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CHIGNIK SALMON STUDIES

Investigations of Salmon Populations, Hydrology, and Limnology of the Chignik Lakes, Alaska, during 2000-2002

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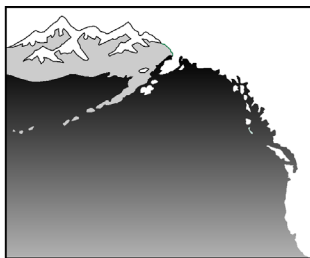
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FINAL REPORT

To

CHIGNIK REGIONAL AQUACULTURE ASSOCIATION

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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 maintenance of the long-term data set 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 requests 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 2000-02 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) conduct a bathymetric survey of the outlet of Black River and Black Lake, 4) re-measure the size of the Black Lake sand-spits, and 5) 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 during 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 by 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 2001 fieldwork was completed in two periods: 10 June through 16 July, and 1 September through 8 September. The 2002 fieldwork was also completed in two periods: 15 June through 25 July, and 1 August through 7 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.
- Daily water temperatures (June to June of each year) were downloaded from thermographs located in Black Lake, Chignik Lake, Chignik River, and daily air temperatures were recorded at the FRI camps near the Chignik Lake village and on Black River.
- Beaches were seined weekly at six established stations on Chignik Lake and two in Chignik Lagoon from June to July, and again during September in Chignik Lagoon, 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 the spring 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, Fig.1) and Chignik Lake (two stations, Fig. 2). 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. After the data from these loggers were downloaded, the loggers were reset to record continuously until retrieval in the 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 (0.48 μ); 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 153 μ 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 153 μ 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

Zooplankton in Chignik Lake during the past decade or more displayed the typical seasonal pattern of relatively high abundance of *Cyclops* spp. during early summer followed by an increase in numbers of cladocerans during late summer and fall (Figure 2, Table 1-Table 3). In contrast to past data, abundance of *Cyclops* in Chignik Lake during Spring 2001 was low and cladocerans and calanoid copepods increased throughout summer, leading to below average zooplankton

abundance in 2001 (Figure 3). Conversely, zooplankton in Black Lake were abundant during spring 2001, but then dropped to almost zero by the end of the season. Typically, *Bosmina* are relatively abundant in Black lake during early September. 2002 zooplankton samples are being processed.

Total zooplankton abundance in Chignik Lake is high compared to sockeye lakes in central and southeast Alaska ($228,000 \pm 48,000 \text{ m}^{-2}$) (Kyle 1991) and western Alaska ($250,000 \text{ m}^{-2}$ for 60 m haul) (D.E. Rogers, unpublished data). However, size of Chignik zooplankton tends to be small, indicating intense grazing pressure (Ruggerone 1994).

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 2001, Secchi depth was above average, ranging from 2.8 m in June to 2.2 m in late August. In 2002, Secchi depth was average, ranging from 2.4 m in June to 1.8 m in early September (Fig. 8). In 2002, chlorophyll *a* was typical of past years.

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 (Figure 5-Figure 6, Table 4-Table 8). 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.

Secchi depths, chlorophyll *a* and surface temperatures of both lakes during 2001 or 2002 were typical of past years (Figure 7-Figure 10).

Seasonal temperatures

Seasonal water and air temperatures during the 2000-2001 and 2001-2002 exhibited slight differences from past years (Figure 11-Figure 14). In 2000, Chignik air temperature and Chignik River water temperature tended to be above average in winter, spring, and fall. In 2001, river and air temperature were typical of past years, but fall temperatures tended to be below average. The larger fluctuations in daily air temperature are due the constant exchange of cooler fronts from the north and warmer fronts from the south. Analysis of the Black Lake water temperature shows a pattern of cooling temperatures until about the 1st of December, then a gradual increase and leveling of temperatures until the about the 1st of April. The stable temperatures are associated with ice forming on the lake and slow rise is associated with the transfer of heat from the sediments. The sharp decline in lake temperature during January 2000 is most likely associated with a period in which the ice thawed and then rapid mixing of the lake, as suggested by above average air temperature during late December and early January. No recordings of Black Lake water temperatures are available for 2001-02 field season because the thermograph failed. This

could either have been due to faulty batteries or a faulty temperature logger. In either event, FRI will be replacing the older thermographs (some of which are 10 years old) with newer ones.

It has been shown that levels of oxygen during the winter can fall to levels that are below what juvenile sockeye need to survive (Ruggerone 1999). The duration of ice coverage on Black Lake is also known to be a factor in reducing the amount oxygen in Black Lake by disallowing mixing of the water column. Therefore, monitoring of the lake temperatures is important for understanding sockeye juvenile winter survival.

Figure 15 shows the first two years worth of sea surface temperature data for Chignik Bay. The thermograph was fixed to the Norquest, as far away as possible from any effluent. The results of the 2000-01 and 2001-02 appear to be synchronous, and with very little daily or weekly variation.

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 1994¹ (Tables 9 and 10). The catches during September 2000 of juvenile sockeye were very high for Chignik Lake (347 per 10 min tow; 81 ft² net) and extremely high for Black Lake (1,591 per 10 min-tow; 36 ft² net). The catches during September 2000 in Black Lake were the highest in history (Figure 16). It is worth noting, however, that the Black Lake sampling was conducted during the day in 2000, due to weather limitations. Past research demonstrated that daytime sampling typically produced fewer fish than nighttime.

Methods

Townet catches were standardized to 10 min (Parr 1972) and arithmetic means were calculated. During 2001, continuously strong winds on Black Lake forced the tow net operations to be conducted during daylight. Past studies indicated daylight catches in Black Lake are lower than those at night, but daylight sampling in 2000 led to exceptionally high catches. Possibly the shallower depth of Black lake in recent years compared with the 1960s has reduced the diel sampling effect. 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 Figure 16 to Figure 19 and Table 9 to Table 10. These data only represent tows made during our annual survey near the 1st of September. There was very little within year variability for the catches during 2001² and 2002. Black Lake produced average catches, while Chignik was below average. Coho and sticklebacks continue to comprise only a small proportion of the tow net catches in Chignik Lake, while pond smelt and three-spine sticklebacks comprise a moderate fraction of the Black Lake tow net catches. Stickleback catches

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

² Tow-netting on Black Lake during 2000 and 2001 was done during the day due to adverse weather conditions.

have declined since the exceptional catches during the 1960s, providing support to Narver's (1966) hypothesis that greater sockeye spawning escapement leads to fewer stickleback.

During the 2002 season water levels in the fall were extremely low. The six-foot tow net touched bottom several times during our tow net sets, and on the last set it became lodged in the mud. The net was destroyed during recovery. Figure 20 shows the location where the net was lost.

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). Catches of juvenile sockeye salmon have been recorded 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 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 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 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 beach seines continue to be well below average for sockeye, three-spine sticklebacks and coho (Figure 21-Figure 22, Table 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. Figure 23 and Table 12 show the catches of key species during the last three years.

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 1960s³. 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 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. 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).

The purpose of the 2003 Alec River investigations 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).

Methods

Measurements of flow were made on both channels by stretching a cable across the river at locations maintained by FRI (Figure 24). 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, period (1990-1993, 1998-2002) as a factor, and year as a continuous variable. Our generalized linear models test for the significance of period, year and flow, and any interaction between the three.

We have also chosen to include an analysis that shows a possible threshold within the river. The model fits show some deviation from normality: we use piece-wise regression (Crawley 2003) to reduce these deviations and discuss the biological implications and reasoning.

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

³ 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.

13). This erosion rate corresponds to a widening of the south channel by approximately 1% every three years.

Discharge

If we treat year as a continuous variable, we find that there is in fact a significant affect of year ($p=0.034$) in addition to total flow (Table 14). The coefficient for the year effect shows that every year approximately 0.4% more water is flowing to the south channel after standardizing for total flow. This finding is consistent with the rate of bank erosion and associated widening of the south channel (0.33% per year).

There is no significant effect of time period in either the full or reduce model (Full:GLM $p=0.17$, Reduced:GLM $p=0.09$). There is, however, a significant effect of flow (GLM $p=0.015$) (Figure 26). Q-Q plots of the residuals show that models show some deviation from normality—at least for the period from 1998-2002 (Figure 27).

Visual inspection of the data suggests a possible threshold around $25 \text{ m}^3/\text{s}$, data below $25 \text{ m}^3/\text{s}$ appear to have a steeper slope than the data above (Figure 28). Although the piece-wise model provides a better (more likely fit) to the data, reducing the residual error from 0.022 to 0.020, using the Akaike Information Criteria (AIC) we would have to reject the model in favor of the model without partitioning (AIC=-80.4 and -85.3, respectively). Nevertheless, the piece-wise model is hydrologically reasonable because at moderately high total flows water begins to spill over the large sandbar at the channel split and the percentage of total flow entering the north channel increases rapidly. This phenomenon probably explains, in part, the recent building of the sandspit in Alec Bay. Sediment transport occurs primarily at high flows, therefore much of the sediment likely enters Alec Bay.

SAND SPIT ANALYSIS

The sandspit extending from the Alec River delta across Black Lake to Sand Pt has been a prominent feature for the past 10 to 20 years. In the 1960s, the sandspit (bar) was continuously covered by water, but it was detectable by depth surveys. Portions of the sandspit were readily visible beginning in the 1980s. In 1990, the spit covered 80% of the lake during a low water period. In 1991 and 1992, the elevation of the sandspit was measured so that measurements in the future could document the rate of change (Ruggerone et al. 1992, 1993).

During the fall 1999 field season we observed a broad sand spit extending west from the Alec River delta and across most of Alec Bay toward the old FRI cabin. This spit was visible during fall 1990, but only when the lake level was extremely low and wind was approximately 60 mph from the southeast. During 1999, the spit was visible during calm winds and moderately low water, indicating potentially significant deposition of sediment in this area. Past research indicated significant sediment transport from Alec River (Ruggerone 1994). The spit was observed again in 2000, 2001, and 2002. The presence of the sandspit across the outlet of Black Lake is important to sockeye salmon. At low river flows, such as that which occurs during early spring when fry are emerging and migrating from Alec River to Black Lake, up to 70% of Alec River flow enters the outlet of the lake (Ruggerone et al. 2000). The lake outlet is separated from the main rearing area by the sandspit, which may inhibit movement of fry into the main lake area and encourage downstream migration of fry to Chignik Lake (Ruggerone 1994).

The outlet area of Black lake has become exceptionally shallow. In recent years, we have been unable to sample fish in the lake outlet with the four-foot deep townet, which was specially designed for the outlet in the early 1990s, because water depth was too shallow. Water depth

across the lake outlet near the river head was approximately 45 cm (18 inches), which is too shallow to operate propeller skiffs at night (we used two jet boats). As described in previous reports, FRI regularly sampled this area with a six foot deep townet in the 1960s.

The objective of this investigation was to re-measure the elevation of the outlet sandspit and to measure the Alec Bay sandspit for the first time.

Methods

The elevation of the sandspit extending from the Alec River delta was re-measured on 18 June 2001. The survey was conducted with a Leica transit with built-in laser range finder and prism. Measurements began at the marker placed on the sandspit in 1992, which was 700 m from the delta. Elevation measurements were taken approximately every 50 m and were calibrated to the outlet benchmark. All measurements were made at the highest sandspit elevation. This methodology differed slightly from previous methods where a level transit, level rod, and 100 m tape were used to estimate elevation every 50 m along the sandspit.

On 19 June 2001, elevations along the Alec Bay sandspit were measured. Methods were the same as described above.

Results

Elevation of the sandspit in 2001 tended to be lower compared with that during 1992 and 1991 (Figure 30). Elevation during 1992 was lower than that during 1991, probably due to the high water during fall 1991. Previous observations indicated that the location and shape of the spit may be slightly altered in response to water level and wind direction.

The length of the spit was not measurably different in 2001. The sandspit extended nearly 1.8 km from the Alec River delta and it inhibited water movement between the main lake and outlet except for the narrow 2 m deep channel next to Sand Point.

Aerial photographs indicate significant vegetation growth has occurred within 1000 m of the Alec River delta since the early 1990s. Growth of vegetation and the somewhat lower elevation of the sandspit in 2001 might be a response to continued lowering of Black Lake water elevation, which may be in response to observed changes in Black River downstream of Chiaktuak Creek. Since 1990, increased growth of vegetation along the shoreline has also been observed in upper Black River, suggesting the lake level may have declined slightly. However, quantitative estimates of the degree to which the level of Black Lake has decreased has not been determined.

Measurements of the Alec Bay sandspit extended from the 1.4 m high berm at the delta to the adjacent shoreline across Alec Bay, approximately 1.85 km away (Figure 31). Elevation declined less than 0.25 m (9.8 inches) within 975 m of the delta. Thereafter, elevation declined somewhat more rapidly. The lowest elevation, corresponding to maximum depth in Alec bay along the path of the spit, was approximately 2 m below the sandspit elevation close to the delta. This low point was approximately 1.6 km from the delta or approximately 300 m from the Alec bay shoreline.

As noted previously, the Alec Bay sandspit was first observed and documented in 1990 during extreme low water conditions. In recent years it has been readily observed during moderately low water. The greater presence of the Alec Bay sandspit is likely the result of significant sediment transport from Alec River during recent flood events. Previous research indicated significant

sediment transport in the Alec River (Ruggerone 1994). Somewhat lower lake level in recent years may also contribute to the greater frequency in observations of the Alec Bay sandspit.

BATHYMETRY

As Black Lake becomes increasingly shallower the need for action may become more apparent. Several restoration and/or mitigation options are currently under review (Ruggerone 2003, in review). FRI felt it was necessary to conduct surveys of both the Black River and Black Lake to add to previous bathymetric survey (CH2M Hill 1991, Ruggerone et al. 1993). The recent surveys were meant to act as both a comparison and baseline study. Comparisons with previous surveys are difficult. In the case of CH2M Hill no final report was produced and the figures of channel profiles are difficult to interpret without text. In the case of the Ruggerone et al. study on Black Lake bathymetry in 1993, we chose to use GPS coordinates instead of timed transects in 2001/2002 to increase accuracy and repeatability.

Methods

The methods in both bathymetry studies were straightforward. In 2001-2002 we surveyed the shorelines of Black River and Black Lake by water at the margin of the water and recording GPS coordinates every 50 paces. These shoreline measurements would be given a depth of zero. To obtain the depth measurements on Black Lake we used a depth sounder with an accuracy of 0.1 meters. The readings from the transducer were calibrated with a measuring rod to determine the actual depth. A GPS coordinate was recorded for each depth measurement, providing a complete matrix of x, y, and z needed to produce bathymetric maps. Lake depth measurements were standardized to a lake elevation of -0.6 m (FRI outlet benchmark).

Measurements on Black River were made at the same locations as the CH2M Hill 1991 survey (Chuck McCallum, Chignik Regional Aquaculture Assoc., pers. comm.). Because we had no coordinates for the CH2M Hill survey, we chose familiar landmarks on the map from which to conduct the survey transects. With the exception of a few deep areas, the river was shallow enough to wade across, therefore we did not require the use of the depth sounder. We also chose to conduct transects in addition to the eight done by CH2M Hill for the purposes of identifying the exact location of the sill, or control point, in the outlet of Black Lake, and gain a more complete coverage of the area directly downstream of the outlet. We also conducted two thalweg transects of the river within the upstream and downstream transects.

Results

Lake Bathymetry

A visual comparison of the 1993 and 2003 surveys shows very similar results (Figure 33 and Figure 34), suggesting significant deposition of sediment throughout Black Lake has not occurred since 1993. It is difficult to compare the two studies because the methods used to gather the data in the two studies are different. The analysis of the 2003 data was done using ArcMap GIS software that accounts for changes in distances for different latitudes; the 1993 survey does not.

Table Table 15 shows that percentage of surface area for a particular depth.

River Bathymetry

A shallow sill exists at the outlet of Black Lake (Figure 35). The sill has a depth of ~0.5m at a lake level of -1.80 at the FRI Black Lake bench mark. The depths from the transect and thalweg measurements (Figure 36-Figure 39) show that the initial drop-off from the lake outlet into the river channel is precipitous. Also, there appears to be a second control point within the river approximately 2000m down river from the outlet sill. It may be suggested that the this downriver point be considered in the mitigation plan as the potential, as the potential for negative consequences may be less.

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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, townet

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Tables

Table 1. 2002 zooplankton counts for the Chignik and Black Lakes.

Lake	Location	Date		Category							
		Mo	Day	Asplanchna	Bosmina	Calanoids	Chydoris	Cyclops	Daphnia	nauplii	Total
Black Lake	Alec	6	28	18	11	30	2	24	0	16	101
		7	3	22	59	22	1	33	0	9	146
		7	19	1	42	4	2	11	0	1	61
		8	30	8	108	28	9	20	0	7	180
Black Lake	Hyrd	6	28	15	55	21	8	84	2	35	220
		7	3	7	48	15	1	24	0	11	106
		7	19	4	182	20	43	54	0	6	309
		8	30	13	409	15	21	62	0	5	525
Black Lake	Outlet	6	28	17	15	9	2	9	0	5	57
		7	3	18	37	8	1	18	0	4	86
		7	19	2	29	5	15	12	0	5	68
		8	30	2	83	1	1	9	0	0	96
Chignik Lake	Clark Bay	6	27	142	11	36	2	85	3	9	279
		7	3	254	14	39	5	118	6	11	436
		7	8	326	22	20	6	52	8	5	434
		7	13	265	13	32	2	81	1	17	394
		7	22	82	59	75	7	55	11	9	289
		9	1	1	238	337	0	137	171	112	884
Chignik Lake	Delta	6	27	56	12	23	3	109	1	2	204
		7	3	279	24	31	10	74	4	9	422
		7	8	283	20	21	6	230	6	46	566
		7	13	80	67	96	13	103	4	82	363
		7	22	3	85	138	4	132	11	73	373
		9	1	1	96	186	6	55	170	42	514

**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 Black zooplankton counts.

Year	Month	Day	# Sites	Category							Total
				Calanoids	<i>Cyclops</i>	<i>Daphnia</i>	<i>Bosmina</i>	<i>Chydoris</i>	Nauplii	<i>Asplanchnia</i>	
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

Table 3. Historical Chignik Lake zooplankton counts.

