Lake Clark Sockeye Salmon Escapement and Population Monitoring

Annual Report for Study FIS 05-402

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ABSTRACT

Sockeye salmon originating from the Kvichak River watershed historically dominated valuable subsistence, sport, and commercial fisheries in Bristol Bay, Alaska. The recent decline in sockeye salmon runs to Bristol Bay has caused economic hardship and raised concerns among fishers and federal managers. Obtaining reliable estimates of spawning escapement over time is the number one priority identified by the Subsistence Fisheries Resource Monitoring Program for Bristol Bay. Estimates of sockeye salmon escapement to Lake Clark were made at river kilometer 36 of the Newhalen River using the same tower site and protocols that were used in previous studies. Sockeye salmon ages and size were determined from otoliths collected from the Newhalen River subsistence fishery and by seines. Total Lake Clark escapement, based on expanded counts was estimated as 445,608 fish (95% confidence interval (CI), 429,560 – 461,656), which was 19% of the total Kvichak River escapement. The age composition of sampled fish was predominately age 1.3 (63%) followed by age 1.2 (23%), age 2.3 (10%), and age 2.2 (5%). The 2005 Lake Clark escapement was 57% higher than the mean escapement from 2000 – 2004, but 61% lower than the mean escapement from 1980 – 1984. Lake Clark escapement comprised 19% of the total Kvichak River escapement, which is similar to the average percentage reported in the 1980s (16%) and 2000s (17%). Run timing, water temperatures and stream discharge were similar to what has been reported in previous years.

INTRODUCTION

The world’s largest most valuable sockeye salmon fisheries occur in Bristol Bay, Alaska, and fish originating in the Kvichak River watershed (Figure 1) historically dominated regional harvests (Forrester 1987, Dunaway and Sonnichsen 2001, Fall et al. 2001, Westing et al. 2005). During 1984–2003 the largest subsistence harvest for sockeye salmon in Bristol Bay took place in the Kvichak River drainage and fishers averaged about 62,000 fish during 1984 – 2003 (Fall et al. 2001, Westing et al. 2005). The sockeye salmon sport fish harvest averaged about 8,000 fish during 1974 – 1998, making it the largest recreational fishery in Bristol Bay (Dunaway and Sonnichsen 2001) while commercial harvest averaged 8.1 million sockeye salmon during 1980 – 1995, making it the dominant producer of sockeye salmon in the region (Forrester 1987, ADF&G 2002).

Since 1996, sockeye salmon returns to the Kvichak River and Lake Clark watersheds have declined for unknown reasons. The Kvichak River escapement (Fair 2003, Figure 2) has been below the minimum escapement goal in four of the last five years (Westing et al. 2005) and the average escapement of sockeye salmon to Lake Clark during 2000 – 2004 was about 75% lower than was documented during 1980 – 1984 (Poe and Rogers 1984, Woody 2004, NPS unpublished data). The decline has affected subsistence, commercial, 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 weak salmon runs and poor prices in 1997, 1998, 2001, and 2002. Annual subsistence harvests declined from a mean of 75,000 salmon during 1974 – 1995, to a mean of 50,000 salmon during 1996 – 2000 and interviews with subsistence fishers indicated catch per unit effort also declined (ADF&G 2001, Fall et al. 2001). Mean sport fish harvest declined due to fishing closures and bag limit reductions (e.g., ADF&G[a], ADF&G[b]), and commercial catches fell from a 1980 – 1995 mean of

8.1 million to a 1996 – 2003 mean of 1.4 million (ADF&G 2004). Economic and ecologic impacts have not yet been quantified and both the Bristol Bay economy and sockeye salmon production from the Kvichak River watershed remain depressed.

Poor returns of salmon across much of western Alaska in 1996 and 1997 suggest marine factors played a role in Kvichak River salmon declines (see review by Kruse 1998). However, freshwater factors may also be involved since escapements to nearby Naknek and the Alagnak River, a tributary to the Kvichak River, are increasing while escapement to the Kvichak River is not. The Naknek River run has increased by about a million fish annually since 1997 (ADF&G 2002) and the Alagnak River had an escapement of 3.8 million sockeye salmon in 2003 (ADF&G 2004), while the Kvichak River only had an escapement of 1.3 million in 2003. Improved information on important component populations will provide managers with a better understanding of population dynamics within the Kvichak system and enable them to make more informed decisions.

The Kvichak River watershed contains two large lake systems, Lake Clark and Iliamna Lake, in which sockeye salmon spawn and rear (Figure 1). Lake Clark is a smaller watershed (9,583 km^2) than Iliamna Lake (11,137 km^2; Demory et al. 1964) and is also less productive due to the influence of active glaciers that make it colder and more turbid (Mathisen and Poe 1969). Despite these characteristics, salmon originating from the Lake Clark drainage have comprised a substantial proportion of the total Kvichak River run (Poe and Rogers 1984, Woody 2004). Escapement monitoring on the upper Newhalen River indicates that Lake Clark contributes 7–30% (0.2 – 3.1 million) to the total Kvichak River escapement (Poe and Rogers 1984, Woody 2004). The ability to track proportional contribution made by the two largest spawning and rearing lakes within the Kvichak River watershed should allow managers to consider component population dynamics in decisions and planning, and may help investigators focus attention on factors contributing to these dynamics.

OBJECTIVES

1) Estimate sockeye salmon escapement to Lake Clark.
2) Determine age and size composition of the Lake Clark escapement

METHODS

Lake Clark Sockeye Salmon Escapement

Lake Clark sockeye salmon escapement estimates were made at river kilometer 36 (Figure 3) on the Newhalen River, using standard ADF&G protocols outlined in Anderson (2000). We used the same site and specific procedures outlined by Poe and Rogers (1984) and used by Woody (2004). Systematic, hourly, 10 minute counts were made from 6 m towers on both banks between 29 June and 7 August 2005. Night counts (00:00 – 04:00 hours) were made using rheostat controlled 12 volt lights powered by solar charged car batteries. 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. 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. in press). Variance estimator '5' in Wolter (1984) was used because of its robustness against underlying autocorrelation, stratification, and nonlinear trends (Reynolds et al. in press). 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). Escapement monitoring was terminated for the season when daily escapement on at least three consecutive days was less than one percent of the total escapement (Anderson 2000).

