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Sitkoh Lake Sockeye Stock Assessment, 2011

2011 Annual Report for Study 10-605

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(Cover photo: L-R, Angoon Community Association employees Jonathon Zuboff, Marcus Jamestown, and Jason Frank marking and recapturing sockeye salmon in Sitkoh Lake, September 6, 2011.)

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ABSTRACT

We estimated the annual abundance of sockeye spawning in a "study area" of Sitkoh Lake in 2011 using data from four, two-day, mark-recapture trips. The numbers of beach spawners in this "study area" adjacent to the West U.S. Forest Service cabin was then compared to similar modified Jolly-Seber mark-recapture estimates from 1997 to 2006 and 2010 to assess the relative strength of the 2011 escapement. In 2011, 2,128 (CV=7%) sockeye spawned in the study area which was the second lowest on record. Other indices computed using the mark-recapture data also show a low relative abundance of sockeye spawners in Sitkoh Lake in 2011.

INTRODUCTION

Sitkoh Lake sockeye salmon have long been an important subsistence resource for residents of Angoon and other rural communities in northern Southeast Alaska and this stock has been fished commercially beginning in the late 1800s (de Laguna 1960, George and Bosworth 1988, Goldschmidt and Haas 1998, Thornton et al., 1990). Sitkoh Lake is near the junction of Chatham and Peril Straits (Figure 1) and sockeye salmon returning to Sitkoh Lake contribute to the commercial purse seine and troll fisheries that target pink, chum and other salmon species returning to, or transiting, Chatham and Peril Straits.

The Alaska Department of Fish and Game and the U.S. Forest Service have funded weir projects to estimate the escapement of sockeye salmon into Sitkoh Lake in 1982 and 1996 (Kelley and Josephson 1997) and spawning area mark-recapture projects to index the annual escapement into the lake from 1997 through 2006 (Cook 1998; Crabtree 2000; Crabtree 2001; Conitz and Cartwright 2002, 2003, 2005, 2007; Burril and Conitz 2007; and Conitz and Burril 2008).

This project was reinstated in 2010 (Van Alen and Mahara 2011b) since it is important to know if escapements are adequate to sustain runs and subsistence opportunity and to assess consequences of management actions related to both fishing and land use activities. This indexing project has worked well for this location because the sockeye do not spawn in inlet streams and there appears to be a single run of sockeye salmon with spawning concentrated in seineable beaches near the West Forest Service cabin "study area".

These spawning area mark-recapture estimates have helped in monitoring the annual escapement of sockeye salmon into Sitkoh Lake. Project findings have shown abundances to be variable and without trend – "study area" abundances from 1997 to 2006 and 2010 ranged from a low of 2,100 in 2004 to a high of 12,300 in 2000.

Prior to 2010, the number of fish estimated in the study area was also expanded by the fraction of fish observed in the rest of the lake. These boat surveys around the perimeter of the lake were discontinued because the expanded estimates were highly correlated with the study area estimates and the counting rates were affected by differences in fish densities in and out of the study area.

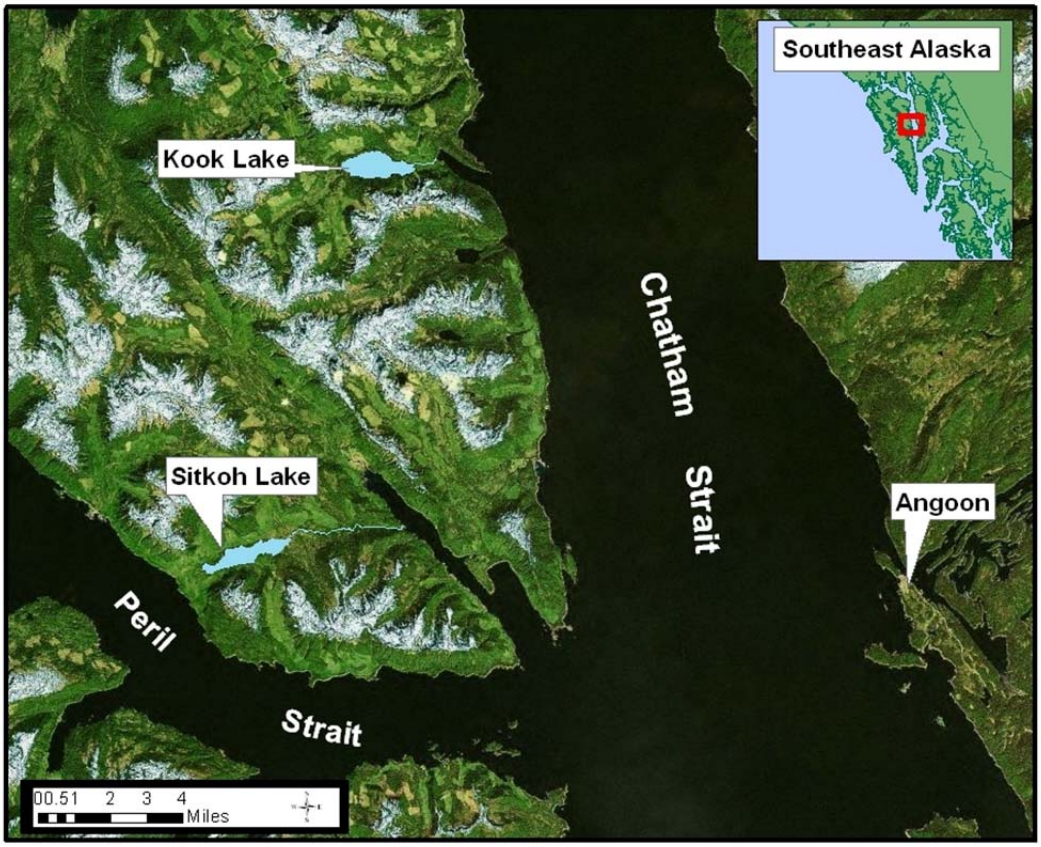

Figure 1. Map showing the location of Sitkoh Lake.

OBJECTIVES

1. Index the annual escapement of sockeye salmon into Sitkoh Lake using mark-recapture methods so that the estimated coefficient of variation is less than 20%.
2. Estimate the age, sex, and length composition of the sockeye salmon spawning in Sitkoh Lake with a coefficient of variation less than 20% for the principal age class.
3. (In 2011) Collect genetic tissue samples from 200 sockeye salmon.

METHODS

This project uses mark-recapture methods to index the abundance of sockeye spawning in the "study area" adjacent to the U.S. Forest Service's West Cabin (Cook 1998; Crabtree 2000, 2001; Conitz and Cartwright 2003, 2005, 2007; Burril and Conitz 2007; Conitz and Burril 2008; and Van Alen and Mahara 2011b). Sockeye salmon were also sampled for scale (age), sex, and length (ASL) data and genetic tissue samples using standard ADF&G methods.

Mark-Recapture

In 2011, four, two-day mark-recapture trips were made to beach seine and mark-recapture sockeye salmon in the predefined "study area". Sampling trips were on September 6-7, September 20-21, October 4-5, and October 18-19. These dates correspond to when approximately 20%, 40%, 60%, and 80% of the sockeye salmon have been observed in the study area.

The "study area" extended along the beach from just east of the island approximately 57.503265°N latitude, -135.097682°W longitude (WGS84 datum) to one set east of the West Forest Service cabin at 57.506710°N latitude, -135.091936°W longitude. This is the same basic study area used in past years although in 1999 and 2000 some additional sets were also made farther east along the beach in an area called "Clyde's Hole".

