Prepared in cooperation with the
National Park Service

Water Quality, Physical Habitat, and Biology of the Kijik River Basin, Lake Clark National Park and Preserve, Alaska, 2004-2005

Scientific Investigations Report 2006-5123

U.S. Department of the Interior
U.S. Geological Survey

Cover Photographs. Kijik Lake, looking to the east and sockeye salmon at the mouth of Little Kijik River, August 2004. Photograph taken by Daniel A. Long, U.S. Geological Survey.

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Conversion Factors, Datums, and Acronyms

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F= (1.8×°C) +32.$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NAVD 29).
Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).
Altitude, as used in this report, refers to distance above the vertical datum.

Acronyms used in this report:

LACL Lake Clark National Park and Preserve

NAWQA National Water-Quality Assessment Program

ISQG Interim Freshwater Sediment Quality Guideline

CCME Canadian Council of Ministers of the Environment

PEL Probable Effect Level

TEC Threshold Effect Concentration

PEC Probable Effect Concentration

DOC Dissolved Organic Carbon

POC Particulate Organic Carbon

NPS National Park Service

USGS United States Geological Survey

NWQL National Water-Quality Laboratory

QMH Qualitative Multi-Habitat

IDAS Invertebrate Data Analysis System

EPT Ephemeroptera, Plecoptera, Trichoptera

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Abstract

The U.S. Geological Survey and the National Park Service conducted a water-quality investigation of the Kijik River Basin in Lake Clark National Park and Preserve from June 2004 to March 2005. The Kijik River Basin was studied because it has a productive sockeye salmon run that is important to the larger Kvichak River watershed. Water-quality, physical habitat, and biological characteristics were assessed. Water type throughout the Kijik River Basin is calcium bicarbonate although Little Kijik River above Kijik Lake does have slightly higher concentrations of sulfate and chloride. Alkalinity concentrations are generally less than 28 milligrams per liter, indicating a low buffering capacity of these waters. Lachbuna Lake traps much of the suspended sediment from the glacier streams in the headwaters of the basin as evidenced by low secchi-disc transparency of 1 to 2 meters and low suspended sediment concentrations in the Kijik River downstream from the lake. Kijik Lake is a fed by clearwater streams and has secchi-disc readings ranging from 11 to 15 meters. Streambed sediments collected from four surface sites analyzed for trace elements indicated that arsenic concentrations at all sites were above proposed guidelines. However, arsenic concentrations are due to the local geology, not anthropogenic factors.

Benthic macroinvertebrate qualitative multi-habitat samples collected from two sites on the Little Kijik River and two sites on the main stem of the Kijik River indicated a total of 69 taxa present among the four sites. The class *Insecta*, made up the largest percentage of macroinvertebrates, totaling 70 percent of the families found. The insects were comprised of four orders; Diptera (flies and midges), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). One-hundred twenty-two species of periphytic algae were identified in qualitative multi-habitat samples collected at the four stream sites. Eight species of non-motile, diatoms were collected from all four stream sites suggesting that the areas from which they were collected are relatively stable and unaffected by sedimentation.

Introduction

The Kvichak River watershed, one of the most prolific salmon-producing basins in Alaska, encompasses about one-third of Lake Clark National Park and Preserve (LACL) and includes Lake Iliamna and Lake Clark, the largest and sixth largest lakes in Alaska (fig. 1). Each year, millions of fish make their way up from Bristol Bay to spawn in lakes, streams, and rivers throughout the Kvichak system. In some years, up to 9 million fish may travel through Lake Iliamna and up the Newhalen River on their way into Lake Clark. From there, salmon migrate to the major Lake Clark tributaries, including the Kijik River system (fig. 2).

Conservation of sockeye (red) salmon and their habitat is one of the primary purposes stated in the LACL's enabling legislation: " . . . protect the watershed necessary for perpetuation of the red salmon fishery in Bristol Bay; . . . maintain unimpaired the scenic beauty and quality, including . . . wild rivers, lakes, waterfalls . . . in their natural state" (Alaska National Interest Lands Conservation Act, 1980). Although the Kijik River appears to be a relatively small contributor to the Lake Clark ecosystem, the river is probably one of the most important rivers for sockeye salmon production of all the tributaries flowing into Lake Clark. Up to 40 percent of the sockeye salmon that enter Lake Clark may spawn in the Kijik River system. The river's physical and chemical characteristics influence the morphology, genetic differentiation, and productivity of salmon. Kijik, Lachbuna, and Portage lakes (fig. 3) trap sediment from upstream tributaries and moderate streamflow variations. Further evidence of the Kijik River as a main source of salmon is the fact that numerous archeological sites, demonstrating a rich history of traditional salmon harvest and use, are found near the mouth of the Kijik in Kijik National Historic Landmark.

Sockeye salmon, a keystone species bridging aquatic and terrestrial ecosystems in LACL, are declining for unknown reasons (fig. 4). Local residents, resource managers, and sports fishing groups are concerned about the decline of sockeye salmon. The decline could be due to many factors within the Kvichak system or outside the basin. One concern is that

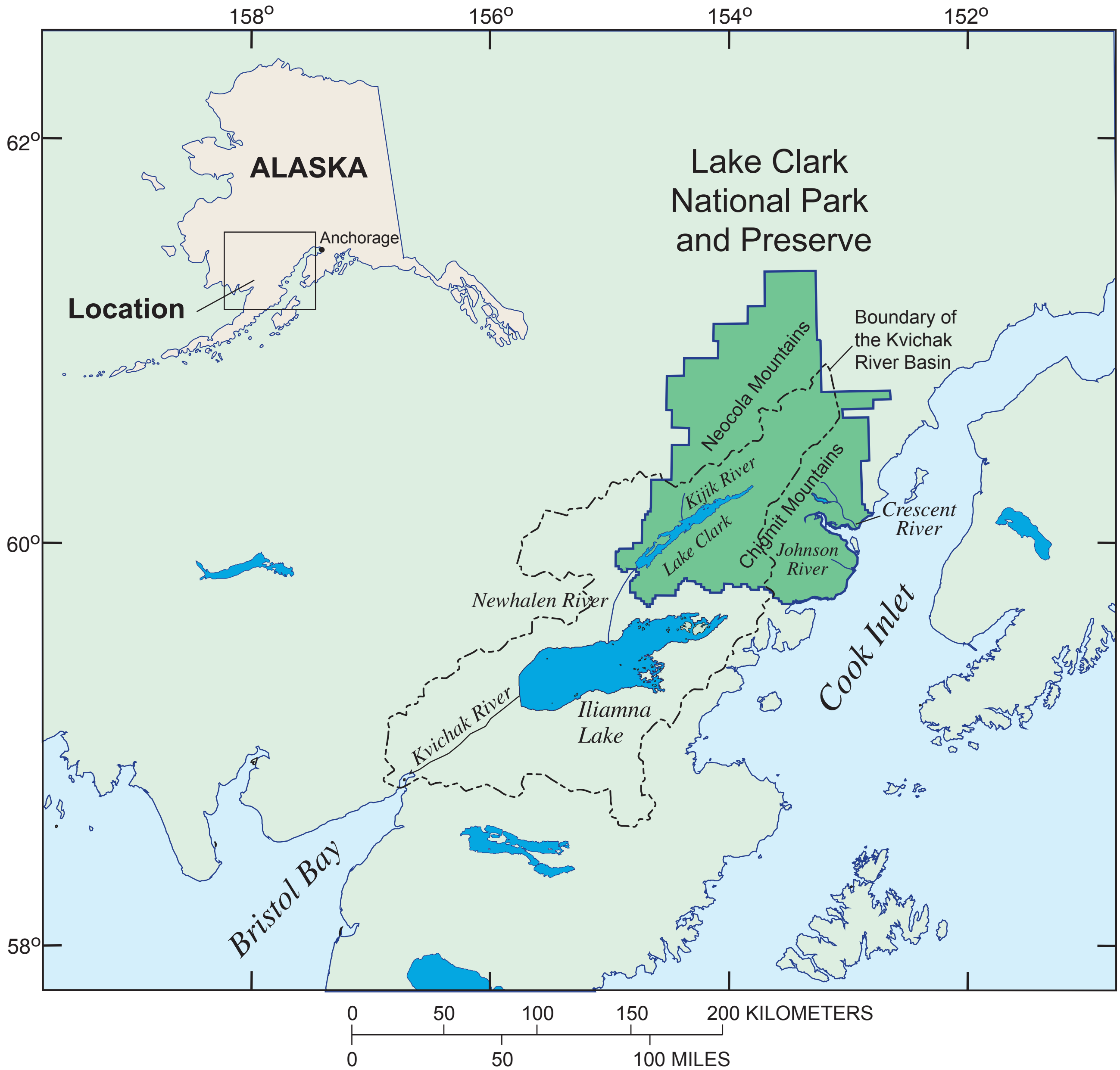
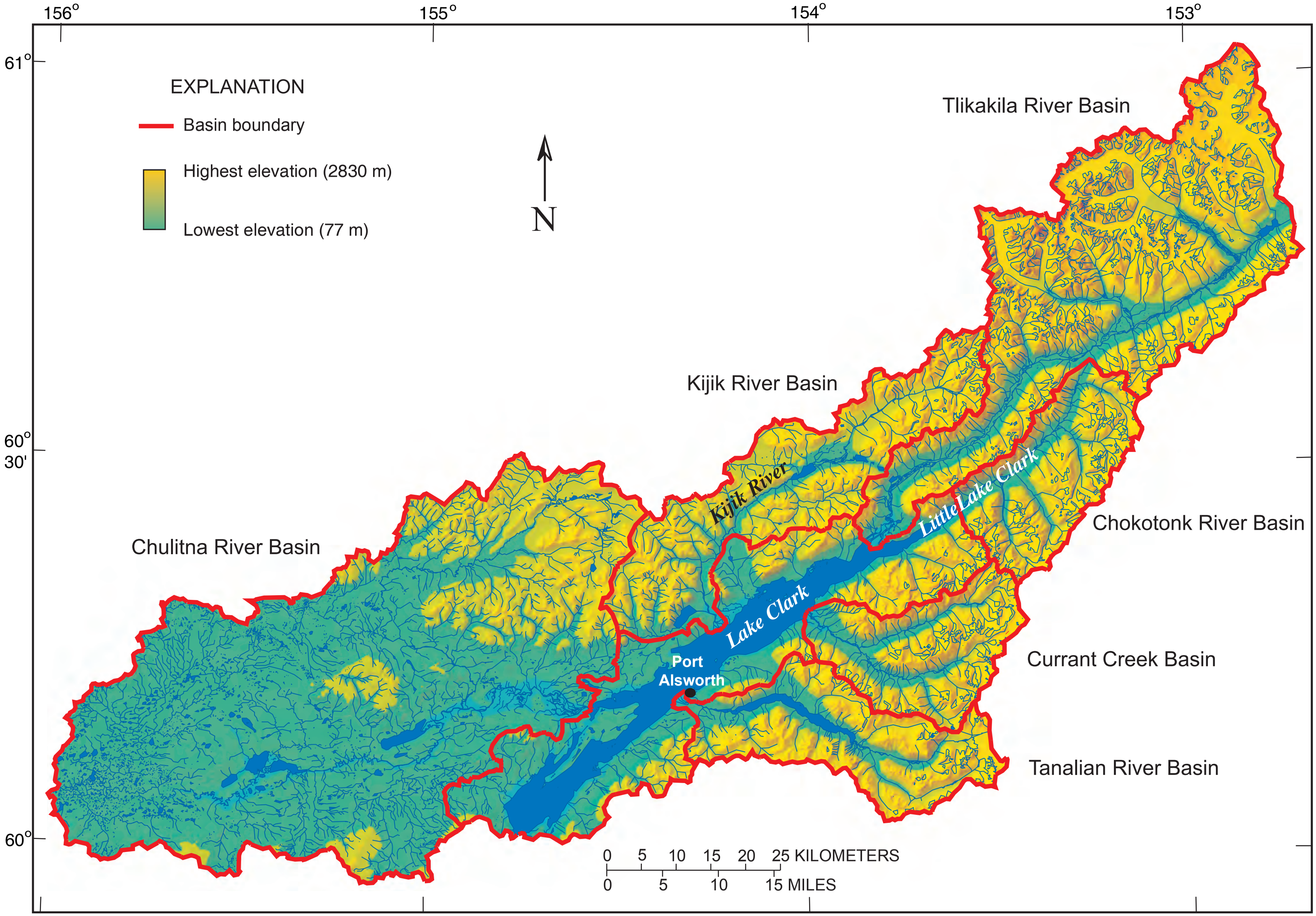


Figure 1. Location of the Kijik River and Lake Clark National Park and Preserve.



Base from U.S. Geological Survey digital data, 1:63,360, 1957
Albers Equal-Area Conic projection
Standard parallels 55°00' N and 65°00' N, central meridian - 154°00' W

Figure 2. Major river basins of the Lake Clark Basin.

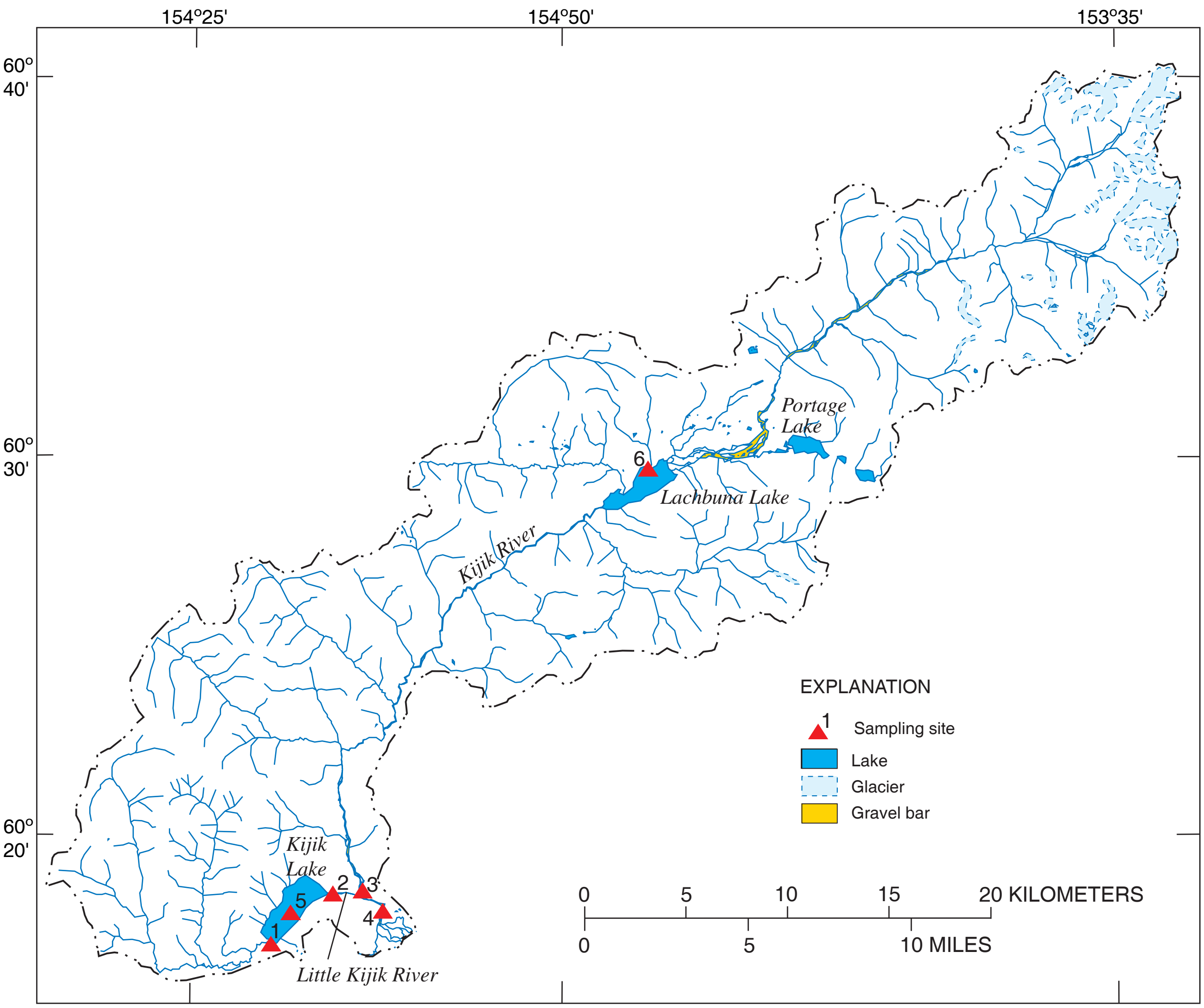


Figure 3. Kijik River Basin and sampling sites.

changes in water-quality characteristics of the Kijik River may be affecting the productivity of salmon in Lake Clark.

Because much of the Kijik River shoreline has been selected for transfer out of federal ownership, it is critical that state and federal managers understand factors important in protecting fish habitat. Private development could threaten the integrity of salmon habitat that ranks among the most productive in the world. The Kijik River Basin is also one of the most popular park destinations for anglers and campers in Alaska, who access the area by motorboat and floatplane. During one 30-day period in 1999, park employees contacted 169 anglers, most of them concentrated in the small, shallow area at the outlet of Kijik Lake and in the Little Kijik River, where salmon spawn in large numbers. Fuel spills, riverbank and shoreline erosion due to intense recreational use, and fecal contamination all could affect water quality and salmon habitat.

An assessment of the water quality and hydrology of the Kijik River Basin is needed in order to understand the natural conditions of the aquatic resources relative to sockeye salmon habitat. Any change in water quality in the Kijik River, whether caused by human activities or natural factors, could contribute to salmon declines. Basic knowledge of the water resources is needed to help understand the conditions in which Kijik salmon spawn. To date, only a sparse amount of water resource and fisheries data exists for the Kijik River system.

To address the above concerns and the need for information, a 2-year study of the Kijik River basin was initiated as a cooperative effort between the National Park Service (NPS) and the U.S. Geological Survey (USGS). The purpose of the study was to determine (1) the water-quality, physical habitat, and biological characteristics of the Kijik River and (2) the limnological features of Kijik and Lachbuna Lakes.

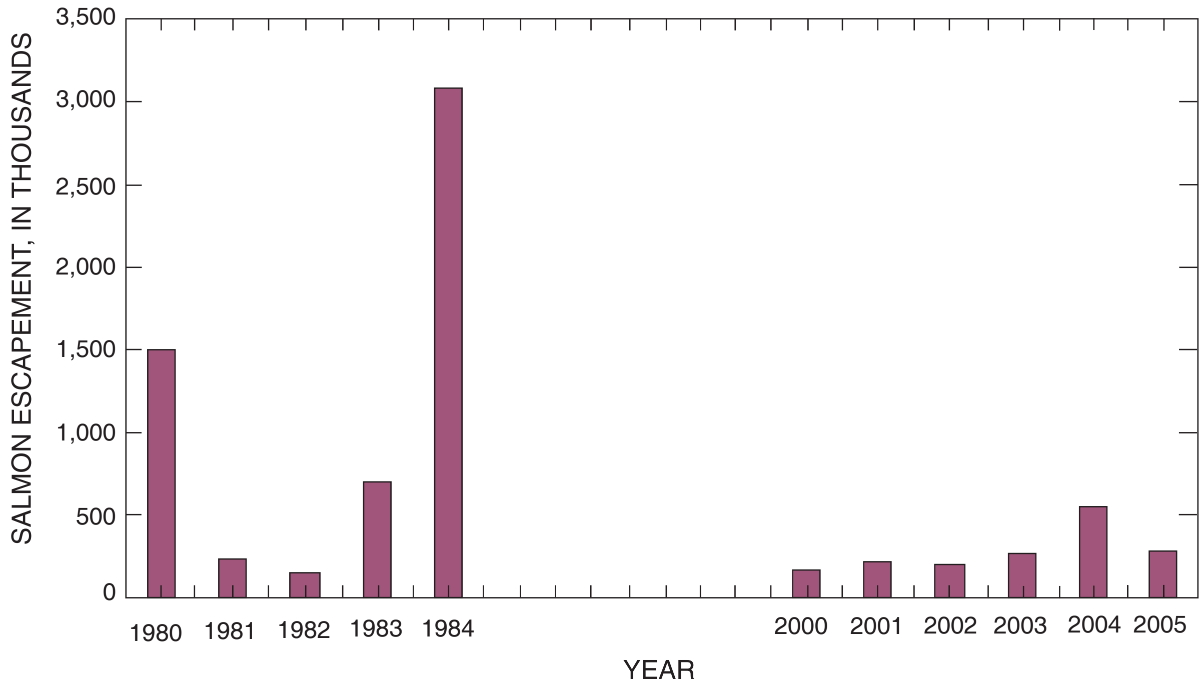


Figure 4. Sockeye salmon escapement from Lake Clark,1980-84 and 2000-2005.

Description of Study Area

The Kijik River, which drains an area of about 777 km^2, originates in a glacial valley to the north of Portage Lake and is fed by Portage, Lachbuna, and Kijik Lakes as it descends approximately 80 km to Lake Clark (figs. 2 and 3). Near its mouth, the river flows through the Kijik National Historic Landmark. The river shifts from a contained single channel to a braided channel, with many side sloughs flanked by numerous beaver dams. The effects from these beaver dams have been to divert flow, forming new channels, or forming small ponds that last until high flows destroy them. On the basis of miscellaneous discharge measurements made in 1999-2001, the Kijik River accounts for about 5 percent of the total inflow to Lake Clark (Brabets, 2002).