An estimate of Iliamna Lake escapement was made for comparative purposes, by subtracting the total annual Lake Clark escapement estimate from the total annual Kvichak River escapement estimate. This estimate did not include fish spawning in the lower Newhalen River, Alexi Creek and Alexi lakes component, Lover's Creek Little Bear Creek and pond, and Steambath Creek. Contribution by these populations is negligible as peak index counts made since 1996 indicate combined peak escapement to these areas is less than 6,000 sockeye salmon (Regnart 1998; ADF&G, Anchorage, Alaska, unpublished aerial escapement data).

Lake Clark Sockeye Salmon Age and Size Composition

Age and size composition of the 2005 Lake Clark escapement were determined by sampling pre-spawning sockeye salmon from subsistence gillnets in the community of Nondalton (Figure 3) and by seine hauls. Samples were obtained from 7−28 July, 2005. Otoliths were extracted and ages were determined by a contracted professional reader (Brenda Rogers, Fisheries Research Institute, University of Washington, Seattle, Washington). 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 ADF&G, MEH measures were converted to MEF estimates using regression equations derived by Woody (2004). These equations were derived from 1005 paired measures of MEH and MEF collected in 2000 and 2001. The conversion equation for females ($r^2 = 0.96$; SE = 8.32) was:

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

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

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

All data were entered, checked for errors three times and saved in an ACCESS database.

Environmental and Hydrological Observations

Surface water temperature and stream discharge data were collected at the Newhalen River escapement monitoring site. Water temperature was recorded every two hours from 1 July to 5 August, 2005 with a Stowaway Tidbit temperature logger (Onset Computer Corporation, Bourne, Massachusetts) and an average daily water temperature was calculated. Staff gage measurements at the counting tower site were used to estimate discharge in the Newhalen River as outlined by

Poe and Rogers (1984). The regression equation derived by Poe and Rogers (1984) used to calculate equivalent stage height/discharge at the USGS gage on the Newhalen River was:

$$Y = .9759 = .8143(x) \tag{3}$$

RESULTS AND DISCUSSION

Lake Clark Sockeye Salmon Escapement

In 2005, sockeye salmon escapement monitoring on the Newhalen River began on 29 June and ended at 0000 on August 6 (Appendix 1). Total passage, based on expanded counts was estimated as 445,608 fish (95% confidence interval (CI), 429,560 – 461,656), which was 19% of the total Kvichak River escapement of 2,320,320 sockeye salmon (Appendix 2). The Lake Clark escapement lagged behind the Kvichak River escapement by 13 days with the first salmon observed past the Newhalen River tower on 30 June and 50% of the cumulative escapement on 21 July (Figure 4 and 5, Appendix 1). The 2005 escapement to Lake Clark was 57% higher than the recent (2000 – 2004) mean of 283,639 (Figure 6, Appendix 3; Woody 2004, NPS unpublished data), but 61% lower than the mean escapement of 1,135,464 during 1980 – 1984 (Poe and Rogers 1984). The relative contribution of Lake Clark to overall Kvichak River escapement in 2005 (19%) was similar to contributions documented from 1980 – 1984 (16%) and 2000 – 2004 (17%; Appendix 3). Run timing past the Newhalen River towers in 2005 was similar to that documented since 2000 (Figure 7).

Low escapements to Lake Clark may have long term effects on salmon productivity as a result of 1) reduced marine derived nutrients (MDN) due to fewer salmon carcasses, 2) loss of genetic diversity due to low spawning populations size, and 3) degradation of spawning habitats due to reduced spawner densities. Sockeye salmon gain about 99% of their body weight in the ocean (Burgner 1991), and the nutrients in their bodies enter both freshwater and terrestrial food webs when they return to spawn in freshwater and then die (Cederholm et al. 2000, Burgner 1991, Koenings and Burkett 1987, Willson and Halupka 1995, Finney et al. 2000). Kline et al. (1993) found that MDN levels in Iliamna Lake sockeye salmon fry were dependent on adult escapement abundance and were important for maintaining sockeye salmon production. Both Lake Clark and Iliamna Lake are oligotrophic, or “nutrient poor”, so MDN inputs can be important to freshwater sockeye salmon productivity. Lake Clark and the upper Newhalen River provide habitat for about 38 known sockeye salmon spawning populations (Demory et al. 1964, Anderson 1968, Young 2004) that exhibit some of the highest levels of genetic population structuring observed within a lake (Ramstad et al. 2004). Genetic bottlenecks, which indicate a loss of genetic diversity due to reduced spawning population numbers (Futuyma 1986), have been observed within both Lake Clark (Ramstad et al. 2004) and Iliamna Lake (Habicht et al. 2004) stocks. Continued low escapement to the greater Kvichak River watershed could contribute to further reductions in genetic diversity if component spawning populations are reduced to very low levels. Continued low salmon escapements may also contribute to a decline in spawning habitat quality and reduced embryo survival as large spawning events by salmon help remove fine sediments from spawning areas, which increases gravel permeability (Kondolf et al. 1993), and improve stream bed resistance to scour by coarsening gravel (Montgomery et al. 1996). As recommended by Rogers and Poe (1984), Kline et al. (1993), and Woody (2004), spawning escapements into the Kvichak River should be increased from the current mimimun goal of 2 million to at least 4 million, with attempts to obtain up to 10 million sockeye salmon whenever possible. This would increase available MDN, maintain population genetic diversity and overall population health, and aid in maintenance of spawning habitats.

Lake Clark Sockeye Salmon Age and Size Composition

A total of 860 sockeye salmon were sampled from the local Nondalton subsistence gillnet fishery and beach seine catches made during this project. Of the samples collected, 495 were female and 365 were male. Age 1.3 fish predominated followed by age 1.2 fish (Table 1). The length of sampled fish ranged from 471 to 654 mm with a mean length of 574 mm (Figure 8, Table 2). Sockeye salmon sampled from subsistence gill nets were significantly (ANOVA, $P<0.05$) larger than those captured with a seine (Table 2). Differences observed in size composition by gear type suggest that our estimates of size at maturity may be biased high. Gear selectivity is well documented, with gill nets generally having a bias to catching larger fish than beach seines (Hubert 1996).

