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CHIGNIK SALMON STUDIES
INVESTIGATIONS OF SALMON POPULATIONS, HYDROLOGY, AND LIMNOLOGY OF THE CHIGNIK LAKES, ALASKA, DURING 2003-2004

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ANNUAL REPORT
ANADROMOUS FISH PROJECT

To

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And

FINAL REPORT

To

CHIGNIK REGIONAL AQUACULTURE ASSOCIATION

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KEY WORDS

Alec River, beach seine, Black Lake, Chignik Lagoon, Chignik Lake, escapement goals, fry emergence, hydrology, limnology, *Oncorhynchus nerka*, Ricker recruitment curve, sockeye salmon, tow-net

INTRODUCTION

Fisheries Research Institute (FRI) has been conducting research on the Chignik lakes system since the 1950s. During that time funding 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). Both institutions have funded FRI with the goal of maintaining the health of the sockeye runs in the Chignik lakes. The government feels the long-term collection of biological data is important to the understanding of ecosystem health, and CRAA feels that analysis of physical changes in the environment and fisheries management are crucial to the health of the fish and the commercial and subsistence fisheries. The purpose of this report is to present analysis of data that recognizes the feelings of both parties.

A key concern among Chignik fishermen, residents and biologists has been the substantial change in the water volume of Black Lake since the late 1960s. This change appears to have caused greater premature out-migration of Black Lake sockeye 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 1997). 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 2003-04 research and monitoring at Chignik were to continue the basic monitoring of biological and physical characteristics that were monitored in past years and to conduct four additional projects: 1) measure bank erosion of lower Alec River, 2) estimate Alec River discharge during different levels of flow, 3) maintain historical ecological datasets, 4) develop models that describe salmon migration through the 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 purpose of the long-term data collection is 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 from spring through fall. These data are complementary to sockeye smolt studies conducted by Alaska Department of Fish and Game (ADF&G) and past winter ecology studies (Ruggerone 1999). A long-term database resulting from these measurements 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 2003 fieldwork was completed in two periods: 15 June through 16 July, and 27 August through 4 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 both Black and Chignik lakes during late August and early September to assess the relative abundance and lengths of juvenile sockeye salmon in the pelagic region.

LIMNOLOGY

Methods

Water temperature, water transparency, phytoplankton, and zooplankton samples were collected on both Black Lake (three stations) and Chignik Lake (two stations) (Figure 1). Water clarity was estimated with a Secchi disk. Water temperatures were taken with a pocket thermometer on the lake's surface at Black Lake and from water taken at several depths with a van Dorn bottle at Chignik Lake. Additionally, temperature data were collected from automatic, year-round thermographs, deployed in Black Lake at Hydro Point, Chignik River, and out of the water at Ron Lind's cabin, and the FRI facility at Chignik Lake. Onset, the company that produces the remote temperature loggers, released a software patch for their loggers that was not available when ours were deployed in the field. As a result of the software problem the loggers failed to record the temperature data throughout the season.

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 500ml water that was sieved through Millipore filters (1.2µ). 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. The same net was towed 20m horizontally along the lake surface in Black Lake. Additional details on sampling methodology are described in the FRI field manual (Rogers et al. 2002).

Results

Biotic

The zooplankton counts were not completed by the time the report was being compiled. The samples were collected and will be present in the 2005 report.

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. During 2003 the secchi and surface temperatures were consistent with historical trends (Figure 2). The chlorophyll, however, was high in Black Lake and Chignik Lake during June and July. Table 1--Table 4 provide the long-term and 2003 values for the Chignik Lake and Black Lake limnology.

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. The standing crop of chlorophyll a in Black Lake and Chignik Lake is high compared to that of other sockeye lakes in Alaska (Burgner et al. 1969, Ruggerone 1994).

Black Lake is shallow and turbid. Water temperature responds quickly to air temperature, and increases rapidly after ice-out. Comparing the seasonal profiles of surface temperature it is apparent that Black Lake is initially much warmer than Chignik, but it also cools faster in the fall. Chignik Lake is much deeper than Black Lake and the water column is typically well mixed by the strong, consistent winds.

Since 1999 FRI has been reporting the lake level in Black Lake. The lake level appears to be stable and maintained at an average depth throughout the 2003 season (Figure 3).

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 the development of relatively stable funding provided by CRAA we have sampled both lakes since 1992, except for 1994[1] (Table 5 and Table 6).

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 (Figure 1). 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 Alaska Salmon Program operations manual (Rogers et al. 2002).

Results

Tow net catches are presented in Figure 4 to Figure 9 and Table 5 to Table 6. These data only represent tows made during our annual survey around the 1st of September. The catches of juvenile sockeye during the fall of 2003 were average for Chignik Lake (485 per 10 min tow; 81 ft^2 net) and low for Black Lake (10 per 10 min-tow; 36 ft^2 net). The variability in the juvenile sockeye catches was high for Chignik Lake and low for Black Lake (Figure 4). One tow in Chignik Lake yielded 2500 sockeye. Coho and continued to comprise only a small proportion of the tow net catches in Chignik Lake (Figure 7). Pond smelt and three-spine sticklebacks, and nine-spine sticklebacks comprise a significant fraction of the Black Lake tow net catches (Figure 5-Figure 8).

Narver's (1966) hypothesis is that greater sockeye spawning escapement leads to fewer sticklebacks because sockeye are able to out-compete sticklebacks for prey resources. Figure 9 shows there is little relationship between the numbers of sockeye captured in the tow net versus the number of sticklebacks captured in the tow net.

During the 2002 season lake levels in Black Lake had become so low that the six-foot tow net was permanently lodged in the bottom of Black Lake (the net later destroyed during the recovery progress). As result we have switched to using a four-foot tow net for Black Lake.

BEACH SEINING

Beach seining was conducted in Chignik Lake several years prior to 1973 and since the mid-1980s (Ruggerone 1989, 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 tow-net catches, which reflects their preference for the nearshore habitat (Ruggerone 1989). 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 the year, or approximately 59% of the emerging sockeye population (Ruggerone and 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 Alaska Salmon Program operations manual (Rogers et al. 2002).

Results

Chignik Lake

Beach seine sampling may not reflect abundance of Chignik Lake sockeye, 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 beach seines continue to be well below average for sockeye, three-spine sticklebacks and coho (Figure 10-Figure 11; Table 7-Table 8). The fish lengths from historical beach seine data are still being compiled, however results on the length distribution from 2002 and 2003 are shown in Figure 13. Lengths of juvenile sockeye from 2002 and 2003 are similar; the 2003 data show slightly larger sockeye than 2002 (Figure 13).

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. Figure 12 and Table 8 show the catches of key species during the last three years. Lengths from juvenile sockeye are shown in Figure 13. Lengths in

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

2003 appear to be slight higher than those in 2002. It is also apparent that sockeye in the lagoon are considerably larger for a given date than those captured in Chignik Lake.

ALEC RIVER HYDROLOGY

Previous research has shown that the south channel of the lower Alec River leading into the Black Lake outlet is becoming larger relative to the north channel leading into the Alec Bay (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.

Erosion of the banks along the south channel of Alec River has been monitored since 1991 (Ruggerone and Denman 1991) 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 via the south channel. 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 2003 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.

[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.

Methods

Measurements of flow were made on both channels by stretching a cable across the river at locations maintained by FRI (Figure 14). Figure 15 shows the relationship between the total discharge for the Alec River, and the percent of the total discharge flowing out the Alec River. Depth is measured in centimeters, and flow is measured using a flow meter with an accuracy of 0.1 m/s.

We use an arcsine transformation of the percentage of water flowing through the south channel, and log transformation of the total flow when modeling the relationship. We treat total flow, percentage to the south channel, and year as a continuous variable. Our generalized linear model (GLM) tests for the significance of year and total flow as predictors of the percent of the discharge flowing out the south channel of Alec River.

Results

Erosion

Annual measurements of erosion along the south channel riverbank at nine locations indicated that approximately 0.25—0.32 m of the right bank is lost per year, depending on location (Table 9). This erosion rate corresponds to a widening of the south channel by approximately 1% every three years.

Discharge

Table 10 shows that coefficients of the GLM for the full model: arcsine (% flow to south channel) = intercept + log (total flow to both channels) + year. We show that the intercept, total flow, and year coefficients have a statistically significant effect ($p<0.05$). The coefficient for year estimates 0.5% more water is flowing to south channel of the Alec River every year. Figure 16 shows the predicted relationship between total Alec River discharge and percent flow to the south channel for the all of the years. The model predicts the as the year increases more of the water is flowing through the south channel for a given total discharge. The standard residuals for the model are heteroschedastic (Figure 17), satisfying the assumption of normally distributed error.