Year	Month	Day	# Sites	Depth (m)	Categories							Total
					Calanoids	Cyclops	Daphnia	Bosmina	Chydoris	Nauplii	Asplanchnia	
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
1995	6	8	2	40	9	115	7	7	2	24	6	170
1995	6	17	2	40	5	124	6	7	3	20	10	175
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

Historical Chignik Lake zooplankton--cont.

Year	Month	Day	# Sites	Depth (m)	Categories							Total
					Calanoids	Cyclops	Daphnia	Bosmina	Chydoris	Nauplii	Asplanchnia	
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

Due to high winds samples were collected over a two period. Only one plankton tow was made on June 6th at the Delta; dates were weighted accordingly.

Table 4. Results of the 2002 survey of Black Lake limnology.

Date	Location	Secchi depth (m)	Surface Temp. (C)	Chlorophyll a (mg/m ³)
28-Jun-02	Outlet	1.50	13.0	3.56
	Hyrdo	1.50	13.0	2.15
	Alec	2.00	11.6	1.24
3-Jul-02	Outlet	1.25	17.0	4.18
	Hyrdo	1.75	16.0	4.21
	Alec	1.75	16.5	3.64
19-Jul-02	Outlet	1.50	13.0	2.98
	Hyrdo	1.50	14.0	1.88
	Alec	2.25	14.0	2.72
30-Aug-02	Outlet	1.50	13.5	
	Hyrdo	1.25	14.5	
	Alec	1.50	14.5	
2002 means		1.6	14.2	2.95

Table 5. Historical limnological data for Black Lake.

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	

Table 6. 2002 results for the Chignik Lake limnological survey .

Date	Clark				Delta			
	Secchi (m)	Depth (m)	Temp (C)	Chl a	Secchi (m)	Depth	Temp (C)	Chl a
6/27	3.00	0	10.5		1.75	0	10.0	
		1	10.0	1.87		1	11.0	4.33
		5	10.0	2.84		5	10.0	2.49
		10	10.5	2.02		10	9.5	1.12
		20	9.5	0.00		20	9.0	2.48
7/3	3.25	0	9.0		1.75	0	8.8	
		1	9.0	2.46		1	8.8	1.29
		5	9.5	2.11		5	8.8	2.28
		10	9.2	3.38		10	8.8	2.35
		20	9.0	2.75		20	11.0	3.08
7/13/2003**	1.75	0	n/a		1.75	0	11.5	
		1	n/a	2.50		1	n/a	2.80
		5	n/a	2.22		5	n/a	2.49
		10	n/a	2.67		10	n/a	2.54
		20	n/a	3.31		20	11	2.79
9/1	2.00	0	13.5		1.75	0	13.5	
		1	14			1	13.5	
		5	14			5	13.5	
		10	13.5			10	13.5	
		20	13.5			20	13.5	
2002 means	2.50		11.0	n/a	1.75		10.9	n/a

**Very windy day--both thermometers were broken.

Table 7. Historical long-term limnological data for Chignik Lake.

Date			Secchi depth (m)	Averages over 1-20 m	
Mo	Day	Year		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		

Table 8. Historical Black Lake limnological surveys.

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	2.40
7	3	02	1.75	13.6	3.91
7	19	02	1.58	n/a	2.84
8	30	02	1.42	14.17	

Table 9. Historical tow-net catches for Black Lake.

Date		No. of tows	Species						
Mo	Year		Sockeye salmon		Juvenile coho	Juvenile chinook	Pond smelt	Stickleback	
			Fry	Yearling				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						
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

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

Table 10. Historical townet catches for Chignik Lake.

Date Mo Year	No. of tows	Species								
		Sockeye salmon			Juvenile coho	Juvenile chinook	Pond smelt	Stickleback		
		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	
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	

* Juvenile scales are no longer read to determine the ages

Table 11. Historical beach-seine catches for Chignik Lake.

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

Table 12. Historical beach-seine catches in Chignik Lagoon.

Date		No. of sets	Species							
			Juvenile sockeye	Juvenile coho	Juvenile chinook	Char	Stickleback		Sculpin	Pygmy whitefish
Mo	Year					3-spine	9-spine			
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

Table 13. Estimates of bank erosion along the upper reach of the south channel of Alec River, 1992-2002.

Stake	Location	Minimum distance from stake to river bank (m)										Present condition	Total change (m)	Change per year (m)	
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000				2002
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	at river	-3.23	-0.32
3	(near S. channel)			3.25	3.00	3.00	2.20	1.78	0.80	0.80	ND	0.80	sunken	-2.45	-0.27
					-0.72	-0.03	-0.55	-0.22	-1.14	-0.03	-0.43	0.00		-2.83	-0.32
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	in water	-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	in water	-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		-3.10	-0.28
2			10.30	9.95	9.08	8.20	7.80	7.80	7.10	6.65	6.65	6.60		-3.70	-0.34
3			10.30	9.75	9.70	9.70	9.50	9.45	8.90	8.60	8.60	6.90	undercut	-3.40	-0.31
4			15.10	13.95	13.70	13.40	13.40	12.15	12.15	12.15	12.15	12.15		-2.95	-0.27
5			12.50	12.50	11.55	11.40	11.00	10.70	10.50	10.15	10.15	9.70	straight down	-2.80	-0.25
6			9.20	8.75	8.70	7.60	7.35	7.40	6.75	6.75	5.49	5.40	straight down	-3.80	-0.35
7	down river		6.70	6.60	6.43	6.25	5.90	5.80	6.10	3.50	3.50	3.50	beaver tunnel	-3.20	-0.29
				-0.46	-0.34	-0.69	-0.24	-0.24	-0.25	-0.53	-0.18	-0.35		-3.28	-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		-1.40	-0.13
			0.00	-0.30	-0.30	-0.10	-0.10	-0.30	-0.25	-0.05	-0.01				

Table 14. Coefficients for the model fits to the Alec River flow data. The flow (m³/s) was log transformed.

Model	parameter	Coefficient	Pr(> t)	Pr(< 0.05)
percent(flow + year) AIC = -87.3	(Intercept)	-6.860	0.069	
	log(flow)	-0.128	0.000	**
	year (continuous variable)	0.004	0.034	**
percent (period + flow) AIC = -85.26	(Intercept)	1.232	< 0.001	**
	period	0.026	0.095	
	log(flow)	-0.130	< 0.001	**
percent (period + flow + period:flow) AIC = -84.72	(Intercept)	1.111	< 0.001	**
	period	0.117	0.167	
	log(flow)	-0.093	0.015	**
	period:log(flow)	-0.028	0.268	
Threshold model AIC = -80.42	(Intercept)	1.103	< 0.001	**
	period	0.022	0.321	
	log(flow)	-0.094	0.007	**
	log(flow) < log(25)TRUE	0.172	0.266	
	period:log(flow) < log(25)TRUE	0.027	0.407	
	log(flow):log(flow) < log(25)TRUE	-0.064	0.144	

Table 15. Comparison of percentage of lake surface covering particular depth intervals.

Depth	2001	1992
<1.00	21%	26%
1.00-1.49	20%	15%
1.50-1.99	18%	14%
2.00-2.49	12%	12%
2.50-3.00	14%	7%
3.00-3.49	12%	17%
>3.49	2%	11%

Figures

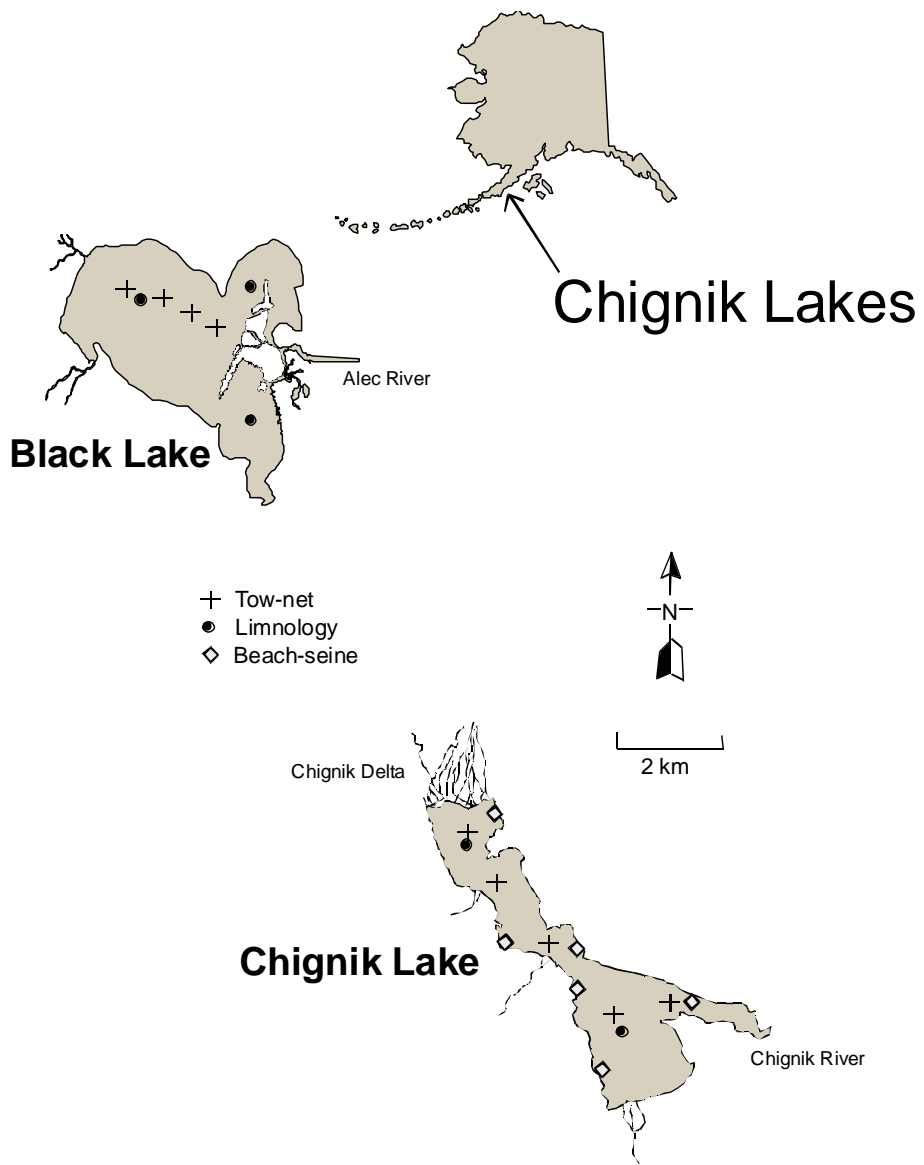


Figure 1. Chignik lakes sampling locations

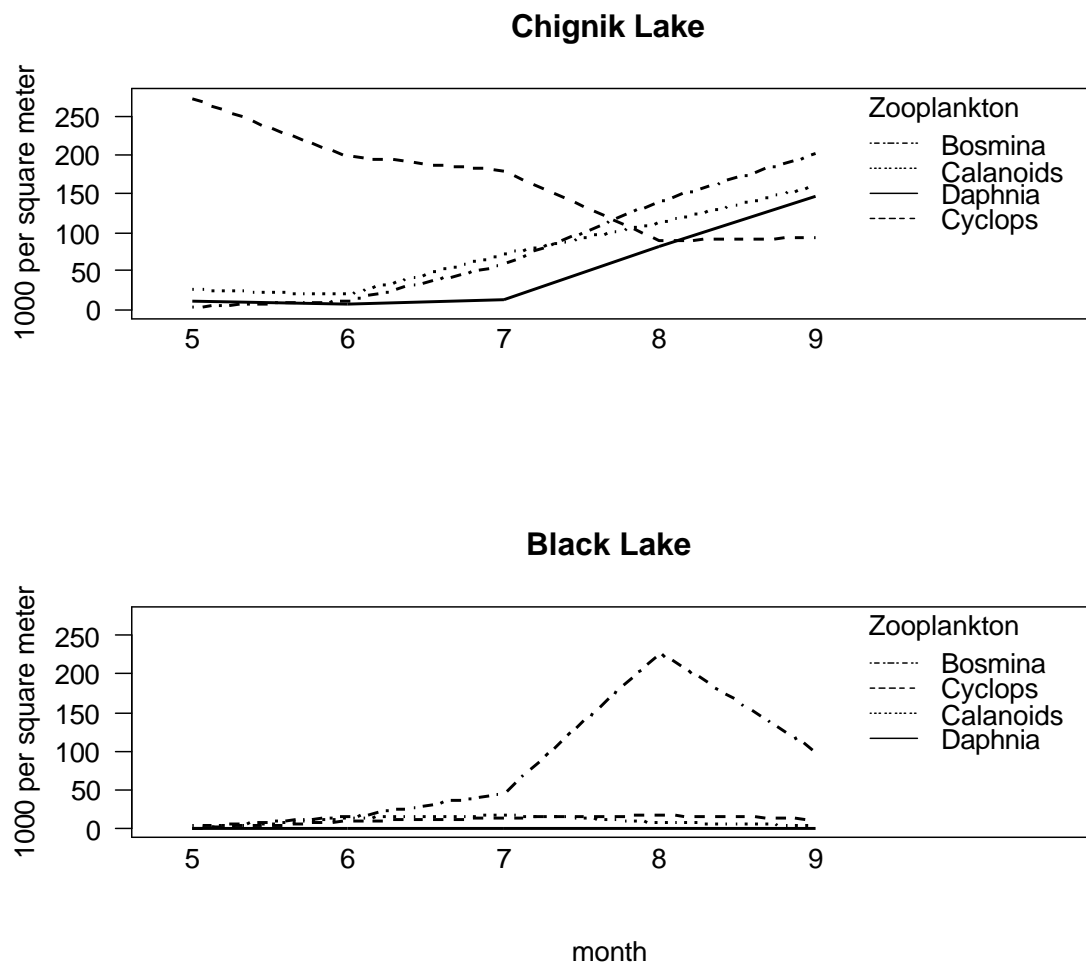


Figure 2. Time series of monthly zooplankton counts in Chignik and Black lakes (years 1968-73 and 1987-2002 for Chignik Lake, 1992-2002 for Black Lake).

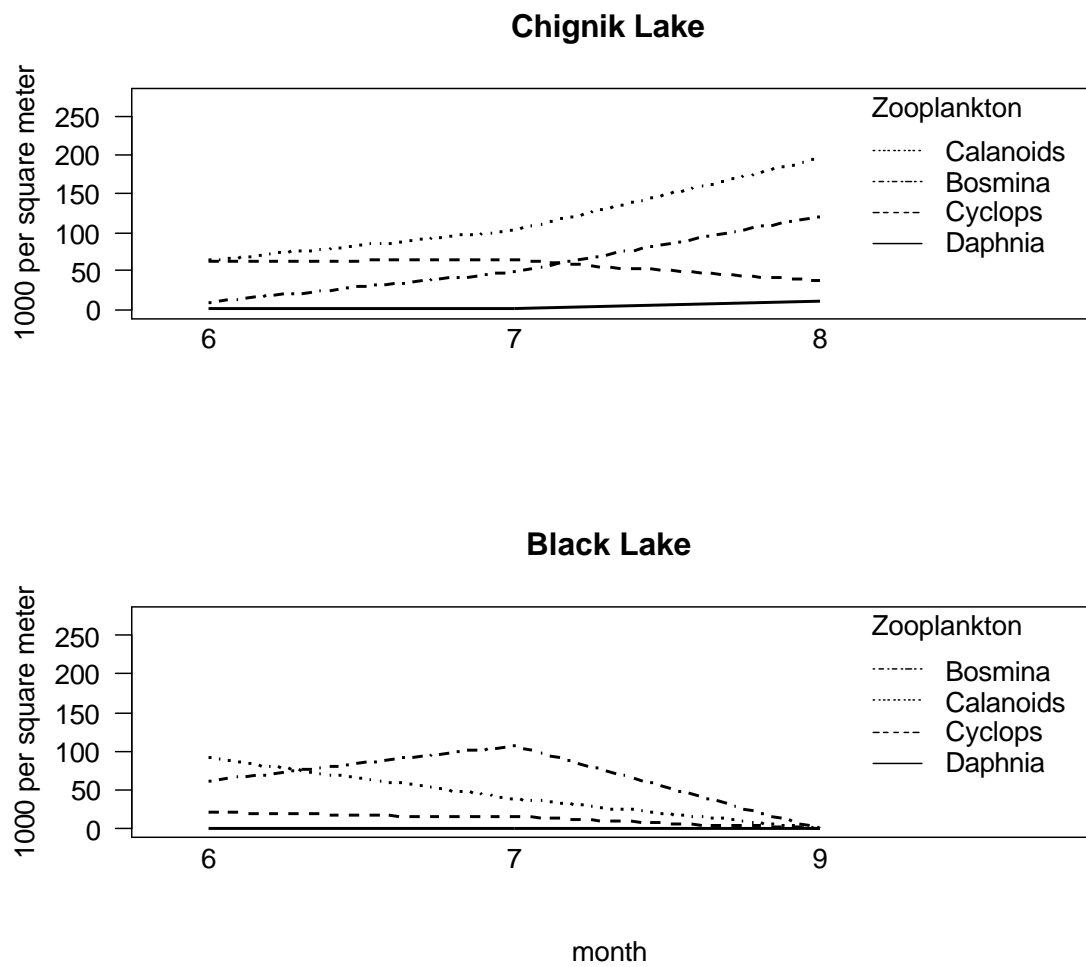


Figure 3. Zooplankton densities by month during 2001.