The Forest Service has two public use cabins on Sitkoh Lake, one at the lake outlet, the "East" cabin and one on the Northwest side of the lake, the "West" cabin. Project personnel were able to reserve and stay at the "West" cabin which is immediately adjacent to the defined "study area". The cabin rental includes the use of a 16' aluminum flat-bottom skiff.

Each sampling trip took two days. A series of 7 to 13 beach seine hauls were made to capture fish each day in the pre-defined "study area". The seine sets were done in a relatively consistent manner on each beach, on each day, and on each trip. Along much of the study area, the next set would begin where the prior set ended whenever there were fish to be caught. The fish were captured by setting a beach seine off the bow of the cabin skiff powered either by a small outboard or oars. The seine measured 60' x 10' and had black 2" stretch-measure webbing made with #13 twine.

Sockeye captured the first day of a trip were given a left opercule punch mark. Sockeye captured the second day were given a right opercule punch mark and a left opercule punch mark if it was not already marked the day before. A different punch was used each trip – round, square, triangle, and heart. Records were kept of the number of fish marked and recaptured each set. Sampling was done without replacement.

We expect that some new fish migrate into the study area between the marking day and the recapture day. Thus, the mark-recapture estimate is the abundance in the study area on the second day, the day of recapture. The estimates are not affected if marked and unmarked fish die at the same rate but fish were not marked on the first day if they were so old and weak that they would likely die before being sampled the following day.

We used Chapman's (1952, Page 287-288) "inverse sampling" formulas, converted here to the notation of Ricker (1975), to get unbiased estimates of the population size ($\hat{N}$) and variance $(Var(\hat{N}))$ when recaptures (*R*) number 3-4 or more (Chapman, 1952, Ricker 1975, and Seber 2002). The number of fish to mark (*M*) were the number marked in the 9 to 13 seine sets on the first day of each trip. The unknown variable was how many fish need to be examined for marks (*C*) on the second day of each trip to get enough recaptures (*R*). Past studies have found that nearly half of the sockeye present in the study area can be captured and marked or examined for marks in the series of seine hauls made from one end of the study area to the other. The high marking and recapture rates yield estimates with low variances and coefficient of variations.

Sampling with or without replacement, the formula for $\hat{N}$ is the same as for the simple Petersen (aka. Lincoln-Petersen) estimate, which is:

$$\hat{N} = \frac{M * C}{R} \qquad (1)$$

and, the unbiased estimate of variance is:

$$Var(\hat{N}) = \frac{CM^2(C-R)}{R^3} \qquad (2)$$

And, the coefficient of variation is:

$$CV\% = \frac{\sqrt{Var(\hat{N})}}{\hat{N}} * 100 \qquad (3)$$

In this study, we expect the coefficient of variation for the escapement estimate to be less than 15% when more than 40 fish are recaptured (Table 1) regardless of the population size. In reality, with up to 50% of the sockeye marked and examined for marks in the study area we expect over a hundred recoveries on most trips.

The Peterson estimates of sockeye abundance each trip ($\hat{N}_i$) and the number of recaptures from previous trips were used in a modified Jolly-Seber estimator (Cook 1998) to estimate the total spawning population (N*) within the study area. These calculations are detailed in the column headings of Table 2). Prior studies (Conitz and Cartwright 2002, 2003, 2005, 2007; Burril and Conitz 2007;Conitz and Burril 2008) used a parametric bootstrap method to estimate confidence

intervals and the coefficient of variation (CV) around N*. We were unable to repeat those calculations but show that these CV's are close to the sum of the Standard Error of $\hat{N}_i$ divided by the sum of $\hat{N}_i$'s (Table 2).

Table 1. Sampling goals for the number you need to recapture (*R*), and number you'll probably examine for marks (*C*), at different marked rates and levels of precision (CV%) around the population estimate ($\hat{N}$) for direct or indirect sampling with or without replacement (modified from Table 1 in Appendix C in Van Alen 2008).

Marked Rate[a] (intended or observed)	Desired CV%											
	5%		10%		15%		20%		25%		30%	
	Sampling Goals for Recaptures (*R*) and the expected number to examine for marks (*C*)[b]											
	R	C	R	C	R	C	R	C	R	C	R	C
0.25%	399	159,600	100	39,900	44	17,733	25	9,975	16	6,384	11	4,433
0.50%	398	79,600	100	19,900	44	8,844	25	4,975	16	3,184	11	2,211
0.75%	397	52,933	99	13,233	44	5,881	25	3,308	16	2,117	11	1,470
1%	396	39,600	99	9,900	44	4,400	25	2,475	16	1,584	11	1,100
2%	392	19,600	98	4,900	44	2,178	25	1,225	16	784	11	544
5%	380	7,600	95	1,900	42	844	24	475	15	304	11	211
10%	360	3,600	90	900	40	400	23	225	14	144	10	100
15%	340	2,267	85	567	38	252	21	142	14	91	9	63
20%	320	1,600	80	400	36	178	20	100	13	64	9	44
25%	300	1,200	75	300	33	133	19	75	12	48	8	33
30%	280	933	70	233	31	104	18	58	11	37	8	26
33%	268	812	67	203	30	90	17	51	11	32	7	23
35%	260	743	65	186	29	83	16	46	10	30	7	21
40%	240	600	60	150	27	67	15	38	10	24	7	17
45%	220	489	55	122	24	54	14	31	9	20	6	14
50%	200	400	50	100	22	44	13	25	8	16	6	11
55%	180	327	45	82	20	36	11	20	7	13	5	9
60%	160	267	40	67	18	30	10	17	6	11	4	7
65%	140	215	35	54	16	24	9	13	6	9	4	6
66%	136	206	34	52	15	23	9	13	5	8	4	6
70%	120	171	30	43	13	19	8	11	5	7		
75%	100	133	25	33	11	15	6	8	4	5		
80%	80	100	20	25	9	11	5	6				
85%	60	71	15	18	7	8	4	4				
90%	40	44	10	11	4	5						
95%	20	21	5	5								
100%												

[a]The "Marked Rate" could be the intended percentage of fish that were marked or the observed percentage of fish that have marks. Actual marking rates might be less so be conservative and use a marked rate 50% less than the intended or observed marking rate.

[b]Recapture goals for *R* <4 are omitted from the table to minimize the inherent statistical bias of *R* < 1 (Ricker 1975 p. 79).

Calculations:

Marked Rate expected = number marked/number counted (i.e., at a weir project)
Marked Rate observed = R/C
R = (1-marked rate)/CV^2
C = R/marked rate

Table 2. Modified Jolly-Seber mark-recapture estimates (N*) of the number of sockeye spawning in the study area adjacent to the West Sitkoh Lake Forest Service cabin, 1997 to 2006, 2010, and 2011.