We have also constructed a retrospective analysis of the previous years data using the same model (Table 11). We subtract individual years of data and ask what conclusion would we have made in their absence. The keys points of interest are: 1) it is not until the two most recent years that the “year” effect has become significant; and 2) the coefficient for year is increasing over time.

Run reconstruction

A method for using age composition data to determine stock-specific migration timing and abundance in a mixed-stock fishery is developed. Catch, escapement, and age composition data from 1978 to 2002 for the sockeye salmon fishery in Chignik, Alaska, are analyzed to estimate the total abundance and migration timing for the Black Lake and Chignik Lake stocks. A maximum likelihood approach is used to estimate the values of the parameters of the model that lead to the best fits to the observed data. The uncertainty associated with the estimates for the parameters and for other model outputs is examined using Bayesian methods. The accuracy of this stock separation model is evaluated by comparing its results to those for the Alaska Department of Fish and Game's direct stock separation technique using scale pattern analysis (SPA). The estimated proportions of the total catch and escapement that were from the Black Lake stock based from the model were highly correlated with those from the SPA for most years from 1978 to 2002 (r=0.83). The estimates of peak arrival date for the Black Lake stock (June 20th ± 6 days) and the Chignik Lake stock (July 25th ± 15 days) was consistent among years, and the posterior distributions for the peak arrival dates for a given year were precise. The results suggest that this model can provide salmon managers with a reliable and inexpensive method for determining stock-specific migration timing and abundance in a mixed-stock fishery. The results of this analysis are detailed in Brandon Chasco's masters thesis, "Estimating stock abundance and migration timing in a mixed-stock fishery for sockeye salmon, (*Oncorhynchus nerka*) in Chignik, Alaska."

Forecasts

Greg Ruggerone has completed a pre-season forecast for CRAA in recent years. His forecasts, as well as ADF&G's, and their accuracy compared to the results from Scale Pattern Analysis post-season results are presented in Table 12.

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Tab les

Table 1. Results of the 2003 survey of Black Lake limnology.

Date	Location	Secchi depth (m)	Surface Temp. (C)	Chlorophyll *a* (mg/m^3)
20-Jun	Outlet	1.75	9.0	11.70
	Hyrdo	1.00	12.0	11.80
	Alec	1.25	12.5	0.00
27-Jun	Outlet	2.00	11.5	0.00
	Hyrdo	1.75	12.5	13.40
	Alec	1.75	11.0	0.00
4-Jul	Outlet	1.25	14.5	21.00
	Hyrdo	1.25	14.5	55.60
	Alec	1.00	14.0	12.30
12-Jul	Outlet	1.50	12.5	11.4
	Hyrdo	1.50	14.5	40.8
	Alec	1.25	14.5	25.1
	2003 means	1.4	12.8	16.93

Table 2. Historical limnological data for Black Lake.

Date			Secchi depth	Surface water	Chloro- phyll a
Mo	Day	Year	(m)	temp. (C)	mg/m^3
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	14.2	
6	20	03	2.0	11.0	7.8
6	27	03	1.8	11.7	4.3
7	4	03	1.2	14.3	29.6
7	12	03	1.4	13.8	25.8

Table 3. 2003 results for the Chignik Lake limnological survey .

	Clark				Delta			
Date	Secchi (m)	Depth (m)	Temp (C)	Chl a	Secchi (m)	Depth	Temp (C)	Chl a
6/18	3.5	0	8.0		1.75	0	10.5	
		1	8.0	1.0		1	10.0	2.3
		5	8.0	15.0		5	10.0	17.3
		10	8.5	10.0		10	9.5	14.0
		20	8.5	6.0		20	8.5	1.5
6/24	4.25	0	8.5		2.75	0	9.0	
		1	8.5	16.0		1	9.0	9.8
		5	8.5	22.0		5	9.0	8.5
		10	8.5	11.0		10	9.0	21.7
		20	8.5	2.0		20	8.5	10.3
6/30	5.5	0	9.5		4.25	0	11.5	
		1	9.5	10.0		1	11.5	7.8
		5	9.5	8.0		5	10.0	23.5
		10	9.0	6.0		10	10.0	9.2
		20	9.0	9.0		20	9.5	7.0
7/9	2.3	0	10.5		1.25	0	10.5	
		1	11.0	13.0		1	11.0	12.7
		5	11.0	9.0		5	11.0	13.1
		10	11.0	10.0		10	10.5	5.1
		20	11.0	15.0		20	10.0	4.7
2003 means	3.9		9.2	10.2	2.50		9.9	10.5

Table 4. Historical limnological data for Chignik Lake.

Date			Secchi depth	Averages over 1-20 m	
				Temp.	Chlorophyll a
Mo	Day	Year	(m)	(C)	(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

Table 4 continued

Date			Secchi depth	Averages over 1-20 m	
Mo	Day	Year	(m)	Temp. (C)	Chlorophyll a (mg/m^3)
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	02	2.4	10.0	2.14
7	3	02	2.5	9.2	2.46
7	13	02	1.8	10.3	2.67
9	1	02	2.9		
6	18	03	2.7	9.0	8.4
6	24	03	3.5	8.7	12.7
6	30	03	4.9	9.9	10.1
7	9	03	1.8	10.8	10.4

Table 5. Historical tow-net catches for Black Lake.

Date		No.	Species						
		of	Sockeye salmon		Juvenile	Juvenile	Pond	Stickleback	
Mo	Year	tows	Fry	Yearling	coho	chinook	smelt	3-spine	9-spine
6	60	12	5	1	0	0	9	18	2
7	60	8	11	0	0	0	0	19	2
7	61	10	2096	0	1	0	11	872	94
8	61	9	1057	0	0	0	113	3439	227
9	61	10	567	0	0	0	43	206	14
7	62	10	570	0	4	0	0	2387	136
8	62	65	279	0	0	0	45	697	52
6	63	4	369	0	1	0	198	188	5
7	63	14	182	3	1	0	90	61	27
8	63	22	304	3	2	0	229	267	55
7	64	28	313	3	1	0	12	121	16
8	64	8	385	5	1	0	65	824	27
9	64	13	221	4	1	0	258	588	64
7	65	10	1426	6	2	0	31	75	21
8	65	21	1001	2	0	0	36	396	36
8	66	22	585	2	1	0	56	64	13
6	67	21	1798	12	1	0	38	13	37
7	67	13	968	8	1	0	473	146	80
8	67	3	338	1	1	0	213	1139	373
9	67	5	294	1	0	0	117	250	109
7	68	15	614	1	2	0	51	100	24
8	68	13	60	1	1	0	170	394	91
9	68	7	102	1	0	0	62	197	74
6	69	1	772	0	6	0	172	2	2
7	69	6	1265	2	5	0	138	35	26
8	69	21	615	0	1	0	59	193	29
6	70	8	126	3	2	0	0	4	3
7	70	8	573	1	1	0	8	36	22
8	70	20	332	1	1	0	19	139	60
7	71	14	637	1	1	0	11	26	17
8	71	13	141	0	1	0	200	32	35
7	72	8	144	7	1	0	8	11	10
8	72	8	406	0	1	0	6	80	21
9	72	12	379	0	0	0	127	10	8
9	73	8	291	0	4	0	905	486	54
11	73	8	20	0	0	0	61	42	31
9	92	7	347	0	1	0	110	70	78
6	93	2	3260	0	0	0	148	10	30
7	93	1	478	0	0	0	13	0	0
8	93	9	143	0	11	0	729	910	1148
9	93	4	126	0	23	0	1914	565	269
6	95	6	28	4	0	0	19	4	2
9	95	5	176	1	0	0	49	15	12
9	96	3	82		(All other fishes released)				
9	97	3	80	0	3	0	173	217	64
9	98	5	303	0	15	0	92	219	128
9	99	4	114	0	23	0	208	95	126
6	00	3§	73	0	0	0	0	0	0
7	00	4§	30	0	0	0	1	0	0
9	00	4§	1591	0	0	0	438	51	153
7	01	1§	700	0	0	0	20	0	0
9	01	5§	251	0	0	0	960	1	3
8	02	4	488	0	0	0	69	84	25
8	03	4	10	0	2	0	24	113	567

§ Tows were made during the day due to strong winds and adverse conditions

Table 6. Historical tow-net catches for Chignik Lake.