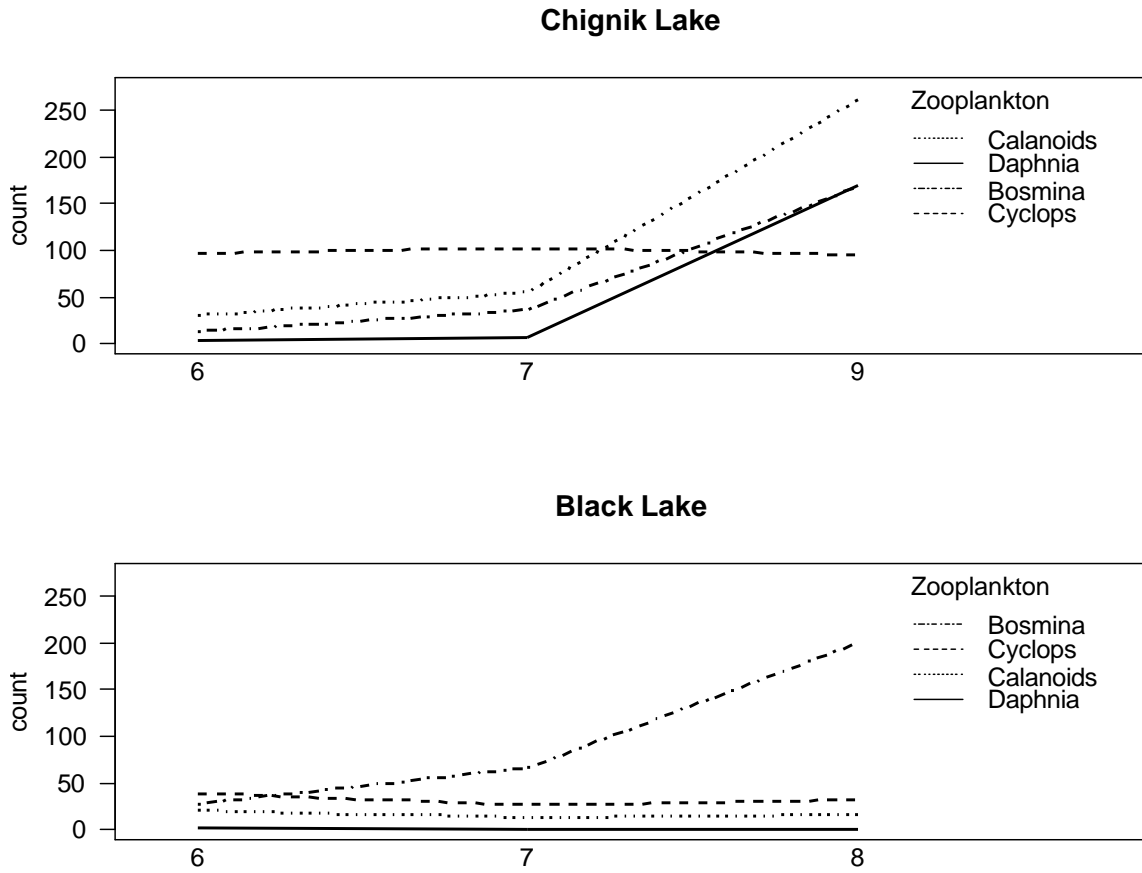


Figure 4. Interaction between zooplankton species abundance by month for the 2002 field season.

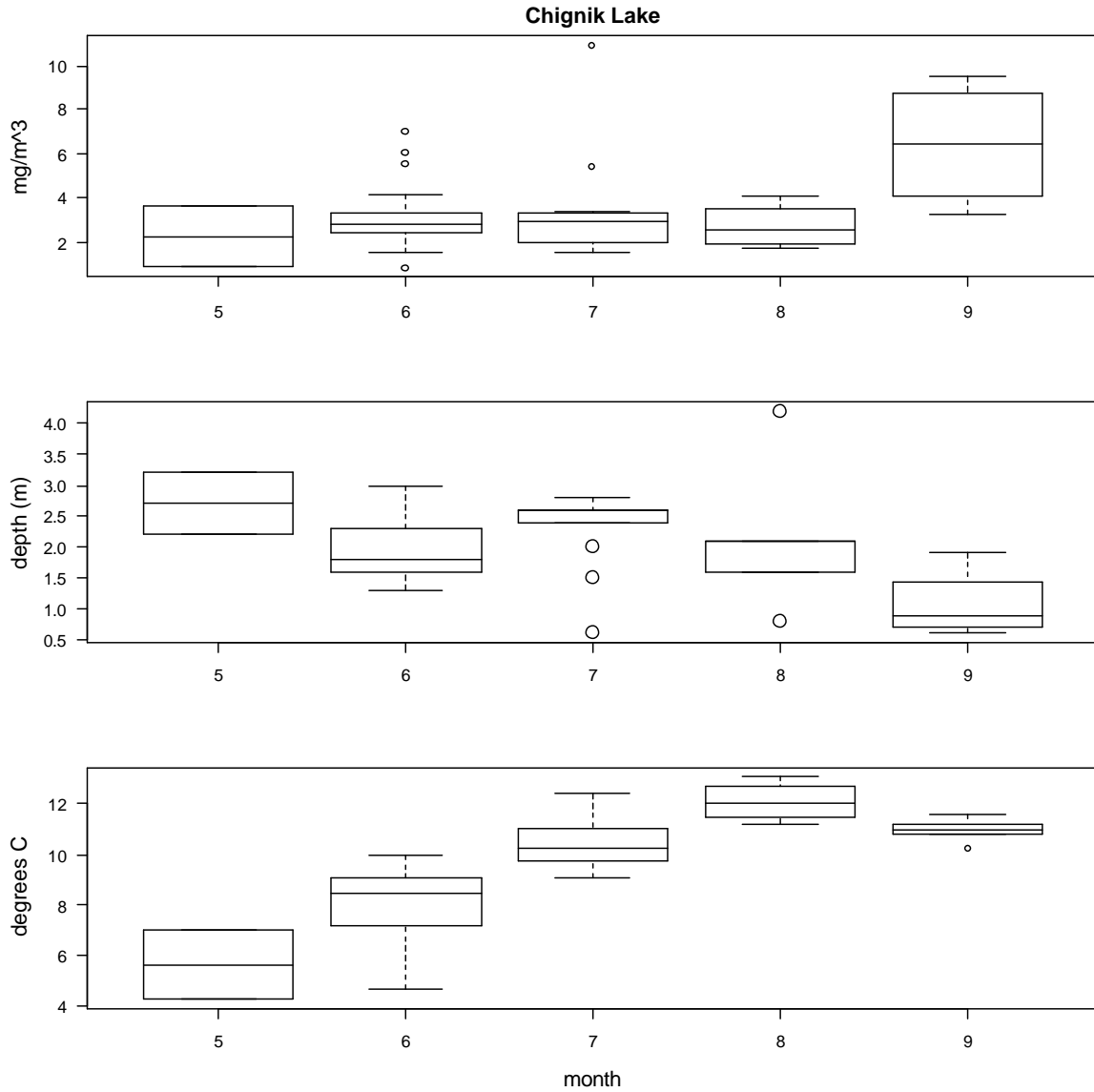


Figure 5. Average monthly chlorophyll concentrations, Secchi depths, and surface temperature in Chignik Lake from 1988-2002 (no measurements were taken in 1994, and no Chl a samples were taken in 2001).

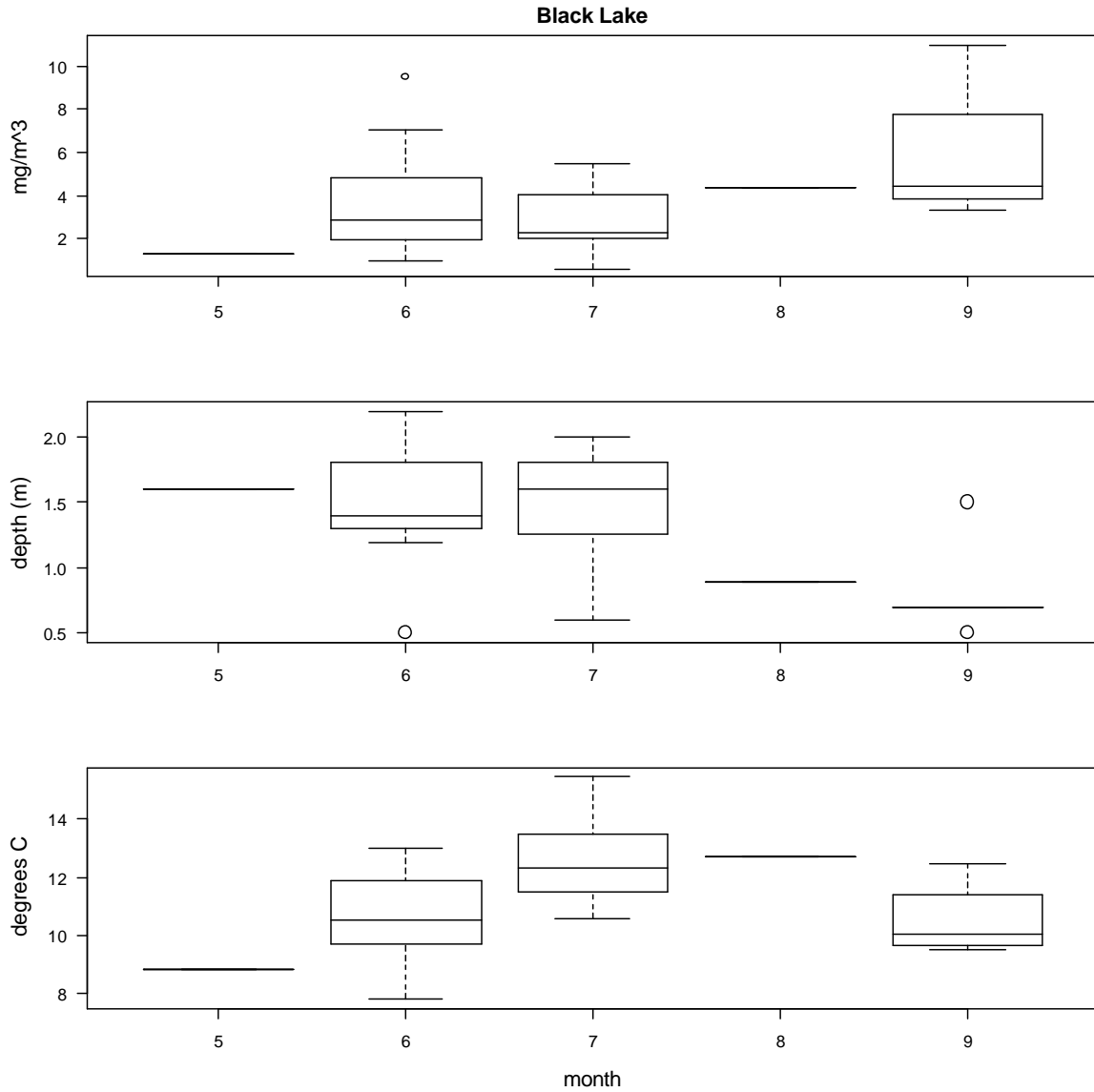


Figure 6. Average monthly chlorophyll concentrations, Secchi depths, and surface temperatures in Black Lake from 1993-2002 (no measurements were taken in 1994, and no Chl a samples were taken in 2001).

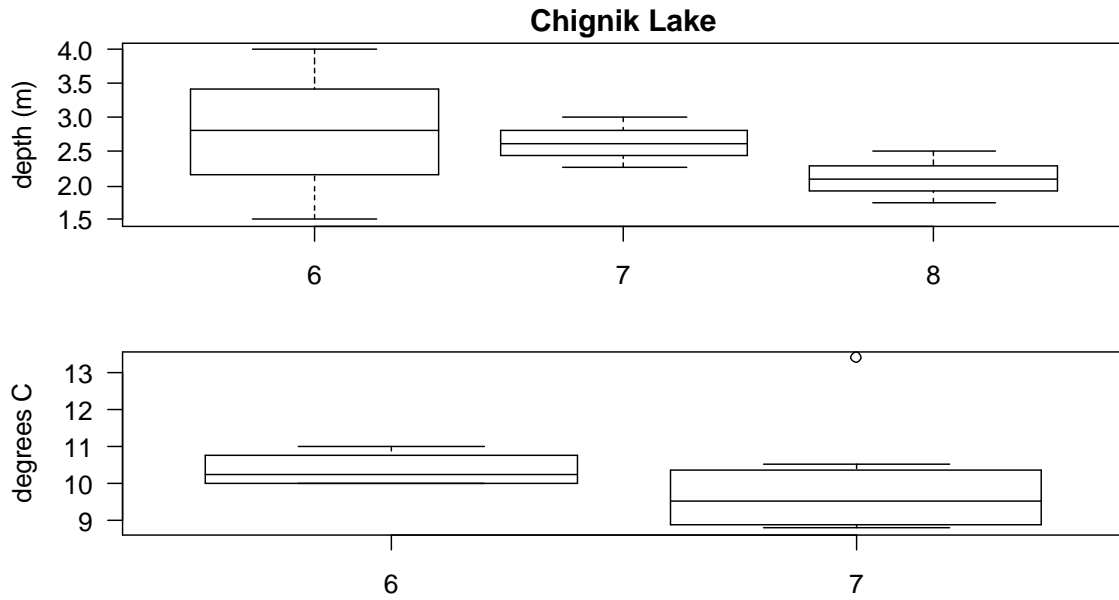


Figure 7. 2001 chlorophyll, Secchi, surface temperature measurements of Chignik Lake by month (no chlorophyll samples were analyzed).

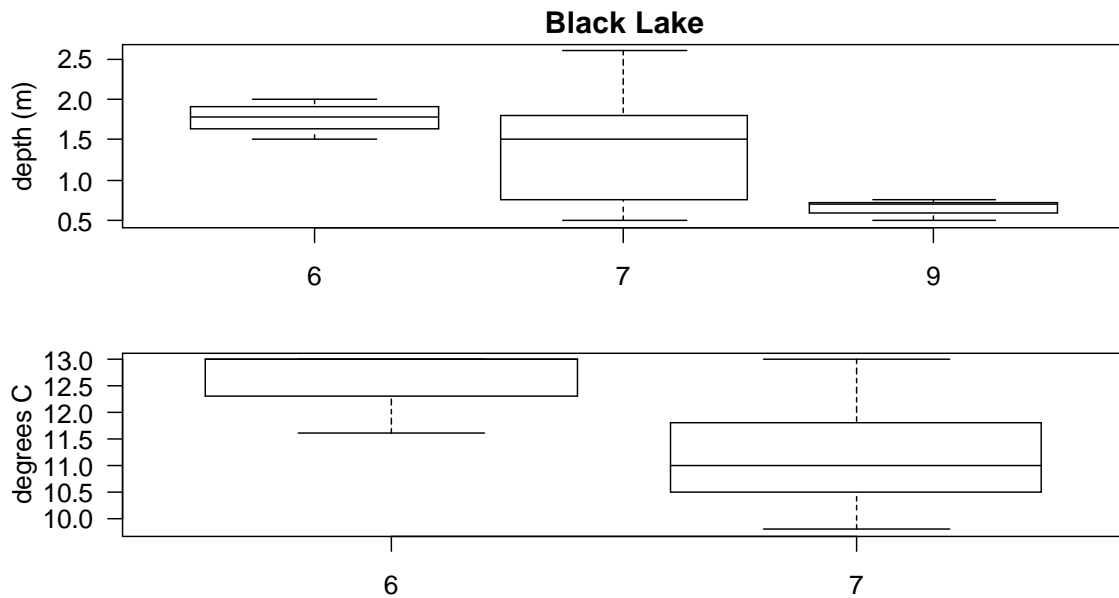


Figure 8. 2001 Secchi depth and surface temperature measurements, by month, on Black Lake (no chlorophyll samples were analyzed).