Year	Trip #	Dates	New Fish Marked on Day 1 (M)	New Fish Marked on Day 2	Recap-tures on Day 2 (R)	Total Caught on Day 2 (C)	2-Day Petersen Estimate (N_i)[a]	Variance of N_i[a]	Std. Error of N_i	95% CI (lower)[b]	95% CI (upper)[b]	cv(N_i)	Marks from Trip 1	Marks from Trip 2	Marks from Trip 3	m = total number recaps this trip	n = total caught (and marked) each trip	M = $m*N_i/n$	$\phi = M_{i+1} / (M-m+n)$	$B = N_{i+1} - \phi N$	$B^* = B \log(\phi)/(\phi-1)$
1997	1	8/25-26	75	116	61	177	218	509	23	169	280	10.4%				0	191	0	0.340	329	660
	2	9/8-10	264	84	159	243	403	354	19	345	471	4.7%	56			56	348	65	0.093	980	2,569
	3	9/24-25	630	262	426	688	1,017	925	30	925	1,119	3.0%	0	29		29	892	33	0.028	344	1,264
	4	10/15-16	217	95	133	228	372	434	21	314	441	5.6%	0	0	21	21	312	25	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					5%								N* for 1997 =	4,493
1998	1	9/9-10	410	101	113	214	776	2,518	50	646	933	6.5%				0	511	0	0.103	534	1,556
	2	9/28-29	283	208	178	386	614	1,140	34	530	711	5.5%	42			42	491	52	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					6%								N* for 1998 =	NA (<3 trips)
1999	1	9/15-16	601	258	350	608	1,044	1,322	36	940	1,159	3.5%				0	859	0	0.024	1,403	5,453
	2	10/4-5	717	387	390	777	1,428	2,606	51	1,294	1,577	3.6%	16			16	1,104	21	0.138	1,247	2,866
	3	10/20-21	802	274	342	616	1,445	2,714	52	1,299	1,606	3.6%	0	114		114	1,076	153	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					4%								N* for 1999 =	8,319
2000	1	8/22-24	328	112	203	315	509	454	21	444	584	4.2%				0	440	0	0.046	1,412	4,646
	2	9/15-17	488	365	188	553	1,435	7,234	85	1,244	1,656	5.9%	12			12	860	20	0.356	767	1,230
	3	9/27-29	389	411	180	591	1,277	6,302	79	1,104	1,478	6.2%	0	224		224	927	309	0.017	1,564	6,487
	4	10/16-18	767	430	403	833	1,585	3,220	57	1,438	1,748	3.6%	0	1	12	13	1,203	17	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					5%								N* for 2000 =	12,364
2001	1	8/28-29	281	171	125	296	665	2,046	45	559	793	6.8%				0	452	0	0.303	372	984
	2	9/9-10	277	134	125	259	574	1,363	37	482	684	6.4%	98			98	411	137	0.042	1,092	3,623
	3	9/26-27	679	215	334	549	1,116	1,461	38	1,003	1,242	3.4%	0	15		15	894	19	0.070	1,022	2,917
	4	10/10-11	370	239	121	360	1,101	6,649	82	921	1,315	7.4%	0	3	32	35	609	63	0.063	434	1,279
	5	10/25-25	149	164	69	233	503	2,582	51	398	637	10.1%	0	2	4	25	313	40	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					6%								N* for 2001 =	8,803
																				Bootstrap Calculated CV =	not reported
2002	1	8/20-22	77	83	38	121	245	1,085	33	179	337	13.4%				0	160	0	0.278	429	881
	2	9/4-6	252	105	108	213	497	1,127	34	412	600	6.8%	32			32	357	45	0.077	573	1,593
	3	9/19-21	358	116	164	280	611	944	31	525	712	5.0%	1	21		22	474	28	0.143	677	1,538
	4	10/2-4	387	159	163	322	765	1,771	42	656	891	5.5%	0	7	42	49	546	69	0.055	705	2,167
	5	10/17-19	342	213	180	393	747	1,679	41	645	864	5.5%	0	0	0	23	555	31	0.006	211	1,093
	6	11/4-5	83	48	30	78	216	955	31	151	308	14.3%	0	0	0	2	131	3	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					7%								N* for 2002 =	7,272
																				Bootstrap Calculated CV =	6%

(continued)

Table 2. (Continued, page 2 of 3)

Year	Trip #	Dates	New Fish Marked on Day 1 (M)	New Fish Marked on Day 2	Recap-tures on Day 2 (R)	Total Caught on Day 2 (C)	2-Day Petersen Estimate (N_i)[a]	Variance of N_i[a]	Std. Error of N_i	95% CI (lower)[b]	95% CI (upper)[b]	cv(N_i)	Marks from Trip 1	Marks from Trip 2	Marks from Trip 3	Marks from Trip 4	Marks from Trip 5	m = total number recaps this trip	n = total caught (and marked) each trip	M = $m*N_i/n$	$\phi = M_{i+1}/(M-m+n)$	$B = N_{i+1} - \phi N$	$B^* = B \log(\phi)/(\phi-1)$
2003	1	8/28-29	131	131	59	190	422	2,080	46	327	544	10.8%						0	262	0	0.113	656	1,728
	2	9/11-12	434	158	254	412	704	748	27	623	796	3.9%	25					25	592	30	0.094	740	1,933
	3	9/26-27	472	133	188	321	806	1,431	38	699	930	4.7%	5	37				42	605	56	0.093	460	1,204
	4	10/9-10	248	133	115	248	535	1,334	37	446	642	6.8%	0	1	40			41	381	58	0.037	70	240
	5	10/22-23	45	16	16	32	90	253	16	55	146	17.7%	0	0	0	10		10	61	15	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					6%										N* for 2003 =	5,105
																				Bootstrap Calculated CV =			5%
2004	1	9/6-7	134	41	53	94	238	465	22	182	311	9.1%						0	175	0	0.103	363	981
	2	9/17-18	186	93	86	179	387	905	30	313	478	7.8%	13					13	279	18	0.085	331	892
	3	10/1-2	232	69	121	190	364	398	20	305	435	5.5%	0	20				20	301	24	0.153	112	249
	4	10/15-16	71	26	19	45	168	860	29	108	263	17.4%	0	0	27			27	97	47	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					9%										N* for 2004 =	2,121
																				Bootstrap Calculated CV =			9%
2005	1	9/2-3	240	57	123	180	351	318	18	294	419	5.1%						0	297	0	0.216	779	1,671
	2	9/13-14	419	181	174	355	855	2,141	46	737	992	5.4%	45					45	600	64	0.375	704	1,105
	3	9/22-23	452	223	176	399	1,025	3,334	58	884	1,188	5.6%	8	145				153	675	232	0.125	631	1,501
	4	10/5-6	498	156	298	454	759	664	26	677	850	3.4%	0	1	80			81	654	94	0.076	610	1,703
	5	10/18-19	388	166	230	396	668	813	29	587	760	4.3%	0	0	0	42		42	554	51	0.048	134	429
	6	11/2-3	58	41	22	63	166	816	29	110	252	17.2%	0	0	0	3	13	16	99	27	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					5%										N* for 2005 =	6,409
																				Bootstrap Calculated CV =			3%
2006	1	8/25-26	108	44	71	115	175	165	13	139	221	7.3%						0	152	0	0.505	414	693
	2	9/8-9	329	109	207	316	502	420	21	438	575	4.1%	67					67	438	77	0.423	455	679
	3	9/20-21	467	115	268	383	667	499	22	592	752	3.3%	1	164				165	582	189	0.118	961	2,330
	4	10/3-4	442	388	287	675	1,040	2,164	47	926	1,167	4.5%	0	1	56			57	830	71	0.081	632	1,729
	5	10/16-17	376	200	221	421	716	1,103	33	628	817	4.6%	0	0	0	55		55	576	68	0.009	226	1,084
	6	11/2-3	206	23	182	205	232	33	6	201	268	2.5%	0	0	0	3	2	5	229	5	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					4%										N* for 2006 =	6,514
																				Bootstrap Calculated CV =			4%
2010	1	9/6-7	279	121	128	249	543	1,118	33	457	645	6.2%						0	400	0	0.194	482	1,195
	2	9/20-21	366	119	197	316	587	659	26	511	675	4.4%	64					64	485	77	0.018	1,353	5,555
	3	10/4-5	330	288	92	380	1,363	15,305	124	1,111	1,672	9.1%	2	2				4	618	9	0.029	799	2,915
	4	10/19-20	357	247	183	430	839	2,209	47	726	970	5.6%	0	1	12			13	604	18	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					7%										N* for 2010 =	9,665

