Fishery Data Series No. 10-15

Disappearance Creek Chum Salmon Weir Study, 2008

by

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and

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March 2010

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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ABSTRACT

For over three decades, the Alaska Department of Fish and Game has managed a fall chum salmon purse seine fishery in Cholmondeley Sound, Prince of Wales Island, Southeast Alaska. Total catch, fishing time, and effort in the fishery have decreased since the late 1990s. The escapement at Disappearance Creek was measured at an adult counting weir that was operated nearly annually from 1961 to 1984. Since 1985, aerial surveys have been used to monitor escapements to Disappearance and Lagoon creeks. In 2009, a formal *Sustainable Escapement Goal* range of 30,000 to 48,000 index spawners was established for Disappearance and Lagoon creeks combined. In 2008, we conducted the first year of a project to monitor the escapement of fall chum salmon at Disappearance Creek. From 25 August to 26 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, and the proportion of stray hatchery chum salmon in the escapement. The chum salmon weir count was 50,640 and the estimated number of fish upstream of the weir at start up was 1,060 chum salmon (=51,700). The point estimate of the mark-recapture study was approximately 55,000 chum salmon. The difference between the weir count and the mark-recapture estimate can be explained by a hole in the weir on 28 September 2008. Therefore, the mark-recapture estimate was used as the official escapement estimate in 2008. The peak aerial survey estimate of 35,500 chum salmon occurred on 17 September 2008 and was 65% of the estimated total escapement of 55,000 chum salmon. There were no thermal-marked fish detected in our sample of 156 chum salmon in 2008.

Key words: chum salmon, *Oncorhynchus keta*, Disappearance Creek, escapement, 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 fishermen with a valuable opportunity to extend their fishing season beyond the end of the directed pink salmon purse seine season, which 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, and only 389 fish in 2007. Fishing time in Cholmondeley Sound historically extended into early October, but in the last five 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.

Management of the fall chum salmon fishery in Cholmondeley Sound has been 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 through 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 observed chum salmon moving into the head waters of Cholmondeley sound and into the spawning streams, fishing areas were 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 indicated 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.

In 2008, we conducted the first year of a proposed three-year project to monitor the escapement of fall chum salmon at Disappearance Creek. From 25 August to 26 October, we enumerated the adult salmon escapement through a weir and conducted a secondary mark-recapture estimate of the total spawning population of adult chum salmon. We also estimated the average weekly stream life of chum salmon and used that information in conjunction with the daily weir counts to estimate the number of live fish present in the creek on any given day. These 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, and to estimate the proportion of stray hatchery chum salmon in the Disappearance Creek escapement.

[1] 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)*.

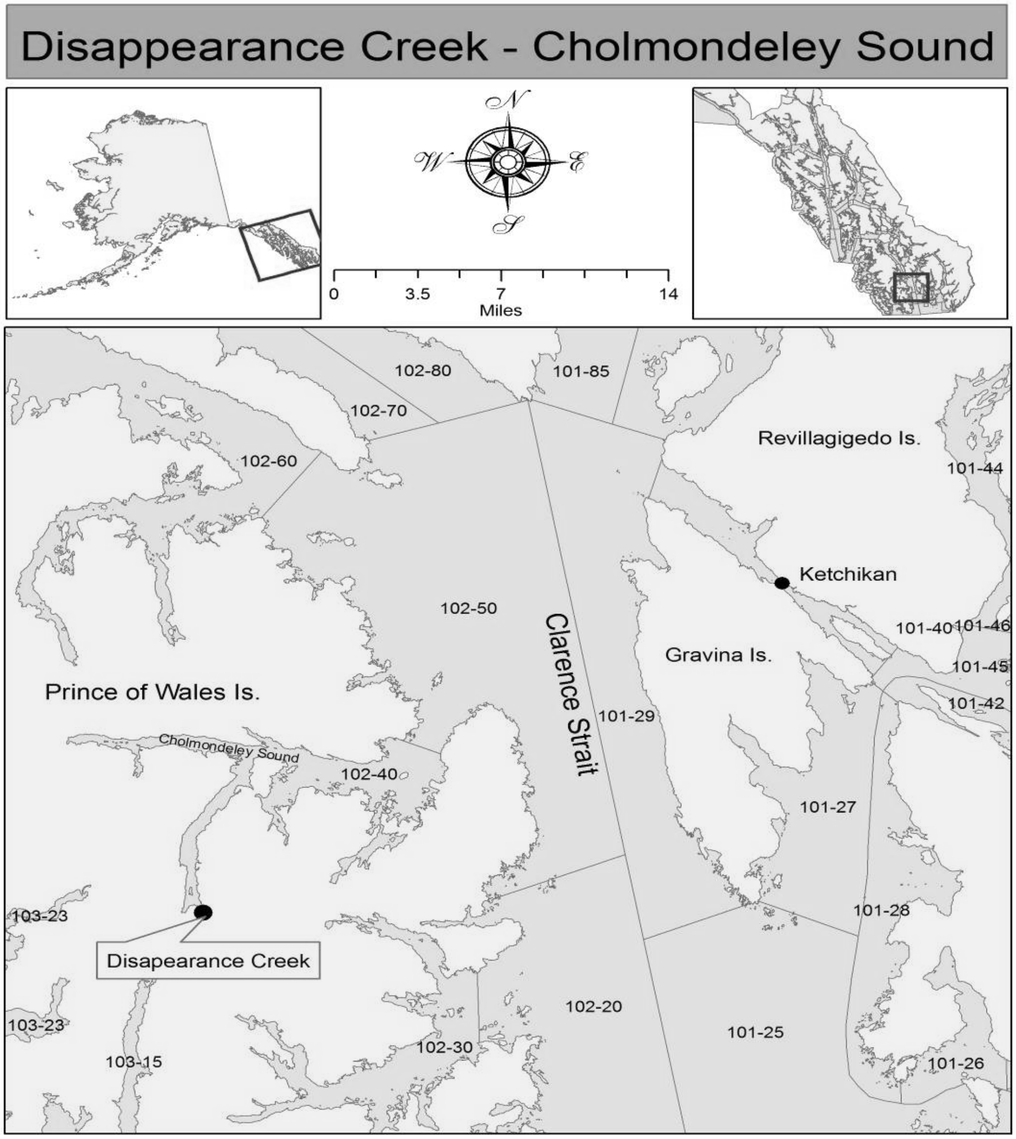


Figure 1.–The geographic location of Disappearance Creek, South Arm, Cholmondeley Sound, Prince of Wales Island, Southeast Alaska. Most of the chum salmon caught in the District 2 fall purse seine fishery are harvested in subdistrict 102-50, and inside Cholmondeley Sound in subdistrict 102-40.

