	362
18-Oct	0	2	2	576	580
19-Oct	0	1	1	147	149
20-Oct	0	0	2	208	210
21-Oct	0	0	0	13	13
Total	486	389	187	50,919	51,981

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 two release and three recovery strata (Table 3). Release strata were (1) right ventral release period, and (2) left ventral/dorsal release period. Recovery strata were (1) 26 August–16 September, (2) 17 September–2 October, and (3) 3–21 October. Using these poolings, we generated a maximum likelihood Darroch estimate of 85,600 chum salmon (SE=2,020; 95% CI 81,600–89,600). The pooled-Peterson estimate was 78,200 (SE=1,375); 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 (85,600) as the mark-recapture estimate for 2010. The combined total of the weir count and the pre-weir foot survey was 62,005, which fell well below the 95% confidence interval of the mark-recapture estimate.

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 2010.

Release Strata	Mark Applied	Number of Marked Fish Released	Recovery Strata 26 Aug–16-Sep	17 Sep–2-Oct	3 Oct–21-Oct	Total
19 Aug–10 Sep	Right Ventral	600	278	208	0	486
11 Sep–19 Oct	Left Ventral and Dorsal	999	0	173	403	576
Number unmarked			4,972	15,935	30,012	50,919
Total number sampled			5,250	16,316	30,415	51,981

Adult Length, Sex, and Scale Sampling

In 2010, a total of 950 chum salmon were sampled for age, sex, and length. Approximately 14% of the scale samples were not readable, which left a total usable sample size of 818 scale samples. The age composition, based on the scale samples, was 8.6% age-0.2, 87.5% age-0.3, and 3.9% age-0.4 fish (Table 4). The mean weighted lengths by age class for males were 581 mm (age 0.2), 634 mm (age 0.3), and 643 mm (age 0.4; Table 5). For females the mean lengths by age class were 585 mm (age 0.2), 635 mm (age 0.3), and 644 mm (age 0.4).

Table 4.–Age composition of the 2010 chum salmon escapement at Disappearance Creek based on scale samples, weighted by statistical week.

		Age Class			
Stat Week		**0.2**	**0.3**	**0.4**	**Total**
34–35	Sample Size	6	50		56
	Esc. Age Class	143	1,193		1,336
	Proportion	11%	89%		
	SE of %	4%	4%		
36	Sample Size	6	191	7	204
	Esc. Age Class	148	4,697	172	5,017
	Proportion	3%	94%	3%	
	SE of %	1%	2%	1%	
37	Sample Size	7	122	6	135
	Esc. Age Class	435	7,584	373	8,392
	Proportion	5%	90%	4%	
	SE of %	2%	3%	2%	
38	Sample Size	2	61	2	65
	Esc. Age Class	76	2,326	76	2,478
	Proportion	3%	94%	3%	
	SE of %	2%	3%	2%	
39	Sample Size	3	84		87
	Esc. Age Class	310	8,678		8,988
	Proportion	3%	97%		
	SE of %	2%	2%		
40	Sample Size	17	126	5	148
	Esc. Age Class	2,112	15,656	621	18,389
	Proportion	12%	85%	3%	
	SE of %	3%	3%	2%	
41	Sample Size	9	60	5	74
	Esc. Age Class	2,094	13,960	1,163	17,217
	Proportion	12%	81%	7%	
	SE of %	4%	5%	3%	
42–43	Sample Size	8	35	6	49
	Esc. Age Class	28	122	21	171
	Proportion	16%	71%	12%	
	SE of %	5%	6%	4%	
Total	Escapement by Age Class	5,346	54,217	2,427	61,990
	SE of Number	98	834	36	
	Proportion by Age Class	8.6%	87.5%	3.9%	
	SE of %	0.2%	1.3%	0.1%	
	Sample Size	58	729	31	818

Table 5.–Weighted lengths, in millimeters, of chum salmon at Disappearance Creek by sex and age-class, 2010.

		Age Class		
		0.2	**0.3**	**0.4**
Male	Number	43	382	16
	Mean Length	581	634	643
	Standard Error	6.6	2.2	12.3
	Maximum	670	725	740
	Minimum	515	510	600
Female	Number	15	345	15
	Mean Length	585	635	644
	Standard Error	8.1	1.9	5.8
	Maximum	665	720	700
	Minimum	510	520	595

Stream Life

From 20 August to 19 October 2010, we released a total of 1,485 spaghetti-tagged chum salmon upstream of the weir. Between 22 August and 20 October 2010, we recovered 528 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 8.1 days.

Table 6.–Weekly and seasonal mean stream life (in days) of chum salmon at Disappearance Creek, 2010.

Statistical Week	Percent of Escapement	Mean Stream Life	Standard Deviation	Tags Recovered
34-35	0.02	14.6	3.5	53
36	0.08	12.9	2.9	79
37	0.14	9.2	2.7	98
38	0.04	7.6	1.9	95
39	0.14	6.6	2.1	65
40	0.30	7.6	2.1	77
41–43	0.28	7.1	2.4	61
Seasonal Weighted Stream Life		8.1		528

Aerial Stream Surveys

Aerial surveys of Disappearance Creek were conducted by Ketchikan area management biologists from 22 August to 30 September in 2010. 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 11 surveys were conducted by three different biologists over the course of the season (Figure 5; Table 7).

The peak aerial survey estimate at Disappearance Creek included the estimated number of live and dead chum salmon in the creek and the estimated number of live chum salmon in the intertidal area and off the mouth of the creek. The peak aerial survey estimate of 45,000 chum salmon occurred on 30 September 2010 and included 25,000 fish in saltwater off the mouth of the creek, none in the intertidal, 9,000 live fish in the stream, and 11,000 dead fish in the stream (Table 7). A multiplier of 1.90 would convert the peak aerial survey count to the estimated total escapement of chum salmon (85,600) at Disappearance Creek in 2010.

