EVOS ANNUAL PROJECT REPORT

Project Number: 040707 and 040703

Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems

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Time Period Covered by Report: October 1, 2004 – September 30, 2005

Date of Report: September 28, 2005

1. **Work Performed**: This report covers the second year of this three-year project. During the second season, we continued with the sampling plan and data collection that we developed during the first year, as the plan was successful. It should be noted that the sampling and analytical plan of this project do not mesh well with the reporting timetable of GEM. For example, we are continuing our field sampling into October 2005, and many of the analyses are done in batches at the end of the sampling season. Thus, we are unable to completely present our project activities for the year.

During winter, the Alaska Department of Fish and Game (ADF&G) and the University of Alaska Fairbanks (UAF) teleconferenced to plan sampling logistics for the year. Logistically, there are five components to this project: (1) smolt studies, (2) basic limnology sampling, (3) lake productivity measurements, (4) periphyton and phytoplankton sampling and (5) stable isotope sampling and analysis. The sections below summarize our activities for these components.

We also attended the Marine Science Symposium in Anchorage in January 2005, where we synthesized our results to that time and made preliminary interpretations of the data. This was incorporated into a poster presented at the meeting entitled "Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems".

Smolt Studies

Smolt studies were conducted at Karluk and Spiridon (control) Lakes (Figs. 1 and 2). At Karluk Lake, smolts were collected and counted using a Canadian fan trap located approximately 2 km downstream from the lake. The site was chosen to coincide with the same project location used from 1999-2003 (ADF&G 2004), and for this GEM project in 2004. During 2005, the smolt trap was installed 9 May and was removed 27 June after 49 days of fishing. During this period, 35,216 sockeye salmon smolt were enumerated through the trap at Karluk Lake (Fig. 3). The first sockeye salmon smolt were caught the first day the trap was operational. The peak count occurred on 20 May (3,287 smolt). The total smolt emigration estimate for 2005 was 1,494,811 sockeye salmon smolt. The 2005 population estimate was lower than the 2004 estimate (2,308,625), and lower than the 1999-2004 average estimate of 2,051,554 salmon smolt (Fig. 4).

The smolt project at Spiridon Lake was funded by the Kodiak Regional Aquaculture Association (KRAA). Sockeye smolts were collected at Spiridon using a waterfall bypass system (ADF&G 2004). The bypass system consists of a smolt weir, two Canadian fan traps, two dewatering tanks, one tank for enumeration and sampling, and a pipeline. The system captures 100% of the emigrating smolt. The bypass system was in place a total of 67 days from 5 May and 11 July 2005 (Fig.5). During the period of operation, an estimated 1,409,374 live sockeye salmon smolt were enumerated. The peak count occurred on 10 July (236,836). A total of 1,421,353 sockeye salmon smolt emigrated from Spiridon Lake in 2005 (Fig. 6). Of these, 1,409,374 smolts survived passing through the bypass system. Smolt mortality through the bypass system was 11,979 (0.8%), with most mortality occurring in the new counting bin. The 2005 sockeye salmon smolt estimate was the largest since 2001, and above the 1995 to 2004 average (Fig. 6).

Smolt scales from both lakes were sampled for AWL, and samples were also obtained for stable isotope analysis.

Basic Limnology

The basic sampling plan presented in the proposal was refined and implemented in 2004. As the plan has worked well, we have continued to follow it during 2005. Water samples are collected at 1, 5, 10, 15, 20, 25, 30, 35, and 50 m at both Spiridon Lake stations and at Karluk station 3. All depths except 50 m were sampled at Karluk station 2, because it is only 37 m deep. In a few instances 30 or 35 m samples had to be eliminated because of aircraft weight limits. Surface water samples were collected at all river stations. Light attenuation was measured using a secchi disk and a Protomatic analog photometer. In addition to dissolved oxygen (DO) profiles (using a YSI 52 DO meter), and light a SBE19 Seacat CTD was used to measure conductivity, temperature and fluorescence. Vertical zooplankton tows are taken at all lake stations using standard protocols. Duplicate 50 m zooplankton tows were collected at both Spiridon Lake stations and Karluk station 3. At Karluk station 2 duplicate 35 m tows were taken. At Karluk station 5, the only river station deep enough, duplicate tows were taken from 3 m or 1 m depth. One sample is used for biomass and species assemblage determination, and the other for stable isotope analysis. Detailed descriptions of analytical methods are provided in ADF&G 2005, Thomsen et al 2002, and Koenings et al 1987.

Our plan calls for 9 basic limnology sampling trips per year timed to capture the entire "growing" season. Sample dates were chosen to coincide with (1) pre-lake stratification (May 1 and June 1); (2) lake stratification and pre-sockeye salmon spawning (July 1, August 1, and August 15); and (3) the influx of carcass derived nutrients (September 1st and 15th, and October 1 and 15th). Additional productivity analyses are conducted during

7 of these trips. Specific sample dates are modified inseason to cope with staff scheduling and weather, but the general schedule structure was maintained.

Each lake has 2 pelagic stations that were chosen to coincide with existing sample stations (Figs. 1 and 2). Samples had not been collected from tributaries feeding Spiridon Lake, so new stations have been established. Many of the tributaries feeding Spiridon Lake are small and steep. We chose East Creek and West Creek. Stations at both river sites were approximately 20 m from the mouth and in approximately 2 m of water (Fig. 1). As stations had not been established for tributaries feeding Karluk Lake, we selected Thumb River and Cottonwood Creek. We chose Thumb River because this river has a large inriver spawning population of sockeye salmon. Cottonwood Creek was selected to represent smaller streams, as it is smaller than Thumb River in terms of depth, width, and numbers of spawning salmon.

For 2004, analysis of dissolved oxygen content, temperature, light attenuation, pH, alkalinity, silicon content, TKN, and zooplankton samples (density, biomass and size) has been completed. Most of the nutrient analyses are complete or in the process of being analyzed. The 2004 CTD data has been compiled. In 2004, we collected a total of 36 dissolved oxygen, temperature, and light regime profiles, 45 zooplankton samples, 177 water samples from Spiridon Lake, and 163 water samples from Karluk Lake.

We are currently in the process of collecting and analyzing the 2005 data. As of mid-August, 114 water samples were collected from Karluk and Spiridon Lakes. The following parameters have been measured for all Spiridon and Karluk Lake stations and sample depths: pH, alkalinity, and silicon (Si). Total filterable phosphorous (TFP), ammonia, total-phosphorous (TP), filterable reactive phosphorous (FRP), and nitrate and nitrites will be analyzed as time allows. We plan to outsource samples for total Kjelhdal nitrogen (TKN) analysis in 2005 to Olsen Biochemistry Lab, South Dakota State University as we did in 2004. The remaining nutrient analyses will be conducted on the auto-analyzer at UAF. For consistency, the remaining samples from 2004 and 2005 will be run as a “batch” following the completion of this years sampling in October.

Chlorophyll *a* and phaeophytin measurements are complete for the 2004 samples. UAF and ADF&G duplicated the chlorophyll *a* and phaeophytin measurements at the 1-m and 50-m (35-m at Karluk station 2) sample depths with slightly different methods. However, a comparison of the duplicated measurements showed no significant difference. Thus in 2005, chlorophyll *a* and phaeophytin samples will be processed at UAF only, and these samples will be run in a “batch” for consistency following the completion of this years sampling in October.

In 2004 and thus far in 2005, duplicate vertical zooplankton tows were collected at both Spiridon and Karluk Lake stations. At Karluk river station 5 (the only river station deep enough), duplicate tows have been obtained.

Because of the large numbers of samples collected and resultant data, the following sections show representative data and highlight some interesting results. Some examples focus on 2004, as it is the only year with sampling to assess the full seasonal cycle. While it is premature to conduct detailed statistical analysis, some interesting differences between lakes and years is apparent.