SUMMARY OF THE DISTRICT 2 FALL CHUM SALMON FISHERY

Purse seine fisheries targeting fall-run chum salmon are conducted annually in District 2, along the eastern shore of Prince of Wales Island. The first openings for fall chum salmon take place beginning in statistical week 37 (average opening date 6 September). Purse seine openings often encompass much of the area in District 2; on average, however, 49.0% of the fall chum salmon harvest has taken place in subdistrict 102-40, inside Cholmondeley Sound, and 37.6% of the harvest has occurred in subdistrict 102-50, in Clarence Strait, adjacent to Cholmondeley Sound (Table 1; Figure 1).

Fishing effort and harvest levels inside Cholmondeley Sound (subdistrict 102-40) increased dramatically through the 1990s (Table 1, Figure 2). The harvest of fall chum salmon inside Cholmondeley Sound averaged 42,000 in the 1970s, 40,000 in the 1980s, 119,000 in the 1990s, and 60,000 since 2000. In the past four seasons, however, the harvest has averaged less than 5,000 fish. 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. In years with low chum salmon abundance in Cholmondeley Sound, the number and length of fisheries 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 2001–2008 (Figure 3). 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. Fishing effort was relatively high in the 1970s although catches were typically lower than during the peak years of the 1990s (Figure 2).

A similar fishing pattern occurred in subdistrict 102-50 in Clarence Strait at the mouth of Cholmondeley Sound and in surrounding waters (Table 1). The harvest of fall chum salmon in subdistrict 102-50 after week 37 averaged 19,000 in the 1970s, 21,000 in the 1980s, 81,000 in the 1990s, and 22,000 since 2000. In the past four seasons the harvest has averaged less than 6,000 fish. Since 2000, this purse seine fishery has not been conducted as late into the season as during the 1980s and 1990s (Figure 4).

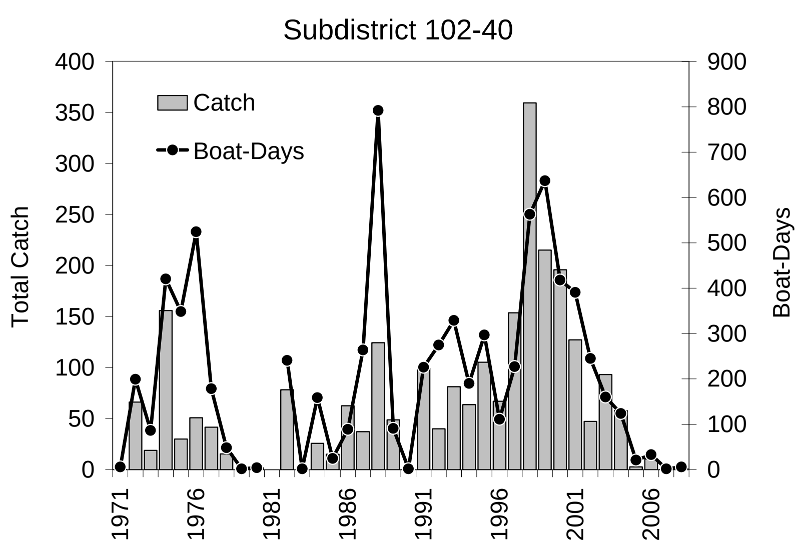


Figure 2.–Fishing effort and catch in the subdistrict 102-40 purse seine fishery inside Cholmondeley Sound, 1971–2008.

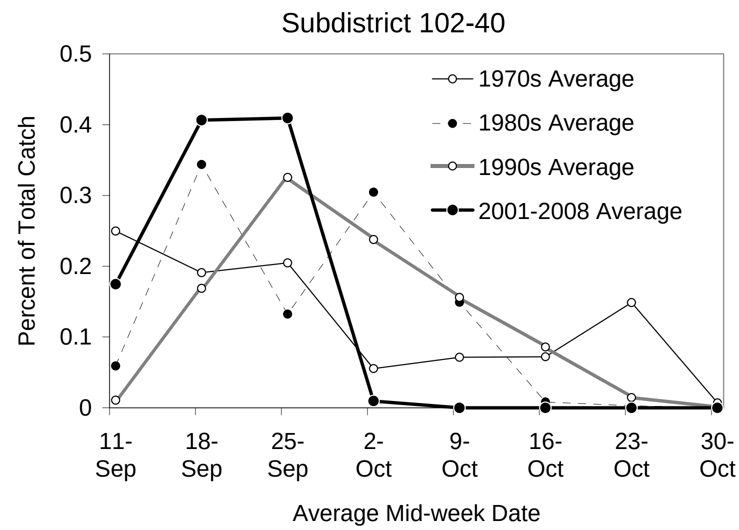


Figure 3.–Average weekly proportion of the total annual fall chum salmon catch in Cholmondeley Sound, subdistrict 102-40, by decade.