Estimates of the number of live fish in the stream on any given day were calculated using daily weir counts and weekly stream life, and these estimates were directly compared to aerial survey estimates (Table 8). In 2010, large numbers of fish passed the weir uncounted on three different dates; 24 September, 5 October, and 6 October. Using the difference between the weir count and the mark-recapture estimate, we estimated that approximately 23,610 chum salmon passed the weir uncounted during flood events on those three days. To compare peak aerial survey estimates to the estimated number of live chum salmon above the weir, we added 7,870 fish to the daily counts for each of the three days that the weir was bypassed by flood waters. Due to the uncertainty involved in assigning the fish that passed the weir uncounted to a specific day we present both unadjusted and adjusted daily live estimates for comparison to aerial survey estimates (Table 8). Only comparisons with the final survey estimate on 30 September 2010 were affected by the adjusted estimates of live chum salmon.

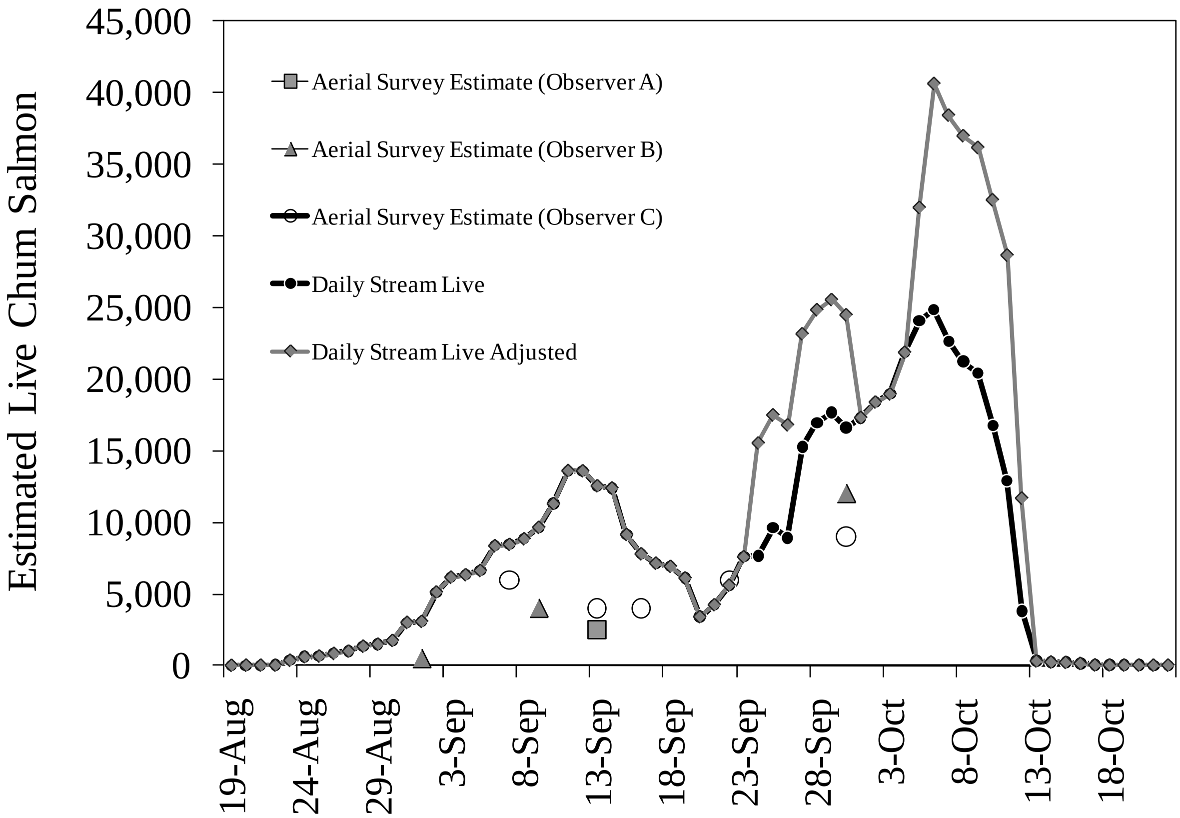

Figure 5.–Daily estimates of live chum salmon in Disappearance Creek in 2010, based on daily weir counts, the mark-recapture estimate, and mean weekly stream life estimates. Aerial survey estimates by three Ketchikan area management biologists are shown in comparison to the daily live estimates, both unadjusted and adjusted for fish passing uncounted during floods on 24 September and 4–5 October 2010.

Table 7.–Aerial survey estimates of chum salmon at Disappearance Creek in 2010.

Date	Area Surveyed	Mouth	Intertidal	Stream Live	Dead	Total	Observer
22-Aug	Complete survey	0	0	500	0	500	C
1-Sep	Complete survey	1,500	0	500	0	2,000	B
7-Sep	Complete survey	3,000	2,000	6,000	0	11,000	C
9-Sep	Complete survey	5,000	0	4,000	0	9,000	B
13-Sep	Complete survey	0	2,500	4,000	500	7,000	C
13-Sep	Complete survey	1,000	1,500	2,500	3,000	8,000	A
16-Sep	Complete survey	10,000	3,000	4,000	500	17,500	C
22-Sep	Complete survey	6,000	2,000	6,000	9,000	23,000	C
22-Sep	Intertidal, Mouth, and Bay	15,000	0	3,500	10,000	28,500	A
30-Sep	Complete survey	17,000	0	12,000	10,000	39,000	B
30-Sep	Complete survey	25,000	0	9,000	11,000	45,000	C
	Mark-Recapture Estimate	Peak Survey		Peak Survey to Total Escapement Multiplier			
	85,600	45,000		1.90			

Surveyors generally underestimated the number of fish present above the weir on the day of the survey. Observer A conducted one survey on 13 September, which had an estimated relative bias of -80% (Table 8). Three surveys conducted by Observer B had relative biases of -84% (1 September), -59% (9 September), and -28% (30 September unadjusted) or -51% (30 September adjusted). Finally, observer C surveyed the stream five times and had an estimated relative bias that ranged from -68% (13 September) to 7% (22 September).

