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Chignik Salmon Studies: Investigations of Salmon Populations, Hydrology, and Limnology of the Chignik Lakes, Alaska, During 2004–2005

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Annual Report to the National Marine Fisheries Service

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Final Report to Chignik Aquaculture Association

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Introduction

The University of Washington Fisheries Research Institute (FRI) has been conducting research on the anadromous and resident fishes of the Chignik lakes system since the 1950s. The Chignik Lake system is situated on the south side of the Alaska Peninsula (56° 16'N Lat., 158° 50'W), and produces the vast majority of the sockeye in the region. The system consists of two interconnected lakes draining into the Gulf of Alaska (Fig. 1). Chignik Lake is small (22 km^2), relatively deep (64 m), and is surrounded by precipitous mountains. In contrast, the upper lake, Black Lake, is larger (41 km^2) and extremely shallow (3 m maximum depth) and turbid, resting in a shallow tundra depression. Black Lake drains via the Black River into Chignik Lake. The outlet of Chignik Lake flows into a semi-enclosed estuary, Chignik Lagoon, and eventually into the Gulf of Alaska (Narver 1966, Dahlberg 1968, Ruggerone 1989b). Funding for FRI's work has come from both the Federal Government through the Anadromous Fish Conservation Act (Public Law 89-304), and the Chignik fishermen through the Chignik Regional Aquaculture Association (CRAA). These institutions have supported FRI with the goal of maintaining the health of the sockeye runs in the Chignik lakes. Both parties feel that the maintenance of FRI's unique long-term data set of biological data is important to the understanding of ecosystem functioning and productivity, and that analysis of physical changes in the environment and fisheries management are crucial for ensuring sustainable extraction of aquatic resources. The purpose of this report is to detail the work conducted in the Chignik system during the summer season of 2004.

A key concern among Chignik fishermen, residents and biologists has been the rapid habitat evolution of Black Lake since the late 1960s. These physical changes in the lake include substantial loss of water volume, increased summer water temperatures, migration of inflow of the Alec River, and creation of a sandspit that currently extends approximately 80% across the lake. These changes are correlated with greater premature out-migration of Black Lake sockeye fry (young of the year) to Chignik Lake (Ruggerone et al. 1993, Ruggerone 1994). Large emigrations of fry appear to reduce growth of juvenile sockeye salmon rearing in Chignik Lake, leading to significant adverse effect on adult returns to Chignik Lake (Ruggerone 1996). The exceptionally low water volume and low dissolved oxygen during some winters appears to reduce survival of juvenile sockeye in Black Lake and influence large annual fluctuations in adult returns (Ruggerone 2003).

The objectives of the 2004-2005 research at Chignik were to continue the monitoring of biological and physical characteristics that were monitored in past years and to conduct three additional projects: 1) estimate Alec River discharge during different levels of flow, 2) maintain historical ecological datasets, and 3) develop and test the effectiveness of models that describe salmon migration through the commercial fishery. The Alec River hydrology project stems from past measurements documenting the shifting of the Alec River from Alec Bay to the Black Lake outlet (Ruggerone 1994).

The overarching goals of the long-term data collection are to annually measure the relative abundance and size of juvenile sockeye salmon (*Oncorhynchus nerka*), relative abundance of potential competitor and predator species, and the biological and physical environment for sockeye salmon in the lakes during spring through fall. These data are complementary to ecological studies conducted by Alaska Department of Fish and Game (Bouwens & Finkle 2003) and past winter ecology studies (Ruggerone 1999). The resulting long-term database provides a basis from which to 1) evaluate changes in the production of adult sockeye salmon from the Chignik Lakes and 2) evaluate potential habitat restoration projects that are being considered by CRAA. This report describes data collected during two field seasons. The 2004 fieldwork was completed in two periods: 21 June through 14 July, and 1 through 8 September. In addition to the specific projects previously mentioned, the following watershed monitoring tasks were completed:

- Temperature, water transparency (Secchi depth), phytoplankton (chlorophyll a), and zooplankton densities were measured to assess conditions that affect the growth of juvenile sockeye.

- Beaches were seined weekly at six established stations on Chignik Lake and two in Chignik Lagoon from June to July to assess the relative near-shore abundance of juvenile sockeye salmon and associated species.
- Tow netting was conducted in Chignik Lake during early September to assess the relative abundance and lengths of juvenile sockeye salmon in the pelagic region. Mechanical problems precluded sampling of Black Lake in 2004; however, the problem has been corrected and sampling will occur in 2005.

Limnology

Methods

Water temperature, water transparency, phytoplankton, and zooplankton samples were collected on both Black Lake (three stations, Fig.2) and Chignik Lake (two stations, Fig. 3). Water clarity was estimated with a Secchi disk. Water temperatures were taken with a pocket thermometer on the surface of Black Lake and from water taken at several depths (1, 5, 10, and 20m) with a van Dorn bottle at Chignik Lake. Additionally, temperature data were collected from automatic, year-round thermographs, deployed out of the water at Ron Lind's cabin. After the data from the logger was downloaded, it was reset to record continuously until retrieval next summer. Water samples for temperature and chlorophyll estimates were taken immediately below the surface for Black Lake, which is shallow and well mixed, and at 1, 5, 10, and 20 m below the surface in Chignik Lake. Chlorophyll *a* analysis was performed on water that was sieved through Millipore filters (0.48µ); the amount filtered depended on how much algae was in the water (i.e., denser samples clogged the filter faster). The filters were then processed with a Spectronic 20 spectrophotometer. Zooplankton samples were taken with a 153µ mesh, 0.5-m diameter net in Chignik Lake by hauling the net 40-m vertically through the water. In Black Lake, zooplankton were collected by hauling the 153µ net horizontally along the lake surface for approximately 20-m. Additional details on sampling methodology are described in the FRI field manual (Rogers et al. 2002).

Results

Biotic

Total zooplankton abundance in Chignik Lake is high compared to sockeye lakes in central and southeast Alaska (228,000 ± 48,000 m^{-2}) (Kyle 1991) and western Alaska (250,000 m^{-2} for 60 m haul) (D.E. Rogers, unpublished data). However, size of Chignik zooplankton tends to be small, indicating intense grazing pressure (Ruggerone 1994). Zooplankton in Chignik Lake during the past decade have displayed a seasonal pattern of relatively high abundance of *Cyclops* spp. during early summer followed by an increase in numbers of cladocerans (*Daphnia, Bosmina, Chydorus*) during late summer and fall. Abundances of zooplankton in Chignik Lake were found in densities during the season similar to the long term average (Table 1). Following the typical pattern of species composition, zooplankton in Chignik Lake were comprised of mostly copepods early in the season and calanoids late in the season (Fig.4). Zooplankton abundances in Black Lake during the summer of 2004 were markedly lower than the long term average (Table 2). Abundances early in the season were very low compared to last few seasons and to the long term average. However, the composition of species in Black Lake followed the typical pattern of dominance by *Bosmina* (Fig. 5). These findings may have been the result of intense competition by rearing fishes for prey resources. Parr (1972) found density dependent growth in Black Lake, indicating that large cohorts of rearing fish are capable of extreme predation pressure on zooplankton and insect resources. Alternatively, these findings may be the result of large quantities of filamentous algae in the sample, which makes the counting of zooplankton difficult. Samples from 2004 contained usually large amounts of algae (B.Rogers, personal communication) and were indeed difficult to accurately count.

Abiotic

Secchi depth (water clarity) in Chignik Lake is influenced by the standing crop of phytoplankton (indexed by chlorophyll *a*) and seasonal inflow of glacial melt from the West Fork River. Secchi depth typically declines from spring through summer. In 2004, Secchi depths were average, ranging from 1.4 m in June to 1.9 m in early September (Table 3). Interestingly, the pattern of decreasing Secchi depth throughout the season did not materialize in 2004, and in general water transparency stayed relatively constant. Chlorophyll *a* concentrations in Chignik Lake during June and July were exceptionally low (Table 4), indicating that the low Secchi depths were more likely the result of glacial melt that phytoplankton production.

Secchi readings in Black Lake are influenced by both phytoplankton and suspended sediments caused by windstorms. The general pattern of declines in secchi depths during spring and summer is a result of the trophic cascade between planktivorous fishes, zooplankton, and phytoplankton. As the season progresses grazing of the zooplankton by sockeye and other planktivorous fishes increases and as a result the standing crop of phytoplankton, chlorophyll *a,* increases in Black Lake, thereby decreasing Secchi depths. We observed this pattern in 2004 with Secchi depths declining from 1.75 m in June to 0.75 m in September (Table 5). Average Secchi depths were similar to historical averages (Table 6).

Seasonal temperatures

Seasonal water and air temperatures during 2004 were warmer than average, with unusually warm water temperatures (20 C) recorded in Chignik Lake in July (Table 4). The lake wide average of 14.2 C on July 11 was the warmest sampling period since 1988. Water temperature in Black Lake was similar to the long term average (Table 6); however, temperatures in mid July were unusually warm (17 C). This sampling period was conducted during an unusually warm and calm period during which both lakes quickly responded. Chignik Lake stratified during this warm period and Black Lake heated beyond the optimal temperature for sockeye growth (Weatherly & Gill 1995), perhaps stimulating migration of juvenile fish out of Black Lake.

Air temperature, measured every 2 hours, at Ron Lind's cabin on the Black River was similar to a long term average. An unusual warm spell to over 20 C was recorded in April and extremely warm temperatures were recorded in mid-July (>27 C), which corresponds to warm water temperatures in Black and Chignik Lakes (Fig. 6). Growing seasons in southwest Alaska are increasing in duration (springs coming earlier, fall later), which has potential consequences for the growth and survival for rearing salmon and resident fishes (Schindler et al. 2005). It is unclear how larger scale climate changes are affecting patterns of growth in the Chignik lakes, and is worthy of further investigation.

Tow net sampling

Tow-net hauls were made annually in the Chignik Lakes from 1960 to 1973 (Rogers et al. 1996). Tow net operations provide a means to estimate size and relative abundance of juvenile sockeye salmon near the end of the growing season. During 1973 to 1991, tow netting was sporadic due to the lack of consistent funding. However, since funding has stabilized (provided by CRAA and NOAA) we have sampled both lakes since 1992, except for 1994[1] and 2004 (Chignik Lake only due to engine problems).

[1] Sampling by ADFG in 1994 using a net towed by a single boat produced only a few sockeye per tow.

Methods

Tow net catches were standardized to 10 min (Parr 1972) and arithmetic means were calculated. Towing begins at the north end of the lake and continues south toward the outlet. Tows have not been made in the outlet of Black Lake since the late 1980s because the outlet has become too shallow. For a complete description of the methods for tow netting see the FRI operations manual (Rogers et al. 2002).