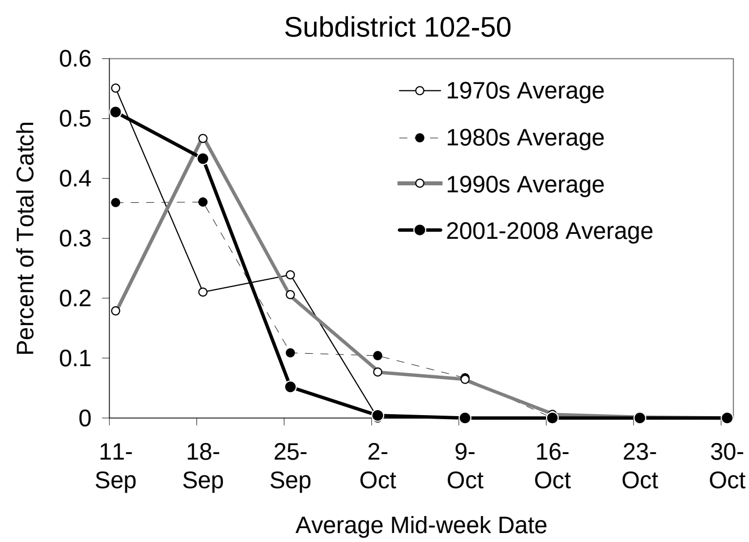


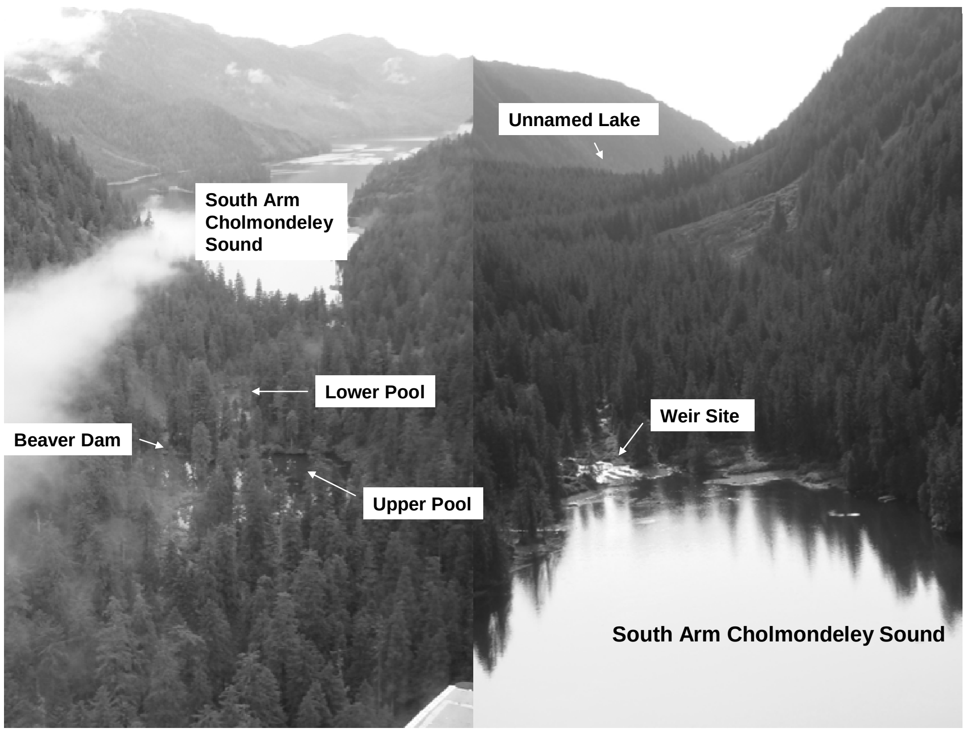
Figure 4.–Average weekly proportion of the total annual fall chum salmon catch in subdistrict 102-50, adjacent to Cholmondeley Sound, by decade.

Table 1.–Harvest of chum salmon by sub-district in the District 2 fall purse seine fishery, 1971–2008.

	Subdistrict								
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
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 5). 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 for 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 6). The creek then enters a narrow, fast reach for approximately 0.25 km before reaching the first of two large pools (Figure 5). 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.



ADF&G Photo Illustration by Scott B. Walker

Figure 5.–Upstream (right) and downstream (left) views of the Disappearance Creek drainage

ADF&G Photo by Scott B. Walker

Figure 6.–Aerial view of Disappearance Creek weir, 25 September 2008 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.

METHODS

ADULT ESCAPEMENT

An adult salmon counting weir was operated at the mouth of Disappearance Creek from 25 August to 23 October, at the extreme upper reach of the tidal flats (Figure 5 and 6). We employed a standard aluminum bi-pod, channel-and-picket weir design, with an upstream trap for enumerating and sampling salmon. Large tides (approximately 14 feet and larger) raised the water level at the weir. Fencing was used along the sides of the weir to keep fish from passing around the weir during high water. The integrity of the weir 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 10 (10%). The marking rate was lowered to 2.5% after 15 September to allow for efficient passage of fish during the peak of the run. 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, 15 August–15 September; left ventral fin clip, 16 September–15 October; and partial dorsal fin clip, 16–23 October. In addition, every marked fish had its adipose fin removed to further 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 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). Scales were read 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 were 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 11th 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.

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 24 August, Appendix B) to week 41 (starting date 5 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 the 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.

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, if any, 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 Mark, Tag, and Age Laboratory, Juneau, Alaska. We estimated the proportions (and standard errors) of wild and stray hatchery chum salmon in the escapement using standard methods (Cochran 1977).

RESULTS

ADULT ESCAPEMENT

In 2008, the adult weir was fish-tight from 25 August to 23 October, and we passed 50,633 chum salmon through the weir (Appendix C). The total chum salmon weir count, including handling mortalities, was 50,640. Immediately after getting the weir structure fish-tight on 25 August, we conducted a foot survey of the stream and estimated that there were approximately 1,060 chum salmon above the weir. The total weir count plus the estimated number of fish upstream of the weir at start up was approximately 51,700 chum salmon. We also passed 10,814 pink salmon between 25 August and 2 October, with the peak occurring from the end of August through mid-September. Surprisingly, the system does not appear to support a run of coho salmon and we observed only three 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 4,000 chum salmon moved upstream. The mid-point of the run occurred on 27 September, which was very close to the long-term average from weir counts conducted between 1965 and 1984 (Figure 7). The 75th percentile of the escapement was reached two days later on 29 September. A total of 17,148 chum salmon passed through the weir during the five-day period 26–30 September 2008. Fish passage remained strong through mid-October and from 17–19 October a final surge of 4,000 chum salmon passed through the weir. After this final push, we no longer observed schools of chum salmon in the bay or within a mile of the creek mouth, and fish passage through the weir dropped quickly, with only five fish passed on the final day of weir operations (23 October).

For most of the season, operation of the weir proceeded smoothly and there were no apparent holes for fish to get through uncounted. As fish started to spawn and die, the number of carcasses washing up on the weir gradually made weir cleaning a constant necessity. On the evening of 28 September, at the peak of the run, a combination of high water and large numbers of carcasses damming the weir caused the substrate to wash out beneath one weir bipod. The problem was quickly corrected the following morning, but we assume that this event accounted for the vast majority of fish that passed the weir uncounted and resulted in the slightly higher estimate we obtained from our mark-recapture study (see below).