Temperature and DO

The typical seasonal cycle of stratification for both lakes is well represented by the 2004 data (Fig. 7). Both lakes are still completely mixed in May, and began to stratify in June. Surface temperatures continue to warm, and further thermocline development occurs until mid-to late August. After this time, surface temperatures cool, stratification begins to break down, and mixing is evident. Temperatures and thermocline depth were similar between stations and lakes, although, measurements were not identical. Subtle differences between lakes in the vertical profiles of temperature (and fluorescence, not shown) indicate some possible differences in the physical conditions between the two lakes. Larger measurement differences were observed for D.O. between stations and between lakes.

Chlorophyll

Profiles of individual chlorophyll *a* samples in Karluk and Spiridon Lakes are shown in Figure 8. There are significant differences in lakes, with much higher concentrations for Karluk during all sampling periods. The seasonal and depth patterns appear to be complex. It is interesting to note that there is little structure in the chlorophyll that corresponds with the temperature structure. Seasonal patterns are subtle and are different between the 2 lakes. Chlorophyll peaks in Spiridon Lake in July, but Karluk Lake has peaks in both May and August. Our data would tend to confirm the hypothesis that MDN may be important in supporting productivity of salmon lakes. Annual mean integrated (0-50m) chlorophyll *a* concentrations in Karluk Lake stations 2 and 3 were 100 mg m^{-2} and 90 mg m^{-2} while Spiridon Lake mean values ranged from 25-40 mg m^{-2}. In addition, the seasonal pattern in Karluk may be different in response to timing of sockeye salmon returns/spawning.

Based on size fraction analyses conducted as part of the chlorophyll measurements, both lakes seem to be dominated by <20 micron phytoplankton. From the initial data set it appears that Karluk station 2 has more >20 micron phytoplankton than the Spiridon stations. In particular, June showed 75% of the population at Karluk station 2 to be >20 microns. Six of the samples have the <5 micron size fraction as dominant.

pH and Alkalinity

Patterns in pH appear to be similar for both years. PH ranged from a low of 6.9 to a high of 7.7 among all stations and all depths between both lakes (Fig. 9). pH is roughly the same and tended to be fairly uniform throughout the water column at all lake stations in both lakes. Subtle seasonal differences are observed between lakes. pH tended to decrease from May through the year in Spiridon Lake, but in Karluk Lake, pH declines from spring into summer, but then increases in October. pH in the rivers at Spiridon was similar to the pH from the lake stations; however, pH in the rivers at Karluk were dissimilar to the pH from the lake stations.

Similar to pH, alkalinity has a very limited range (16 to 23 μg/L) among all lake stations and depths, between both lakes. Unlike pH, alkalinity tended to oscillate between high and low values through the water column. At both lakes, the highest alkalinity was measured in July and at a river station, but also in both cases, the high alkalinity was not duplicated at the other river station of the same lake. We are comparing this data to other variables to assess the controls on alkalinity.

TP

The seasonal and depth profiles for TP for both lakes in 2004 are shown in Figure 10. TP is generally higher in Karluk than Spiridon by a factor of ~2. TP does vary by depth, station, and month at both lakes. For example, some high near bottom values are found in Karluk Lake. Typically, there appears to be little coherent vertical structure in the TP profiles. In general, TP is highest in springtime for both lakes. In Spiridon, overall TP values tend to decrease throughout the season, while in Karluk, there is a hint of higher values during some of the August sampling periods.

Silicon

Seasonal changes in the vertical profiles of dissolved silicon are significantly different between lakes (Fig. 11). Silicon tended to be uniformly distributed through the water column at Spiridon Lake and demonstrated more variation through the water column at Karluk Lake. It is noteworthy that concentrations are substantially higher at Spiridon Lake (~20 X) than Karluk Lake. This is likely due to greater concentrations of salmon-derived nutrients at Karluk, and higher productivity. As salmon carcasses lack Si, high levels of fertilization from carcasses may result in relative depletion of Si. Our data suggests that Si may approach limitation in this lake. Silicon concentrations from the river stations at Karluk Lake were higher than the concentrations at the lake stations (Figure 25), suggesting the depletion is due to biological uptake in the lake. Such processes do not appear to be extensive in Spiridon Lake. Seasonal patterns in Si profiles also differ between lakes. Si has only minor seasonal variability in Spiridon (<10% change form mean values). However, in Karluk Lake, Si values are highest in spring, and decrease by a factor of ~X2 during the season.

Zooplankton

Analysis of zooplankton samples is complete for 2004, and in the process of being analyzed for 2005. As the complete data is available for 2004, we focus on these results for this section. There are some differences between stations within a lake, but these differences are minor compared to the between lake differences. Thus for each lake we use mean values for the 2 pelagic stations. Composition among all lake stations is generally similar, and dominated by C*yclops* with *Bosmina* the second in abundance. However, densities are vastly different between lakes, with Karluk Lake having higher densities of the 2 most abundant types. Cyclops densities (in #/m^2) average 70,000 in Spiridon Lake, and 501,000 in Karluk Lake, while *Bosmina* densities averaged 31,000 in Spiridon Lake and 54,500 in Karluk Lake. Mean lengths of *Bosmina* (~0.45 mm) and *Cyclops* (~01.05 mm) were similar between stations and lakes. There are significant differences in biomass between lakes, with total zooplankton biomass (mg/m^2) in Karluk Lake averaging 772, and in Spiridon Lake 355.

Zooplankton composition at the river station at Karluk Lake was different from all other lake stations, and densities were low. *Bosmina* were predominant.

Productivity Samples

Productivity measurements were obtained during most sampling trips 2004 and 2005. During the spring sampling trips nitrogen and carbon-based productivity was determined at Karluk stations 2 and 5 and Spiridon stations 1 and 5 from the surface depth only. During the remainder of the trips productivity has been determined from samples at three light depths (surface, 30%, 1%) from all the lake stations and at the surface from the river station. Chlorophyll and nutrient samples are collected at all productivity depths, in addition to the regular sampling intervals. Mass spectrometric analysis has been completed on the 2004 samples, and reveal that our sampling and incubation protocols are adequate for quality results. Statistical calculations need to be finalized based on the specific nutrient data, but the results clearly show higher productivity levels in Karluk Lake. Productivity is higher during all sampling periods (by up to a factor of ~X2). The data also suggest a different seasonal pattern, with Karluk having an additional peak in productivity in late August. Our preliminary productivity data is consistent with productivity inferred from the chlorophyll and TP data. Following the 2005 sampling season, we will finalize the results for both the 2004 and 2005 seasons.

Periphyton and Phytoplankton Samples

Water samples have been collected from Karluk station 2 and Spiridon station 1 for phytoplankton analysis. Water was collected various depths in the euphotic zone. From this combined sample, an integrated sample was made and subsamples were set aside for pigment analyses (frozen) and phytoplankton speciation (preserved with Lugols). phytoplankton data from the first year's sampling demonstrated that algal biomass was consistently at least twice as great in Karluk Lake as in Spiridon Lake (Fig. 12). Karluk algal biomass as estimated from the phytoplankton analysis show higher biomass in Karluk during every sampling period by a factor of 2-3. The algal biomass at Karluk Lake is highest in spring and shows a sustained high biomass until just after the early run of spawners, though based on these data, there is no response in phytoplankton biomass to the late run of spawners.