Lachbuna Lake (sampling site number 6) is in the middle of the basin, has a surface area of about 3 km^2 and an average depth of about 30 meters (fig. 5B). Lachbuna Lake receives the glacier-fed water of the Kijik River system. Kijik Lake is a clearwater lake near the mouth of the Kijik River, has a surface area of about 4 km^2 and an average depth of about 100 meters (fig. 5A). Most salmon that enter the Kijik River travel to Kijik Lake, and of the three lakes within the Kijik River Basin, Kijik Lake is the most popular for sportfishing. The Little Kijik River, the lake's wide, shallow outlet stream, flows about 2 km before emptying into the mainstem of the Kijik River. Little Kijik River is a clear, gravel-bottomed river flowing through mixed spruce-birch-poplar forest. Its deep pools and shallow riffles provide habitat for numerous fish species and are important areas for salmon spawning (fig. 5A).

Climate change is occurring in the study area. For example, a previous study on the glacial history of the Tlikakila River Basin (fig. 2), remote sensing and airborne laser profiling showed that most glaciers in the Tlikakila River Basin have retreated and thinned from 1957 to the present (Brabets and others, 2004). Volume loss from 1957 to 2001 from the Tanaina Glacier, the largest glacier in the Tlikakila River Basin, was estimated to be 6.09 x 10^9 m^3 or 1.38 x 10^8 m^3/year. For the study period, the 2004 winter snowpack and spring breakup was near normal. However, the summer of 2004 was hot and dry. Record high temperatures and low rainfall produced record low flows at clearwater streams throughout Alaska. Glacier-fed streams showed the opposite response to hot, dry conditions. Many long-term glacier-fed streams experienced the highest average streamflow of record in July through September.

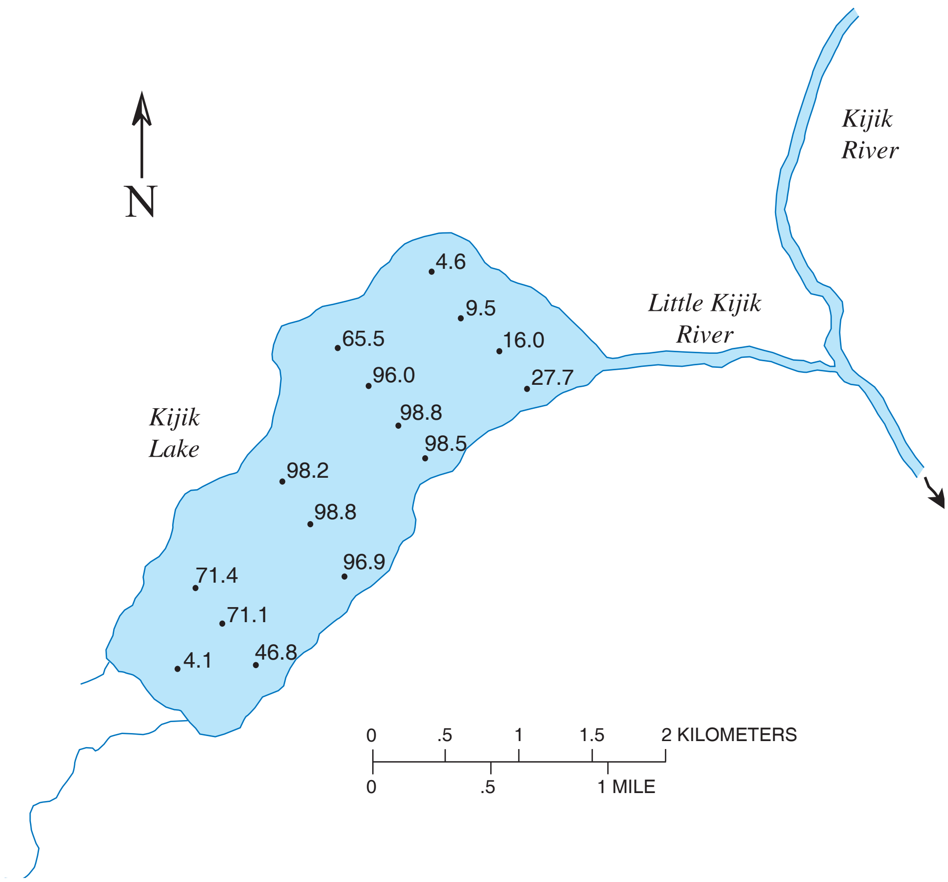


Figure 5A. Kijik Lake depth soundings taken in 1979 (depth in meters).

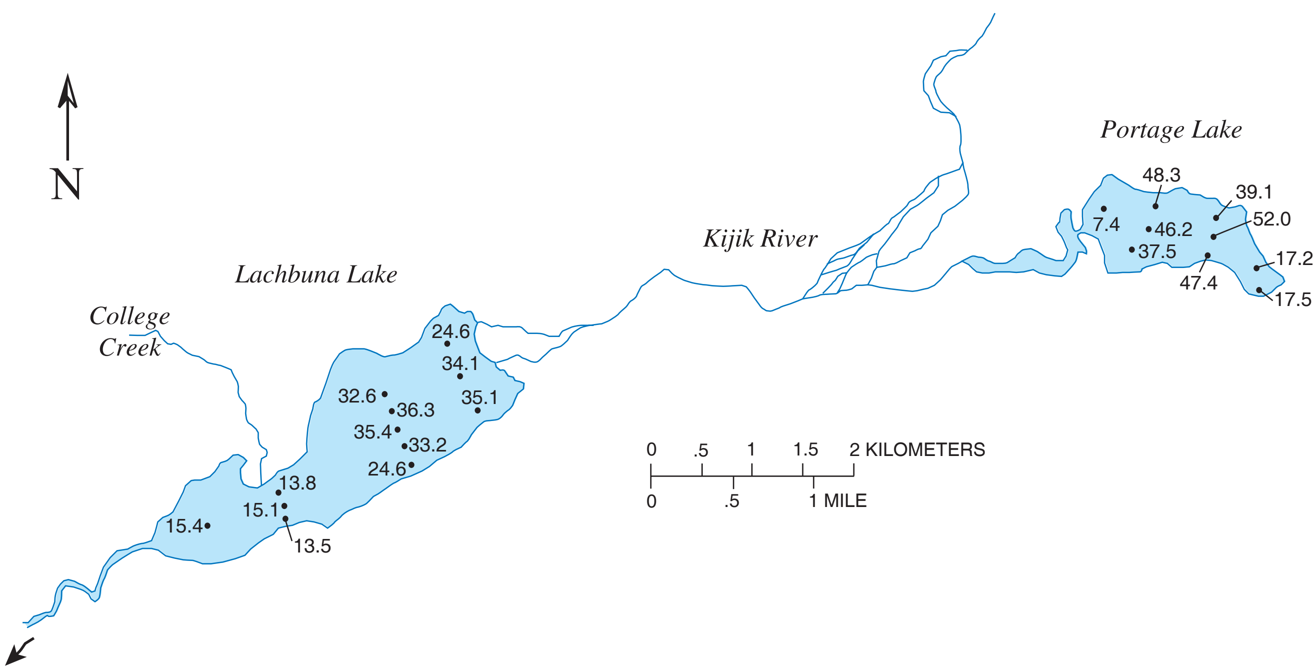


Figure 5B. Lachbuna and Portage Lakes depth soundings taken in 1979 (depth in meters).

Methods of Data Collection and Analysis

For this study, characterization of the water quality and habitat conditions in the Kijik River Basin included four stream sites and two lake sites (fig. 3 and table 1). The four stream sites were located on the Kijik River above the Little Kijik River, above and below Kijik Lake, and about 2 km above the mouth of the Kijik River. Lachbuna Lake and Kijik Lake were sampled at one location, the middle of each lake. Water quality and biological data were collected throughout the summer of 2004 and the winter of 2005 from these sites to gain a better understanding of the Kijik River Basin.

Water samples were collected at all sites in June, July, August, and October 2004 and at Kijik Lake and Lachbuna Lake in February and March 2005. The samples collected from the streams were analyzed for field parameters, major ions and total dissolved solids, total and dissolved nutrients, dissolved organic carbon, phytoplankton chlorophyll-*a*, and trace elements (table 2). The field-collection and processing equipment used was made from Teflon, glass, or stainless steel to prevent sample contamination and to minimize analyte losses through adsorption. All sampling equipment was cleaned prior to use with a nonphosphate laboratory detergent and deionized water, followed by a native-water rinse prior to sample collection. Depth-integrated water samples were collected across the stream using the equal-width-increment method (Edwards and Glysson, 1988) and processed in the field using methods and equipment described by Shelton (1994). Samples were collected from Lachbuna and Kijik Lakes using a 6.2 liter acrylic Van Dorn sampler. Samples to be analyzed for dissolved constituents were filtered through 0.45 micrometer (µm) capsule filters. Water samples were sent to the USGS National Water-Quality Laboratory (NWQL) for analysis using standard USGS analytical methods (Fishman and Friedman, 1989; Patton and Truitt, 1992; Fishman, 1993). A Hydrolab multi-parameter sonde was used to measure field parameters (water temperature, dissolved-oxygen concentration, specific conductance, and pH) at the time of sampling. Discharge measurements also were made at the time of sampling using methods of Rantz and others (1982).

Streambed sediments were sampled from several depositional areas at each site and analyzed for trace elements. Sediments were collected from the surface of the streambed using Teflon tubes or Teflon coated spoons and composited in glass bowls (Shelton and Capel, 1994). Because the concentration of trace elements on streambed materials is strongly affected by the particle-size distribution of the sample, only that portion of the sample that was finer than 63 µm was analyzed. Stream water was used for sieving the trace-element sample through a 63 µm mesh. Water included in the trace-element sample was decanted after very fine-grained sediments had settled (about 24 hours). Arbogast (1990) describes laboratory procedures followed for processing streambed samples for trace-element analysis. Trace elements in streambed sediments were analyzed following a total digestion procedure.

Stream characteristics data were collected at the four stream sites in August 2004. Certain physical characteristics of each stream reach were collected according to protocols described by Fitzpatrick and others (1998). Physical characterization of each stream reach included measurements of riparian, bank, and instream aquatic-habitat features such as channel aspect, open-canopy angles, and canopy closure, as well as the presence of any submerged habitat features such as boulders or woody debris. Physical characteristics of each stream reach were also documented with a set of notes and photographs depicting major geomorphic channel units such as sloughs, riffles, rapids, and other features such as beaver dams within the identified study reach.

Table 1. Location of water-quality sites and basin characteristics, Kijik River Basin (fig. 3).

[Values in square kilometers, °, degrees; ’, minutes; ”, seconds]

Site Number	Latitude/longitude	Station Name	Area	Glaciers	Lakes
1	60° 17’ 08” 154° 20’ 35”	Little Kijik River above Kijik Lake near Port Alsworth, AK	91	0	0
2	60° 18’ 28” 154° 17’ 17”	Little Kijik River below Kijik Lake near Port Alsworth, AK	108	0	4.4
3	60° 18’ 33” 154° 15’ 41”	Kijik River above Little Kijik River near Port Alsworth, AK	619	19	6
4	60° 18’ 01” 154° 14’ 36”	Kijik River 2.5 kilometers above mouth near Port Alsworth, AK	818	19	10
5	60° 17’ 58” 154° 19’ 32”	Kijik Lake near Port Alsworth, AK	4.4*		
6	60° 29’ 43” 154° 02’ 00”	Lachbuna Lake near Port Alsworth, AK	3.4*		

* surface area of lake

Table 2. Analyses made on water samples and streambed sediments collected during the study period.

Field parameters	Trace elements in streambed sediments
Water temperature	Aluminum
Specific Conductance	Antimony
pH	Arsenic
Dissolved Oxygen	Barium
Streamflow	Cadmium
	Cerium
Water-quality constituents	Chromium
	Cobalt
Alkalinity	Copper
Bicarbonate	Europium
Calcium	Gallium
Chloride	Gold
Dissolved solids	Holmium
Fluoride	Iron
Magnesium	Lanthanum
Potassium	Lead
Silica	Lithium
Sodium	Manganese
Sulfate	Mercury
	Molybdenum
Nutrients	Nickel
	Niobium
Nitrogen, ammonia – dissolved	Scandium
Nitrogen, ammonia + organic – dissolved and total	Selenium
Nitrogen, NO_2 – dissolved	Silver
Nitrogen, NO_2 + NO_3 – dissolved	Strontium
Phosphorus – dissolved and total	Tantalium
Orthophosphate – dissolved	Thallium
	Thorium
Trace elements in water	Tin
	Titanium
Iron	Uranium
Manganese	Vanadium
	Ytterbium
Suspended sediment	Yttrium
	Zinc
Concentration	
	Organics
	Dissolved organic carbon
	Pheophytin phytoplankton
	Chlorophyll-a phytoplankton

Table 3. Physical field parameters measured at surface water sites in the Kijik River Basin.

[Values in m^3/s, cubic meter per second; mg/L, milligram per liter; µs/cm, microsiems per centimeter; °C, degrees Celsius]

Date	Time	Discharge (m^3/s)	Dissolved Oxygen (mg/L)	pH (units)	Specific Conductance (µs/cm at 25°C)	Water Temperature (°C)	Suspended Sediment (mg/L)
Little Kijik River above Kijik Lake (site 1)							
6/9/2004	1430	1.0	10.1	7.2	40	9.3	5
7/14/2004	1200	0.3	11.3	6.4	48	6.7	1
8/24/2004	1345	0.1	10.2	6.2	56	6.5	5
10/6/2004	1700	0.3	9.8	6.8	54	5.3	2
Little Kijik River below Kijik Lake (site 2)							
6/9/2004	1420	2.2	11.3	7.2	56	9.9	1
7/14/2004	1630	1.0	9.9	7.8	60	19.4	1
8/25/2004	1100	0.5	9.2	7.2	64	16.0	5
10/6/2004	1415	0.7	10.9	6.2	62	8.3	1
Kijik River above Little Kijik River (site 3)							
6/8/2004	1200	6.4	12.2	7.0	82	6.7	21
7/13/2004	1500	5.2	9.8	7.3	81	16.9	4
8/26/2004	1345	3.3	10	7.6	79	12.3	3
10/4/2004	1450	2.2	11.4	7.4	92	6.5	1
Kijik River 2.5 kilometers above mouth (site 4)							
6/8/2004	1530	8.7	11.9	7.2	77	7.6	15
7/13/2004	1630	6.2	9.6	7.2	80	16.6	6
8/26/2004	1130	3.7	10.0	7.4	78	11.4	3
10/4/2004	1610	3.0	11.1	7.5	87	6.8	5

Qualitative Multi-Habitat (QMH) (Cuffney and others, 1993) benthic macroinvertebrate samples were collected from the variety of available habitats present in the stream reach. Macroinvertebrates were identified at the USGS NWQL's Biological Unit. Subsampling techniques are used in the identification and enumeration of macroinvertebrates at the Biological Unit. QMH samples are subsampled by timed method, allowing no more than 2 hours total sorting time (Moulton and others, 2000), rather than by the specific number of organisms. Because the abundance of organisms is not determined for QMH samples, the taxonomist need only sort out a few individuals of each taxon for identification.

QMH algae samples were collected according to protocols outlined by Porter and others (1993). An assessment of the algal community was done to identify the species of algae present at multiple habitats within each stream reach. Algae samples were collected in habitats similar to the QMH macroinvertebrate samples (depositional zones, woody debris, and rocks). Algae samples were analyzed by the Philadelphia Academy of Natural Science in Philadelphia, Pennsylvania.

Zooplankton samples were collected from Lachbuna and Kijik Lakes in July, August, and October 2004. Samples were collected using a 0.5-meter-diameter, 153-µm meshed, conical plankton net. Vertical tows were made from 1 meter above the lake bottom at Lachbuna Lake and from 30 meters at Kijik Lake to the surface, and the contents were preserved in 10 percent buffered formalin. Macro-zooplankton were identified to species, enumerated from triplicate subsamples, and sized (length) to the nearest 0.02 millimeters in the laboratory using a 70X-power dissecting scope by the Alaska Department of Fish and Game. Counts were converted to areal and volumetric zooplankton density estimates.

After the data were collected, checked, and compiled, data analysis was undertaken. The concentrations of various water-quality constituents in the Kijik River were compared to known or published concentrations that are recommended for fish survival. Trace-element concentrations in streambed sediments were compared with those collected by the USGS National Water-Quality Assessment (NAWQA) program, and with guidelines established by the Canadian Council of Ministers of the Environment (1999). The macroinvertebrate and algae data were also compared with those collected by the NAWQA program.

Water Quality of the Kijik River Basin

Water-quality data collected in the Kijik River Basin in 2004 and 2005 included 1) field measurements of streamflow, specific conductance, pH, water temperature, and dissolved oxygen, 2) collection and analysis of water samples for suspended sediment, major inorganic ions, nutrients, dissolved organic carbon (DOC), and chlorophyll-*a*, and 3) collection and analysis of streambed sediments for trace elements. Biological data included samples of algae and invertebrates from streams and samples of zooplankton from Kijik and Lachbuna Lakes. These data provide baseline biological and water quality information for the Kijik River Basin from which future changes can be measured and can be used to evaluate the current conditions as they relate to salmon production in the Kijik River Basin.

Streamflow Discharge and Suspended Sediment

Typical of most rivers in southwest Alaska, most of the annual flow of the Kijik River occurs from June to September. Flow in June is dominated by snowmelt; in July through September, by rainfall. Measured discharge ranged from .45 cubic meter per second (m^3/s) to 3.5 m^3/s at Little Kijik River above Kijik Lake (site 1) and from 1.7 m^3/s to 7 m^3/s at Little Kijik River below Kijik Lake (table 3). At the Kijik River above Little Kijik River (site 3), discharge ranged from 7 m^3/s to 21 m^3/s, and at the Kijik River 2.5 km above the mouth (site 4), discharge ranged from 10 m^3/s to 28 m^3/s (table 3). Highest discharges at all sites were measured in June, which is generally the highest runoff period due to snowmelt. The lowest discharges on the main stem of the Kijik River were measured in October, reflecting the effects of lake runoff when outflow from Lachbuna and Kijik Lakes is minimal. The lowest discharges at the Little Kijik River were measured in late August, reflecting a dry period with minimal rainfall.

Sediment in rivers is transported in suspension (water column) and along the bed (bedload). Suspended sediment generally consists of fine particles such as clay, silt, and fine sand that are transported in the stream while being held in suspension by the turbulence of flowing water. Bedload consists of coarse sediment particles such as sands, gravels, and sometimes boulders that are transported along or near the streambed.

Measured values of suspended sediment in the Kijik River Basin were low at all four surface-water sites. The maximum concentrations of suspended sediment measured were 21 milligrams per liter (mg/L) at the Kijik River above Little Kijik River and 15 mg/L at the Kijik River 2.5 km above the mouth (table 3). Both of these measurements were made during the high-flow period in June. Minimum concentrations of 1.0 mg/L were measured several times. Concentrations of suspended sediment at Little Kijik River above Kijik Lake and at Little Kijik River below Kijik Lake ranged from 1 mg/L to 5 mg/L (table 3). Secchi-disc transparencies, an indicator of the clarity of lake water, were between 11 and 15 meters at Kijik Lake and 0.9 and 2 meters at Lachbuna Lake (tables 4 and 5). These values provide some general information on sediment content of these lakes. For example, Kijik Lake, a clear-water lake with little or no suspended sediment inflow, will have higher Secchi-disc transparency, which indicates the clarity of the water. Lachbuna Lake is a glacier-fed lake and the relatively lower values are indicative of suspended sediment, mainly from glacier flour, that has entered the lake and is in suspension.

Water Temperature

Water temperature determines the amount of oxygen water can contain when at equilibrium with the atmosphere, and it also controls the metabolic rates of fish and their rates of growth. Sockeye salmon have adapted to specific spawning times and water temperatures in order that incubation and emergence occur at the most favorable time of the year – spring and early summer (R&M Consultants Inc., 1981). For this species, the range in water temperature for all life stages (migration, spawning, incubation, and rearing) ranges from 2.0°C to 17.8°C (R&M Consultants Inc., 1981).

Water temperatures were as high as 20°C at Little Kijik River below Kijik Lake, reflecting the warm summer air temperatures in 2004 (fig. 6). At the Little Kijik River above Kijik Lake, water temperatures reached a high of only 6.5°C, reflecting the influence of springs and shading on this inflow stream to Kijik Lake. Depth profiles of water temperature of Lachbuna and Kijik Lakes indicate changing temperatures with depth throughout the summer months (figs. 7 and 8, tables 4 and 5). At Lachbuna Lake, water temperature profiles indicate mixing/changing temperatures throughout the entire depth of the lake and a weak stratification. By October, the lake was isothermal, with a constant temperature of 7°C. At Kijik Lake, water temperature profiles indicated strong stratification in the summer, and below 30 meters, water temperature remained constant at 4°C.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electric current and can be used to indicate the dissolved solids or ion content of the water. As the concentration of ions in solution increases or decreases, so does the conductance of the solution. Frequently a statistical relation can be developed between specific conductance and the ionic components making up the dissolved solids in water. During low flow, the conductance of a stream or river is generally the highest, indicating a greater component of ground-water inflow. Ground water has greater potential to dissolve minerals, having spent more time in contact with rocks and soil materials than does rainwater or snowmelt. Periods of low specific conductance reflect runoff of rain or snowmelt, which typically contain small amounts of dissolved ions. Values of

Table 4. Physical field parameters measured at Kijik Lake (site 5).