Environmental and Hydrological Observations

Water temperature and stream discharge during the operation of the Newhalen River counting tower ranged from 7.6 to 14.6° C (average , 11.8° C) and 19,180 – 22,510 ft^3/sec (average, 21,310 ft^3/sec; Figure 9 and 10, Appendix 3). Newhalen River surface water temperature fluctuated through the counting season with high temperatures on 8 July, 22 July, and 4 August (Figure 9). Decreases in water temperatures starting on 9 July and 21 August may indicate an increased contribution of cooler glacial water from Lake Clark to the Newhalen River. Water temperatures were similar to those recorded at this site in the 1980s (Poe and Rogers 1984) as well as to those recorded in other sockeye salmon systems (Hodgson and Quinn 2002). The peak summer flow of 22,510 ft^3/sec, recorded at the monitoring site on 13 July, was lower than t flows measured by Poe and Rogers (1984) and well below the high flows of 1980 (28,000 – 32,568 ft^3/sec) that created a velocity barrier for upstream passage of sockeye salmon on the Newhalen River.

CONCLUSIONS

1. Lake Clark sockeye salmon escapements remain at lower levels than those observed in the 1980s. While the 2005 Lake Clark escapement was 57% higher than the 2000-2004 mean escapement, it was 61% lower than the 1980-1984 mean escapement.

2. The 2005 sockeye salmon escapement into Lake Clark comprised 19% of the total Kvichak River escapement, which was similar to its contribution in the 1980s (16%) and 2000s (17%).

3. Run timing past the Newhalen River monitoring site was similar to that observed during 2000 – 2004. Peak escapement occurred on 22 July, and timing lagged 13 days behind that at the Kvichak River tower site.

4. Newhalen River surface water temperatures and stream discharge were similar to those recorded in past years and seem to be within normal ranges for sockeye salmon passage.

ACKNOWLEDGEMENTS

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This project would not have been possible without the support and participation of the wonderful people of Nondalton. Special thanks to June and Bob Tracy who continue to provide a base camp for all tower operations. Olga and Kristy Balluta shared their home, provided meals and support to weary field crews. The Kijik Corporation permitted use of tribal lands for field operations and gave written support for this project. Special thanks to the Nondalton Tribal Council and Regional Advisory Council for their continued support.

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FIGURES AND TABLES

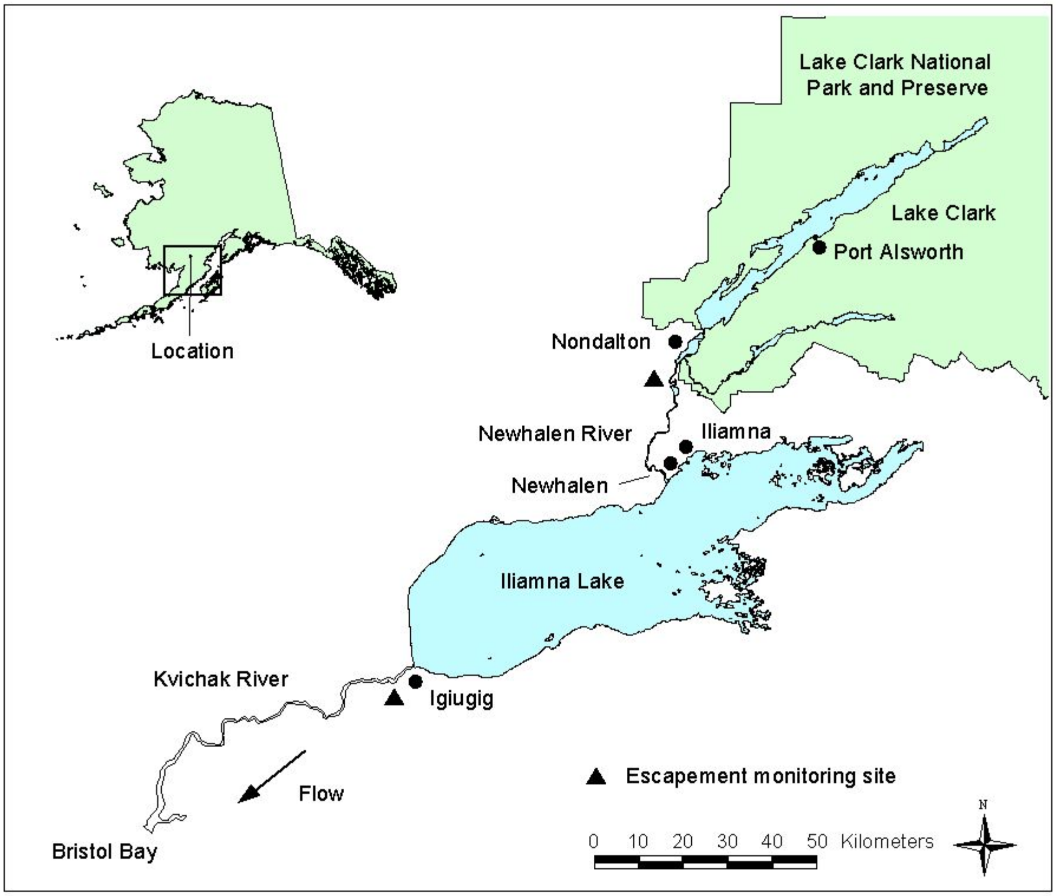

Figure 1. Location of the Kvichak and Newhalen River escapement monitoring sites within the Kvichak River drainage. The monitoring site located by the community of Igiugig is operated by the Alaska Department of Fish and Game.