Date		No. of	Species							
			Sockeye salmon			Juvenile	Juvenile	Pond	Stickleback	
Mo	Year	tows	Fry	Yearling	Total	coho	chinook	smelt	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			*485	1	0	436	2	25

* Juvenile scales are no longer read to determine the ages

Table 7. Historical beach-seine catches for Chignik Lake.

Date		No.	Species								
		of	Sockeye salmon		Juvenile	Juvenile		Stickleback			Pygmy
Mo	Year	sets	< 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		No.	Species								
		of	Sockeye salmon		Juvenile	Juvenile		Stickleback			Pygmy
Mo	Year	sets	< 45mm	> 45mm	coho	chinook	Char	3-spine	9-spine	Sculpin	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

Table 8. Historical beach-seine catches in Chignik Lagoon.

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

Table 9. Estimates of bank erosion along the upper reach of the south channel of Alec River, 1992-2003.

Stake	Location	Minimum distance from stake to river bank (m)												Present	Total	Change per
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	condition	change (m)	year (m)
Wye Pt																
1	Wye Pt.			4.00	3.40	3.40	2.96	2.80	1.20	1.20	missing	missing		sunken	-2.80	-0.35
2				4.40	3.10	3.00	2.60	2.53	1.70	1.60	1.17	1.17	1.17	at river	-3.23	-0.29
3	(near S. channel)			3.25	3.00	3.00	2.20	1.78	0.80	0.80	ND	0.80	0.80	sunken	-2.45	-0.25
					-0.72	-0.03	-0.55	-0.22	-1.14	-0.03	-0.43	0.00	0.00		-2.83	-0.30
Straight channel																
1	(rebar)	3.3	3.10	2.85	*2.53*	2.20	1.10	1.08	0.60	0.60	0.60	0.00	*0.80*	new 2003	-3.30	-0.28
2	Discharge area		2.37	2.30	1.95	1.30	0.90	0.90	0.90	0.13	0.13	0.00	*0.62*	new 2003	-2.37	-0.22
				-0.16	-0.34	-0.49	-0.75	-0.01	-0.24	-0.39	0.00	-0.36			-2.84	-0.25
River bend																
1	upriver		8.30	7.65	7.60	5.40	5.32	5.32	5.35	5.35	5.35	5.20	5.20	vertical	-3.10	-0.26
2			10.30	9.95	*9.08*	8.20	7.80	7.80	7.10	6.65	6.65	6.60	6.10	vertical	-4.20	-0.35
3			10.30	9.75	9.70	9.70	9.50	9.45	8.90	8.60	8.60	6.90	6.47	sloping	-3.83	-0.32
4			15.10	13.95	13.70	13.40	13.40	12.15	12.15	12.15	12.15	12.15	12.15	undercut	-2.95	-0.25
5			12.50	12.50	11.55	11.40	11.00	10.70	10.50	10.15	10.15	9.70	8.95	sloping	-3.55	-0.30
6			9.20	8.75	8.70	7.60	7.35	7.40	6.75	6.75	5.49	5.40	5.20	undercut	-4.00	-0.33
7	down river		6.70	6.60	*6.43*	6.25	5.90	5.80	6.10	3.50	3.50	3.50	3.50	beaver tunnel	-3.20	-0.27
				-0.46	-0.34	-0.69	-0.24	-0.24	-0.25	-0.53	-0.18	-0.35	-0.27		-3.55	-0.30
Left bank Pt.																
1	Lt. bank Pt.	2.5	2.50	2.20	1.90	1.80	*1.70*	*1.40*	1.15	1.10	1.09	missing	nissing		-1.40	-0.13
			0.00	*-0.30*	*-0.30*	*-0.10*	*-0.10*	*-0.30*	*-0.25*	*-0.05*	*-0.01*					

Table 10. Coefficients for the model fit to the Alec River flow data; the model includes are the years sampled between 1990 and 2003. The full generalized linear model is arcsin(% south channel flow) = intercept + log(total flow) + year.

Coefficients:	Estimate	Std. Error	t-value	p-value
Intercept	-8.66	3.54	-2.45	0.02
log(total flow)	-0.15	0.01	-11.83	0.00
year	0.005	0.002	2.766	0.01

Table 11. Retrospective analysis looking at the significance of the "year" effect in the model.

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 12. FRI and ADFG forecasts for adult sockeye salmon returns to Black Lake and Chignik Lake.

	Preseason Forecast		
	Ruggerone	ADFG	Actual
	1996		
Black Lake	1.7	1.4	2.1
Chignik Lake	1.1	1.6	1.1
	1997		
Black Lake	1.0	1.0	0.66
Chignik Lake	1.2	1.6	0.92
	1998		
Black Lake	1.1	0.9	0.72
Chignik Lake	1.3	1.1	1.24
	1999		
Black Lake	Greater than Chignik [a]	1.0	2.49
Chignik Lake	Lower than Black Lk	1.3	1.97
	2000		
Black Lake	2.1 to 2.7	3.90	2.20
Chignik Lake	1.2 to 1.5	1.09	0.96
Total	3.3 to 4.2	4.99	3.16
	2001		
Black Lake	0.8 to 1.0	1.00	1.3
Chignik Lake	1.4 to 1.9	0.91	1.7
Total	2.2 to 2.9	1.91	3.00
	2002		
Black Lake	0.8 to 1.0	1.03	1.06
Chignik Lake	0.8 to 1.3	1.09	0.91
Total	1.6 to 2.3	2.12	1.97
	2003		
Black Lake	1.9 to 2.4	1.64	?
Chignik Lake	0.9 to 1.2	1.19	?
Total	2.8 to 3.6	2.83	?