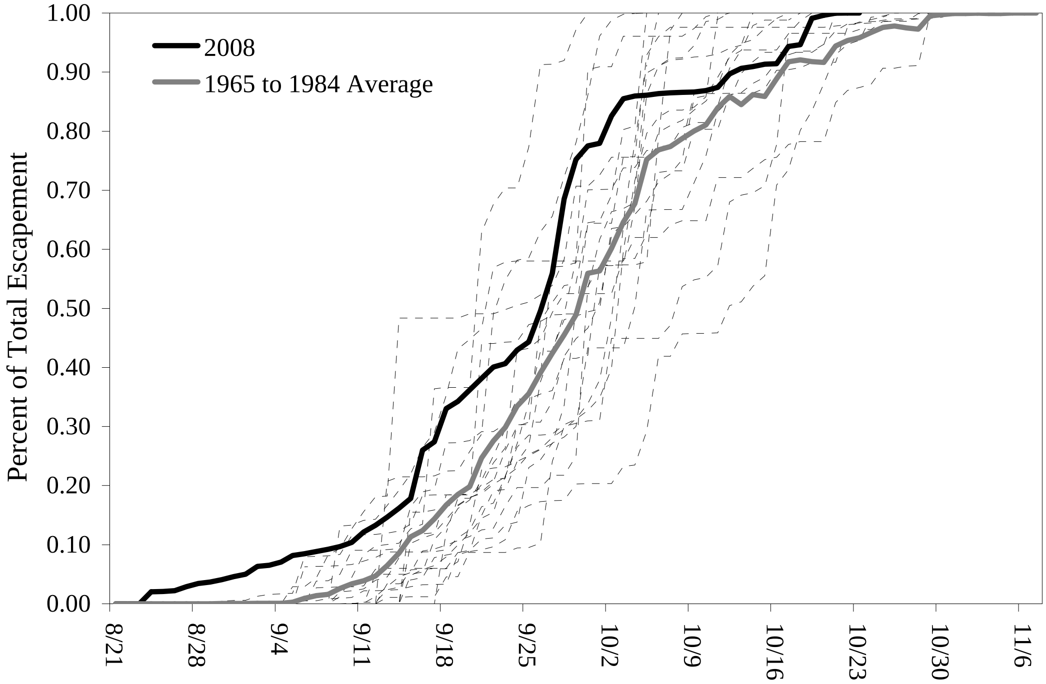


Figure 7.–Chum salmon run-timing at Disappearance Creek, 1965–1984 and 2008. In many years prior to 2008, the weir was not installed until the second week of September.

Mark Recapture

In 2008, a total of 1,871 chum salmon were marked with different fin clips over three marking strata (Appendix C). The strata were chosen prior to the season and the vast majority of the marks were applied in the first two strata. Between 25 August and 15 September, 840 chum salmon were marked with a right ventral fin clip at a 10% marking rate. Beginning 16 September, fish were marked at a 2.5% marking rate: from 16 September to 15 October, 925 chum salmon were marked with a left ventral fin clip; and from 16–23 October, 106 chum salmon were marked with a partial dorsal fin clip.

Recapture sampling on the spawning grounds was conducted over the course of the entire spawning season, from 5 September to 26 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 40,090 fish were examined for fin clips, of which 1,392 were marked (Table 2). Thus, approximately 74% 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, 2008.

	Number of Marked Fish			Number	Total Number
Date	**Left Ventral**	**Right Ventral**	**Dorsal**	**Unmarked**	**Sampled**
5-Sep	0	1	0	42	43
11-Sep	0	11	0	415	426
13-Sep	0	26	0	542	568
15-Sep	4	86	0	1091	1177
16-Sep	2	48	0	547	595
17-Sep	2	39	0	419	458
18-Sep	0	49	0	591	644
19-Sep	7	66	0	515	583
20-Sep	22	47	0	480	529
21-Sep	22	65	0	547	612
22-Sep	33	51	0	590	648
23-Sep	45	70	0	886	978
24-Sep	41	43	0	1039	1104
25-Sep	16	29	0	1243	1305
26-Sep	34	5	0	1272	1322
27-Sep	26	9	0	1211	1261
28-Sep	33	1	0	442	459
29-Sep	18	6	0	1358	1398
30-Sep	18	2	0	1103	1131
1-Oct	47	1	0	1022	1056
2-Oct	25	0	0	625	643
3-Oct	49	0	0	832	850
4-Oct	23	1	0	2759	2807
5-Oct	57	0	0	2005	2030
6-Oct	46	0	0	2973	3022
7-Oct	17	0	0	1146	1169
8-Oct	40	1	0	4124	4182
9-Oct	19	0	0	2277	2323
10-Oct	19	0	0	680	697
11-Oct	17	0	0	1827	1867
12-Oct	12	0	0	631	650
13-Oct	10	0	0	1188	1207
14-Oct	2	0	0	730	747
15-Oct	5	0	0	419	431
16-Oct	3	0	0	182	192
17-Oct	4	0	1	107	110
18-Oct	4	0	3	96	104
19-Oct	0	0	0	181	184
20-Oct	1	0	2	285	291
21-Oct	0	0	5	120	129
22-Oct	0	0	1	83	84
23-Oct	0	0	0	14	15
24-Oct	0	0	0	23	23
26-Oct	0	0	0	36	36
Total	723	657	12	38,698	40,090

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 ultimately pooled the dorsal clip stratum with the left ventral clip stratum, because we consistently failed to produce a valid Darroch estimate due to a negative probability of recapture of the fish released in the dorsal stratum. 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 and dorsal release periods pooled. Recovery strata were (1) 5–18 September, (2) 19 September–10 October, and (3) 11–26 October. Using these poolings, we generated a maximum likelihood Darroch estimate of 55,000 chum salmon (SE=867; 95% CI 53,400–56,800). The chi-square test of fit of the predicted values to the observed values was 0.05 (P=0.83). The pooled-Peterson estimate was 54,000 (SE=717); however, 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 (55,000) as the mark-recapture estimate for 2008. The combined total of the weir count and the pre-weir foot survey was 51,700, which fell below the 95% confidence interval of the mark-recapture estimate. We assume that the difference between the weir count and the mark-recapture estimate is explained by fish passing through the hole in the weir that was discovered on the morning of 29 September.

Adult Length, Sex, and Scale Sampling

In 2008, a total of 688 chum salmon were sampled for age, sex, and length. The age composition, based on the scale samples, was 15% 2-ocean, 71% 3-ocean, and 13% 4-ocean fish (Table 4). The run-timing of 2-ocean fish was later than that of the older age classes, and nearly 90% of the 2-ocean fish passed through the weir after 21 September. The mean lengths by age class for males were 609 mm (age 0.2), 649 mm (age 0.3), and 682 mm (age 0.4; Table 5). For females the mean lengths by age class were 617 mm (age 0.2), 650 mm (age 0.3), and 665 mm (age 0.4).

Stream Life

From 26 August to 22 October 2008, we released a total of 1,632 spaghetti-tagged chum salmon upstream of the weir. Between 5 September and 24 October 2008, we recovered 696 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 in the first two weeks of the run, was fairly stable through the peak weeks of fish passage, then dropped off towards the end of the run (Table 6). The seasonal mean stream life, weighted by week, was 8.4 days.