(continued)

Table 2. (Continued, page 3 of 3)

Year	Trip #	Dates	New Fish Marked on Day 1 (M)	New Fish Marked on Day 2	Recap-tures on Day 2 (R)	Total Caught on Day 2 (C)	2-Day Petersen Estimate (N_i)[a]	Variance of N_i[a]	Std. Error of N_i	95% CI (lower)[b]	95% CI (upper)[b]	cv(N_i)	Marks from Trip 1	Marks from Trip 2	Marks from Trip 3	Marks from Trip 4	Marks from Trip 5	m = total number recaps this trip	n = total caught (and marked) each trip	M = $m*N_i/n$	$\phi = M_{i+1}/(M-m+n)$	$B = N_{i+1} - \phi N$	$B^* = B \log(\phi)/(\phi-1)$
2011	1	9/6-7	223	125	127	252	442	765	28	372	526	6.2%						0	348	0	0.459	386	848
	2	9/20-21	270	136	115	251	589	1,636	40	491	707	6.9%	110					110	406	160	0.138	363	835
	3	10/4-5	225	115	118	233	444	826	29	371	532	6.5%	3	45				48	340	63	0.107	178	445
	4	10/19-20	122	50	59	109	225	395	20	175	291	8.8%	0	4	25			29	172	38	0.000	0	
							Approximated CV% (sum of S.E./sum of N_i) =					7%										N* for 2011 =	2,128

[a] Petersen, direct sampling with or without replacement (Ricker 1975, page 78, equations 3.5 and 3.6):

$$\hat{N}_i = \frac{M * C}{R} \qquad \mathrm{var}\left(\hat{N}_i\right) = \frac{\left(C * M^2\right)\left(C - R\right)}{R^3}$$

[b] Confidence interval for R>50:

$$-95\%CI = M*C/(R+1.92+1.960*\sqrt{R+1.0}) \qquad +95\%CI = M*C/(R+1.92-1.960*\sqrt{R+1.0})$$

[c]The numbers reported for 1997 are from Appendix 5 in Cook (1998). These numbers differ slightly from those in report tables but the total estimate (N*) of 4,488 is close to the 4, 493 reported here.

Age, Sex, and Length

Three hundred and thirty sockeye salmon were sampled from the study area for scale (age), sex, and length data (ASL). Samples were collected roughly in proportion to abundance with 80, 80, 100, and 70 fish sampled in trips one to four, respectively. Scale sampling and processing methods followed standard ADF&G procedures (ADF&G 2001). Tweezers were used to pluck three scales from the preferred area on the left side of the each fish (INPFC 1963). Scales were mounted on gummed "scale cards" (Clutter and Whitesel 1956) and sex and length data recorded directly on optical scanner data forms. Mid-eye to fork length was measured to the nearest half-centimeter. Fish lengths were measured by either holding the fish flat on a ruler or using a ruler to measure the fish as it is held flat on a custom hinged aluminum and net sampling board (Figure 2). Scales were aged at the ADF&G, Commercial Fisheries Division, salmon aging laboratory in Douglas, Alaska. Age classes were recorded in European notation where a period separates the number of fresh water and marine annuli (Koo 1962). The total age of the fish is the sum of these two numbers plus one – the first year (winter) when the fish was an egg/alevin in the redd.

Figure 2. Custom hinged aluminum and net fish sampling board.

Genetic

Left axillary fins were collected for genetic samples from 285 sockeye salmon. Fin clips were sampled from 77, 57, 79, and 72 sockeye salmon on 9/6, 9/20, 10/4, and 10/18. The fins sampled on each date were preserved in denatured alcohol in 250ml bottles. These samples were sent to ADG&G's Gene Conservation Lab in Anchorage.

RESULTS

Abundance

Four, two-day, mark-recapture trips were made in 2011 (Table 2). The 2-day Peterson estimates of sockeye spawning in the study area were 442 (CV 6.2%), 589 (CV6.9%), 444 (CV 6.5%) and 225 (CV 8.8%) for September 7, September 21, October 5, and October 19, respectively. The modified Jolly-Seber estimate of the total number of sockeye spawning in the study area (N*) was 2,128 with an approximate coefficient of variation of 7%. This was the second lowest abundance observed since this study was initiated in 1997 (Tables 2 and 3). If we had expanded this estimate by boat survey counts around the perimeter of the lake the escapement into the lake would be indexed at 3,374, again, the second lowest observed since 1997 (Table 3, Figure 3).

Assuming that nearly all the sockeye salmon are in the study area from August 1 to November 30 each year, I interpolated the daily abundances between these dates using the 2-day Peterson estimates (Table 4) and summed the four estimates obtained every 14 days from September 7 to October 19 as another standardized index of abundance (Table 3). Both the sum of these estimates and the sum of the daily interpolated estimates from August 1 to November 30 find the 2011 abundance the second lowest in the past 12 years (Table 3). Excluding 1999 and 2000, when the study area was extended to include "Clyde's Hole", there is a good correlation (R^2 = 0.96) between these daily interpolated estimates and the modified Jolly-Seber estimate of the number of sockeye salmon in the study area (Figure 4). Run strength and timing differences are evident between years (Figures 5 and 6).

Table 3. Abundance indices for sockeye salmon in Sitkoh Lake, 1997 to 2006, 2010, and 2011.

Year	Modified Jolly-Seber Mark-Recapture Estimate in Study Area (as previously reported)	Modified Jolly-Seber Mark-Recapture Estimate in Study Area (as reported here)	Expanded Estimate for the Whole Lake Based on Boat Survey Counts (as previously reported)	Study Area Abundance on 9/7	Study Area Abundance on 9/21	Study Area Abundance on 10/5	Study Area Abundance on 10/22	Sum of Study Area Abundance Estimates on 9/7, 9/21, 10/5, and 10/22.	Sum of Interpolated Daily Estimates from August 1 to November 30
1997	4,488	4,493	5,984	338	906	807	304	2,355	37,360
1998		4,047 [a]	6,649	770	701	560	430	2,461	53,759
1999	8,318	8,319	10,499	852	1,157	1,428	1,461	4,899	107,824
2000	12,362	12,364	17,040	1,146	1,403	1,345	1,584	5,478	118,616
2001	8,788	8,803	14,134	574	938	1,170	774	3,457	66,042
2002	7,254	7,272	11,915	508	611	771	747	2,637	46,765
2003	5,100	5,105	8,700	615	807	667	206	2,295	38,467
2004	2,100	2,121	3,700	238	401	332	135	1,106	17,438
2005	6,400	6,409	13,400	534	1,011	775	668	2,988	45,579
2006	6,700	6,514	14,800	461	667	1,038	661	2,827	45,630
2010		9,665	15,324 [b]	543	587	1,363	873	3,366	64,972
2011		2,128	3,374	442	589	444	225	1,700	30,459

[a]Estimated from the linear regression on the whole lake estimate.

[b]Estimated from the linear regression on the modified Jolly-Seber estimate.