[Values in mg/L, milligrams per liter; µs/cm, microsiems per centimeter; °C, degrees Celcius]

Date	Depth (meters)	Dissolved Oxygen (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25°C)	Water Temperature (°C)	Secchi-Disc Transparency (meters)
6/9/2004	0	11.3	98	7.5	52	9.4	15
	5	11.5	96	7.2	52	7.9	
	10	11.5	95	7.2	51	7.1	
	15	11.6	93	7.2	51	6.1	
	20	11.7	91	7.2	51	5.1	
	25	11.4	88	7.1	52	4.4	
	30	11.2	85	7.1	52	4.1	
	35	10.9	83	7.1	52	4.0	
	40	10.9	83	7.0	52	3.9	
	45	10.9	82	7.0	52	3.9	
	50	10.8	82	7.0	52	3.8	
	55	10.7	80	6.9	52	3.8	
7/14/2004	0	10.2	100	7.1	56	18.4	14
	5	10.9	100	7.1	58	15.5	
	10	11.9	100	7.0	58	12.0	
	15	12.8	100	7.1	58	9.5	
	20	13.4	100	7.2	57	6.9	
	25	13.0	100	7.1	57	4.9	
	30	12.2	93	7.0	57	4.2	
	35	11.8	89	6.9	58	4.0	
	40	11.8	90	6.8	58	4.0	
	45	11.6	88	6.7	58	4.0	
	50	11.5	87	6.7	58	3.9	
	55	11.3	86	6.7	58	3.9	
	60	11.2	85	6.6	58	3.8	
	65	11.1	84	6.6	58	3.8	
8/24/2004	0	9.5	98	7.1	63	17.0	11
	5	9.3	96	7.2	63	16.9	
	10	11.2	100	7.3	62	14.0	
	15	12.3	100	7.6	62	10.0	
	20	12.8	100	7.6	61	6.2	
	25	12.4	96	7.5	61	5.2	
	30	11.3	87	7.3	62	4.6	
	35	10.9	83	7.2	62	4.3	
	40	10.6	80	7.1	62	4.0	
	45	10.4	79	7.0	63	3.9	
	50	10.3	78	7.0	63	3.9	
	55	10.2	77	7.0	63	3.9	
	60	10.1	76	6.9	63	3.9	
	65	10.0	75	6.9	63	3.8	

Table 4. Physical field parameters measured at Kijik Lake (site 5).—Continued

[Values in mg/L, milligrams per liter; µs/cm, microsiems per centimeter; °C, degrees Celcius]

Date	Depth (meters)	Dissolved Oxygen Concentration (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25°C)	Water Temperature (°C)	Secchi-Disc Transparency (meters)
3/1/2005	0	9.8	70	6.6	66	1.5	
	2.5	10.1	74	6.6	63	2.3	
	5	10.1	74	6.5	64	2.3	
	7.5	10.4	76	6.6	64	2.3	
	10	10.6	77	6.6	64	2.3	
	15	10.5	76	6.6	63	2.4	
	20	10.5	76	6.9	62	2.6	
	25	10.3	76	7.0	63	2.7	
	30	10.0	74	7.0	63	2.7	

Table 5. Physical field parameters measured at Lachbuna Lake (site 6).

[Values in mg/L, milligrams per liter; µs/cm, microsiems per centimeter; °C, degrees Celsius]

Date	Depth (meters)	Dissolved Oxygen Concentration (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25°C)	Water Temperature (°C)	Secchi-Disc Transparency (meters)
7/14/2004	0	9.5	92	7.4	60	14.6	0.9
	5	9.9	91	7.3	57	12.1	
	10	10.0	90	7.3	57	10.9	
	15	10.2	89	7.3	60	9.8	
	20	10.6	89	7.2	68	8.0	
	25	10.8	88	7.2	73	6.7	
	30	10.7	85	7.1	76	6.0	
	35	10.4	82	7.1	77	5.8	
8/24/2004	0	9.7	90	7.5	57	12.6	1
	2.5	9.6	89	7.3	56	12.2	
	5	9.6	89	7.3	56	11.7	
	7.5	9.8	89	7.3	56	11.4	
	10	9.8	89	7.3	56	11.1	
	12.5	9.9	88	7.2	56	10.7	
	15	9.9	88	7.2	57	10.5	
	17.5	9.8	87	7.2	61	10.2	
	20	9.8	86	7.2	62	9.9	
	22.5	9.9	85	7.2	65	9.3	
	25	9.9	84	7.2	69	8.5	
	27.5	9.9	82	7.2	75	7.4	
	30	9.9	81	7.1	76	7.0	
	35	9.7	78	7.1	80	6.2	
	38	9.1	73	7.3	82	6.0	

Table 5. Physical field parameters measured at Lachbuna Lake (site 6).—Continued

[Values in mg/L, milligrams per liter; µs/cm, microsiems per centimeter; °C, degrees Celsius]

Date	Depth (meters)	Dissolved Oxygen Concentration (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25°C)	Water Temperature (°C)	Secchi-Disc Transparency (meters)
10/6/2004	0	10.6	86	6.6	65	6.9	2
	2.5	10.2	83	6.8	64	6.9	
	5	10.2	83	6.8	64	6.9	
	7.5	10.2	83	6.8	64	6.9	
	10	10.1	83	6.8	64	6.9	
	12.5	10.1	82	6.9	64	6.9	
	15	10.1	82	6.9	64	6.9	
	17.5	10.1	82	6.9	63	6.9	
	20	10.0	82	6.9	64	6.9	
	22.5	10.0	82	6.9	64	6.9	
	25	10.0	82	6.9	64	6.9	
	27.5	9.9	80	7.0	65	6.8	
	30	9.8	80	7.0	65	6.8	
	35	9.5	77	7.0	68	6.7	
	38	9.3	75	7.0	69	6.7	
3/1/2005	0	7.7	55		87	0.6	
	2.5	8.4	59		83	1.0	
	5	8.6	61		80	1.2	
	7.5	8.7	62		77	1.6	
	10	9.0	65		74	1.9	
	15	9.2	66		75	2.1	
	20	9.1	66		72	2.3	
	25	8.8	65		73	2.5	

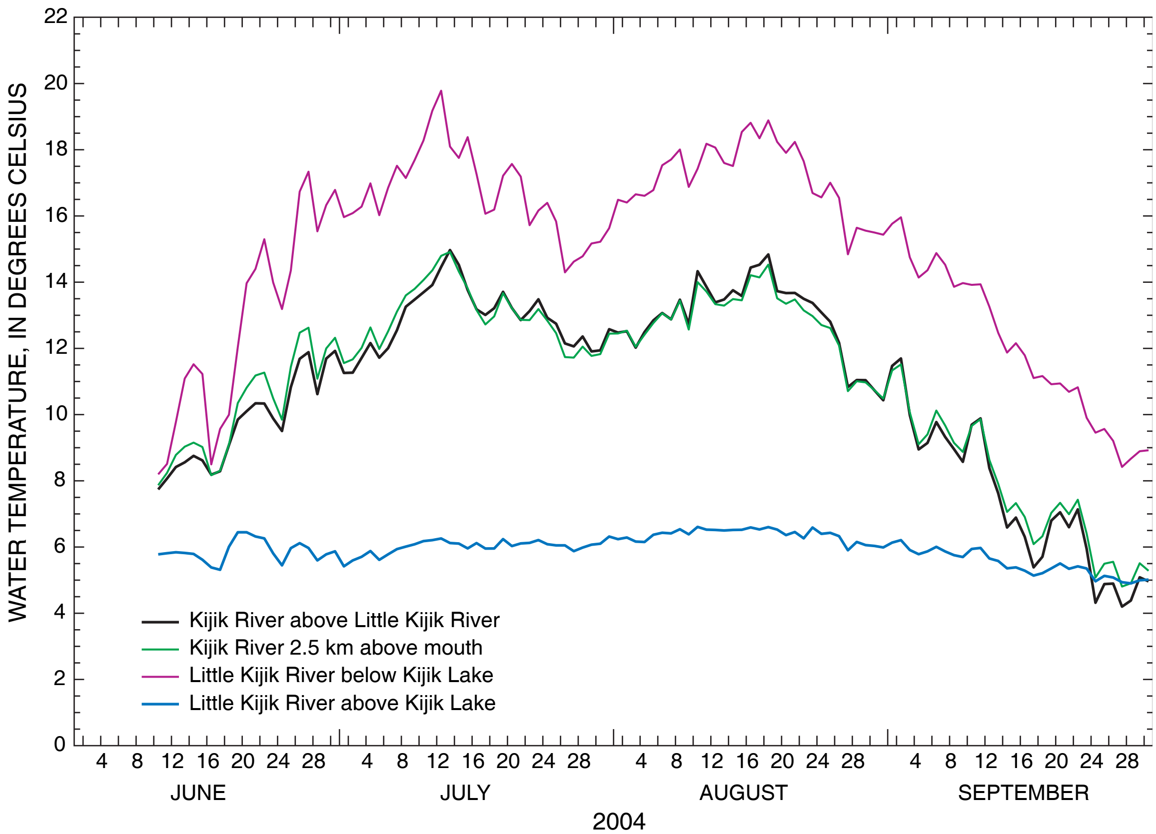


Figure 6. Average daily water temperature from June 8, 2004, to September 30, 2004, for the four stream sites in the Kijik River Basin.

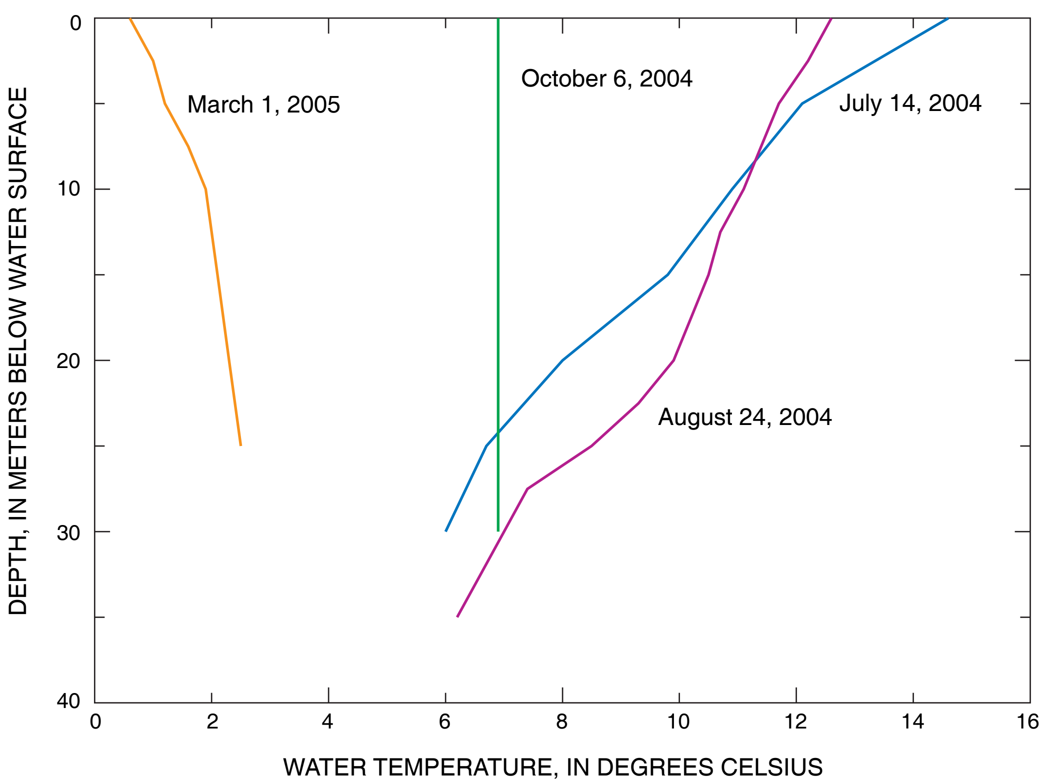


Figure 7. Water temperature profiles of Lachbuna Lake, 2004-2005.

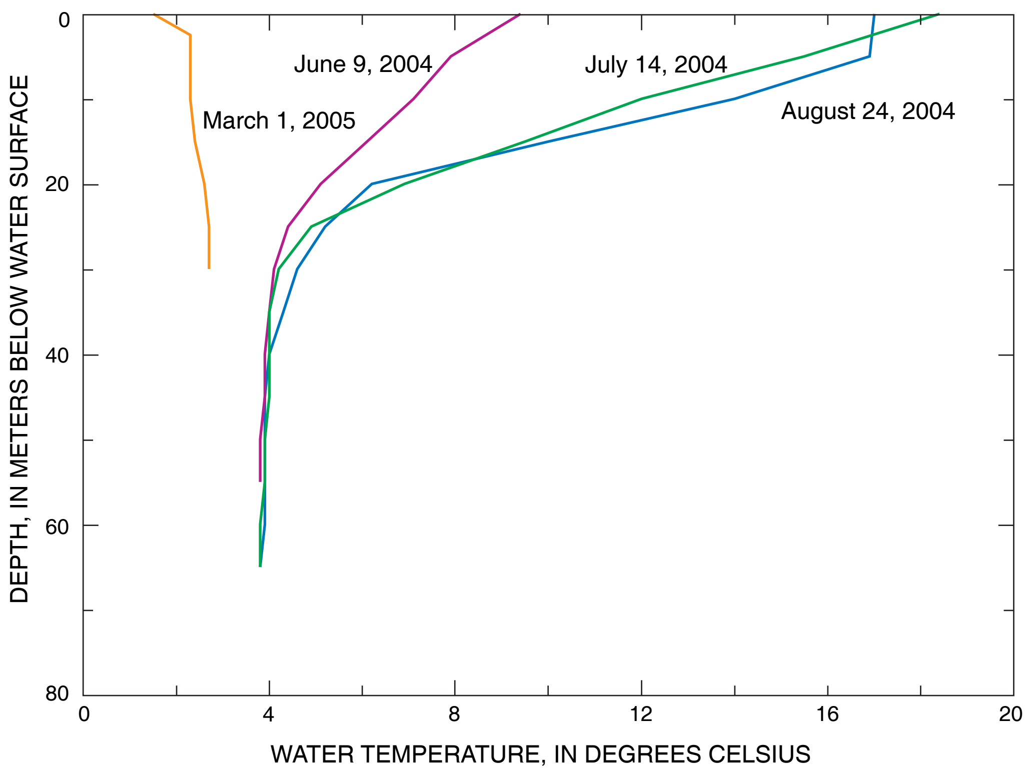


Figure 8. Water temperature profiles of Kijik Lake, 2004-2005.

specific conductance during the study period showed only small variations among sites. Specific conductance at the two sites on Little Kijik River ranged from 40 to 64 microsiemens per centimeter (µs/cm) at 25°C and from 77 to 92 µs/cm at 25°C at the two sites on the Kijik River (table 3). At Kijik Lake and Lachbuna Lake, depth profiles of specific conductance were fairly uniform throughout the water column—values ranged from 51 to 63 µs/cm at 25°C at Kijik Lake and from 56 to 82 µs/cm at 25°C at Lachbuna Lake (tables 4 and 5).

pH

The pH of water is a measure of its hydrogen-ion activity and typically ranges from 0 (acidic) to 14 (alkaline) standard units. The pH of natural river water typically ranges between 6.5 and 8.0 standard units (Hem, 1985). During the study period, measured values of pH for all sites ranged from 6.2 to 7.8 (table 3). The pH values in depth profiles at Lachbuna Lake and Kijik Lake varied only slightly, ranging from 6.5 to 7.6 (tables 4 and 5). All values were within the typical range for fish growth and survival.

Dissolved Oxygen

The dissolved-oxygen concentration in a stream is controlled by several factors, including water temperature, air temperature and atmospheric pressure, hydraulic characteristics of the stream, photosynthetic or respiratory activity of stream biota, and the quantity of organic matter present (Hem, 1985). Salmon and other species of fish require well-oxygenated water at every stage in their life history, as do many forms of aquatic invertebrates. Young fish tend to be more susceptible to oxygen deficiencies than adults. Measurements of dissolved oxygen at all Kijik River stream sites during the study period ranged from 9.2 mg/L to 12.2 mg/L (table 3), the range of values being nearly identical at the two Kijik River sites. At Lachbuna Lake and Kijik Lake, depth profiles of dissolved oxygen indicated a minimum concentration of 7.7 mg/L and a maximum concentration of 13.4 mg/L (tables 4 and 5). All measured dissolved-oxygen concentrations were adequate to support populations of salmonids.

The affect of water clarity on primary production in Kijik and Lachbuna Lakes is demonstrated by the dissolved oxygen profiles (tables 4 and 5). Photosynthesis occurs at depths in the water column oftentimes estimated to be about twice the secchi-disc transparency. At Kijik Lake, the secchi-disc transparency was 11 to 14 m in July and August 2004, times at which primary production should be at a maximum, and the dissolved oxygen saturation was 100 percent as deep as 25 m. Below that depth, respiration exceeds photosynthesis and the percent saturation declines. In comparison, the glacier-fed Lachbuna Lake had secchi-disc transparencies of 1 m or less in July and August 2004. Dissolved oxygen saturation at Lachbuna Lake was a maximum of 92 percent at the surface and declined steadily with depth (table 5).

Alkalinity

Alkalinity is a measure of the capacity of the substances dissolved in water to neutralize acid. In most natural waters, alkalinity is produced mainly by bicarbonate and carbonate ions, which are formed when carbon dioxide or carbonate rocks dissolve in water (Hem, 1985). The alkalinity at Lachbuna Lake, the farthest upstream site, ranged from 18 to 23 mg/L (table 6). Downstream, at the two sites on the mainstem of the Kijik River, concentrations of alkalinity ranged from 23 to 28 mg/L, slightly higher than concentrations at Lachbuna Lake (table 6). In the Little Kijik River watershed, the lowest values of alkalinity, ranging from 12 to 15 mg/L, were found at Little Kijik River above Kijik Lake (table 6). At Kijik Lake, alkalinity ranged from 18 to 19 mg/L (table 6), and at Little Kijik River below Kijik Lake, alkalinity concentrations ranged from 18 to 20 mg/L (table 6), the same concentrations found in Kijik Lake. The range of pH measured at all sites in the Kijik River Basin indicates that all of the alkalinity can be attributed to dissolved bicarbonate (Hem, 1985). Alkalinity measurements of this magnitude indicate that Little Kijik River and Kijik River have a low buffering capacity.

Major Ions, Dissolved Solids, Iron, and Manganese

Major ions and dissolved solids in rivers consist of inorganic minerals derived primarily from soil and rock weathering. Dissolved cations that constitute a majority of the dissolved solids content in natural waters are calcium, magnesium, sodium, and potassium; the major anions are usually represented by sulfate, chloride, fluoride, nitrate, and those making up the alkalinity (carbonate and bicarbonate) (Hem, 1985). Streams draining basins with rocks and soils containing insoluble minerals contain lower concentrations of dissolved solids than streams draining basins with easily dissolved minerals. Analyses of the samples from Kijik River and Little Kijik River indicated that dissolved solid concentrations are generally low, ranging from about 38 to 62 mg/L (table 6). Dissolved solids concentrations in samples from Lachbuna Lake and Kijik Lake ranged from 34 to 51 mg/L. Low concentrations of dissolved solids such as these are representative of basins containing thin soils and rocks that are not easily dissolved.

Calcium and magnesium are common alkaline-earth metals that are essential elements in plant and animal nutrition. Both elements are major anion components in most natural waters (Hem, 1985). Concentrations ranged from 6.6 to 13.2 mg/L for calcium and from 0.41 to 1.5 mg/L for magnesium (table 6). Concentrations of these constituents tended to be higher at the Kijik River sites and lower at the Little Kijik River sites. Sodium and potassium are both present in most natural waters, but usually in low concentrations in rivers. Sodium concentrations ranged from 1.2 to 2.5 mg/L and potassium concentrations ranged from 0.26 mg/L to 0.50 mg/L at all sites (table 6).

Bicarbonate (HCO_3) was the dominant anion at both the stream and lake sites. Concentrations were more variable at the river sites and ranged from 16 to 47 mg/L and less variable at the lake sites, ranging from 23 to 30 mg/L (table 6). Silica and sulfate, which are dissolved from rocks and soils, are the next most abundant anions with concentrations ranging from 5.2 to 8.6 mg/L for silica and 5.8 to 12.8 mg/L for sulfate. Chloride and fluoride concentrations were less than 1.0 mg/L at all sites (table 6).

Iron is dissolved from many rocks and soils and is an essential element in the metabolism of animals and plants. Iron in drinking water does not pose a health threat provided concentrations are less than 300 μg/L. Concentrations at all sites were less than 29 μg/L (table 6). Manganese has chemistry similar to that of iron and concentrations should generally be less than 50 μg/L. All concentrations were less than 5.4 μg/L.

Trilinear diagrams were used to plot the major ions in milliequivalents per liter. The trilinear diagram permits the chemical composition of multiple samples to be represented on a single graph and facilitates classification of the sample chemistry. On the basis of analyses of the samples collected during this study, the water of the Kijik River sites can be classified as calcium bicarbonate water (fig. 9), although the Little Kijik River above Kijik Lake does have slightly higher concentrations of sulfate and chloride.

Nutrients and Dissolved Organic Carbon

Nitrogen is present in the crustal rocks of the earth and in the atmosphere. In its reduced or organic forms, it is converted by soil bacteria into nitrite and nitrate. Biological fixation is accomplished by blue-green algae and certain related organisms that have the capacity of photosynthesis. Nitrogen is an important water-quality constituent largely due to its role as a component of the chlorophyll in plants and thus is essential for primary productivity in lakes, streams, and rivers. In aquatic ecosystems, nitrogen commonly occurs in three ionic forms: ammonium (NH_4), nitrite (NO_2), and nitrate (NO_3). In the laboratory, ammonium is analyzed as ammonia (NH_3); thus nitrogen concentrations are reported as total and dissolved ammonia plus organic nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, and dissolved nitrite. Nitrate is generally more abundant than nitrite in natural waters because nitrite readily oxidizes to nitrate in oxygenated water (Hem, 1985). Total ammonia plus organic nitrogen concentrations for whole water samples represent the sum of biologically derived organic nitrogen compounds plus any ammonia present. Nitrate and nitrite are oxidized forms of inorganic nitrogen that make up most of the dissolved nitrogen in well-oxygenated streams such as Kijik River. The dissolved concentrations represent the ammonium or nitrite plus nitrate in solution and are associated with material capable of passing through a 0.45-μm-pore filter.