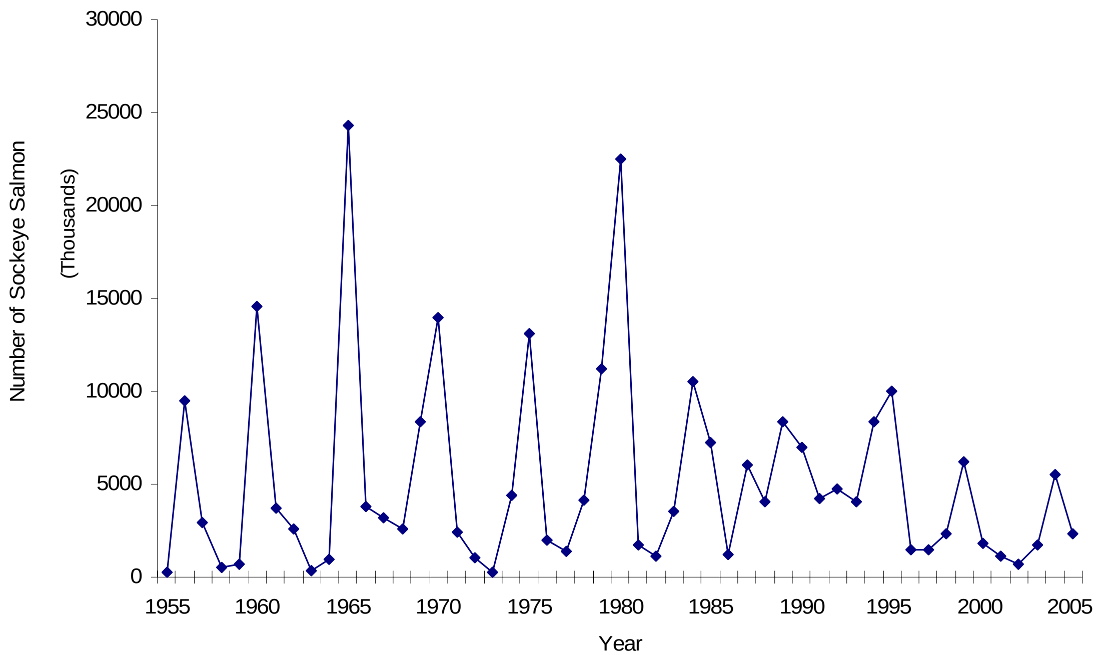

Figure 2. Annual sockeye salmon escapements to the Kvichak River, 1955 to 2005. Data provided by the Alaska Department of Fish and Game, Anchorage, Alaska.

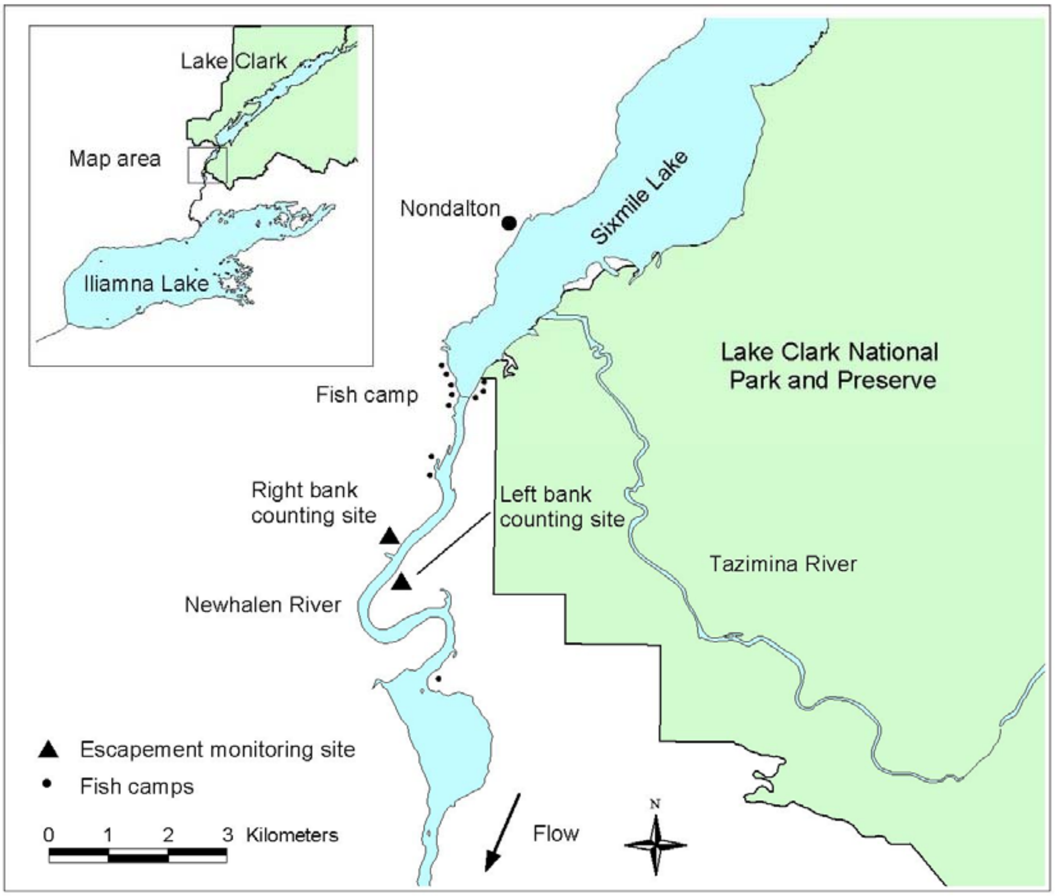

Figure 3. Location of the Newhalen River escapement monitoring sites.