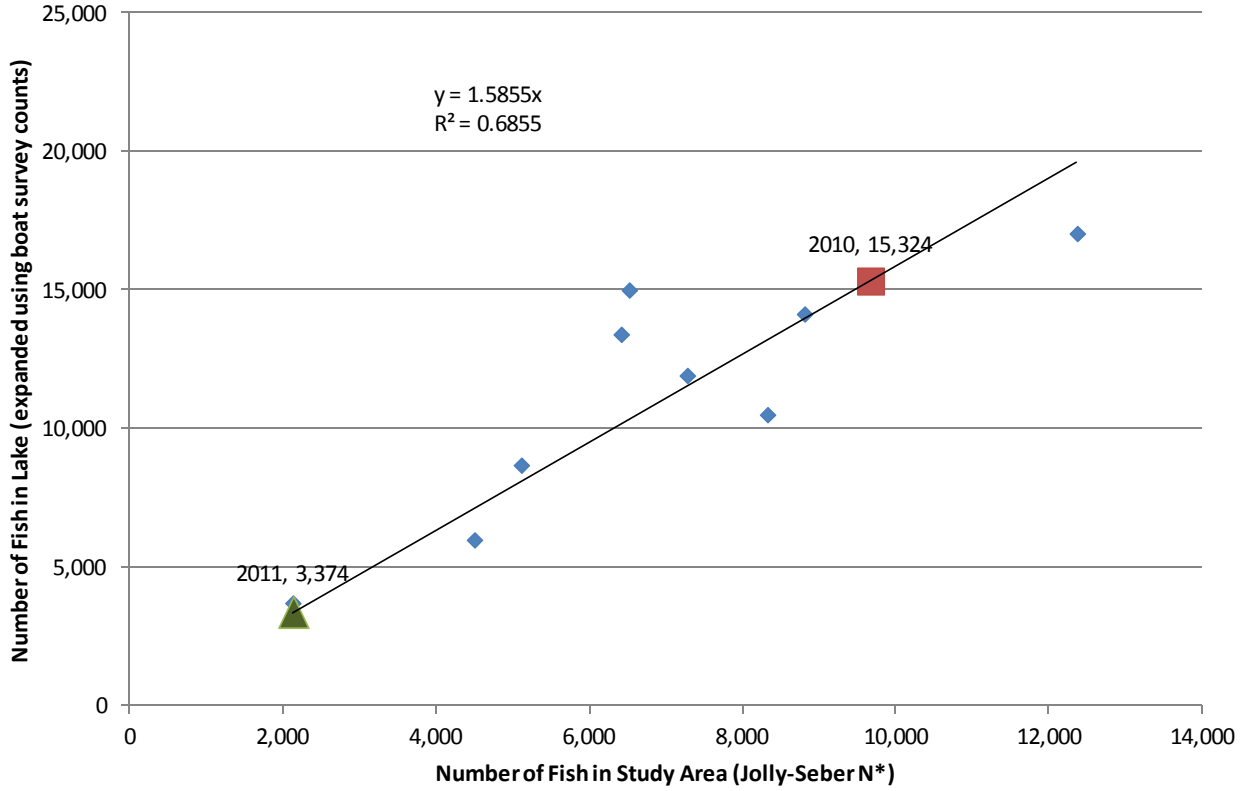

Figure 3. Relationship between the estimated number of sockeye salmon in Sitkoh Lake and the estimated number in the study area in 1997 and 1999 to 2006 and what the prediction would be for 2010 and 2011.

Table 4. Direct (bold) and interpolated estimates of the daily number of sockeye salmon in the study area in Sitkoh Lake, 1997 to 2006 and 2010 and 2011.

Date	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2010	2011
8/1	0	0	0	0	0	0	0	0			0	0
8/2	7	38	24	14	45	9	12	1			23	13
8/3	13	75	49	30	88	18	24	2			45	26
8/4	20	111	73	45	130	27	36	4			67	39
8/5	27	146	97	62	170	37	49	6			89	52
8/6	35	180	121	79	209	47	61	8			110	64
8/7	42	213	145	97	246	57	74	11			130	77
8/8	50	245	169	116	281	68	88	14			150	90
8/9	57	276	193	135	315	79	101	17		0	170	102
8/10	65	307	217	155	348	90	115	21		3	189	115
8/11	74	336	241	176	379	101	129	24		7	208	127
8/12	82	364	264	197	408	113	143	28		12	226	140
8/13	91	392	288	219	435	125	158	33		19	244	152
8/14	99	418	311	242	462	137	172	37		26	261	164
8/15	108	444	335	266	486	149	187	42		33	278	176
8/16	117	468	358	290	509	162	203	48		42	295	189
8/17	127	492	381	315	530	175	218	53		52	311	201
8/18	136	515	405	341	550	189	234	59		62	326	213
8/19	146	537	428	367	569	202	250	65		73	341	225
8/20	155	557	451	394	585	216	266	72	0	85	356	237
8/21	165	577	474	422	600	230	282	78	5	98	370	249
22-Aug	176	596	497	450	614	**245**	299	85	22	112	384	260
23-Aug	186	614	519	479	626	260	316	93	41	126	397	272
24-Aug	196	631	542	**509**	636	276	333	100	61	142	410	284
25-Aug	207	647	565	541	645	294	350	108	83	158	423	296
26-Aug	**218**	662	587	577	653	311	368	116	106	**175**	435	307
27-Aug	228	677	610	617	658	329	386	125	131	194	446	319
28-Aug	237	690	632	659	662	348	404	134	158	214	457	330
29-Aug	246	702	655	704	**665**	366	**422**	143	186	237	468	342
30-Aug	253	714	677	751	664	385	441	152	216	261	478	353
31-Aug	261	724	699	799	658	403	461	162	247	286	488	364
1-Sep	268	733	721	849	649	421	483	172	280	311	497	376
2-Sep	277	742	743	899	637	438	504	182	315	337	506	387
3-Sep	286	750	765	950	623	454	527	193	**351**	363	514	398
4-Sep	296	756	787	1,001	609	470	549	204	391	389	522	409
5-Sep	308	762	809	1,050	596	484	571	215	435	414	529	420
6-Sep	322	767	831	1,099	584	**497**	593	226	483	439	536	431
7-Sep	338	770	852	1,146	574	508	615	**238**	534	461	**543**	**442**
8-Sep	357	773	874	1,191	569	519	635	251	585	483	547	454
9-Sep	378	775	896	1,234	569	528	655	265	637	**502**	548	466
10-Sep	**403**	**776**	917	1,274	**574**	536	673	280	688	519	545	480
11-Sep	433	776	938	1,310	586	543	689	296	736	534	541	493
12-Sep	470	773	960	1,343	605	549	**704**	312	781	547	535	507
13-Sep	513	770	981	1,372	630	555	718	327	821	559	530	521
14-Sep	559	765	1,002	1,396	660	561	731	342	**855**	570	525	534
15-Sep	609	758	1,023	1,415	695	567	745	356	885	580	522	547
16-Sep	661	751	**1,044**	1,428	732	573	758	368	913	591	521	559
17-Sep	713	742	1,065	**1,435**	772	579	770	379	939	603	524	569
18-Sep	765	733	1,088	1,435	813	586	781	**387**	961	616	531	577
19-Sep	815	722	1,110	1,429	855	593	791	393	981	631	543	583
20-Sep	863	712	1,134	1,418	897	602	800	398	998	648	562	588
21-Sep	906	701	1,157	1,403	938	**611**	807	401	1,011	**667**	**587**	**589**
22-Sep	945	689	1,181	1,385	978	622	813	403	1,020	691	623	588
23-Sep	977	678	1,204	1,365	1,014	633	816	403	**1,025**	720	670	584
24-Sep	1,001	666	1,228	1,344	1,047	646	817	403	1,024	754	727	579
25-Sep	**1,017**	655	1,251	1,325	1,076	660	816	401	1,016	790	791	571
26-Sep	1,024	644	1,274	1,307	1,099	674	813	398	1,001	827	860	562
27-Sep	1,023	633	1,296	1,292	**1,116**	688	**806**	395	982	866	932	551
28-Sep	1,014	623	1,317	1,282	1,129	702	797	390	959	903	1,006	539
29-Sep	999	**614**	1,337	**1,277**	1,141	715	784	385	933	938	1,077	527
30-Sep	978	605	1,356	1,278	1,151	728	770	378	905	970	1,146	513