Results

Tow net catches are presented in Table 7 and 8. These data only represent tows made during our annual survey near the 1st of September. The average tow net catch for Chignik Lake was similar to past years with one notable exception. The catch of pond smelt was the highest on record since 1960. It is unclear whether pond smelt are responding to changing conditions in the Chignik system or are experiencing natural population fluctuations. Regardless, the numbers observed in 2004 are truly exceptional and worthy of additional analysis. Lengths of fish are reported in figures 7-11.

Black Lake was not sampled in 2004 due to logistical constraints arising from catastrophic engine failure. The problem has been fixed and sampling is planned for 2005.

Beach seining

Beach seining was conducted in Chignik Lake several years prior to 1973 and since the mid-1980s (Ruggerone 1989c, Rogers et al. 1996). The total length of the all fishes was measured from tip-of-snout to the fork in the tail, but we typically report catches of juvenile sockeye salmon as larger or smaller than 45 mm. The small fish were likely to be fry (age 0) whereas the larger fish likely were a mixture of yearlings from Chignik Lake and large fry from Black Lake. Juvenile coho salmon are usually more abundant in beach seine catches than in townet catches, which reflects their preference for the nearshore habitat (Ruggerone 1989a). An intensive study of coho predation on sockeye salmon during the mid-1980s showed that coho consumed approximately 24 to 78 million sockeye salmon fry depending on year or approximately 59% of the emerging sockeye population (Ruggerone & Rogers 1992).

Methods

Beach seining of Chignik Lake is conducted during June and July. For a complete description of the methods for beach seining see the FRI operations manual (Rogers et al. 2002).

Results

Chignik Lake

Beach seine sampling may not reflect abundance of Chignik Lake sockeye; especially fry, because fry are readily consumed by juvenile coho that are abundant nearshore and because fry rapidly move offshore apparently to avoid predation (Ruggerone 1989). The numbers of fish captured in 2004 were well above average for sockeye, three-spine sticklebacks and coho compared to the past several years. The fish lengths from historical beach seine data are still being compiled; however, results on the length distribution from 2004 are shown in figures 7-11.

Chignik Lagoon

Beach seining in Chignik Lagoon was recently adopted as part of our regular sampling routine. With fewer boats now fishing in the lagoon it will be interesting to see whether relative juvenile abundance changes over time. Table 11 shows the catches of key species during the last five years. Catches in 2004 were similar to past years, but significantly lower than the catches in 2000. This may be a result of true abundance or an artifact of reduced sampling effort.

Alec River Hydrology

Previous research has shown that the south channel of the lower Alec River leading into the lake outlet is becoming larger relative to the north channel leading into the main lake (Ruggerone 1994). The cause of the shifting Alec River channels appears to be related to the lowering of Black Lake elevation, which was apparently initiated by downstream migration of the West Fork River and subsequent degradation of Black River since the late 1960s[2]. The migration of Alec River channels is important to sockeye salmon because greater discharge to the south channel during early spring will likely carry larger numbers of emerging sockeye fry to the outlet of Black Lake and may encourage more fry to emigrate to Chignik Lake. During low water periods, an exposed sandspit crosses approximately 80% of the lake and separates the main lake from the outlet.

Erosion of the banks along the south channel of Alec River has been monitored since 1991 (Ruggerone & Denman 1990) and in 1993 and 1999 the relationship between total river discharge and the percentage of river water entering the south channel was quantified. During low flows, such as those occurring during fry emergence, approximately 70% of the river flow (and presumably 70% of fry) entered the lake outlet. During exceptionally high flow events, the percentage of total discharge to the outlet declined to approximately 40%. The most recent study indicates flow has continued to shift toward the outlet since 1993 (Ruggerone et al. 2000).

It is now apparent that the U.S. Army Corp of Engineers is interested in mitigating the changes taking place in the Alec River. The purpose of the 2004 Alec River investigation was to continue monitoring of the river bank erosion and to determine the extent to which discharge was shifting toward the south channel and the lake outlet (Ruggerone 1994). We hope this analysis of historical data will aid the Army Corp in making informed and reliable decisions.

Methods

Measurements of flow were made on both channels by stretching a cable across the river at locations maintained by FRI (Fig.12). Depth is measured in centimeters, and flow is measured using a flow meter with an accuracy of 0.1 m/s.

We use an arcsin transformation of the percentage and log transformation of the total flow when modeling the relationship. We treat total flow and percentage to the south channel as continuous variables, and year as a continuous variable. Our generalized linear model (GLM) tests for the significance year and total flow, and any interaction between the three.

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[2] Significant changes in the Black River channel continue to occur between Chiatuak Creek and the area immediately below the old West Fork channel. At the FRI camp across from Chiaktuak Creek approximately 50 feet or more of the bank has been lost, including two cabins since 1984. During the past 6-7 years, the large sandbars in this area have been invaded by dense perennial vegetation. It appears that the channel is continuing to degrade since the sandbars appear to be covered less frequently by river flows. The implication of channel degradation is that it will likely lead to additional lowering of Black Lake water elevation.

Results

Discharge

As we continue to add more years of data to the discharge measurements we are seeing a more significant affect of year on shifts in the river flow (Fig. 13). Table 12 shows that coefficients of the GLM for the full model: arcsin(% flow to south channel)=log(total flow to both channels)+year. We show that all the coefficients intercept, total flow, and year to have a significant effect. Effectively, an estimated 0.5% more water is flowing to south channel of the Alec River every year.

In 2003, we conducted a retrospective analysis of the previous years data using the same model. Table 13 illustrates two interesting points: 1) the coefficient for year is increasing over time, which means not only is more water flowing to the south channel each year, the rate at which the change is occurring is also increasing. 2) The level of significance is also increasing for the coefficient of year. This tells us that our level of certainty that there is an affect of year on the south channel discharge is increasing as we acquire more years of information.

Modeling Escapement in a Mixed Stock Fishery

The Chignik sockeye salmon fishery is a mixed-stock fishery, with salmon returning to spawn in either Black Lake or Chignik Lake between June 1 and September 15. The return and spawning timing in the two lakes is quite different (Dahlberg 1968), as is their annual pattern of productivity, primarily because of differences in rearing environment (Narver 1966). Thus, the salmon returning to these lakes are treated as separate stocks by the Alaska Department of Fish and Game, and each lake has been given a set of escapement goals to maintain its biocomplexity (Table 14)(Witteveen & Botz 2003). In their evaluation of whether the escapement goals are being met and, hence the limits on fishing, managers have traditionally relied on scale pattern analysis (SPA) (Conrad 1983) and a historical understanding of migration timing to determine the proportion of fish passing the weir that are from each stock. However, recently the funding for SPA has been cut from the Chignik budget and new methods of stock separation are needed to fulfill management objectives.

Methods and Results

We have developed a method for using age composition data to determine stock-specific migration timing and abundance in a mixed-stock salmon fishery. The Chignik sockeye fishery has two stocks, but only aggregate catch and escapement data are available. However, the age composition of the two stocks is known to be consistently different, and age composition data are collected from one stock at the beginning of the commercial fishing season and from the commercial catch throughout the season we estimate the total abundance and migration timing for the two Chignik stocks using maximum likelihood and Bayesian analyses. The accuracy of this stock separation model was highly correlated with that of scale pattern analysis for most years from 1978 to 2002 (r=0.89). The results suggest that age-composition may provide salmon managers with a reliable and inexpensive method for determining stock-specific migration timing and abundance in a mixed-stock fishery (Fig.14).

The 2005 season will be the first season for which our stock separation model is in-season and post-season. There has been an enormous amount of cooperation between ADF&G and FRI on this project, and we are looking for to working together this season while judging the effectiveness of the model.

Acknowledgements

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Key Words

Alec River, beach seine, Black Lake, Chignik Lagoon, Chignik Lake, escapement goals, scale pattern analysis (SPA), age composition model, hydrology, limnology, *Oncorhynchus nerka*, sockeye salmon, townet

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Figures

Fig.1 Map and location of the Chignik Lake system, Alaska

Fig. 2 Locations of limnology sampling and Alec River transects on Black Lake, Alaska.

Fig. 3. Location of limnolgy, beach seining, and tow net sampling on Chignik Lake, Alaska.

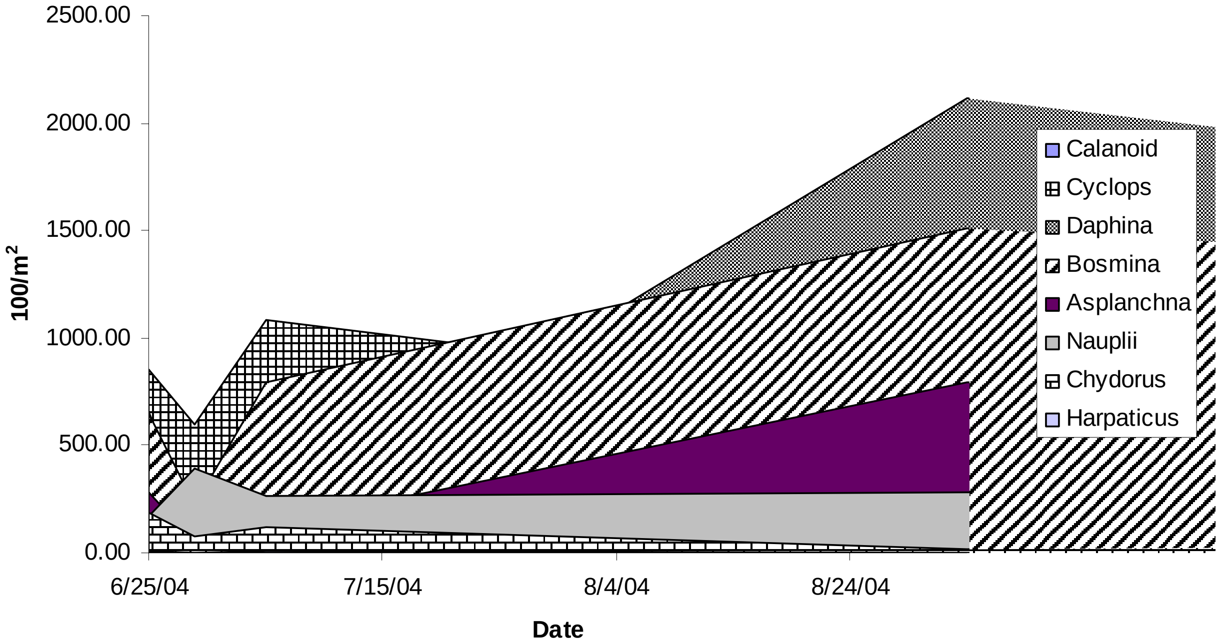


Fig.4. Abundance (100/m^2) of macrozooplankton in Chignik Lake during the summer of 2004.