Table 8.–Comparison of aerial survey counts of live chum salmon above the Disappearance Creek weir to the estimated number of live chum salmon above the weir in 2010. The estimated number of live chum salmon in the creek at the time of the survey was calculated by applying the average weekly chum salmon stream life to the daily chum salmon weir counts. The adjusted estimate incorporated an approximation for fish passed uncounted during flood events and only affected the 30 September survey.

	Survey Date								
	1-Sep	**7-Sep**	**9-Sep**	**13-Sep**	**13-Sep**	**16-Sep**	**22-Sep**	**30-Sep**	**30-Sep**
Estimated Live Chum Salmon	3083	8,461	9,648	12,548	12,548	7,799	5,609	16,607	16,607
Adjusted Estimate								24,477	24,477
Observer A					2,500				
Observer B	500		4000						12,000
Observer C		6,000		4000		4,000	6,000	9,000	
Relative Bias	-84%	-29%	-59%	-68%	-80%	-49%	7%	-46%	-28%
Relative Bias Adjusted								-63%	-51%

Otolith Sampling

We collected otoliths on a weekly basis beginning in statistical week 37 (5–11 September) and ending in week 42 (10–16 October). All of the otolith samples were collected from carcasses, and we distributed the sampling throughout the length of the creek. We recovered only one potential otolith-marked fish in our sample of 239 fish (Table 9). The mark did not match any known mark variant and may have been a strongly patterned wild fish or an unknown variant from a hatchery fish (Lorna Wilson, ADF&G Mark, Tag, and Age Laboratory, personal communication). In either case, the overall proportion of stray hatchery fish, weighted by the weekly weir counts, was <1%.

Table 9.–Weekly otolith sampling results from the 2010 fall chum escapement at Disappearance Creek.

Stream	Statistical Week	Total Sampled	Unmarked	Marked	% Hatchery Strays
Disappearance Creek	37	40	40	0	0.0%
Disappearance Creek	38	40	40	0	0.0%
Disappearance Creek	39	39	39	0	0.0%
Disappearance Creek	40	40	40	0	0.0%
Disappearance Creek	41	40	40	0	0.0%
Disappearance Creek	42	40	39	1[a]	2.5%
Total		239	238	1	<1.0%

[a] This mark did not match any known mark variant and may have been a strongly patterned wild fish.

Stream Temperature Monitoring

Stream temperatures were monitored at three locations in Disappearance Creek, from 24 July 2009 to 14 October 2010. Daily mean stream temperatures in the lower spawning pool were very stable through the monitoring period and varied from a high of 8.8 ºC on 24 September 2010 to a low of 4.6 ºC on 10 March and 2 April 2010 (Table 10). Monthly mean temperatures in the lower spawning pool ranged from a high of 8.4 ºC in September 2010 to a low of 4.8 ºC in March 2010, a variation of only 3.6 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 9.1 ºC above the first rapids on 13 October 2010 and the lowest daily mean temperature was 4.3 ºC on 10 March 2010 above the first rapids and at the weir. The difference between the maximum daily mean temperature and the minimum daily mean temperature was 4.7 ºC at the weir, 4.8 ºC above the first rapids, and 4.2 ºC at the lower spawning pool (Table 10).

Table 10.–Daily mean air and water temperatures (ºC) at Disappearance Creek, 24 July 2009 through 14 October 2010.

Month	Year	Monthly Mean Water Temperature at Weir	Monthly Mean Water Temperature Above First Rapids	Monthly Mean Water Temperature in Lower Spawning Pool
July	2009	7.3	7.2	6.9
August	2009	7.7	7.6	7.5
September	2009	8.3	8.2	8.2
October	2009	7.8	7.8	7.8
November	2009	6.9	6.9	7.0
December	2009	5.9	6.0	6.2
January	2010	5.3	5.3	5.5
February	2010	5.0	5.0	5.1
March	2010	4.8	4.8	4.8
April	2010	4.9	4.9	4.9
May	2010	5.5	5.5	5.4
June	2010	6.2	6.2	6.1
July	2010	7.4	7.3	7.1
August	2010	8.3	8.2	7.9
September	2010	8.6	8.6	8.4
October	2010	8.4	8.5	8.4
Overall Mean		6.7	6.7	6.6
Max. Daily Mean Temperature		9.0	9.1	8.8
Min. Daily Mean Temperature		4.3	4.3	4.6
Range		4.7	4.8	4.2

DISCUSSION

The point estimate from the mark-recapture study was 85,600 chum salmon in 2010, which was approximately 23,600 fish higher than the weir count and our pre-season foot survey estimate combined (62,005). There were very few fish present in the creek at the start of the project, so underestimating the number of fish present above the weir at the time of installation was not a contributing factor to the discrepancy between the weir count and mark-recapture estimate. The weir structure remained stable through the entire season and we did not have problems with the substrate washing out beneath bipods as happened on several occasions during the 2008 season (Piston and Heinl 2010a). In addition to the ground cloth, which was positioned beneath the weir in 2009 and 2010 to prevent scouring, we redesigned the extreme edge of the weir in 2010 by replacing the fencing we used in 2008 and 2009, with tripods made of aluminum channel and pickets. The modifications we made eliminated most of the problems we experienced in past years with bears crushing and ripping holes in the fencing along the extreme edge of the weir. Despite these improvements, extreme high water and carcass buildup led to water flowing over and around the edges of the weir on three days during the 2010 season.

The first breech of the weir occurred on 24 September 2010. After two weeks of dry weather and low stream flow, a large storm dropped approximately 14 cm of rain on 23 and 24 September. Typically, carcasses and dying chum salmon constantly wash up on the weir, but low stream flows during much of September left most of the carcasses from the first month of the run in the stream channel. When heavy rainfall started on 23 September, a rapid rise in water level washed thousands of carcasses and debris onto the weir. On the morning of the 24th, the crew found the creek extremely high and muddy, a condition exacerbated by an enormous carcass dam on the weir. Fish were observed swimming through and around the extreme west edge of the weir and through the woods in a new temporary channel created by the flood waters. In order to clear the weir, which clogged with carcasses and debris as fast as the crew could clean it, the crew pulled pickets to open the weir and remove debris. Large numbers of fish moved through the open weir but the water was too murky to estimate numbers. Once the water began to clear late in the day, large numbers of fish were observed on the upstream side of the weir. It is likely that several thousand fish passed the weir uncounted on 24 September, based on the fact that over 2,000 fish were passed on each of the days before and after the flood event (Appendix C).