-Continued-

Table 4. (Continued, page 2 of 2)

Date	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2010	2011
1-Oct	952	596	1,374	1,284	1,159	739	753	372	876	997	1,209	499
2-Oct	921	587	1,390	1,294	1,165	749	734	**364**	848	1,019	1,264	485
3-Oct	886	578	1,404	1,308	1,169	758	713	355	821	1,034	1,310	471
4-Oct	848	569	1,417	1,325	1,171	**765**	691	344	796	**1,040**	1,343	457
5-Oct	807	560	**1,428**	1,345	1,170	771	667	332	775	1,038	**1,363**	**444**
6-Oct	764	551	1,437	1,367	1,166	776	642	319	**759**	1,029	1,369	430
7-Oct	720	542	1,446	1,390	1,160	782	616	304	747	1,014	1,362	416
8-Oct	675	533	1,453	1,414	1,150	786	590	289	739	993	1,346	401
9-Oct	630	524	1,460	1,439	1,137	790	562	273	733	968	1,321	385
10-Oct	586	515	1,465	1,464	1,121	793	**535**	256	729	939	1,288	368
11-Oct	543	505	1,470	1,488	**1,101**	795	505	240	726	908	1,249	352
12-Oct	502	496	1,473	1,510	1,076	796	473	224	724	875	1,205	335
13-Oct	464	487	1,475	1,531	1,044	795	437	209	721	841	1,157	318
14-Oct	429	477	1,476	1,549	1,007	792	399	194	718	808	1,108	301
15-Oct	398	468	1,476	1,564	966	788	360	180	714	775	1,057	284
16-Oct	**372**	459	1,474	1,575	921	781	321	**168**	707	744	1,007	269
17-Oct	349	449	1,471	1,582	874	772	281	157	698	**716**	959	253
18-Oct	326	440	1,467	**1,585**	824	761	243	146	685	689	914	239
19-Oct	304	430	1,461	1,584	774	**747**	206	135	**668**	661	873	**225**
20-Oct	283	421	1,454	1,581	724	729	172	125	646	631	**839**	212
21-Oct	263	411	**1,445**	1,577	674	707	140	115	620	601	808	200
22-Oct	243	401	1,435	1,571	627	682	113	105	590	571	778	187
23-Oct	224	392	1,423	1,563	582	653	**90**	96	557	540	748	176
24-Oct	205	382	1,410	1,554	540	621	72	87	521	509	719	164
25-Oct	187	372	1,396	1,543	**503**	587	57	78	484	477	690	153
26-Oct	170	363	1,381	1,530	469	551	45	70	445	447	662	143
27-Oct	154	353	1,364	1,515	436	515	35	62	406	416	634	132
28-Oct	138	343	1,346	1,499	404	477	28	54	366	386	607	122
29-Oct	123	333	1,326	1,481	374	440	22	47	327	357	580	113
30-Oct	109	323	1,305	1,461	344	402	18	40	290	329	554	103
31-Oct	95	313	1,283	1,440	316	366	14	34	254	303	529	95
1-Nov	82	303	1,259	1,416	289	331	11	28	222	277	504	86
2-Nov	70	293	1,235	1,392	262	298	8	22	192	254	479	78
3-Nov	58	283	1,208	1,365	238	268	5	16	**166**	**232**	455	70
4-Nov	47	273	1,181	1,337	214	240	**0**	11	143	212	431	63
5-Nov	37	263	1,152	1,307	191	**216**		6	121	192	408	56
11/6	27	253	1,122	1,275	170	194		2	101	174	386	49
11/7	18	243	1,091	1,242	149	174		0	82	156	364	43
11/8	10	233	1,058	1,206	130	155			64	139	342	37
11/9	2	223	1,024	1,170	112	136			47	124	321	32
11/10	0	212	988	1,131	95	119			32	109	301	26
11/11		202	951	1,091	80	103			18	95	281	22
11/12		192	913	1,049	65	88			5	81	261	17
11/13		181	874	1,005	52	74			0	69	242	13
11/14		171	833	960	40	61				58	224	9
11/15		161	791	912	29	49				48	206	6
11/16		150	747	864	19	38				38	189	3
11/17		140	703	813	10	28				29	172	0
11/18		129	657	761	2	20				22	156	
11/19		118	609	707	0	12				15	140	
11/20		108	560	651		6				9	125	
11/21		97	510	594		0				4	110	
11/22		87	459	535						0	95	
11/23		76	406	474							82	
11/24		65	352	411							69	
11/25		54	297	347							56	
11/26		44	240	281							44	
11/27		33	182	213							32	
11/28		22	123	144							21	
11/29		11	62	73							10	
11/30		0	0	0							0	
Total	37,360	53,759	107,824	118,616	66,042	46,765	38,467	17,438	45,579	45,630	64,972	30,459

