

Lake Clark Sockeye Salmon Escapement and Population Monitoring, 2008 - 2011

Final Report for Project 08-405



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ABSTRACT

The Lake Clark sockeye salmon run, a key component of the Kvichak River run, supports important Federal subsistence fisheries. This report describes findings from a salmon counting tower project conducted on the Newhalen River from 2008 – 2011. Specific objectives were to 1) estimate sockeye salmon escapement to Lake Clark and 2) determine age, sex, and length of the Lake Clark escapement. Estimates of escapement were made at river kilometer 36 on the Newhalen River using the same tower site and protocols used in previous studies. In 2009, turbid water conditions compromised counts after July 22 and escapement after this date was estimated using historical count data. Sockeye salmon age and size were determined from otoliths collected from the Newhalen River subsistence fishery and from post-spawning fish at Lake Clark spawning habitats. During 2008 – 2011, total Lake Clark escapement averaged 316,496 salmon and ranged from a low of 210,372 salmon in 2009 to a high of 472,962 salmon in 2008. The 2008 – 2011 mean escapement to Lake Clark was 22% lower than the 2000 – 2007 mean of 403,991 and 72% lower than the mean escapement of 1,135,464 during 1980 – 1984. During the study period, the Lake Clark escapement comprised, on average, 11% of the total Kvichak River escapement, about 5% less than observed in the 1980s and 8% less than observed during the period from 2000 – 2007. The estimated mid-point of the run was similar to previous years in 2008 and 2011 but was likely earlier than average in 2009 and 10 days later than average in 2010. The age composition of sampled fish from Lake Clark was predominately age 1.3 (48-65%), followed by age 1.2 (22-34%), age 2.2 (1-21%), and age 2.3 (0-9%).

INTRODUCTION

The world's largest and most valuable sockeye salmon fisheries occur in Bristol Bay, Alaska, and sockeye production from the Kvichak River watershed, which includes Iliamna Lake and Lake Clark, has historically dominated harvests (Forrester 1987, Ruggerone and Link 2006, Dye and Schwanke 2012, Salomone et al. 2011, Holen and Lemons 2012). During peak years in the 1960s and 1970s the Kvichak River watershed produced 23-42 million sockeye salmon per year (Figure 1), which represented up to 80% of the total Bristol Bay sockeye salmon production (Ruggerone and Link 2006). Subsistence harvests of sockeye salmon in the Kvichak River watershed have historically been the largest within the Bristol Bay region and averaged 57,379 sockeye salmon during 1987 – 2007 with 49,901 caught in 2007 (Sands et al. 2008). During 2003 – 2008 the average sport fish harvest in the watershed was 5,184 sockeye salmon, making it one of the larger recreational fisheries in the Bristol Bay region (Dye and Schwanke 2012).

Unpredicted declines in the sockeye salmon returns to the Kvichak River and Lake Clark watersheds in the late 1990s and early 2000s impacted regional commercial, subsistence, and sport fisheries. The Bristol Bay region was declared an economic disaster by the federal government due to poor salmon runs in 1997 and 1998 and by the State of Alaska due to poor salmon runs and low prices in 1997, 1998, 2001, and 2002. Annual subsistence harvests declined from a mean of 75,000 sockeye salmon during 1974 – 1995, to a mean of 47,496 during 1997 –

2006 (Holen and Lemons 2012), Sands et al. 2008). Annual commercial harvests fell from a mean of 8.1 million sockeye salmon during 1980-1995 to a mean of 1.4 million during 1996 – 2003 (Morstad and Baker 2006). Annual sport fish harvests also declined due to fishing closures and bag limit reductions (e.g., ADFG 2001 and 2002).

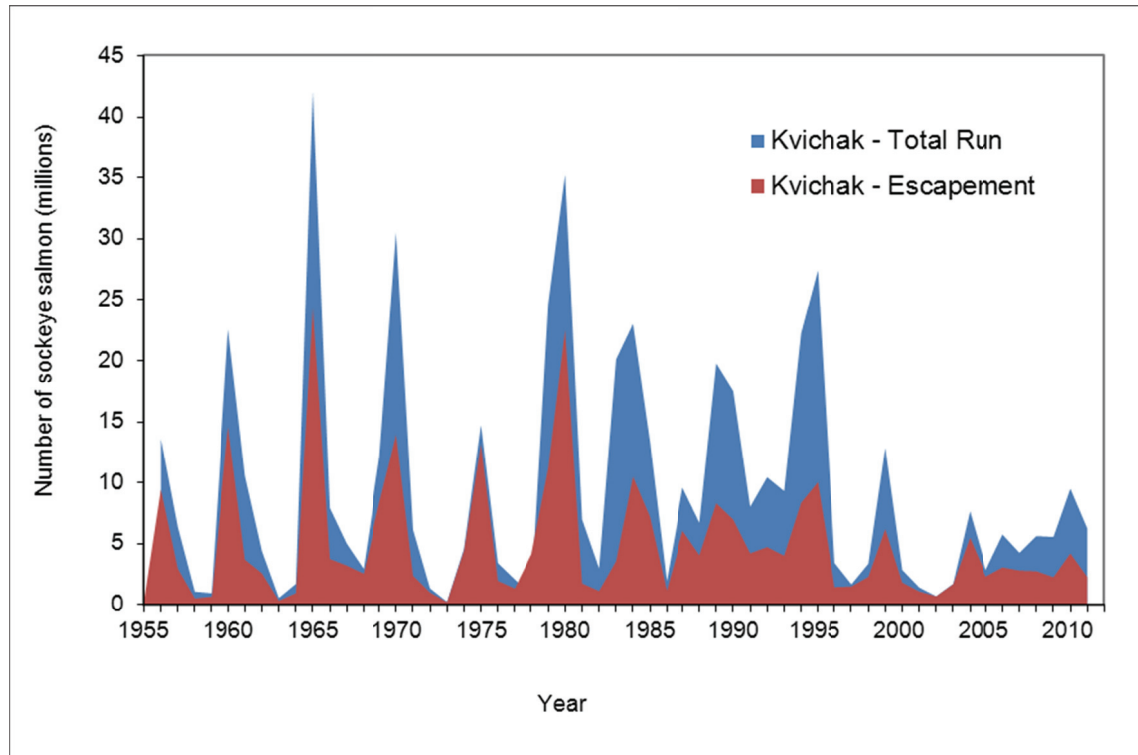


Figure 1. Annual sockeye salmon total run and escapement to the Kvichak River, 1956 to 2011. Data from the Alaska Department of Fish and Game, Anchorage, Alaska (2012).

Because of these declines and their potential impact on federal subsistence users in the Lake Clark watershed, a fisheries resource monitoring project, funded by the U.S. Fish and Wildlife Service, Office of Subsistence Management, was started on the Newhalen River in 2000. This project re-established counting towers along the upper Newhalen River to estimate the escapement of sockeye salmon to Lake Clark; using the same location and protocols used by the University of Washington from 1980 – 1984. Obtaining reliable estimates of spawning escapement over time is the number one priority identified in the 2005 strategic plan for the Subsistence Fisheries Monitoring program for Bristol Bay. Annual escapement estimates from this location have ranged from 0.2 - 3.1 million sockeye salmon during 1980 – 1984 and from 0.2 – 0.7 million sockeye salmon during 2000 – 2007 (Poe and Rogers 1984, Woody 2004, Young and Woody 2009).

Sockeye salmon returning to spawn in the Lake Clark watershed are harvested in Federal subsistence fisheries within Lake Clark National Park and Preserve, as well as in state managed subsistence, commercial and sport fisheries. The subsistence harvest of salmon in these fisheries

provides 44-89% of the total wild resource harvest for residents in the communities of Newhalen, Iliamna, Nondalton, and Port Alsworth (Fall et al. 2006). In 2007 and 2008 the estimated annual subsistence harvest for these communities was around 26,000 sockeye salmon with approximately 14,000 harvested in Iliamna/Newhalen, 10,000 harvested in Nondalton, and 2,000 harvested in Port Alsworth (Fall et al. 2010).

STUDY AREA

The Newhalen River watershed, located in southwest Alaska, is part of the Kvichak River watershed and is comprised of the Newhalen River, Sixmile Lake, Tazimina River, Lake Clark, and associated tributaries (Figure 2). The Lake Clark and Tazimina River drainages are located within the federally managed Lake Clark National Park and Preserve. The Newhalen River, a tributary of Iliamna Lake, is 40 km long and has mean July flows between 16,000 and 26,000 cubic feet per second (cfs), and a maximum recorded July flow of 36,000 cfs (USGS 2014). A series of rapids and waterfalls located at river kilometer 11 creates a barrier to upstream salmon migration during years when flows exceed 28,000 cfs (Poe and Rogers 1984). Sixmile Lake is a clear-water lake that is 10 km long, 1.0 - 2.5 km wide, and has an average depth of 5 m and a maximum depth of 35 m (NPS unpublished data). The Tazimina River, a clear-water tributary to Sixmile Lake, is about 87 km long and drains an area of 829 km². Water from the upper portion of the Tazimina River watershed flows through two lakes, pours over a 30 m waterfall at river kilometer 15, flows through a canyon (~ 1.6 km) and finally winds 13.7 km through a low gradient (~3%) braided floodplain to its outlet in the upper Newhalen River. Lake Clark is located approximately 50 km upstream from Iliamna Lake and connected to it by Sixmile Lake and the Newhalen River to the southwest. Lake Clark, the sixth largest lake within Alaska and the largest lake within Lake Clark National Park and Preserve, is a semi-glacial oligotrophic lake that is 66 km long, 5-8 km wide and has an average depth of 103 m, a maximum depth of 265 m, and drains an area of 7,620 km² (Anderson 1969; Wilkens 2002). Lake Clark has six major tributaries of which three are glacier fed, two are clear, and one is organically stained (Brabets 2002). Seasonal runoff from the glacial tributaries is greatest between June and September, and creates a marked gradient in water clarity from the turbid upstream end of the lake to the relatively clear downstream end (Brabets 2002; Wilkens 2002).

The Newhalen River watershed is a significant producer of sockeye salmon with annual runs ranging from 0.2 million to 3.1 million sockeye salmon (Poe and Rogers 1984; Woody 2004, Young and Woody 2009). The watershed contains over 35 known spawning areas (Woody et al. 2003, Young and Woody 2007), but most sockeye salmon spawn in the Tazimina River, Lake Clark outlet, shoreline beaches of Lake Clark and Little Lake Clark, Kijik Lake, Currant Creek, and the Tlikakila River (Regnart 1998, Young 2004, Young and Woody 2007).

OBJECTIVES

- 1) Estimate sockeye salmon escapement to Lake Clark
- 2) Determine age and length of the Lake Clark subsistence harvest and escapement

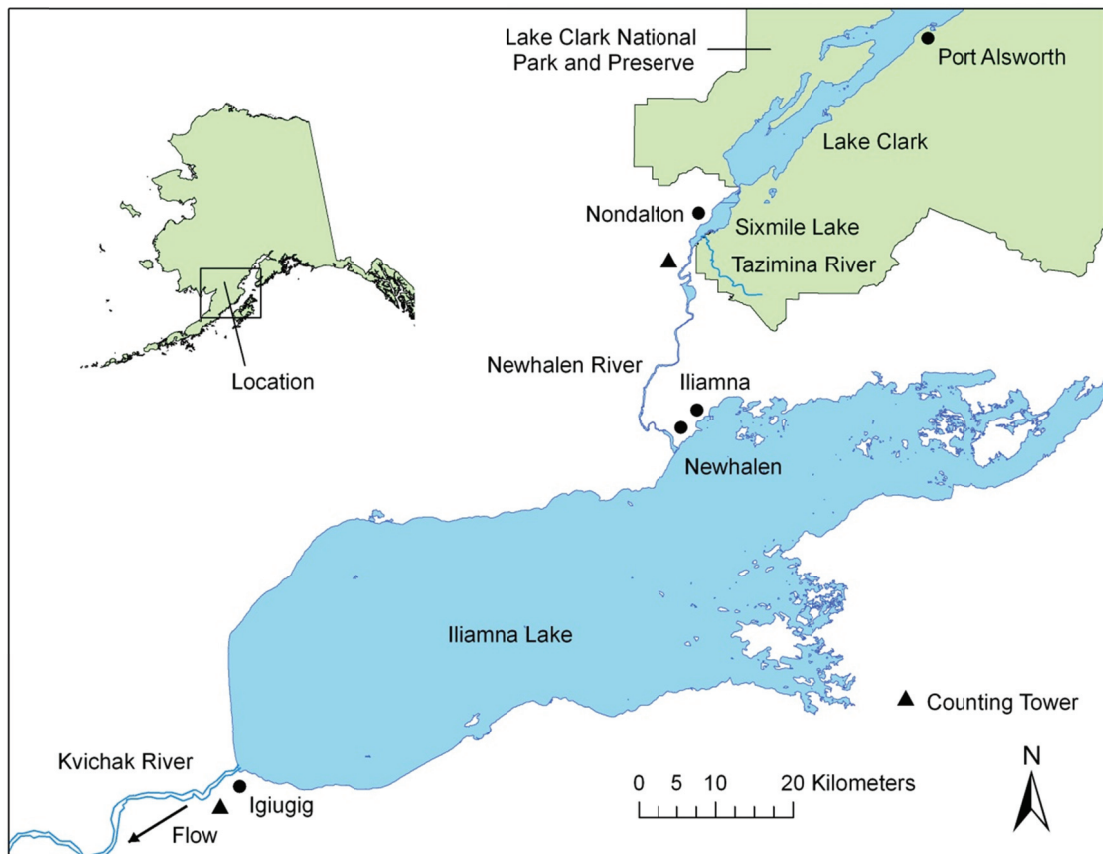


Figure 2. Location of the Kvichak and Newhalen River counting towers within the Kvichak River drainage. The counting tower located near the community of Igiugig is operated by the Alaska Department of Fish and Game.