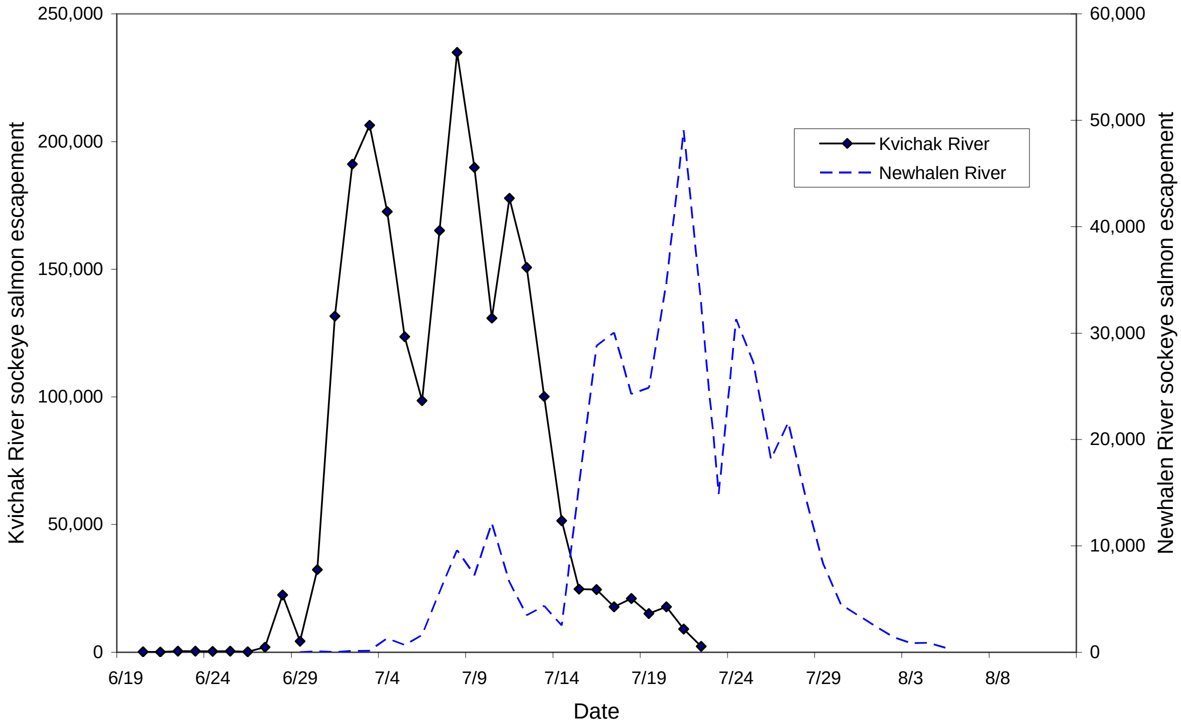

Figure 4. Daily sockeye salmon escapement to the Kvichak and Newhalen Rivers, 2005. Kvichak River data provided by the Alaska Department of Fish and Game, Anchorage, Alaska.

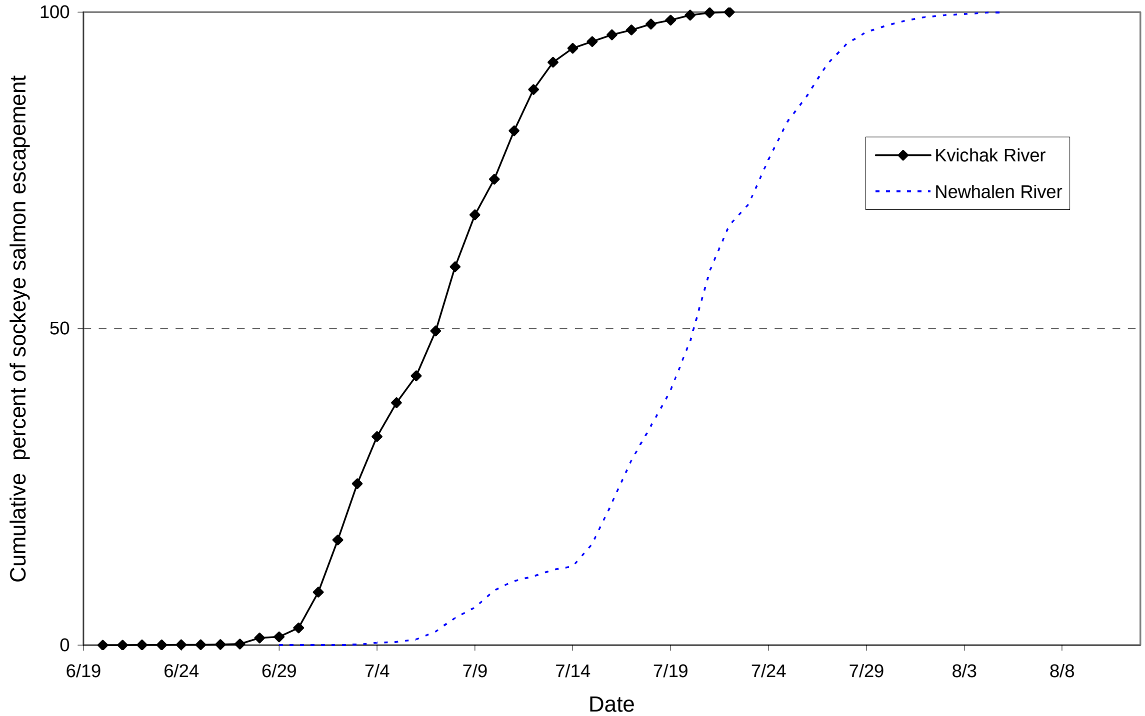

Figure 5. Cumulative percent of total sockeye salmon escapement to the Kvichak and Newhalen Rivers by date, 2005. Kvichak River escapement data provided by the Alaska Department of Fish and Game.