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 2008.

		Recovery Strata			
Release Strata	**Number Tags Released**	**5 Sep–18-Sep**	**19 Sep–10-Oct**	**11 Oct–26-Oct**	**Total**
25 Aug–16 Sep	840	260	397	0	657
17 Sep–23 Oct	1,031	4	583	148	735
Number unmarked		3,647	29,129	5,922	38,698
Total number sampled		3,911	30,109	6,070	40,090

Table 4.–Age composition of the 2008 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**	**Total**
35	Sample Size	2	40	7	49
	Esc. Age Class	42	845	148	1,035
	Proportion	4%	82%	14%	—
	SE of %	3%	6%	5%	—
36	Sample Size	9	89	16	114
	Esc. Age Class	181	1,790	322	2,293
	Proportion	8%	78%	14%	—
	SE of %	3%	4%	3%	—
37	Sample Size	8	114	24	146
	Esc. Age Class	175	2,488	524	3,187
	Proportion	6%	78%	16%	—
	SE of %	2%	3%	3%	—
38	Sample Size	7	96	24	127
	Esc. Age Class	615	8,431	2,108	11,153
	Proportion	6%	76%	19%	—
	SE of %	2%	4%	4%	—
39	Sample Size	9	68	12	89
	Esc. Age Class	1,031	7,791	1,375	10,197
	Proportion	10%	76%	14%	—
	SE of %	3%	5%	4%	—
40	Sample Size	15	54	8	77
	Esc. Age Class	3,020	10,874	1,611	15,505
	Proportion	20%	70%	10%	—
	SE of %	5%	5%	4%	—
41	Sample Size	5	9	—	14
	Esc. Age Class	274	492	—	766
	Proportion	36%	64%	—	—
	SE of %	13%	13%	—	—
42	Sample Size	25	8	5	38
	Esc. Age Class	2,460	787	492	3,739
	Proportion	66%	21%	13%	
	SE of %	8%	7%	6%	
43	Sample Size	—	33	1	34
	Esc. Age Class	—	2,684	81	2,765
	Proportion	—	97%	3%	—
	SE of %	—	3%	3%	—
Total	Escapement by Age Class	7,798	36,182	6,660	50,640
	SE of Number	868	1,073	804	—
	Proportion by Age Class	15%	71%	13%	—
	SE of %	2%	2%	2%	—
	Sample Size	80	511	97	688

Table 5.–Lengths in millimeters of chum salmon at Disappearance Creek by sex and age-class, 2008

		Age Class		
Stratum	**Parameter**	**0.2**	**0.3**	**0.4**
Male	Sample Size	53	289	59
	Mean Length	609	649	682
	Median Length	605	650	685
	Standard Deviation	26	38	38
	Maximum	655	755	775
	Minimum	535	540	555
Female	Sample Size	26	214	27
	Mean Length	617	650	665
	Median Length	613	650	660
	Standard Deviation	32	32	33
	Maximum	710	735	735
	Minimum	575	520	575

Table 6.–Weekly and seasonal mean stream life (in days) of chum salmon at Disappearance Creek, 2008.

Statistical Week	Percent of Escapement	Mean Stream Life	Standard Deviation	Tags Recovered
35	0.02	17.0	2.3	39
36	0.05	12.7	2.9	79
37	0.06	7.9	3.0	116
38	0.22	8.5	2.6	118
39	0.20	7.9	2.6	118
40	0.31	8.9	3.1	112
41	0.02	7.2	2.1	77
42–43	0.13	5.7	2.3	37
Seasonal Weighted Stream Life		8.4	—	696

Aerial Stream Surveys

Aerial surveys of Disappearance were conducted by Ketchikan area management biologists from late August to early October in 2008. 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 eight surveys were conducted by three different biologists, with surveys occurring on the following dates: 28 and 29 August, 3, 11, 17, 20, and 25 September, and 6 October (Figure 8; Table 7). 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 compared directly to aerial survey estimates (Figure 8). On average, surveyors underestimated the number of live fish in the stream by 21%, but the relative bias of survey estimates ranged widely between +19% to -59% (Table 8).

The peak aerial survey estimate of 35,500 chum salmon occurred on 17 September 2008 and included 25,000 chum salmon in saltwater off the mouth of the creek, 2,000 in the intertidal, 4,000 live fish in the stream, and 4,500 dead fish in the stream. A multiplier of 1.55 would convert the peak aerial survey count to the estimated total escapement of chum salmon (55,000) at Disappearance Creek in 2008.