METHODS

Lake Clark Sockeye Salmon Escapement

During 2008 to 2011, Lake Clark sockeye salmon escapement estimates were made at river kilometer 36 (Figure 3) on the Newhalen River, using standard counting tower protocols

described in Anderson (2000) and Woody (2007). We used the same site and specific procedures described by Poe and Rogers (1984) and used by Woody (2004) and Young and Woody (2009). Systematic, hourly, 10 minute counts were made from 6 m towers on both river banks between late June and August 1. Night counts were made possible using rheostat controlled 12 volt lights powered by solar charged car batteries. Counting was terminated for the season when daily escapement was less than one percent of the total escapement for at least three consecutive days.

In 2008 and 2009, counting tower operations were affected by external factors. In 2008, night counts (0000 – 0400) were stopped after July 26 to avoid encounters with problem bears in the dark. In 2009, poor water clarity limited our ability to view salmon swimming upstream after July 22.

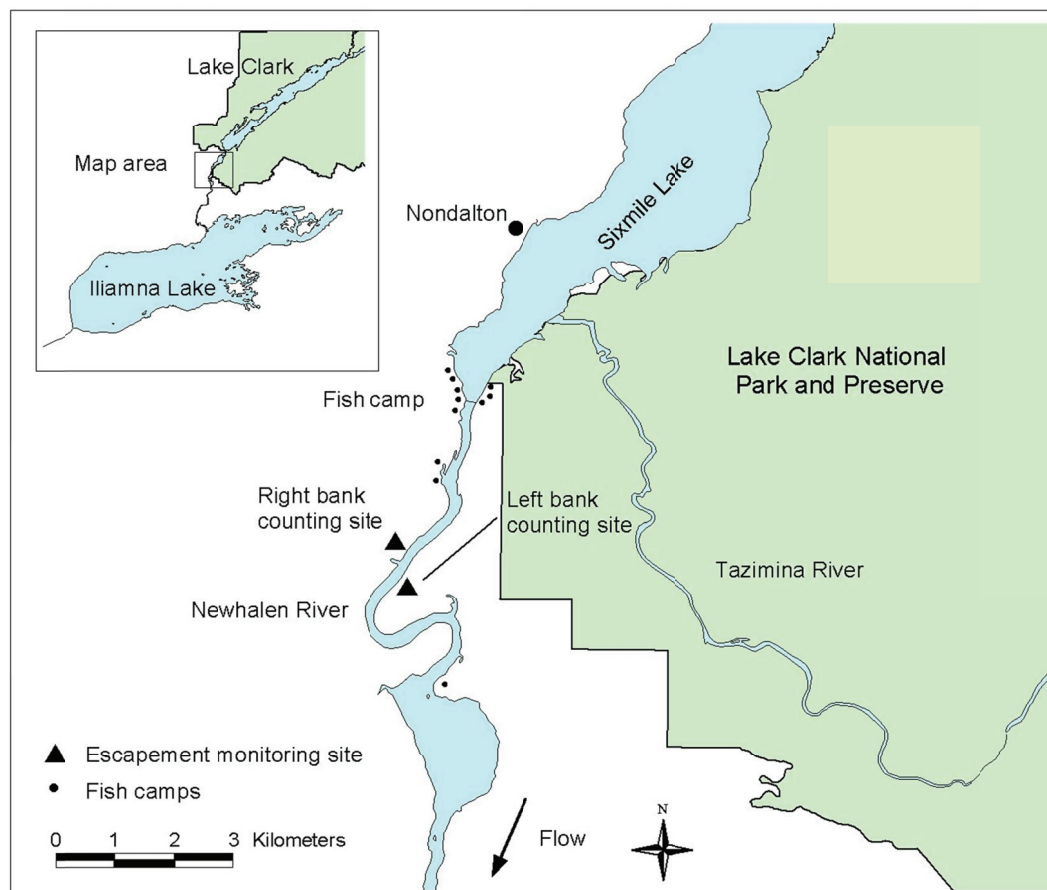


Figure 3. Location of the Newhalen River counting towers.

Data analyses included calculations to estimate hourly, daily, and total escapements, missed counts, and run timing. Ten minute counts were expanded by a factor of six to yield an estimate of hourly escapement past the counting towers. Daily escapement was the sum of the 24 hourly estimates, and total escapement was the sum of all daily estimates. Values for missed counts were estimated using the mean proportion of hourly escapement that migrated past the tower in previous years; this method was similar to what was used by Poe and Rogers (1984) and Woody (2004). In 2009, daily counts after July 22 were estimated using the 2000 – 2008 mean daily

proportion multiplied by the estimated 2009 total escapement, and rounded to the nearest integer. Lag time between the Kvichak River and Newhalen River escapements was estimated by comparing the date when each escapement estimate reached the 50th percentile. Run timing was estimated from the cumulative percentage of the total escapement that passed the tower each day. Run duration was the number of days elapsed between the dates when 1% and 99% of the total escapement passed the tower site.

Variance was estimated by considering tower counts as a systematic sample and then applying relevant methods developed for such sampling designs (see Reynolds et al. 2007). Variance estimator ‘5’ in Wolter (1984) was used because of its robustness against underlying autocorrelation, stratification, and nonlinear trends (Reynolds et al. 2007). To estimate variance, the seasonal mean count per observation period was calculated, expanded to a mean hourly count based on observation period length and number of hours observed per day, and then multiplied by the number of days in the observation season (see Woody 2004). In 2009, variance was estimated in two ways; using estimator ‘5’ for data from June 30 to July 22; and using methods outlined by Cochran (1977) for the estimated proportion that passed the tower after July 22.

Lake Clark Sockeye Salmon Age and Size Composition

Age and size composition of the Lake Clark escapement were estimated from samples of pre-spawning sockeye salmon obtained from the subsistence fishery in Sixmile Lake (Figure 3) and from post-spawning sockeye salmon collected from Lake Clark spawning areas, hereafter referred to as “Lake Clark,” using seines (Appendix 1). Otoliths were extracted and ages were determined by National Park Service personnel. Lengths were measured from mid-eye to hypural plate (MEH) in millimeters. To make these data comparable with to mid-eye to fork lengths (MEF) collected by Alaska Department of Fish and Game at the Kvichak River, MEH measurements were converted to MEF estimates using regression equations derived from 1,005 paired MEH and MEF measurements collected in 2000 and 2001 (Woody 2004).

The conversion equation for females ($r^2 = 0.96$; SE = 8.32) was:

$$MEF = 25.95 + 1.07 * MEH \quad (1)$$

The conversion equation used for males ($r^2 = 0.96$; SE = 8.1) was:

$$MEF = 27.8 + 1.06 * MEH \quad (2)$$

Differences in age composition between sockeye salmon sampled from the Kvichak River, Lake Clark, and Sixmile Lake subsistence fishery were examined using a Chi square test ($\alpha = 0.05$). Age categories represented by fewer than 10 individuals were not included.

Differences in median size at age for females and males sampled from the Kvichak River, Lake Clark, and Sixmile Lake subsistence fishery were examined using a Kruskal-Wallis one-way ANOVA on ranks ($\alpha = 0.05$); Dunn’s method was applied to test for differences among groups when the test was significant (Zar 1984). The non-parametric ANOVA on ranks test was used

rather than an ANOVA because length data violated assumptions of normality and equal variance.

Environmental and Hydrological Observations

Surface water temperature and stream discharge data were collected at the Newhalen River counting tower site. Water temperature was recorded hourly during escapement monitoring with a StowAway TidbiT temperature logger (Onset Computer Corporation, Bourne, Massachusetts), and average daily water temperatures were calculated for the season. Staff gauge measurements (ft) were recorded daily at the Newhalen River counting tower site. The regression equation derived by Poe and Rogers (1984) was used to estimate stream discharge in the Newhalen River (Y) from staff gauge measurements at the counting tower site (x):

$$Y = .9759 + .8143(x) \quad (3)$$

RESULTS

Lake Clark Sockeye Salmon Escapement

Lake Clark sockeye salmon escapement during 2008 – 2011 averaged 316,496 salmon, ranged from 210,372 to 472,962 salmon, and contributed, on average, 11% of the total Kvichak River escapement (Table 1). Sockeye escapement into Lake Clark began around July 1, ended by the middle of August, and lagged behind the Kvichak River escapement by 11 to 23 days (Figures 4-8, Appendices 2-5). Run timing was similar in 2008 and 2011, but was later than average in 2010, and appeared to be earlier than average in 2009 (Figure 5). Run duration was, on average, 30 days and ranged from 23 days in 2010 to 34 days in 2008 and 2011 (Figure 9). No estimate of run duration was made in 2009 because of the lack of data after July 22. During each year, over 80% of the salmon migrated upstream past the left bank tower and migration occurred between the hours of 0600 and 1700 (Figure 10, Appendix 6).

Table 1. Summary of sockeye salmon escapement for Lake Clark and Kvichak River. Variance, quantified in terms of the 90% confidence interval (CI), was calculated as recommended by Reynolds et al. (2007). For 2009, CI was calculated using methods recommended by Reynolds et al. (2007) and by Cochran (1977). Kvichak River data provided by the Alaska Department of Fish and Game, Anchorage, Alaska (2014).

Year	Lake Clark Escapement	90% CI	% of Kvichak	Kvichak River Escapement
2008	472,962	455,540 - 490,383	17	2,757,912
2009	210,372	150,436 - 321,608	9	2,266,140
2010	327,930	312,976 - 342,884	8	4,207,410
2011	254,718	242,610 - 266,825	11	2,264,352
All years	316,496		11	2,873,954

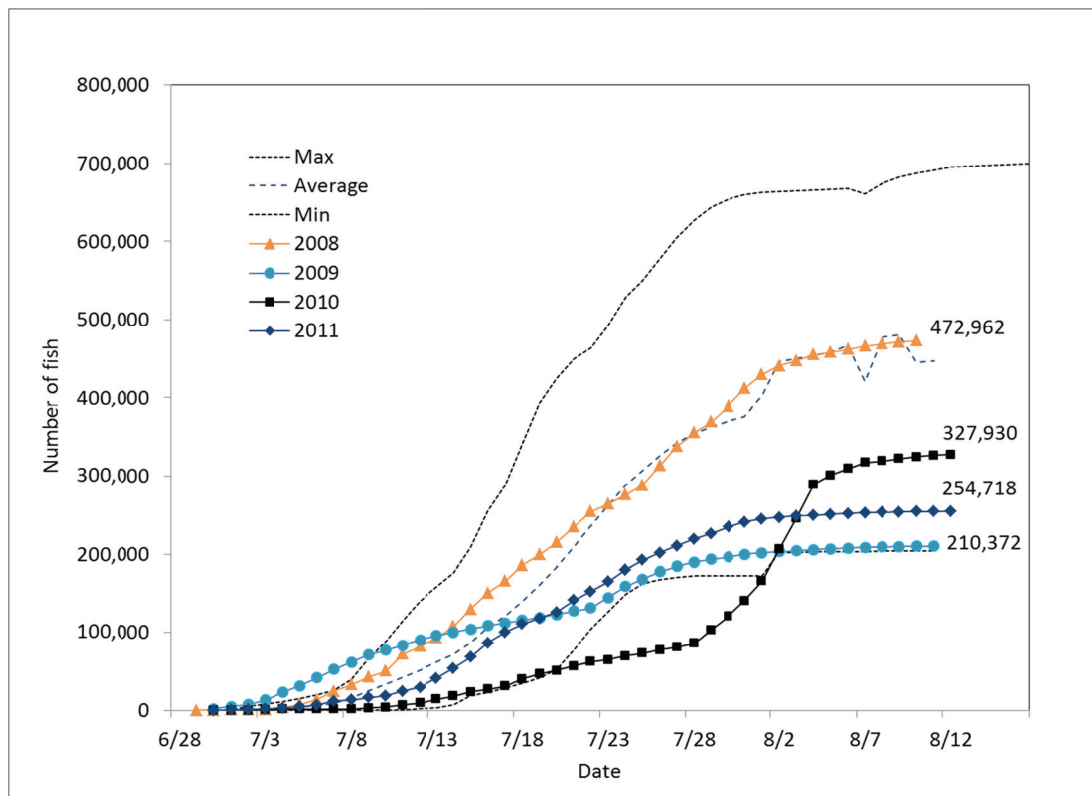


Figure 4. Cumulative sockeye salmon escapement at the Newhalen River counting tower by date, 2008 – 2011. Minimum, Average, and Maximum curves were plotted from escapement data collected from 2000 – 2007. Note: In 2009, data after July 22 were estimated using the 2000 – 2008 mean proportion of fish that pass the tower after this date.