Algal composition at a coarse taxonomic level shows a high degree of similarity in the seasonal dynamics between Karluk and Spiridon lakes (Fig. 12). Overall, the phytoplankton assemblages of both lakes are dominated by diatoms, chrysophytes and pyrrhophytes (i.e. dinoflagellates). The most dominant group, the diatoms, are generally considered to be a high quality food for cladocerans. At a species level, however, we see a strong distinction between Spiridon and Karluk lakes. *Cyclotella* cf. *bodanica*, which is common in oligotrophic to mesotrophic systems dominates (by biomass) the spring assemblage of Karluk Lake whereas *Asterionella formosa* (also an oligo- to mesotrophic indicator) dominates the spring assemblage at Spiridon Lake. The difference in dominant diatoms between these two lakes may be explained by resource competition theory, as Karluk Lake has a lower Si:P ratio than Spiridon. *Asterionella formosa* has been shown to be a good competitor for phosphorus and whereas a closely related species to *Cyclotella* cf. *bodanica* (i.e. *Cyclotella meneghiana*) has been shown to be a good competitor for silica. Expressing the phytoplankton data as cell densities, *Stephanodiscus parvus* is the numerically dominant diatom species in Karluk (instead of *Cyclotella* cf. *bodanica* which is biomass dominant), but like *Cyclotella, Stephanodiscus* is a good competitor for silica.

Additionally, the bottom substrate was collected from fixed quadrats for periphyton analysis near river stations in both lakes during both years. Analysis of these samples is in progress to determine both periphyton biomass and isotopic composition, and their seasonal signatures. Preliminary observations indicate much higher biomass in Karluk Lake, and significant seasonal changes in both lakes. This work will be completed "in batch" for consistency of results following completion of collection of the 2005 samples.

Stable Isotope Sampling and Analysis

Samples have been obtained from all sampling trips for POM (particulate organic matter - phytoplankton) and zooplankton. POM samples were obtained from filtering water taken at all depths at each lake station, and at the river station. Zooplankton samples were obtained from vertical zooplankton hauls at all lake stations, and one Karluk River station. Sockeye smolt samples were obtained from the Karluk Lake smolt trap. Adult sockeye will be sampled from scale collections obtained at the Karluk weir. Collection of terrestrial samples was described above. All samples have been frozen, and will be processed and run in a single batch at the end of the sampling season to ensure maximum consistency. The 2004 results for POM analysis are shown in Figure 13. The data from the river stations reveal significant differences between lakes, while in-lake trends are similar. The mean values in $\delta^{15}N$ in riverine POM for Spiridon are about 4 ‰ with little seasonal variability. However in Karluk, the $\delta^{15}N$ in riverine POM ranges from 6-10, and has peaks in both the early spring and in mid-summer. The mid-summer peak appears to correspond with the first run of spawning sockeye. The pelagic lake POM $\delta^{15}N$ results are somewhat unexpected. The average values for Karluk Lake POM ($\delta^{15}N$ ~10 ‰) are higher than the mean for Spiridon Lake ($\delta^{15}N$ ~6 ‰), but during a few sampling intervals values are actually higher in Spiridon. Clearly, some recycling of nitrogen is occurring in Spiridon, enriching the POM and subsequent food web. We will try do determine the mechanism of this enrichment. Nonetheless, the $\delta^{15}N$ of pelagic POM is higher in Karluk and has large seasonal variability with peaks in the spring and late summer. The late summer peak could reflect a lag of transfer of salmon-derived nutrients that we observed earlier in the year in the riverine samples. Like POM, the average $\delta^{15}N$ values of zooplankton and sockeye smolts are higher in Karluk Lake than Spiridon Lake, by more than 4 ‰. For example, the mean $\delta^{15}N$ value of smolts from Karluk Lake is ~14-15 ‰, and ~10 ‰ in Spiridon Lake.

Pilot studies of terrestrial samples are underway. Brown bear samples have been obtained through collaboration with ADF&G biologist, Larry VanDaele, and analysis of claws is underway to determine seasonal changes in diet. Terrestrial plant and soil samples have been analyzed for stable isotopes, that were obtained from a previous year, and reveal that both soils and plants are enriched in the Karluk samples. However, we observe a sharp decline in $\delta^{15}N$ away from spawning streams, with background values found at about ~100 m from the streams.

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2. **Future Work**: Work planned for the upcoming year should not be substantially different from the proposal. Flight costs continue to be higher than anticipated because of sampling time, and cost increases. This has hindered the addition of pilot studies that require significant time on the ground. To save on costs, we are doing samples in large batches for efficiency, and data consistency. The budget of this project is lean, and we are striving to make it work and perform all necessary tasks.

3. **Coordination/Collaboration**: This project involves extensive coordination and collaboration. Smolt data from the Spiridon smolt project are integral to our results. Flights to Spiridon Lake were shared when possible to reduce costs. The Karluk

escapement weir is still in place; total counts for the early and late sockeye salmon runs are available through to this project. Outside funding of adult catch sampling and scale analysis continues. Aged scales will be used in conjunction with age-marker analysis to reconstruct the Karluk Lake sockeye salmon run. Flights to re-supply the Karluk smolt research project were shared with the Frazer Lake fish pass project to reduce costs. We will integrate the results of this project with the paleoecological work of the EVOS/GEM project "Reconstructing Sockeye Populations in the Gulf of Alaska over the last Several Thousand Years (D. Mann, B.Finney, PIs).

4. **Community Involvement/TEK & Resource Management Applications**: The ADF&G presented the project design to the Kodiak National Wildlife Refuge Staff, the Kodiak Regional Salmon Planning Team, and the U.S. Coast Guard for review and comment. The results of these consultations were considered prior to finalizing the operational plans and implementing the field project. Data collected will also be shared with these groups through copies of annual reports. The ADF&G gave preference to local residents, including qualified residents of the Villages of Karluk, when hiring sampling crews. The study sites were located in areas of high recreational use and frequent interaction with the public occurred. Employees were encouraged to provide accurate information to the public regarding the goals and objectives of the project. The results from this project have management implications regarding the effect to which fisheries may influence the overall productivity of watersheds. The results from this project will provide information critical in developing a monitoring program to detect annual changes in levels of marine nutrients in watersheds.

5. **Information Transfer**: This project is currently in the second year of gathering data. A poster presentation was made at the Marine Science Symposium in Anchorage in January 2005, entitled “Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems”. In addition, Finney and phytoplankton collaborator I. Gregory-Eaves (McGill University) presented a poster at the 2005 Annual meeting of the Ecological Society of America (ESA) entitled “Assessing the role of salmon-derived nutrients in shaping algal composition and biomass in Alaskan sockeye salmon nursery lakes”. The ADF&G is developing a limnology database to integrate the current data with historical data and facilitate future data requests.

6. **Budget**: As indicated in the ‘Future Work’ section, flight costs were higher than expected because of the underestimated amount of time required to collect all of the samples. However, due to collaborative cost-sharing, total costs to this project are reduced. To assist with future expenditures, it would be very beneficial if supplemental funding could be obtained.

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Project Web Site Address:
www.cf.adfg.state.ak.us/region4/finfish/salmon/kodiak/gem_res.php