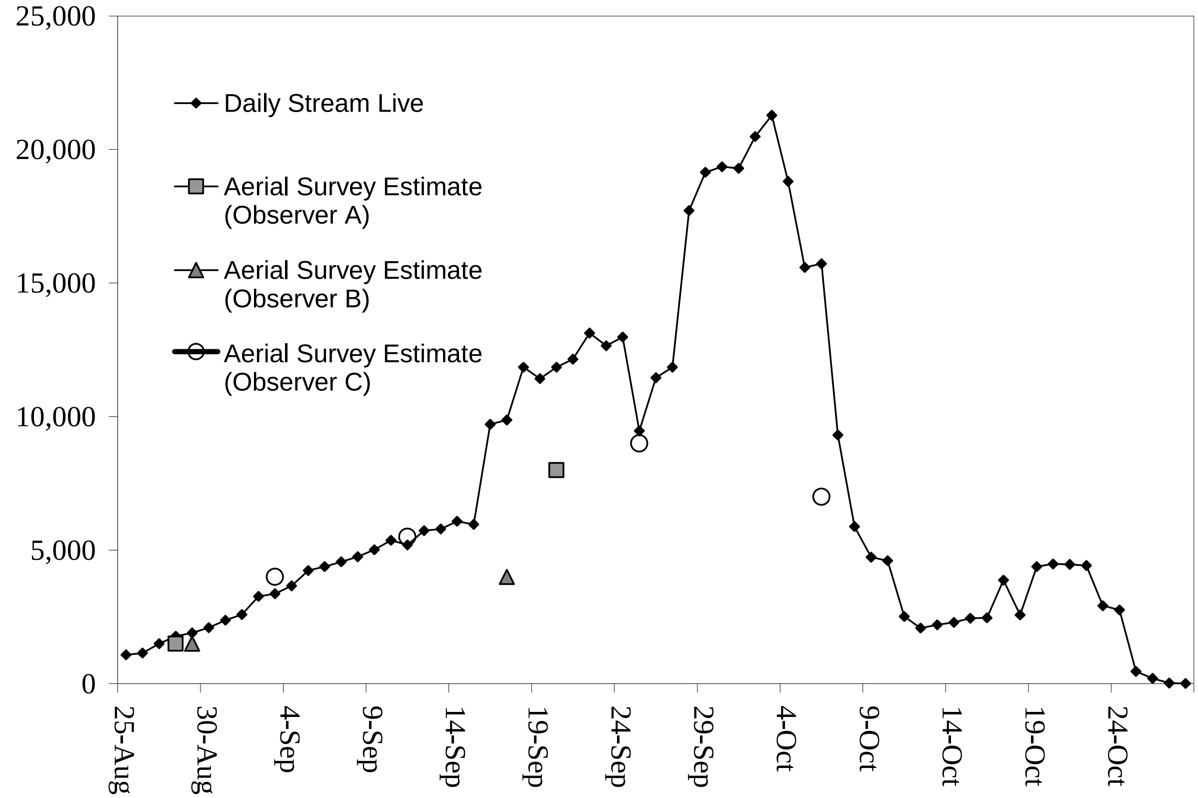


Figure 8.–Daily estimates of live chum salmon in Disappearance Creek, based on daily weir counts and mean weekly stream life estimates. Aerial survey estimates by three Ketchikan area management biologists are shown in comparison to the daily live estimates.

Table 7.–Aerial survey estimates of chum salmon at Disappearance Creek in 2008.

Date	Area Surveyed	Mouth	Intertidal	Stream Live	Dead	Total	Observer
28-Aug	Complete survey	5,000	0	1,500	0	6,500	A
29-Aug	Complete survey	0	2,500	1,500	0	4,000	B
3-Sep	Complete survey	5,000	1,000	4,000	0	10,000	C
8-Sep	Intertidal, Mouth, and Bay	12,000	0	0	0	12,000	B
11-Sep	Complete survey	25,000	500	5,500	1,500	32,500	C
17-Sep	Complete survey	25,000	2,000	4,000	4,500	35,500	B
20-Sep	Complete survey	10,000	0	8,000	5,000	23,000	A
25-Sep	Complete survey	6,000	3,000	9,000	0	18,000	C
6-Oct	Complete survey	15,000	500	7,000	10,000	32,500	C
	Mark-Recapture Estimate	Peak Survey	Peak Survey to Total Escapement Multiplier				
	55,057	35,500	1.55				

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 2008. 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								
	28-Aug	29-Aug	3-Sep	11-Sep	17-Sep	20-Sep	25-Sep	6-Oct	Average
Estimated Live Chum	1,782	1,903	3,371	5,193	9,876	11,848	9,461	15,724	—
Observer A	1,500	—	—	—	—	8,000	—	—	—
Observer B	—	1,500	—	—	4,000	—	—	—	—
Observer C	—	—	4,000	5,500	—	—	9,000	7,000	—
Relative Bias	-16%	-21%	19%	6%	-59%	-32%	-5%	-55%	-21%

Otolith Sampling

We collected otoliths on a weekly basis beginning in statistical week 35 (24–30 August) and ending in week 40 (28 September–4 October). A total of 156 otolith samples were collected from carcasses that were distributed throughout the length of the creek. The nearest hatchery release site to Disappearance Creek is Southern Southeast Regional Aquaculture Association's (SSRAA) 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 hatchery 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.) No otolith marked fish were detected in our samples (Table 9).

Table 9.–Weekly otolith sampling results from the 2008 fall chum escapement at Disappearance Creek.

Stream	Statistical Week	Total Sampled	Unmarked	Marked	% Hatchery Strays
Disappearance Creek	35	8	8	0	0%
Disappearance Creek	36	22	22	0	0%
Disappearance Creek	37	15	15	0	0%
Disappearance Creek	38	41	41	0	0%
Disappearance Creek	39	46	46	0	0%
Disappearance Creek	40	24	24	0	0%
Total		156	156	0	0%

DISCUSSION

The point estimate from the mark-recapture study (55,000) was approximately 3,300 fish higher than the weir count and our pre-season foot survey estimate combined (51,700). It is likely that many of the uncounted fish passed through the hole in the weir that occurred during the evening of 28 September. In addition, it is likely that our estimate of the fish alive in the creek at the start of weir operations was an underestimate, since surveyors tend to underestimate the number of fish present in a creek at the time of a survey (Dangel and Jones, 1988, Jones et al. 1998). Our very high examination rate on carcasses led to an extremely precise mark-recapture estimate (CV=1.5%). We sampled carcasses throughout the system nearly every day, and the counting weir kept carcasses from washing out of the system unexamined. We examined approximately 40,000 chum salmon carcasses for marks, and we recovered 1,392 out of the 1,871 chum salmon released with marks (74%).

The weir structure at Disappearance Creek was set directly on the stream substrate, which was composed primarily of medium to small cobbles, with some areas of large gravel. We anticipated that the relatively large size of the substrate and the small size of the creek would keep scouring under the weir to a minimum. Due to the very large escapement of chum salmon in 2008, cleaning the weir of carcasses became a constant battle as chum salmon began dying in large numbers. By late September it became impossible for the field crew to keep up with the constant stream of floating carcasses piling up on the weir through the day and night. Each morning from late September through October, the face of the weir was piled with carcasses a foot or more deep, which created a small waterfall to the back side of the weir. On the evening of 28 September, near the peak of the run, a high water event, combined with tremendous piles of carcasses, caused severe scouring under one of the bipods and left a hole under the weir that allowed free passage of fish. The problem was quickly fixed in the morning, but it is likely that many fish passed through the hole uncounted. We experienced no additional problems with the weir until the day before we intended to pull the weir out of the creek at which time another major rain event led to severe scouring that undercut several bipods. We plan on laying a ground cloth beneath the weir structure in 2009 to help prevent some of the scouring that occurred in 2008.

The fall chum salmon escapement at Disappearance Creek was above average in 2008, and the combined peak aerial survey estimates from Disappearance and Lagoon creeks (50,000 chum salmon) exceeded the upper end of the Cholmondeley Sound fall chum salmon sustainable escapement goal of 30,000 to 48,000 index spawners (Figure 9). Although fall chum salmon escapements at Cholmondeley Sound were below the escapement goal in 2005 and 2007, escapements have been within or above the escapement goal in all other years (Figure 9). The peak aerial survey estimate for Disappearance Creek of 35,500 chum salmon was the fifth highest peak survey estimate since 1980, and was approximately 66% higher than the 1980–2007 average of 23,600 fish.