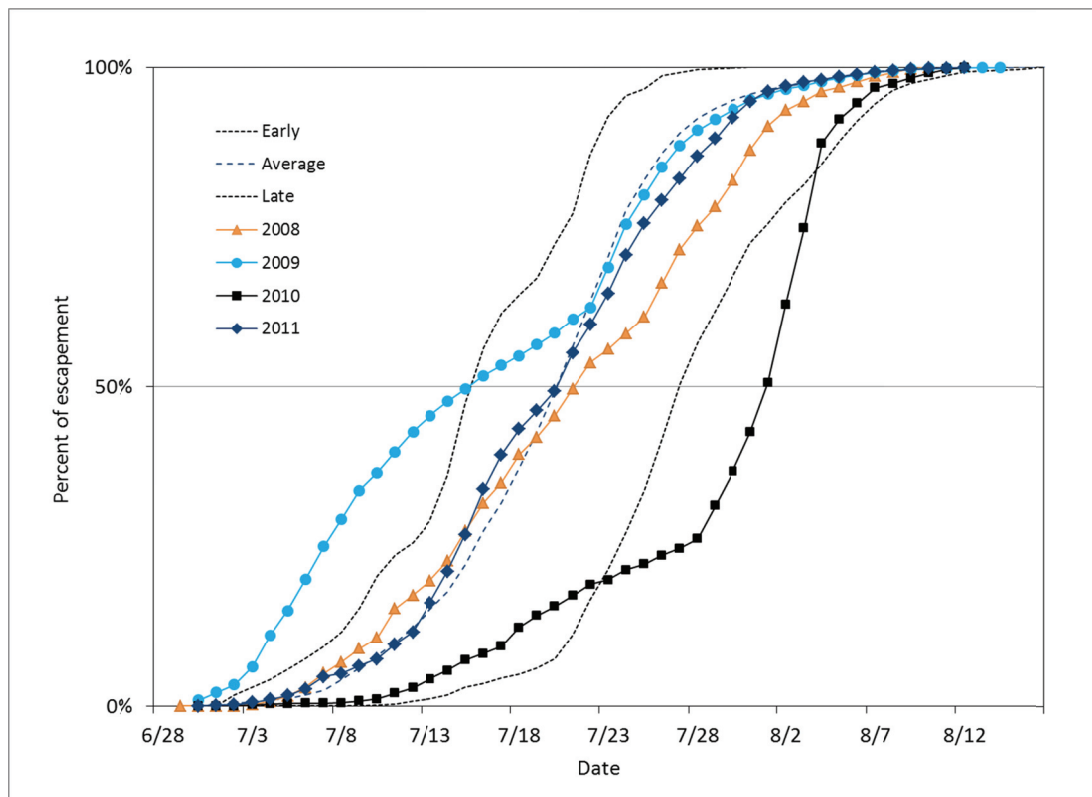


Figure 5. Percent of total sockeye salmon escapement to the Newhalen River by date, 2008 – 2011. Early, Average, and Late curves were plotted from escapement data collected from 2000 – 2007. Note: In 2009, data after July 22 were estimated using the 2000 – 2008 mean proportion of fish that pass the tower after this date.

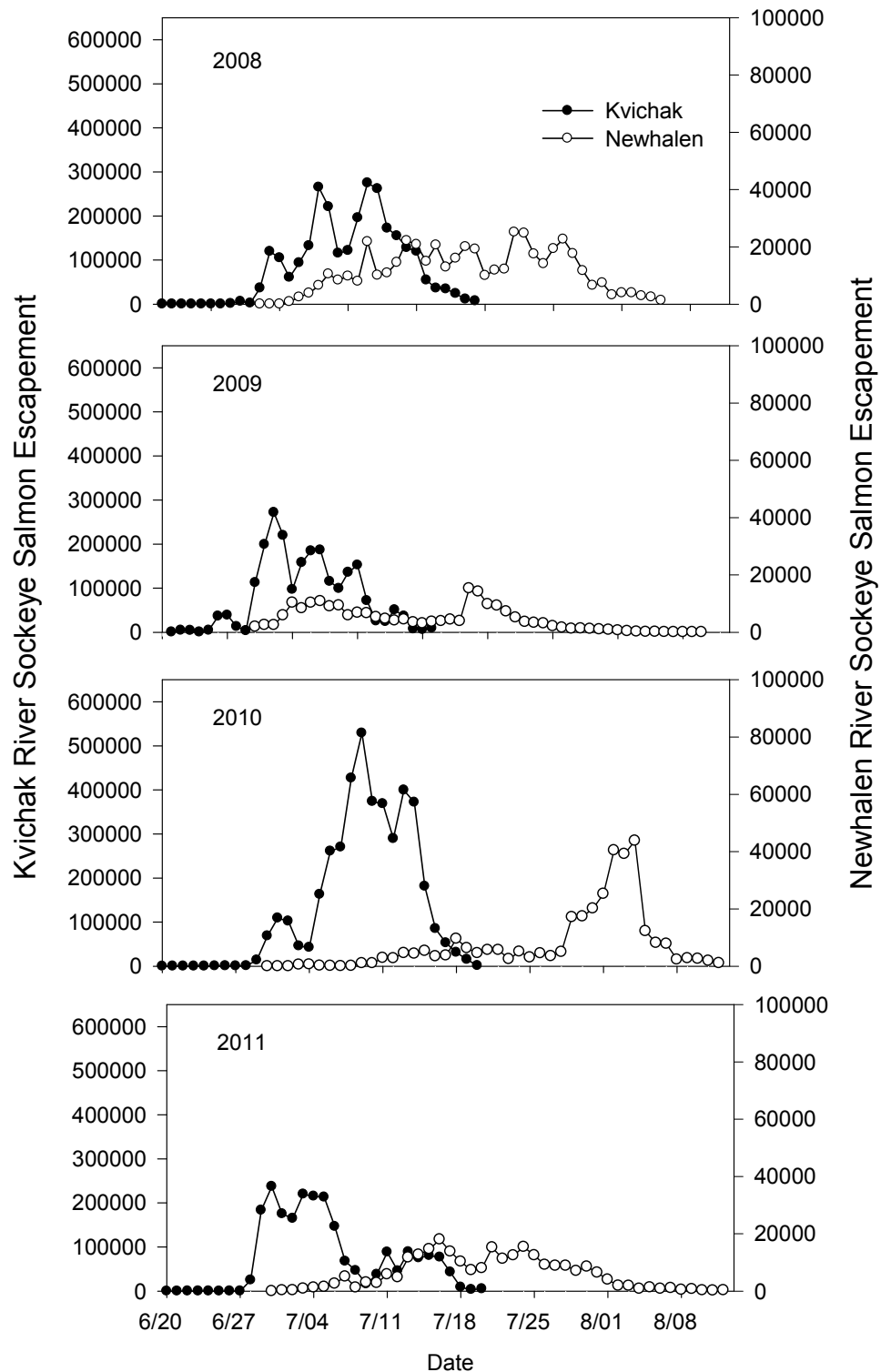


Figure 6. Daily sockeye salmon escapement at the Kvichak and Newhalen River counting towers, 2008 – 2011. Kvichak River data from the Alaska Department of Fish and Game (ADFG 2014).

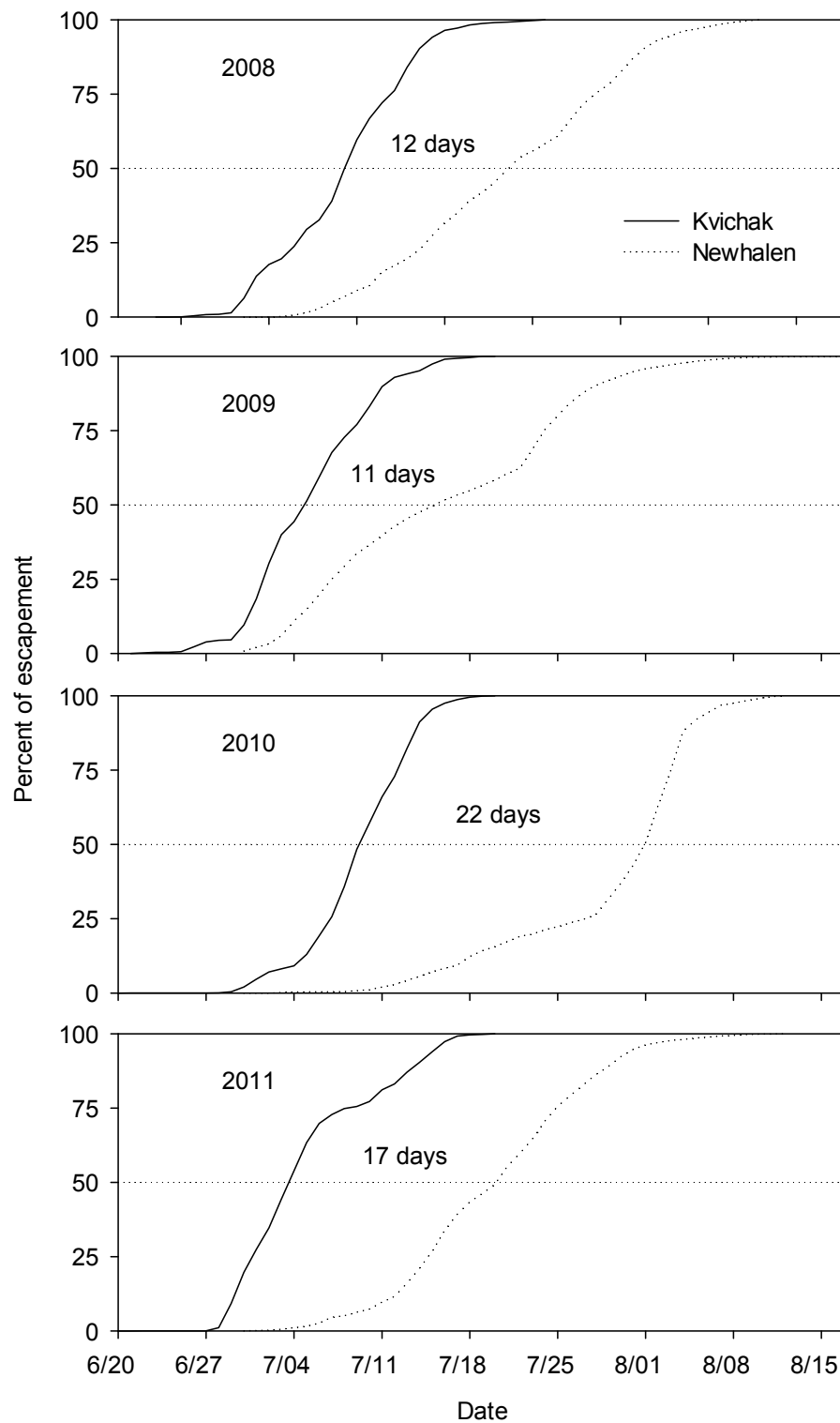


Figure 7. Percent of total sockeye salmon escapement to the Kvichak River and Newhalen River by date, 2008 – 2011. The number of days between the midpoint of the Kvichak and Newhalen River escapements, i.e., the lag time, is indicated.

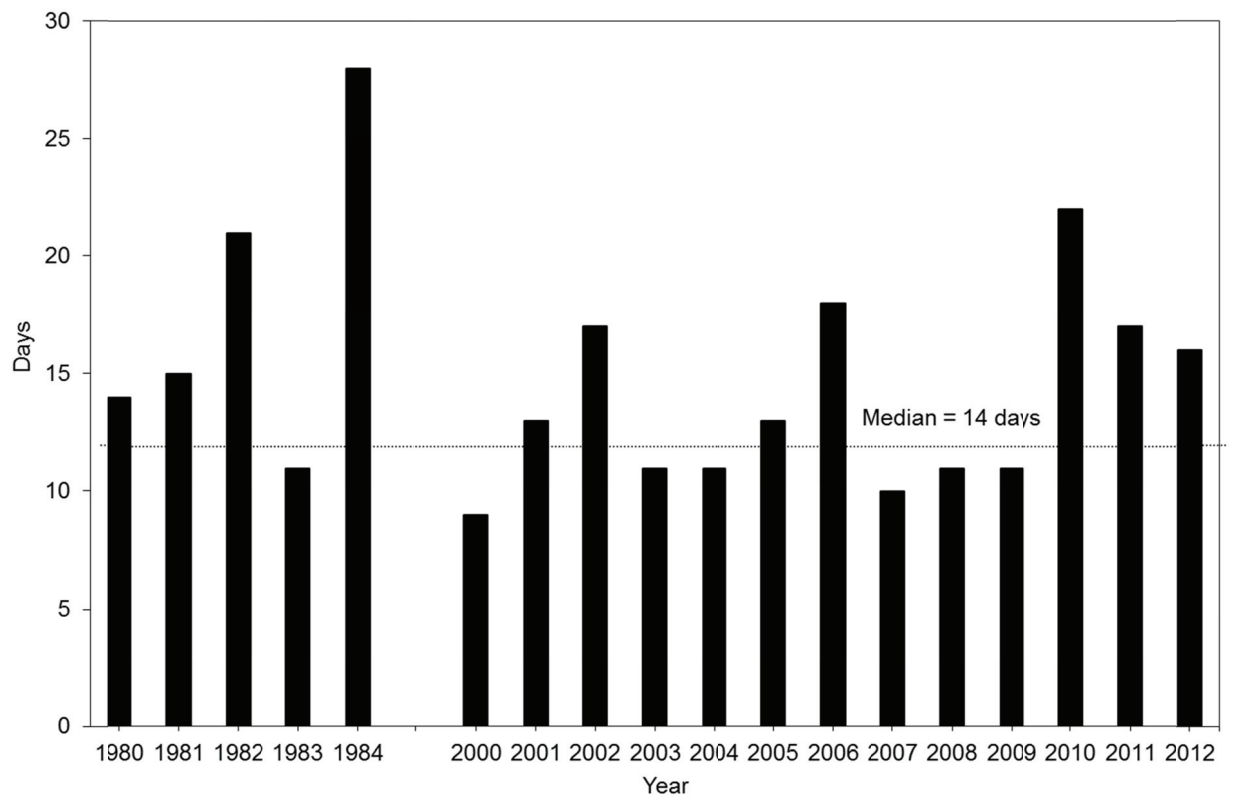


Figure 8. Lag time between the Kvichak River and Newhalen River escapement; estimated by comparing the date when each escapement estimate reached the 50th percentile, 1980 – 1984 and 2000 – 2011. Kvichak River data are from Alaska Department of Fish and Game, Anchorage, Alaska (ADFG 2014).