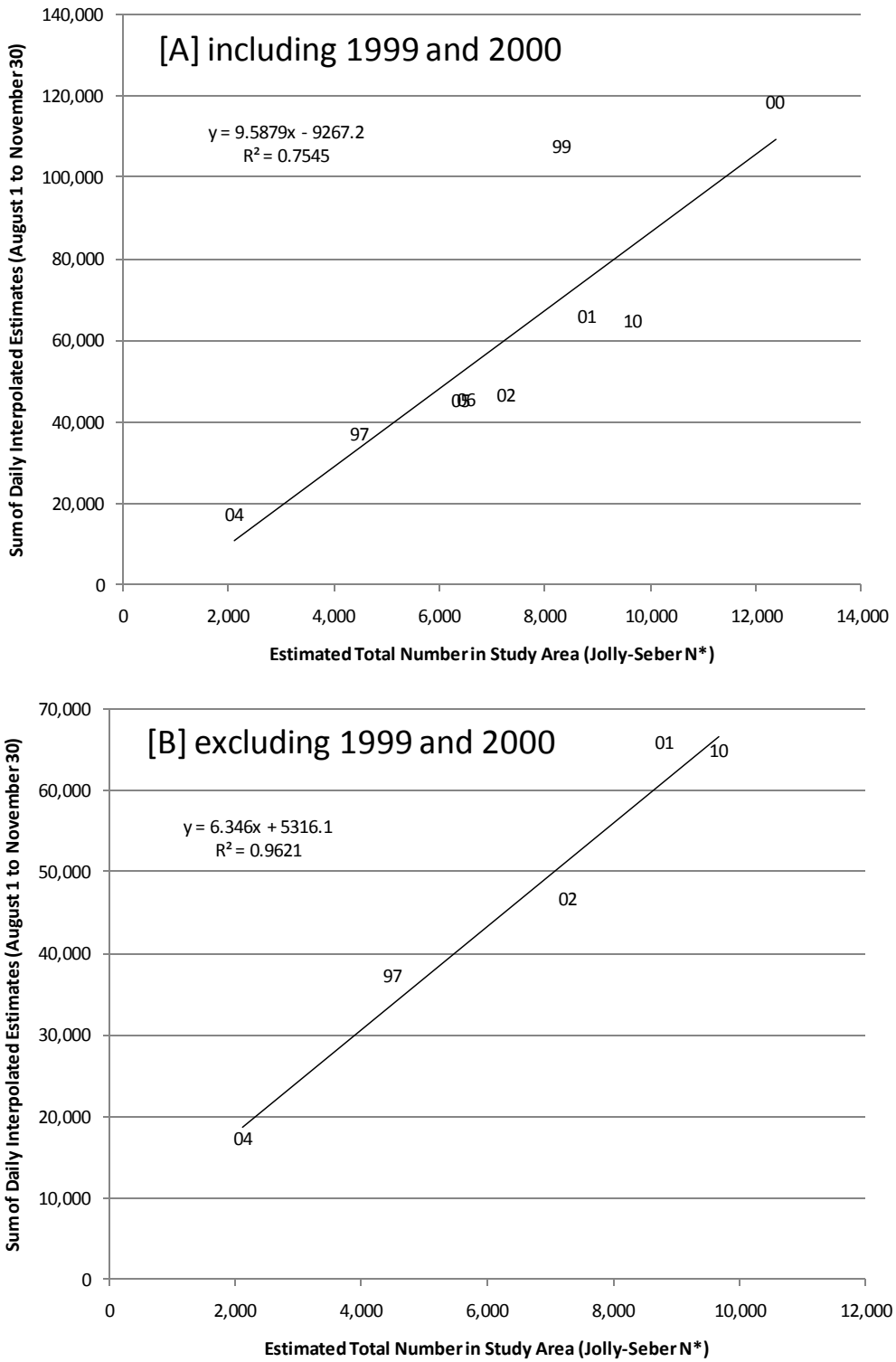

Figure 4. Regression of the sum of the daily interpolated estimates from August 1 to November 30 on the modified Jolly-Seber estimate of the total number in the study area (N*) for years 1997 to 2000 [A] and excluding [B] years 1999 and 2000 when "Clyde's Hole" was included in the study area.

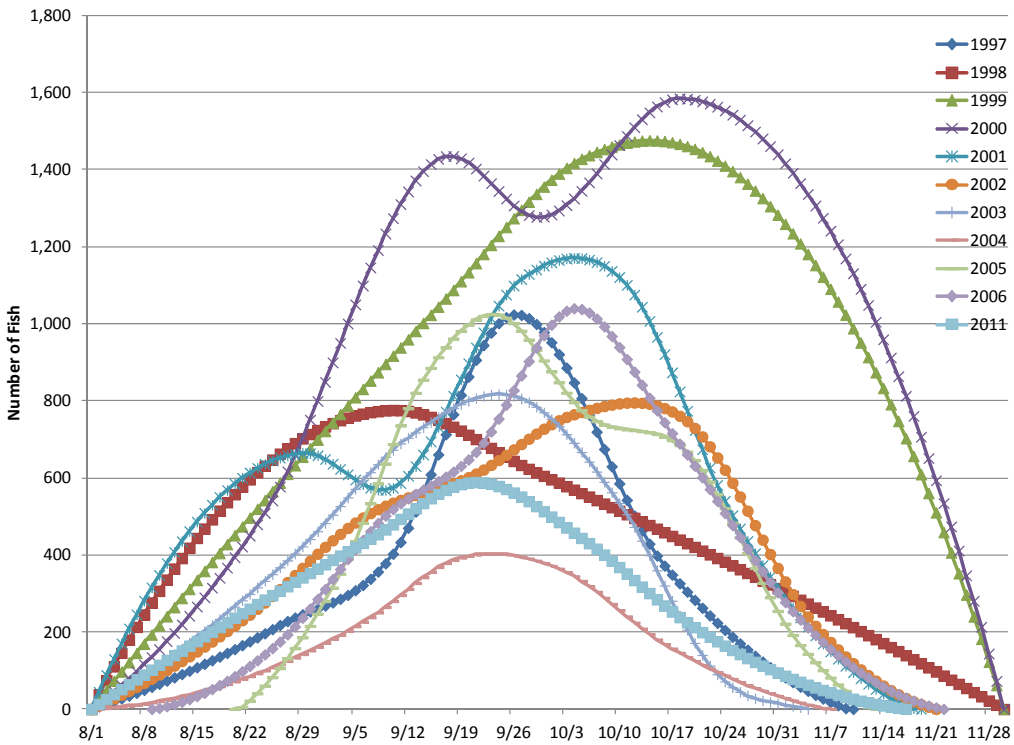

Figure 5. Estimated daily abundance of sockeye salmon in the study area adjacent to the West Sitkoh Lake Forest Service cabin, 1997 to 2006, 2010, and 2011.

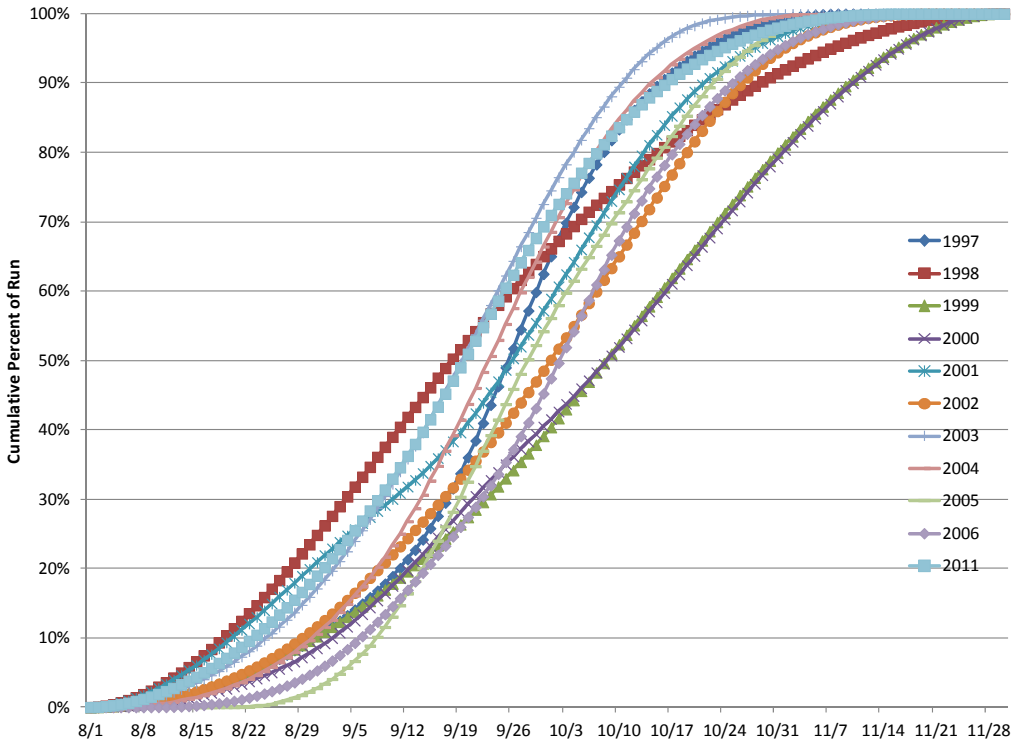

Figure 6. Timing of sockeye spawning in the index area of Sitkoh Lake, 1997 to 2006, 2010, and 2011.

Age, Sex, and Length

Of the 330 sockeye sampled, 208 (63%) had ageable scales. Of the ageable fish, most were aged 1.2 (39%) and 1.3 (55%; Table 5). Three "jacks" (age-.1) and 11 "two-check" (age 2.-) fish were sampled.

Table 5. Age and length (mm) composition, by sex, of sockeye salmon in the Sitkoh Lake escapement, 2011.