Figures

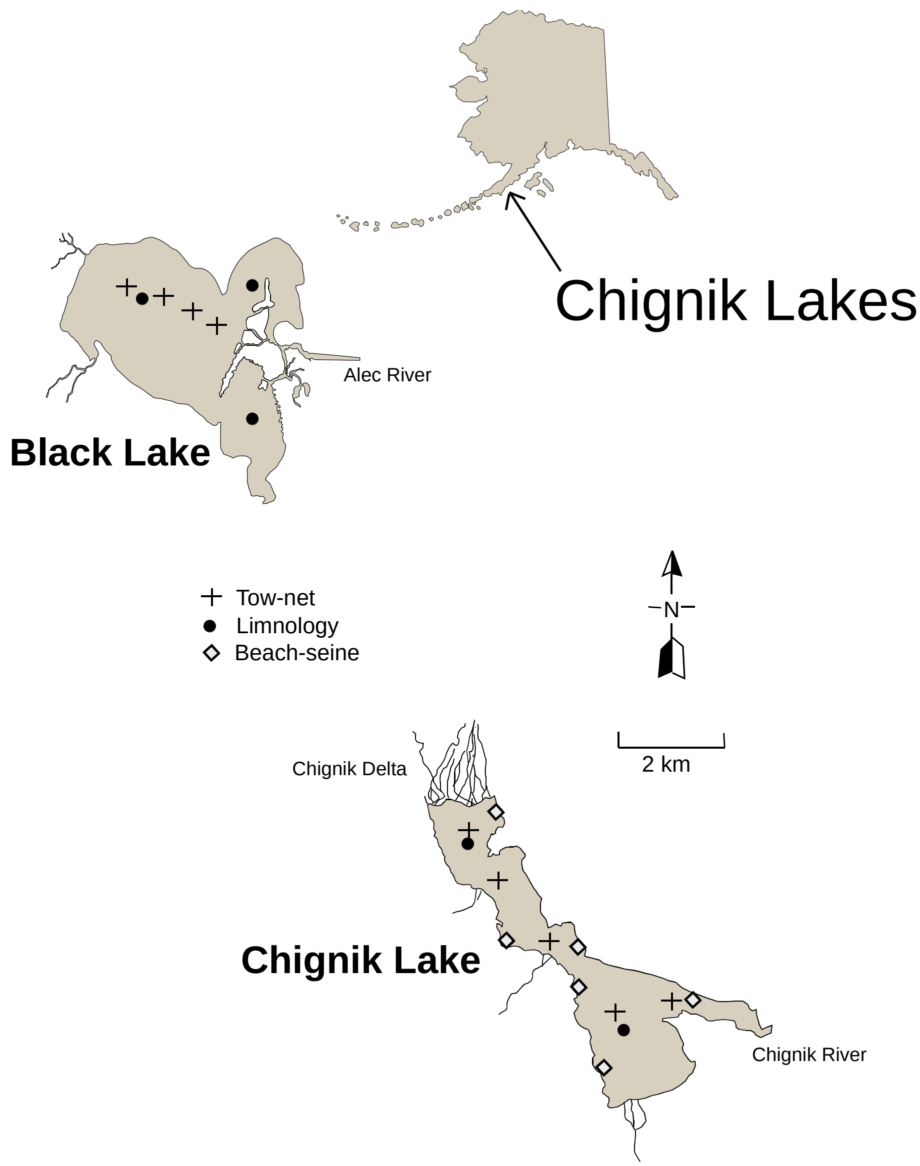


Figure 1. Chignik lakes sampling locations

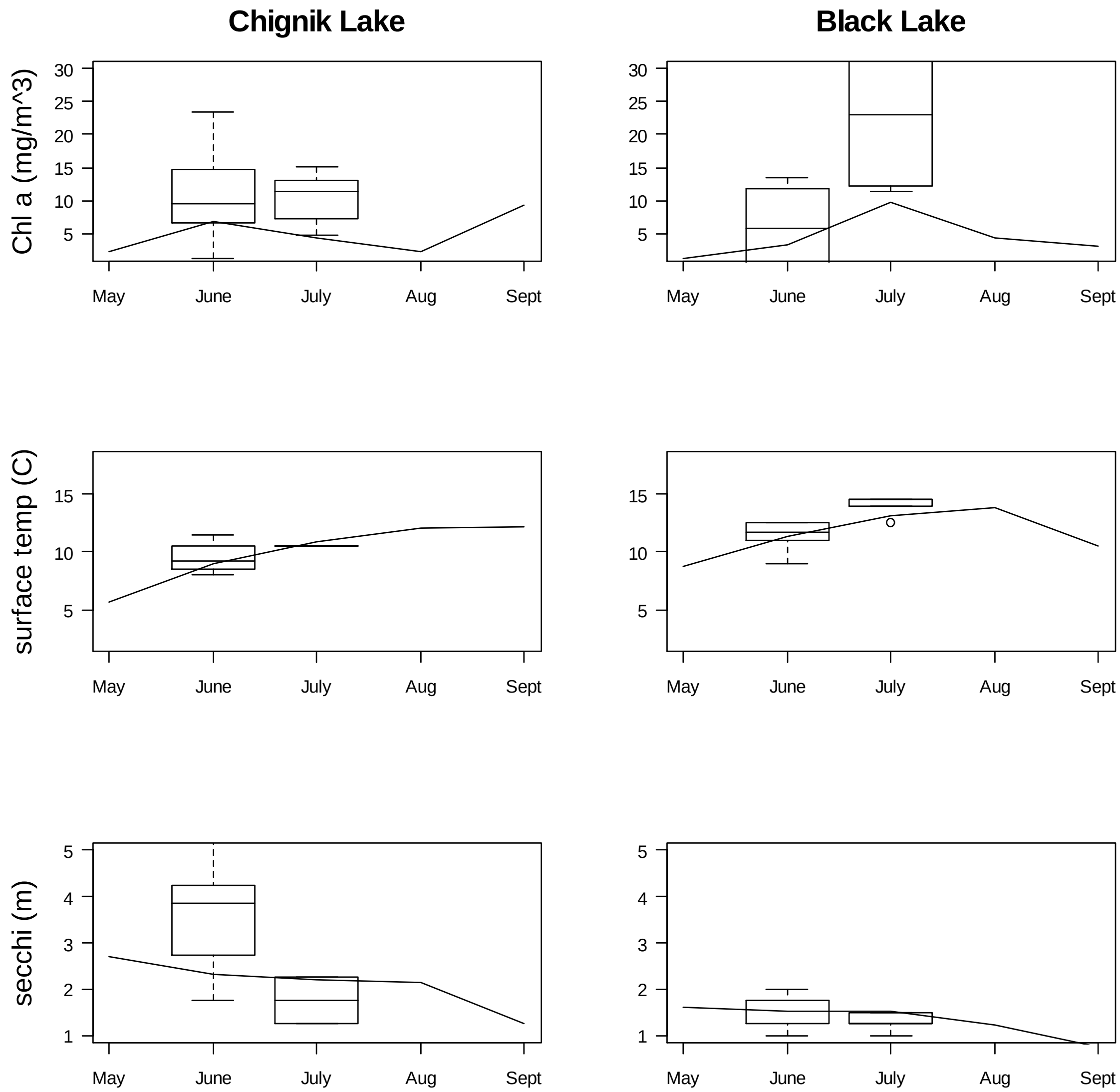
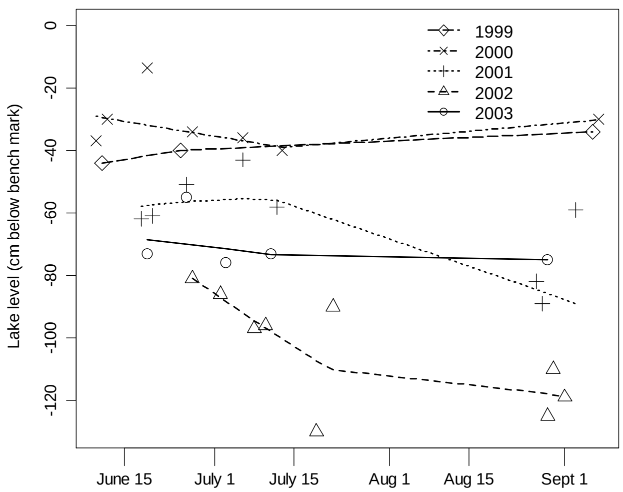


Figure 2. Limnology results Chignik Lake and Black Lake, 2003. Boxes represent the mean and 50% confidence intervals, and whiskers present the 95% confidence intervals. The solid line is the historical trend for all the years that data have been collected for the individual lakes.



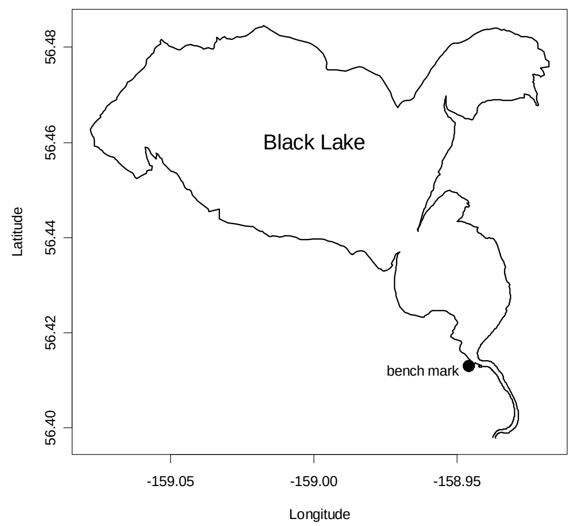


Figure 3. Black Lake levels for 1999-2003, and the location of the FRI bench mark.