Table 6. Concentrations of major ions and trace elements iron and manganese in water samples collected in the Kijik River Basin.

[Values in milligrams per liter unless otherwise noted; <, less than; E, estimated; µg/L, microgram per liter]

Date	Time	Alkalinity	Bicarbonate	Calcium	Chloride	Dissolved Solids	Fluoride	Iron (µg/L)	Manganese (µg/L)	Magnesium	Potassium	Silica	Sulfate	Sodium
Little Kijik River above Kijik Lake (site 1)														
6/9/2004	1430	12	16	6.6	0.48	38	<0.2	<6	E0.6	0.73	0.40	7.0	7.7	1.3
7/14/2004	1200	14	18	7.1	0.41	39	<0.2	E6	1.4	0.81	0.49	7.6	8.4	1.4
8/24/2004	1345	15	20	8.2	0.54	42	<0.2	21	3.2	0.92	0.47	8.6	8.8	1.4
10/6/2004	1700	14	18	7.5	0.41	44	E0.1	9	1.6	0.85	0.36	7.8	9.4	2.0
Little Kijik River below Kijik Lake (site 2)														
6/9/2004	1420	19	25	9.0	0.61	43	<0.2	<6	E0.6	0.41	0.46	6.7	7.5	1.5
7/14/2004	1630	18	23	8.7	0.63	43	<0.2	E6	E0.7	0.84	0.43	6.7	7.6	1.5
8/25/2004	1100	20	26	9.5	0.63	39	<0.2	<6	1.1	0.91	0.41	6.8	7.9	1.4
10/6/2004	1415	19	25	8.6	0.50	38	0.1	E3	0.8	0.87	0.34	6.4	7.5	2.1
Kijik River above Little Kijik River (site 3)														
6/8/2004	1200	28	36	13.0	0.5	57	<0.2	E4	1.2	1.5	0.44	6.6	12.8	1.8
7/13/2004	1500	25	32	11.8	0.4	56	<0.2	E5	E0.7	1.3	0.45	6.1	11.9	1.6
8/26/2004	1345	23	30	11.5	0.5	44	<0.2	<6	E0.6	1.2	0.39	6.1	10.8	1.5
10/4/2004	1450	28	36	13.2	0.5	62	0.2	8	1.0	1.3	0.27	7.1	12.8	2.5
Kijik River 2.5 kilometers above mouth (site 4)														
6/8/2004	1530	26	34	12.3	0.54	57	<0.2	E4	1.1	1.3	0.41	6.8	11.8	1.8
7/13/2004	1630	24	31	11.8	0.47	52	<0.2	E4	0.9	1.3	0.43	6.3	11.6	1.7
8/26/2004	1130	24	31	11.6	0.36	46	<0.2	<6	1.2	1.2	0.48	6.4	10.7	1.6
10/4/2004	1610	26	47	12.5	0.45	58	0.2	9	0.7	1.2	0.35	7.1	11.8	2.3
Kijik Lake (site 5)														
6/9/2004	1200	18	23	8.7	0.62	41	<0.2	<6	<.8	0.85	0.5	6.9	5.8	1.5
7/14/2004	1530	19	25	8.6	0.61	45	<0.2	<6	<.8	0.84	0.49	6.5	7.5	1.5
8/24/2004	1555	19	25	9.4	0.65	47	<0.2	<6	<0.8	0.88	0.37	6.7	7.7	1.4
10/6/2004	1600	19	25	8.5	0.49	43	0.1	E5	E0.4	0.87	0.36	6.5	7.4	2.2
3/1/2005	1600	18	23	8.8	0.52	38	0.1	<6	<0.6	0.89	0.44	6.7	--	1.4
Lachbuna Lake (site 6)														
6/9/2004	1000	23	30	11.5	0.51	51	<0.2	7	5.4	1.3	0.42	6.2	11.3	1.8
7/14/2004	930	20	26	9.1	0.45	46	<0.2	<6	E0.7	1.0	0.41	5.3	9.0	1.4
8/24/2004	1015	18	23	8.7	0.3	34	<0.2	17	3.0	0.9	0.36	5.2	7.5	1.2
10/6/2004	1200	21	27	9.0	0.35	48	<0.2	29	2.6	1.0	0.26	5.9	8.7	2.2
2/24/2005	1645	21	27	11.3	0.41	47	0.2	E3	0.8	1.2	0.46	6.3	10.4	1.7

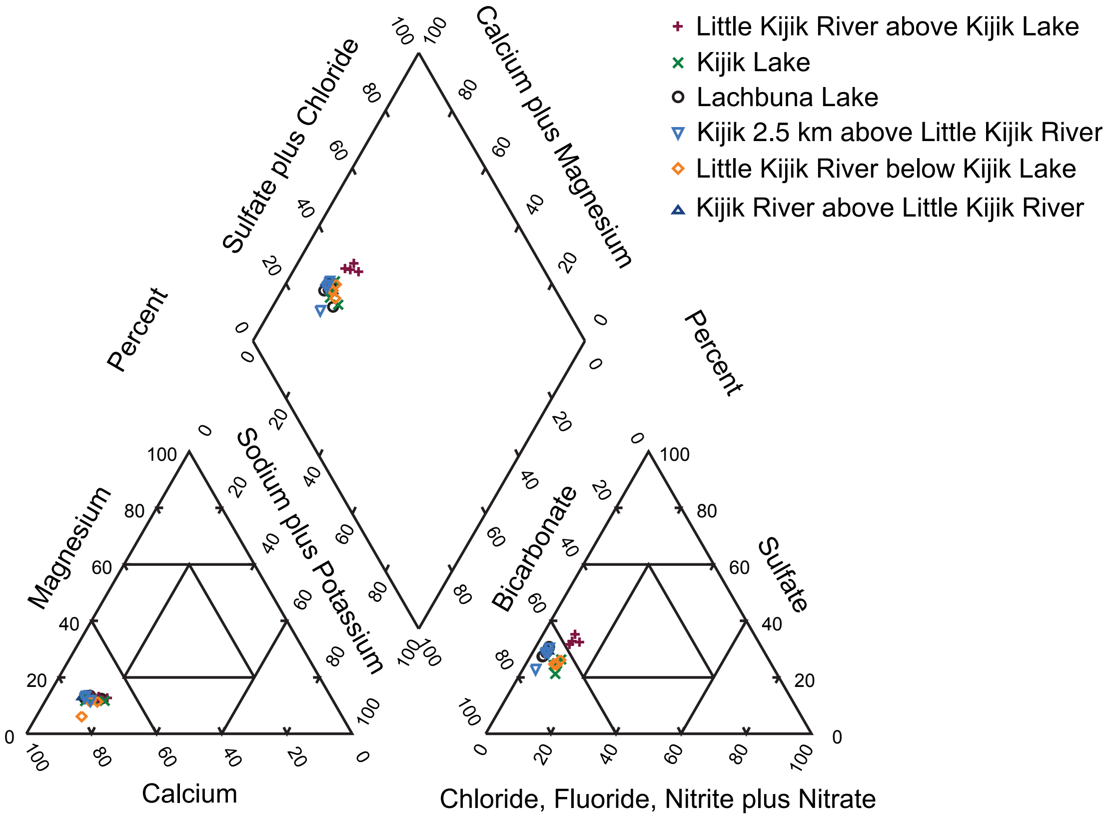


Figure 9. Trilinear diagram of water samples collected from six sites in the Kijik River Basin.

All concentrations of the various nitrogen forms were less than 1 mg/L (table 7). Due to its toxicity to freshwater aquatic organisms, the U.S. Environmental Protection Agency (USEPA) (1976) suggests a limitation of 0.02 mg/L of ammonia as un-ionized ammonia for waters to be suitable for fish propagation. Concentrations of ammonia (both ionized and unionized) were all below this level at all Kijik River sites.

Phosphorus is a rather common element in igneous rock. It is fairly abundant in sediments, but concentrations present in solution in natural waters are normally no more than a few tenths of a milligram per liter. Phosphorus is an element vital to all forms of aquatic biota because it is involved in the capture and transfer of chemical energy, and it is an essential element in nucleic acids (Gaudy and Gaudy, 1988). It occurs as organically bound phosphorus or as phosphate. Elevated concentrations of phosphorus in water are not considered toxic to human or aquatic life. Elevated concentrations can, however, stimulate the growth of algae in lakes and streams. Phosphorus concentrations are reported as total phosphorus and dissolved orthophosphate. Total phosphate concentrations represent the phosphorus in solution, associated with colloidal material, and contained in or attached to biotic and inorganic particulate matter. Dissolved concentrations are determined from the filtrate that passes through a filter with a nominal pore size of 0.45 µm. The orthophosphate ion, PO_4, is a significant form of phosphorus because it is directly available for metabolic use by aquatic biota. Concentrations of total phosphorus, dissolved phosphorus and orthophosphate were typically low, with values near or below minimum detection levels in nearly all Kijik River samples (table 7).

Phytoplankton (algae) can assimilate only three of the several different nutrient (nitrogen and phosphorus) compounds available in aquatic ecosystems. The only forms of nitrogen that phytoplankton can use for growth are nitrate, nitrite, and ammonia (inorganic nitrogen), whereas orthophosphate is the only form of phosphorus that phytoplankton can use for growth (Horne and Goldman, 1994). In general, a N:P ratio greater than 10 (by weight) indicates that phosphorus is the limiting nutrient, whereas a ratio less than 10 indicates that nitrogen is limiting (Horne and Goldman, 1994). For Lachbuna Lake N:P ratios ranged from 7 to 15 while at Kijik Lake, N:P ratios ranged from 70 to 82 (table 7). For Kijik Lake, the N:P ratios strongly suggest that phosphorus is the limiting nutrient. For Lachbuna Lake, since the ratios are closer to 10, the lake may be in a transition zone between phosphorus and nitrogen limitation.

Table 7. Concentrations of nutrients, dissolved organic carbon, and chlorophyll-*a* in water samples collected in the Kijik River Basin.

[Values in milligrams per liter unless otherwise noted; <, less than; E, estimated; µg/L, microgram per liter; N:P, nitrogen-phosphorus ratio; --, no data]

Date	Time	Dissolved Ammonia Nitrogen (NH_4)	Dissolved Nitrogen (NH_4 +Org)	Total Nitrogen (NH_4+ Org)	Dissolved Nitrogen (NO_2 +NO_3)	Dissolved Nitrogen (NO_2)	Dissolved Phosphorus	Dissolved Ortho Phosphate	Total Phosphorus	N:P ratio	Dissolved Organic Carbon	Pheophytin Phytoplankton (µg/L)	Chlorophyll-a Phytoplankton (µg/L)
Little Kijik River above Kijik Lake (site 1)													
6/9/2004	1430	<0.01	<0.1	<0.1	0.50	0.002	<0.004	<0.006	0.006		1.7	0.2	0.3
7/14/2004	1200	<0.01	<0.1	<0.1	0.42	<0.002	<0.004	E0.002	E0.002		0.5	<0.1	<0.1
8/24/2004	1345	<0.01	<0.1	<0.1	0.41	E0.001	<0.004	0.008	0.008		0.3	0.3	0.3
10/6/2004	1700	<0.01	E0.05	<0.1	0.42	<0.002	<0.004	0.006	0.006		0.4	<0.1	<0.1
Little Kijik River below Kijik Lake (site 2)													
6/9/2004	1420	<0.01	<0.1	<0.1	0.44	0.003	<0.004	<0.006	E0.003		1.0	0.1	<0.1
7/14/2004	1630	<0.01	<0.1	E0.06	0.42	0.004	E0.004	E0.003	<0.004		0.7	0.1	0.2
8/25/2004	1100	E0.006	<0.1	E0.06	0.40	0.004	<0.004	<0.006	E0.002		0.7	0.5	0.5
10/6/2004	1415	0.027	0.11	E0.08	0.40	0.003	0.008	<0.006	0.004		0.6	0.5	0.8
Kijik River above Little Kijik River (site 3)													
6/8/2004	1200	<0.010	<0.10	<0.10	0.13	0.002	<0.004	<0.006	0.016		1.0	1.0	1.0
7/13/2004	1500	<0.010	<0.10	<0.10	0.07	<0.002	<0.004	<0.006	E0.004		0.5	0.5	0.5
8/26/2004	1345	<0.010	<0.10	<0.10	0.07	E0.001	<0.004	<0.006	E0.003		E0.3	E0.3	E0.3
10/4/2004	1450	<0.010	<0.10	<0.10	0.21	E0.001	<0.004	<0.006	<0.004		0.4	0.4	0.4
Kijik River 2.5 kilometers above mouth (site 4)													
6/8/2004	1530	<0.010	<0.010	<0.10	0.21	0.002	<0.004	<0.006	0.012		1.9	0.4	0.6
7/13/2004	1630	<0.010	<0.010	E0.06	0.13	E0.001	<0.004	<0.006	0.006		0.5	0.3	0.3
8/26/2004	1130	<0.010	<0.010	<0.10	0.12	E0.001	E0.002	<0.006	E0.004		0.4	0.2	0.2
10/4/2004	1610	E0.007	<0.010	<0.10	0.25	E0.001	<0.004	<0.006	E0.002		0.8	0.2	0.3
Kijik Lake (site 5)													
6/9/2004	1200	<0.01	<0.10	<0.10	0.44	0.002	<0.004	<0.006	0.006	75	1.5	1	1.6
7/14/2004	1530	<0.01	<0.10	E0.09	0.42	E0.001	<0.004	<0.006	E0.002	72	0.6	0.7	0.5
8/24/2004	1555	E0.006	<0.10	E0.06	0.42	0.002	<0.004	<0.006	E0.002	72	0.6	0.4	0.8
10/6/2004	1600	0.013	E0.07	E0.06	0.41	0.003	<0.004	<0.006	E0.003	70	0.6	0.5	0.8
3/1/2005	1600	<0.01	<0.10	E0.06	0.48	0.002	<0.004	<0.006	E0.003	82	--	--	--

Table 7. Concentrations of nutrients, dissolved organic carbon, and chlorophyll-*a* in water samples collected in the Kijik River Basin.—Continued

[Values in milligrams per liter unless otherwise noted; <, less than; E, estimated; µg/L, microgram per liter; N:P, nitrogen-phosphorus ratio; --, no data]

Date	Time	Dissolved Ammonia Nitrogen (NH_4)	Dissolved Nitrogen (NH_4 +Org)	Total Nitrogen (NH_4 + Org)	Dissolved Nitrogen (NO_2 +NO_3)	Dissolved Nitrogen (NO_2)	Dissolved Phosphorus	Dissolved Ortho Phosphate	Total Phosphorus	N:P ratio	Dissolved Organic Carbon	Pheophytin in Phytoplankton (µg/L)	Chlorophyll-a Phytoplankton (µg/L)
Lachbuna Lake (site 6)													
6/9/2004	1000	<0.010	<0.10	<0.10	0.08	0.002	<0.004	<0.006	0.006	15	1.6	0.2	0.3
7/14/2004	930	<0.010	<0.10	E0.08	0.05	<0.002	<0.004	<0.006	0.006	10	0.5	0.1	E0.7
8/24/2004	1015	<0.010	<0.10	<0.10	0.028	E0.001	<0.004	<0.006	0.007	7	0.4	<0.1	<0.1
10/6/2004	1200	<0.010	<0.10	<0.10	0.047	E0.001	<0.004	<0.006	<0.004	10	E0.3	0.2	0.3
2/24/2005	1645	<0.010	<0.10	<0.10	0.066	0.002	<0.004	<0.006	<0.004	13	--	--	--

DOC is commonly a major component of organic matter in aquatic ecosystems. DOC is defined as organic carbon in the filtrate (dissolved and colloidal phases) that passes through a 0.45-µm pore-size filter (Aiken and Cotsaris, 1995). Generally, DOC is in greater abundance than particulate organic carbon (POC), accounting for about 90 percent of the total organic carbon of most waters (Aiken and Cotsaris, 1995). For the Kijik River and lake sites, concentrations of DOC were all less than 1.0 mg/L for the July, August, and October samples. For the June samples, concentrations of DOC were higher than those found at other times of the year, ranging from 1.0 to 1.9 mg/L. These higher concentrations of DOC reflect the spring runoff.

Trace Elements in Streambed Sediments

Streambed sediments at the 4 stream sites in the Kijik River Basin were collected and analyzed for 39 trace elements and organic carbon content (table 8). Most of the trace elements do not have an aquatic-life criteria. Thus, to provide a general comparison, the concentrations of trace elements in samples from the Kijik River sites were compared to concentrations in the NAWQA program data set, which consists of about 1,000 samples collected throughout the contiguous United States, Alaska, and Hawaii (V. Cory Stephens, U.S. Geological Survey, written commun, 2004). Of these samples, about 250 samples represent reference or forested areas (V. Cory Stephens, U.S. Geological Survey, written commun, 2004). The concentrations of trace elements at the Kijik River sites were also compared to concentrations in streambed sediments collected from two other basins in Lake Clark National Park and Preserve: the Crescent River Basin and the Johnson River Basin. Both of these basins are in the eastern portion of LACL near Cook Inlet (fig. 1). The Crescent River Basin is about 647 km^2 and supports a strong sockeye salmon fishery. The Johnson River Basin is about 249 km^2 and also supports sockeye and coho salmon.

Most median concentrations of the trace elements collected in the Kijik River Basin were similar to the medians of the NAWQA reference/forested sites, with the exception of higher concentrations of arsenic and strontium at the Kijik River sites (table 9). Concentrations of most trace elements found in streambed samples from the Crescent, Johnson, and Kijik Rivers were similar. Notable exceptions were higher concentrations of arsenic, cerium, chromium, lanthanum, lithium, neodymium, thorium, and uranium in the Kijik River samples. Concentrations of cadmium, lead, and zinc were highest at the Johnson River sites. However, some of these sites drain highly mineralized areas which explain these higher concentrations (Brabets and Riehle, 2003).

The focus in the literature on criteria for streambed sediments has been limited to nine trace elements: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc. The Canadian Council of Ministers of the Environment (CCME) (1999) has established guidelines for

Table 8. Trace-element concentrations and percent organic carbon measured in streambed sediments collected from stream sites in the Kijik River Basin, October 2004 (fig.3).

[Values of carbon, aluminum, iron, and titanium in percent; all other values in micrograms per gram; <, less than]

Site #	Site	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Cerium
1	Little Kijik River above Kijik Lake	7.7	1.1	29	850	2.0	<1	0.97	82
2	Little Kijik River below Kijik Lake	6.7	1.2	26	680	2.0	<1	0.63	72
3	Kijik River above Little Kijik River	7.4	1.9	24	810	2.4	<1	0.44	68
4	Kijik River 2.5 km above mouth	7.4	2.0	32	790	2.4	<1	0.73	66

Site #	Site	Chromium	Cobalt	Copper	Europium	Gallium	Gold	Holmium	Iron
1	Little Kijik River above Kijik Lake	110	16	40	1.4	20	<1	1.3	4.7
2	Little Kijik River below Kijik Lake	47	8.7	25	1.2	18	<1	1.1	2.9
3	Kijik River above Little Kijik River	62	10	26	1.2	19	<1	1.0	3.7
4	Kijik River 2.5 km above mouth	69	12	34	1.2	19	<1	1.0	3.9

Site #	Site	Lanthanum	Lead	Lithium	Manganese	Mercury	Molybdenum	Neodymium	Nickel
1	Little Kijik River above Kijik Lake	43	28	48	1600	0.03	3.2	44	32
2	Little Kijik River below Kijik Lake	40	24	32	720	0.03	3.9	40	14
3	Kijik River above Little Kijik River	36	24	32	1000	0.02	1.6	37	16
4	Kijik River 2.5 km above mouth	38	32	33	1200	<0.02	2.4	37	20

Site #	Site	Niobium	Scandium	Selenium	Silver	Strontium	Tantalum	Thallium	Thorium
1	Little Kijik River above Kijik Lake	21	20	0.95	0.38	240	1.2	<1	12.0
2	Little Kijik River below Kijik Lake	16	14	0.63	0.29	230	1.1	<1	7.9
3	Kijik River above Little Kijik River	17	15	0.11	0.36	230	1.3	<1	7.0
4	Kijik River 2.5 km above mouth	17	15	0.25	0.43	230	1.1	<1	7.6

Site #	Site	Tin	Titanium	Uranium	Vanadium	Ytterbium	Yttrium	Zinc	Carbon (Organic)
1	Little Kijik River above Kijik Lake	3.2	0.59	6.2	140	3.3	34	170	2.43
2	Little Kijik River below Kijik Lake	3.1	0.41	10.0	75	2.8	30	120	3.13
3	Kijik River above Little Kijik River	3.4	0.50	3.5	90	2.7	28	120	0.42
4	Kijik River 2.5 km above mouth	3.6	0.46	4.7	90	2.6	30	150	1.06

Table 9. Comparison of concentrations of trace elements measured in streambed sediments from the USGS National Water-Quality Assessment (NAWQA) program, and from four stream sites in the Kijik River Basin, three stream sites in the Crescent River Basin, and eight stream sites in the Johnson River Basin.