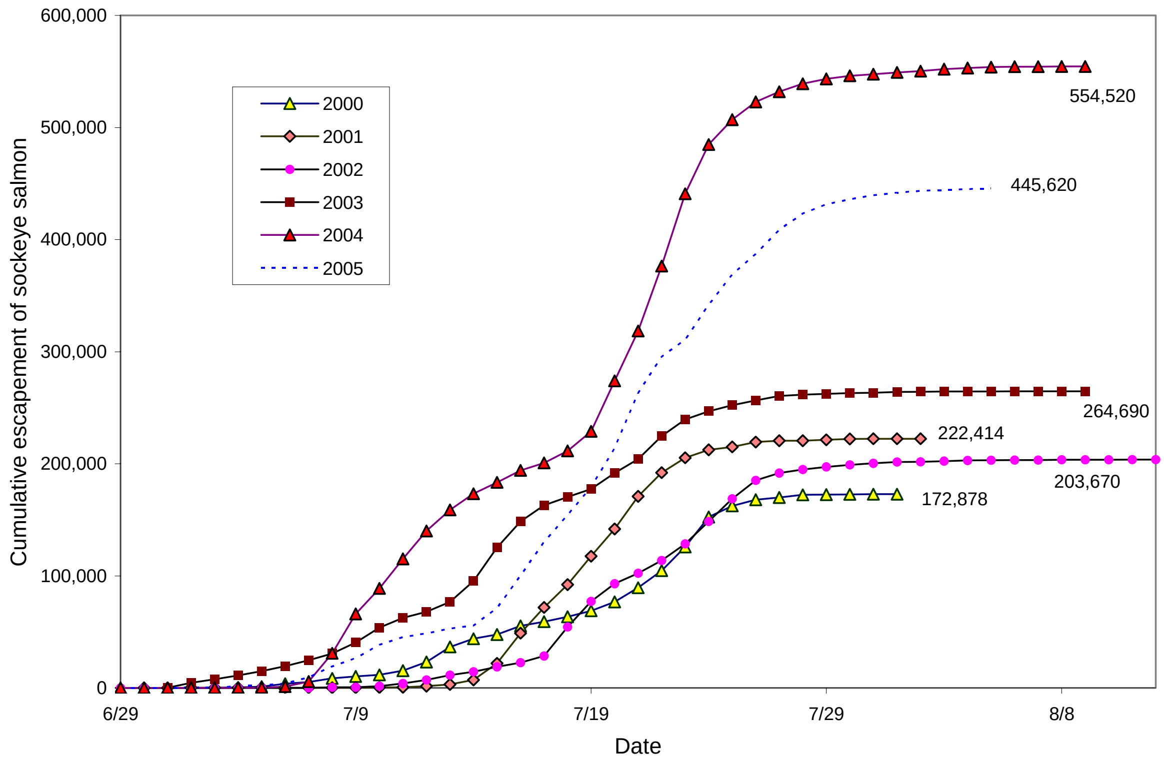

Figure 6. Cumulative escapement of sockeye salmon at the Newhalen River monitoring site, 2000 – 2005.

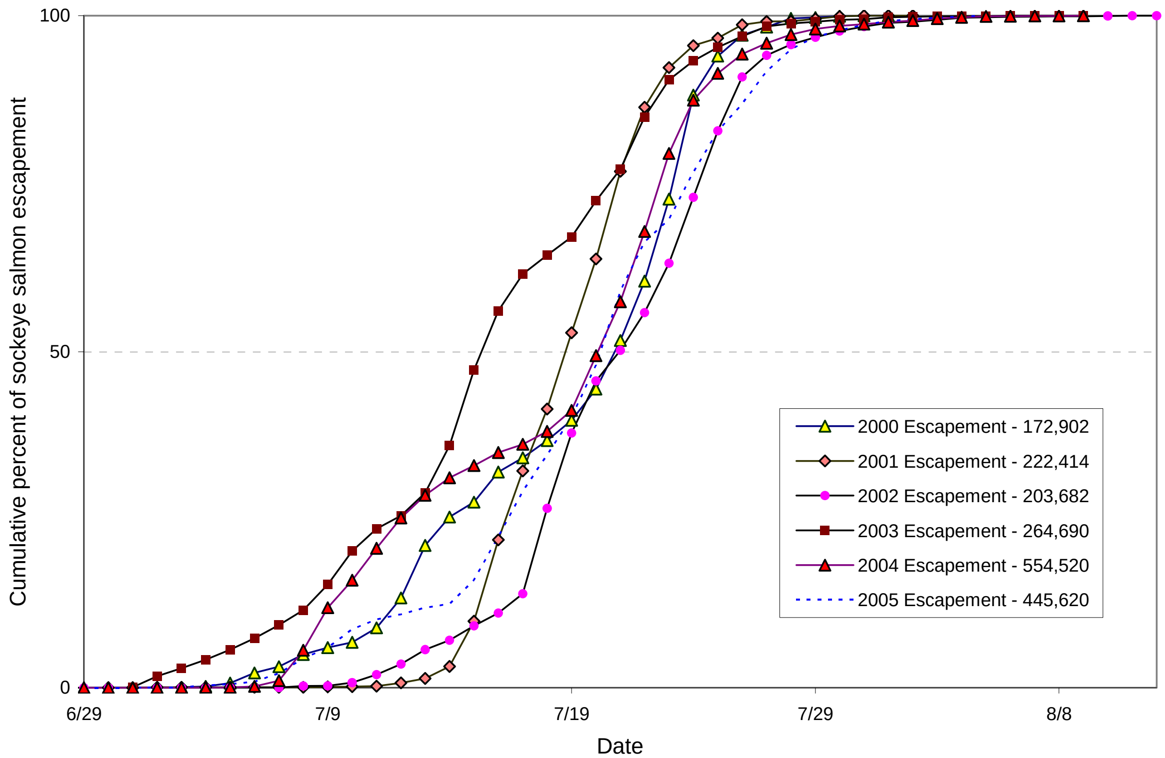

Figure 7. Cumulative percent of total sockeye salmon escapement to the Newhalen River by date, 2000 – 2005.

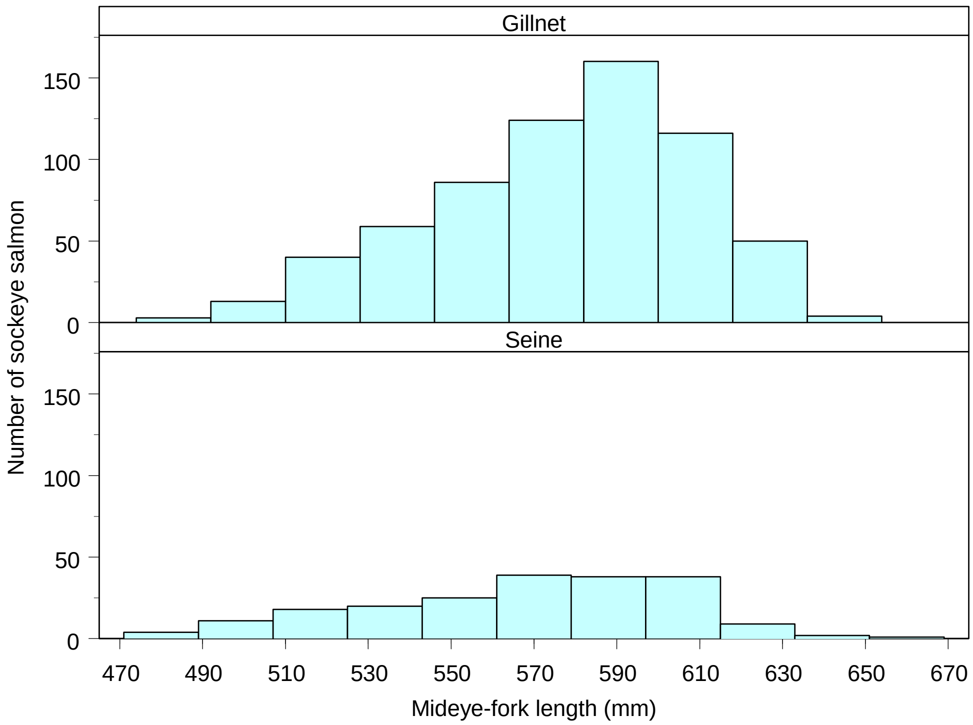

Figure 8. Length frequency distribution of sockeye salmon captured in Newhalen River and Sixmile Lake by subsistence gill nets and seines.