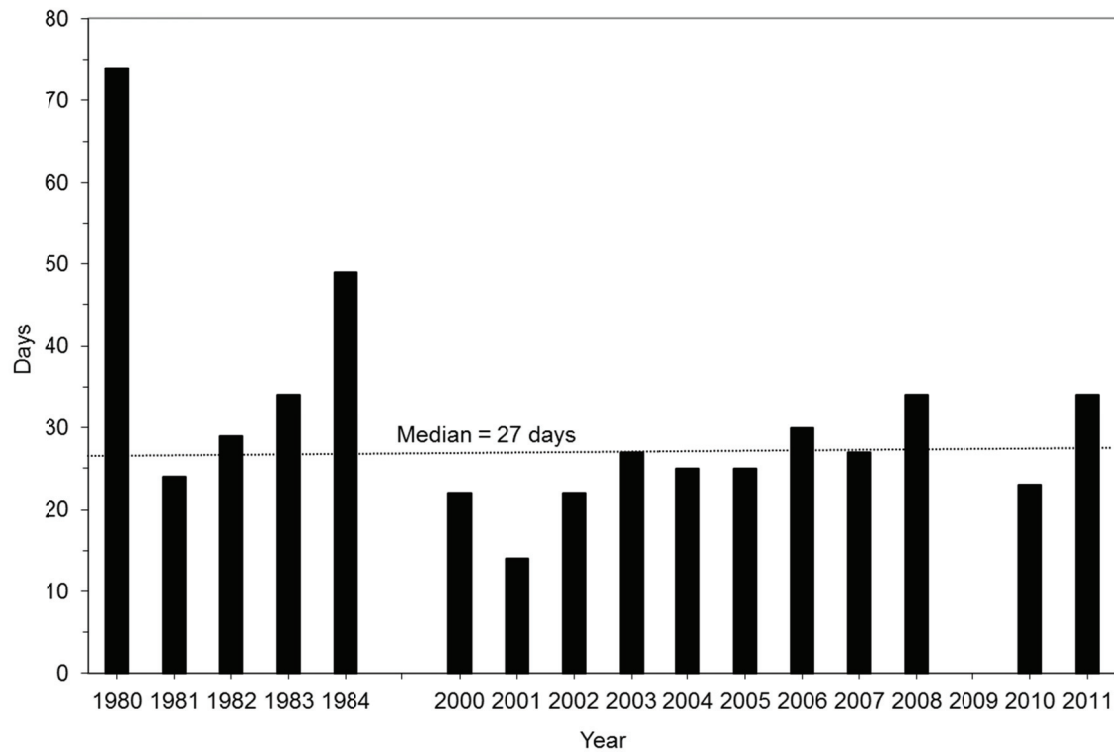


Figure 9. Newhalen River sockeye salmon run duration; number of days between 1st and 99th percentile, 1980 – 1984 and 2000 – 2011.

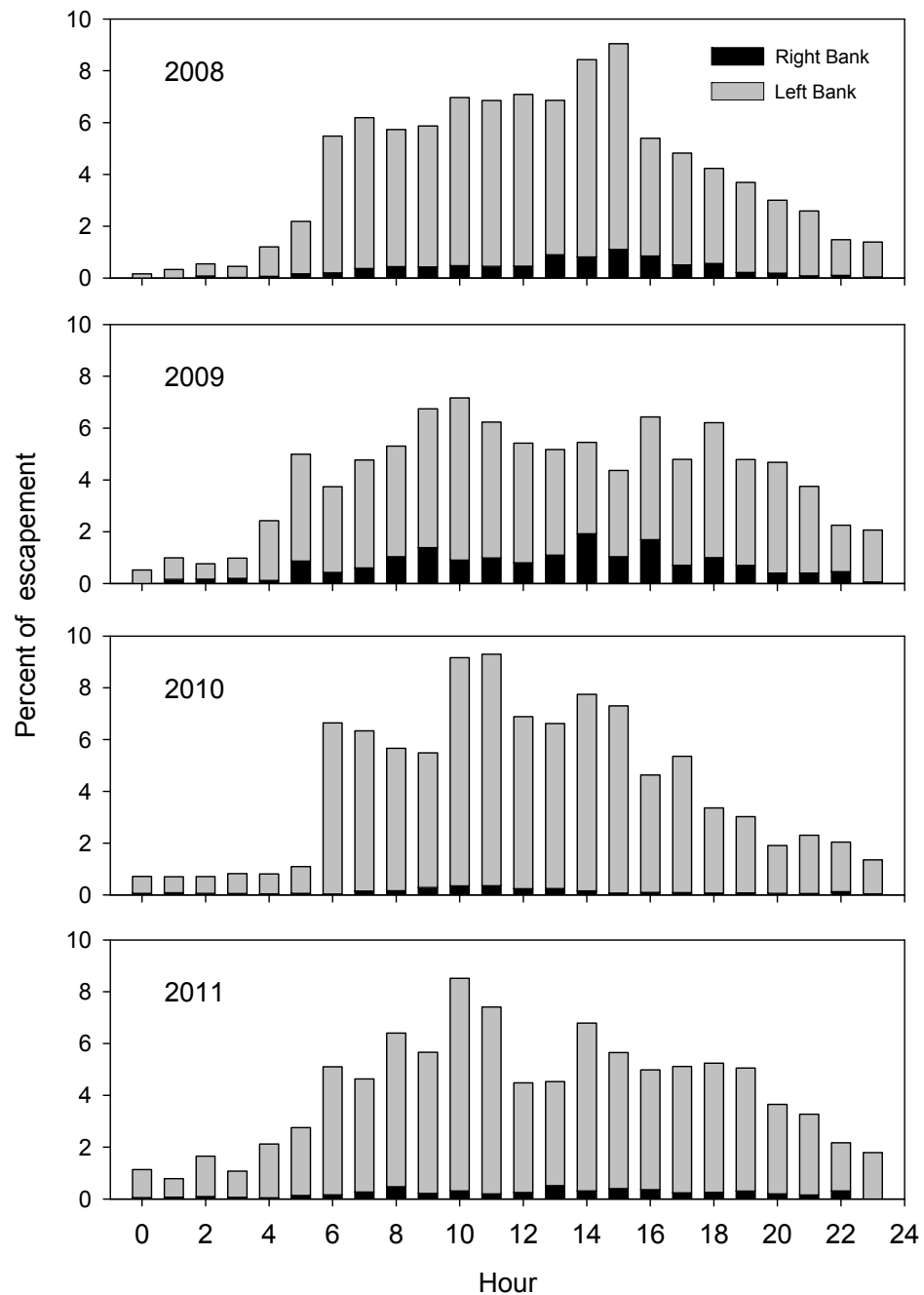


Figure 10. Percent of sockeye salmon counted at the Newhalen River counting towers by hour and bank (looking downstream), 2008 – 2011.

Lake Clark Sockeye Salmon Age and Size Composition

The age composition of sockeye salmon sampled varied across both location and year sampled. For all years, except 2008, the age composition of samples from the Kvichak River, Lake Clark, and Sixmile Lake subsistence fishery were significantly different (Chi square test, $p < 0.05$) from one another. In 2008, the age composition of the Kvichak River and Sixmile Lake subsistence samples were similar (Chi square test, $p = 0.18$), but different than Lake Clark samples ($p < 0.05$). Similar to differences among sample locations, the age composition varied significantly by year for each sample location (Chi square test, $p < 0.05$).

For Lake Clark samples, although age composition varied among years, a general pattern was observed with approximately 50% of the samples age 1.3 each year followed by ages 1.2, 2.2, and 2.3 (Figure 11, Table 2). For all years, the age composition of Lake Clark samples was primarily freshwater age 1 (72-99% of samples annually) and saltwater age 3 (48-65% of samples annually). In 2011, three sockeye salmon sampled on the Tazimina River were “jacks” or saltwater age 1.

For Sixmile Lake subsistence samples, age composition varied among years with age 1.2 more abundant in 2008 and 2011 and age 1.3 more abundant in 2009 and 2010 (Figure 11, Table 2). Ages 2.2 and 2.3 were less abundant and comprised 0-23% of all samples. Similar to Lake Clark, the age composition of the subsistence samples was primarily freshwater age 1 (79-100% of all samples). Saltwater age varied among years and was either age 2 (26-79% of samples annually) or age 3 (21-74% of samples annually).

Kvichak River samples had more variability in age composition compared to Lake Clark and Sixmile Lake subsistence samples (Figure 11, Table 2). In 2008, age 1.2 was most abundant followed by age 1.3. In 2009 and 2010, age 2.2 fish were most abundant followed by 1.3, 1.2, and 2.3 in 2009, and 1.2, 1.3, and 2.3 in 2010. In 2011, the age composition was distributed more evenly among age classes with age 1.3 most abundant followed by ages 1.2, 2.3, and 2.2. Kvichak River samples were primarily freshwater age 1 (53-99% of samples annually) and saltwater age 2 (47-82% of samples annually).

The length of sockeye salmon sampled for all years ranged from 362 to 660 mm and had a median length of 547 mm (Figure 12, Table 3). Differences in the length frequency distribution among sample locations generally reflect differences in age composition rather than differences in length at age. Within each age class, the median length of sockeye salmon sampled was generally similar among sample locations, including those sampled at the Kvichak River (Table 3). In 2008 and 2010, age 1.2 and age 2.2 sockeye salmon from the Kvichak River were significantly smaller (ANOVA on ranks, $p < 0.05$) than Lake Clark and Sixmile Lake samples (Table 3). In 2009, age 1.3 and 2.2 sockeye salmon sampled from the Sixmile Lake subsistence fishery were significantly larger (ANOVA on ranks, $p < 0.05$) than those sampled from Kvichak River or Lake Clark (Table 3). Sixmile Lake samples were also significantly larger (ANOVA on ranks, $p < 0.05$) for age 1.2, female sockeye salmon in 2008 and age 1.3, females in 2010.

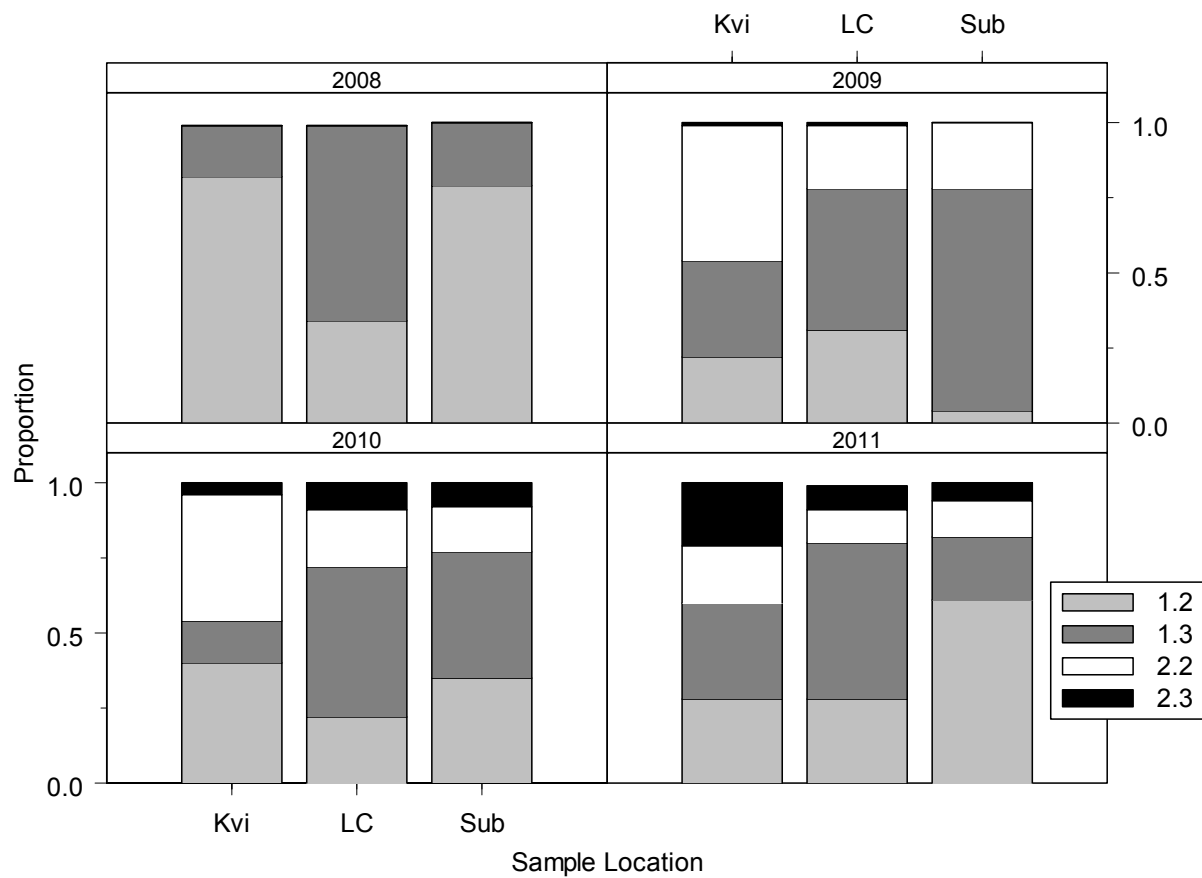


Figure 11. Age composition of sockeye salmon sampled from the Kvichak River (Kvi), Lake Clark spawning areas (LC), and Sixmile Lake subsistence fishery (Sub), 2008 – 2011. Kvichak River data courtesy of Alaska Department of Fish and Game, Anchorage, Alaska.