	Brood Year and Age Class					
	2008	2007	2007	2006	2006	
	1.1	1.2	2.1	1.3	2.2	Total
Male						
Sample Size	1	40	2	68	3	114
Percent	0.5%	19.2%	1.0%	32.7%	1.4%	54.8%
SE	0.5%	2.7%	0.7%	3.3%	0.8%	3.5%
Ave. Length	360	501	390	550	507	527
SE		3.1	10.0	1.7	6.7	3.5
CV		4%	4%	3%	2%	7%
Female						
Sample Size	0	41	0	47	6	94
Percent	0.0%	19.7%	0.0%	22.6%	2.9%	45.2%
SE	0.0%	2.8%	0.0%	2.9%	1.2%	3.5%
Ave. Length		496		541	495	519
SE		3.1		1.7	9.6	2.9
CV		4%		2%	5%	5%
All Fish						
Sample Size	1	81	2	115	9	208
Percent	0.5%	38.9%	1.0%	55.3%	4.3%	100.0%
SE	0.5%	3.4%	0.7%	3.4%	1.4%	0.0%
Ave. Length	360	499	390	547	499	508
SE		2.2	10.0	1.3	6.8	2.8
CV		4%	4%	3%	4%	8%

DISCUSSION

In 2011, the modified Jolly-Seber estimate was only 2,128 (CV=7%) sockeye salmon in the study area of Sitkoh Lake (Tables 2 and 3). This is the second lowest index of sockeye escapement into the lake. In 2004, the lowest year, the index was 2,121 fish. If the escapement index for 2011 had been expanded by boat survey counts for the proportion of fish in and out of the study area, the indexed escapement for the entire lake would have been only 3,374 sockeye

salmon (Figure 3; Table 3). We have observed and would expect annual escapements at least four times higher than this. Annual runs are dependent on the quantity and quality of escapements and climate and ocean conditions affecting survivals. Annual escapements are also dependent on the commercial purse seine effort in Icy, Chatham, and Peril Straits and the subsistence/personal use effort in Sitkoh Bay. The relatively high seine effort in 2004 and 2011 likely contributed to the low escapements observed in these two years.

The reliability of this escapement index depends on a consistent distribution of the annual escapement in and out of the study area. However, as mentioned in the report for 2010 (Van Alen and Mahara 2011b), in the past 10 years there have been hydrological changes affecting the study area and, possibly, the distribution of spawners. The water flowing out of the valley above the study area used to percolate underground though a broad alluvial fan and upwell along the lake shore throughout the study area. There were no perennial or intermittent/seasonal streams in the study area, or elsewhere around the lake - except for a small intermittent stream near the East Forest Service cabin. The only surface flows into the lake observed 10 years ago were from heavy rain-on-snow events in the spring or heavy rains in the fall. The study area was centered in the middle of this alluvial fan where the sockeye spawners were most abundant. This upwelling of water through the sand and gravel substrate in the study area likely contributed to higher survival of the sockeye salmon spawning in this index area and the high proportion of sockeye spawning in the index area.

There is now a stream that bisects the alluvial fan and flows directly into the study area (Figures 7 and 8). This perennial stream reduces the amount of water upwelling along the shore. The formation of this stream is likely a result of the clear-cut logging and roading that has been done in the watershed (Figure 9). There is a possibility that this hydrologic change could lower survivals of fish in the study area and change the distribution of spawners in the lake and the usefulness of these annual escapement indices.

We recommend that this project be expanded to also estimate the total escapement of sockeye salmon into Sitkoh Lake to better calibrate past and present index counts with actual escapements. The potential of using a redundant net weir and video system (Van Alen 2008; Van Alen and Mahara 2011a) at the outlet of the lake should be evaluated. Two lake net weirs with video chutes could easily work in the narrow constriction near the outlet of the lake (Figure 10). Personnel from the Kook Lake sockeye stock assessment project (Van Alen 2008; Van Alen and Mahara 2011a) could service the video net weirs and exchange the SD memory cards from each mini-DVR (digital video recorder) on each crew exchange flight out of Angoon since Kook and Sitkoh Lakes are relatively close (Figure 1) and personnel would have the time to review the Sitkoh video while they are on the job at Kook Lake. With these double redundant, two video chute/four camera video weir setups, project personnel could validate the daily escapements by comparing counts from just one of the lower cameras and just one of the upper cameras. Video from the second camera in each chute would only need to be reviewed if there were problems or questions with footage on the opposite camera. Thus, by discontinuing

counting both cameras from each chute, the same two employees could work the same hours and get validated counts of the sockeye escapement into both Kook and Sitkoh Lakes. The risk that such a remote unattended fish counting project could unknowingly block fish passage could be alleviated by uploading pictures of the project site each day through the Forest Service radio system.

Figure 7. Picture of the beach in front of Sitkoh Lake's West Forest Service cabin prior to formation of an inlet stream, August 28, 2001.

Figure 8. Picture of the beach in front of Sitkoh Lake's West Forest Service cabin after formation of an inlet stream, September 7, 2010.

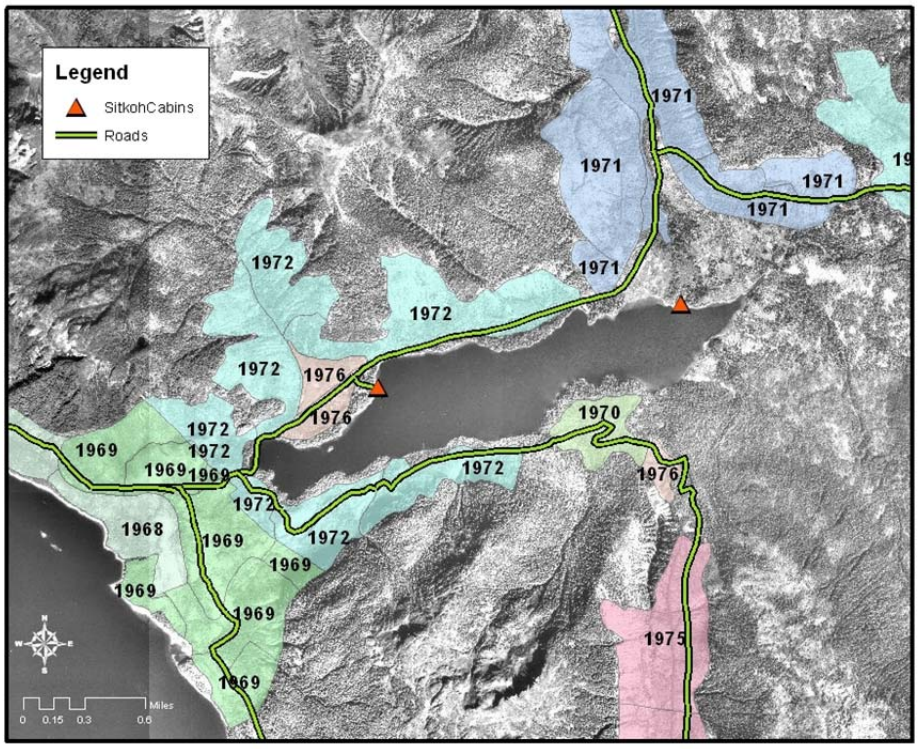

Figure 9. Map showing the clear-cuts (with year logged) and roads in the Sitkoh Lake watershed. The roads on the south side of the lake have not been maintained.

Figure 10. Photo of the outlet (east) end of Sitkoh Lake showing the narrow channel where two video lake net weirs could be fished to estimate the total escapement of sockeye salmon into the lake.

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