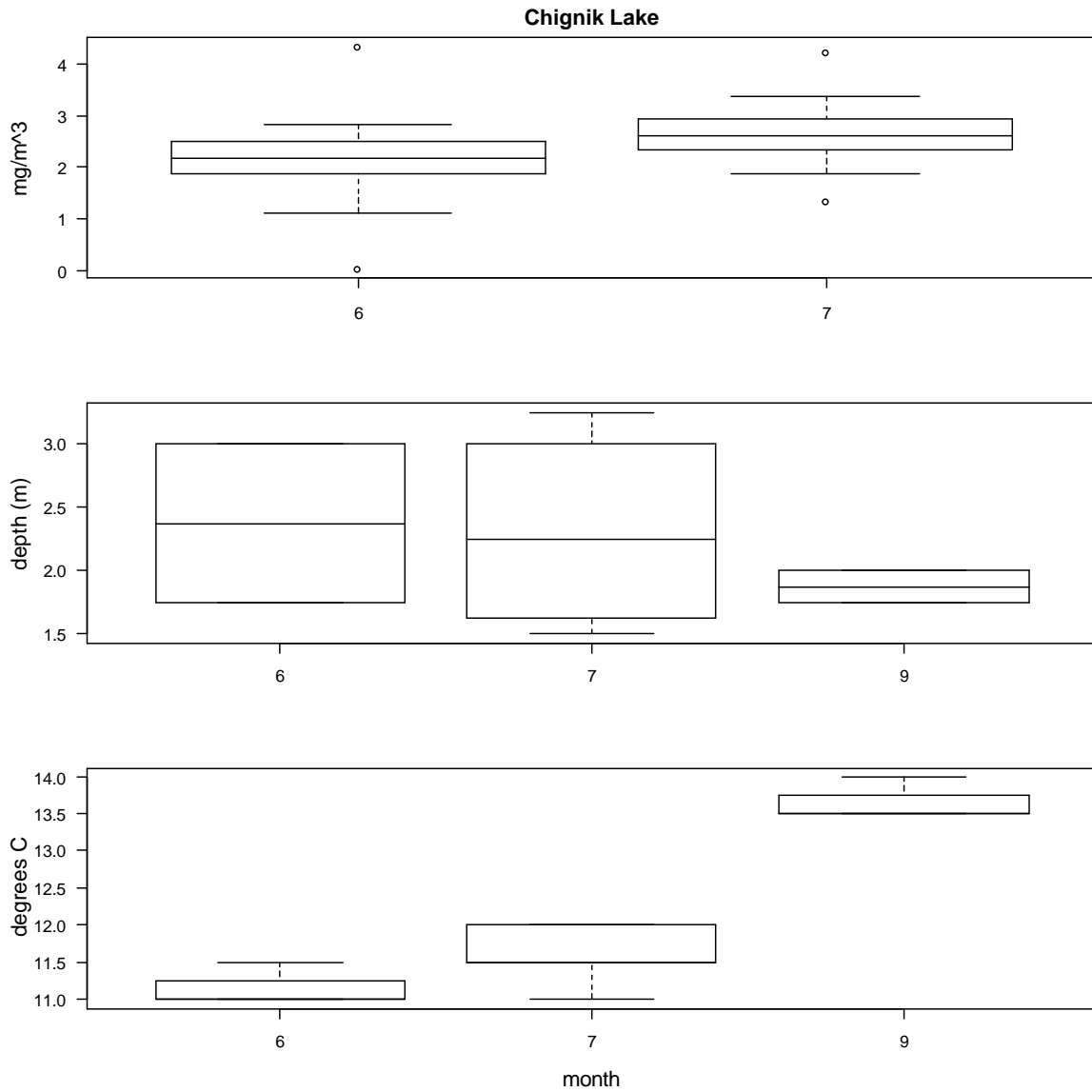


Figure 9. 2002 chlorophyll, Secchi and surface temperature measurements, by month, on Chignik Lake.

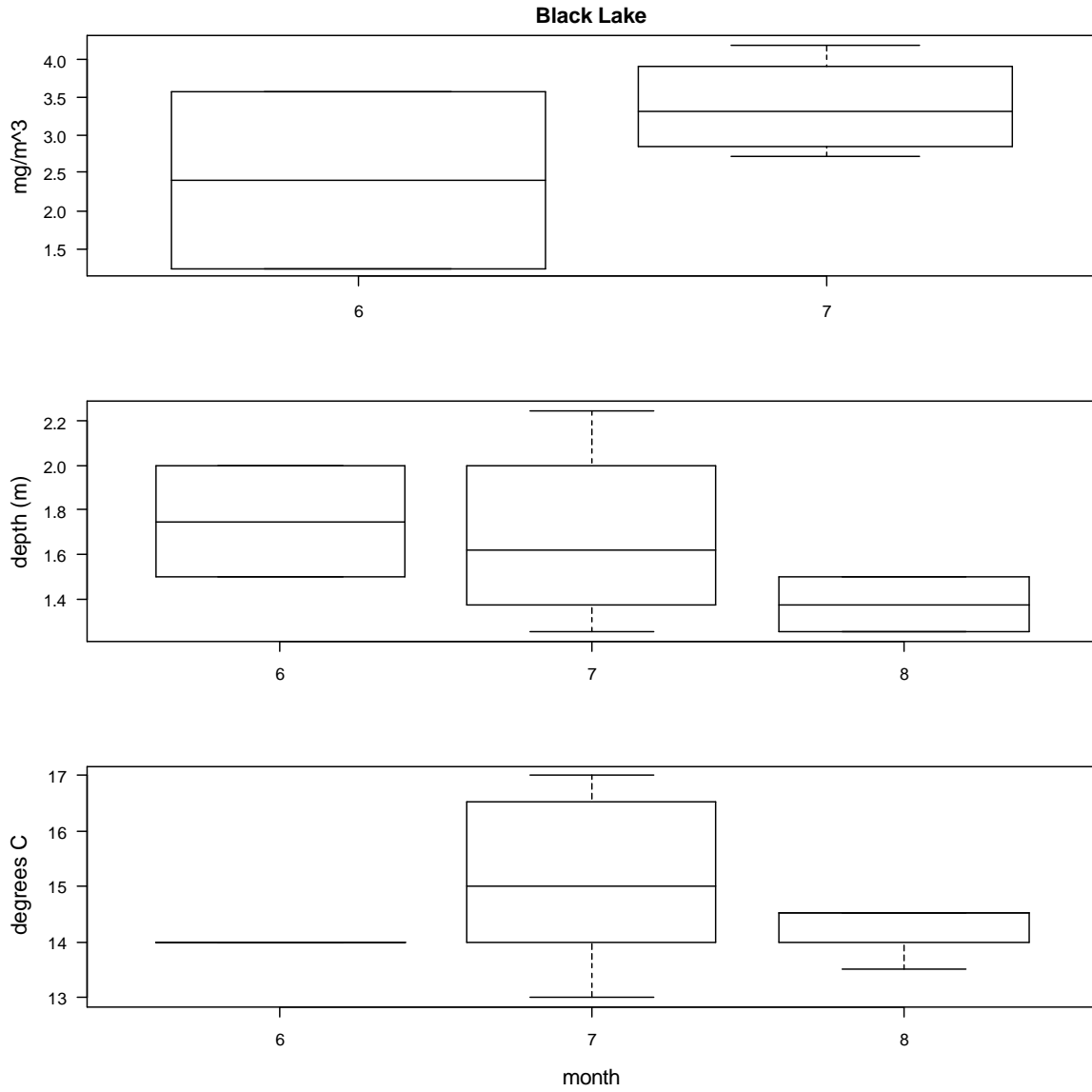


Figure 10. 2002 chlorophyll, Secchi, and surface temperature measurements, by month, on Black Lake.

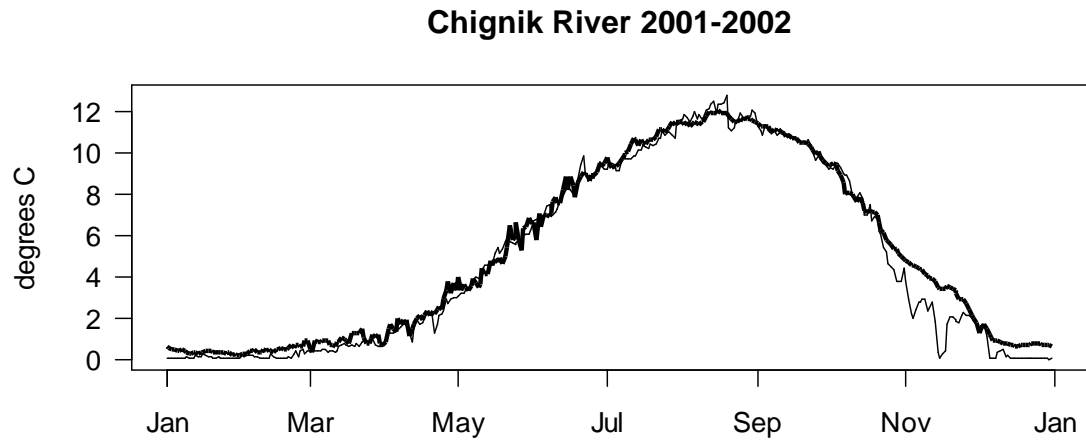
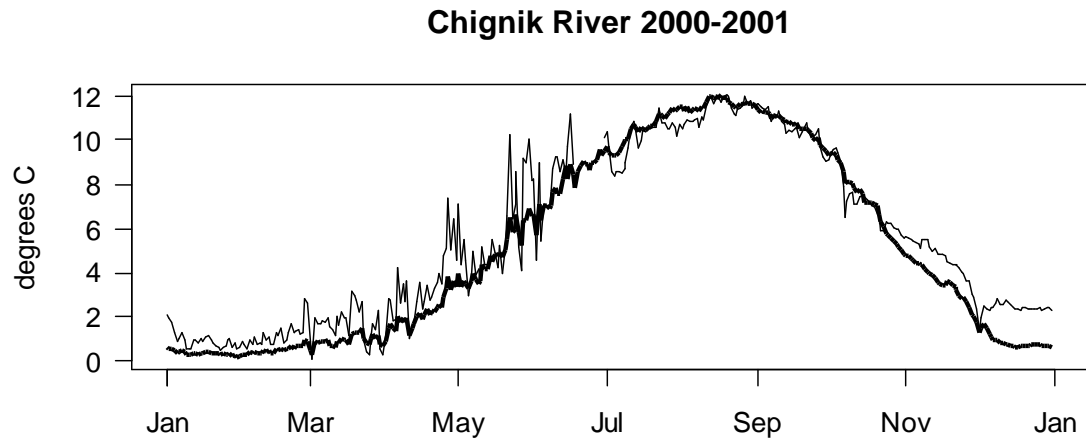
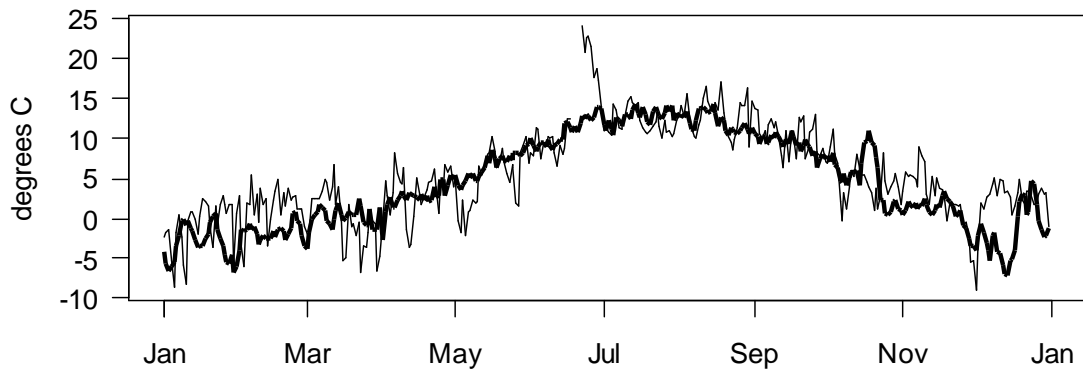


Figure 11. Chignik River temperatures for 2000-2002 (heavy black line is 10 year average). Thermograph was deployed in the June of the initial year and recovered in June of the following year

Chignik Lake air 2000-2001



Chignik Lake air 2001-2002

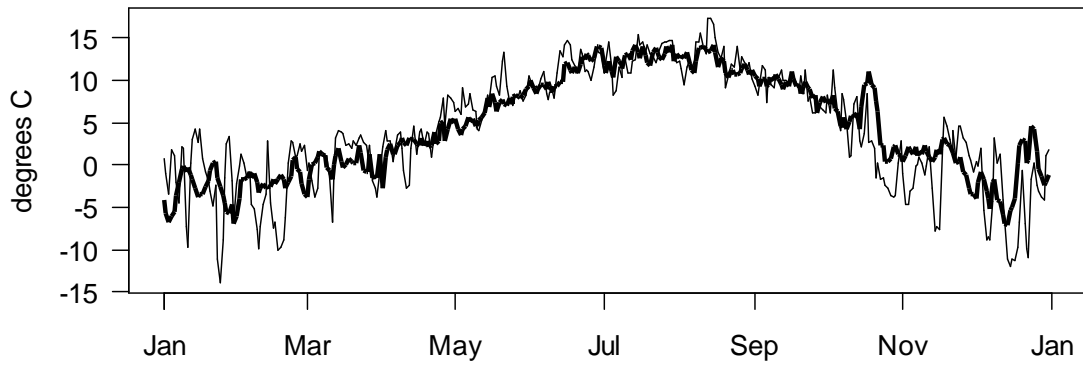


Figure 12. Chignik Lake air temperatures for 2000-2002 (heavy black line in the 10 year average). Thermograph was deployed in the June of the initial year and recovered in June of the following year.

Black Lake air 2001-2002

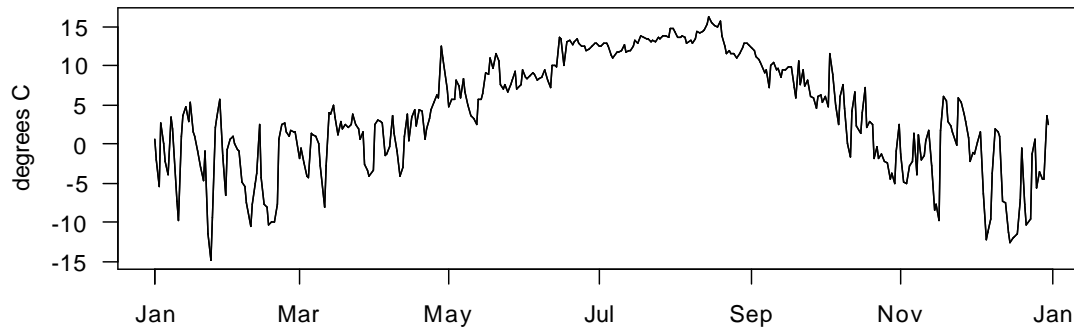


Figure 13. Black Lake air temperatures for 2001-2002. Thermograph was deployed in the June of the initial year and recovered in June of the following year.

Black Lake water 2000-2001

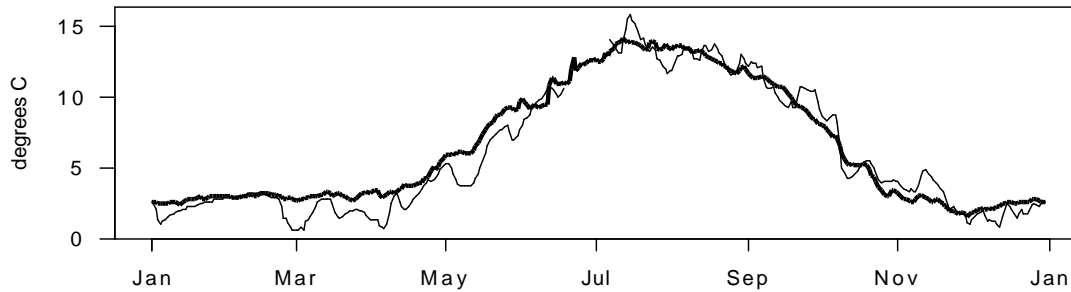


Figure 14. Black Lake water temperatures for 2000-2001 (heavy black line represents 10 year average). The thermograph was deployed in the June of the initial year and recovered in June of the following year.

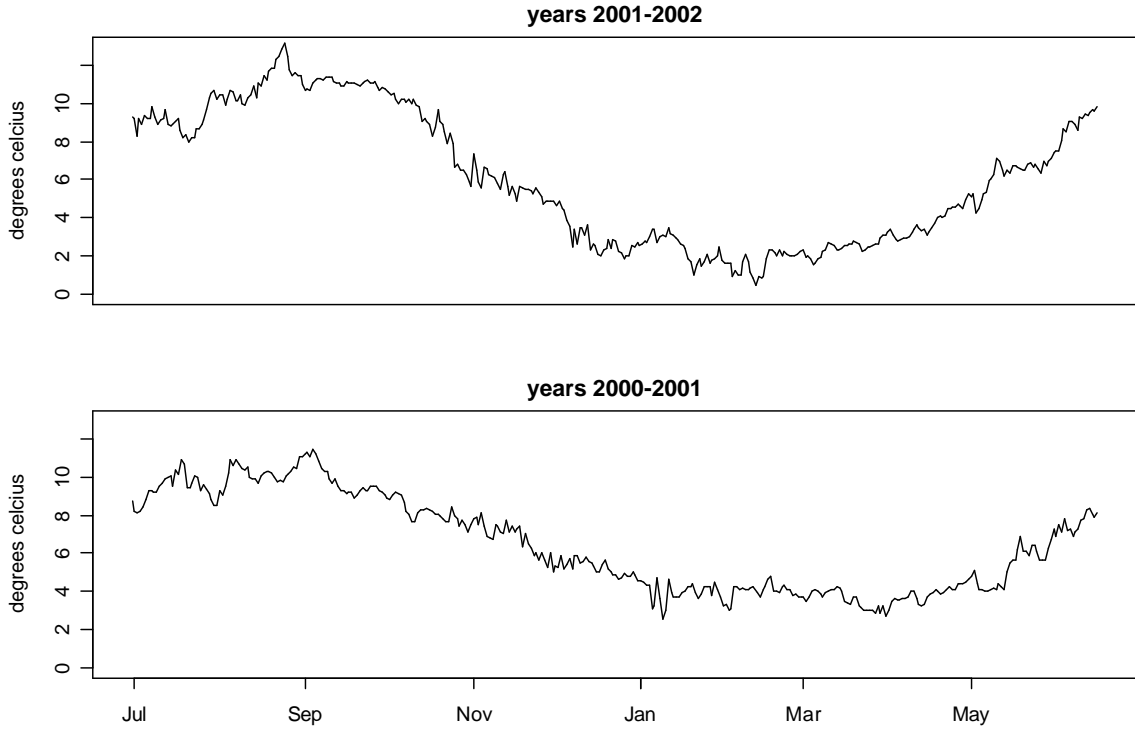


Figure 15. Sea temperatures of Chignik Bay during the summer of 2000 through late spring of 2002.