Table 2. Age composition of salmon sampled from the Kvichak River (Kvichak), Lake Clark spawning areas (Lake Clark), and Sixmile Lake subsistence fishery (Subsistence), 2008 – 2011. Sample sizes (Count) and percent composition (%) are shown. Kvichak River data courtesy of Alaska Department of Fish and Game, Anchorage, Alaska.

		Age										
		1.2		1.3		2.1		2.2		2.3		
Year	Sample type	Count	%	Count	%	Count	%	Count	%	Count	%	Total
2008	Kvichak	1019	81.5	218	17.4	10	0.8	3	0.2		0.0	1250
	Lake Clark	269	33.8	514	64.5		0.0	11	1.4	3	0.4	797
	Subsistence	284	79.1	75	20.9		0.0	0	0.0		0.0	359
2009	Kvichak	306	21.5	461	32.4		0.0	638	44.9	16	0.0	1421
	Lake Clark	184	30.7	285	47.5		0.0	124	20.7	7	1.2	600
	Subsistence	10	3.8	195	74.1		0.0	57	21.7	1	0.4	263
2010	Kvichak	526	40.4	180	13.8		0.0	544	41.8	52	4.0	1302
	Lake Clark	195	21.9	448	50.3		0.0	170	19.1	77	8.7	890
	Subsistence	138	34.6	169	42.4		0.0	59	14.8	33	8.3	399
2011	Kvichak	373	27.5	434	32.0	13	1.0	259	19.1	279	20.5	1358
	Lake Clark	249	28.1	460	52.0	3	0.3	99	11.2	74	8.4	885
	Subsistence	259	60.8	89	20.9		0.0	51	12.0	27	6.3	426

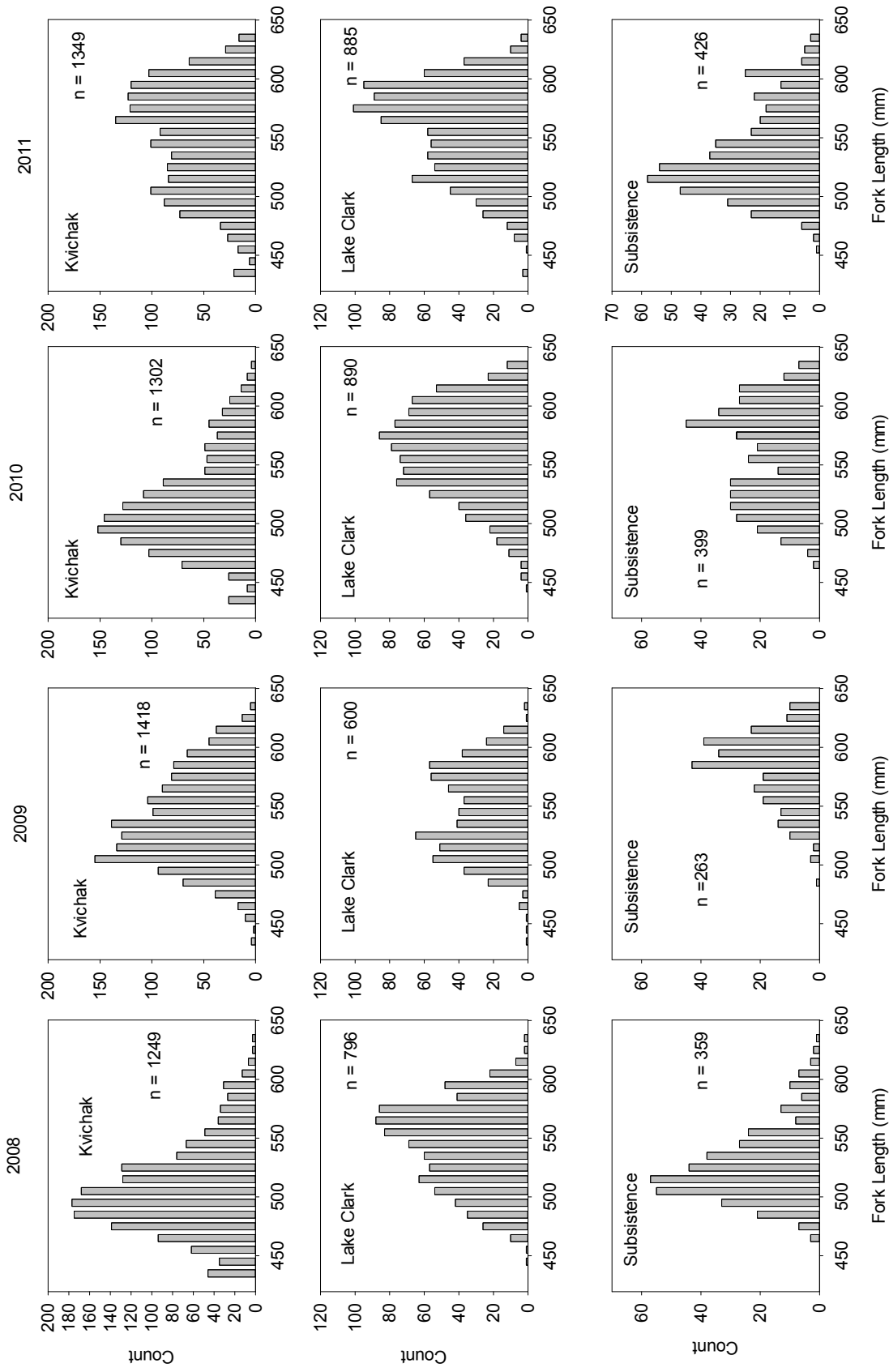


Figure 12. Length frequency distribution of sockeye salmon sampled from Kvichak River (Kvichak), Lake Clark spawning areas (Lake Clark), and Sixmile Lake subsistence fishery (Subsistence), 2008 – 2011. Kvichak River data courtesy of Alaska Department of Fish and Game, Anchorage, Alaska.

Table 3. Median mid-eye to fork length (MEF; mm) by age for female and male sockeye salmon sampled from the Kvichak River (Kvi), Lake Clark spawning areas (LC), and Sixmile Lake subsistence fishery (Sub), 2008 – 2011. Sample size for each category = Count. Kvichak River data courtesy of Alaska Department of Fish and Game, Anchorage, Alaska.

			Age											
			1.2			1.3			2.2			2.3		
Year	Sex		Kvi	LC	Sub	Kvi	LC	Sub	Kvi	LC	Sub	Kvi	LC	Sub
2008	Female	MEF	481	490	501	555	545	547	486	524		538	522	
		Count	549	138	91	156	255	25	6	3		3	2	
	Male	MEF	504	512	515	565	566	574	493	511			564	
		Count	470	131	193	61	258	50	4	8			1	
2009	Female	MEF	500	494	530	565	563	583	506	507	532	605	515	
		Count	171	81	3	237	156	84	360	60	20	3	3	
	Male	MEF	520	515	527	585	583	595	530	529	548	586	580	
		Count	133	104	7	220	128	111	276	63	38	13	4	
2010	Female	MEF	487	505	501	562	568	585	493	522	517	563	557	580
		Count	287	104	57	83	230	74	294	75	22	18	38	8
	Male	MEF	500	530	520	582	590	590	514	549	537	583	598	587
		Count	239	91	81	97	218	95	250	95	37	34	39	25
2011	Female	MEF	496	502	506	570	567	571	509	519	512	573	574	573
		Count	187	129	136	254	236	44	143	43	25	165	35	12
	Male	MEF	513	514	521	591	590	592	531	532	529	595	994	600
		Count	183	120	123	177	224	45	115	56	26	112	39	15

Environmental and Hydrological Observations

Water temperature measured during the operation of the Newhalen River tower from 2008 – 2011 ranged from 6.3 to 14.4° C and water discharge ranged from 13,530 to 23,170 ft³/sec (Figures 13 and 14, Appendix 7). On average, water temperatures were warmer in 2008 and 2009 compared to 2010 and 2011 (Appendix 7).

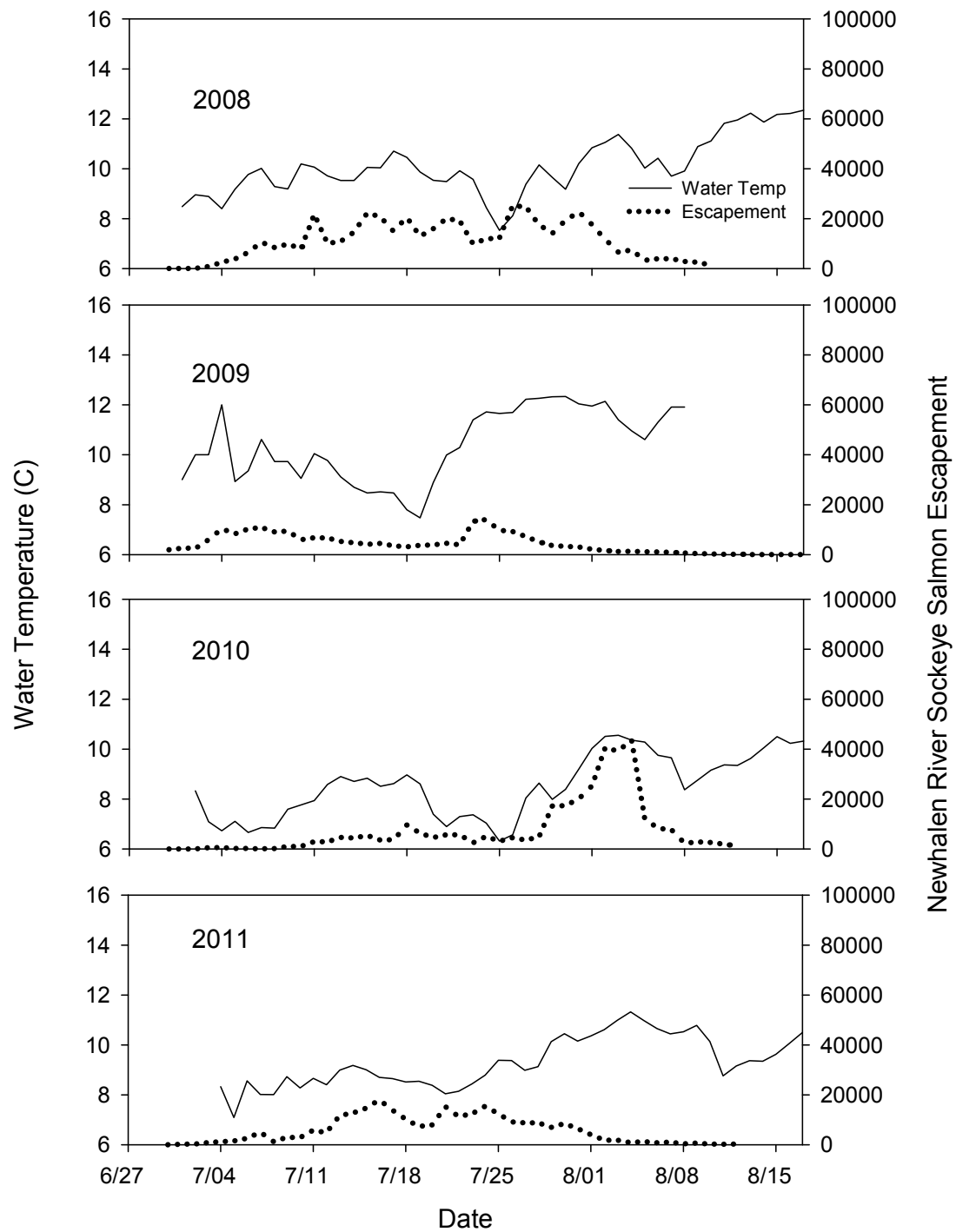


Figure 13. Daily average water temperature and estimated sockeye salmon escapement at the Newhalen River counting tower, 2008 – 2011.