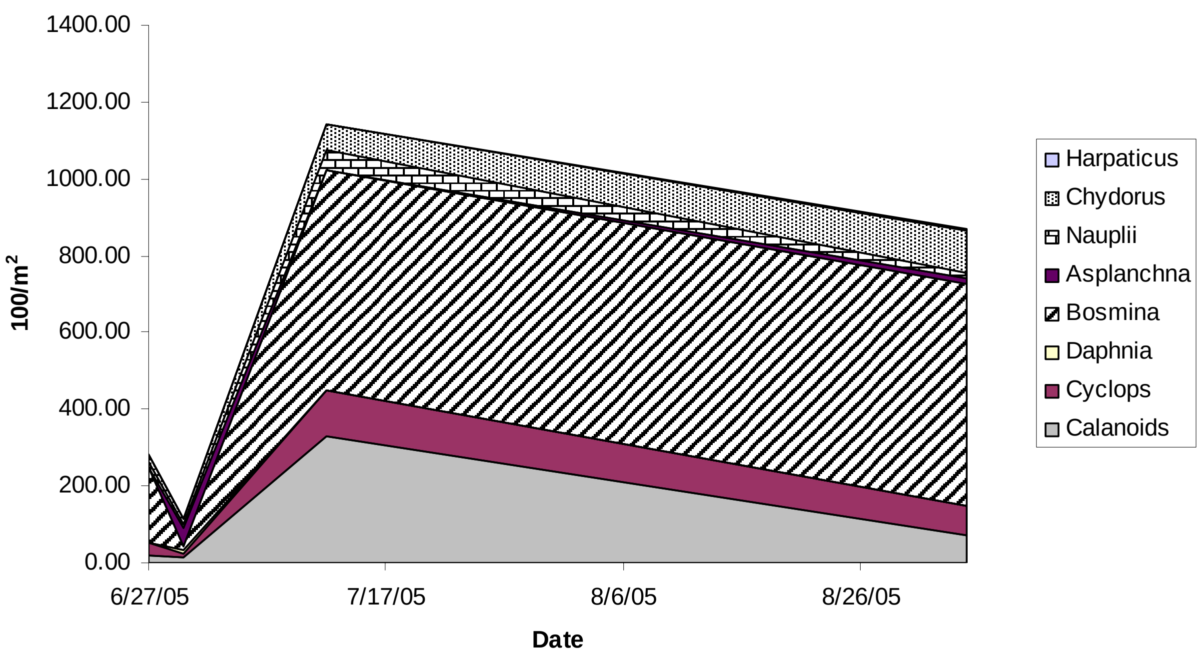


Fig.5. Abundance (100/m^2) of macrozooplankton in Black Lake during the summer of 2004.

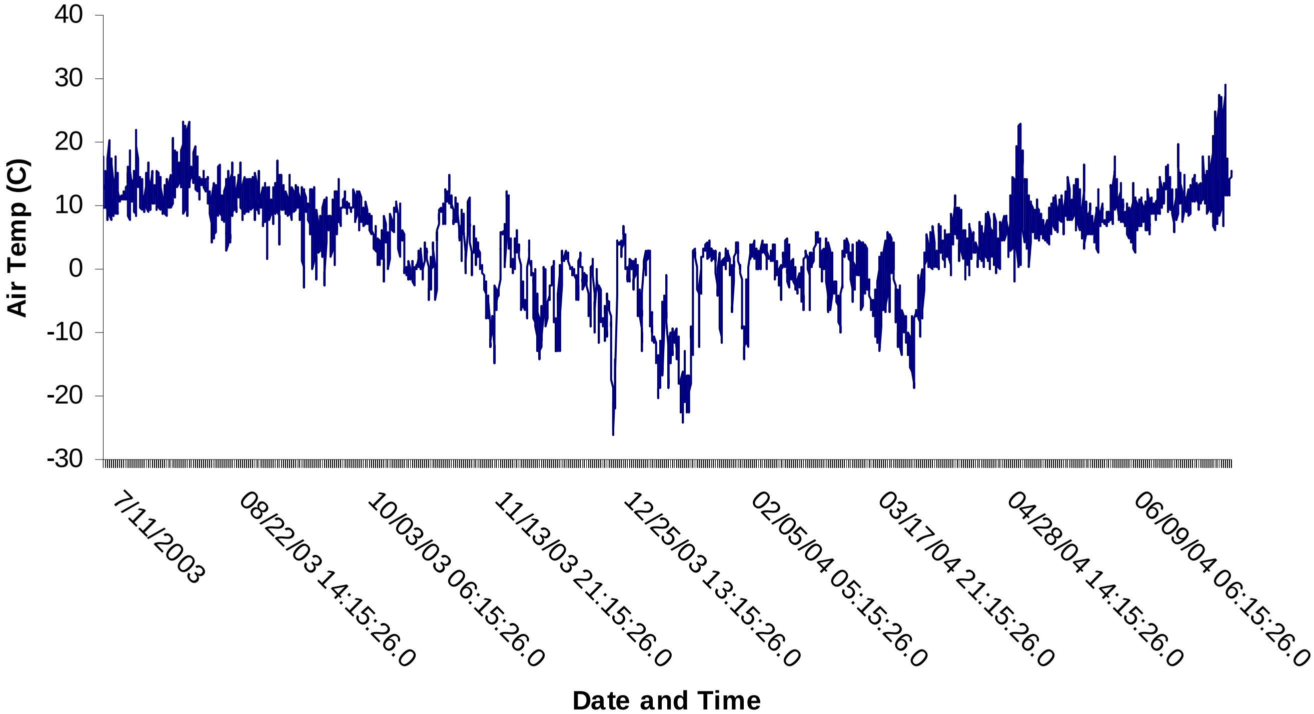
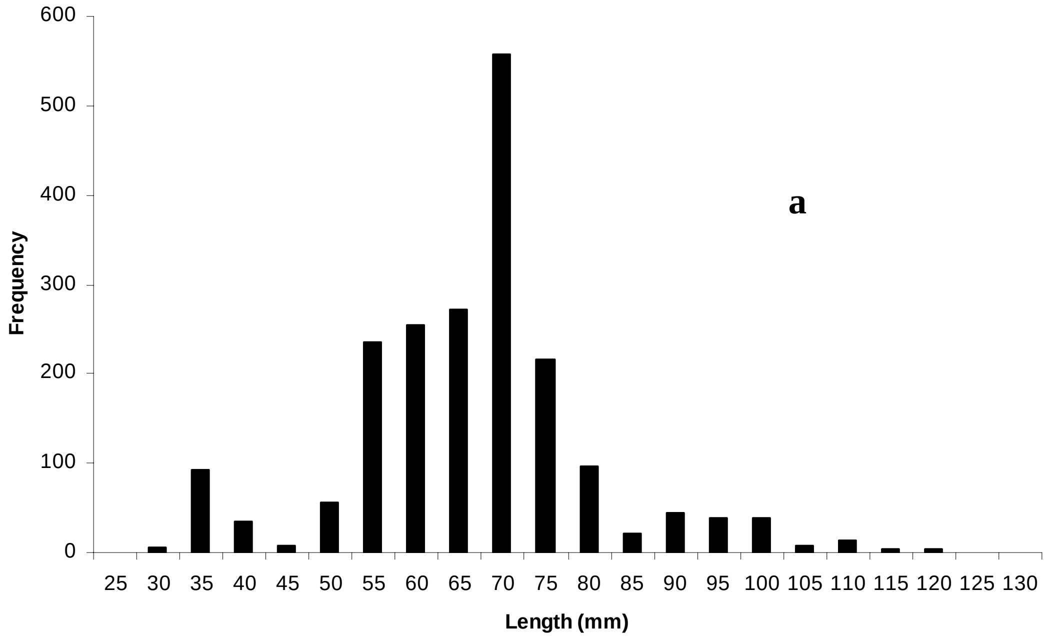


Figure 6. Air temperature (Celsius) recorded every 2 hours from July 11, 2003 to July 13-2004. Temperature logger was affixed to Ron Lind's cabin on Black Lake.



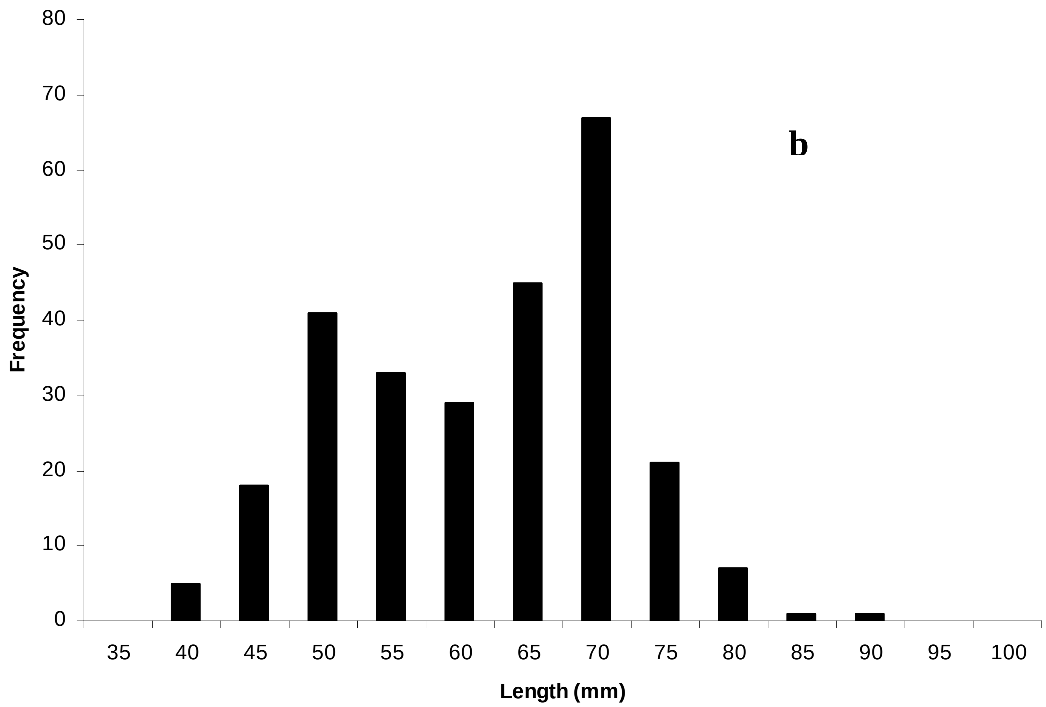


Figure 7. Fork length (mm) of sockeye salmon caught via beachseining (a) and townetting (b) in Chignik Lake and Lagoon during FRI's 2004 summer field season.