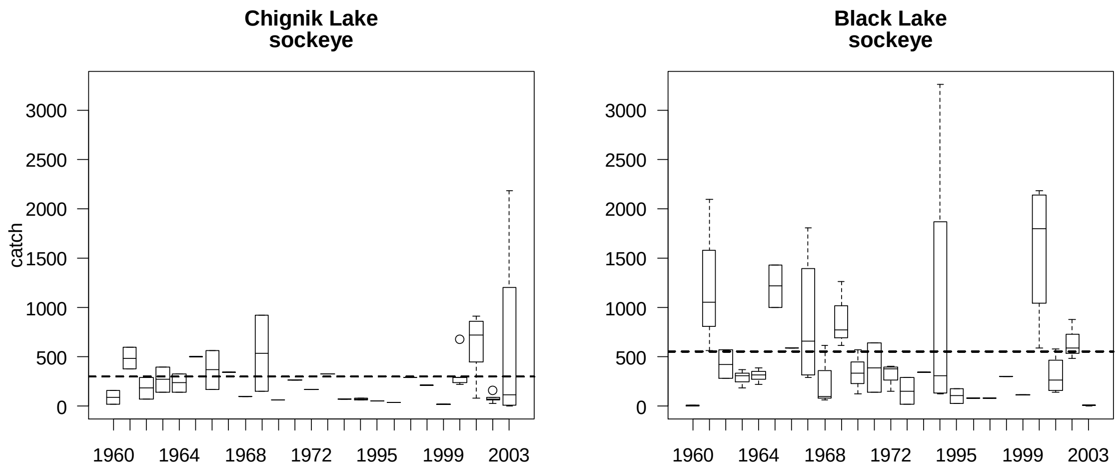


Figure 4. Sockeye tow-net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

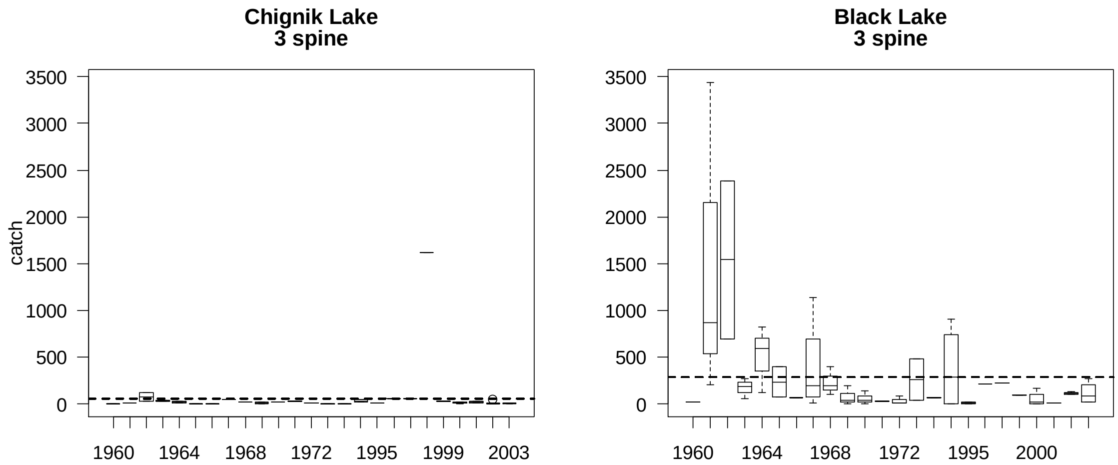


Figure 5. Three-spine stickleback tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

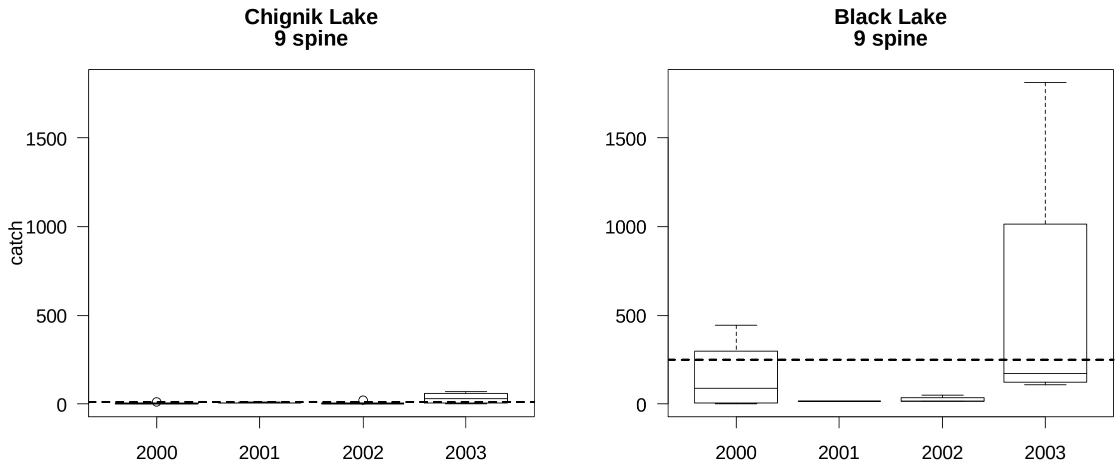


Figure 6. Three-spine stickleback tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