[Values for aluminum, iron, and titanium in percent; all other values in micrograms per gram; --, no data; <, less than]

Trace element	NAWQA Reference Forested Sites (number of samples varies between 241 and 262)	Range in concentration from Kijik River sites	Range in concentration from Crescent River sites	Range in concentration from Johnson River sites
Aluminum	6.5	6.7-7.7	7.5-9.1	8.0-10
Antimony	0.7	1.1-2.0	0.3-0.5	0.4-10
Arsenic	7.0	24-32	2.9-9.0	16-64
Barium	470	680-850	400-600	200-1100
Beryllium	2.0	2.0-2.4	0.5-0.8	0.2-1.0
Bismuth	--	<1	<1	<1
Cadmium	0.4	0.44-0.97	<0.1-0.2	<0.1-4.6
Cerium	70	66-82	22-30	21-36
Chromium	63	47-110	20-43	14-66
Cobalt	15	8.7-16	15-31	18-44
Copper	26	25-40	44-110	47-92
Europium	1.0	1.2-1.4	1	1.0-2.0
Gallium	16	18-20	17-20	15-20
Gold	--	<1	<1	<1
Holmium	--	1.0-1.3	<1-1	1.0-2.0
Iron	3.6	2.9-4.7	4.1-9.3	4.8-13
Lanthanum	--	36-43	10-13	8-15
Lead	24	24-32	4-8	4.0-230
Lithium	--	32-48	12-16	9-20
Manganese	955	720-1600	1000-1700	1200-2000
Mercury	0.07	<0.02-0.03	<0.02-0.04	0.10-0.93
Molybdenum	1	1.6-3.9	0.9-1.1	0.5-4.0
Neodymium	--	37-44	14-20	15-22
Nickel	26	14-32	12-19	4-25
Niobium	--	16-21	7-8	<4.0
Scandium	12	14-20	19-49	29-56
Selenium	0.7	0.11-0.95	<0.1-0.2	0.2-2.6
Silver	0.2	0.29-0.43	0.2-0.7	<0.1-0.8
Strontium	140	230-240	180-450	8.5-200
Tantalium	--	1.1-1.3	<1	<1
Thallium	--	<1	<1	<1-1.3
Thorium	12.0	7-12	2-6	<1-2
Tin	2.5	3.1-3.6	1-2	1-2
Titanium	0.37	0.41-0.59	0.37-0.87	0.5-0.8
Uranium	3.9	3.5-10	1-2.9	0.8-1.1
Vanadium	84	75-140	130-380	140-550
Ytterbium	--	2.6-3.3	2-4	3-4
Yttrium	--	28-34	13-19	27-43
Zinc	110	120-170	72-150	85-1800

Table 10. Comparison of streambed sediment quality guidelines to concentrations measured in streambed sediments in the Kijik River Basin for selected trace elements.

[Values in µg/g micrograms per gram; --, no guideline established]

Trace Element	Interim Freshwater Sediment Quality Guideline (ISQG)[1]	Threshold Effect Concentration (TEC)[2]	Probable Effect Level (PEL)[1]	Probable Effect Concentration (PEC)[2]	Range of concentrations from Kijik River sites
Arsenic	5.9	9.8	17.0	33.0	24 - 32
Cadmium	0.6	0.99	3.5	5.0	0.44 - 0.97
Chromium	37.3	43.4	90	111	47 - 110
Copper	35.7	31.6	197	149	25 - 40
Lead	35.0	35.8	91.3	128	24 - 32
Mercury	0.17	0.18	0.49	1.06	0.02 - 0.03
Nickel	--	22.7	--	48.6	14 - 32
Selenium[3]	--	2.5	--	4.0	0.11 - 0.95
Zinc	123	121	315	459	120 - 170

[1] Canadian Council of Ministers of the Environment (1999)

[2] MacDonald and others (2000)

[3] Van Derveer and Canton (1997)

some trace elements in unsieved streambed sediment. These guidelines use two assessment values: a lower value, called the “interim freshwater sediment quality guideline” (ISQG), is the concentration below which adverse effects in aquatic biota are expected to occur rarely; an upper value, called the “probable effect level” (PEL), is the concentration above which adverse effects are expected to occur frequently (table 10). Because trace-element samples for this study are from sediments finer than 0.063 mm, in which concentrations tend to be greatest, comparisons with the Canadian guidelines may overestimate the effects on aquatic organisms (Deacon and Stephens, 1998). However, it was felt that the PEL would be useful for comparative purposes when applied to the finer than 0.063-mm size fraction sediment samples analyzed for this study.

MacDonald and others (2000) proposed sediment quality guidelines for eight trace elements, and Van Derveer and Canton (1997) proposed guidelines for selenium (table 10). These guidelines use the following two concentrations for a given trace element: the threshold effect concentration (TEC) and the probable effect concentration (PEC) and assume a 1 percent organic carbon concentration (Kijik River sites ranged from 0.42 to 3.13 percent). The TEC is the concentration below which sediment-dwelling organisms are unlikely to be adversely affected, and the PEC is the concentration above which toxicity is likely. When compared to the different guidelines, the concentrations of arsenic from all sites were four to five times higher than the ISQG. These concentrations reflect the local geology of the area rather than anthropogenic sources. Three sites exceeded the ISQG for cadmium, with the highest concentration 0.97 µg/g, 0.37 µg/g higher than the 0.60 µg/g standard. Chromium concentrations at all sites exceeded the guideline of 37.3 µg/g, with the exceedances ranging from 11.6 µg/g to 72.7 µg/g. Only one site (40 µg/g) was above the copper ISQG of 35.7 µg/g, and two sites (150 µg/g and 170 µg/g) were above the zinc concentration guideline of 123 µg/g. The TEC of these elements are similar to the ISQG concentrations and comparing the concentrations from the Kijik River sites indicated that concentrations of arsenic, chromium, copper, nickel, and zinc also were above the TEC at approximately the same magnitudes. All concentrations of arsenic were about twice as high as the PEL, and one chromium concentration was 20 µg/g higher than the PEL of 90 µg/g. No concentrations were above the PEC levels.

In addition, MacDonald and others (2000) developed a Mean PEC Quotient, which is the toxicity of the combined trace element concentrations. The Mean PEC Quotient is computed by summing the concentrations of all the trace elements analyzed and dividing by the number of elements. MacDonald and others (2000) found that sediments with mean PEC quotients less than 0.5 accurately predicted the absence of toxicity in 83 percent of the samples they examined. Mean PEC quotients greater than 0.5 accurately predicted toxicity in 85 percent of the samples. Comparison of the concentrations of the trace elements with the percent organic carbon and Mean PEC Quotient provides some insights about the bioavailability of these trace elements. The concentration of organic carbon in sediment is used to indicate the concentration of organic matter. The ability of organic matter in concentrating some trace elements in stream sediment is well recognized (Gibbs, 1973; Horowitz, 1991), and this ability varies with the type of organic matter. For example, complexation by organic matter, such as humic and fulvic acids, has generally been thought to reduce bioavailability of certain metals (Spacie and Hamelink, 1985, Newman and Jagoe, 1994). Results of studies by Decho and Luoma (1994) and Winner (1985), however, suggest that organic carbon compounds may in some cases enhance uptake of certain trace elements. The organic carbon content in three of the four streambed sediment samples from the Kijik River

Table 11. Concentrations of priority pollutant trace elements in streambed sediments finer than 0.063 millimeter for sites located in Lake Clark National Park and Preserve.

[Concentrations in micrograms per gram, dry weight, organic carbon in percent; As, arsenic; Cd, cadmium; Cr, chromium; Cu, copper; Pb, lead; Hg, mercury; Ni, nickel; Se, selenium; Zn, zinc; values in bold are concentrations that when normalized to 1 percent organic carbon, exceed Probable Effect Concentration (PEC), or for the mean PEC quotient, indicate toxicity for the sum of trace elements excluding selenium (MacDonald and others, 2000)]

Site name	Latitude	Longitude	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Zn	Organic carbon	Mean PEC Quotient
Kijik River Basin Lake Clark National Park and Preserve													
Little Kijik River above Kijik Lake	60°17’08”	154°20’35”	29	0.97	110	40	28	0.03	32	0.95	170	2.43	0.19
Little Kijik River below Kijik Lake	60°18’28”	154°17’17”	26	0.63	47	25	24	0.03	14	0.63	120	3.13	0.09
Kijik River above Little Kijik River	60°18’33”	154°15’41”	**24**	0.44	**62**	26	24	0.02	16	0.11	120	0.42	**0.70**
Kijik River 2.5 km above mouth	60°18’01”	154°14’36”	32	0.73	69	34	32	0.02	20	0.25	150	1.06	0.35
Crescent River Basin Lake Clark National Park and Preserve													
North Fork Crescent River	60°26’04”	152°54’00”	4.7	0.1	26	44	6	0.02	12	0.1	72	1.90	0.08
Lake Fork Crescent River	60°21’29”	152°49’07”	9.0	0.2	43	110	8	0.04	19	0.2	120	3.00	0.09
Crescent River near mouth	60°14’36”	152°34’49”	2.9	0.1	20	72	4	0.02	14	0.1	150	7.00	0.03
Johnson River Basin Lake Clark National Park and Preserve													
North Fork Ore Creek near mouth near Johnson Glacier	60°06’58”	152°58’14”	**34**	<.1	**41**	**54**	<1	**0.53**	**15**	0.2	**120**	0.16	**2.21**
East Fork Ore Creek near mouth near Johnson Glacier	60°07’13”	152°57’40”	**64**	**4.3**	14	76	**230**	0.93	4	2.6	**1000**	1.00	**0.72**
Ore Creek near mouth near Johnson Glacier	60°07’15”	152°57’28”	**44**	**4.6**	23	**92**	**180**	**0.28**	8	1.2	**1800**	0.24	**4.60**
Kona Creek 4.8 km above mouth above Lateral Glacier	60°08’26”	152°55’44”	**19**	<.1	**38**	**56**	6	**0.75**	11	0.6	**120**	0.25	**1.27**
Kona Creek 4.0 km above Lateral Glacier	60°08’03”	152°55’24”	**18**	0.1	**42**	**57**	5	0.16	11	0.6	**140**	0.26	**0.98**
Kona Creek 1.3 km above mouth above Lateral Glacier	60°06’36”	152°55’14”	**16**	0.4	48	63	17	0.28	14	0.7	150	0.49	**0.62**
Unnamed tributary to Kona Creek above Lateral Glacier	60°06’35”	152°55’09”	18	<.1	77	47	4	0.10	25	0.2	85	1.30	0.23
Johnson River above Lateral Glacier	60°05’41”	152°54’38”	**16**	0.2	**66**	**75**	4	**0.13**	**17**	0.3	**130**	0.05	**6.02**

sites was greater than 1 percent (1.06, 2.43, and 3.13 respectively), whereas most of the samples from the Crescent and Johnson River basins contained less than 1 percent organic carbon (table 11). With the exception of one sample, the mean PEC quotient in the Johnson River samples was greater than 0.50, which would indicate some level of potential toxicity (table 11). As MacDonald and others (2000) noted, sites containing relatively low concentrations of organic carbon have higher potential toxicity. When normalized to percent organic carbon, concentrations of arsenic and chromium in the Kijik River above Little Kijik River were above the PEC level.

Physical Habitat, Benthic Communities, and Lake Zooplankton of the Kijik River Basin

Physical Habitat

The physical habitats of the two sites on the Little Kijik River and the two sites on the main stem of the Kijik River were surveyed in August 2004. Discharge at the time of the surveys was .45 m^3/s at Little Kijik River above Kijik Lake, 1.7 m^3/s at Little Kijik River below Kijik Lake, 11 m^3/s at Kijik River above Little Kijik River, and 12 m^3/s at Kijik River 2.5 km above the mouth. The channel gradients of the 2 Little Kijik River sites are relatively flat, as evidenced by the low average velocities at each site, 0.1 m/s and 0.2 m/s, respectively. In contrast, the gradients of the 2 Kijik River sites are relatively steep, as evidenced by the high average velocities at these sites of 1 m/s and 1 m/s, respectively. The channel widths at the 4 sites ranged from 18 to 27 m.

The Little Kijik River sites (figs. 10 - 13) represent pristine complex habitats characterized by deep pools, long riffles, and extensive gravel bars. A beaver dam is present in the upper part of the Little Kijik River above Kijik Lake reach, and some woody debris is present in the Little Kijik River below Kijik Lake reach. The vegetation at both sites consists of native tall shrubs, willows, spruce, and cottonwood. Substrate is dominated by sand, small cobbles, and gravel. Banks are completely vegetated.

The physical habitat reaches for the 2 sites on the Kijik River are characterized by steep cut banks about 1 to 2 meters high (figs. 14 and 15) along the right bank. The substrate is dominated by small cobbles with boulders and sand distributed throughout the reaches and both reaches have mobile beds. Streambanks are completely bare of vegetation and cutbanks are present at both reaches. The surrounding land cover consists of shrubs and alders. Open canopy characterizes both reaches. Instream structure is formed predominantly by the distribution of cobbles and boulders, as woody debris was nearly absent due to the relatively high velocities in these areas.

Zooplankton

Zooplankton samples were collected three times during the study period at both Lachbuna Lake—the glacier fed lake—and Kijik Lake—the clear-water lake (tables 12 and 13). At both lakes the following taxa were identified: *Cyclops*, ovigerous (egg-bearing) *Cyclops*, *Diaptomus*, ovigerous *Diaptomus*, *Bosmina*, *Daphnia*, and ovigerous *Daphnia*. *Cyclops* and *Diaptomus* are primary food sources for rearing sockeye salmon juveniles. Notable differences in the taxa number are evident between Kijik Lake and Lachbuna Lake (table 12). *Diaptomus* at Kijik Lake averaged about 11 times more than at Lachbuna Lake, while *Cyclops* averaged about 3 times more than at Lachbuna Lake. Average size of the zooplankton at the two lakes were similar (table 13), but the average biomass was approximately five times higher at Kijik Lake. These differences can be attributed to the turbidity of Lachbuna Lake affecting primary production. Previous studies (Lloyd and others, 1987) indicated that seasonal densities in glacially turbid lakes were observed to be as little as 5 percent of those in clear-water lakes.

Macroinvertebrates

Benthic macroinvertebrate QMH samples were collected from two sites on the Little Kijik River and two sites on the main-stem of the Kijik River (table 14). Invertebrate QMH data represents an overview of the community of organisms found in the various types of microhabitats within the stream reach being sampled. This sampling technique focuses on the simple presence of an organism rather than how many (abundance) of an organism are in a particular area (density). A comparison was performed between the two Little Kijik River and the two Kijik River sites, as well as comparisons with all invertebrate data similarly collected throughout the Cook Inlet Basin during the 2000 NAWQA sampling.

Preparation of the raw data (presence/absence) was accomplished using the Invertebrate Data Analysis System (IDAS) (Cuffney, 2005, version 3.7.6). IDAS is a software application designed to parse, organize, and calculate metrics related to macroinvertebrate data collected as part of the NAWQA Program. The software adds accuracy and precision to data interpretation by tracking and documenting settings used in metric generation, thereby yielding easily reproducible and comparable results. The options for data processing were set for the default, with the exception of dropping the “parent” species and keeping the “children” species in the case of identification ambiguities. The Kijik and Little Kijik River sites and all of the Cook Inlet Basin sites were processed in a similar fashion.

A total of 69 taxa (organisms identified to the lowest practical level by the USGS NWQL Biological Unit, Denver, CO) were collected among the Kijik and Little Kijik River sites (table 15). Little Kijik River above Kijik Lake had 31 taxa collected within the sample reach, and Little Kijik River

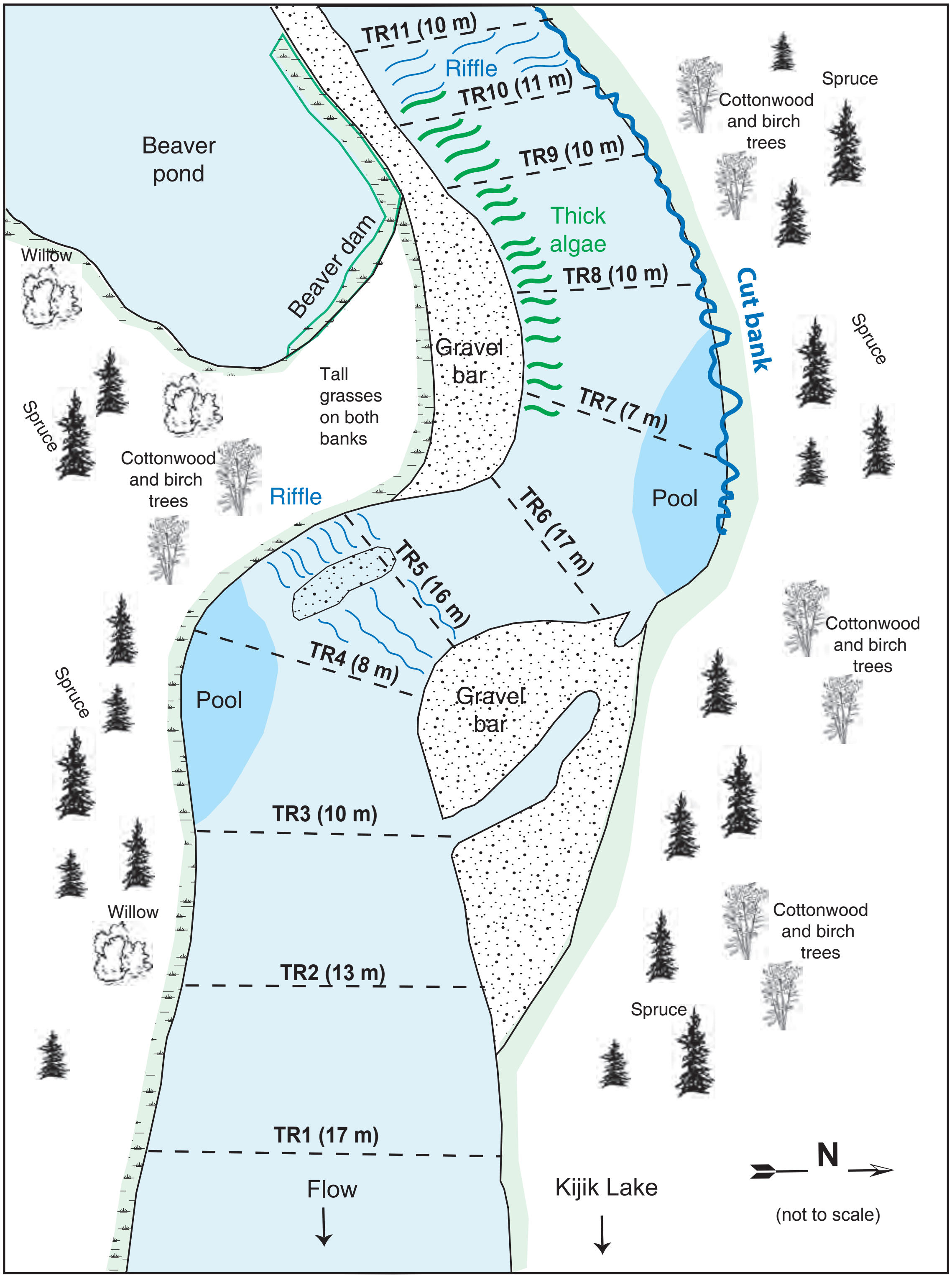


Figure 10. Major geomorphic features of the Little Kijik River above Kijik Lake study reach.

Figure 11. Little Kijik River above Kijik Lake physical habitat reach looking upstream.

below Kijik Lake had 25 taxa. The Kijik River above Little Kijik River had 28 taxa, and 22 taxa were collected at Kijik River 2.5 km above the mouth. The Little Kijik River sites shared 7 taxa in common, whereas the Kijik River sites shared 14 taxa. All four sites shared only two taxa.

Twenty-seven macroinvertebrate families were found within the four sites. The class *Insecta*, made up the largest percentage of macroinvertebrates, totaling 70 percent of the families collected. The insects were comprised of four orders; Diptera (flies and midges), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Dipterans and Plecopterans each had six families represented among the study sites (table 14). However, the Dipterans had the greatest diversity below the family level, with the family Chironomidae (midges) yielding by far the greatest number of genera (28) of all identified macroinvertebrates. Plecopterans accounted for six families, but only four genera were able to be identified. One Plecopteran, *Zapada cinctipes*, was identified to the species level (*Zapada sp.* was one of the four genera mentioned above). Trichopterans accounted for four families, seven of which were identified to genus, and two of the seven were identified to species. There were three Ephemeropteran families identified, which included eight genus identifications, five of those refined to the species level.

Examination of insects found at the study sites revealed that only the Dipteran (Chironomidae), *Cricotopus/Orthocladius sp.*, was common to all four Kijik and Little Kijik River sites. Insects found only at the two Little Kijik River sites were the Dipterans (Chironomidae–midges, and Tipulidae–craneflies) *Tribelos sp.* and *Tipula sp.*, respectively, and the Trichopteran (Limnephilidae), *Psychoglypha sp.* The two Kijik River sites had the two Dipterans (Chironomidae and Simuliidae–blackflies) *Pagastia sp.* and *Simulium sp.*, an Ephemeropteran (Ephemerellidae) *Ephemerella aurivillii*, and a Plecopteran (Taeniopterygidae) common to only that basin.

The Little Kijik River above Kijik Lake had eight insects formerly undocumented in samples collected using NAWQA protocols in Alaska including seven Dipterans (all Chironomidae) and one Plecopteran (Pteronarcyidae) (table 16). Five Chironomids were found only at this site. Eight insects, all identified to the genus level or lower (five Chironomids, one Ephemeropteran, one Plecopteran, and one Trichopteran), were found only at the Little Kijik River below Kijik Lake site. Three Chironomids were documented as shared by at least one other study site. The Kijik River above Little Kijik River site included four Dipterans (three Chironomids and one Tipulid) unique to the site and shared three Chironomids with the other study sites. Finally, at the Kijik River 2.5 km above the mouth site, no taxa unique to the site were found, but a shared Chironomid and Plecopteran were noted as endemic to the four study sites.