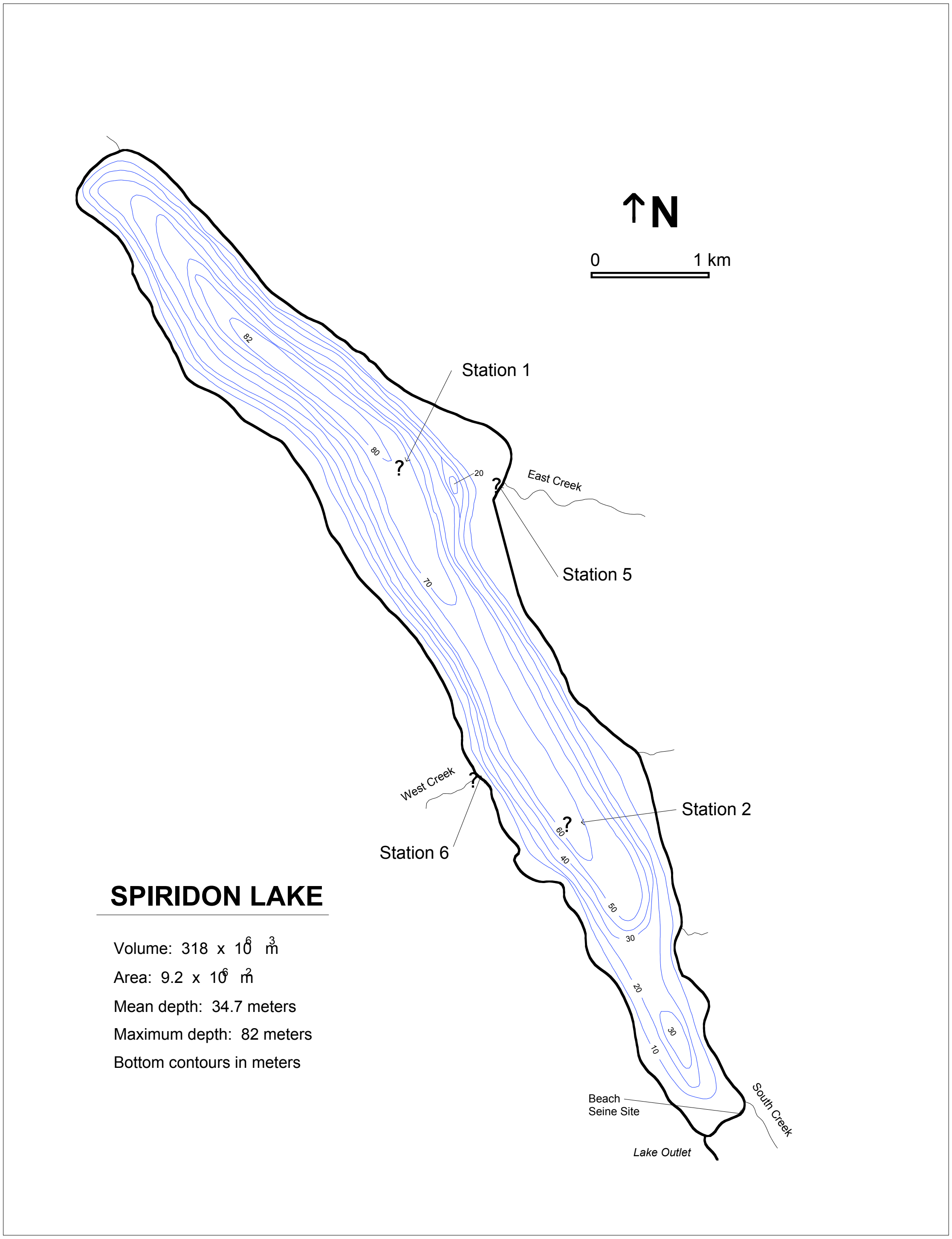


Figure 1. Bathymetric map of Spiridon Lake indicating sample stations.

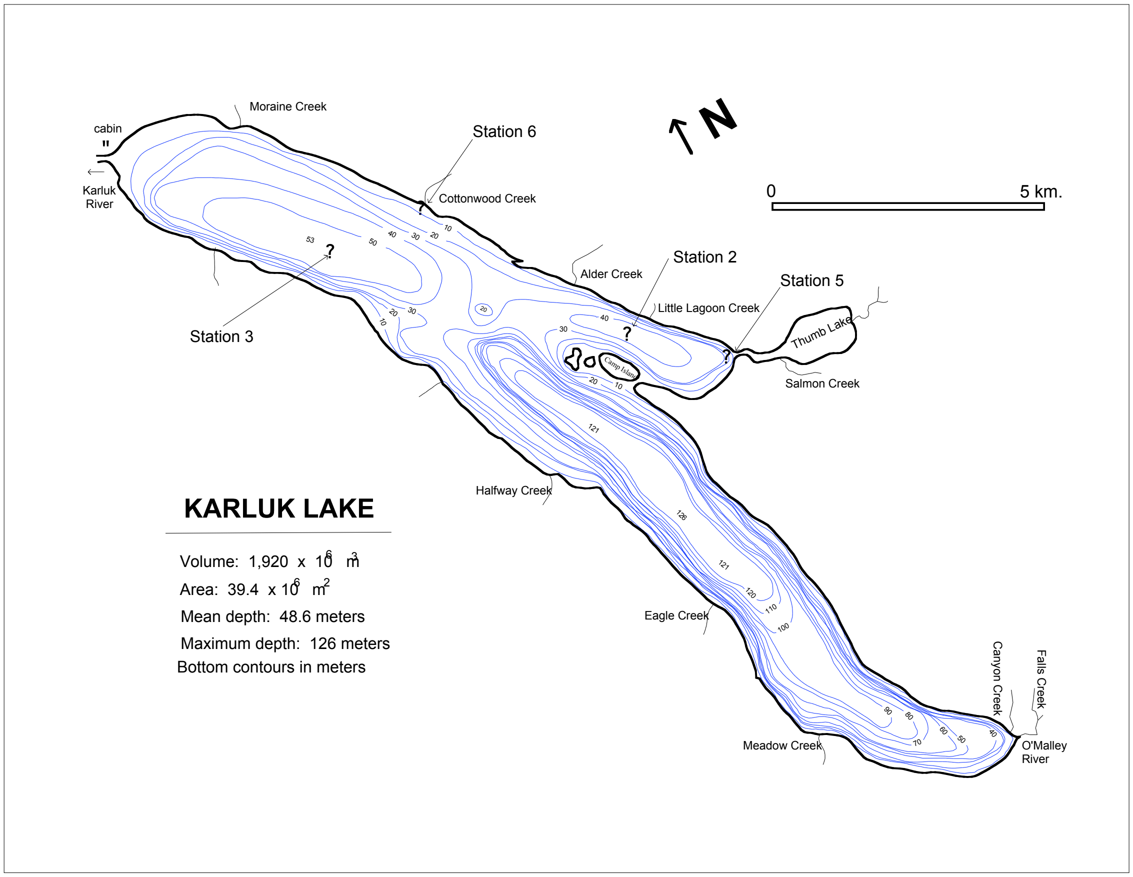


Figure 2. Bathymetric map of Karluk Lake indicating sample station

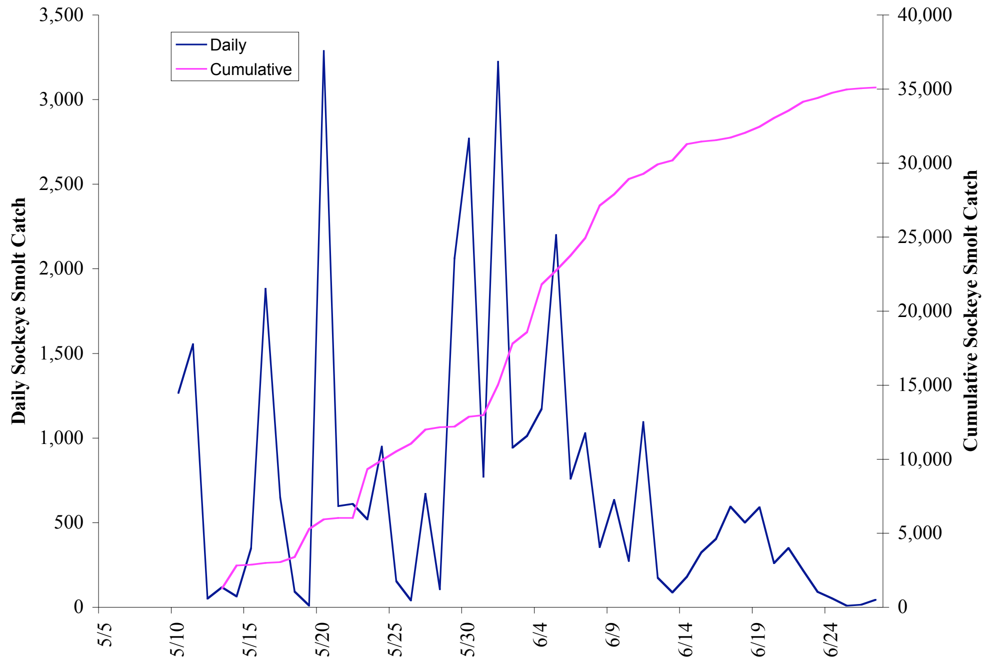


Figure 3. Karluk Lake daily and cumulative sockeye salmon smolt counts, 2005.