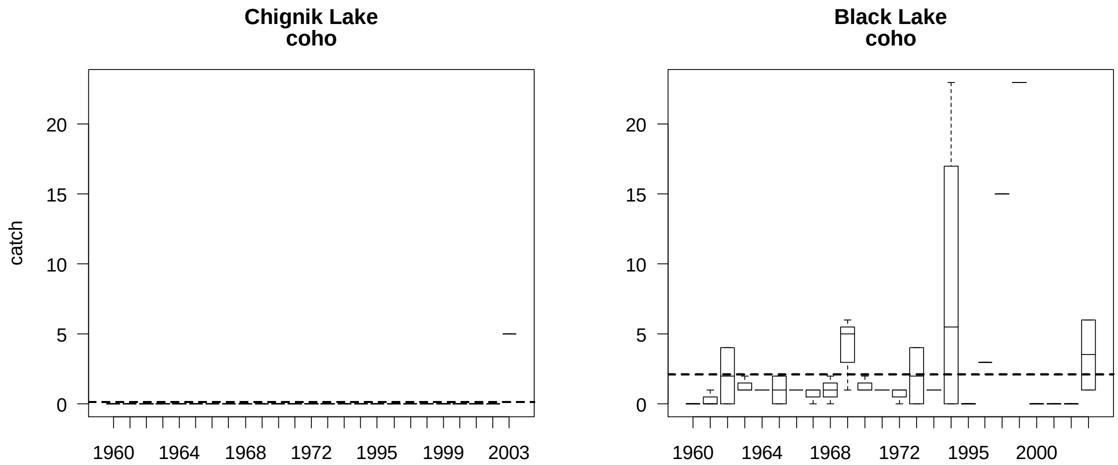


Figure 7. Coho tow-net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

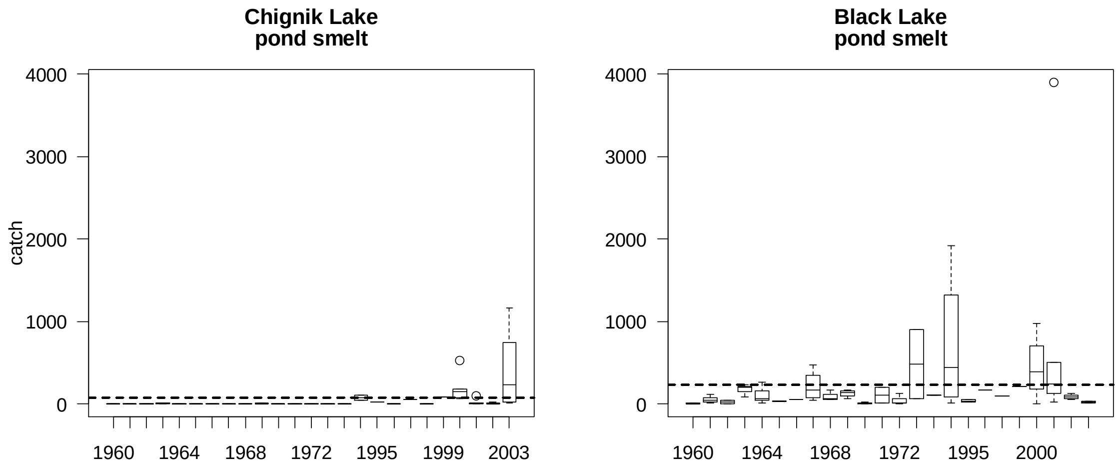


Figure 8. Pond smelt tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

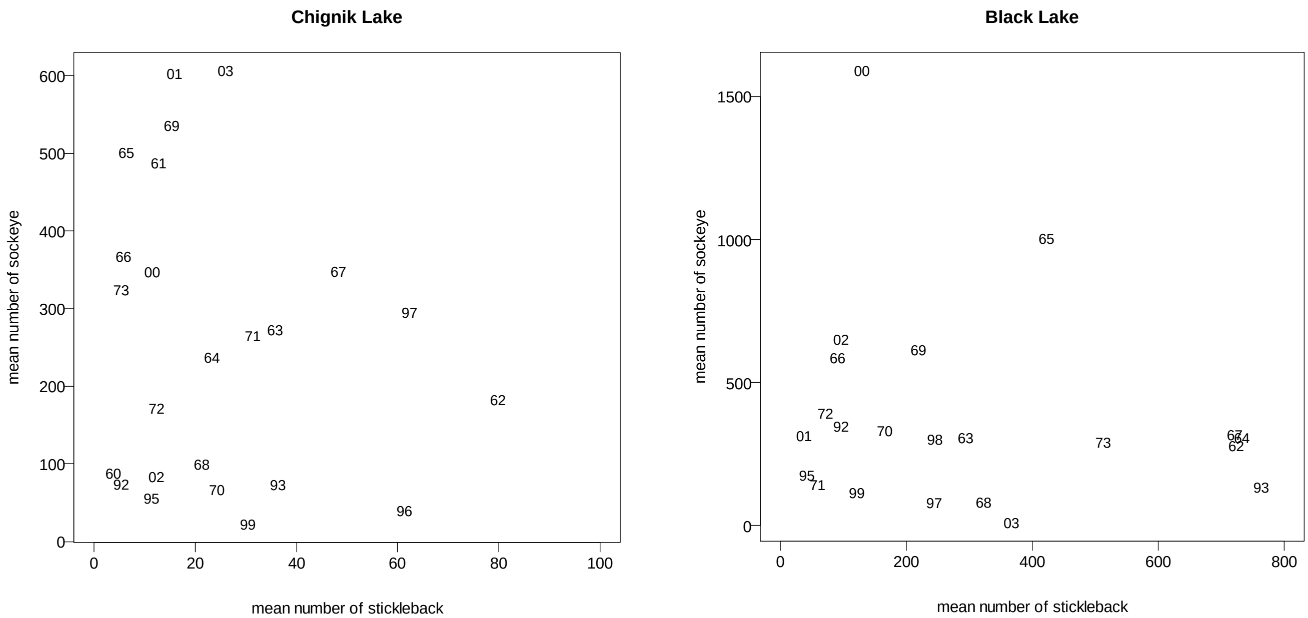


Figure 9. Relationship between the average number of sockeye vs. the average number of sticklebacks (3-spine and 9-spine) captured during a 10 minute tow on Chignik Lake and Black Lake.

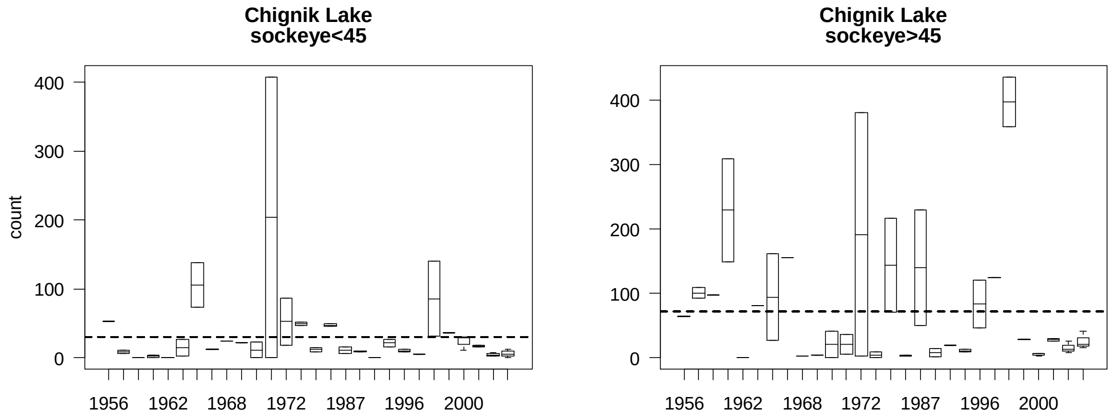


Figure 10. Historical beach seine catches of juvenile sockeye salmon in Chignik Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

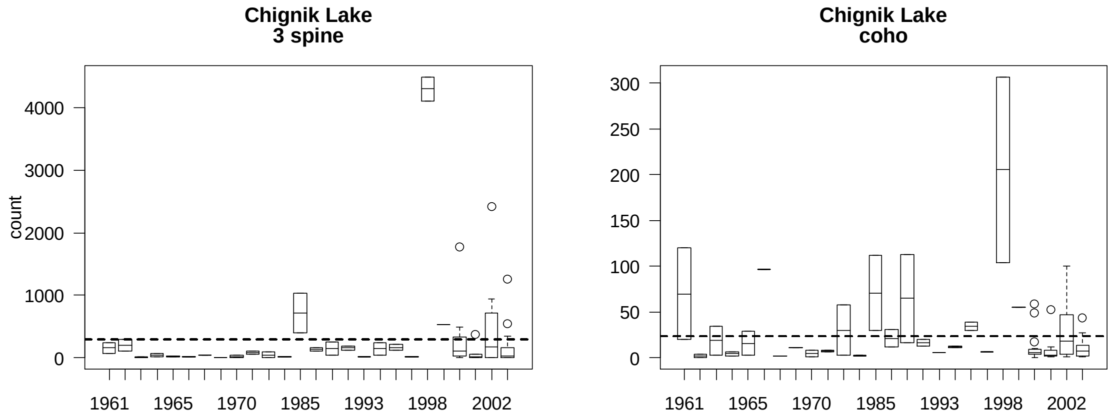


Figure 11. Three-spine stickleback and coho beach seine catches (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

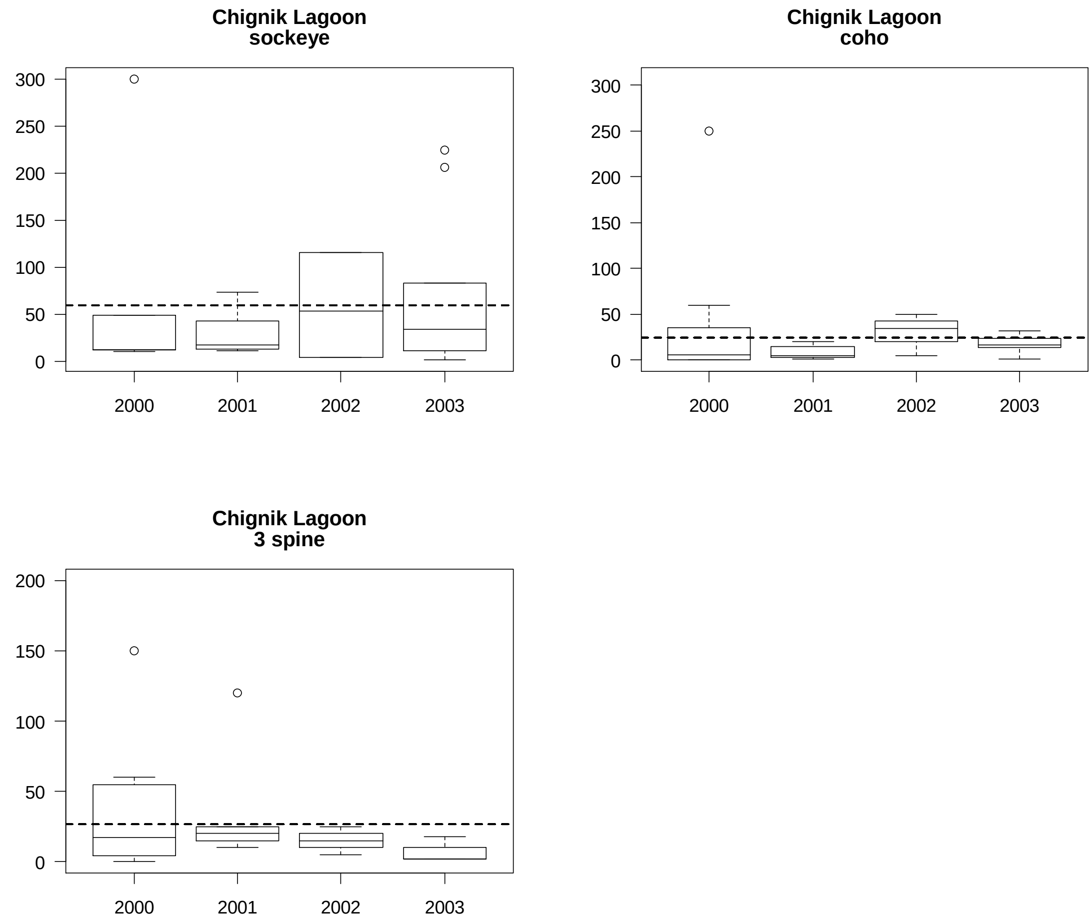


Figure 12. Catches of sockeye, coho, and Three-spine sticklebacks made during and July in Chignik Lagoon (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, whiskers the 95% confidence intervals, and solid lines represent means).