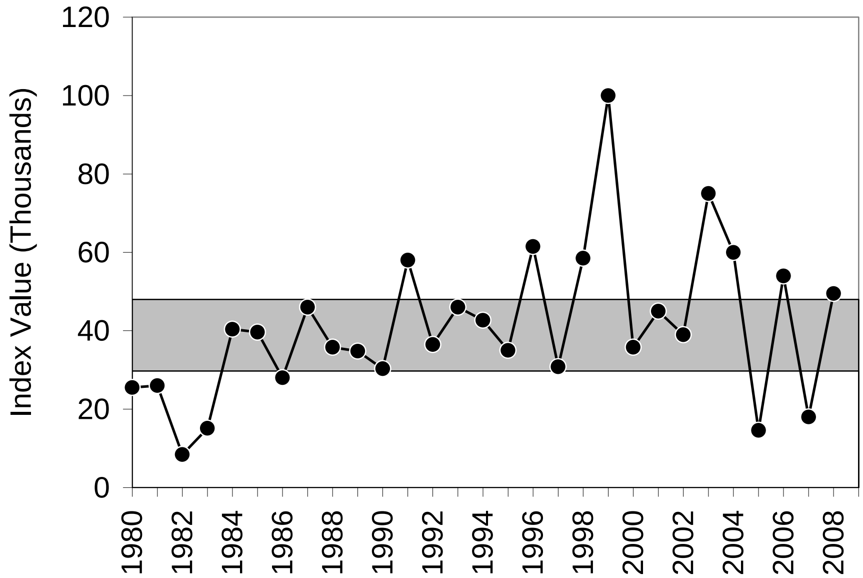


Figure 9.–Cholmondeley Sound fall chum salmon escapement index, 1980–2008. The index is based on the combined peak aerial survey estimates for Disappearance and Lagoon creeks.

Although escapements to Disappearance and Lagoon creeks surpassed the upper end of the escapement goal range in 2006 and 2008, the very small harvests of fall chum salmon in those years suggest that total runs to these streams 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. From 1995 to 2004, the average chum salmon harvest inside of Cholmondeley Sound was approximately 140,000 fish. Although we do not know what percentage of the total Cholmondeley Sound fall chum salmon spawning population ultimately spawns in Disappearance and Lagoon creeks, these two creeks have consistently had by far the largest peak aerial survey estimates and likely contribute a substantial proportion of the chum salmon harvested inside of Cholmondeley Sound. Despite excellent escapements to Disappearance and Lagoon creeks in 2006 and 2008, there were not large harvestable surpluses of fish in the Sound and more aggressive fishery openings would likely have resulted in relatively low harvests and possibly poor escapements. In light of escapements below the escapement goal range in 2005 and 2007, and concerns about some of the smaller chum salmon streams in Cholmondeley Sound, ADF&G management biologists have managed the fishery conservatively in recent years.

Over the course of the 2008 season, management biologists from the Ketchikan ADF&G office conducted regular aerial survey flights of Disappearance Creek through the peak of the run. By comparing peak survey estimates with total escapement estimates, from weir counts or mark-recapture estimates, we can calculate an expansion factor to convert a peak survey estimate to an estimate of total escapement. Expansion of peak survey counts has been used extensively to estimate salmon escapements in Southeast Alaska (e.g., see McPherson et al. 2003, Pahlke 2007). Currently, we have only two years of paired escapement and peak survey estimates, so several more years of information will need to be collected before we can estimate escapements using an expansion factor. Unfortunately, in almost all years prior to 1984, aerial surveys were not conducted throughout the entire run, and in almost all prior years there was no survey that could be reliably considered a "peak" count to compare with historic weir counts. The one exception is 1981, when surveys were conducted from early September through 9 October and the peak survey had estimates for the mouth, intertidal, and stream live and stream dead. The conversion from the 1981 peak survey estimate to the weir count for that year was 1.52, which is very close to the 2008 conversion factor of 1.55.

Studies of observer counting rates of spawning salmon elsewhere in Southeast Alaska (Dangel and Jones 1988, Jones et al. 1998, ADF&G unpublished studies at Traitors Creek) have shown that aerial observers tend to underestimate the number of fish present in a creek at the time of a survey, and that peak counts are generally underestimates of the total spawning population for a particular creek. The peak or maximum aerial survey estimate at Disappearance Creek in 2008 underestimated the total spawning population of fish in the creek. Due to the relatively short stream life of chum salmon (mean weighted stream life in 2008 was 8.44 days), fish spawning early and late in the season at Disappearance Creek were not present during the peak of the run, and even a perfect estimate of the number of fish present at the peak would have underestimated the total escapement. Including dead counts and live fish counted at the mouth of the creek in the peak survey estimate reduced the bias caused by loss of fish to some extent, but the relatively long spawning period (approximately two months) and short stream life of chum salmon meant that many dead fish were no longer present for counting at the peak, and late returning fish may not yet have been staging at the mouth of the creek at the peak of the run, resulting in a peak estimate that was too low. In addition, bears remove a large number of fish from the stream throughout the season and in years where no weir structure is put in place many carcasses would be washed out of the creek and would not be counted by aerial observers.

The relative bias of aerial survey estimates at Disappearance Creek in 2008, when compared to our estimates of live fish in the creek on the day of the survey, ranged between +19% to -59% (Table 8). As fish numbers increased, survey estimates tended to show an increasing negative bias. For example, observer C conducted four surveys of Disappearance Creek over the course of the season during which time the estimated number of live fish in the creek increased from 3,400 to 15,700 fish. The relative bias of observer C's survey estimates stepped down from positive to negative values with increasing escapement; 19%, 6%, -5%, and -55%. Observers B and C each conducted surveys in late August and late September and in both cases their relative bias was increasingly negative during the September survey when fish abundance was much higher. This pattern was also reported by Dangel and Jones (1988) and Jones et al. (1998) in their studies with pink salmon elsewhere in Southeast Alaska.

In 2008, the passage of chum salmon upstream of the first major spawning pool of Disappearance Creek was partially blocked by a large beaver dam located at the outlet of the upper spawning pool. Water levels in the creek were low through most of late August and September and only a handful of chum salmon managed to pass the dam through late September. The dam was large enough that removal by hand was impossible. We continually breeched the dam along one side of the creek to allow for fish passage, but low water apparently made it difficult for fish to navigate the swift and narrow stretch of rapids between the lower pool and the upper pool where the dam was located. At the end of September, a return to the normal heavy rainfall pattern of southern Southeast Alaska raised water levels in the creek and allowed chum salmon to pass above the beaver dam. On the last aerial survey of the season on 6 October, an estimated 750 chum salmon were in the large pool above the beaver dam. The field crew reported that during high water events in October water flowed through and around the beaver dam and fish could easily pass upstream. Due to the blockage through most of September, the majority of the chum salmon escapement at Disappearance Creek in 2008 spawned in the lower 0.5 kilometer of the creek.