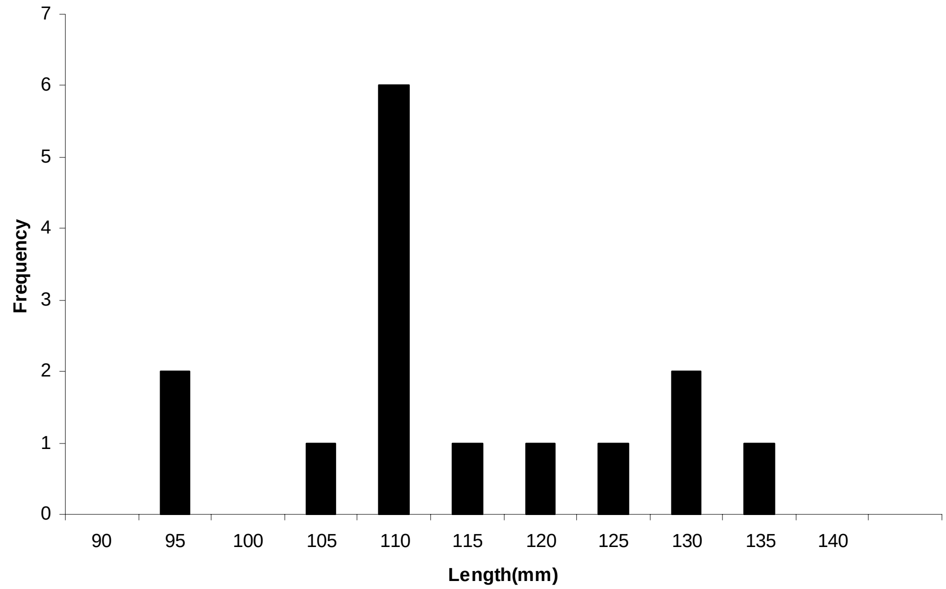


Figure 8. Fork length (mm) of chinook salmon caught via beachseining in Chignik Lake and Lagoon during FRI's 2004 summer field season.

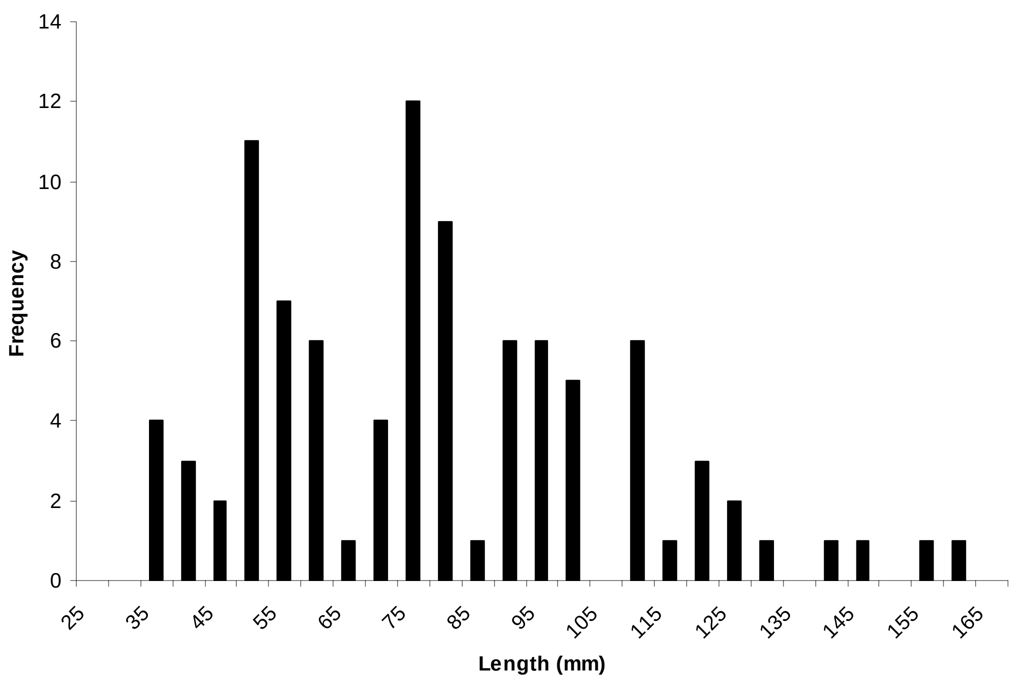
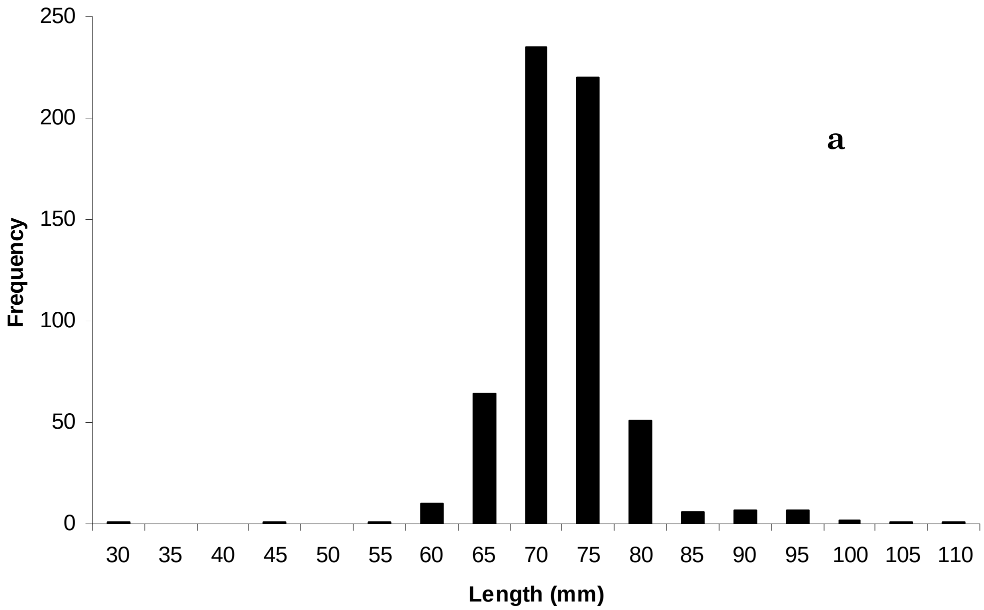


Figure 9. Fork length (mm) of coho salmon caught via beachseining in Chignik Lake and Lagoon during FRI's 2004 summer field season.



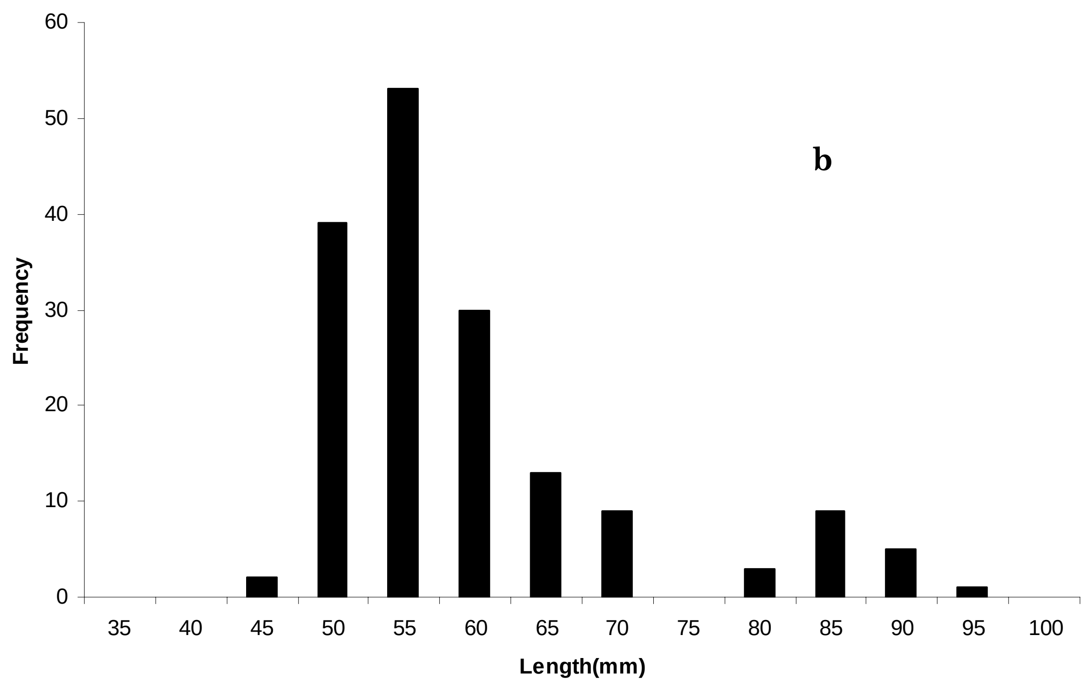
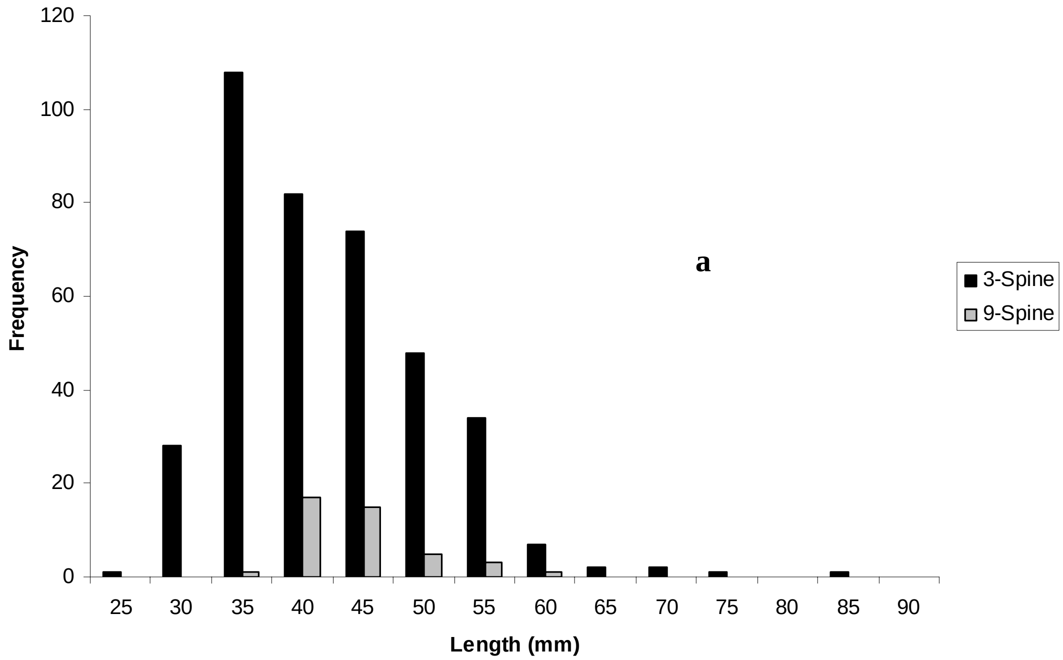


Figure 10. Fork length (mm) of pond smelt caught via townetting (a) and beachseining (b) in Chignik Lake and Lagoon during FRI's 2004 summer field season.