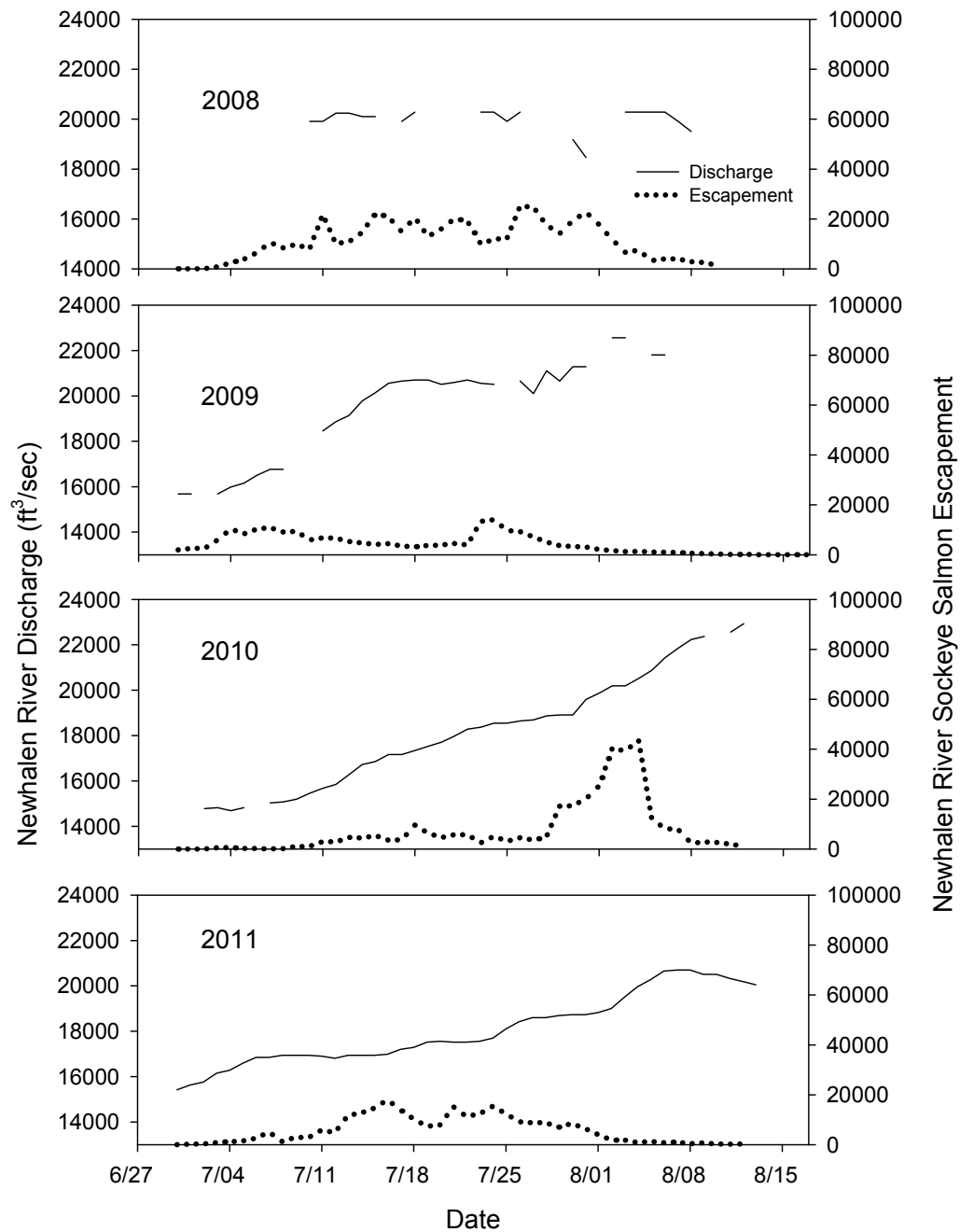


Figure 14. Estimated Newhalen River discharge (ft^3/sec) and sockeye salmon escapement at the Newhalen River counting tower, 2008 – 2011.

DISCUSSION

Compared to previous years, the Lake Clark sockeye salmon escapements during 2008 – 2011 were below average (Figure 15, Appendix 8). During the early 1980s, the Lake Clark escapement was characterized by years of high (1.5 – 3.1 million), medium (0.7 million), and low (0.2 million) escapements. In contrast, the period since 2000 has been relatively stable with low escapements (0.2 – 0.3 million) during 2000 – 2003 and medium (0.5 – 0.7 million) escapements during 2004 – 2007 (Appendix 8). During 2008 – 2011, escapements were more variable but were consistently lower than average; the 2008 – 2011 mean was 72% lower than the 1980 – 1984 mean and 22% lower than the 2000 – 2007 mean escapement. Lower than average escapement counts at the counting towers were consistent with observations made at spawning areas; fewer spawners were observed compared to the period from 2004 – 2007.

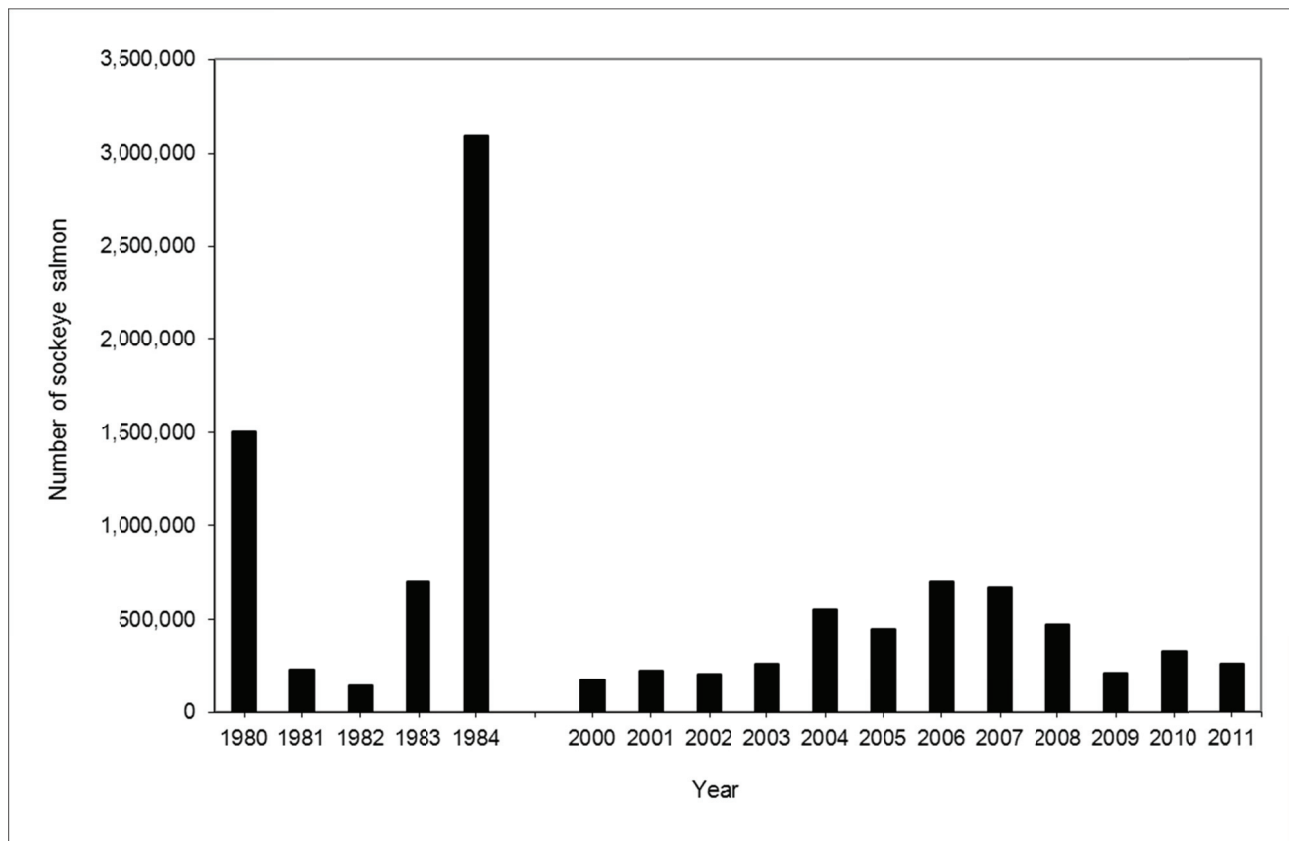


Figure 15. Newhalen River sockeye salmon escapement by year 1980 – 1984 and 2000 – 2011. Data for 1980 – 2007 are from Poe and Rogers (1984), Woody (2004), and Young and Woody (2009).

The relative contribution of Lake Clark escapement to the total Kvichak River escapement was lower during 2008 – 2011 than previous years (Appendix 8). While estimates were within the historical range (7-29%), the average Lake Clark contribution for these years was 31% lower than the period from 1980 – 1984 and 39% lower than the period from 2000 – 2007. Reasons for the relatively low contribution are unknown, but are likely related to differences in freshwater or

marine survival for Lake Clark stocks compared to other Kvichak River stocks. Interannual variability in returns among Bristol Bay stocks is well documented (Schindler et al. 2010) and emphasizes the biological and habitat diversity experienced by sockeye salmon.

In 2009, we were unable to effectively count sockeye salmon after July 22 because of turbid water conditions. As such, the confidence interval around the 2009 estimate is greater than other years (Table 1). The arrival of turbid water at the counting towers was likely the result of several factors. First, the eruption of Redoubt Volcano in the spring of 2009 deposited ash throughout the headwaters of the Lake Clark watershed. This ash likely increased the rate of glacial melt and, when mixed with the glacial runoff, decreased water clarity in Lake Clark (Shearer and Moore 2010). Second, an unusually high wind event in July transported the turbid water down-lake into Sixmile Lake and the Newhalen River. A similar period of poor water clarity in Lake Clark was observed after the 1989/1990 eruption of Redoubt Volcano (Stottlemeyer 1990).

In 2010, the colder than average water temperatures coincided with a later than average run timing. This pattern was also observed in 1982 and 2006 when cooler water and later run timing occurred (Poe and Rogers 1984, Young and Woody 2009). This is consistent with findings elsewhere as colder water temperatures are generally correlated with later run timing (Hodgson and Quinn 2002, Hodgson et al. 2006). However, cooler water in 2011 was not correlated with later run timing. As water temperature and discharge were similar between 2010 and 2011, it is unknown why the run was more protracted in 2010 compared to 2011. The peak summer flow (20,370 to 23,170 ft³/sec) in 2008 – 2011 was similar to previous study years (Poe and Rogers 1984, Young and Woody 2009), and well below the extremely high flows of 1980 (28,000 – 32,568 ft³/sec) that created a velocity barrier to upstream passage of sockeye salmon on the Newhalen River. Generally, daily sockeye salmon escapements appeared more related to fluctuations in daily water temperatures than stream discharge.

Patterns in bank orientation and diurnal migration were similar to past observations at the Newhalen River towers and at other sites within Bristol Bay (Becker 1962, Poe and Rogers 1984, Anderson 2000, Young and Woody 2009). It is unknown why a greater proportion of the escapement migrated upstream past the right bank tower in 2008 and 2009.

The age and size of sockeye salmon sampled from Lake Clark and the Sixmile Lake subsistence fishery were similar to what has been observed previously (Woody 2004, Young and Woody 2009). Since 2000, the age of sockeye salmon sampled has ranged from 3-6 years old with seven different age classes observed (Appendix 9 and 10). From 2008 – 2011 six age classes were observed and 84% were either age 1.2 or 1.3, 11% age 2.2, and 5% age 2.3. The relative contribution of each age class has remained consistent over time with approximately 84% of all sockeye salmon sampled from 2000 – 2007 freshwater age 1 (range 42-96% annually) and the remaining freshwater age 2. Marine age continues to be different between sample types with Lake Clark samples primarily saltwater age 3 (average of all samples = 59%, range 17-94% annually) and subsistence samples primarily saltwater age 2 (average of all samples = 59%, range 20-83% annually). The reason for the different age composition among sample locations is unknown, but as indicated by Young and Woody (2009) may indicate sampling bias with the subsistence fishery catching a greater proportion of fish bound for the Tazimina River rather than Lake Clark.

CONCLUSIONS

1. The 2008 – 2011 mean escapement of sockeye salmon into Lake Clark (316,496) was 22% lower than the 2000 – 2007 mean of 403,991 and 72% lower than the mean escapement of 1,135,464 during 1980 – 1984.
2. The Lake Clark sockeye salmon escapement comprised, on average, 11% of the total Kvichak River system escapement, about 5% less than observed in the 1980s and 8% less than observed during the period from 2000 – 2007.
3. In 2009, turbid water conditions compromised counts after July 22 and escapement after this date was estimated using historical count data.
4. Run timing past the Newhalen River counting towers was similar to previous years except for 2009 when the run appeared to be earlier than average and 2010 when the mid-point of the run was approximately 10 days later than average.
5. The duration of the run ranged from 23 days in 2010 to 34 days in 2008 and 2011; the historical average is 27 days.
6. For all years, except 2008, the age composition of samples from the Kvichak River, Lake Clark, and Sixmile Lake subsistence fishery were significantly different from one another.
7. The age composition of sockeye salmon sampled at Lake Clark spawning areas was generally similar among years with approximately 50% of the samples age 1.3 each year followed by ages 1.2, 2.2, and 2.3.
8. The age composition of sockeye salmon sampled from the Sixmile Lake subsistence fishery varied among years with age 1.2 more abundant in 2008 and 2011 and age 1.3 more abundant in 2009 and 2010.
9. In general, the median lengths of sockeye salmon were similar among age class and sample locations, including those sampled at the Kvichak River.
10. Similar to previous years, sockeye salmon sampled from the subsistence fishery were often significantly larger at age than those sampled from spawning areas, and indicated a bias in fishery samples towards larger fish.
11. Newhalen River surface water temperatures and stream discharge during the study were similar to those recorded in past years and were within normal ranges for sockeye salmon passage.