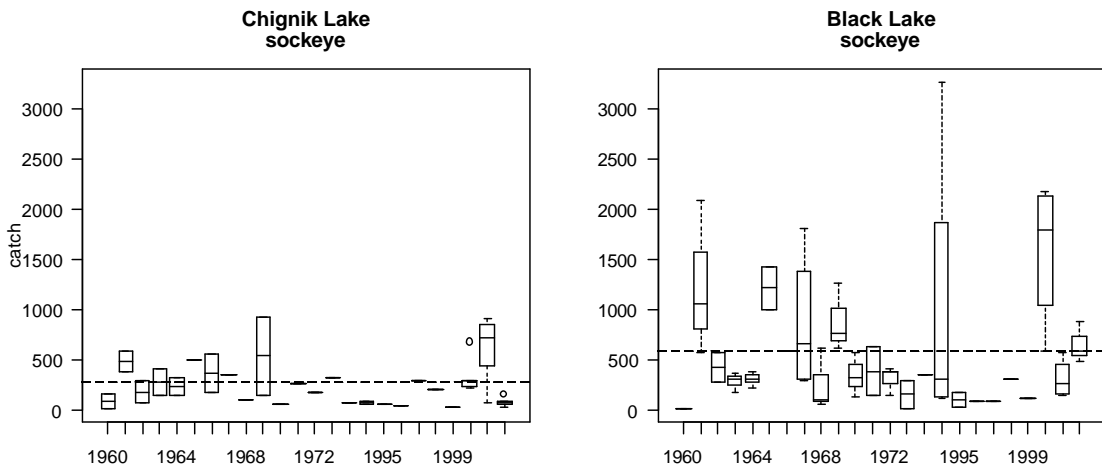


Figure 16. Sockeye tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, and solid lines represent means).

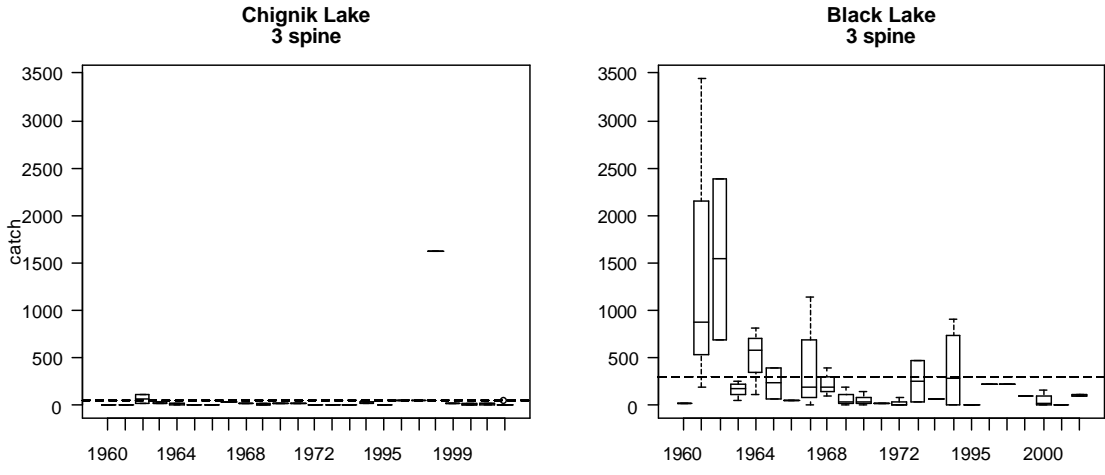


Figure 17. Three spine stickleback tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, and solid lines represent means).

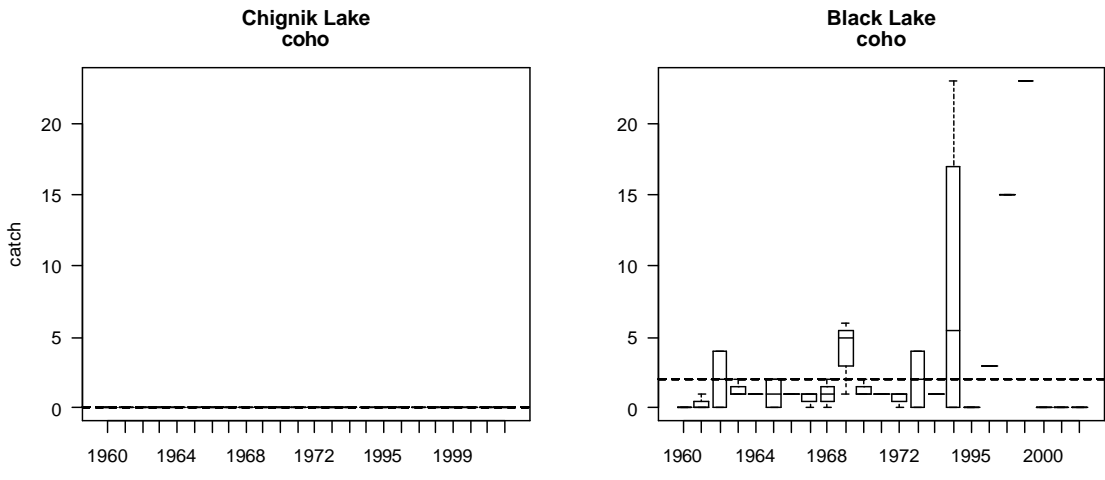


Figure 18. Coho townet catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, and solid lines represent means).

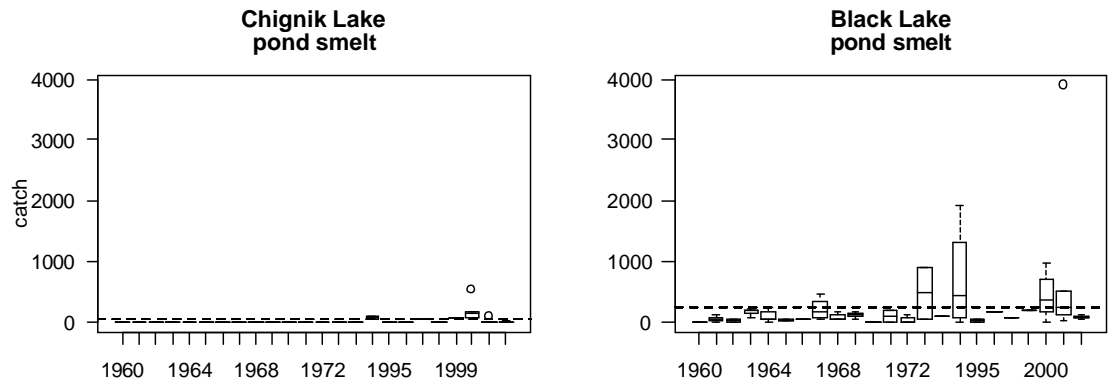


Figure 19. Pond smelt tow net catches for Chignik Lake and Black Lake (horizontal dashes lines represent mean catches, boxes represent 50% confidence intervals, and solid lines represent means).

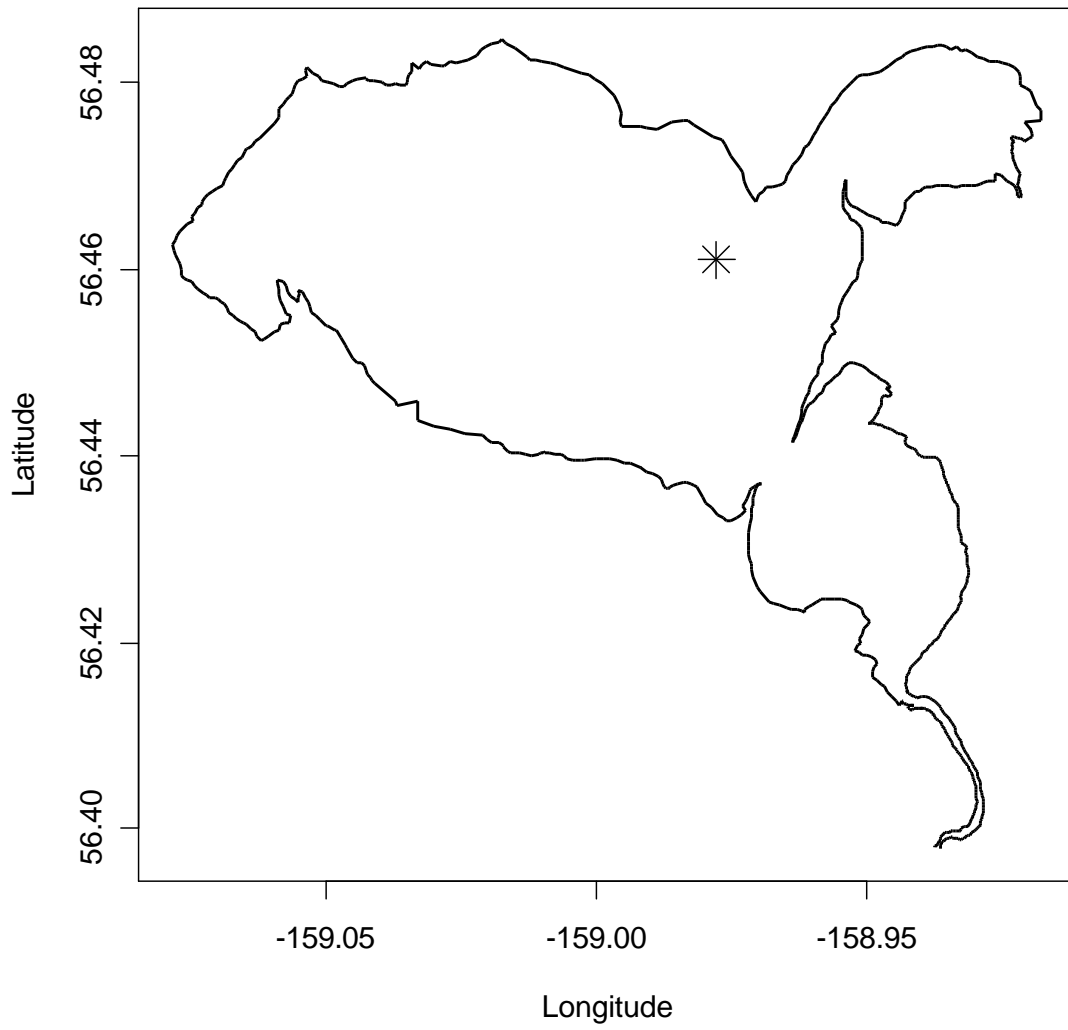


Figure 20. Coordinate map of Black Lake and the location where the six-foot tow net was grounded on the mud bottom.

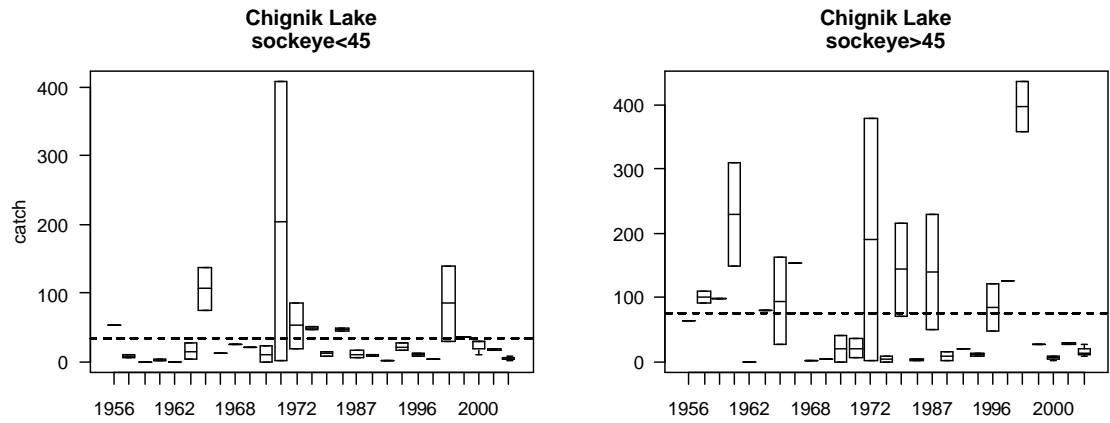


Figure 21. Historical beach seine catches of juvenile sockeye salmon in Chignik Lake (dashed line represent the mean catch over all years, box plots represent 50% confidence intervals, lines represent yearly means).

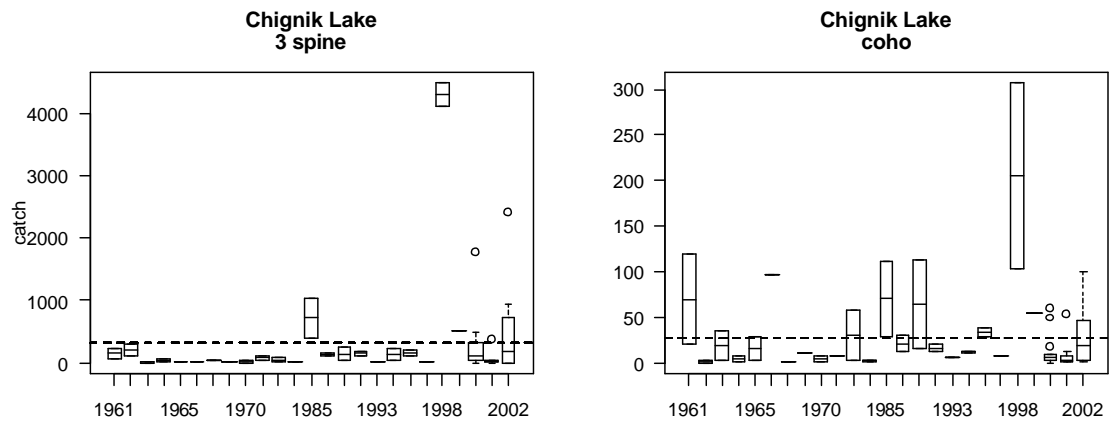


Figure 22. Three spine stickleback and coho beach seine catches (dashed line represent the mean catch over all years, box plots represent 50% confidence intervals, lines represent yearly means).

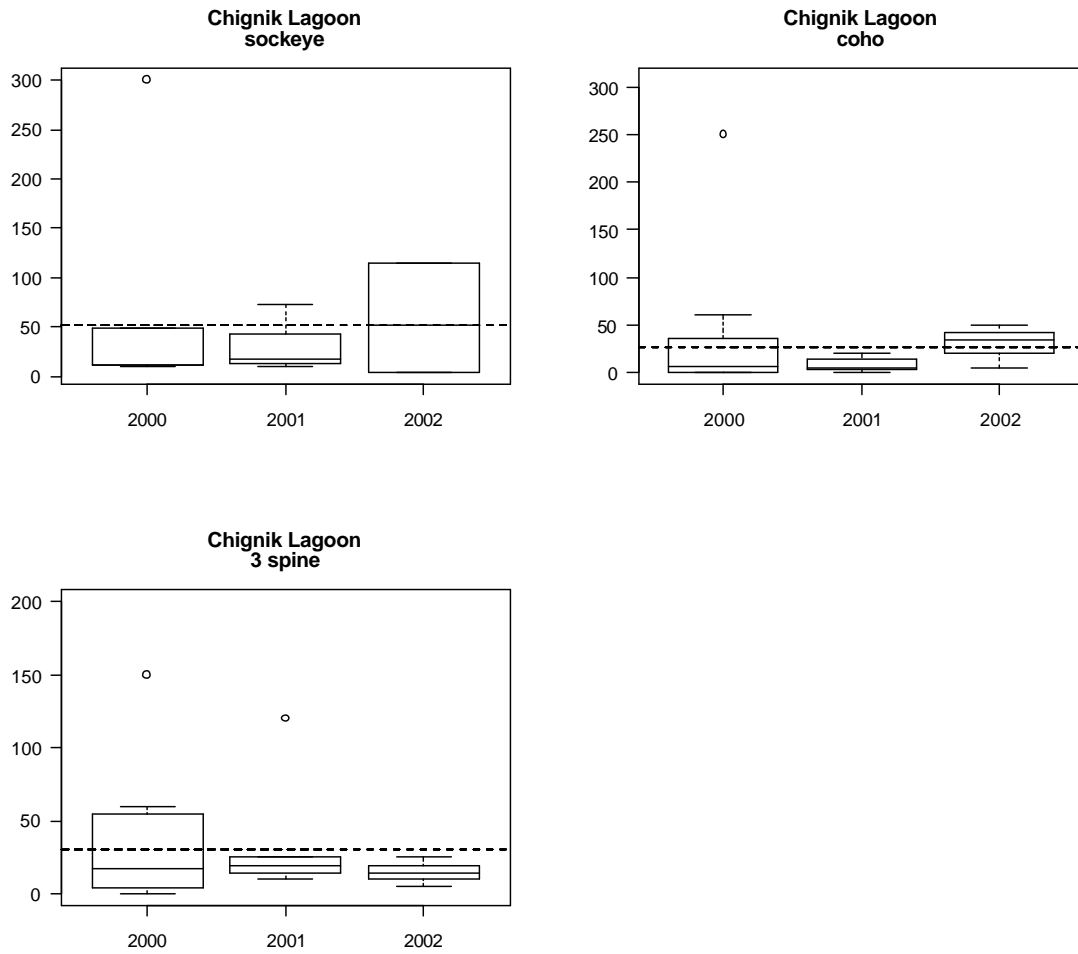


Figure 23. Catches of sockeye, coho, and three spine sticklebacks made during June and July in Chignik Lagoon.