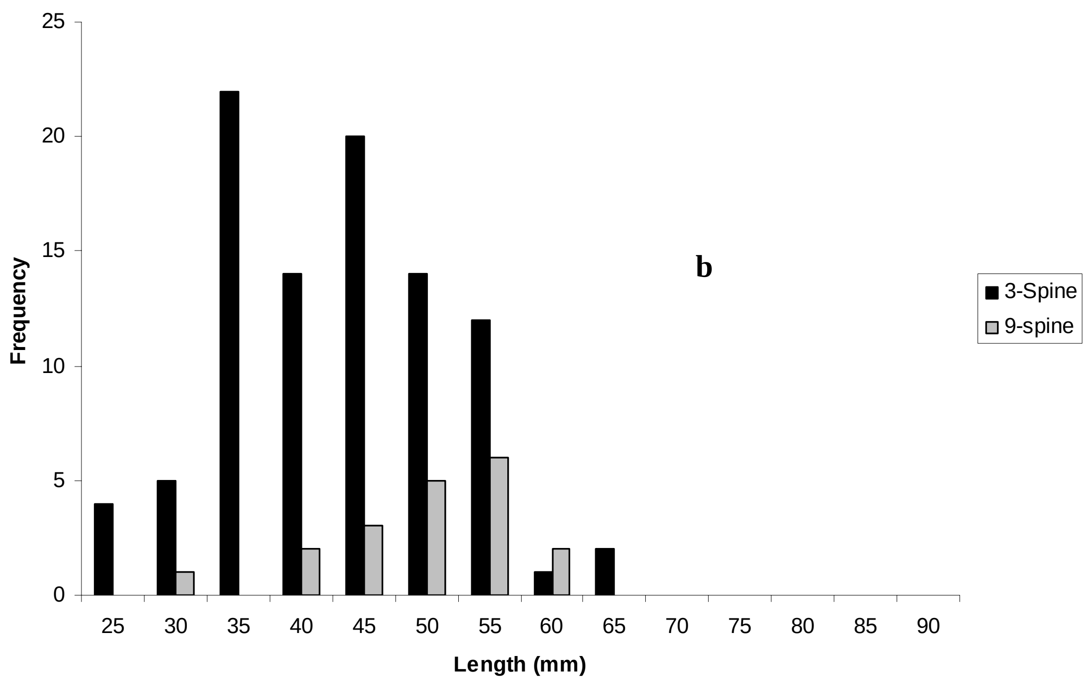


Figure 11. Fork length (mm) of 3 and 9 spine stickleback caught via beachseining (a) and townetting (b) in Chignik Lake and Lagoon during FRI's 2004 summer field season.

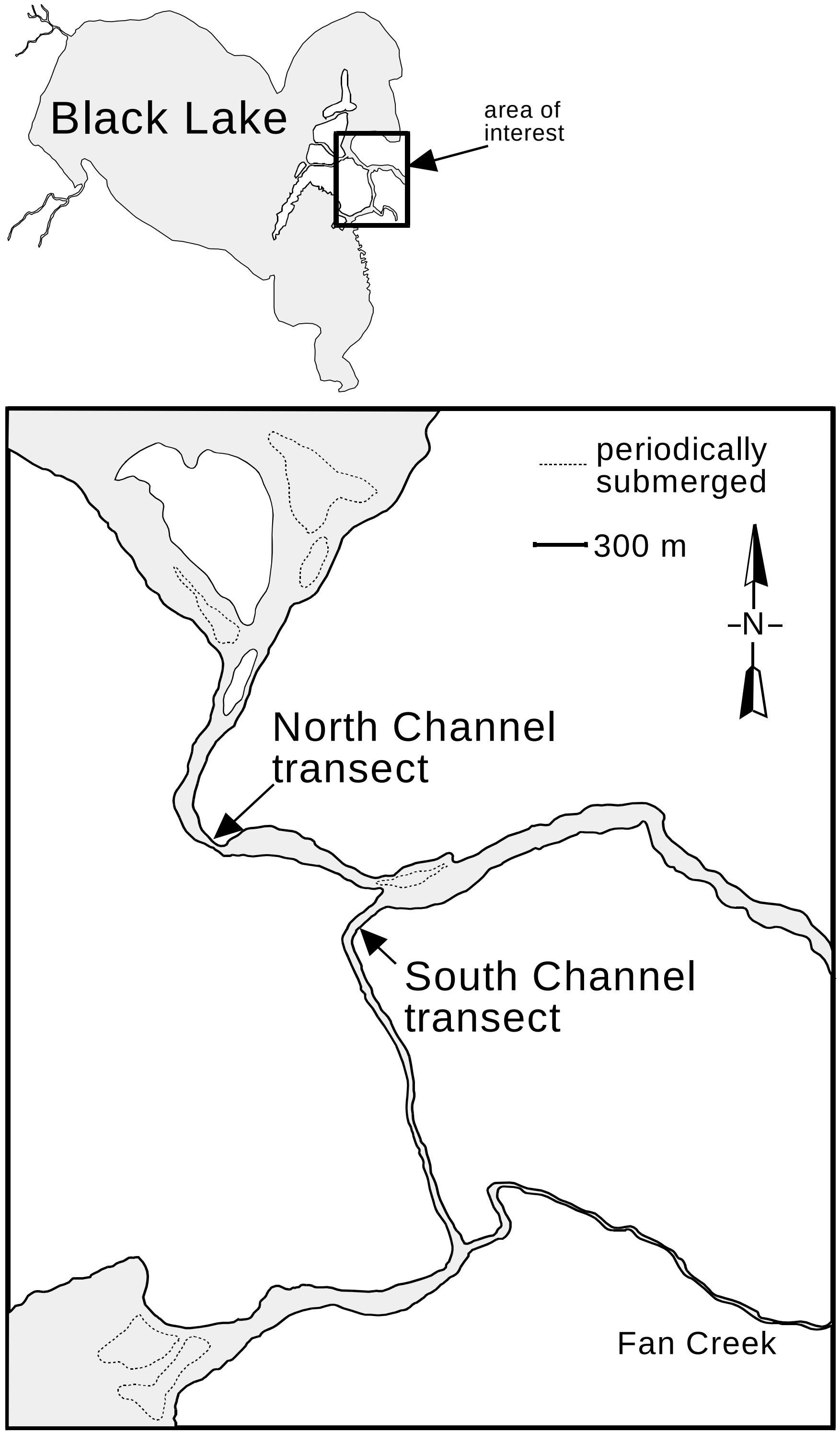


Figure 12. Alec River hydrology transects (dashed areas represent delta or sandbars).

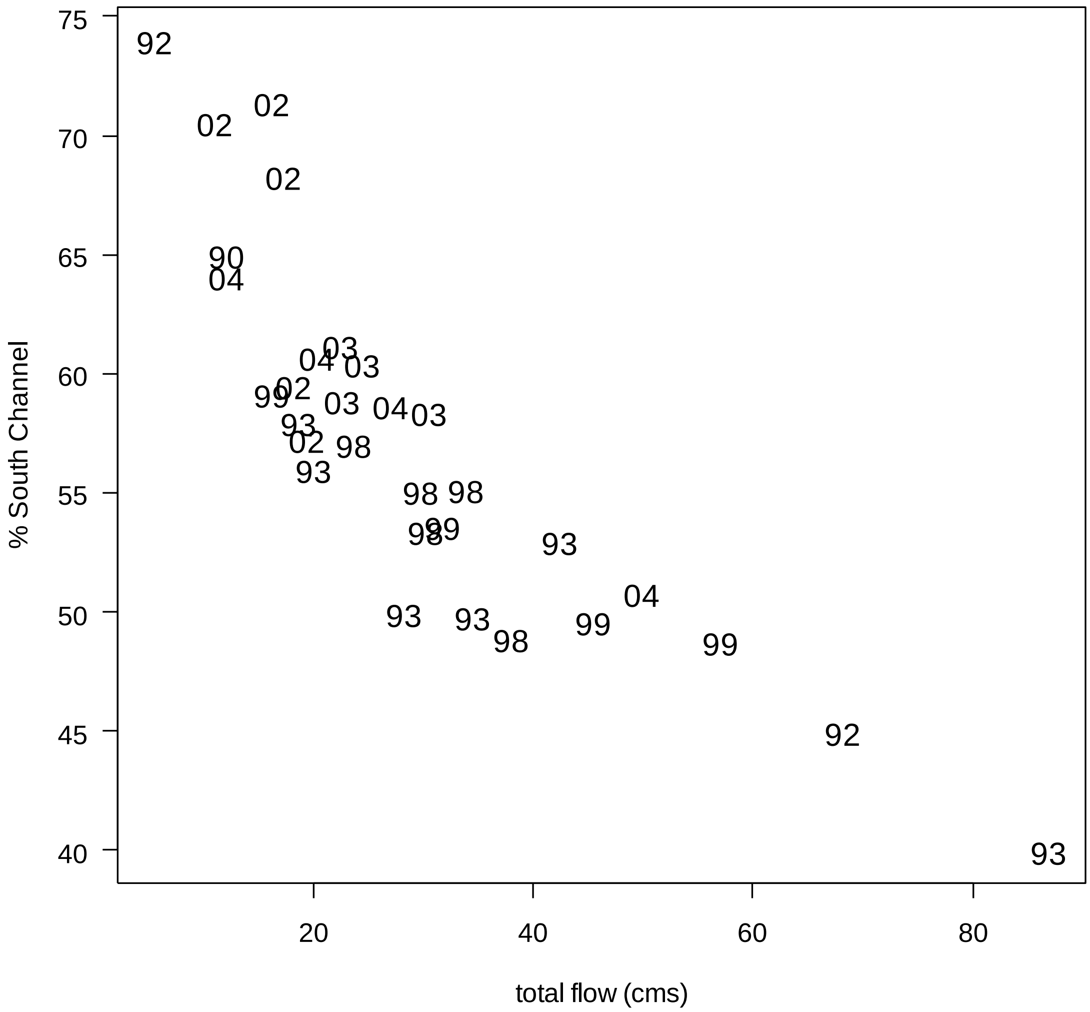


Figure 13. Plot of the relationship between total flow and percentage flowing to the south channel of Alec River, shown with year of sample collection.