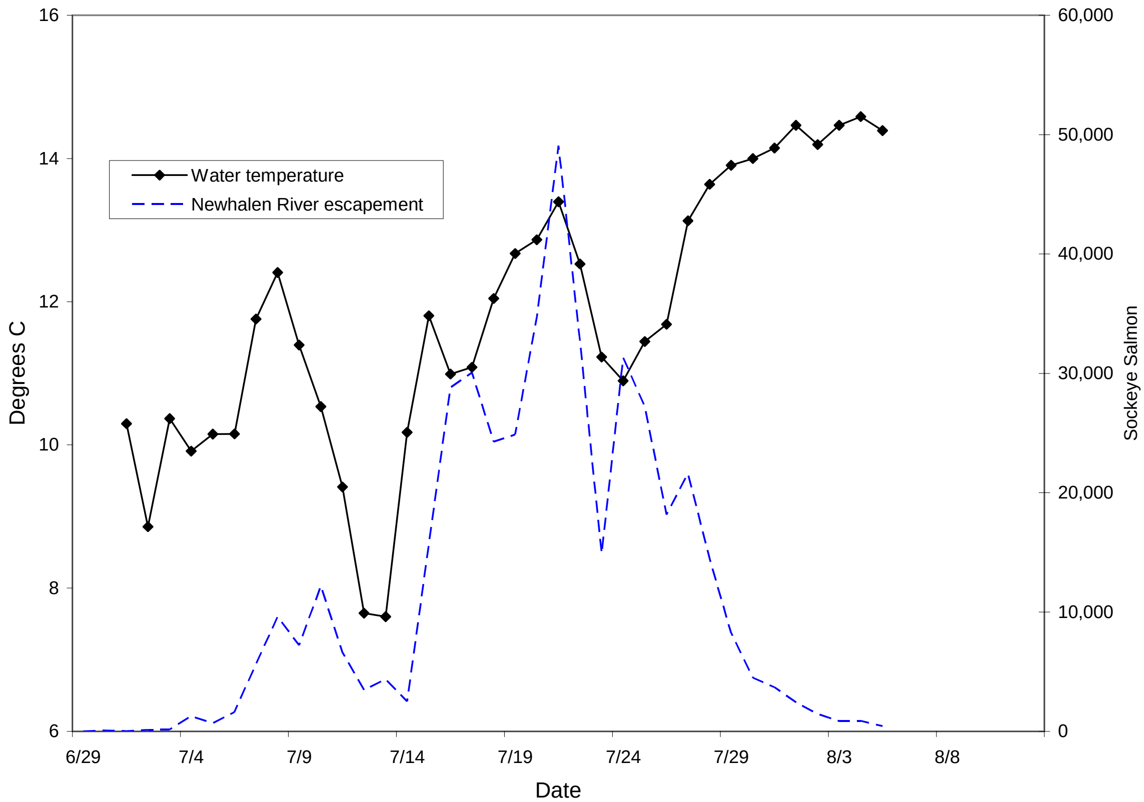

Figure 9. Daily average water temperature and sockeye salmon escapement recorded at the Newhalen River escapement monitoring site.

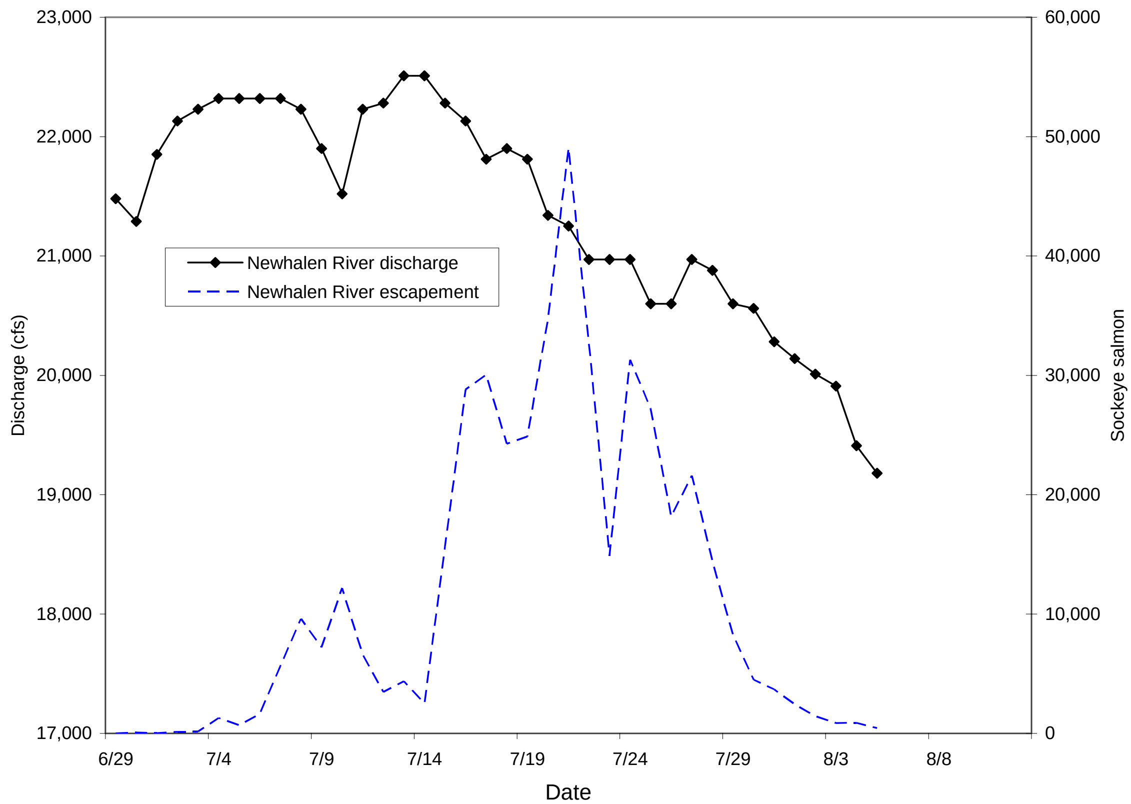

Figure 10. Estimated Newhalen River discharge (ft^3/sec) and sockeye salmon escapement recorded at the Newhalen River escapement monitoring site.