RECOMMENDATIONS

1. Continue monitoring Lake Clark sockeye salmon escapement to:
 - Provide the basis for Lake Clark abundance, size, and age trend analyses.
 - Supply data for construction of Lake Clark sockeye salmon brood year tables.
 - Provide state and federal managers more complete and accurate data with which to analyze management options for sockeye salmon subsistence, sport, and commercial fisheries.
2. Continue to monitor age and size of sockeye salmon harvested in the upper Newhalen River subsistence fishery to provide data for brood table construction.
3. Continue to monitor age and size of sockeye salmon in the Tazimina River to provide data for brood table construction; over 30 years of age and size data have been collected from this location since 1965.
4. Provide Newhalen River escapement data on the web in a standardized format similar to ADFG's Fish Count website.
5. Compile and standardize historical and contemporary age and size data for the Newhalen River/Lake Clark escapement.
6. Compile and standardize historical and contemporary harvest data for subsistence, commercial and sport fisheries in the Kvichak River drainage.
7. Continue monitoring water temperature and discharge in the Newhalen River.
8. Determine resulting production from adult escapement through implementation of a Lake Clark smolt estimation program.
9. Determine factors affecting growth, freshwater residency, and age at migration of Lake Clark sockeye salmon through analysis of otoliths collected within the drainage since the 1960s.
10. Prepare a synthesis paper that explores the long term trends and factors affecting the escapement, age, and size of Lake Clark sockeye salmon.

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APPENDIX

Appendix 1. Location and dates that Lake Clark spawning areas and the Sixmile Lake subsistence fishery were sampled 2008 – 2011. Latitude and longitude coordinates are reported in decimal degrees and WGS 84 datum.

Water Body	Location	Latitude	Longitude	Dates
Lake Clark	Chi Point	60.075562	-154.604218	9/22 - 10/11
Lake Clark	Chulitna Lodge	60.280749	-154.264898	9/26 - 10/11
Lake Clark	Hatchet Point	60.374555	-153.914123	10/3 - 10/20
Kijik Lake	Kijik Lake	60.287034	-154.344779	9/30 - 10/15
Little Kijik River	Little Kijik River	60.307900	-154.293283	9/30 – 10/3
Little Lake Clark	Little Lake Clark	60.418352	-153.696577	10/6 - 10/17
Sixmile Lake	Sixmile Lake	59.943740	-154.866530	7/10 - 7/28
Sucker Bay Lake	Sucker Bay Lake	60.021547	-154.663638	9/11 - 9/14
Tazimina River	Tazimina River	59.931333	-154.813772	8/29 - 9/9
Tlikakila River	Tlikakila River	60.553744	-153.506704	10/7 - 10/17

Appendix 2. Estimated Lake Clark and Kvichak River sockeye salmon escapement, 1980 – 1984 and 2000 – 2011. Kvichak River data are from the Alaska Department of Fish and Game (2012).

Year	Escapement		% of Kvichak
	Newhalen River ^{abc}	Kvichak River ^d	
1980	1,502,898	22,505,268	7
1981	231,714	1,754,358	13
1982	147,294	1,134,840	13
1983	702,792	3,569,982	20
1984	3,091,620	10,490,670	29
2000	172,902	1,827,780	9
2001	222,414	1,095,348	20
2002	203,682	703,884	29
2003	264,690	1,686,804	16
2004	554,520	5,550,134	10
2005	445,620	2,320,332	19
2006	700,524	3,068,226	23
2007	667,572	2,810,208	24
2008	472,962	2,757,912	17
2009	210,372	2,266,140	9
2010	327,930	4,207,410	8
2011	254,718	2,264,352	11
1980 – 1984 Average	1,135,264	7,891,024	16
2000 - 2007 Average	403,991	2,546,544	16
2008 - 2011 Average	316,496	2,873,954	11
All years	598,482	4,118,450	16

^a 1980 - 1984 data from Poe and Rogers (1984)

^b 2000 - 2003 data from Woody (2004)

^c 2004 - 2007 data from Young and Woody (2009)

^d Alaska Department of Fish and Game (2012)

Appendix 3. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2008. Kvichak River escapement data are from Alaska Department of Fish and Game (2012). Newhalen River counts from 26 July - 10 August were estimated using 20 hr counts that were expanded to 24 hr counts using historical passage rates.

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
6/20	42	42	0.00	0.00				
6/21	36	78	0.00	0.00				
6/22	36	114	0.00	0.00				
6/23	30	144	0.00	0.01				
6/24	132	276	0.01	0.01				
6/25	6	282	0.00	0.01				
6/26	60	342	0.00	0.01				
6/27	1,296	1,638	0.06	0.06				
6/28	6,084	7,722	0.26	0.28				
6/29	2,322	10,044	0.10	0.36				
6/30	36,558	46,602	1.58	1.69	36	36	0.01	0.01
7/1	119,400	166,002	5.15	6.02	36	72	0.01	0.02
7/2	105,030	271,032	4.53	9.83	36	108	0.01	0.02
7/3	60,804	331,836	2.62	12.03	852	960	0.18	0.20
7/4	93,840	425,676	4.04	15.43	2454	3,414	0.52	0.72
7/5	132,642	558,318	5.72	20.24	3858	7,272	0.82	1.54
7/6	265,296	823,614	11.43	29.86	6492	13,764	1.37	2.91
7/7	221,028	1,044,642	9.53	37.88	10524	24,288	2.23	5.14
7/8	115,488	1,160,130	4.98	42.07	8364	32,652	1.77	6.90
7/9	121,740	1,281,870	5.25	46.48	9768	42,420	2.07	8.97
7/10	195,756	1,477,626	8.44	53.58	7,956	50,376	1.68	10.65
7/11	274,878	1,752,504	11.85	63.54	21,762	72,138	4.60	15.25
7/12	261,954	2,014,458	11.29	73.04	10,092	82,230	2.13	17.39
7/13	172,236	2,186,694	7.42	79.29	10,872	93,102	2.30	19.68
7/14	154,908	2,341,602	6.68	84.90	14,568	107,670	3.08	22.77
7/15	128,316	2,469,918	5.53	89.56	22,164	129,834	4.69	27.45
7/16	119,868	2,589,786	5.17	93.90	20,784	150,618	4.39	31.85
7/17	54,786	2,644,572	2.36	95.89	14,916	165,534	3.15	35.00
7/18	36,174	2,680,746	1.56	97.20	20,634	186,168	4.36	39.36
7/19	34,302	2,715,048	1.48	98.45	12,936	199,104	2.74	42.10
7/20	24,054	2,739,102	1.04	99.32	16,008	215,112	3.38	45.48
7/21	11,490	2,750,592	0.50	99.73	20,028	235,140	4.23	49.72
7/22	7,320	2,757,912	0.32	100.00	19,188	254,328	4.06	53.77
7/23					9,978	264,306	2.11	55.88
7/24					11,850	276,156	2.51	58.39
7/25					12,186	288,342	2.58	60.97
7/26					25,104	313,446	5.31	66.27
7/27					24,780	338,226	5.24	71.51
7/28					17,514	355,740	3.70	75.22

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Appendix 3. Continued.

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
7/29					14,112	369,852	2.98	78.20
7/30					19,356	389,208	4.09	82.29
7/31					22,668	411,876	4.79	87.08
8/1					17,640	429,516	3.73	90.81
8/2					11,658	441,174	2.46	93.28
8/3					6,552	447,726	1.39	94.66
8/4					7,440	455,166	1.57	96.24
8/5					3,252	458,418	0.69	96.92
8/6					3,936	462,354	0.83	97.76
8/7					3,960	466,314	0.84	98.59
8/8					2,844	469,158	0.60	99.20
8/9					2,490	471,648	0.53	99.72
8/10					1,314	472,962	0.28	100.00
Totals		2,757,912		100.00		472,962		100.00

Appendix 4. Calculated daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2009. Note: Newhalen River data after 22 July were calculated using the 2000 – 2008 mean proportion of fish that pass the tower after this date. Kvichak River escapement data are from Alaska Department of Fish and Game (2012).

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
6/20	0	0	0.00	0.00				
6/21	330	330	0.01	0.01				
6/22	4464	4,794	0.19	0.21				
6/23	4206	9,000	0.18	0.40				
6/24	594	9,594	0.03	0.42				
6/25	4248	13,842	0.18	0.61				
6/26	36528	50,370	1.57	2.22				
6/27	38472	88,842	1.66	3.92				
6/28	13014	101,856	0.56	4.49				
6/29	3390	105,246	0.15	4.64				
6/30	112410	217,656	4.84	9.60	1,938	1,938	0.92	0.92
7/1	198996	416,652	8.58	18.39	2,550	4,488	1.21	2.13
7/2	271620	688,272	11.71	30.37	2,472	6,960	1.18	3.31
7/3	219396	907,668	9.46	40.05	5,910	12,870	2.81	6.12
7/4	96708	1,004,376	4.17	44.32	10,308	23,178	4.90	11.02
7/5	158004	1,162,380	6.81	51.29	8,334	31,512	3.96	14.98
7/6	184302	1,346,682	7.94	59.43	10,296	41,808	4.89	19.87
7/7	186546	1,533,228	8.04	67.66	10,854	52,662	5.16	25.03
7/8	115128	1,648,356	4.96	72.74	9,018	61,680	4.29	29.32
7/9	99096	1,747,452	4.27	77.11	9,360	71,040	4.45	33.77
7/10	135822	1,883,274	5.85	83.10	5,886	76,926	2.80	36.57
7/11	152244	2,035,518	6.56	89.82	6,774	83,700	3.22	39.79
7/12	71580	2,107,098	3.08	92.98	6,624	90,324	3.15	42.94
7/13	25470	2,132,568	1.10	94.11	5,280	95,604	2.51	45.45
7/14	24120	2,156,688	1.04	95.17	4,698	100,302	2.23	47.68
7/15	50796	2,207,484	2.19	97.41	4,086	104,388	1.94	49.62
7/16	36552	2,244,036	1.58	99.02	4,470	108,858	2.12	51.75
7/17	7362	2,251,398	0.32	99.35	3,474	112,332	1.65	53.40
7/18	5898	2,257,296	0.25	99.61	3,090	115,422	1.47	54.87
7/19	8844	2,266,140	0.38	100.00	3,678	119,100	1.75	56.61
7/20					3,828	122,928	1.82	58.43
7/21					4,524	127,452	2.15	60.58
7/22					3,882	131,334	1.85	62.43
7/23					13,338	144,672	6.34	68.77
7/24					14,016	158,688	6.66	75.43
7/25					9,660	168,348	4.59	80.02
7/26					9,192	177,540	4.37	84.39
7/27					7,140	184,680	3.39	87.79

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Appendix 4. Continued

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
7/28					5,040	189,720	2.40	90.18
7/29					3,564	193,284	1.69	91.88
7/30					3,240	196,524	1.54	93.42
7/31					3,036	199,560	1.44	94.86
8/1					2,088	201,648	0.99	95.85
8/2					1,566	203,214	0.74	96.60
8/3					1,212	204,426	0.58	97.17
8/4					1,332	205,758	0.63	97.81
8/5					1,128	206,886	0.54	98.34
8/6					984	207,870	0.47	98.81
8/7					840	208,710	0.40	99.21
8/8					606	209,316	0.29	99.50
8/9					396	209,712	0.19	99.69
8/10					222	209,934	0.11	99.79
8/11					96	210,030	0.05	99.84
8/12					150	210,180	0.07	99.91
8/13					48	210,228	0.02	99.93
8/14					42	210,270	0.02	99.95
8/15					30	210,300	0.01	99.97
8/16					36	210,336	0.02	99.98
8/17					36	210,372	0.02	100.00
Total		2,266,140		100.00		210,372		100.00

Appendix 5. Calculated daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2010. Kvichak River escapement data are from Alaska Department of Fish and Game (2012).