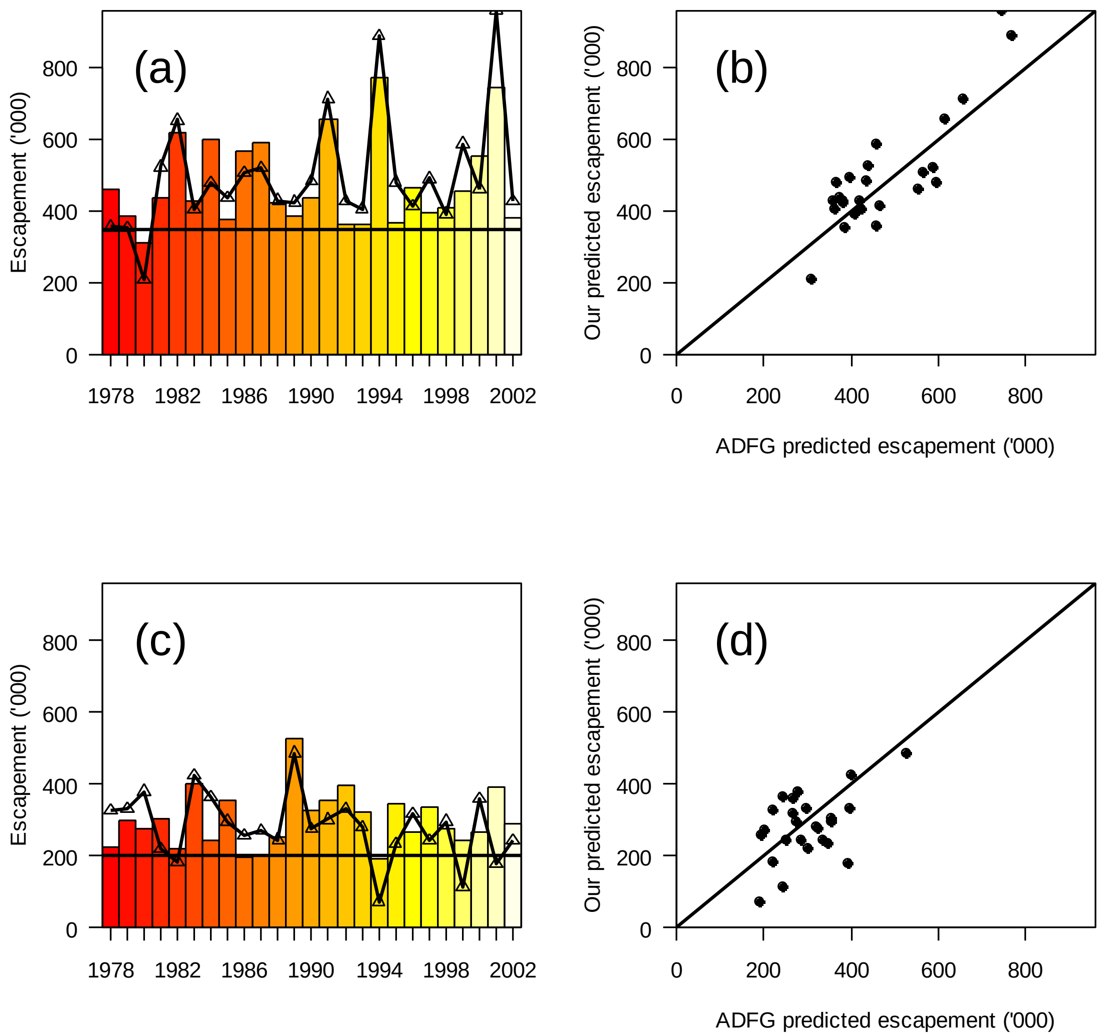


Figure14. Black Lake, (a) and (b), and Chignik Lake, (c) and (d), stock separation results as determined by age composition analysis (lines with triangles) and scale pattern analysis (bars). The horizontal lines in (a) and (c) represent the minimum seasonal escapement for each stock.

Tables

Table 1. Historical zooplankton densities in Chignik Lake (1000 m^2), 1968-2004

					Categories							
Year	Month	Day	# Sites	Depth (m)	Calanoids	*Cyclops*	*Daphnia*	*Bosmina*	*Chydoris*	Nauplii	*Asplanchia*	Total
1968	6	25	5	30	12	25	1	2	3	0	0	43
1968	7	20	5	30	15	11	3	11	8	0	0	48
1968	8	4	5	30	41	32	13	51	7	0	0	144
1968	8	29	5	30	98	24	110	67	5	0	0	304
1969	6	29	5	44	5	364	4	7	2	0	0	382
1969	7	27	5	47	13	329	11	22	2	0	0	377
1969	8	15	5	42	26	161	34	45	3	0	0	269
1969	8	30	5	44	33	28	42	51	2	0	0	156
1970	6	28	4	30	24	83	5	3	1	0	0	116
1970	7	27	4	30	39	37	10	20	2	0	0	108
1970	8	29	4	30	99	32	31	59	7	0	0	228
1971	7	3		45	0	126	4	2	0	0	0	132
1971	7	28		45	3	263	18	10	0	0	0	294
1971	8	29		42	1	132	27	70	0	0	0	230
1972	7	14		15	12	19	1	5	7	0	0	44
1972	8	6		15	3	82	3	5	4	0	0	97
1972	8	31		15	0	17	3	7	0	0	0	27
1973	7	21		45	11	659	40	35	14	0	55	814
1987	6	5	5	40	10	56	2	3	0	0	4	75
1988	6	16	5	40	15	277	3	11	2	0	2	310
1988	7	14	5	40	7	35	3	39	2	0	3	89
1989	6	22	5	40	19	212	3	16	14	2	4	270
1990	6	11	1	40	6	650	1	1	0	0	8	666
1990	6	24	2	40	14	189	10	9	0	0	56	278
1991	6	27	5	40	21	41	1	19	0	0	31	113
1992	5	19	5	40	1	488	29	1	0	11	7	537
1992	6	6	3	40	2	292	12	1	0	6	19	332
1992	6	23	5	40	17	251	18	4	0	11	66	367
1992	7	11	5	40	22	199	34	16	0	9	231	511
1992	8	31	5	40	285	177	206	338	0	133	37	1176
1993	5	9	2	40	74	144	2	4	0	0	0	224
1993	6	19	2	40	48	77	0	22	0	0	0	147
1993	7	26	2	40	380	239	16	423	0	0	0	1058
1993	8	16	2	40	82	67	35	120	0	0	0	304
1993	9	9	2	40	17	26	82	109	0	0	0	234

Historical Chignik Lake zooplankton--cont.

Year	Month	Day	# Sites	Depth (m)	Calanoids	*Cyclops*	*Daphnia*	*Bosmina*	*Chydoris*	Nauplii	*Asplanchia*	Total
					Categories							
1995	6	29	2	40	7	155	16	20	4	16	38	256
1995	7	7	2	40	15	205	25	56	7	44	68	420
1995	7	16	2	40	39	258	32	107	3	52	78	569
1995	9	5	2	40	356	224	537	498	18	108	43	1784
1996	6	17	2	40	33	69	4	19	11	20	59	215
1996	7	4	2	40	51	131	4	27	24	78	116	431
1996	7	12	2	40	286	258	10	97	34	215	152	1052
1996	7	29	2	40	108	96	10	62	34	13	176	499
1996	8	8	2	40	182	117	36	159	17	62	159	732
1997	5	26	2	40	2	187	2	6	2	30	1	230
1997	6	11	2	40	8	189	6	3	6	14	0	224
1997	8	15	2	40	145	42	234	195	1	83	40	739
1997	8	28	2	40	68	51	108	164	1	30	22	444
1998	6	23	2	40	16	128	4	8	108	21	1	286
1998	7	4	2	40	24	93	7	18	222	20	1	385
1998	7	14	2	40	41	65	8	12	212	19	1	358
1998	9	5	2	40	154	98	73	181	7	88	5	606
1999	6	8	2	40	10	135	7	6	0	19	3	180
1999	6	16	2	40	17	147	8	6	1	21	1	200
1999	6	24	2	40	55	95	25	20	0	29	2	226
1999	7	6	2	40	45	77	13	10	2	33	5	185
1999	9	6	2	40	97	37	20	30	3	26	1	214
2000	6	9	2	40	23	143	3	11	1	33	1	215
2000	6	18	2	40	27	123	4	22	1	20	2	199
2000	6	26	2	40	28	668	3	26	3	26	3	757
2000	7	05	2	40	42	109	2	37	5	17	2	214
2000	7	11	2	40	71	122	2	47	8	5	9	264
2000	9	05	2	40	170	79	22	193	13	41	54	572
2001	6	29	2	40	63	63	3	10	0	11	2	152
2001	7	7**	2	40	83	88	2	40	0	11	2	223
2001	7	13	2	40	122	39	1	58	0	23	14	258
2001	8	30	2	40	196	39	11	121	0	53	28	447
2002	6	27	2	40	30	97	2	12	3	6	99	247
2002	7	3	2	40	35	96	5	19	8	10	267	439
2002	7	8	2	40	21	141	7	21	6	26	305	526
2002	7	13	2	40	64	92	3	40	8	50	173	428
2002	7	22	2	40	107	94	11	72	6	41	43	372
2002	9	1	2	40	262	96	171	167	3	77	1	776
2004	6	25	2	40	68	85	66	64	19	17	28	347
2004	6	29	2	40	59	60	12	22	7	39	5	204
2004	7	5	2	40	50	108	14	80	12	26	13	303
2004	7	11	2	40	83	129	16	59	12	13	32	344
2004	9	3	2	40	25	68	211	151	2	28	79	564

**Due to high winds, samples for the half the samples on the delta were taken on June 6th. The results reflect the two day average.

Table 2. Historical zoolankton densities (1000 m^2) in Black Lake, 1992-2004.