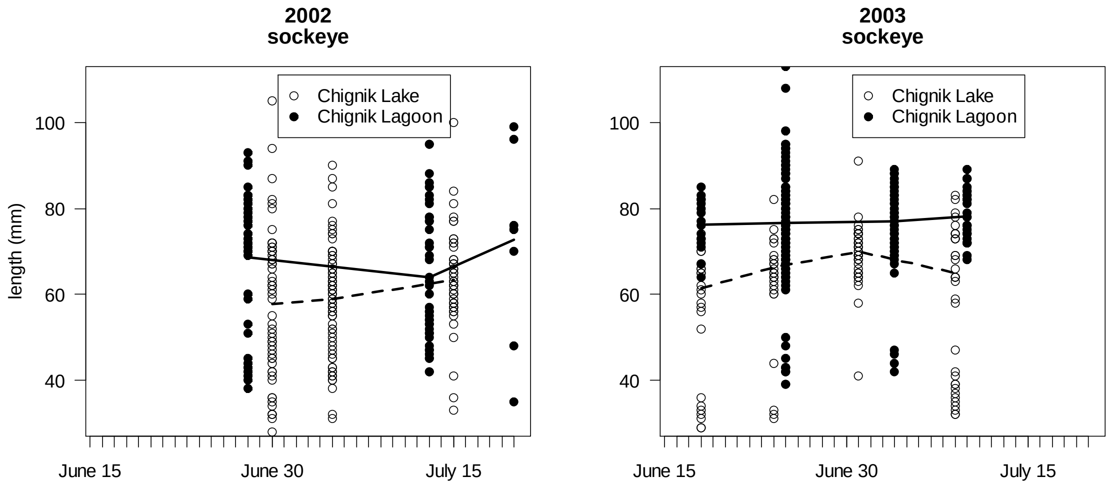


Figure 13. Distribution of sockeye lengths for Chignik Lake and Chignik Lagoon during the 2002 and 2003 field season. The solid lines and dashed lines represent smoothed fits to the lagoon and lake data points, respectively.

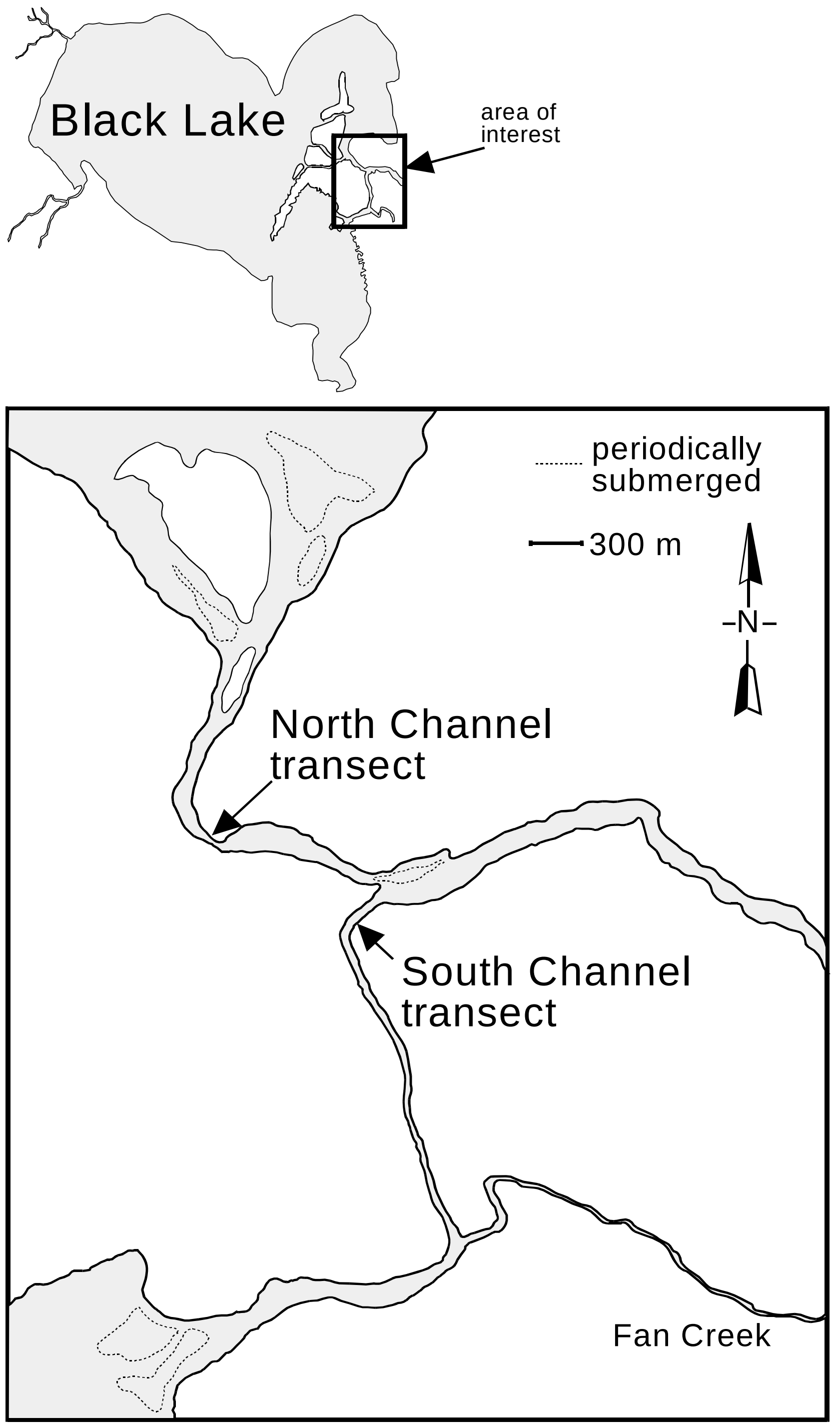


Figure 14. Alec river hydrology transects (dashed areas represent delta or sandbars).

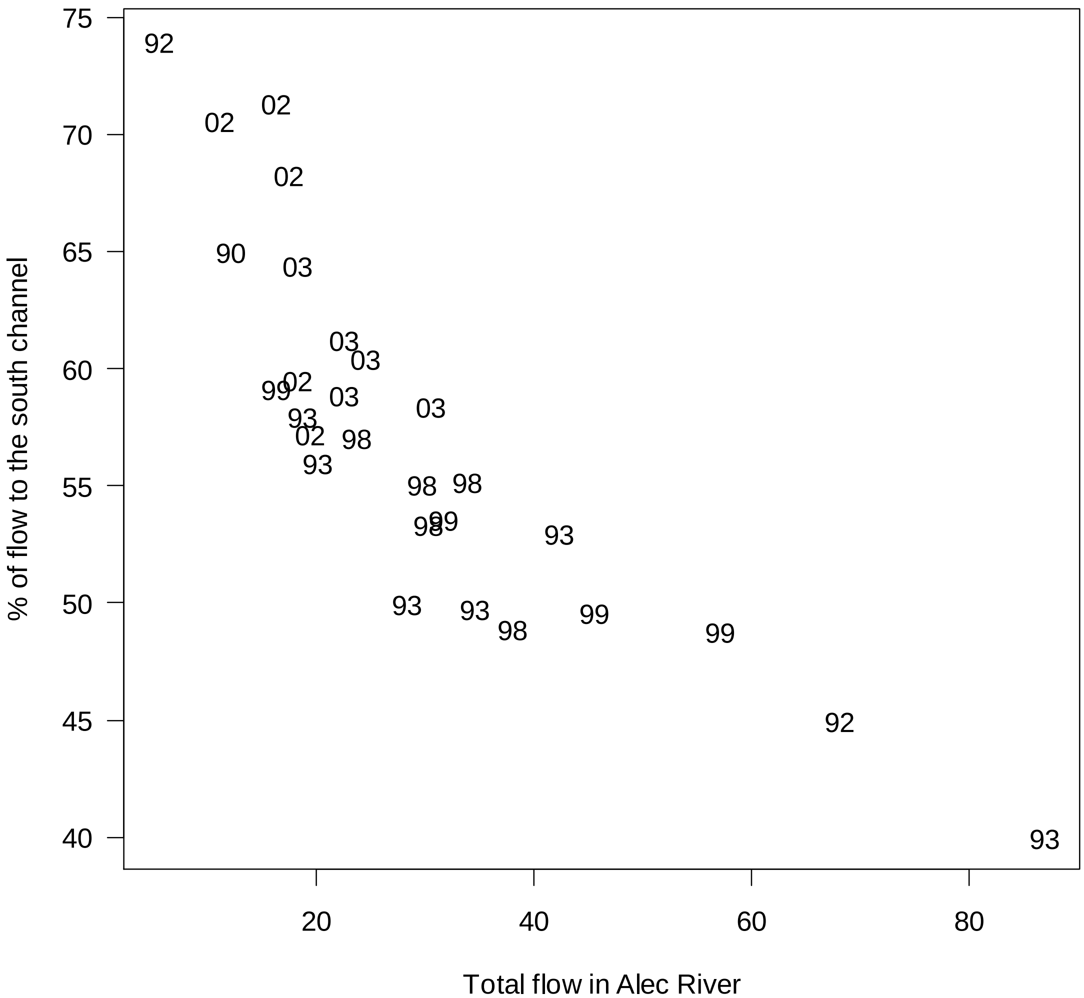


Figure 15. Plot of the relationship between total flow and percentage flowing to the south channel of Alec River; the collection year is shown.