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
6/20	0	0	0.00	0.00				
6/21	84	84	0.00	0.00				
6/22	12	96	0.00	0.00				
6/23	12	108	0.00	0.00				
6/24	30	138	0.00	0.00				
6/25	390	528	0.02	0.01				
6/26	840	1,368	0.04	0.03				
6/27	474	1,842	0.02	0.04				
6/28	966	2,808	0.04	0.07				
6/29	13770	16,578	0.59	0.39				
6/30	68622	85,200	2.96	2.02	0	0	0.00	0.00
7/1	109290	194,490	4.71	4.62	0	0	0.00	0.00
7/2	102336	296,826	4.41	7.05	0	0	0.00	0.00
7/3	45774	342,600	1.97	8.14	522	522	0.16	0.16
7/4	42456	385,056	1.83	9.15	564	1,086	0.17	0.33
7/5	162894	547,950	7.02	13.02	174	1,260	0.05	0.38
7/6	261054	809,004	11.25	19.23	120	1,380	0.04	0.42
7/7	269910	1,078,914	11.63	25.64	18	1,398	0.01	0.43
7/8	426630	1,505,544	18.39	35.78	114	1,512	0.03	0.46
7/9	528822	2,034,366	22.79	48.35	1,020	2,532	0.31	0.77
7/10	373512	2,407,878	16.10	57.23	996	3,528	0.30	1.08
7/11	368334	2,776,212	15.87	65.98	2,928	6,456	0.89	1.97
7/12	289470	3,065,682	12.48	72.86	2,784	9,240	0.85	2.82
7/13	399252	3,464,934	17.21	82.35	4,602	13,842	1.40	4.22
7/14	371706	3,836,640	16.02	91.19	4,350	18,192	1.33	5.55
7/15	181416	4,018,056	7.82	95.50	5,346	23,538	1.63	7.18
7/16	84918	4,102,974	3.66	97.52	3,456	26,994	1.05	8.23
7/17	52794	4,155,768	2.28	98.77	3,690	30,684	1.13	9.36
7/18	31440	4,187,208	1.35	99.52	9,582	40,266	2.92	12.28
7/19	15258	4,202,466	0.66	99.88	6,312	46,578	1.92	14.20
7/20	4,944	4,207,410	0.21	100.00	4,566	51,144	1.39	15.60
7/21					5,670	56,814	1.73	17.33
7/22					5,652	62,466	1.72	19.05
7/23					2,472	64,938	0.75	19.80
7/24					5,034	69,972	1.54	21.34
7/25					3,042	73,014	0.93	22.27
7/26					4,476	77,490	1.36	23.63
7/27					3,540	81,030	1.08	24.71

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Appendix 5. Continued

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
7/28					4,956	85,986	1.51	26.22
7/29					17,142	103,128	5.23	31.45
7/30					17,358	120,486	5.29	36.74
7/31					20,100	140,586	6.13	42.87
8/1					25,254	165,840	7.70	50.57
8/2					40,434	206,274	12.33	62.90
8/3					39,156	245,430	11.94	74.84
8/4					43,770	289,200	13.35	88.19
8/5					12,216	301,416	3.73	91.91
8/6					8,112	309,528	2.47	94.39
8/7					7,824	317,352	2.39	96.77
8/8					2,298	319,650	0.70	97.48
8/9					2,772	322,422	0.85	98.32
8/10					2,574	324,996	0.78	99.11
8/11					1,902	326,898	0.58	99.69
8/12					1,032	327,930	0.31	100.00
Total		4,207,410		100.00		327,930		100.00

Appendix 6. Calculated daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2011. Kvichak River escapement data are from Alaska Department of Fish and Game (2012).

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
6/20	0	0	0.00	0.00				
6/21	0	0	0.00	0.00				
6/22	150	150	0.01	0.01				
6/23	24	174	0.00	0.01				
6/24	30	204	0.00	0.01				
6/25	0	204	0.00	0.01				
6/26	18	222	0.00	0.01				
6/27	60	282	0.00	0.01				
6/28	24,990	25,272	1.08	1.12				
6/29	183,318	208,590	7.90	9.21				
6/30	237,216	445,806	10.22	19.69	0	0	0.00	0.00
7/1	175,224	621,030	7.55	27.43	264	264	0.10	0.10
7/2	164,916	785,946	7.11	34.71	282	546	0.11	0.21
7/3	219,726	1,005,672	9.47	44.41	864	1,410	0.34	0.55
7/4	215,136	1,220,808	9.27	53.91	1,212	2,622	0.48	1.03
7/5	213,144	1,433,952	9.19	63.33	1,476	4,098	0.58	1.61
7/6	146,418	1,580,370	6.31	69.79	2,598	6,696	1.02	2.63
7/7	67,788	1,648,158	2.92	72.79	5,040	11,736	1.98	4.61
7/8	46,344	1,694,502	2.00	74.83	1,212	12,948	0.48	5.08
7/9	16,260	1,710,762	0.70	75.55	2,988	15,936	1.17	6.26
7/10	37,572	1,748,334	1.62	77.21	2,820	18,756	1.11	7.36
7/11	88,410	1,836,744	3.81	81.12	5,850	24,606	2.30	9.66
7/12	45,966	1,882,710	1.98	83.15	4,836	29,442	1.90	11.56
7/13	88,950	1,971,660	3.83	87.07	11,712	41,154	4.60	16.16
7/14	75,312	2,046,972	3.25	90.40	12,690	53,844	4.98	21.14
7/15	80,700	2,127,672	3.48	93.96	14,610	68,454	5.74	26.87
7/16	76,680	2,204,352	3.30	97.35	17,988	86,442	7.06	33.94
7/17	43,104	2,247,456	1.86	99.25	13,776	100,218	5.41	39.34
7/18	8,544	2,256,000	0.37	99.63	10,278	110,496	4.04	43.38
7/19	3,390	2,259,390	0.15	99.78	7,302	117,798	2.87	46.25
7/20	4,962	2,264,352	0.21	100.00	7,932	125,730	3.11	49.36
7/21					15,234	140,964	5.98	55.34
7/22					11,274	152,238	4.43	59.77
7/23					12,396	164,634	4.87	64.63
7/24					15,408	180,042	6.05	70.68
7/25					12,450	192,492	4.89	75.57
7/26					9,138	201,630	3.59	79.16
7/27					8,838	210,468	3.47	82.63

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Appendix 6. Continued.

Date	Kvichak River				Newhalen River			
	Daily Count	Cumulative Count	Percent of Total		Daily Count	Cumulative Count	Percent of Total	
			Daily	Cumulative			Daily	Cumulative
7/28					8,826	219,294	3.47	86.09
7/29					6,990	226,284	2.74	88.84
7/30					8,502	234,786	3.34	92.17
7/31					6,438	241,224	2.53	94.70
8/1					4,002	245,226	1.57	96.27
8/2					1,872	247,098	0.73	97.01
8/3					1,830	248,928	0.72	97.73
8/4					816	249,744	0.32	98.05
8/5					1,266	251,010	0.50	98.54
8/6					798	251,808	0.31	98.86
8/7					1,044	252,852	0.41	99.27
8/8					420	253,272	0.16	99.43
8/9					678	253,950	0.27	99.70
8/10					276	254,226	0.11	99.81
8/11					210	254,436	0.08	99.89
8/12					282	254,718	0.11	100.00
		2,264,352		100.00		254,718		100.00

Appendix 7. Percent of fish counted at the Newhalen River counting towers by hour and bank, 2008 - 2011. Left Bank (LB) and Right Bank (RB) orientation are for observer looking downstream. Note: 2008 data are only through July 26 and 2009 data are through July 22.

Hour	2008		2009		2010		2011	
	LB	RB	LB	RB	LB	RB	LB	RB
0	0.15	0.01	0.50	0.02	0.66	0.06	1.08	0.05
1	0.30	0.02	0.83	0.16	0.62	0.08	0.72	0.07
2	0.47	0.08	0.60	0.16	0.65	0.06	1.57	0.09
3	0.43	0.02	0.78	0.19	0.77	0.06	1.01	0.06
4	1.13	0.06	2.31	0.12	0.78	0.04	2.08	0.04
5	2.03	0.16	4.12	0.87	1.06	0.06	2.62	0.13
6	5.28	0.20	3.32	0.42	6.56	0.03	4.94	0.16
7	5.83	0.37	4.17	0.60	6.15	0.15	4.37	0.27
8	5.30	0.44	4.27	1.03	5.47	0.16	5.93	0.47
9	5.45	0.43	5.36	1.38	5.38	0.29	5.44	0.21
10	6.50	0.47	6.26	0.90	8.89	0.35	8.21	0.31
11	6.41	0.45	5.25	0.98	8.91	0.35	7.22	0.19
12	6.63	0.46	4.61	0.80	6.66	0.24	4.24	0.25
13	5.97	0.89	4.08	1.09	6.32	0.25	4.02	0.51
14	7.62	0.81	3.53	1.92	7.55	0.15	6.48	0.31
15	7.95	1.10	3.33	1.03	7.16	0.07	5.26	0.40
16	4.55	0.85	4.74	1.69	4.51	0.09	4.62	0.36
17	4.32	0.50	4.09	0.70	5.28	0.09	4.88	0.24
18	3.68	0.56	5.22	1.00	3.29	0.07	4.99	0.25
19	3.48	0.21	4.09	0.70	2.92	0.08	4.76	0.30
20	2.81	0.19	4.28	0.40	1.88	0.06	3.46	0.19
21	2.50	0.09	3.35	0.40	2.26	0.05	3.12	0.15
22	1.38	0.10	1.80	0.45	1.91	0.12	1.87	0.30
23	1.35	0.04	2.01	0.06	1.34	0.04	1.78	0.01
Total	91.50	8.50	82.91	17.09	96.99	3.01	94.68	5.32

Appendix 8. Daily average water temperature (C) and discharge (ft³/sec) recorded at the Newhalen River counting tower, 2008 – 2011.

Date	Water Temperature (C)				Discharge (ft ³ /sec)			
	2008	2009	2010	2011	2008	2009	2010	2011
6/30						15,940	14,520	15,420
7/1	8.5					15,890	14,610	15,630
7/2	9.0		8.3		18,460		14,950	15,760
7/3	8.9		7.1			15,940	15,030	16,150
7/4	8.4	10.4	6.7	7.4		16,280	14,860	16,280
7/5	9.2	8.9	7.1	7.6		16,450	15,030	16,590
7/6	9.8	9.4	6.7	7.8		16,940		16,850
7/7	10.0	10.6	6.9	7.7		17,290	15,200	16,850
7/8	9.3	9.7	6.8	6.8		16,810	15,250	16,940
7/9	9.2	9.7	7.6	6.4			15,420	16,940
7/10	10.2	9.1	7.8	6.6	19,910		15,630	16,940
7/11	10.1	10.0	7.9	7.5	19,910	18,100	15,850	16,900
7/12	9.7	9.8	8.6	8.0	20,240	18,510	16,020	16,810
7/13	9.5	9.1	8.9	8.8	20,240	19,090	16,450	16,940
7/14	9.5	8.7	8.7	9.5	20,100	19,410	16,900	16,940
7/15	10.1	8.5	8.8	9.7	20,100	19,780	17,030	16,940
7/16	10.0	8.5	8.5	9.4		20,190	17,340	16,990
7/17	10.7	8.5	8.6	8.6	19,910	20,280	17,340	17,210
7/18	10.5	7.8	9.0	8.4	20,280	20,330	17,520	17,290
7/19	9.9	7.5	8.6	8.1		20,330	17,700	17,520
7/20	9.5	8.9	7.4	8.3		20,140	17,920	17,560
7/21	9.5	10.0	6.9	8.9	20,370	20,240	18,150	17,520
7/22	9.9	10.3	7.3	8.8		20,280	18,460	17,520
7/23	9.6	11.4	7.4	9.2	20,280	20,190	18,550	17,560
7/24	8.4	11.7	7.0	8.7	20,280	20,100	18,730	17,700
7/25	7.5	11.7	6.3	8.5	19,910		18,730	18,100
7/26	8.1	11.7	6.6	8.3	20,280	20,280	18,820	18,420
7/27	9.4	12.2	8.0	9.1		19,680	18,910	18,600
7/28	10.2	12.3	8.6	9.6		19,910	19,050	18,600
7/29	9.7	12.3	8.0	10.5		20,280	19,090	18,690
7/30	9.2	12.3	8.4	10.6	19,180	20,880	19,090	18,730
7/31	10.2	12.0	9.2	10.6	18,460	20,930	19,780	18,730
8/1	10.8	12.0	10.0	9.6			20,050	18,820
8/2	11.1	12.1	10.5	9.4		22,130	20,370	19,000
8/3	11.4	11.4	10.6	9.9	20,280	22,130	20,370	19,500
8/4	10.8	11.0	10.4	10.5	20,280		20,700	19,960
8/5	10.0	10.6	10.3	9.5	20,280	21,340	21,060	20,280
8/6	10.4	11.3	9.7	8.8	20,280	21,340	21,620	20,650
8/7	9.7	11.9	9.7	9.1	19,910		22,040	20,700
8/8	9.9	11.9	8.4	9.2	19,500		22,420	20,700
8/9	10.9		8.8	8.5			22,560	20,510
8/10	11.1		9.2	9.4				20,510
8/11	11.8		9.4	10.0			22,750	20,330
8/12	12.0		9.3	10.5			23,170	20,190

Appendix 9. Continued

Brood Year	Sample type	Age														Total
		1.1		1.2		1.3		1.4		2.1		2.2		2.3		
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	
2004	Lake Clark			269	35.7	284	37.7					123	16.3	77	10.2	753
	Subsistence			284	49.8	195	34.2					58	10.2	33	5.8	570
2005	Lake Clark	1	0.1	186	21.2	448	51.0					170	19.3	74	8.4	879
	Subsistence			10	3.8	169	63.8					59	22.3	27	10.2	265
2006	Lake Clark			195		460						99				754
	Subsistence			138	48.1	89	31.0					51	17.8	9	3.1	287
2007	Lake Clark			249						3						252
	Subsistence			259												259
All years	Lake Clark	2		3,465		5,261		4		3		1,141		646		10,522
	Subsistence	0		2,975		2,459		2		0		720		236		6392
	Both	2		6,440		7,720		6		3		1,861		882		16,914

Appendix 10. Continued

Brood Year	Sample type	Age												Total		
		1.1		1.2		1.3		1.4		2.1		2.2			2.3	
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%		Count	%
2004	Lake Clark			269	35.7	284	37.7					123	16.3	77	10.2	753
	Subsistence			284	49.8	195	34.2					58	10.2	33	5.8	570
2005	Lake Clark	1	0.1	186	21.2	448	51.0					170	19.3	74	8.4	879
	Subsistence			10	3.8	169	63.8					59	22.3	27	10.2	265
2006	Lake Clark			195		460						99				754
	Subsistence			138		89						51				278
2007	Lake Clark			249						3						252
	Subsistence			259												259
All years	Lake Clark	2		3465		5261			4	3		1141		646		10522
	Subsistence			2975		2459			2			720		236		6392
	Both	2		6440		7720			6	3		1861		882		16914

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