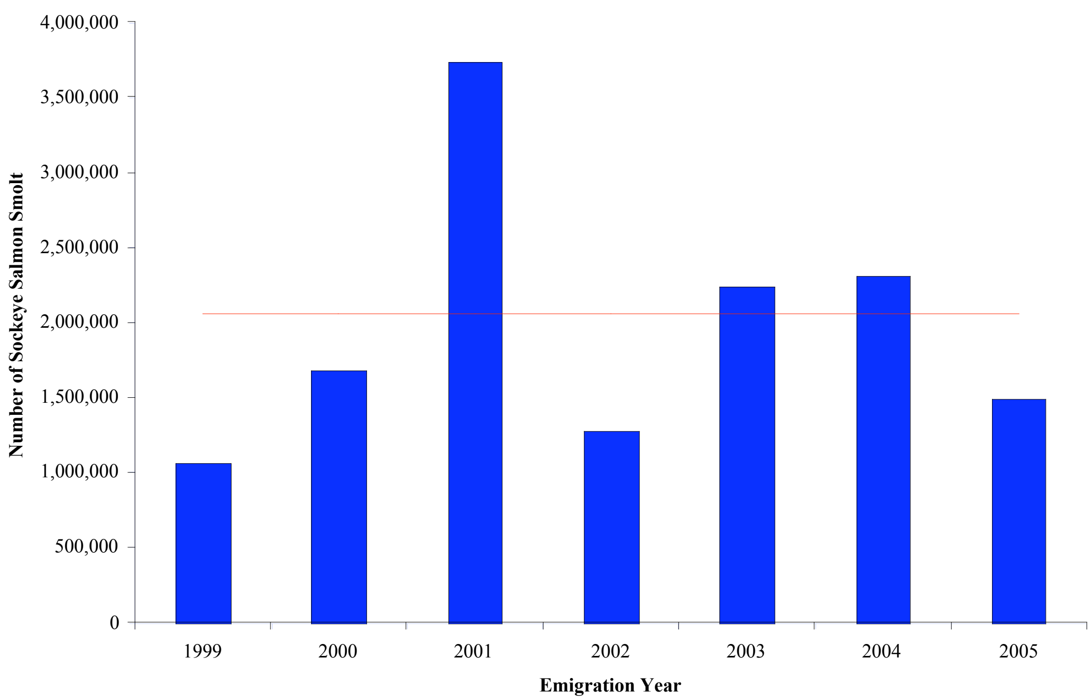


Figure 4. Karluk Lake sockeye salmon smolt population estimates, 1999-2005.

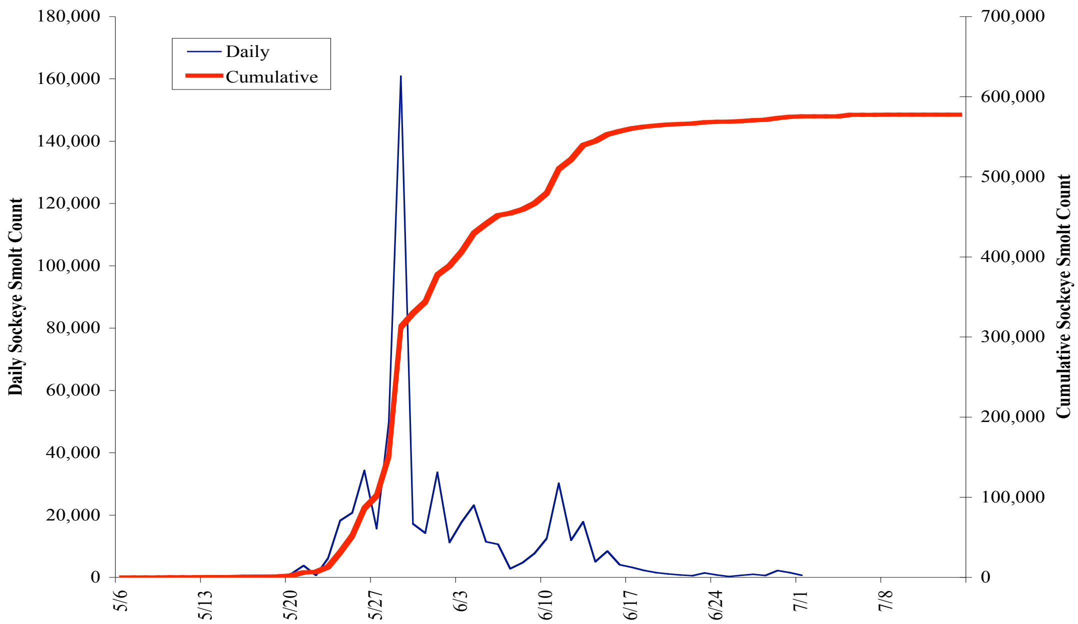


Figure 5. Spiridon Lake daily and cumulative sockeye salmon smolt counts, 2005.