A similar situation occurred on 5 and 6 October, which coincided with a tremendous push of fish through the weir. We measured 18 cm of rain at the weir 4–6 October, and the resulting high water and massive carcass/debris dam caused water to flow over and around both sides of the weir. Approximately 12,600 chum salmon were counted through the weir 5–6 October; however, fish swam around the edges of the weir during the night and more passed uncounted through open pickets while the crew tried to clear the weir of debris. Based on the tremendous numbers of fish counted through the weir during the flood, it is likely that a large portion of the fish that contributed to the 23,600 fish discrepancy between the weir count and mark-recapture estimate swam past the weir uncounted on those two days.

The combined peak aerial survey estimates for Disappearance and Lagoon creeks (76,000 chum salmon) was well above the Cholmondeley Sound fall chum salmon sustainable escapement goal of 30,000 to 48,000 index spawners for the two creeks (Figure 6). The overall escapement index was the second highest since 1980, and was exceeded only by the 1999 index value of 100,000 index spawners. The peak aerial survey at Disappearance Creek of 45,000 on 30 September 2010 was tied for the second highest estimate since 1980 (50,000 in 1999, 45,000 in 2003). The expansion factor needed to expand the 2010 peak aerial survey estimate of 45,000 chum salmon to the total escapement estimate of 85,600 is 1.90. The peak survey to total escapement expansion factors were 2.37 in 2009 (Piston and Heinl 2010a) and 1.55 in 2008 (Piston and Heinl 2010b). For all three years of this study the mean expansion factor was 1.94.

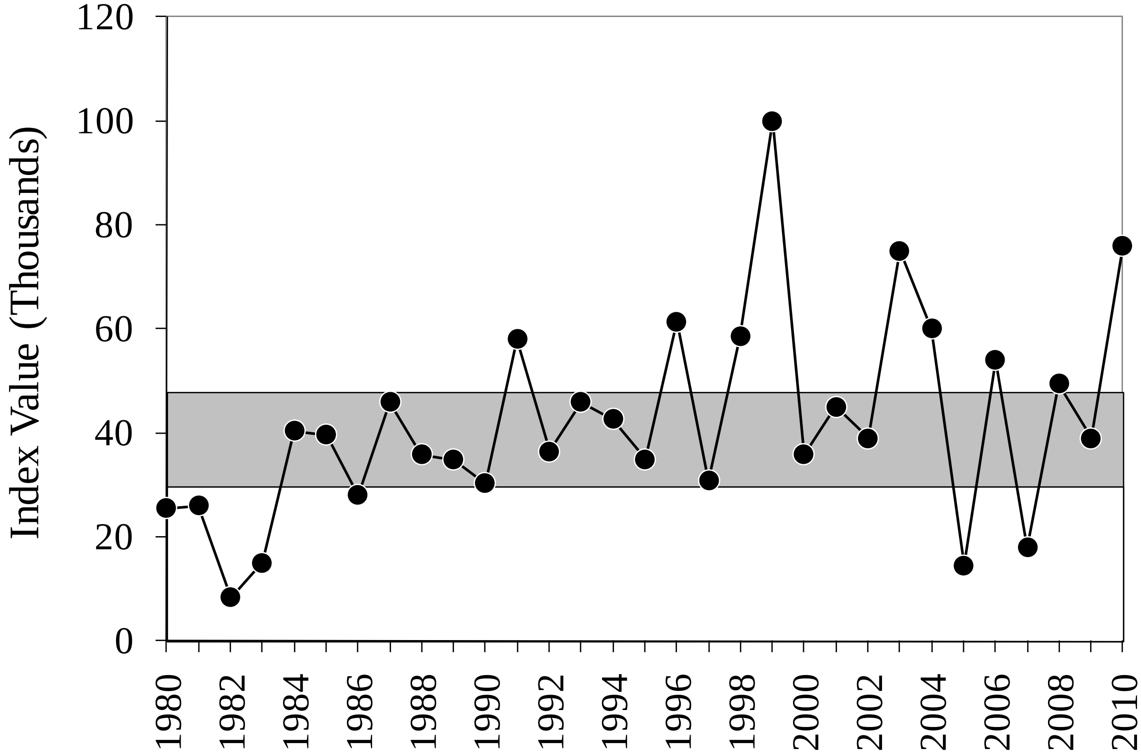

Figure 6.–Cholmondeley Sound fall chum salmon escapement index, 1980–2010. The index is based on the peak aerial survey estimates for Disappearance and Lagoon creeks combined. The shaded gray bar represents the sustainable escapement goal range of 30,000–48,000 index spawners.

The age composition of the chum salmon escapement in 2010 was highlighted by a very strong showing of age-0.3 fish. An estimated 87.5% of the total escapement of 85,600 fish was age 0.3, while age-0.2 fish (8.6%) and age-0.4 fish (3.9%) comprised the remainder of the escapement (Table 4). In all three years of our study, 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. The very large return of age-0.3 fish in 2010 (approximately 75,000 fish) followed a very strong showing of age-0.2 fish in 2009 (approximately 40% of the escapement of 61,500 fish), suggesting that it may be possible to forecast relative run strength based on the age composition and total escapement size of chum salmon each year. The larger number and proportion of age-0.3 fish in 2010 likely reflected the strong brood year escapement in 2006 as measured by the peak aerial survey estimate for that year (Figure 6). The estimated number of age-0.2 fish in the escapement in 2010 (approximately 7,400 fish, adjusted to total escapement) was far below the estimated 24,600 age-0.2 fish we observed in 2009, but was only slightly lower than the 2008 total of approximately 8,500 age-0.2 fish (adjusted to total escapement).