				Category							
Year	Month	Day	# Sites	Calanoids	*Cyclops*	*Daphnia*	*Bosmina*	*Chydoris*	Nauplii	*Asplanchia*	Total
1992	6	20		6	37	0	5	0	13	3	64
1993	5	17		1	1	0	3	0	0	0	5
1993	6	15		13	1	0	21	0	0	0	35
1993	7	15		1	1	0	3	0	0	0	5
1993	8	14		9	19	0	227	0	0	0	255
1993	9	8		6	6	0	149	0	0	0	161
1995	6	9		1	14	0	1	1	5	1	23
1995	6	20		0	5	0	2	0	1	0	8
1995	7	11		2	12	0	8	2	2	9	35
1995	9	5		3	6	0	24	6	3	3	45
1998	6	20	2	2	8	0	1	0	3	1	15
1998	7	3	2	6	22	0	9	1	5	3	46
1998	7	16	2	5	5	0	14	0	6	1	31
1998	9	3	2	4	16	0	53	4	4	6	87
1999	6	12	3	13	5	0	6	0	7	0	30
1999	6	21	3	5	6	0	8	1	8	0	28
1999	6	26	3	17	13	0	39	1	14	0	84
1999	7	5	3	38	29	0	55	3	22	1	146
1999	9	7	3	1	6	0	83	1	2	0	93
2000	6	10	3	2	9	0	14	2	9	0	35
2000	6	18	3	6	10	0	19	4	16	0	54
2000	6	26	3	0	0	0	7	0	0	0	7
2000	7	05	3	9	9	0	25	4	4	0	51
2000	7	11	3	5	5	0	24	1	3	0	38
2000	9	05	3	14	40	0	294	48	2	0	399
2001	6	27	3	91	21	0	62	0	10	0	184
2001	7	7	3	73	23	0	200	1	17	0	314
2001	7	10	3	23	12	0	85	0	10	0	130
2001	7	13	3	24	10	0	38	0	14	0	86
2001	9	4	3	0	0	0	0	0	0	0	0
2002	6	28	3	20	39	1	27	4	19	17	126
2002	7	3	3	15	25	0	48	1	8	16	113
2002	7	19	3	10	26	0	84	20	4	2	146
2002	8	30	3	15	30	0	200	10	4	8	267
2004	6	27	3	2	3	0	20	2	1	0	28
2004	6	30	3	2	1	1	1	1	1	5	12
2004	7	12	3	33	12	0	57	7	5	0	114
2004	9	4	3	7	7	0	58	11	2	2	86

Table 3. Historical averages of linmological data from Chignik Lake, 1988-2004.

Date			Secchi depth	Averages over 1-20 m	
Mo	Day	Year	(m)	Temp. (C)	Chlorophyll a (mg/m^3)
6	16	88	n/a	n/a	4.13
7	14	88	n/a	n/a	2.92
6	24	89	2.4	9.2	3.38
6	24	90	1.8	8.6	2.40
6	21	91	n/a	8.3	2.55
6	23	92	1.8	9.6	3.27
7	11	92	2.6	9.9	2.68
9	3	92	n/a	10.8	5.42
5	10	93	2.2	4.3	7.96
6	17	93	1.4	9.1	0.88
7	26	93	0.6	12.4	0.81
8	18	93	0.8	11.7	1.49
9	10	93	0.8	11.6	1.71
6	8	95	1.7	7.5	4.89
6	17	95	1.6	9.0	3.23
6	29	95	2.5	9.1	2.61
7	7	95	2.4	10.1	1.85
7	17	95	2.7	11.1	2.91
6	17	96	2.0	9.0	3.22
7	4	96	2.7	n/a	1.50
7	12	96	2.6	9.6	2.03
7	30	96	2.8	12.3	1.94
8	8	96	4.2	11.2	1.92
5	26	97	3.2	7.0	2.93
6	11	97	2.3	9.2	3.64
8	15	97	1.6	13.1	1.73
8	28	97	2.1	12.3	2.10
6	22	98	1.6	8.2	n/a
7	4	98	2.4	10.1	2.80
7	14	98	2.5	11.0	2.00
9	5	98	1.9	11.2	n/a
6	8	99	3.0	4.7	3.23
6	16	99	2.0	7.2	4.16
6	24	99	1.8	7.1	3.37
7	6	99	n/a	n/a	n/a
9	6	99	0.6	10.2	2.91
6	9	00	2.2	6.2	9.50
6	18	00	1.3	7.0	7.00
6	26	00	1.6	8.0	6.00
7	5	00	1.5	9.1	5.50
7	11	00	2.0	10.5	3.30
9	5	00	1.0	11.0	10.90
6	27	01	2.8	10.0	2.00
7	2	01	2.6	9.2	2.42
7	13	01	2.6	10.3	2.65
8	30	01	2.1		
6	28	01	2.4	10.0	2.14
7	3	01	2.5	9.2	2.46
7	13	01	1.8	10.3	2.67
9	1	01	2.9		
6	25	04	1.9	9.2	1.02
6	29	04	2.4	9.25	1.62
7	5	04	2.0	9.75	0.79
7	11	04	1.8	14.2	n/a
9	3	04	1.4	12.5	n/a

Table 4. Limnological data from Chignik Lake, 2004.

	Clark				Delta			
Date	Secchi (m)	Depth (m)	Temp (C)	Chl a	Secchi (m)	Depth	Temp (C)	Chl a
6/25	2.25	0	9.5	n/a	1.50	0	9.5	n/a
		1	9	0.25		1	9.5	1.76
		5	9	1.27		5	9.5	1.81
		10	9	1.04		10	9	0.47
		20	9	1.10		20	9	0.46
6/29	2.75	0	9	n/a	2.00	0	9.5	n/a
		1	9	1.33		1	9.5	1.75
		5	9	1.31		5	9.5	2.37
		10	9	1.52		10	9.5	1.74
		20	9	1.38		20	9.5	1.55
7/5	2.5	0	10	n/a	1.5	0	10	n/a
		1	10	0.71		1	10	0.30
		5	10	0.97		5	10	0.42
		10	9.5	1.10		10	9.5	0.68
		20	9.5	1.45		20	9	0.68
7/11	2.50	0	16	n/a	1.00	0	20	n/a
		1	15			1	17	
		5	13			5	13	
		10	13			10	12	
		20	11			20	12	
9/3	1.00	0	13	n/a	1.75	0	12.5	n/a
		1	13			1	12	
		5	13			5	12	
		10	13			10	12	
		20	12.5			20	12	
2004 means	2.20		10.9	1.1	1.55		11.1	1.2

Table 5. Limnological data from Black Lake, 2004.

Date	Location	Secchi depth (m)	Surface Temp. (C)
27-Jun-04	Outlet	1.75	12
	Hyrdo	1.5	13
	Alec	1.25	13
30-Jun-04	Outlet	0.75	9
	Hyrdo	2.25	12
	Alec	2	13
12-Jul-04	Outlet	1	17
	Hyrdo	2.5	18
	Alec	1.5	18
4-Sep-04	Outlet	1	13
	Hyrdo	0.75	12.5
	Alec	0.75	13
	2004 means	1.4	13.6

Table 6. Historical averages of limnological data from Black Lake, 1990-2004

Date			Secchi depth (m)	Surface water temp. (C)	Chloro-phyll a mg/m^3
Mo	Day	Year			
6	27	90	1.8	13.0	2.65
6	20	92	n/a	n/a	3.24
7	8	92	n/a	n/a	2.28
9	3	92	n/a	n/a	4.59
5	18	93	1.6	8.8	1.26
6	16	93	1.7	9.7	0.98
7	16	93	1.8	15.5	0.60
8	15	93	0.9	12.7	4.33
9	9	93	0.7	12.5	3.32
6	9	95	1.4	11.2	3.67
6	20	95	1.4	10.7	1.34
7	11	95	1.5	12.3	1.15
7	23	96	1.8	13.8	2.26
6	2	97	2.2	12.5	1.75
6	20	98	1.2	9.7	n/a
7	3	98	1.0	12.3	4.02
7	16	98	1.3	13.2	1.99
9	3	98	0.5	10.3	n/a
6	12	99	0.5	7.8	2.13
6	21	99	1.3	11.3	2.65
6	26	99	1.3	10.4	3.01
7	5	99	1.2	11.0	4.75
9	7	99	1.5	9.8	4.29
6	10	00	1.3	10.0	9.50
6	19	00	1.3	9.0	7.03
6	27	00	2.0	n/a	6.00
7	6	00	1.7	12.0	5.47
7	13	00	2.0	15.3	3.27
9	7	00	0.7	9.5	10.94
6	27	01	1.8	12.5	n/a
7	7	01	0.6	10.6	n/a
7	10	01	1.6	12.3	n/a
7	13	01	1.8	10.9	n/a
9	4	01	0.7	n/a	n/a
6	28	02	1.67	16.5	2.32
7	3	02	1.75	13.6	4.01
7	19	02	1.58	n/a	2.53
8	30	02	1.42	14.17	
6	27	04	1.5	12.7	n/a
6	30	04	1.7	11.3	n/a
7	12	04	1.7	17.7	n/a
9	4	04	0.8	12.8	n/a

Table 7. Catches from FRI's 2004 annual townet survey in Chignik Lake

Location	**Species**					
	3 spine stickleback	9 spine stickleback	Coho salmon	Pond smelt	Sculpin	Sockeye salmon
Clark Bay	20	8	0	264	2	98
Delta	7	2	0	161	0	58
North Hatchery	1	0	0	47	0	25
Outlet	25	6	0	144	0	91
South Hatchery	102	14	6	246	0	90
Totals	155	30	6	862	2	362

Table 8. Historical tow net catches for Chignik Lake (10 min tows), 1960-2004.

Date		No. of tows	Species							
			Sockeye salmon			Juvenile coho	Juvenile chinook	Pond smelt	Stickleback	
Mo	Year		Fry	Yearling	Total				3-spine	9-spine
6	60	15	6	33	39	0	0	0	0	1
7	60	42	5	25	30	0	0	0	1	3
8	60	9	74	83	157	0	0	0	1	9
9	60	1	6	12	18	0	0	0	0	0
7	61	14	1	136	137	0	0	0	1	12
8	61	65	308	286	594	0	0	0	13	50
9	61	1	278	103	381	0	0	1	6	10
7	62	17	46	648	694	1	0	0	2	12
8	62	80	55	238	293	0	0	0	32	14
9	62	11	14	58	72	0	0	3	121	6
6	63	4	66	76	142	2	1	1	2	11
7	63	22	28	147	175	1	0	1	5	26
8	63	44	56	87	143	0	0	4	26	15
9	63	13	230	171	401	0	0	16	39	16
7	64	13	5	28	33	0	0	0	2	7
8	64	38	61	83	144	0	0	1	10	15
9	64	15	251	79	330	0	0	0	30	15
7	65	14	65	152	217	1	2	0	1	15
8	65	27	91	410	501	0	0	4	3	24
7	66	6	60	319	379	1	1	1	1	3
8	66	16	419	144	563	0	0	0	1	3
9	66	15	137	34	171	0	0	0	4	5
6	67	11	145	74	219	0	1	0	0	4
7	67	18	1338	177	1515	0	0	3	1	76
9	67	18	295	53	348	0	0	1	45	9
6	68	2	86	100	186	2	2	53	0	5
7	68	18	138	163	301	1	0	1	1	3
8	68	26	36	64	100	0	0	3	18	5
6	69	10	48	0	48	4	0	0	2	2
8	69	20	124	26	150	0	0	1	4	6
9	69	14	910	13	923	0	0	9	20	7
6	70	10	67	440	507	10	0	2	3	1
7	70	10	59	120	179	0	0	1	3	18
8	70	15	14	52	66	0	0	0	21	2
7	71	20	183	63	246	1	0	0	4	7
9	71	15	247	18	265	0	0	4	28	4
7	72	10	25	27	52	3	0	0	1	2
8	72	30	131	41	172	0	0	0	9	15
7	73	10	78	76	154	0	0	0	1	5
8	73	20	156	168	324	0	0	1	2	11
7	80	20	52	50	102	0	0	20	2	8