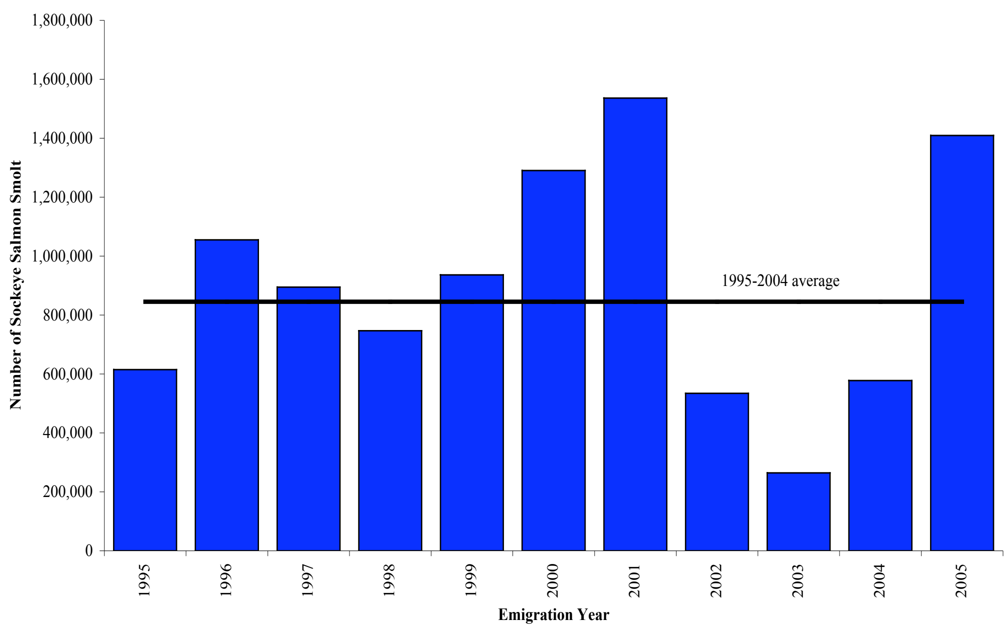


Figure 6. Spiridon Lake sockeye salmon smolt population estimates, 1992-2005

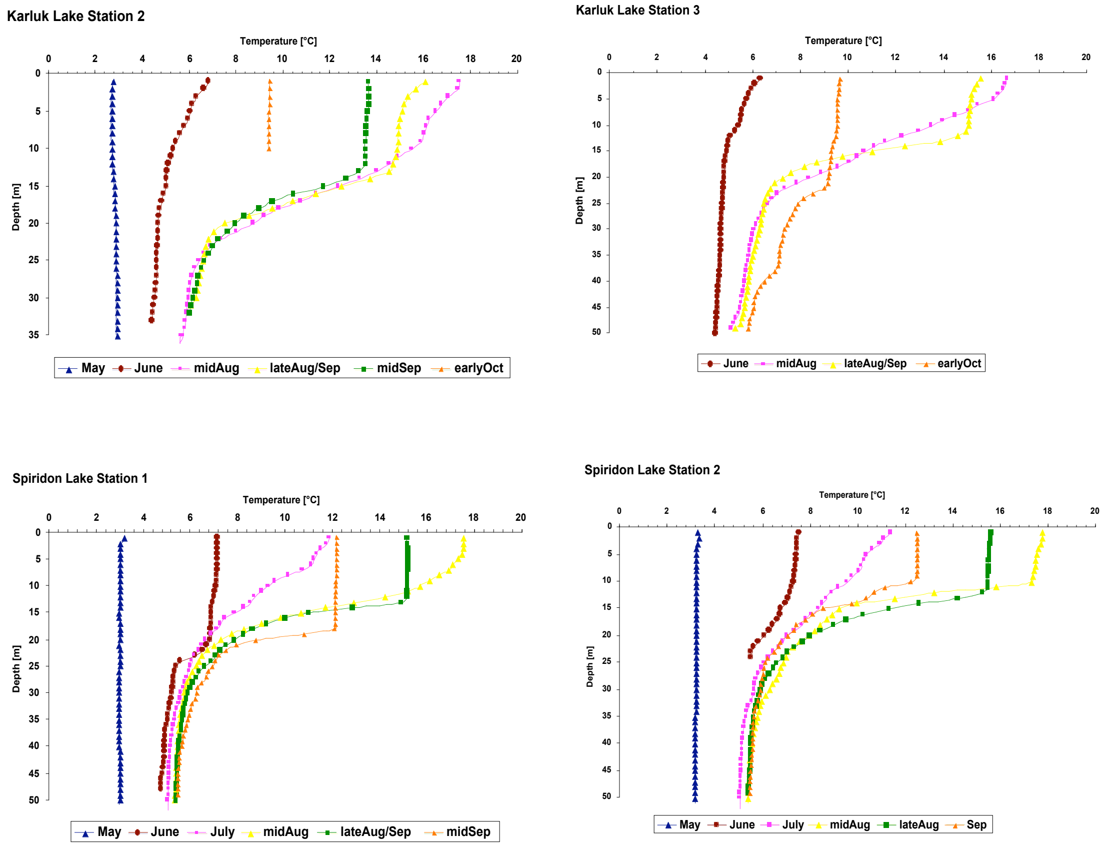


Figure 7. CTD temperature profiles from Karluk and Spiridon Lake stations, 2004.

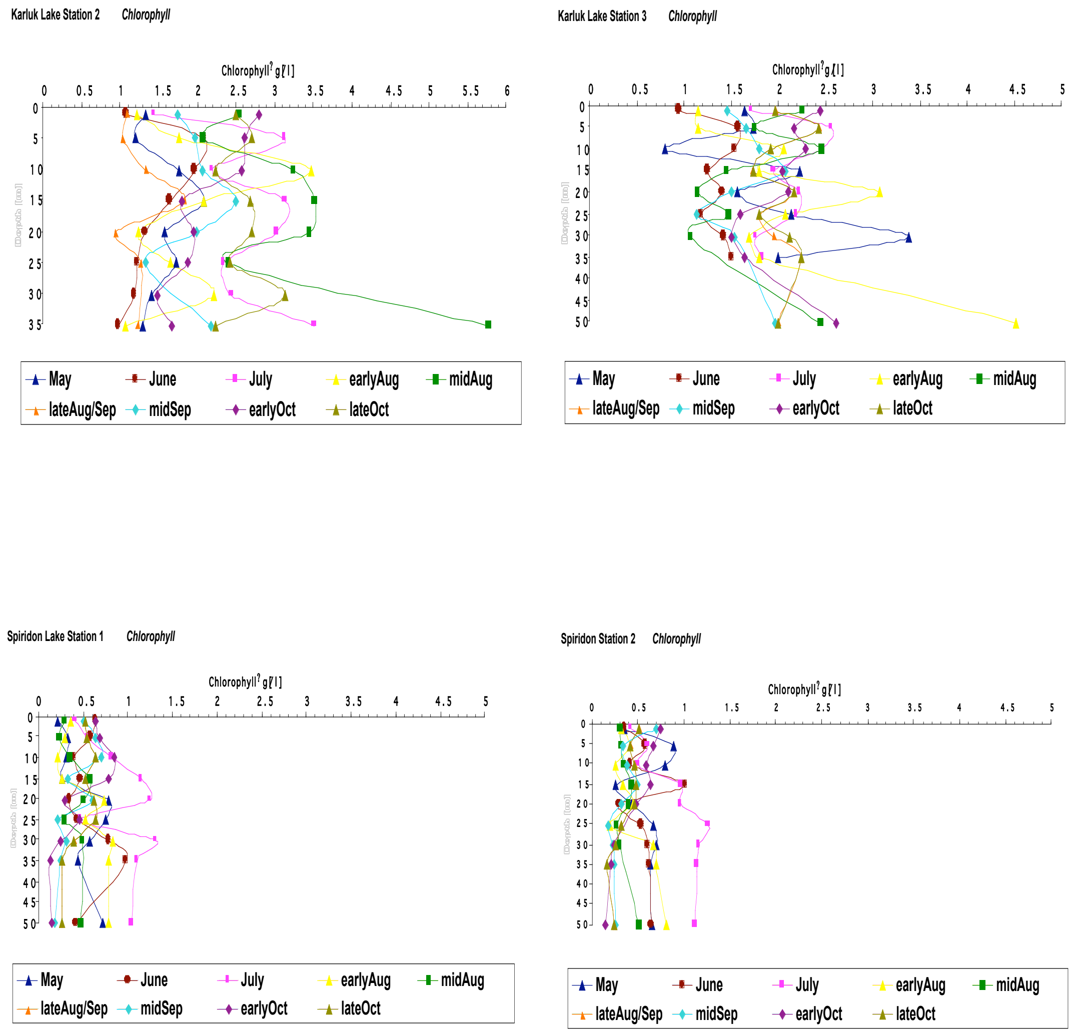
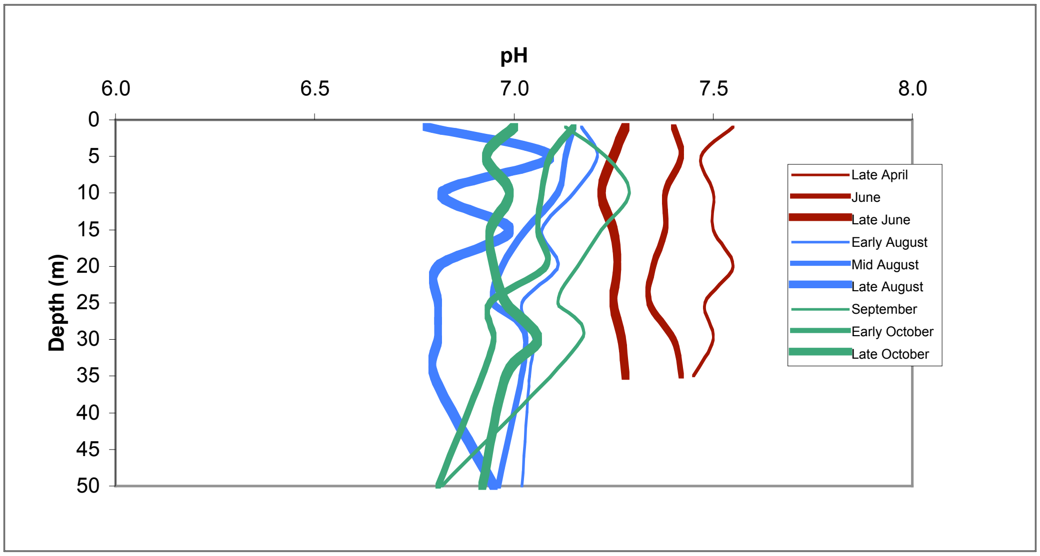
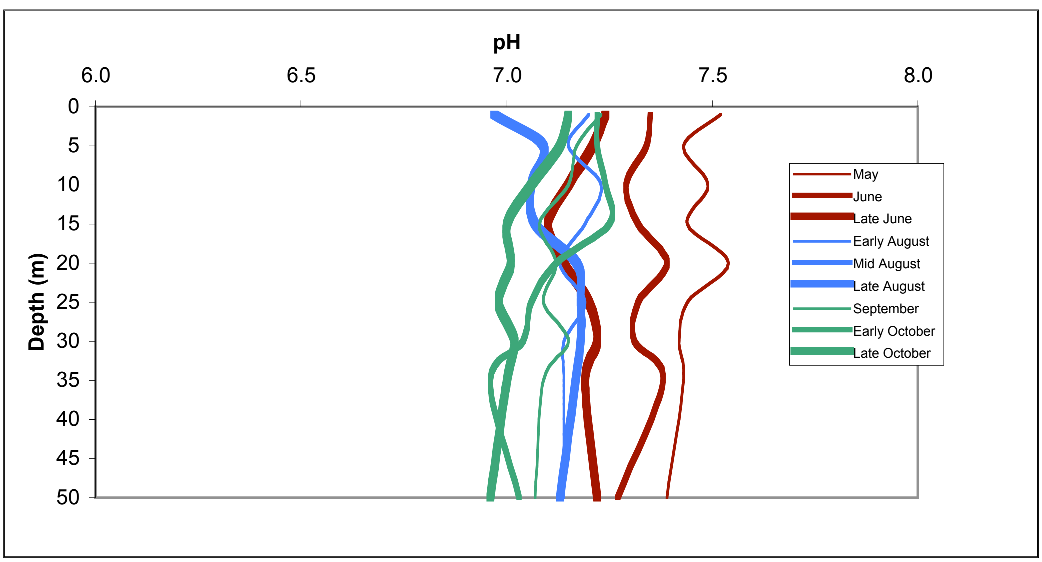