Based on the relatively low numbers of age-0.2 fish in the 2010 escapement and the poor parent year escapement for that same year class, we might expect to see a relatively weak showing of the typically dominant age-0.3 fish in 2011. The peak aerial survey for Disappearance Creek in 2007 was only 9,500 fish, which was the fourth lowest peak survey estimate since 1980. In contrast, the age-0.2 fish that will return in 2011 were produced by the 2008 total escapement of 55,000 (Piston and Heinl 2010a) and the age-0.4 fish were the product of another very large escapement in 2006. Thus, the strong parent-year escapement for the age-0.2 fish, and the possibility of a strong return of age-0.4 fish, based on the large returns of their cohorts in 2010, may provide some buffer if age-0.3 fish do indeed return in sub-optimal numbers. We recommend implementing a long-term program to collect age, sex, and length data at Disappearance Creek, which will provide relatively inexpensive pre-season indications of run strength that may improve management of the Cholmondeley Sound fall chum salmon fishery.

Similar to 2008 and 2009 (Piston and Heinl 2010a, Piston and Heinl 2010b), there was only one potential hatchery fish detected in a sample of 239 chum salmon in 2010. 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 facilities, approximately 90 km and 158 km from Disappearance Creek, respectively. (SSRAA's fall chum salmon broodstock was originally taken at Disappearance and Lagoon creeks, in Cholmondeley Sound.) The proportion of hatchery strays in the escapement at Disappearance Creek has not exceeded 1% in the three years of this study. 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. From 2008 to 2010, ADF&G conducted a study to sample chum salmon index streams throughout the region for hatchery strays. Preliminary results from the three years of sampling indicates that the proportion of hatchery fish in wild stock streams is typically low for systems, like Disappearance Creek, that are located >90 km from the nearest release site; therefore, we would not expect to see high proportions of stray hatchery fall chum salmon in Cholmondeley Sound given current levels and locations of hatchery fall chum salmon releases.

When we arrived at Disappearance Creek in mid-August, we found the upstream passage of chum salmon into the main spawning pools blocked by beaver dams located at the outlet of the lower spawning pool, in the middle of the lower spawning pool, and at the outlet of the upper spawning pool. We found beaver dams in the same locations at the start of the 2009 season (Piston and Heinl 2010b) and one beaver dam at the outlet of the upper spawning pool at the start of the 2008 season (Piston and Heinl 2010a). It seems likely that the primary spawning areas may become inaccessible to chum salmon without the annual removal of dams, assuming beaver activity in the area continues or increases. As in 2009, we completely removed the beaver dams during the first week of the project and chum salmon had complete access to all available spawning habitat throughout the entire spawning period. Beavers did not attempt to rebuild the dams in 2009 or 2010. In 2008, however, they repaired the upper dam continuously throughout the season and the upper spawning pool was inaccessible to chum salmon for most of the spawning season (Piston and Heinl 2010a). We hypothesized that beavers did not repair the dams during the 2009 season because the water flow was generally higher due to three times as much rain in September 2009, compared to the same period in 2008 (Piston and Heinl 2010b). In 2010, however, we experienced a stretch of sixteen days (7–22 September) with only 2 cm of rainfall. Despite the associated low water levels during this time, beavers made no attempt to repair dams, suggesting that it may be possible to provide continued access for chum salmon in Disappearance Creek by removing dams just prior to the arrival of fall chum salmon in late August, assuming that dams are not rebuilt as they were in 2008.

We have no evidence to indicate that complete blockages to fish passage occurred annually prior to 2008. ADF&G removed beaver dams at Disappearance Creek on at least three occasions prior to 2008 (Philip S. Doherty, retired Ketchikan Area Management Biologist, ADF&G, personal communication), and it is possible that undocumented beaver dam removal occurred during other years when a weir crew was present at the creek from 1965 to 1984. Any impediment to fish passage should be readily apparent to managers flying the creek due to the absence of fish in the two main spawning pools. The extent to which changes in beaver populations have affected the frequency and extent of dam building at Disappearance Creek is not known.

Beaver harvest records from Prince of Wales Island going back to the mid-1980s indicate that the harvest has been highly variable with no obvious long-term trend, and recent pelt prices have not been high enough to draw much trapping pressure to remote areas of Prince of Wales Island (Porter 2007). There is only one year (1996) for which ADF&G has a record of beaver harvest in the South Arm of Cholmondeley Sound, so it seems unlikely that the presumed increase in beaver activity at Disappearance Creek is a result of reduced trapping effort in the area. It is possible that a recent major population decline in wolves on Prince of Wales Island (D. K. Person, Wildlife Research Biologist, ADF&G, Ketchikan, personal communication) has had an effect on resident beaver populations. Beavers can be important prey for wolves, and 31% of wolf scats collected on Prince of Wales Island in 1992–1994 contained beaver remains (Kohira and Rexstad 1997). However, ADF&G does not conduct beaver population surveys in Southeast Alaska (Porter 2007), and we have no data to show that there has been an increase in beaver numbers in Cholmondeley Sound, despite the apparent increase in activity observed at Disappearance Creek. If beaver dams are rebuilt in locations and of sizes similar to what we have observed the past three seasons, the amount of spawning habitat available to chum salmon at Disappearance Creek could be greatly reduced. Even if we assume that flood events might allow for the passage of some chum salmon, the very short stream life of these fish indicates that even short-term blockages would force fish to crowd into smaller areas of accessible spawning habitat and lead to reduced chum salmon production in the watershed.

The estimated seasonal mean stream life, weighted by week, was very similar from 2008 to 2010—8.4 days in 2008, 7.7 days in 2009, and 8.1 days in 2010. In all three years, stream life followed a similar seasonal pattern of gradual decline as the season progressed; the stream life of fish that entered the system in the final weeks of the season was approximately half that of fish that arrived early in the season (Table 6; Piston and Heinl 2010a and Piston and Heinl 2010b). This same pattern of declining stream life through the season has also been documented 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).