Table 1. Age composition (%) of sockeye salmon sampled in the Newhalen River in 2005.

Age	Count	Percent
1.2	185	21.5
1.3	544	63.3
2.2	43	5.0
2.3	88	10.2

Table 2. Mid-eye to fork length (mm) of the sockeye salmon captured in Newhalen River and Sixmile Lake by subsistence gill nets and seines.

Sex		Gill Net	Seine
Male	Mean Length	527	517
	Standard Deviation	30	33
	Sample Size	263	102
Female	Mean Length	510	497
	Standard Deviation	28	32
	Sample Size	392	103

Appendix 1. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2005. Kvichak River escapement provided by the Alaska Department of Fish and Game, Anchorage, Alaska.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20	144	144	0.01	0.01				
6/21	126	270	0.01	0.01				
6/22	402	672	0.02	0.03				
6/23	426	1,098	0.02	0.05				
6/24	336	1,434	0.01	0.06				
6/25	420	1,854	0.02	0.08				
6/26	204	2,058	0.01	0.09				
6/27	1,938	3,996	0.08	0.17				
6/28	22,410	26,406	0.97	1.14				
6/29	4,242	30,648	0.18	1.32	0	0	0.00	0.00
6/30	32,310	62,958	1.39	2.71	72	72	0.02	0.02
7/1	131,670	194,628	5.67	8.39	18	90	0.00	0.02
7/2	191,190	385,818	8.24	16.63	132	222	0.03	0.05
7/3	206,346	592,164	8.89	25.52	144	366	0.03	0.08
7/4	172,584	764,748	7.44	32.96	1,284	1,650	0.29	0.37
7/5	123,630	888,378	5.33	38.29	672	2,322	0.15	0.52
7/6	98,496	986,874	4.24	42.53	1,608	3,930	0.36	0.88
7/7	165,186	1,152,060	7.12	49.65	5,616	9,546	1.26	2.14
7/8	234,966	1,387,026	10.13	59.78	9,594	19,140	2.15	4.30
7/9	189,894	1,576,920	8.18	67.96	7,218	26,358	1.62	5.92
7/10	130,872	1,707,792	5.64	73.60	12,162	38,520	2.73	8.65
7/11	177,822	1,885,614	7.66	81.26	6,588	45,108	1.48	10.13
7/12	150,690	2,036,304	6.49	87.76	3,462	48,570	0.78	10.90
7/13	100,140	2,136,444	4.32	92.07	4,356	52,926	0.98	11.88
7/14	51,498	2,187,942	2.22	94.29	2,502	55,428	0.56	12.44
7/15	24,750	2,212,692	1.07	95.36	15,684	71,112	3.52	15.96
7/16	24,558	2,237,250	1.06	96.42	28,806	99,918	6.47	22.43
7/17	17,760	2,255,010	0.77	97.18	30,042	129,960	6.74	29.17
7/18	21,006	2,276,016	0.91	98.09	24,264	154,224	5.45	34.62
7/19	15,120	2,291,136	0.65	98.74	24,864	179,088	5.58	40.20
7/20	17,808	2,308,944	0.77	99.51	34,710	213,798	7.79	47.99
7/21	9,096	2,318,040	0.39	99.90	49,050	262,848	11.01	59.00
7/22	2,292	2,320,332	0.10	100.00	32,646	295,494	7.33	66.33
7/23					14,892	310,386	3.34	69.67
7/24					31,296	341,682	7.03	76.70
7/25					27,186	368,868	6.10	82.80
7/26					18,156	387,024	4.08	86.88
7/27					21,588	408,612	4.85	91.72
7/28					14,448	423,060	3.24	94.97

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Appendix 1. Continued.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					8,232	431,292	1.85	96.81
7/30					4,488	435,780	1.01	97.82
7/31					3,684	439,464	0.83	98.65
8/1					2,418	441,882	0.54	99.19
8/2					1,440	443,322	0.32	99.52
8/3					852	444,174	0.19	99.71
8/4					876	445,050	0.20	99.90
8/5					432	445,482	0.10	100.00
Totals		2,320,332		100.00		445,482		100.00

Appendix 2. Lake Clark and Kvichak River sockeye salmon escapement, in numbers of fish from 1980 - 1984 and 2000 - 2005. Kvichak River data provided by the Alaska Department of Fish and Game, Anchorage, Alaska (Westing et al. 2005, ADF&G[c]).

	Escapement		
Year	Lake Clark[abc]	Kvichak River[d]	% of Kvichak
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	203,670	703,884	29
2003	264,690	1,686,804	16
2004	554,520	5,550,134	10
1980 – 1984 Average	1,135,264	7,891,024	16
2000 – 2004 Average	283,639	2,172,790	17
2005	445,620	2,320,332	19

[a] 1980 – 1984 data from Poe and Rogers (1984)

[b] 2000 – 2003 data from Woody (2004)

[c] 2004 data unpublished, National Park Service, Port Alsworth, Alaska

Appendix 3. Daily average water temperature (C) and discharge (ft3/sec) recorded at the Newhalen River escapement monitoring site.

Date	Water Temperature	Discharge (ft^3/sec)
6/29		21,480
6/30		21,290
7/1	10.3	21,850
7/2	8.9	22,130
7/3	10.4	22,230
7/4	9.9	22,320
7/5	10.2	22,320
7/6	10.2	22,320
7/7	11.8	22,320
7/8	12.4	22,230
7/9	11.4	21,900
7/10	10.5	21,520
7/11	9.4	22,230
7/12	7.7	22,280
7/13	7.6	22,510
7/14	10.2	22,510
7/15	11.8	22,280
7/16	11.0	22,130
7/17	11.1	21,810
7/18	12.0	21,900
7/19	12.7	21,810
7/20	12.9	21,340
7/21	13.4	21,250
7/22	12.5	20,970
7/23	11.2	20,970
7/24	10.9	20,970
7/25	11.4	20,600
7/26	11.7	20,600
7/27	13.1	20,970
7/28	13.6	20,880
7/29	13.9	20,600
7/30	14.0	20,560
7/31	14.1	20,280
8/1	14.5	20,140
8/2	14.2	20,010
8/3	14.5	19,910
8/4	14.6	19,410
8/5	14.4	19,180