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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, 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 *i*th 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 2008.

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

Appendix C.–Daily chum salmon counts at the Disappearance Creek weir, 2008. Marks (fin clips) applied to chum salmon at the weir were right ventral (RV), left ventral (LV), and dorsal (D).

Date	Stat Week	Mark	Marked Daily	Marked Cum	Unmarked Daily	Unmarked Cum	Total LiveAdults Daily	Total LiveAdults Cum	Adult Mortalities Daily	Adult Mortalities Cum	Total Adults
25-Aug	35	RV	0	0	19	19	19	19	0	0	19
26-Aug	35	RV	9	9	59	78	68	87	0	0	87
27-Aug	35	RV	33	42	320	398	353	440	0	0	440
28-Aug	35	RV	28	70	254	652	282	722	0	0	722
29-Aug	35	RV	12	82	109	761	121	843	0	0	843
30-Aug	35	RV	15	97	177	938	192	1,035	0	0	1,035
31-Aug	36	RV	18	115	260	1,198	278	1,313	0	0	1,313
1-Sep	36	RV	17	132	198	1,396	215	1,528	0	0	1,528
2-Sep	36	RV	83	215	597	1,993	680	2,208	0	0	2,208
3-Sep	36	RV	8	223	95	2,088	103	2,311	0	0	2,311
4-Sep	36	RV	25	248	263	2,351	288	2,599	0	0	2,599
5-Sep	36	RV	53	301	523	2,874	576	3,175	0	0	3,175
6-Sep	36	RV	14	315	137	3,011	151	3,326	2	2	3,328
7-Sep	37	RV	16	331	162	3,173	178	3,504	0	2	3,506
8-Sep	37	RV	21	352	168	3,341	189	3,693	1	3	3,696
9-Sep	37	RV	25	377	239	3,580	264	3,957	0	3	3,960
10-Sep	37	RV	35	412	317	3,897	352	4,309	0	3	4,312
11-Sep	37	RV	87	499	816	4,713	903	5,212	0	3	5,215
12-Sep	37	RV	59	558	542	5,255	601	5,813	0	3	5,816
13-Sep	37	RV	78	636	621	5,876	699	6,512	0	3	6,515
14-Sep	38	RV	81	717	703	6,579	784	7,296	4	7	7,303
15-Sep	38	RV	123	840	738	7,317	861	8,157	0	7	8,164
16-Sep	38	LV	147	987	4,084	11,401	4,231	12,388	0	7	12,395
17-Sep	38	LV	26	1,013	692	12,093	718	13,106	0	7	13,113
18-Sep	38	LV	60	1,073	2,840	14,933	2,900	16,006	0	7	16,013
19-Sep	38	LV	16	1,089	615	15,548	631	16,637	0	7	16,644
20-Sep	38	LV	23	1,112	1,001	16,549	1,024	17,661	0	7	17,668
21-Sep	39	LV	30	1,142	971	17,520	1,001	18,662	0	7	18,669
22-Sep	39	LV	20	1,162	959	18,479	979	19,641	0	7	19,648
23-Sep	39	LV	5	1,167	299	18,778	304	19,945	0	7	19,952
24-Sep	39	LV	30	1,197	1,160	19,938	1,190	21,135	0	7	21,142
25-Sep	39	LV	30	1,227	684	20,622	714	21,849	0	7	21,856
26-Sep	39	LV	50	1,277	2,660	23,282	2,710	24,559	0	7	24,566
27-Sep	39	LV	60	1,337	3,239	26,521	3,299	27,858	0	7	27,865
28-Sep	40	LV	137	1,474	6,354	32,875	6,491	34,349	0	7	34,356
29-Sep	40	LV	64	1,538	3,401	36,276	3,465	37,814	0	7	37,821
30-Sep	40	LV	37	1,575	1,146	37,422	1,183	38,997	0	7	39,004

–continued–

Appendix C.–continued (page 2 of 2)

Date	Stat Week	Mark	Marked Daily	Marked Cum	Unmarked Daily	Unmarked Cum	Total LiveAdults Daily	Total LiveAdults Cum	Adult Mortalities Daily	Adult Mortalities Cum	Total Adults
1-Oct	40	LV	10	1,585	233	37,655	243	39,240	0	7	39,247
2-Oct	40	LV	49	1,634	2,328	39,983	2,377	41,617	0	7	41,624
3-Oct	40	LV	33	1,667	1,481	41,464	1,514	43,131	0	7	43,138
4-Oct	40	LV	15	1,682	217	41,681	232	43,363	0	7	43,370
5-Oct	41	LV	8	1,690	73	41,754	81	43,444	0	7	43,451
6-Oct	41	LV	5	1,695	133	41,887	138	43,582	0	7	43,589
7-Oct	41	LV	2	1,697	74	41,961	76	43,658	0	7	43,665
8-Oct	41	LV	2	1,699	34	41,995	36	43,694	0	7	43,701
9-Oct	41	LV	1	1,700	39	42,034	40	43,734	0	7	43,741
10-Oct	41	LV	3	1,703	107	42,141	110	43,844	0	7	43,851
11-Oct	41	LV	6	1,709	279	42,420	285	44,129	0	7	44,136
12-Oct	42	LV	14	1,723	1,148	43,568	1,162	45,291	0	7	45,298
13-Oct	42	LV	10	1,733	487	44,055	497	45,788	0	7	45,795
14-Oct	42	LV	5	1,738	159	44,214	164	45,952	0	7	45,959
15-Oct	42	LV	27	1,765	169	44,383	196	46,148	0	7	46,155
16-Oct	42	D	3	1,768	52	44,435	55	46,203	0	7	46,210
17-Oct	42	D	20	1,788	1,493	45,928	1,513	47,716	0	7	47,723
18-Oct	42	D	11	1,799	141	46,069	152	47,868	0	7	47,875
19-Oct	43	D	20	1,819	2,284	48,353	2,304	50,172	0	7	50,179
20-Oct	43	D	33	1,852	229	48,582	262	50,434	0	7	50,441
21-Oct	43	D	15	1,867	162	48,744	177	50,611	0	7	50,618
22-Oct	43	D	4	1,871	13	48,757	17	50,628	0	7	50,635
23-Oct	43	D	0	1,871	5	48,762	5	50,633	0	7	50,640