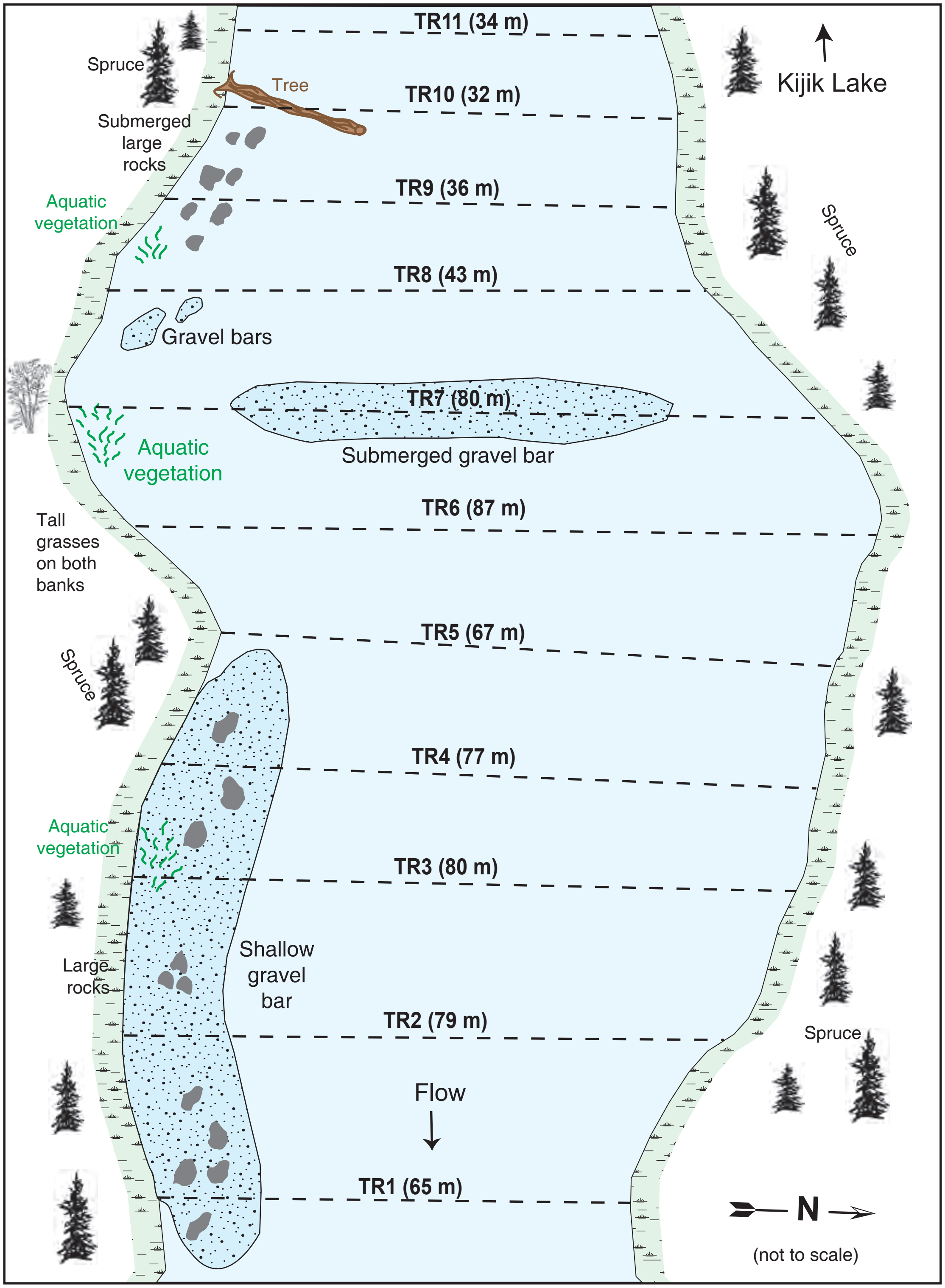


Figure 12. Major geomorphic features of the Little Kijik River below Kijik Lake study reach.

Figure 13. Little Kijik River below Kijik Lake physical habitat reach looking upstream.

Non-insect macroinvertebrates made up the remaining 30 percent of families (or coarser taxonomic levels) identified at the two Kijik and two Little Kijik River sites (table 14). Classes of non-insects included Arachnida (ticks and water mites), Bivalvia (freshwater clams and mussels), Gastropoda (snails), Malacostraca (scuds), Oligochaeta (worms), Turbellaria (flatworms), and the phylum Nematoda (roundworms). The Gastropods were resolved to three separate families and then to three separate genera. Oligochaeta also was resolved to three families, though further classification of the worms to the generic level was not performed by the lab. The Arachnids are broken down only to the subclass Acari, as this is an extensive group (many tens of thousands known taxa). Only one family, Sphaeriidae (fingernail clams), and more specifically of the genus *Pisidium sp.*, was identified as part of the class Bivalvia. One Malacostracan (family Gammaridae, *Gammarus sp.*) was identified as belonging to the ubiquitous order Amphipoda. Turbellarians (flatworms including *Dugesia sp.* or *Planaria sp.*) were identified only to the class level, and the Nematodes were left at the phylum level due to the great diversity of the group.

One water mite (Acari) and a member of the phylum Nematoda were found only at the Kijik River above Little Kijik River site. Molluscs (Bivalves and Gastropods) and the Turbellarian were collected only at the Little Kijik River above Kijik Lake site. The Malacostracan, *Gammarus sp.*, was confined to the two sites in the Little Kijik River basin. The Oligochaete, Enchtraeidae, was found only at the Little Kijik River above Kijik Lake site, whereas Lumbriculidae was found at the other three sites. The only non-insect collected at all four sites was the Oligochaete, Naididae.

A cluster analysis was used to compare the similarity of the Kijik and Little Kijik River sites. Results of the analysis indicated the Kijik River sites as being most closely related, owing to the many common taxa between Kijik River sites and few common taxa between Little Kijik River sites (fig. 16, table 17). The Little Kijik sites are relatively unrelated to the Kijik River sites, as noted in figure 16, and share five taxa between one Kijik and one Little Kijik site. The Little Kijik River above Kijik Lake site had 14 taxa found only there and not at the 3 other study sites. The Little Kijik River below Kijik Lake had 15 taxa found only there and not at the other sites in this study.

Examination of the percent richness metrics (used here to measure the variety of biotic assemblages collected relative to the sites or other biota at the sites) reveals some of the possible factors that tend to differentiate the Little Kijik River sites from each other as well as the two Kijik sites (table 17). The Little Kijik River below Kijik Lake site was the only site where there were Gastropods and Molluscs, a disproportionate number of non-midge/non-insect fauna, and a very low occurrence of the common invertebrate metric, percent EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa, when compared to the other sites. The two Kijik River sites again reveal their overall similarity when Jaccard and Sorenson similarity coefficients are examined (table 18). Both coefficients are basically the same and corroborate the dendrogram for the four sites. When the Kijik and Little Kijik River sites

Table 12. Macrozooplankton data for Kijik Lake and Lachbuna Lake.

[Taxa in number per cubic meter]

Kijik Lake							
Date	***Diaptomus***	**Ovigerous *Diaptomus***	***Cyclops***	**Ovigerous *Cyclops***	***Bosmina***	***Daphnia***	**Ovigerous *Daphnia***
7/14/2004	6,158	475	6,498	158	611	3,351	91
8/24/2004	825	0	425	3	506	958	54
10/6/2004	3,184	0	5,943	0	1,231	5,540	64
Mean	3,389	158	4,288	54	783	3,283	70

Lachbuna Lake						
Date	***Diaptomus***	**Ovigerous *Diaptomus***	***Cyclops***	**Ovigerous *Cyclops***	***Bosmina***	***Daphnia***
7/14/2004	401	7	1,457	109	0	0
8/24/2004	3	0	125	1	0	0
10/6/2004	598	143	2,520	7	68	7
Mean	334	50	1,367	39	23	2

Table 13. Seasonal means of length and biomass of zooplankton from Kijik Lake and Lachbuna Lake.

[Values in millimeters for length and micrograms per cubic meter for biomass]

Kijik Lake			Lachbuna Lake		
	Mean Length	**Mean Biomass**		**Mean Length**	**Mean Biomass**
Diaptomus	1.08	18	*Diaptomus*	1.31	3
Ovigerous *Diaptomus*	1.29	1	Ovigerous *Diaptomus*	1.34	<1
Cyclops	0.75	8	*Cyclops*	0.91	4
Ovigerous *Cyclops*	1.34	<1	Ovigerous *Cyclops*	1.33	<1
Bosmina	0.54	2	*Bosmina*	0.62	<1
Ovigerous *Bosmina*	0.65	<1	*Daphnia*	0.86	<1
Daphnia	0.65	6			
Ovigerous *Daphnia*	1.09	<1			

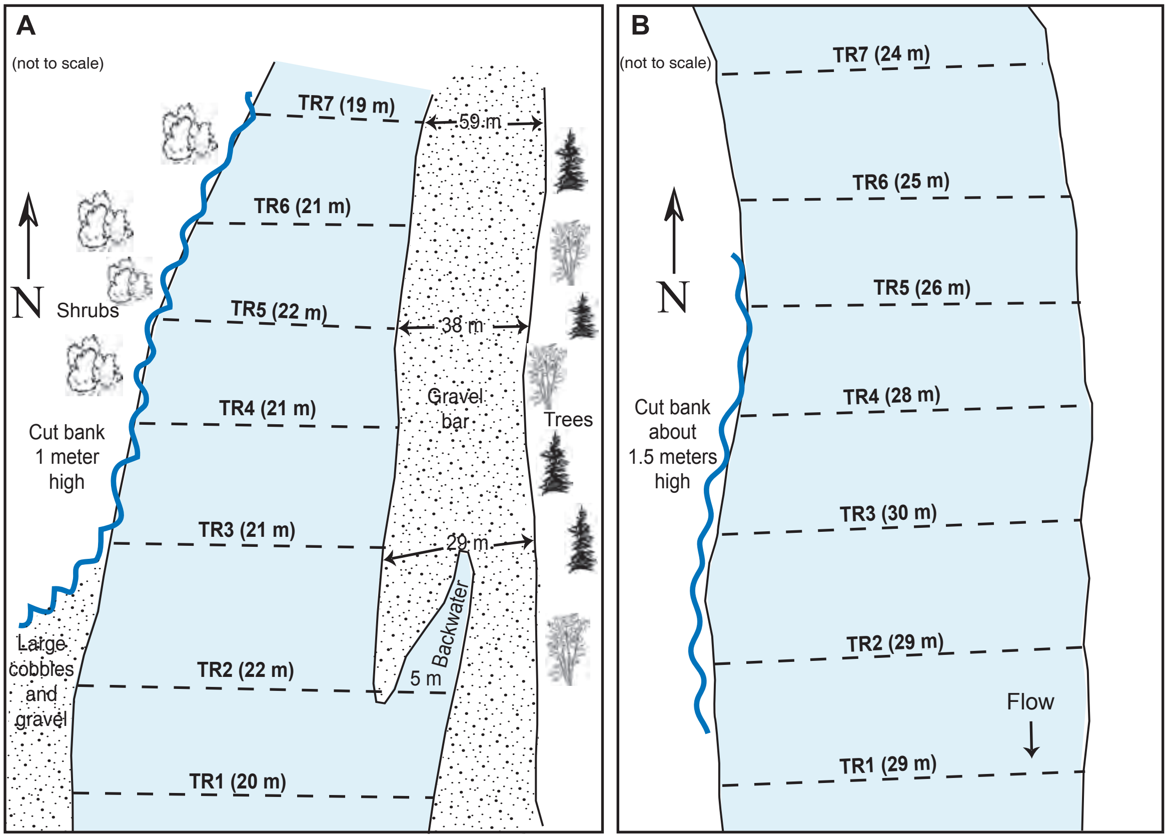


Figure 14. Major geomorphic features of the Kijik River above Little Kijik River and Kijik River 2.5 kilometers above mouth study reaches.

Figure 15. Physical habitat reach of the Kijik River 2.5 kilometers above mouth.

Table 14. Macroinvertebrate taxa for qualitative-multi-habitat (QMH) samples collected at four sites in the Kijik River Basin.

[*, total for that category]

Class	Order	Family	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Total
Arachnida			Acari	0	0	1	0	1
		*		0	0	1	0	1
	*			0	0	1	0	1
Arachnida*				0	0	1	0	1
Bivalvia	Veneroida	Sphaeriidae	*Pisidium sp.*	0	1	0	0	1
		Sphaeriidae*		0	1	0	0	1
	Veneroida*			0	1	0	0	1
Bivalvia*				0	1	0	0	1
Gastropoda	Basommatophora	Lymnaeidae	*Stagnicola sp.*	0	1	0	0	1
		Lymnaeidae*		0	1	0	0	1
		Planorbidae	*Gyraulus sp.*	0	1	0	0	1
		Planorbidae*		0	1	0	0	1
	Basommatophora*			0	2	0	0	2
	Mesogastropoda	Valvatidae	*Valvata sp.*	0	1	0	0	1
		Valvatidae*		0	1	0	0	1
	Mesogastropoda*			0	1	0	0	1
Gastropoda*				0	3	0	0	3
Insecta	Diptera	Ceratopogonidae	Ceratopogonidae	1	0	0	1	2
		Ceratopogonidae*		1	0	0	1	2
		Chironomidae	*Brillia sp.*	1	0	0	0	1
			Chaetocladius sp.	1	0	0	0	1
			Chironomini	1	0	0	0	1
			Chironomus sp.	0	1	0	0	1
			Corynoneura sp.	1	0	0	0	1
			Cricotopus sp.	0	1	0	1	2
			Cricotopus/Orthocladius sp.	1	1	1	1	4
			Demicryptochironomus sp.	0	1	0	0	1
			Diamesa sp.	1	0	0	0	1
			Eukiefferiella sp.	1	0	1	1	3
			Heleniella sp.	0	0	1	0	1
			Heterotrissocladius sp.	0	1	0	0	1
			Hydrobaenus sp.	1	0	1	0	2
			Micropsectra sp.	0	1	0	0	1

Table 14. Macroinvertebrate taxa for qualitative-multi-habitat (QMH) samples collected at four sites in the Kijik River Basin.—Continued

[*, total for that category]

Class	Order	Family	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Total
			Pagastia sp.	0	0	1	1	2
			Pentaneurini	0	0	1	0	1
			Phaenopsectra/ Tribelos sp.	1	0	0	0	1
			Polypedilum sp.	1	0	0	0	1
			Procladius sp.	0	1	0	0	1
			Protanypus sp.	0	1	0	0	1
			Pseudodiamesa sp.	1	0	0	0	1
			Stempellinella sp.	0	0	1	0	1
			Tanytarsus sp.	0	0	1	0	1
			Thienemanniella sp.	1	0	0	0	1
			Thienemannimyia group sp. (Coffman and Ferrington, 1996)	0	1	1	0	2
			Tribelos sp.	1	1	0	0	2
			Tvetenia sp.	1	0	1	1	3
		Chironomidae*		15	11	11	5	42
		Empididae	*Chelifera/Metachela sp.*	0	0	1	0	1
		Empididae*		0	0	1	0	1
		Psychodidae	*Pericoma/Telmatoscopus sp.*	0	1	0	0	1
		Psychodidae*		0	1	0	0	1
		Simuliidae	*Simulium sp.*	0	0	1	1	2
		Simuliidae*		0	0	1	1	2
		Tipulidae	*Dicranota sp.*	1	0	1	1	3
			Rhabdomastix sp.	0	0	1	0	1
			Tipula sp.	1	1	0	0	2
		Tipulidae*		2	1	2	1	6
	Diptera*			18	13	15	8	54
	Ephemeroptera	Baetidae	*Acentrella turbida (McDunnough)*	0	0	0	1	1
			Baetis bicaudatus (Dodds)	0	0	0	1	1
			Baetis tricaudatus (Dodds)	0	0	1	0	1
		Baetidae*		0	0	1	2	3

Table 14. Macroinvertebrate taxa for qualitative-multi-habitat (QMH) samples collected at four sites in the Kijik River Basin.—Continued

[*, total for that category]

Class	Order	Family	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Total
		Ephemerellidae	*Drunella doddsi (Needham)*	0	0	0	1	1
			Ephemerella aurivillii (Bengtsson)	0	0	1	1	2
			Ephemerella sp.	0	1	0	0	1
		Ephemerellidae*		0	1	1	2	4
		Heptageniidae	*Cinygmula sp.*	1	0	1	1	3
			Epeorus sp.	1	0	1	1	3
		Heptageniidae*		2	0	2	2	6
	Ephemeroptera*			2	1	4	6	13
	Plecoptera	Capniidae	Capniidae	0	0	1	0	1
		Capniidae*		0	0	1	0	1
		Chloroperlidae	*Suwallia sp.*	1	0	1	1	3
		Chloroperlidae*		1	0	1	1	3
		Nemouridae	*Zapada cinctipes (Banks)*	0	0	1	0	1
			Zapada sp.	1	0	0	0	1
		Nemouridae*		1	0	1	0	2
		Perlodidae	Perlodidae	1	0	0	0	1
			Skwala sp.	0	1	0	0	1
		Perlodidae*		1	1	0	0	2
		Pteronarcyidae	*Pteronarcella sp.*	1	0	0	1	2
		Pteronarcyidae*		1	0	0	1	2
		Taeniopterygidae	Taeniopterygidae	0	0	1	1	2
		Taeniopterygidae		0	0	1	1	2
	Plecoptera*			4	1	4	3	12
	Trichoptera	Brachycentridae	*Brachycentrus americanus (Banks)*	0	0	0	1	1
		Brachycentridae		0	0	0	1	1
		Glossosomatidae	*Glossosoma sp.*	0	0	0	1	1
		Glossosomatidae		0	0	0	1	1
		Leptoceridae	*Mystacides alafimbriata (Hill-Griffin)*	0	1	0	0	1
		Leptoceridae*		0	1	0	0	1
		Limnephilidae	*Ecclisomyia sp.*	1	0	1	1	3

Table 14. Macroinvertebrate taxa for qualitative-multi-habitat (QMH) samples collected at four sites in the Kijik River Basin.—Continued

[*, total for that category]

Class	Order	Family	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Total
			Psychoglypha sp.	1	1	0	0	2
		Limnephilidae*		4	1	1	1	7
	Trichoptera*			4	2	1	3	10
Insecta				28	17	24	20	89
Malacos-traca	Amphipoda	Gammaridae	*Gammarus sp.*	1	1	0	0	2
		Gammaridae*		1	1	0	0	2
	Amphipoda*			1	1	0	0	2
Malacos-traca				1	1	0	0	2
Oligochaeta	Enchytraeida	Enchytraeidae	Enchytraeidae	1	0	0	0	1
		Enchytraeidae*		1	0	0	0	1
	Enchytraeida			1	0	0	0	1
	Lumbriculida	Lumbriculidae	Lumbriculidae	0	1	1	1	3
		Lumbriculidae*		0	1	1	1	3
	Lumbriculida			0	1	1	1	3
	Tubificida	Naididae	Naididae	1	1	1	1	4
		Naididae*		1	1	1	1	4
	Tubificida*			1	1	1	1	4
Oligochaeta				2	2	2	2	8
Turbellaria			Turbellaria	0	1	0	0	1
				0	1	0	0	1
Turbellaria				0	1	0	0	1
			Nematoda	0	0	1	0	1
		*		0	0	1	0	1
	*			0	0	1	0	1
*				0	0	1	0	1

Table 15. Macroinvertebrate taxa collected at the Kijik and Little Kijik River sites

Class	Order	Family	Tribe	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth	Count of taxa at all NAWQA-sampled sites. Larger values equal more ubiquitous taxa
Arachnida				Acari	0	0	1	0	37
Bivalvia	Veneroida	Sphaeriidae		*Pisidium sp.*	0	1	0	0	21
Gastropoda	Basommatophora	Lymnaeidae		*Stagnicola sp.*	0	1	0	0	2
Gastropoda	Basommatophora	Planorbidae		*Gyraulus sp.*	0	1	0	0	3
Gastropoda	Mesogastropoda	Valvatidae		*Valvata sp.*	0	1	0	0	7
Insecta	Diptera	Ceratopogonidae		*Ceratopogonidae*	1	0	0	1	4
Insecta	Diptera	Chironomidae	Tanytarsini	*Thienemannimyia group sp.* (Coffman and Ferrington, 1996)	0	1	1	0	2
Insecta	Diptera	Chironomidae	Tanytarsini	*Brillia sp.*	1	0	0	0	42
Insecta	Diptera	Chironomidae	Tanytarsini	*Chaetocladius sp.*	1	0	0	0	3
Insecta	Diptera	Chironomidae	Tanytarsini	*Chironomini*	1	0	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Chironomus sp.*	0	1	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Corynoneura sp.*	1	0	0	0	10
Insecta	Diptera	Chironomidae	Tanytarsini	*Cricotopus sp.*	0	1	0	1	11
Insecta	Diptera	Chironomidae	Tanytarsini	*Cricotopus/Orthocladius sp.*	1	1	1	1	48
Insecta	Diptera	Chironomidae	Tanytarsini	*Demicryptochironomus sp.*	0	1	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Diamesa sp.*	1	0	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Eukiefferiella sp.*	1	0	1	1	44
Insecta	Diptera	Chironomidae	Tanytarsini	*Heleniella sp.*	0	0	1	0	16
Insecta	Diptera	Chironomidae	Tanytarsini	*Heterotrissocladius sp.*	0	1	0	0	5
Insecta	Diptera	Chironomidae	Tanytarsini	*Hydrobaenus sp.*	1	0	1	0	10
Insecta	Diptera	Chironomidae	Tanytarsini	*Micropsectra sp.*	0	1	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Micropsectra/Tanytarsus sp.*	1	1	1	0	3
Insecta	Diptera	Chironomidae	Tanytarsini	*Pagastia sp.*	0	0	1	1	2
Insecta	Diptera	Chironomidae	Tanytarsini	*Pentaneurini*	0	0	1	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Phaenopsectra/Tribelos sp.*	1	0	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Polypedilum sp.*	1	0	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Procladius sp.*	0	1	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Protanypus sp.*	0	1	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Pseudodiamesa sp.*	1	0	0	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Stempellinella sp.*	0	0	1	0	1