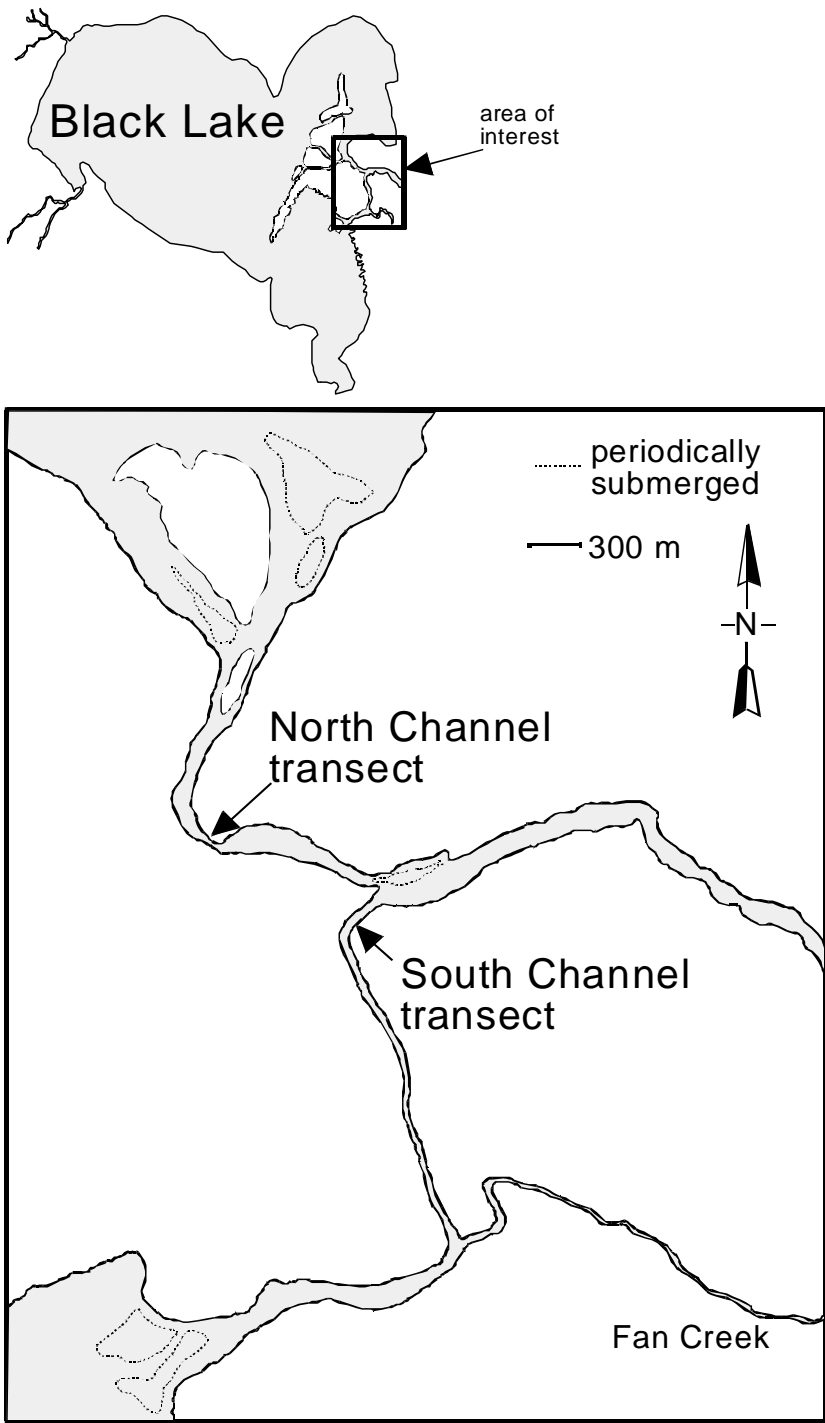


Figure 24. Alec river hydrology transects (dashed areas represent delta or sandbars).

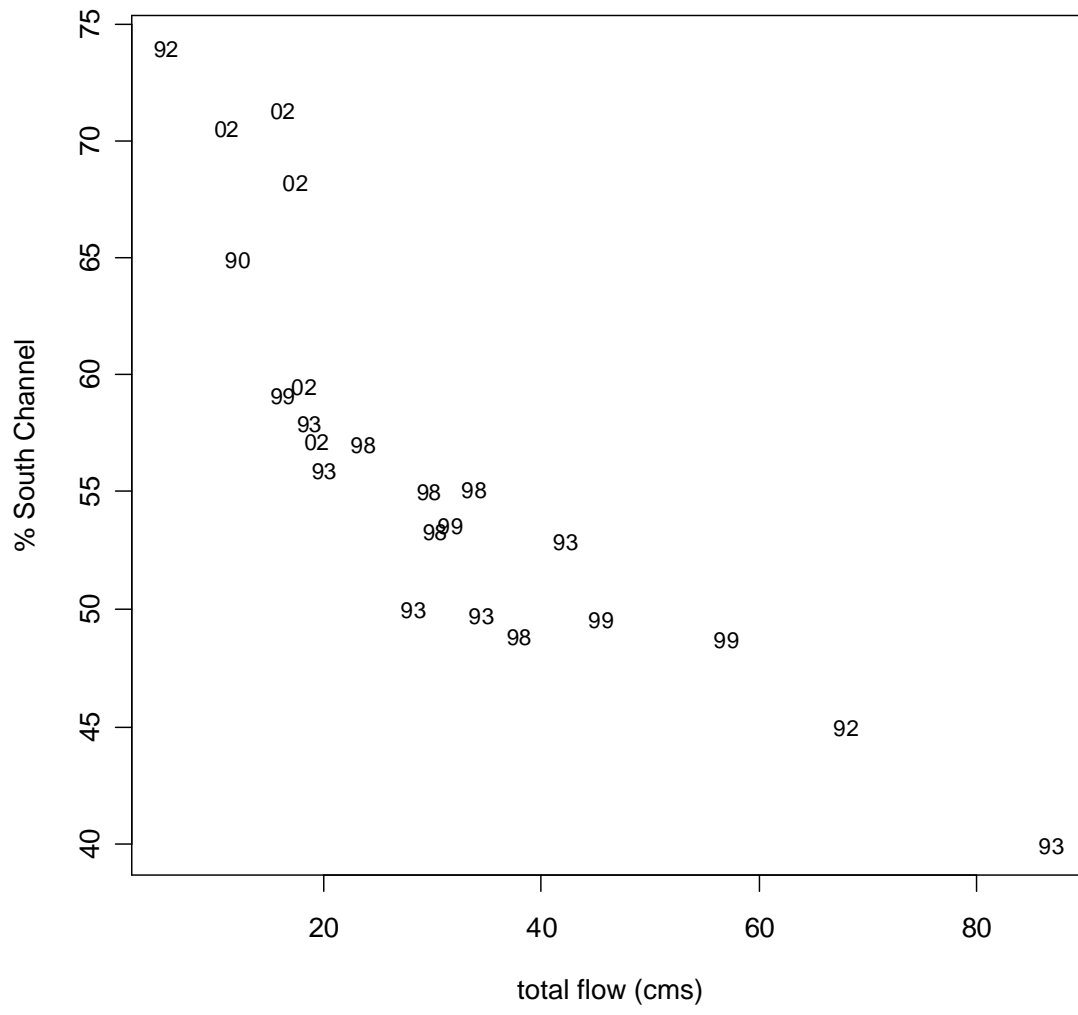


Figure 25. Plot of the relationship between total flow and percentage flowing to the south channel of Alec River. Tthe year of sample collection is shown.

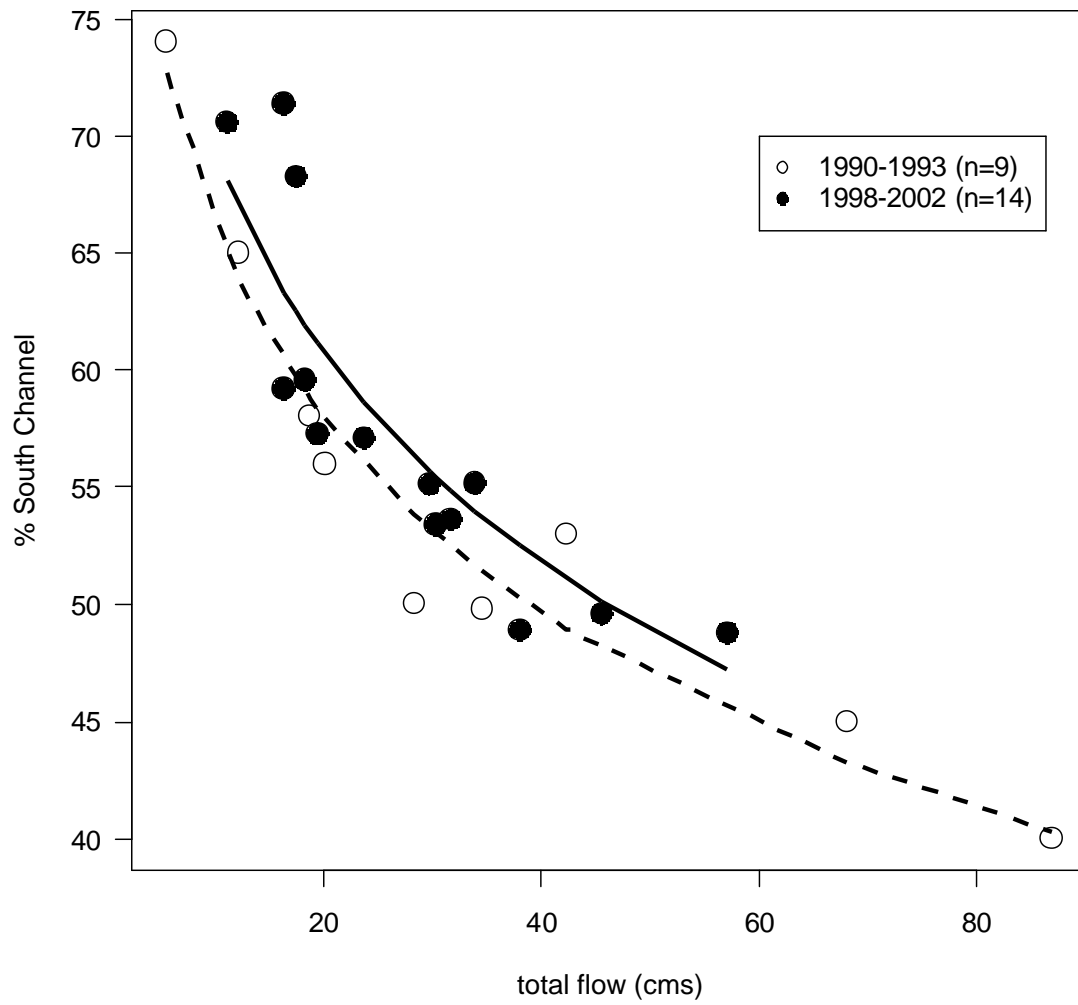


Figure 26. Percent of the total discharge of Alec River flowing to the South Channel as a function of total discharge and sampling period .

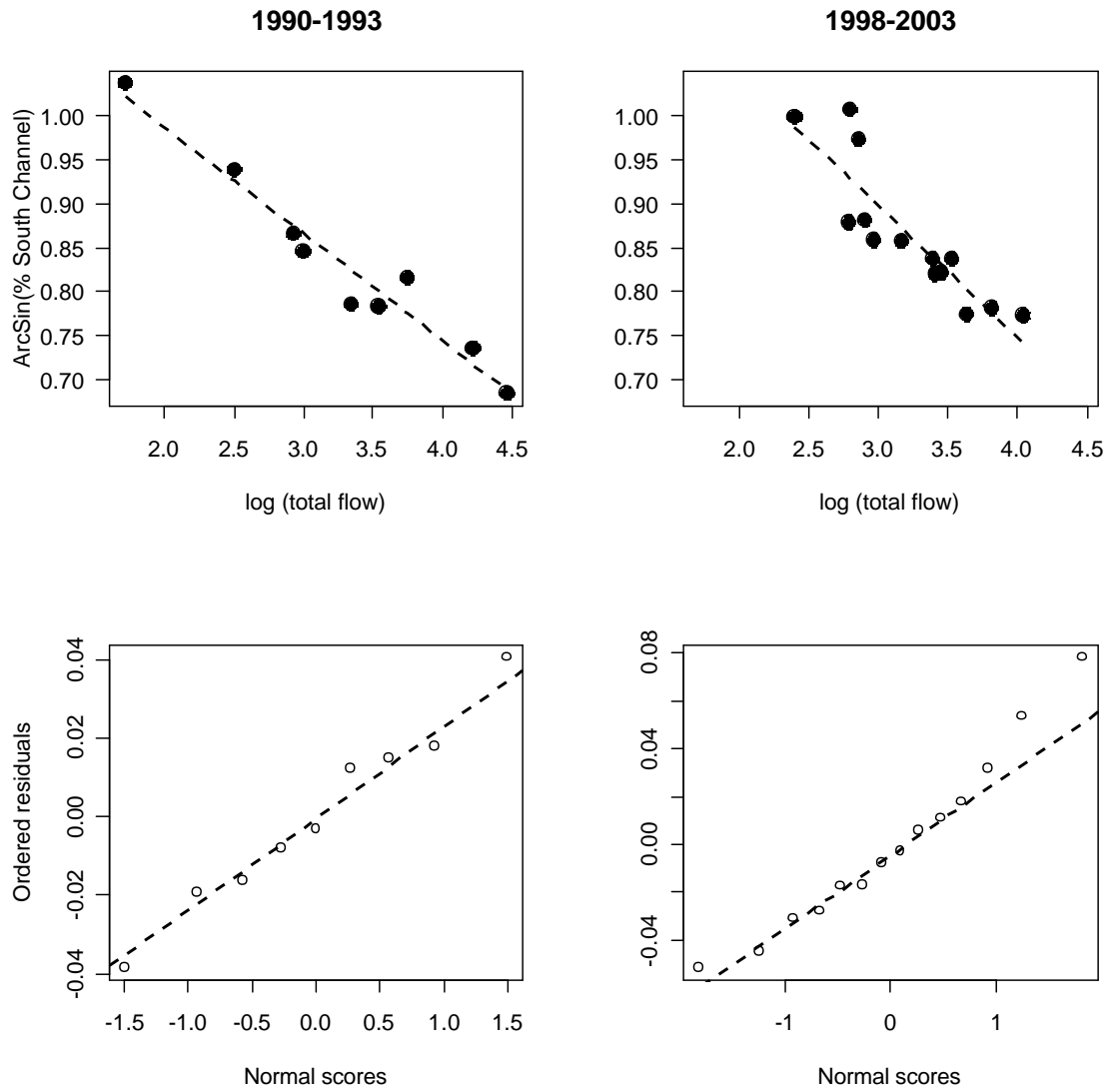


Figure 27. Transformed model fits Q-Q plots of the residuals for the periods 1990-1993, and 1998-2002.

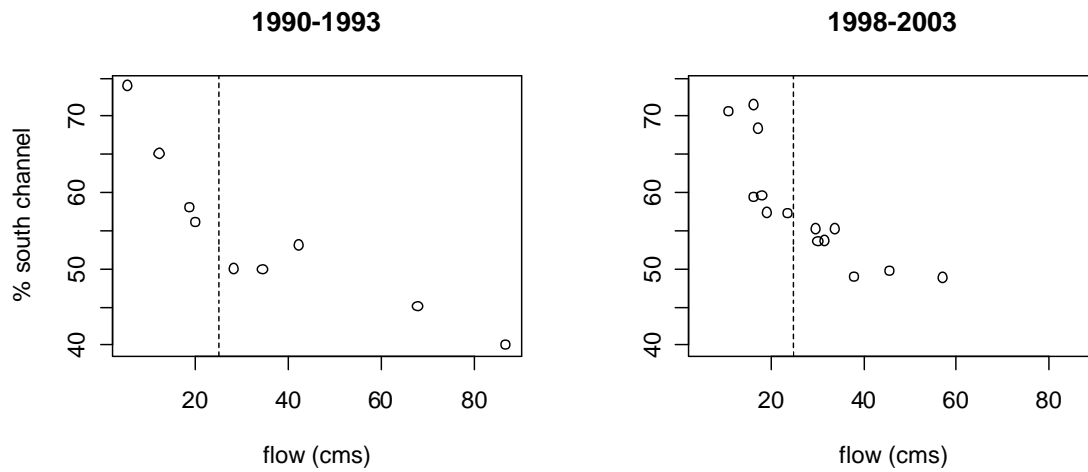


Figure 28. Presence of a possible threshold effect, suggesting a rapid increase in flow to the south channel at flows less than 25 m³/s.