Although, the Cholmondeley Sound escapement index was far above the upper end of the escapement goal range in 2010, the harvest and number of fishery openings inside of Cholmondeley Sound (subdistrict 102-40) were very low (Table 1, Figure 7). The amount of fishing time inside of Cholmondeley Sound is determined by management biologists' assessments of building escapements at the major spawning streams in the area and by the strength of catches in the final weeks of the pink salmon fishery and initial fall fishery openings. In years of 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 2001–2010 (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). In 2010, it appeared that the majority of the harvestable surplus of chum salmon in Cholmondeley Sound had already past the fishery by late September.

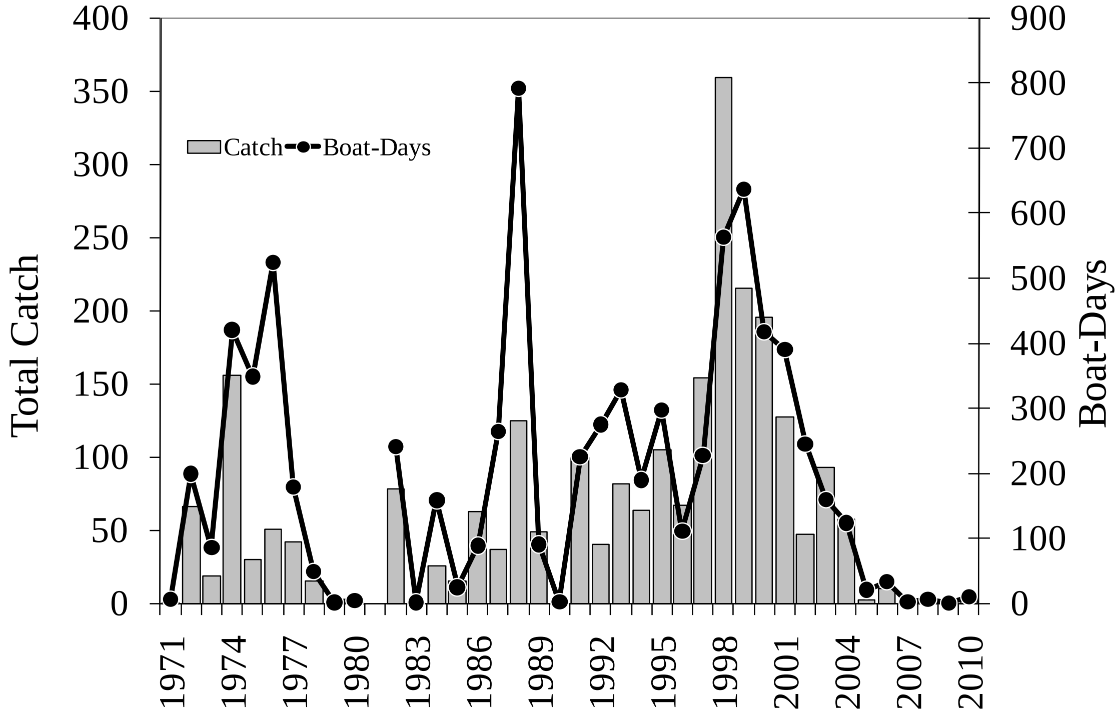

Figure 7.–Fishing effort and catch in the subdistrict 102-40 purse seine fishery inside Cholmondeley Sound, 1971–2010.

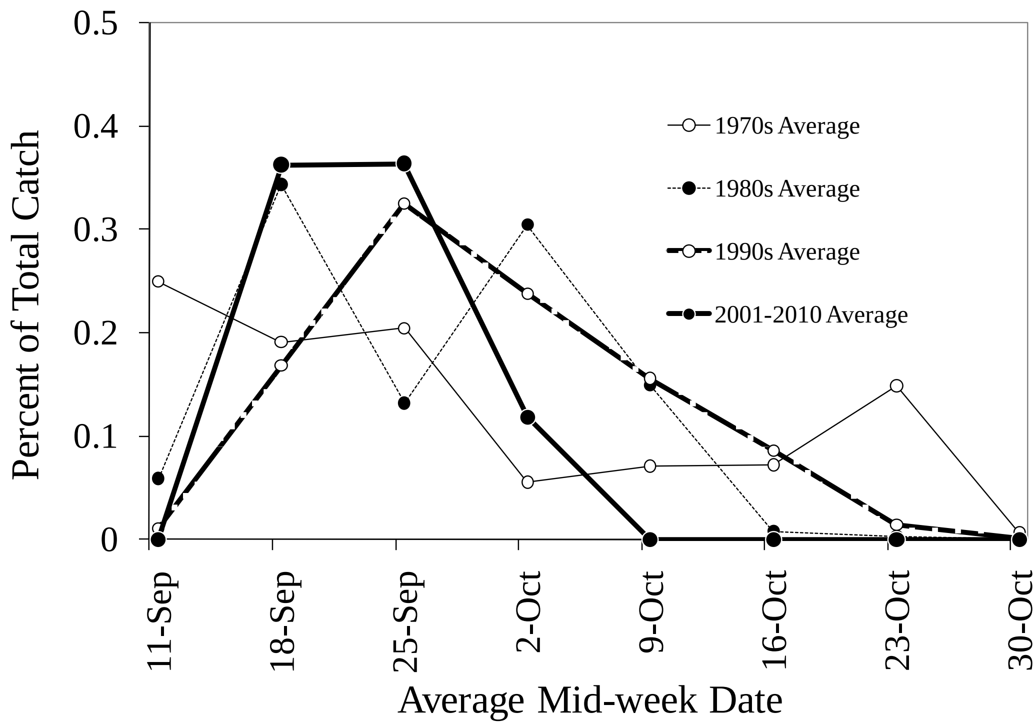

Figure 8.–Average weekly proportion of the total annual fall chum salmon catch in Cholmondeley Sound, subdistrict 102-40, by decade.