Figure 8. Chlorohyll *a* from Karluk and Spiridon Lakes, 2004.

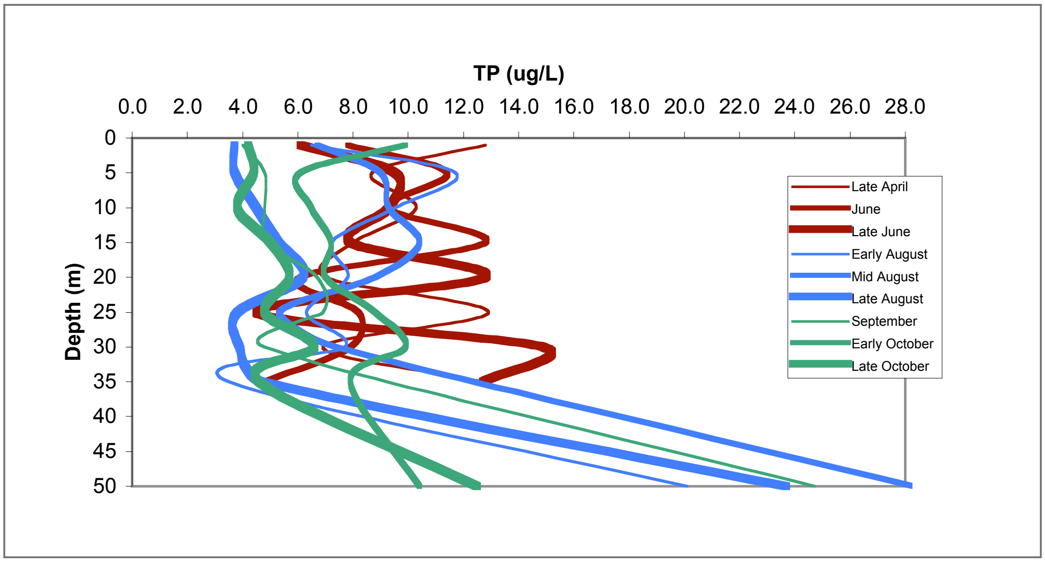


Karluk Station 3

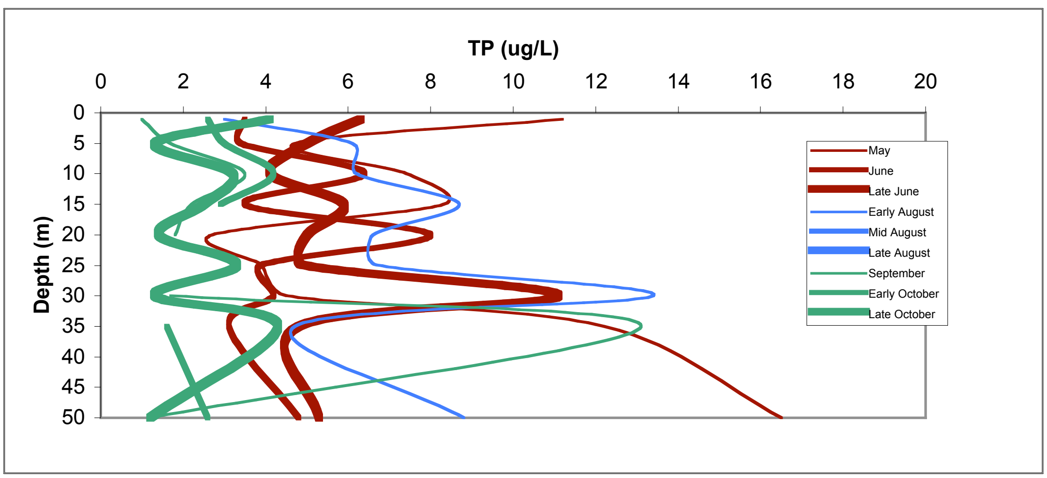


Spiridon Station 2

Figure 9. pH profiles from Karluk and Spiridon Lakes, 2004.