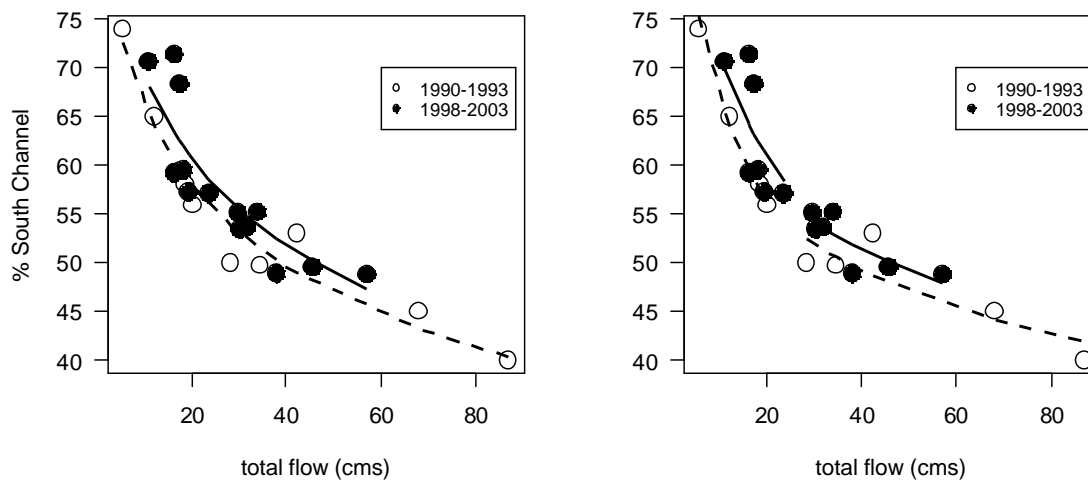


Figure 29. Model fits without threshold effect (left), and with threshold effect (right).

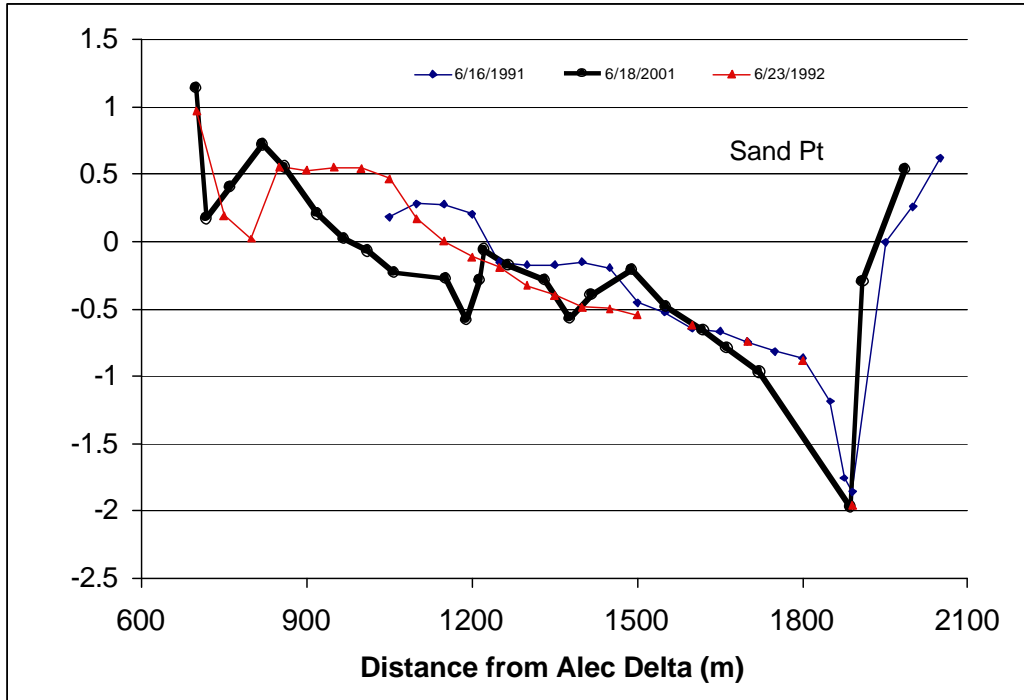


Figure 30. Sandspit elevations between the Alec River delta and Sand Pt during 1991, 1992, and 2001. 0 elevation is -0.8 m at the outlet benchmark, which is a typical water level for the lake during summer.

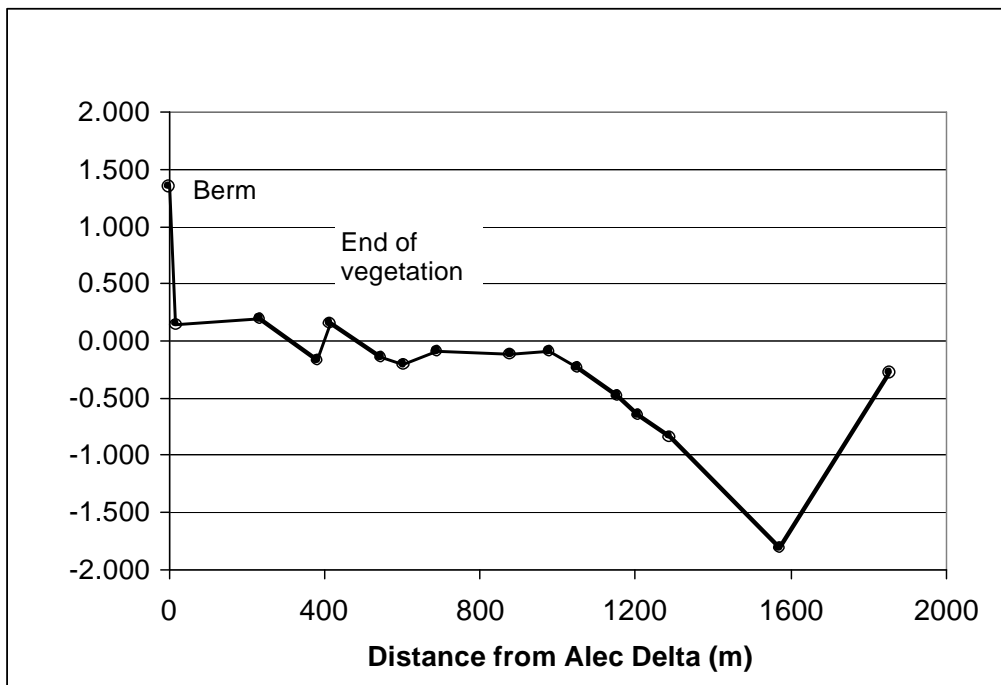


Figure 31. Elevation of relatively recent sandspit crossing Alec Bay. Elevation is relative to -0.8 m at benchmark. Water was about -0.1m on this Y axis.

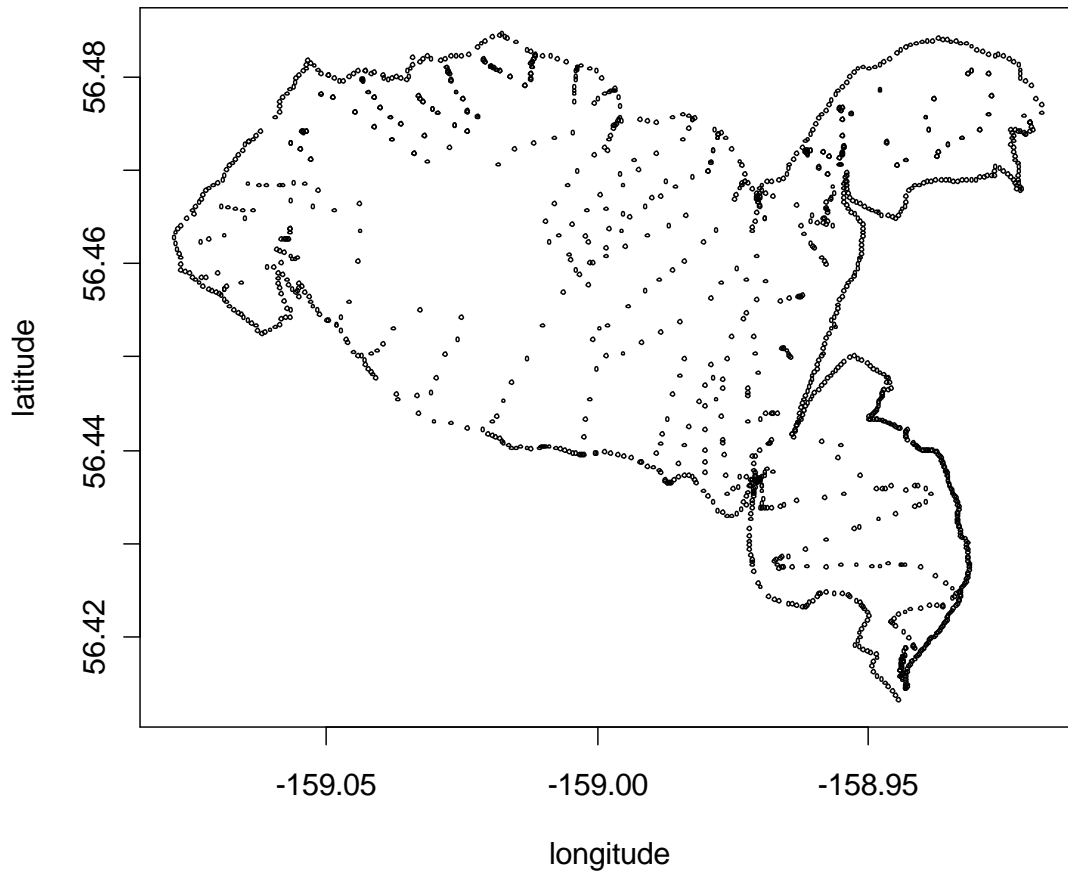


Figure 32. Location of 2001-02 depth survey points on Black Lake.

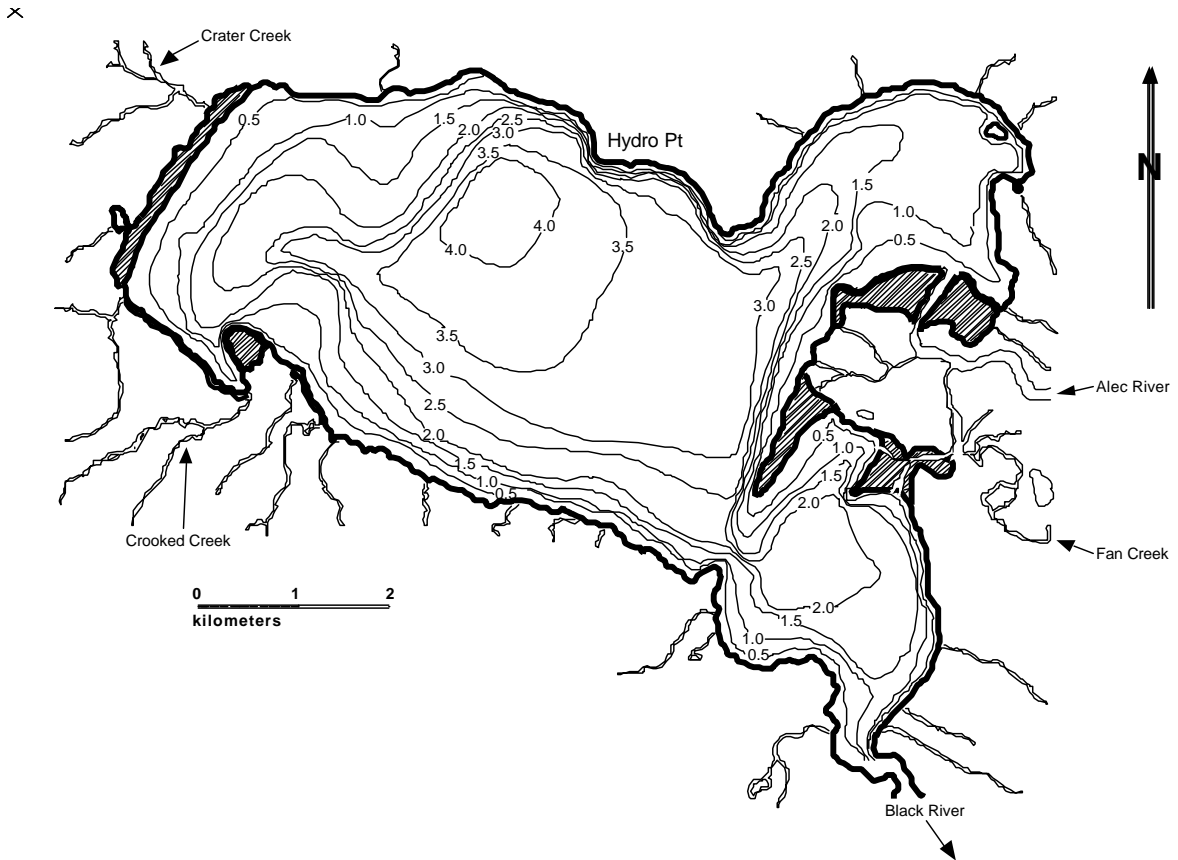


Figure 33. Depth contours of Black Lake (0.5 m intervals). Measurements taken during June 1992; water elevation: -0.6 m. Shaded regions identify exposed areas that were underwater in the 1950s (Ruggerone et al. 1993).

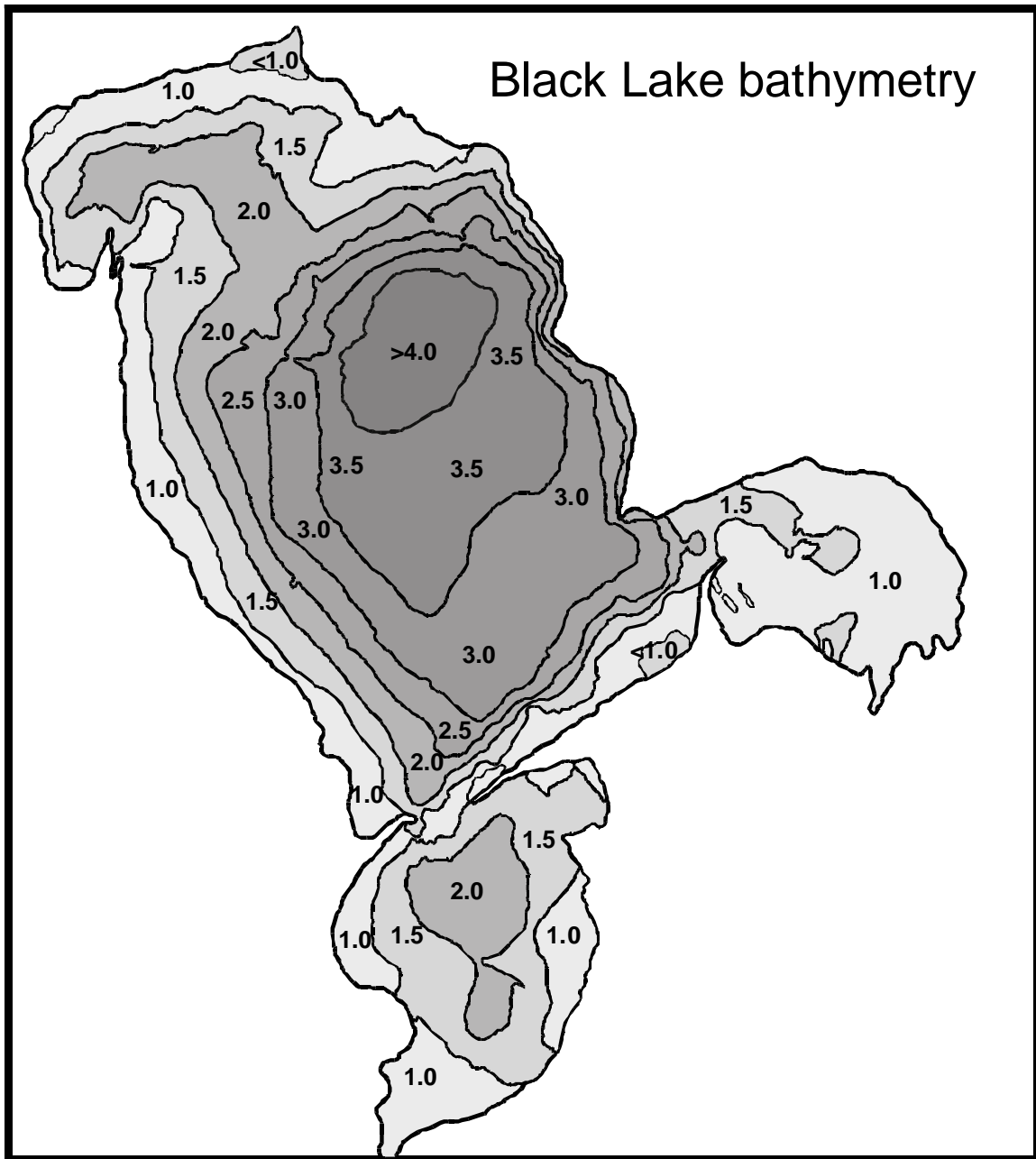


Figure 34. Depth contours of Black Lake (0.5 m intervals). Measurements taken during August 2001 and 2002.