Historical Chignik Lake tow net catches--cont'd

Date		No.	Species							
		of	Sockeye salmon			Juvenile	Juvenile	Pond	Stickleback	
Mo	Year	tows	Fry	Yearling	Total	coho	chinook	smelt	3-spine	9-spine
7	82	5	8	1	9	2	0	0	1	1
6	83	5	33	87	120	0	0	0	0	1
7	83	10	173	101	274	0	0	1	0	1
9	92	9	65	9	74	0	0	5	2	3
8	93	7	61	23	84	0	0	39	47	11
9	93	8	44	18	62	0	0	108	19	16
9	95	5	38	17	55	0	0	17	8	3
9	96	6	16	24	40	0	0	4	58	4
9	97	5	95	200	295	0	0	58	59	24
9	98	5	53	156	209	0	0	6	1618	12
9	99	5	13	9	22	0	0	90	27	5
6	00	3			* 116	0	0	0	134	26
7	00	3			* 38	1	0	0	54	3
9	00	5			* 347	0	0	198	14	2
7	01	1			*13	0	0	0	2	0
8	01	5			*603	0	0	25	9	4
9	02	5			*83	0	0	5	13	2
8	03	5			*347	0	0	199	2	25
9	04	5			*362	6	0	862	155	30

* Juvenile scales are no longer read to determine the ages

Table 9. Historical beachseine catches for Chignik Lake, 1956-2004.

Date		No. of sets	Species								
			Sockeye salmon		Juvenile	Juvenile		Stickleback			Pygmy
Mo	Year		< 45mm	> 45mm	coho	chinook	Char	3-spine	9-spine	Sculpin	whitefish
5	56	5	0	94							
7	56	4	53	65							
8	56	10	28	57							
5	57	3	0	167							
6	57	4	6	109							
7	57	6	11	92							
8	57	6	1	98							
5	59	4	5	81							
6	59	1	0	98							
6	61	1	4	309	120	0	0	248	0	0	90
7	61	2	1	149	20	0	0	70	0	0	52
8	61	4	17	283	19	0	3	441	140	1	54
9	61	3	16	216	0	0	0	86	7	3	35
6	62	2	0	0	0	0	22	291	5	0	29
7	62	5	0	0	4	0	39	114	4	1	83
8	62	3	7	208	26	0	3	30	2	59	4
9	62	2	1	527	19	0	3	20	0	4	1
6	63	4	27	81	35	0	2	18	6	1	2
7	63	4	3	81	3	0	2	1	2	1	0
8	63	4	8	114	0	0	0	124	0	0	0
9	63	3	8	291	0	0	0	61	0	0	0
6	64	9		49	2	0	2	22	3	5	32
7	64	10		83	7	0	15	69	5	13	2
8	64	9		264	26	24	26	667	72	2	95
6	65	4	138	162	3	2	2	27	2	4	7
7	65	10	74	27	29	6	14	12	1	4	9
8	65	2	51	227	16	5	3	546	50	4	28
6	67	4	13	155	97	97	66	23	8	8	3
6	68	4	24	3	2	0	0	42	1	6	27
6	69	4	22	4	11	22	23	7	23	20	3
6	70	4	23	41	1	0	0	3	0	1	32
7	70	5	0	0	8	0	25	45	17	22	22
8	70	7	0	0	25	0	64	55	0	3	10
6	71	10	408	36	7	0	3	112	27	6	3
7	71	5	1	6	8	0	2	53	4	15	4
6	72	6	87	380	3	0	1	9	6	13	4
7	72	6	19	3	58	0	36	92	25	29	18
6	80	5	47	0	2	0	7	16	1	28	0
7	80	12	52	9	3	1	2	22	1	16	1
5	85	10	113	189	103	2	6	3317	53	12	2
6	85	18	15	71	112	3	36	1031	136	18	28
7	85	17	9	217	30	4	104	399	28	11	6
8	85	6	20	183	9						
9	85	6	0	2	7	0	18	943	18	25	6
5	86	33	33	85	48	8	10	499	33	22	7
6	86	49	49	3	31	8	17	111	15	14	7
7	86	46	46	4	12	2	12	162	9	13	5
8	86	12	2	15	6	2	24	154	5	14	11

Historical Chignik Lake beachseine catches--con't

Date Mo	Year	No. of sets	Sockeye salmon < 45mm	Sockeye salmon > 45mm	Juvenile coho	Juvenile chinook	Char	Stickleback 3-spine	Stickleback 9-spine	Sculpin	Pygmy whitefish
5	87	12	1048	714	136	7	25	639	54	13	19
6	87	54	6	230	113	9	65	260	6	13	15
7	87	58	16	51	17	0	8	44	5	14	3
6	92	15	10	15	13	0	7	123	22	13	2
7	92	6	9	2	20	2	23	192	16	7	7
5	93	6	1	173	57	0	13	224	7	9	41
6	93	6	1	20	6	0	15	24	0	8	13
6	95	21	27	9	11	1	13	244	26	18	8
7	95	21	16	13	13	1	10	49	6	17	6
6	96	7	12	121	39	1	15	117	3	22	<1
7	96	21	9	47	30	0	24	215	9	7	19
8	96	7	3	16	41	0	22	82	7	1	9
5	97	6	77	324	15	7	19	1367	24	61	0
6	97	6	5	125	7	0	6	14	3	6	2
6	98	11	140	436	104	43	58	4488	214	74	16
7	98	9	31	359	307	11	374	4106	219	79	17
6	99	18	36	28	55	9	77	527	16	8	2
6	00	12	33	17	13	0	17	317	7	10	9
7	00	6	32	6	4	0	1	110	3	1	1
6	01	6	10	38	12	0	20	94	6	2	0
7	01	6	17	26	2	2	22	18	3	2	3
6	02	6	50	0	13	0	17	317	7	10	10
7	02	6	46	14	18	3	57	315	16	24	6
6	03	12	1	7	10	0	10	43	2	4	1
7	03	12	3	5	5	0	3	167	2	2	2
6	04	15	24	29	35	17	8	2161	32	14	13
7	04	18	209	771	167	4	36	5083	129	59	46

Table 10. Number of fish caught at each sampling location during 2004

Date	Location	3 spine stickleback	9 spine stickleback	Char	Coho	Chinook	Pink	Pond smelt	Sculpin	Sockeye	Starry Flounder	Whitefish
6/28/2004	Clark	1	0	2	12	1	0	0	5	19	0	0
	Cucumber	0	0	1	5	1	0	0	6	11	0	0
	Delta	0	0	5	2	0	0	0	2	2	0	1
	Outlet	2160	32	0	12	8	0	0	0	52	8	12
	South Hatchery	0	0	0	4	7	0	0	1	2	0	0
	North Hatchery	0	0	0	0	0	0	0	0	0	0	0
7/3/2004	Clark	0	1	2	0	1	0	0	1	16	0	1
	Cucumber	2	0	5	2	0	0	0	10	1	0	0
	Delta	0	0	0	8	0	0	0	20	104	0	8
	Outlet	3176	0	0	59	0	0	135	0	347	0	0
	South Hatchery	0	0	3	0	3	0	0	8	12	0	0
	North Hatchery	1	0	1	0	0	0	0	2	5	0	12
7/10/2004	Clark	4	0	4	9	0	0	2	2	26	1	4
	Cucumber	4	0	9	1	0	0	7	1	118	0	1
	Delta	264	12	8	80	0	0	904	8	132	0	8
	Outlet	1632	116	0	8	0	0	24	4	208	4	12
	South Hatchery	0	0	4	0	0	0	0	1	3	0	0
	North Hatchery	0	0	0	0	0	0	4	2	8	0	0
Totals		**7244**	**161**	**44**	**202**	**21**	**0**	**1076**	**73**	**1066**	**13**	**59**

Table 11. Historical Beach seine catches in Chignik Lagoon from 2000-2004

Date		No. of sets	Species							
			Juvenile	Juvenile	Juvenile		Stickleback			Pygmy
Mo	Year		sockeye	coho	chinook	Char	3-spine	9-spine	Sculpin	whitefish
6	00	10	83	57	0	49	31	0	0	0
7	00	1	300	20	0	25	60	0	0	0
6	01	3	117	12	0	47	12	0	1	1
7	01	6	42	4	1	55	46	0	3	0
8	01	2	16	3	0	6	0	0	1	0
7	02	4	119	28	0	127	20	0	2	0
6	03	6	79	4	0	7	1	0	3	0
7	03	6	63	12	0	9	3	0	0	0
7	04	6	97	9	0	9	1	1	3	1

Table 12. Coefficients for the model fits to the Alec River flow data; the model includes are the years sampled between 1990 and 2002. The full generalized linear model is arcsin(% south channel flow)= log(total flow) + year.

Coefficients	Esimate	SE	t-value	p-value
Intercept	-7.206223	3.010003	-2.394	0.0236
log(total flow)	-0.149657	0.011843	-12.637	<<0.001
year	0.004154	0.001504	2.762	0.01

Table 13. Retrospective analysis looking at the significance of the "year" variable in the full GLM model. "Increase in flow" represents the coefficient for year.

Years	**Coefficient of "year"**	**p-value**
1990, 1992-93, 1998	0.09%	0.745
1990, 1992-93, 1998-99	0.10%	0.637
1990, 1992-93, 1998-99, 2002	0.48%	0.046
1990, 1992-93, 1998-99, 2002-03	0.49%	0.011

Table 14. Cumulative in-season escapement goals for the sockeye salmon stocks in Black Lake and Chignik Lake (Alaska Department of Fish and Game, Area Management Report).

Black Lake stock				Chignik Lake stock			
Date	Lower		Upper	Date	Upper		Lower
12-Jun	0	-	40 000	6-Jul	0		0
14-Jun	50 000	-	65 000	8-Jul	0	-	0
16-Jun	75 000	-	100 000	10-Jul	0	-	40 000
18-Jun	125 000	-	150 000	12-Jul	50 000	-	60 000
20-Jun	175 000	-	200 000	14-Jul	65 000	-	75 000
22-Jun	225 000	-	250 000	16-Jul	80 000	-	90 000
25-Jun	275 000	-	325 000	19-Jul	100 000	-	115 000
30-Jun	350 000	-	400 000	21-Jul	125 000	-	135 000
				23-Jul	145 000	-	160 000
				26-Jul	170 000	-	180 000
				29-Jul	185 000	-	195 000
				31-Jul	195 000	-	200 000
				31-Aug	200 000	-	250 000