Table 15. Macroinvertebrate taxa collected at the Kijik and Little Kijik River sites.—Continued

Class	Order	Family	Tribe	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth	Count of taxa at all NAWQA-sampled sites. Larger values equal more ubiquitous taxa
Insecta	Diptera	Chironomidae	Tanytarsini	*Tanytarsus sp.*	0	0	1	0	1
Insecta	Diptera	Chironomidae	Tanytarsini	*Thienemanniella sp.*	1	0	0	0	26
Insecta	Diptera	Chironomidae	Tanytarsini	*Tribelos sp.*	1	1	0	0	2
Insecta	Diptera	Chironomidae	Tanytarsini	*Tvetenia sp.*	1	0	1	1	33
Insecta	Diptera	Empididae		*Chelifera/Metachela sp.*	0	0	1	0	20
Insecta	Diptera	Psychodidae		*Pericoma/Telmatoscopus sp.*	0	1	0	0	28
Insecta	Diptera	Simuliidae		*Simulium sp.*	0	0	1	1	22
Insecta	Diptera	Tipulidae		*Dicranota sp.*	1	0	1	1	50
Insecta	Diptera	Tipulidae		*Rhabdomastix sp.*	0	0	1	0	1
Insecta	Diptera	Tipulidae		*Tipula sp.*	1	1	0	0	10
Insecta	Ephemeroptera	Baetidae		*Acentrella turbida* (McDunnough)	0	0	0	1	12
Insecta	Ephemeroptera	Baetidae		*Baetis bicaudatus* (Dodds)	0	0	0	1	31
Insecta	Ephemeroptera	Baetidae		*Baetis tricaudatus* (Dodds)	0	0	1	0	22
Insecta	Ephemeroptera	Ephemerellidae		*Drunella doddsi* (Needham)	0	0	0	1	39
Insecta	Ephemeroptera	Ephemerellidae		*Ephemerella aurivillii* (Bengtsson)	0	0	1	1	30
Insecta	Ephemeroptera	Ephemerellidae		*Ephemerella sp.*	0	1	0	0	1
Insecta	Ephemeroptera	Heptageniidae		*Cinygmula sp.*	1	0	1	1	36
Insecta	Ephemeroptera	Heptageniidae		*Epeorus sp.*	1	0	1	1	34
Insecta	Plecoptera	Capniidae		Capniidae	0	0	1	0	13
Insecta	Plecoptera	Chloroperlidae		*Suwallia sp.*	1	0	1	1	38
Insecta	Plecoptera	Nemouridae		*Zapada cinctipes* (Banks)	0	0	1	0	31
Insecta	Plecoptera	Nemouridae		*Zapada sp.*	1	0	0	0	19
Insecta	Plecoptera	Perlodidae		Perlodidae	1	0	0	0	13
Insecta	Plecoptera	Perlodidae		*Skwala sp.*	0	1	0	0	1
Insecta	Plecoptera	Pteronarcyidae		*Pteronarcella sp.*	1	0	0	1	2
Insecta	Plecoptera	Taeniopterygidae		Taeniopterygidae	0	0	1	1	4

Table 15. Macroinvertebrate taxa collected at the Kijik and Little Kijik River sites.—Continued

Class	Order	Family	Tribe	Biological Unit ID	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth	Count of taxa at all NAWQA-sampled sites. Larger values equal more ubiquitous taxa
Insecta	Trichoptera	Brachycentridae		*Brachycentrus americanus* (Banks)	0	0	0	1	33
Insecta	Trichoptera	Glossosomatidae		*Glossosoma sp.*	0	0	0	1	27
Insecta	Trichoptera	Leptoceridae		*Mystacides alafimbriata* (Hill-Griffin)	0	1	0	0	1
Insecta	Trichoptera	Limnephilidae		*Ecclisomyia sp.*	1	0	1	1	36
Insecta	Trichoptera	Limnephilidae		*Hydatophylax sp.*	1	0	0	0	4
Insecta	Trichoptera	Limnephilidae		*Limnephilus sp.*	1	0	0	0	4
Insecta	Trichoptera	Limnephilidae		*Psychoglypha sp.*	1	1	0	0	12
Malacostraca	Amphipoda	Gammaridae		*Gammarus sp.*	1	1	0	0	2
Oligochaeta	Enchytraeida	Enchytraeidae		Enchytraeidae	1	0	0	0	31
Oligochaeta	Lumbriculida	Lumbriculidae		Lumbriculidae	0	1	1	1	37
Oligochaeta	Tubificida	Naididae		Naididae	1	1	1	1	32
Turbellaria				Turbellaria	0	1	0	0	36
				Nematoda	0	0	1	0	5

Table 16. Sites used in cluster analysis.

Site Number	Name
15239840	Anchor River above Twitter Creek near Anchor Point
600321151325000	Ninilchik River below tributary 3 near Ninilchik
15240000	Anchor River at Anchor Point
600204151401800	Deep Creek 1.0 km above Sterling Highway near Ninilchik
15240300	Stariski Creek near Anchor Point
595506152403300	Stariski Creek 3.2 km below unnamed tributary near Ninilchik
594507151290000	Beaver Creek 3.2 km above mouth near Bald Mountain near Homer
595126151391000	Chakok River 12 km above mouth near Anchor Point
600945151210900	Ninilchik River 2.4 km below tributary 1 near Ninilchik
600107151112800	North Fork Deep Creek 6.4 km above mouth near Ninilchik
15241600	Ninilchik River at Ninilchik
15266010	Kenai River below Russian River near Cooper Landing
15283550	Moose Creek above Wishbone Hill near Sutton
15276200	Ship Creek at Glenn Highway near Anchorage
15266020	Kenai River at Jim’s Landing near Cooper Landing
585750154101100	Kamishak River near Kamishak
15276570	Ship Creek below power plant at Elmendorf AFB
15294700	Johnson River below Lateral Glacier near Tuxedni Bay
631018149323700	Costello Creek near Colorado
15292304	Costello Creek below Camp Creek near Colorado
15292700	Talkeetna River near Talkeetna
15273020	Rabbit Creek at Hillside Drive near Anchorage
15273100	Little Rabbit Creek near Anchorage
15273090	Little Rabbit Creek at Nickleen Street near Anchorage
15273097	Little Rabbit Creek at Goldenview Drive near Anchorage
15273030	Rabbit Creek at East 140th Avenue near Anchorage
15273040	Rabbit Creek at Porcupine Trail Road near Anchorage
15283700	Moose Creek near Palmer
631629149352000	Colorado Creek near Colorado
15274395	Campbell Creek at New Seward Highway near Anchorage
15274557	Campbell Creek at C Street near Anchorage
15274796	South Branch of South Fork Chester Creek at Tank Trail near Anchorage
15274830	South Branch of South Fork Chester Creek at Boniface Parkway near Anchorage
15292302	Camp Creek at mouth near Colorado
15294630	North Fork Crescent River near Tuxedni Bay
15294650	Crescent River near mouth near Tuxedni Bay
15266110	Kenai River below Skilak Lake outlet near Sterling
15266300	Kenai River at Soldotna
15275100	Chester Creek at Arctic Boulevard at Anchorage
15274000	South Fork Campbell Creek near Anchorage
15294100	Deshka River near Willow

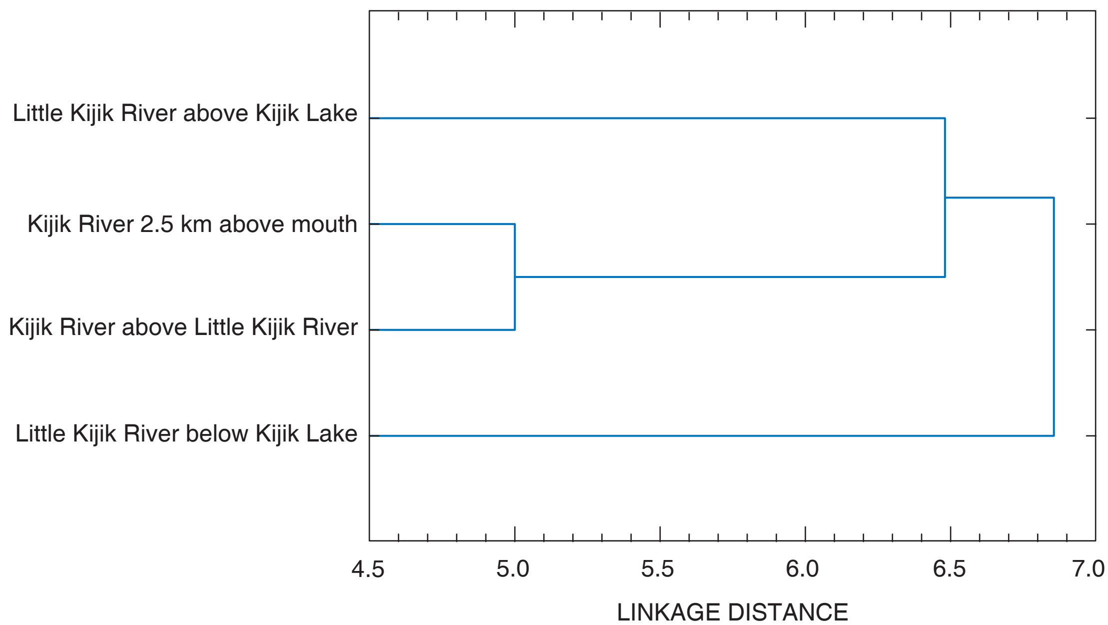


Figure 16. Dendrogram from the results of cluster analysis on the presence or absence of macroinvertebrates found at the four Kijik river sites.

Table 17. Macroinvertebrate community metrics for four stream sites in the Kijik River Basin.

Station	EPTRp	EPT_CHRp	EPEMRp	PLECORp	PTERYRp	TRICHRp	ODONORp	COLEOPRp	DIPRp	CHRp	OR-THORp	ORTHO_CHRp
Little Kijik above Kijik Lake	32.3	0.7	6.5	12.9	0.0	12.9	0.0	0.0	58.1	48.4	25.8	0.5
Kijik River 2.5 km above mouth	54.5	2.4	27.3	13.6	0.0	13.6	0.0	0.0	36.4	22.7	18.2	0.8
Little Kijik River below Kijik Lake	16.0	0.4	4.0	4.0	0.0	8.0	0.0	0.0	52.0	44.0	12.0	0.3
Kijik River above Little Kijik River	32.1	0.8	14.3	14.3	0.0	3.6	0.0	0.0	53.6	39.3	17.9	0.5

Station	TANYRp	TANY_CHRp	NCHDIPRp	NONINSRp	ODIPNIRp	MOLCRURp	GASTRORp	BIVALRp	CORBICRp	AMPHIRp	ISOPRp	OLIGORp
Little Kijik above Kijik Lake	0.0	0.0	9.7	9.7	19.4	3.2	0.0	0.0	0.0	3.2	0.0	6.5
Kijik River 2.5 km above mouth	0.0	0.0	13.6	9.1	22.7	0.0	0.0	0.0	0.0	0.0	0.0	9.1
Little Kijik River below Kijik Lake	0.0	0.0	8.0	32.0	40.0	20.0	12.0	4.0	0.0	4.0	0.0	8.0
Kijik River above Little Kijik River	0.0	0.0	14.3	10.7	25.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1

Percent Richness Metrics	Definitions	Percent Richness Metrics	Definitions
EPTRp	Percentage of total richness composed of mayflies, stoneflies, and caddisflies	ORTHO_CHRp	Ratio of orthoclad percent richness to midge percent richness
EPT_CHRp	Ratio of ept percent richness to midge percent richness	NCHDIPRp	Percentage of total richness composed of non-midge diptera
EPEMRp	Percentage of total richness composed of mayflies	TANY_CHRp	Ratio of percent tanytarsanii richness to percent midge richness
PLECORp	Percentage of total richness composed of stoneflies	ODIPNIRp	Percentage of total richness composed of non-midge diptera and non-insects
PTERYRp	Percentage of total richness composed of pteronarcys	NONINSRp	Percentage of total richness composed on non-insects
TRICHRp	Percentage of total richness composed of caddisflies	GASTRORp	Percentage of total richness composed of gastropoda
ODONORp	Percentage of total richness composed of odonata	MOLCRURp	Percentage of total richness composed of molluscs and crustaceans
DIPRp	Percentage of total richness composed of diptera	CORBICRp	Percentage of total richness composed of corbicula
COLEOPRp	Percentage of total richness composed of coleoptera	BIVALRp	Percentage of total richness composed of bivalvia
ORTHORp	Percentage of total richness composed of orthocladinae midges	OLOGORp	Percentage of total richness composed of oligochaeta
CHRp	Percentage of total richness composed of midges	ISOPODRp	Percentage of total richness composed of isopoda

were compared to the 39 other sites sampled within the Cook Inlet Basin, the downstream Little Kijik River site was more closely related to sites on the Kenai River below Kenai Lake (15266010 and 15266020) than to other sites in this study. This suggests that large lakes in the two systems have a similar effect on the downstream macroinvertebrate community composition (fig. 17).

Comparison of the metrics calculated for the Little Kijik River and Kijik River should be done with caution because the national data set is based on data from streams in the contiguous United States. Because Little Kijik River and Kijik River are at relatively high latitudes, MacLean and others (1999) have noted that there are probably natural stressors such as frozen sediments and extreme temperature ranges that contribute to differences between these sites and streams in the contiguous United States. A database for Alaska streams currently does not exist; however, it was felt that comparing data from Little Kijik River and Kijik River with the existing national data set would still provide some information.

Algae

Periphytic algae QMH samples were collected from Little Kijik River and Kijik River in 2004 (table 19). No quantitative data were collected at any of the Kijik or Little Kijik River sites and thus no quantitative assessments of biovolume or standing crop were performed. However, 122 species of algae were found within the four drainages and several generalizations can be drawn from the simple presence/absence dataset.

Eight species were identified in samples from all four sites, all of which were diatoms. The species include *Achnanthes minutissima*, *Fragilaria vaucheriae*, *Fragilaria capucina*, *Tabellaria flocculosa*, *Encyonema minutum*, *Staurosirella pinnata*, *Encyonopsis aff. cesatii*, and *Brachysira microcephala*. These 8 species do not fix nitrogen from the atmosphere, and all but one (*Tabellaria flocculosa*) are benthic. All are nonmotile, suggesting that the areas from which they were collected are relatively stable. Most of these species also tend to prefer neutral to slightly acidic conditions, with salinity values of less than 0.9 parts per thousand (ppt) (Stephen Porter, U.S. Geological Survey, written commun., 2002).

The 2 Kijik River sites had a total of 50 algal species including 42 diatom species, 3 green algae species, and 5 blue-

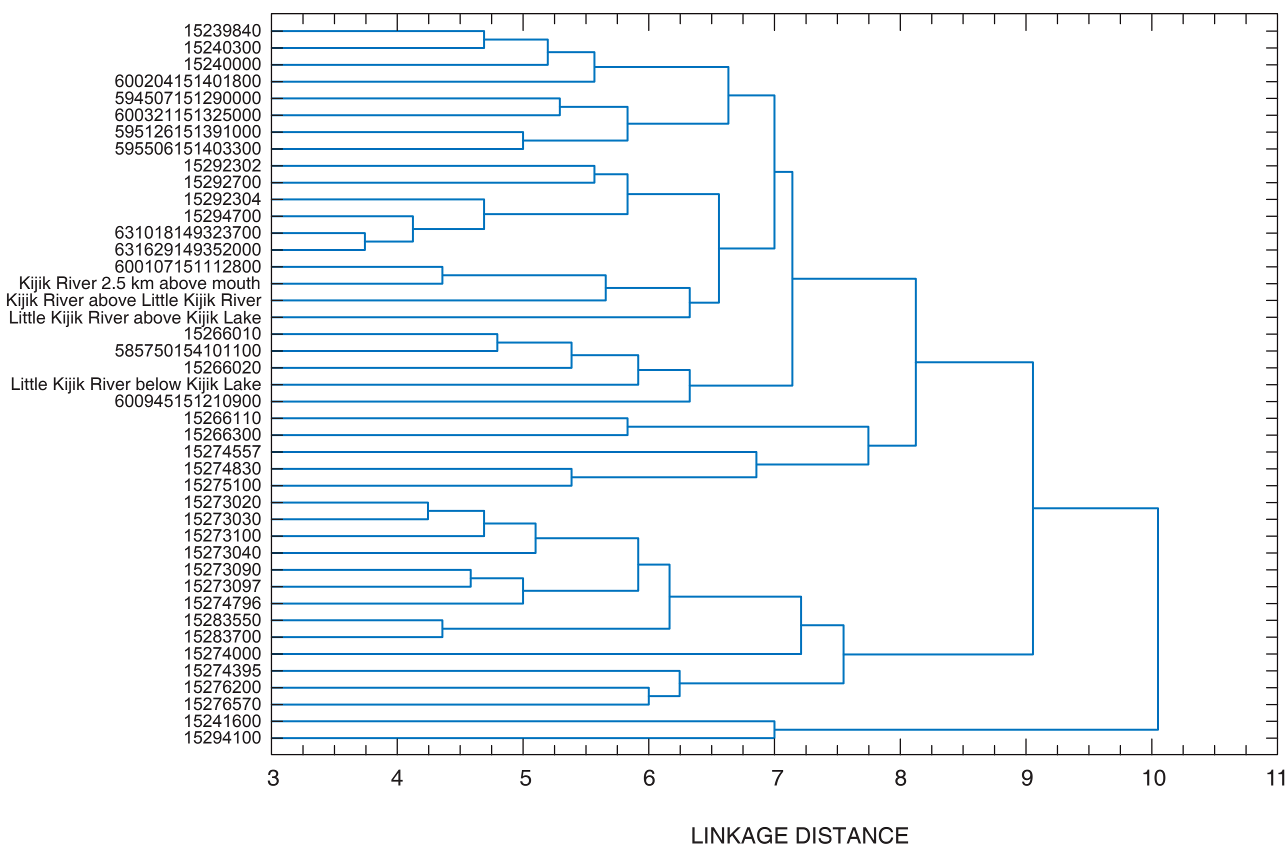


Figure 17. Dendrogram from the results of cluster analysis on the presence or absence of macroinvertebrates found at the four Kijik river sites and sites in the Cook Inlet Basin.

Table 18. Jaccard and Sorenson similarity coefficients for stream sites in the Kijik River Basin.

Station 1	Station 2	Jaccard	Sorenson
Little Kijik River above Kijik Lake	Kijik River above Little Kijik	0.23	0.37
Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	0.14	0.25
Little Kijik River above Kijik Lake	Kijik River 2.5 km above mouth	0.26	0.42
Kijik River 2.5 km above mouth	Kijik River above Little Kijik River	0.39	0.56
Kijik River 2.5 km above mouth	Little Kijik River below Kijik Lake	0.09	0.17
Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	0.10	0.19

Table 19. Algal taxa present in qualitative-multi-habitat samples collected at four stream sites in the Kijik River Basin.