The first commercial fishery openings for fall chum salmon in the Cholmondeley Sound area occurred primarily in subdistrict 102-50, just outside of Cholmondeley Sound (Figure 1), on 9 and 15 September 2010. Approximately 6,150 chum salmon were harvested by 8 boats in a 12-hour opening on 9 September and approximately 2,900 chum salmon were harvested by 8 boats in a 12-hour opening on 15 September. These catches were considered well below average and no fishery opening was scheduled for the following week. In addition, fish passage through the Disappearance Creek weir during statistical week 38 (12–18 September) was relatively low and the number of live fish in the creek had declined significantly at a time when managers had to make a decision about the next fishery opening (Figure 5). During the middle of week 39 (19–25 September) fish passage at the weir increased considerably, and by the end of the week a tremendous mass of fish was staged in the bay in front of Disappearance Creek. After conducting aerial surveys of Cholmondeley Sound streams on 22 September 2010, Ketchikan area managers announced that the numbers of fish committed to Disappearance and Lagoon creeks were sufficient to conduct a fishery opening inside Cholmondeley Sound (District 102-40). The final 12-hour opening of the year took place on 26 September and a total of 9 boats participated in the fishery. Despite the large numbers of fish in the major creeks in the area and the tremendous school of fish in saltwater near Disappearance Creek, only 4,180 chum salmon were harvested. The final aerial survey of Cholmondeley Sound was conducted on 30 September 2010, at which time it was clear that nearly all the chum salmon remaining in the area had already entered streams or were holding near the mouth of Disappearance Creek.

Although the run timing of the chum salmon escapements in 2008 and 2009 appeared to be relatively normal compared to rough estimates of run timing from weir projects in the mid-1960s to mid-1980s (Piston and Heinl 2010b), the Disappearance Creek run timing in 2010 was clearly earlier than average. In particular, the run came to an abrupt end after the first week of October (Figures 4 and 5). Over 99% of the escapement had passed the weir through 6 October. In contrast, we had only reached the 50^{th} percentile of the run on the same date in 2009 and the 86^{th} percentile of the run in 2008 (Figure 4). In many years from 1965 to 1984, the weir was pulled while hundreds of fish were still passing each day. For the seven years when the weir was maintained past 20 October, on average only 66% of the run had passed through the weir through 6 October and the 99^{th} percentiles were not reached until the last few days of October. In 2010, most of the fish that passed the weir during the first week of October were schooled up at the mouth of the creek by the last week of September. Although fisheries have occurred into late October in the past (Figure 8), it appears that very few fish were available for harvest by the last week of September in 2010.

The Cholmondeley Sound fall chum salmon fishery has been managed conservatively in recent years due to poor escapements in 2005 and 2007 and concerns about escapements to some of the smaller streams in the Sound. Although harvests of chum salmon in the last weeks of the pink salmon fishery and initial fall fishery openings outside of Cholmondeley Sound (District 102-50) provide managers some indication about overall run strength, managers need to see fish numbers building at the major spawning streams in the area before they can be confident that adequate escapement will be achieved. Strong escapements to Disappearance and Lagoon creek over the past three seasons may allow for a slightly more aggressive management approach in the near future that would allow more fishery openings and ensure that harvestable surpluses of chum salmon are not already out of reach by the time the waters inside of Cholmondeley Sound are opened to fishing. We recommend continuing to collect age, sex, and length data from Disappearance Creek chum salmon, which may provide some degree of predictive power for forecasting relative run strength prior to the fishing season. In addition, we recommend that management biologists conduct annual foot surveys of Disappearance and Lagoon creeks to ground-truth their aerial survey observations. Conducting foot surveys will allow management biologists to improve their aerial survey estimates by providing an opportunity to better assess the relative abundance of chum salmon versus pink salmon early in the season and to identify carcasses to species more reliably late in the season. Surveying from the ground would also provide opportunity to ensure that fish have access to the primary spawning pools, which have been blocked by beaver dams in recent years. In the absence of a weir, collecting scale samples for ageing and conducting additional foot surveys to complement the aerial survey program will provide information that could prove valuable to the management of the Cholmondeley Sound fall chum salmon fishery.

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APPENDICES

Appendix A.–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:

$$\hat{p}_{hj} = n_{hj} / n_h \ . \tag{1}$$

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):

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

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

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

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):

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

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,

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

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

Appendix B.–ADF&G statistical week calendar for 2010.