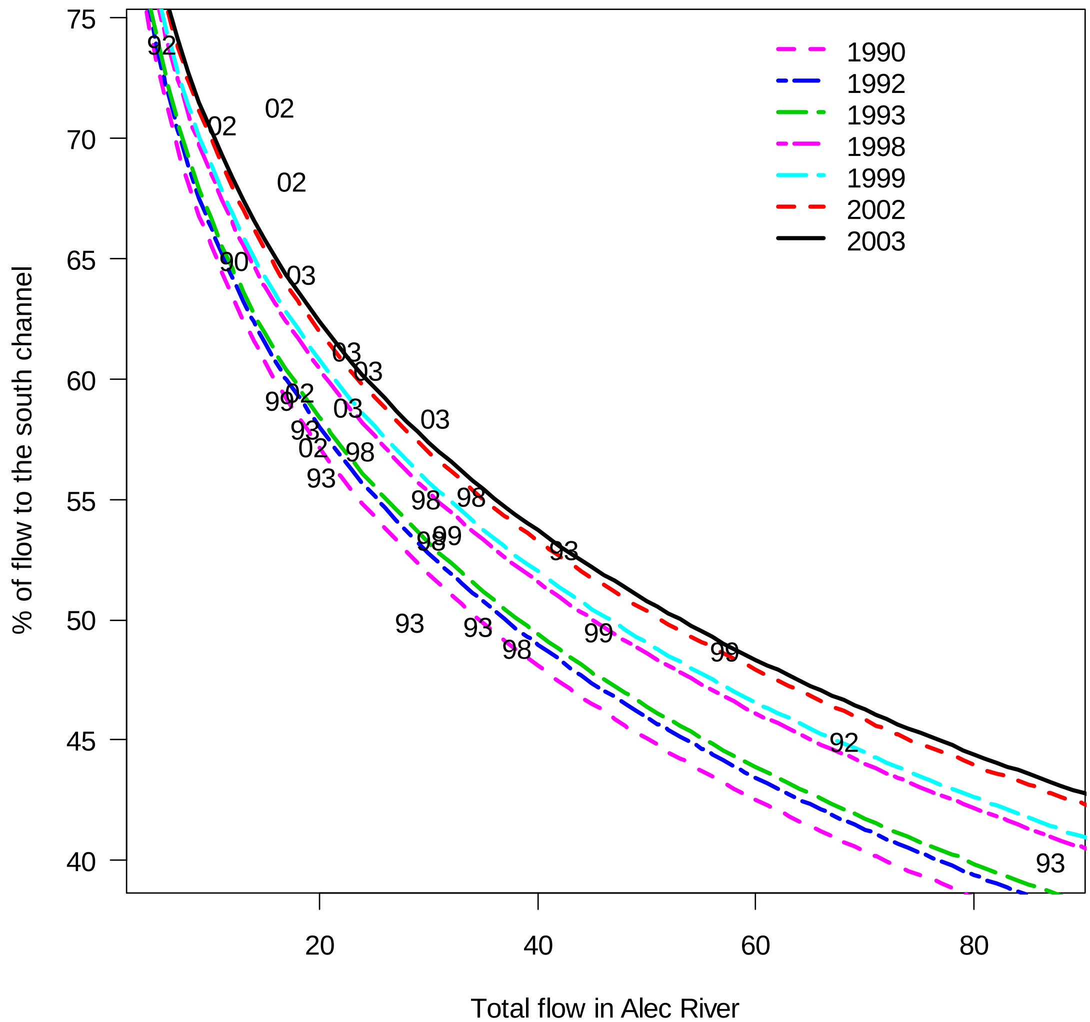


Figure 16. Model predictions for the percent of the total Alec River discharge flowing through the south channel for a given year.

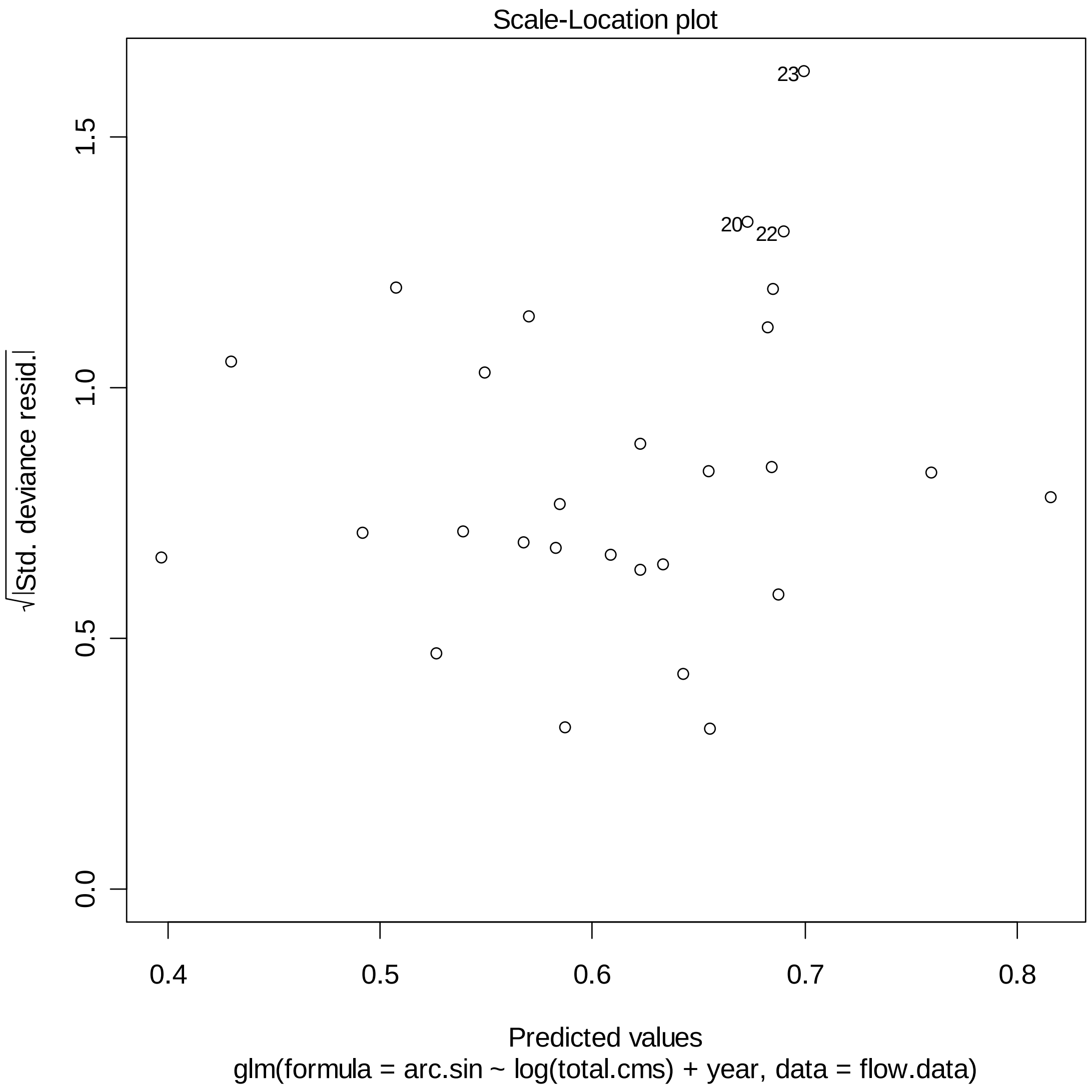


Figure 17. Standardized residuals for the Alec River discharge model.