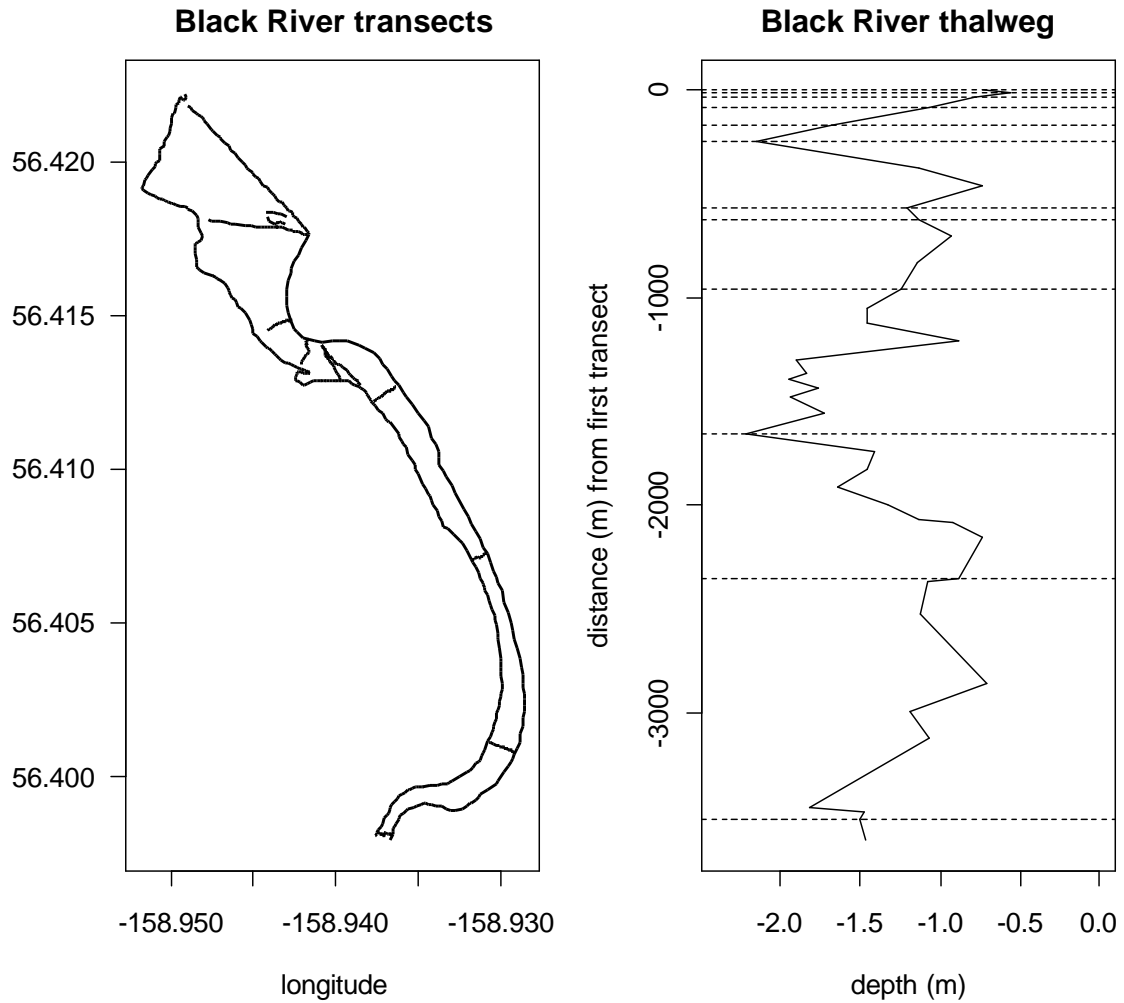


Figure 35. Black River transects and thalweg profile produced from 2002 data. The figure on the left shows the river outline and transects that were made. The figure on the right shows the thalweg measurement, with horizontal dotted lines representing the transects on the left.

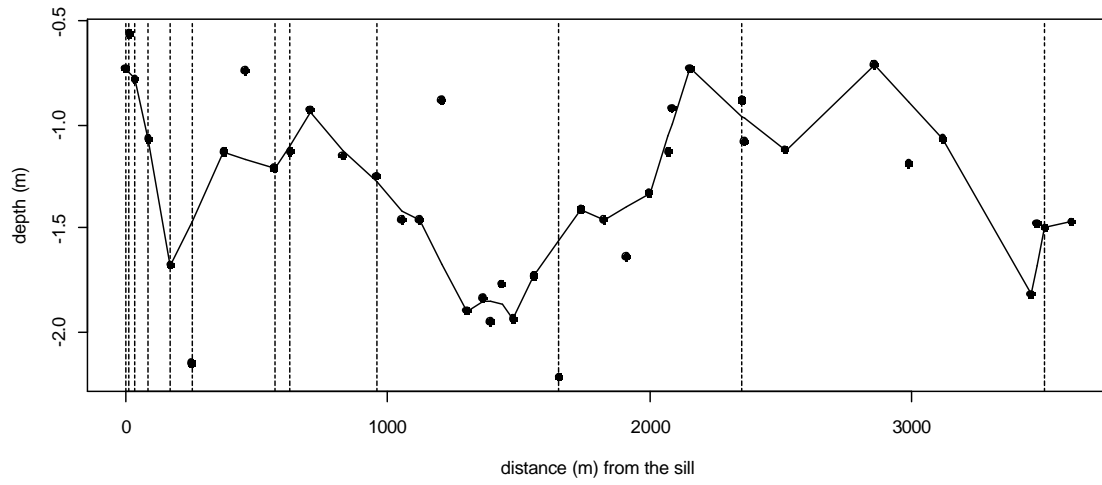


Figure 36. Thalweg profile. The solid line represent the "smoothed" relationship between distance and depth and dotted lines represent transects.

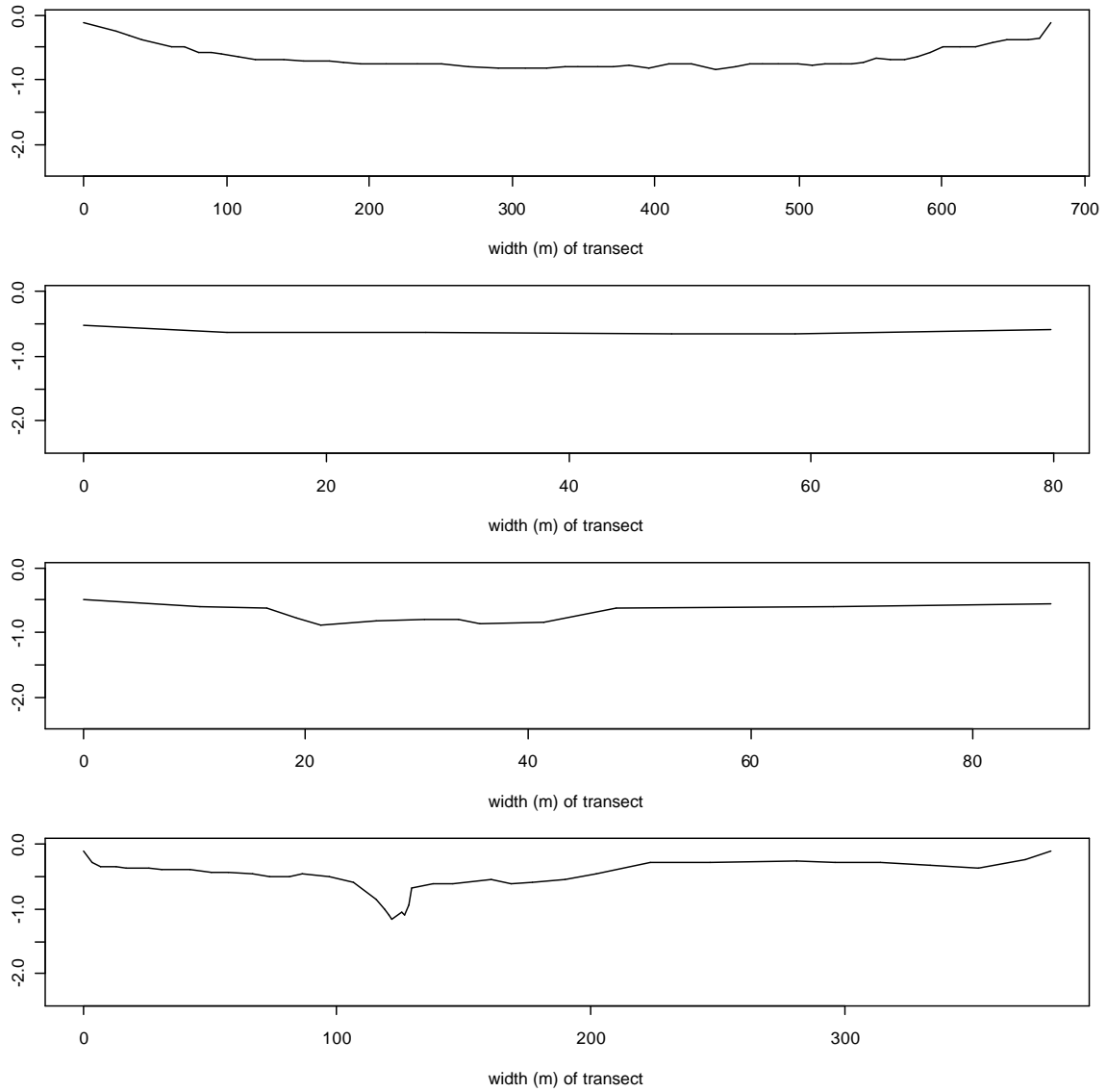


Figure 37. Transect depths for the first four transects starting at the outlet of Black Lake. The second transect is the Black Lake sill. The right side of the figure is river right.

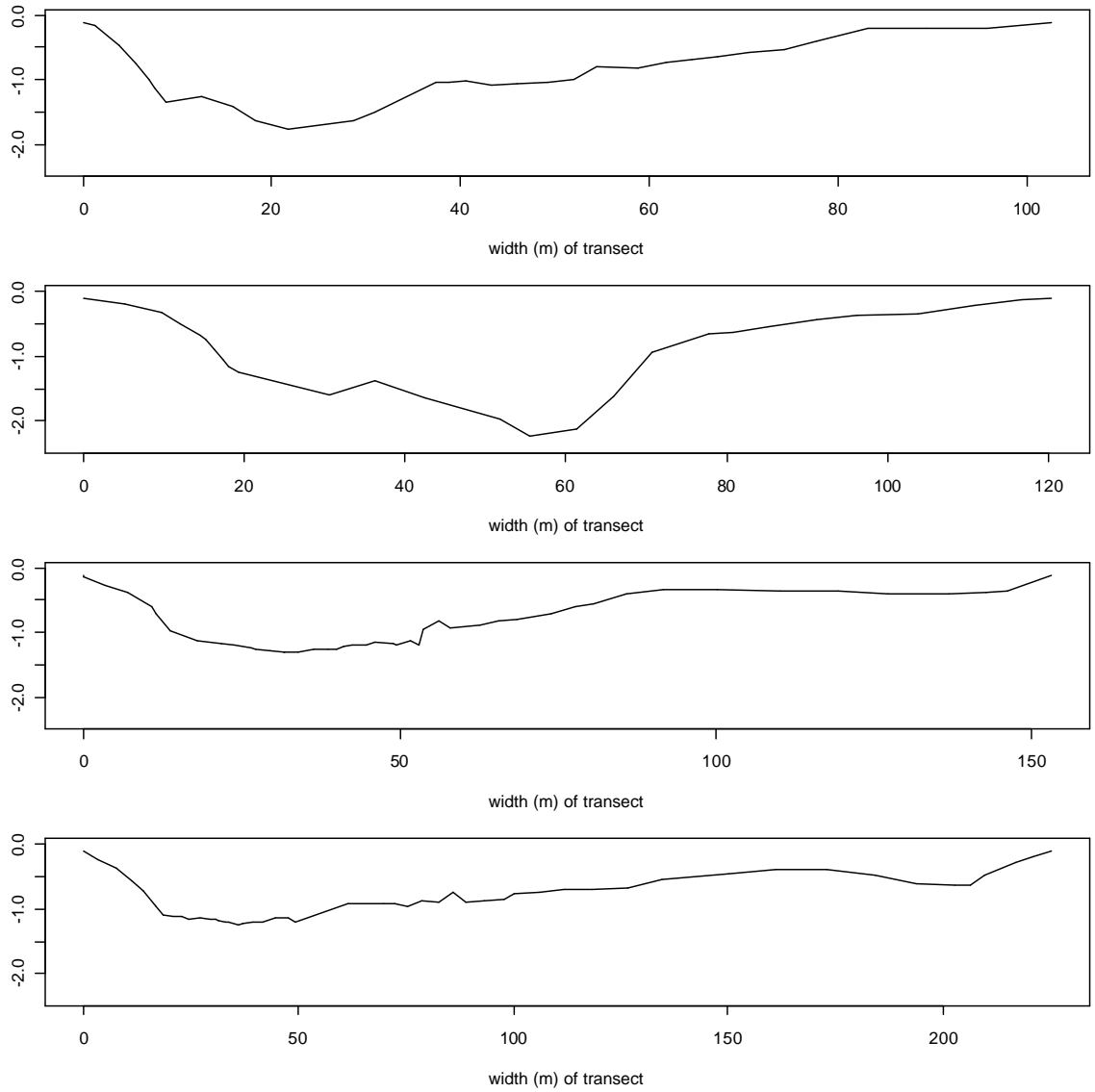


Figure 38. The next four transects from the outlet of Black Lake. The first two transect are in front of Ted Shangins' cabin. The right side of the figure is river right.

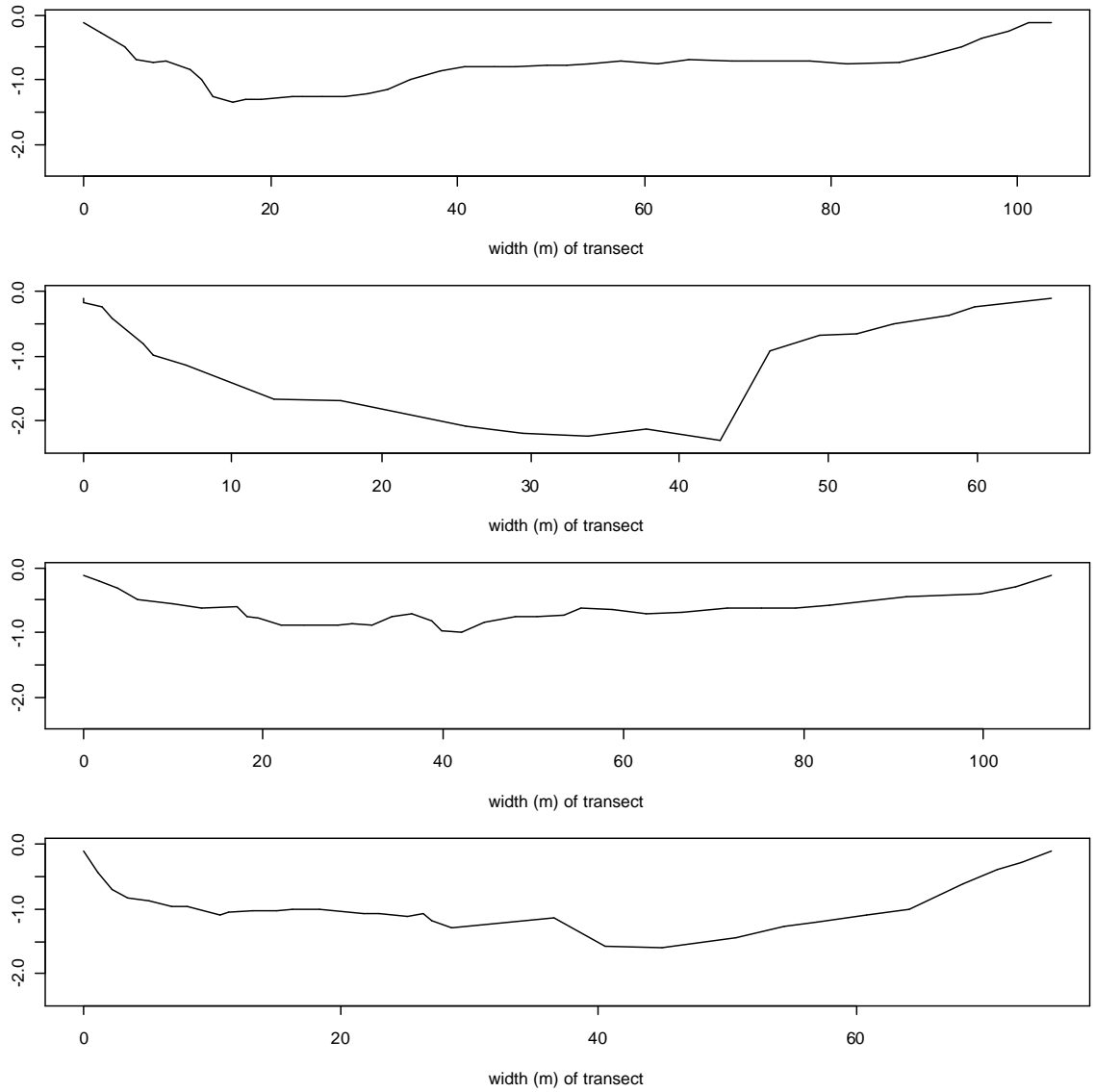


Figure 39. The final four transects as you work down river from the outlet of Black Lake. The first two are on the long straight stretch of river. The right side of the figure is river right.