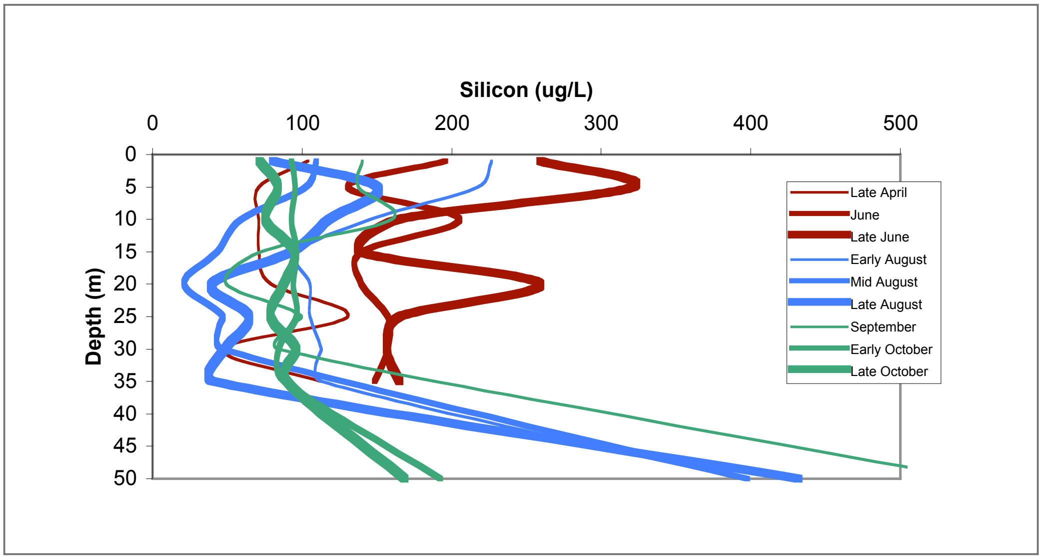


Karluk Station 3

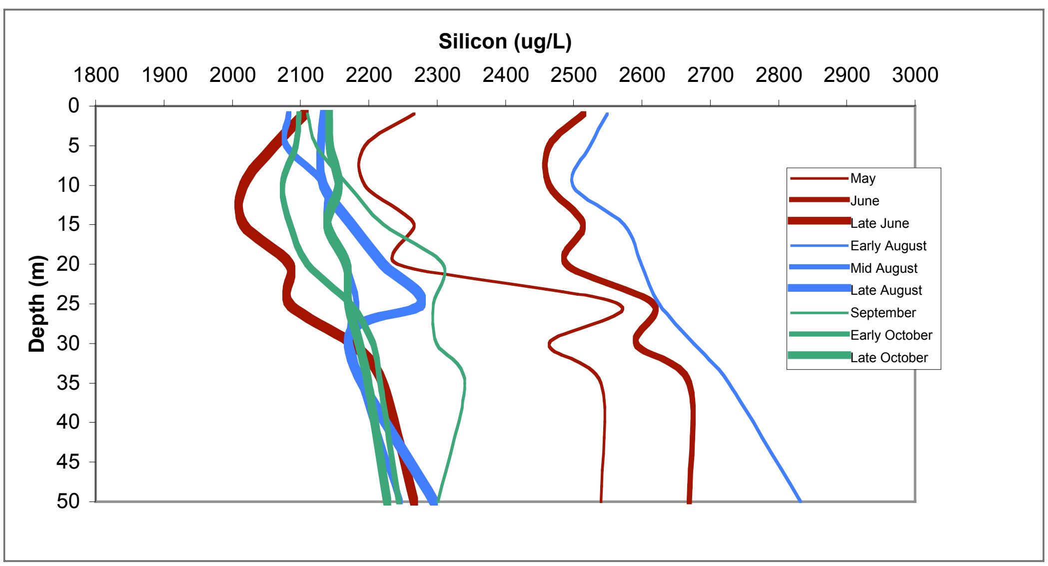


Spiridon Station 1

Figure 10. Total Phosphous profiles from Karluk and Spiridon Lakes, 2004.

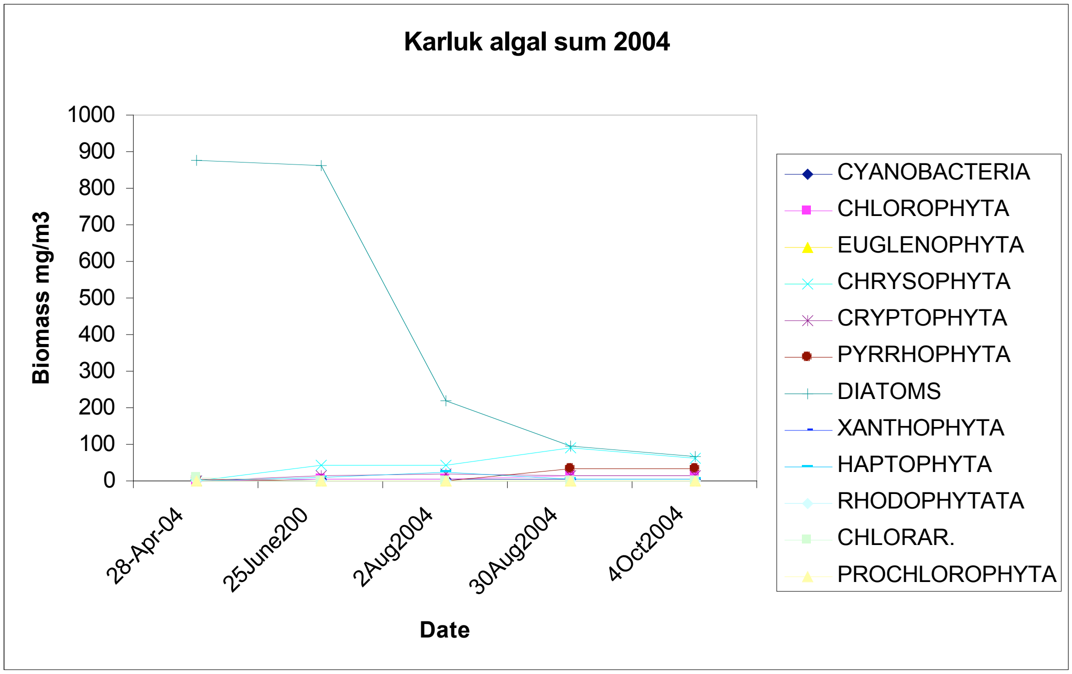


Karluk Station 3



Spiridon Station 2

Figure 11. Silicon profiles from Karluk and Spiridon Lakes, 2004. (Note Si scale difference between lakes).



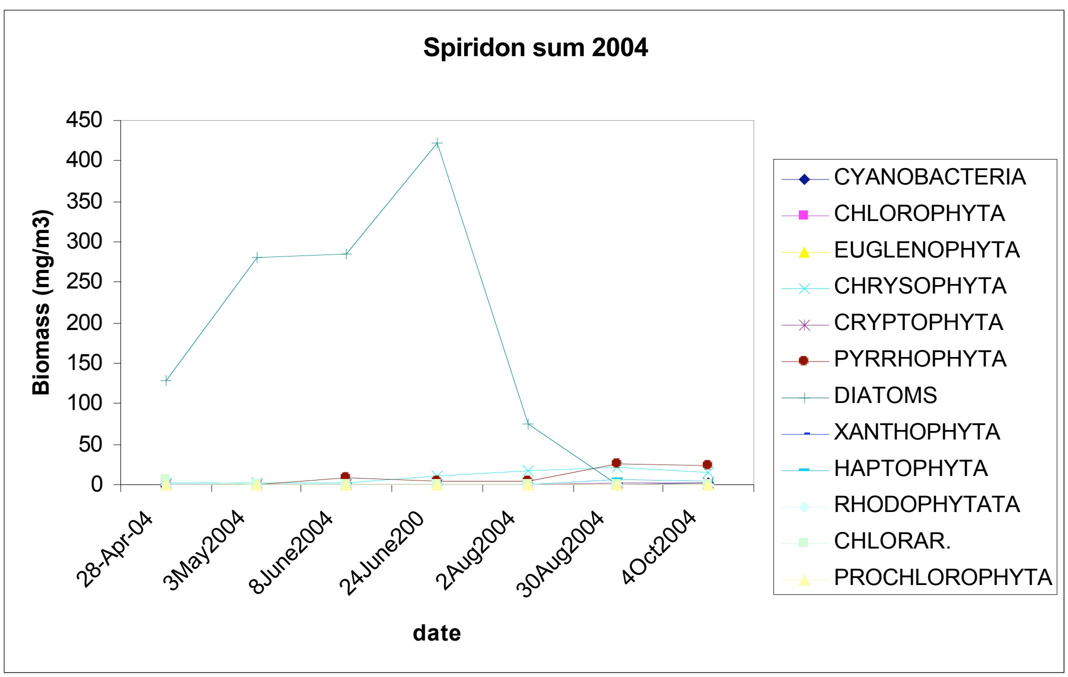


Figure 12. Phytoplankton analysis for Karluk and Spiridon Lakes, 2004.

Figure 13. $\delta^{15}N$ analysis of POM from river and pelagic stations, Karluk and Spiridon Lakes, 2004.