Week	Start	End
1	1-Jan	2-Jan
2	3-Jan	9-Jan
3	10-Jan	16-Jan
4	17-Jan	23-Jan
5	24-Jan	30-Jan
6	31-Jan	6-Feb
7	7-Feb	13-Feb
8	14-Feb	20-Feb
9	21-Feb	27-Feb
10	28-Feb	6-Mar
11	7-Mar	13-Mar
12	14-Mar	20-Mar
13	21-Mar	27-Mar
14	28-Mar	3-Apr
15	4-Apr	10-Apr
16	11-Apr	17-Apr
17	18-Apr	24-Apr
18	25-Apr	1-May
19	2-May	8-May
20	9-May	15-May
21	16-May	22-May
22	23-May	29-May
23	30-May	5-Jun
24	6-Jun	12-Jun
25	13-Jun	19-Jun
26	20-Jun	26-Jun
27	27-Jun	3-Jul
28	4-Jul	10-Jul
29	11-Jul	17-Jul
30	18-Jul	24-Jul
31	25-Jul	31-Jul
32	1-Aug	7-Aug
33	8-Aug	14-Aug
34	15-Aug	21-Aug
35	22-Aug	28-Aug
36	29-Aug	4-Sep
37	5-Sep	11-Sep
38	12-Sep	18-Sep
39	19-Sep	25-Sep
40	26-Sep	2-Oct
41	3-Oct	9-Oct
42	10-Oct	16-Oct
43	17-Oct	23-Oct
44	24-Oct	30-Oct
45	31-Oct	6-Nov
46	7-Nov	11-Nov
47	12-Nov	20-Nov
48	21-Nov	27-Nov
49	28-Nov	4-Dec
50	5-Dec	11-Dec
51	12-Dec	18-Dec
52	19-Dec	25-Dec
53	26-Dec	31-Dec
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Appendix C.–Daily chum salmon counts at the Disappearance Creek weir, 2010. 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
19-Aug	34	RV	0	0	4	4	4	4	0	0	4
20-Aug	34	RV	1	1	9	13	10	14	0	0	14
21-Aug	34	RV	0	1	3	16	3	17	0	0	17
22-Aug	35	RV	0	1	2	18	2	19	0	0	19
23-Aug	35	RV	16	17	319	337	335	354	0	0	354
24-Aug	35	RV	8	25	239	576	247	601	0	0	601
25-Aug	35	RV	7	32	41	617	48	649	0	0	649
26-Aug	35	RV	9	41	175	792	184	833	0	0	833
27-Aug	35	RV	9	50	155	947	164	997	0	0	997
28-Aug	35	RV	16	66	323	1,270	339	1,336	0	0	1,336
29-Aug	36	RV	7	73	136	1,406	143	1,479	0	0	1,479
30-Aug	36	RV	13	86	249	1,655	262	1,741	0	0	1,741
31-Aug	36	RV	62	148	1,194	2,849	1,256	2,997	0	0	2,997
1-Sep	36	RV	5	153	66	2,915	71	3,068	0	0	3,068
2-Sep	36	RV	103	256	1,950	4,865	2,053	5,121	0	0	5,121
3-Sep	36	RV	53	309	994	5,859	1,047	6,168	0	0	6,168
4-Sep	36	RV	10	319	175	6,034	185	6,353	0	0	6,353
5-Sep	37	RV	15	334	285	6,319	300	6,653	0	0	6,653
6-Sep	37	RV	80	414	1,649	7,968	1,729	8,382	0	0	8,382
7-Sep	37	RV	28	442	405	8,373	433	8,815	0	0	8,815
8-Sep	37	RV	31	473	601	8,974	632	9,447	0	0	9,447
9-Sep	37	RV	42	515	808	9,782	850	10,297	0	0	10,297
10-Sep	37	RV	85	600	1,758	11,540	1,843	12,140	0	0	12,140
11-Sep	37	LV	49	649	2,556	14,096	2,605	14,745	0	0	14,745
12-Sep	38	LV	15	664	573	14,669	588	15,333	0	0	15,333
13-Sep	38	LV	5	669	207	14,876	212	15,545	0	0	15,545
14-Sep	38	LV	4	673	209	15,085	213	15,758	0	0	15,758
15-Sep	38	LV	10	683	531	15,616	541	16,299	0	0	16,299
16-Sep	38	LV	2	685	128	15,744	130	16,429	0	0	16,429
17-Sep	38	LV	3	688	159	15,903	162	16,591	0	0	16,591
18-Sep	38	LV	12	700	621	16,524	633	17,224	0	0	17,224
19-Sep	39	LV	20	720	1,007	17,531	1,027	18,251	0	0	18,251
20-Sep	39	LV	10	730	490	18,021	500	18,751	0	0	18,751
21-Sep	39	LV	47	777	993	19,014	1,040	19,791	0	0	19,791
22-Sep	39	LV	30	807	1,546	20,560	1,576	21,367	0	0	21,367
23-Sep	39	LV	50	857	2,476	23,036	2,526	23,893	0	0	23,893
24-Sep	39	LV	2	859	198	23,234	200	24,093	0	0	24,093
25-Sep	39	LV	42	901	2,077	25,311	2,119	26,212	0	0	26,212
26-Sep	40	LV	20	921	943	26,254	963	27,175	0	0	27,175
27-Sep	40	LV	137	1,058	6,722	32,976	6,859	34,034	0	0	34,034
28-Sep	40	LV	50	1,108	2,669	35,645	2,719	36,753	0	0	36,753
29-Sep	40	LV	50	1,158	2,231	37,876	2,281	39,034	0	0	39,034
30-Sep	40	LV	29	1,187	1,437	39,313	1,466	40,500	0	0	40,500

–continued–

Appendix C.–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	20	1,207	883	40,196	903	41,403	0	0	41,403
2-Oct	40	D	67	1,274	3,132	43,328	3,199	44,602	0	0	44,602
3-Oct	41	D	10	1,284	556	43,884	566	45,168	0	0	45,168
4-Oct	41	D	65	1,349	3,801	47,685	3,866	49,034	0	0	49,034
5-Oct	41	D	160	1,509	8,940	56,625	9,100	58,134	0	0	58,134
6-Oct	41	D	65	1,574	3,432	60,057	3,497	61,631	0	0	61,631
7-Oct	41	D	2	1,576	74	60,131	76	61,707	0	0	61,707
8-Oct	41	D	1	1,577	25	60,156	26	61,733	0	0	61,733
9-Oct	41	D	1	1,578	85	60,241	86	61,819	0	0	61,819
10-Oct	42	D	1	1,579	111	60,352	112	61,931	0	0	61,931
11-Oct	42	D	1	1,580	7	60,359	8	61,939	0	0	61,939
12-Oct	42	D	8	1,588	4	60,363	12	61,951	0	0	61,951
13-Oct	42	D	2	1,590	0	60,363	2	61,953	0	0	61,953
14-Oct	42	D	4	1,594	1	60,364	5	61,958	0	0	61,958
15-Oct	42	D	1	1,595	1	60,365	2	61,960	0	0	61,960
16-Oct	42	D	1	1,596	12	60,377	13	61,973	0	0	61,973
17-Oct	43	D	1	1,597	6	60,383	7	61,980	0	0	61,980
18-Oct	43	D	1	1,598	3	60,386	4	61,984	0	0	61,984
19-Oct	43	D	1	1,599	5	60,391	6	61,990	0	0	61,990