[1, species present; --, species not present]

Taxonomy	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth
PHYLUM				
Family				
Genus species				
CYANOPHYTA (blue-green algae)				
(undetermined)				
Unknown Cyanophyte coccoid	--	1	--	--
Borziaceae				
Komvophoron schmidlei (Jaag) Anagnostidis & Kom rek	1	--	--	--
Merismopediaceae				
Merismopedia arctica (Kosinskaja) Kom rek et Anagnostidis	--	--	1	--
Oscillatoriaceae				
Oscillatoria lutea Agardh	1	--	1	--
Phormidiaceae				
Phormidium autumnale (CA Agardh) Gomont	1	--	1	--
Pseudanabaenaceae				
Geitlerinema splendidum (Greville) Anagnostidis	--	1	--	--
Homoeothrix sp.	1	--	1	--
Pseudanabaena sp.	1	--	1	1
CHLOROPHYTA (green algae)				
Chaetophoraceae				
Stigeoclonium lubricum (Dillwyn) Kurtzing	--	1	--	--
Desmidiaceae				
Staurastrum sp.	1	--	--	1
Hydrodictyaceae				
Pediastrum boryanum (Turpin) Meneghini	--	1	--	--
Scenedesmaceae				
Scenedesmus ecornis (Ralfs) Chodat	1	--	--	--
Volvocaceae				
Eudorina elegans Ehrenberg	1	--	--	--
Zygnemataceae				

Table 19. Algal taxa present in qualitative-multi-habitat samples collected at four stream sites in the Kijik River Basin.—Continued

[1, species present; --, species not present]

Taxonomy	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth
Mougeotia sp.	1	--	--	1
Zygnema sp.	--	1	1	--
CHRYSOPHYTA (diatoms)				
Achnanthaceae				
Achnanthes kriegeri Krasske	1	--	--	1
Achnanthes minutissima var. jackii (Rabhenhost) Lange-Bertalot et Ruppel	1	1	1	1
Achnanthes nodosa Cleve	1	1	--	--
Achnanthidium altergracillima (Lange-Bertalot) Round et Bukhtiyarova	--	--	1	--
Achnanthidium kranzii (Lange-Bertalot) Round et Bukhtiyarova	1	--	--	--
Achnanthidium minutissimum (Ktzing) Czarnecki	1	1	--	--
Cocconeis placentula var. lineata (Ehrenberg) Van Heurck	--	--	--	1
Eucocconeis flexella (Kützing) Cleve	1	--	1	1
Eucocconeis laevis (Ostrup) Lange-Bertalot	1	--	--	1
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	--	1	--	--
Planothidium lanceolatum	1	1	--	--
Psammothidium grischunum fo. daonensis (Lange-Bertalot ex Lange-Bertalotet Krammer) Bukhtiyarova et Round	--	1	--	--
Psammothidium helveticum (Hustedt) Bukhtiyarova et Round	1	1	--	--
Psammothidium lacus-vulcani (Lange-Bertalot et Krammer) Bukhtiyarova et Round	--	1	--	--
Psammothidium subatomoides (Hustedt) Bukhtiyarova et Round	--	1	--	--
Psammothidium ventralis (Krasske) Bukhtiyarova et Round	1	--	--	--
Rossithidium petersennii (Hustedt) Round et Bukhtiyarova	1	1	--	1
Rossithidium pusillum (Grunow) Round et Bukhtiyarova	--	1	--	--
Diatomaceae				
Diatoma mesodon (Ehrenberg) Kützing	1	--	--	--
Diatoma tenuis Agardh	1	--	1	1
Fragilaria capucina DesmaziŠres	--	1	1	--
Fragilaria capucina var. mesolepta Rabenhorst	--	1	--	--
Fragilaria capucina var. rumpens (Kützing) Lange-Bertalot	1	1	1	1
Fragilaria nanana Lange-Bertalot	1	--	--	--
Fragilaria sp. 8 NAWQA EAM	1	1	--	--
Fragilaria tenera (Smith) Lange-Bertalot	1	--	--	--
Fragilaria vaucheriae (Kützing) Petersen	1	1	1	1
Fragilariforma bicapitata (Mayer) Round et Williams	1	--	--	--
Fragilariforma sp. 1 NAWQA EAM	1	--	--	--
Hannaea arcus (Ehrenberg) Patrick	1	--	1	1
Meridion circulare (Greville) Agardh	1	--	--	--
Meridion circulare var. constrictum (Ralfs) Van Heurck	1	--	--	--
Opephora martyi H,ribaud	--	1	--	--

Table 19. Algal taxa present in qualitative-multi-habitat samples collected at four stream sites in the Kijik River Basin.—Continued

[1, species present; --, species not present]

Taxonomy	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth
Pseudostaurosira pseudoconstruens (Marciniak) Williams et Round	--	1	--	--
Pseudostaurosira robusta (Fusey) Williams et Round	--	1	--	--
Pseudostaurosira sp. 2 NAWQA EAM	--	1	--	--
Stauroforma exiguiformis Flower, Jones et Round	1	--	--	--
Staurosira construens (Ehrenberg) Williams et Round	--	--	1	--
Staurosira construens var. binodis (Ehrenberg) Hamilton	--	1	1	--
Staurosira construens var. venter (Ehrenberg) Hamilton	--	1	--	--
Staurosira elliptica (Schumann) Williams et Round	1	1	--	--
Staurosirella lapponica (Grunow) Williams et Round	--	1	--	--
Staurosirella leptostauron var. rhomboides (Grunow) Bukhtiyarova	--	1	--	--
Staurosirella pinnata (Ehrenberg) Williams et Round	1	1	1	1
Staurosirella sp. 7 NAWQA EAM	--	1	--	--
Synedra amphicephala var. austriaca (Grunow) Hustedt	--	1	1	1
Synedra delicatissima Smith	--	1	1	1
Synedra delicatissima var. angustissima Grunow	--	1	--	--
Synedra ulna (Nitzsch) Ehrenberg	1	--	1	1
Tabellaria fenestrata (Lyngbye) Kützing	1	--	--	--
Tabellaria flocculosa (Roth) Kützing	1	1	1	1
Eunotiaceae				
Eunotia flexuosa Br,bisson ex Kützing	1	--	--	--
Eunotia minor (Kützing) Grunow	1	--	--	--
Eunotia paludosa Grunow	1	--	--	--
Naviculaceae				
Amphora pediculus (Kützing) Grunow	--	1	1	--
Amphora sp. 6 NAWQA EAM	--	1	1	--
Brachysira microcephala (Grunow) CompŠre	1	1	1	1
Caloneis bacillum (Grunow) Cleve	--	1	--	--
Caloneis silicula (Ehrenberg) Cleve	1	--	--	--
Cavinula pseudoscutiformis (Grunow ex Schmidt) Mann et Stickle	--	1	--	--
Cymbella cistula (Ehrenberg) Kirchner	--	1	--	--
Cymbella delicatula Kützing	--	1	1	--
Cymbella dorsenotata Oestrup	--	--	--	1
Cymbella hilliardii Manguin	--	1	--	--
Cymbella latens Krasske	1	--	--	--
Cymbella mesiana Cholnoky	1	--	1	--
Cymbella naviculiformis Auerswald ex H,ribaud	1	--	--	--
Cymbella stauroneiformis Lagerstedt	1	--	--	--
Diadesmis confervacea Kützing	--	--	1	--
Diadesmis contenta (Grunow ex Van Heurck) Mann	1	--	--	--

Table 19. Algal taxa present in qualitative-multi-habitat samples collected at four stream sites in the Kijik River Basin.—Continued

[1, species present; --, species not present]

Taxonomy	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik River	Kijik River 2.5 km above mouth
Didymosphenia geminata (Lyngbye) Schmidt	--	--	1	--
Diploneis parma Cleve	--	1	--	--
Encyonema minutum (Hilse) Mann	1	1	1	1
Encyonema reichardtii (Krammer) Mann	1	--	--	--
Encyonema silesiacum (Bleisch) Mann	1	1	1	--
Encyonema triangulum (Ehrenberg) Kützing	--	1	--	--
Encyonopsis aff. cesatii EAM (Rabenhorst) Krammer	1	1	1	1
Encyonopsis cesatii (Rabenhorst) Krammer	--	1	--	--
Encyonopsis descripta (Hustedt) Krammer	--	1	--	--
Encyonopsis microcephala (Grunow) Krammer	--	1	1	--
Encyonopsis sp. 1 NAWQA EAM	--	1	1	--
Frustulia saxonica Rabenhorst	--	1	--	--
Gomphonema angustatum (Kützing) Rabenhorst	1	1	--	1
Gomphonema micropus Kützing	1	--	--	--
Gomphonema olivaceum (Lyngbye) Kützing	--	--	1	1
Gomphonema sarcophagus Gregory	1	--	--	--
Navicula cf. kriegerii NAWQA KM Krasske	--	--	--	1
Navicula cryptocephala Kützing	1	--	--	--
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	--	1	--	1
Navicula indifferens Hustedt	--	1	--	--
Navicula sp. 44 NAWQA EAM	--	1	--	--
Navicula vulpina Kützing	--	1	--	--
Reimeria sinuata (Gregory) Kociolek et Stoermer	1	--	--	1
Sellaphora pupula (Kützing) Meresckowsky	--	1	--	--
Sellaphora seminulum (Grunow) Mann	--	1	--	--
Stauroneis anceps Ehrenberg	1	--	--	--
Nitzschiaceae				
Denticula kuetzingii Grunow	--	1	--	--
Denticula tenuis Kützing	--	1	1	1
Nitzschia angustata (Smith) Grunow	--	1	--	--
Nitzschia frustulum (Kützing) Grunow	--	1	1	--
Nitzschia linearis (Agardh ex Smith) Smith	1	--	--	--
Nitzschia palea (Kützing) Smith	--	--	--	1
Nitzschia solita Hustedt	1	--	--	--
Thalassiosiraceae				
Aulacoseira crenulata (Ehrenberg) Thwaites	1	--	--	--
Aulacoseira granulata (Ehrenberg) Simonsen	1	--	--	--
Cyclotella ocellata Pantocsek	--	--	1	--
Cyclotella stelligera (Cleve et Grunow) Van Heurck	--	--	1	1

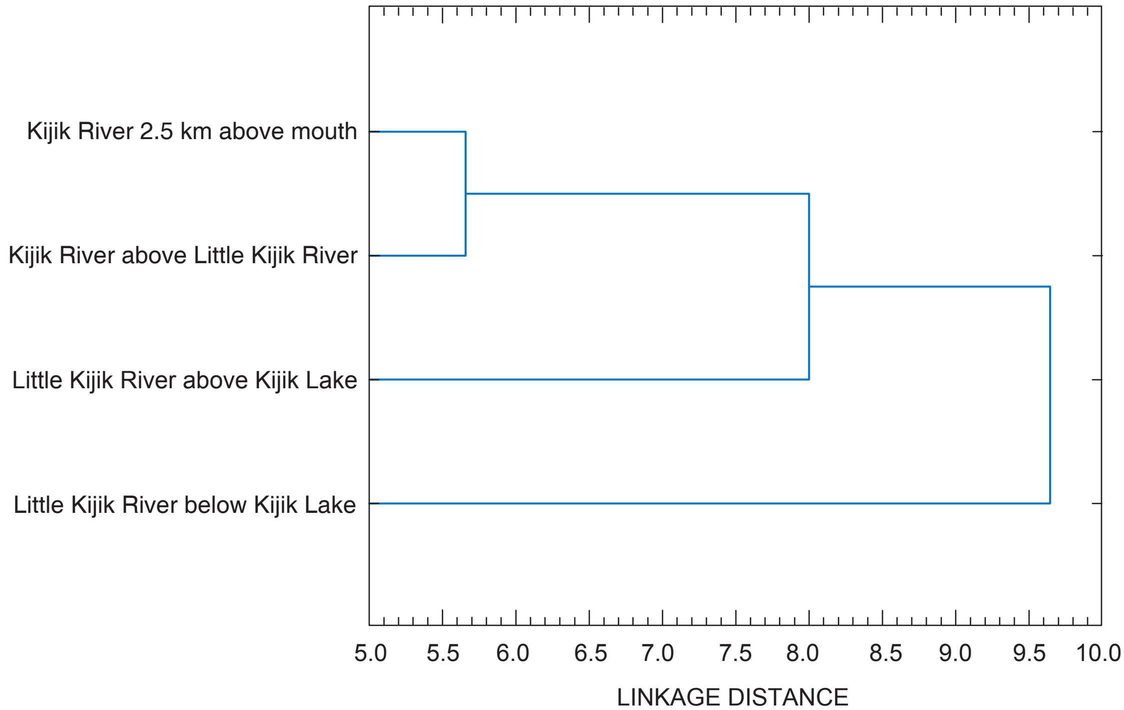


Figure 18. Dendrogram from the results of cluster analysis on the presence or absence of algae found at the four Kijik river sites.

green algae species (table 19). Two species were unique to the Kijik River when compared to the Little Kijik River.

Samples from the 2 Little Kijik River sites yielded 110 algae species. The 2 sites shared 6 unique species, 96 diatoms, 7 green algae, and 7 blue-green algae. The diversity of the Little Kijik River algae community may be attributed to the fact that both sites are downstream of lakes. The upstream site is immediately below a very large, old beaver dam lake (mature trees were growing out of the dam). The site below that was just downstream of Kijik Lake, known to be a very productive sockeye salmon spawning area. The proximity of both sites to lakes, and thus additional habitat types and potential sources for nutrients, increases the probability of the existence of a much larger (more taxa) algal community in the Little Kijik River. Nutrient enrichment from marine sources (salmon) and local inputs (for example, beaver scat and alder trees) are likely to contribute favorably, especially when considering the importance of the lakes proximal to the Little Kijik River sites as temporary nutrient storage units. The lakes (or impoundments, in the case of the beaver dam pond) have the potential to contribute significantly to river basin nutrient budgets when compared to river or stream sites without lakes nearby, as in the case of the Kijik River sites.

A cluster analysis was performed on the presence/absence (1 or 0, respectively) of algae found at all four sites in order to visualize “relatedness” based on which algal species were present (fig. 18). The diagram shows the Kijik River sites to be very closely related, as they share 18 of the 50 (36 percent) species found in the 2 Kijik River sites. The shift in the linkage distance for the Little Kijik River sites shows less similarity to each other as only 17 of 110 (about 15 percent) species are shared. Shorter linkage distance between the two Little Kijik River sites when compared to the linkage distance between Little Kijik River above Kijik Lake and the two Kijik River sites suggests that the Little Kijik sites are more closely related to each other.

The algal communities were also used to calculate metrics based on percentages and species-, genus-, and family-richness (table 20). Because of the complex response patterns of these metrics, they are most useful for relative comparisons to larger datasets, but the values do provide useful baseline measures. In addition, a number of indicators of community structure and autecology can be used to further explain water-quality conditions where certain species are found (Stephen Porter, U.S. Geological Survey, written commun., February 2005).

The Little Kijik River tended to have a higher percentage of nitrogen autotrophs, or those taxa that are generally intolerant to organically bound nitrogen; the reverse was true for the Kijik River. The downstream sites on both rivers had taxa that required elevated concentrations of organically bound nitrogen (that is, facultative nitrogen heterotrophs). None of these taxa were present in samples collected at upstream sites. Species that prefer low nutrient concentrations were more prevalent at the two upstream sites, whereas species preferring higher nutrient concentrations dominated the two downstream sites. Furthermore, none of the species found at any site was known to fix nitrogen from atmospheric sources.

Table 20. Metrics of algae data collected at four sites in the Kijik River Basin.

Metric	Little Kijik above Kijik Lake	Little Kijik below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Little Kijik River Averages	Kijik River Averages	Differ-ence	Percent Differ-ence
Motile	13	18	11	12	15	11	4	15
NonMotile	87	82	89	88	85	89	4	2
Nitrogen Fixing	0	0	0	0	0	0	0	0
Non-Nitrogen Fixing	100	100	100	100	100	100	0	0
pHAcidobiontic	2	0	0	0	1	0	1	100
pHAcidophilous	14	6	5	4	10	5	5	34
pHCircumneutral	39	31	42	25	35	34	1	2
pHAlkaliphilous	41	58	37	50	50	43	6	7
pHAlkalibiontic	0	0	5	4	0	5	5	100
pHIndifferent	5	6	11	17	5	14	9	46
SalinityFresh	36	18	22	18	27	20	7	14
SalinityFreshBrackish	59	79	72	68	69	70	1	1
SalinityBrackishFresh	5	3	6	14	4	10	6	44
SalinityBrackish	0	0	0	0	0	0	0	0
OrgNAutoLow	51	52	38	38	52	38	14	15
OrgNAutoHigh	49	41	54	50	45	52	7	7
OrgNHeteroHighFacultative	0	4	0	6	2	3	1	26
OrgNHeteroHighObligate	0	4	8	6	2	7	5	58
OxyTolAlwaysHigh	59	56	54	50	58	52	6	5
OxyTolFairlyHigh	22	19	8	13	20	10	10	33
OxyTolModerate	19	22	31	38	21	34	14	25
OxyTolLow	0	4	8	0	2	4	2	35
OxyTolVeryLow	0	0	0	0	0	0	0	0
Oligosaprobic	45	37	33	33	41	33	8	10
BetaMesoSaprobic	40	43	40	39	42	39	2	3
AlphaMesoSaprobic	13	13	13	22	13	18	5	16
AlphaMesoPolySaprobic	3	7	7	6	5	6	2	14
PolySaprobic	0	0	7	0	0	3	3	100
Oligotrophic	20	17	27	11	18	19	1	1
Oligomesotrophic	15	7	7	6	11	6	5	28
Mesotrophic	15	17	13	17	16	15	1	3
Mesoeutrophic	10	23	0	22	17	11	6	20
Eutrophic	18	20	27	28	19	27	8	18
Polytrophic	0	0	7	0	0	3	3	100
Eurytrophic	23	17	20	17	20	18	1	3
Moisture_1	20	24	23	35	22	29	7	14
Moisture_2	31	20	23	12	26	17	8	19
Moisture_3	40	56	54	53	48	53	5	5
Moisture_4	9	0	0	0	4	0	4	100

Table 20. Metrics of algae data collected at four sites in the Kijik River Basin.—Continued

Metric	Little Kijik above Kijik Lake	Little Kijik below Kijik Lake	Kijik River above Little Kijik	Kijik River 2.5 km above mouth	Little Kijik River Averages	Kijik River Averages	Differ-ence	Percent Differ-ence
Moisture_5	0	0	0	0	0	0	0	0
BahlsPollClass1	0	4	6	0	2	3	1	27
BahlsPollClass2	33	46	38	37	40	37	3	4
BahlsPollClass3	67	50	56	63	58	60	1	1
BenthicSpp	86	96	92	91	91	91	0	0
SestonicSpp	14	4	8	9	9	9	0	3
Counts of values								
Percent Family Richness	14	9	8	10	12	9	3	12
Percent Genus Richness	38	31	23	27	35	25	10	16
Percent Species Richness	62	65	30	38	64	34	30	30

Many species of diatoms have a preferred range of stream pH. Although all sites had diatoms with preference for slightly acidic conditions and diatoms with preference for slightly alkaline conditions, upstream sites showed a general preference for acidic conditions and downstream sites for alkaline conditions (table 20). Overall, the greatest percentage of diatoms known to exhibit a particular pH preference at all sites were the alkaliphilous species. Diatom species that prefer neutral pH (circumneutral, pH near 7) conditions were found in roughly similar higher percentages at both upstream sites and similarly lower percentages at the downstream sites. The Little Kijik River had 34 percent more diatom species that preferred acidic (acidophilous, pH<7, optimum < 7) waters when compared to the Kijik River sites (table 20). Only the upstream Little Kijik River site had species requiring only acidic pH conditions (acidobiontic, pH <7, optimum < 5.5). The greatest percentage of diatom species preferring more alkaline (alkaliphilous, pH >7, occurring ~ 7) conditions was found at the downstream site of the Little Kijik River (58 percent). Alkalibiontic species, those preferring only alkaline conditions (pH >7), were found only at the two Kijik River sites, the upper site making up 5 percent and the lower site yielding 4 percent, which corresponds well with the pH values collected at the sites. Diatom species indifferent to various pH conditions (pH~ 7) were found in greater percentages at the Kijik River sites, with the lower site having the greater percentage (16 percent) than the upper site (10 percent).

The salinity of water (measured in ppt, or milligrams per liter of chloride) may affect the composition of the algal community. By conventional definition, the water sampled at all four sites is considered fresh (<500 mg/L chloride), as the highest chloride measurement was 0.63 mg/L. However, the preferences noted for many of the species used in the autecological categories (fresh, fresh-brackish, brackish-fresh, and brackish) were those that typically exhibit preferences for higher salinity levels. The upstream sites sampled on both rivers had the highest percentage of species that are typically known to prefer fresh water. The percentage of fresh water species declined downstream, with the greatest decline at the Kijik River downstream site. The fresh-brackish category comprised the greatest percentage of species, including 79 percent of the community at the downstream Little Kijik site. Given the paucity of data on autecology of algae species of far northern climates, the sensitivity of this metric may be too coarse and requires further analysis.

Motile taxa are those algae that are capable of movement either in the water column or on various types of submerged surfaces. The ability of an organism to move, especially in depositional environments, can be advantageous as it has a better chance of remaining on the surface where light availability is high. Typically, a community with a high proportion of motile species may be indicative of high sedimentation rates. Sites sampled on the Kijik and Little Kijik Rivers had fewer than 20 percent of the community composed of motile species. The subtle difference between the Kijik and Little Kijik River sites may be attributed to the lower velocities measured in the Little Kijik River.

Summary

The Kijik River Basin, located in Lake Clark National Park and Preserve, drains an area of about 777 km^2 and supports a strong sockeye salmon fishery. Due to the concern about the decline in the number of sockeye salmon, the river and lake system were studied from 2004-2005. Major findings are:

- Water samples from all sites indicate that the water type is similar throughout the basin—a calcium bicarbonate type—although Little Kijik River above Kijik Lake has slightly higher concentrations of sulfate and chloride. Concentrations of nutrients, major ions, dissolved organic carbon, and chlorophyll-*a* were generally low at all sites. Concentrations of DOC were higher in the June samples than at other times of the year due to spring runoff carrying more organic material into the surface water bodies. Suspended sediment concentrations were also low, indicating that most suspended sediment is trapped by Lachbuna and Kijik Lakes.

- Water temperature data collected at the four stream water sites all show diurnal variations throughout the summer. Water temperatures were as high as 20°C, reflecting the warm summer air temperatures in 2004. However, water temperatures of the Little Kijik River above Kijik Lake only reached a high of 6.5°C, reflecting the spring-fed nature of this inflow stream to Kijik Lake.

- Depth profiles of Lachbuna and Kijik Lakes show differences between the two lakes. Secchi-disc transparencies were between 1 and 2 m at the glacier-fed Lachbuna Lake whereas at Kijik Lake secchi-disc transparencies were between 11 and 15 m. Water temperature profiles indicate complete mixing of Lachbuna Lake whereas stratification occurs in Kijik Lake which remains isothermal below 30 m.

- Streambed sediments collected from four stream sites were analyzed for trace elements. When compared to different guidelines, concentrations of arsenic at all sites were above the PEL and one concentration was above the PEL for chromium. When normalized for the percent organic carbon (to account for the bioavailability of these trace elements), concentrations of arsenic and chromium in the Kijik River above Little Kijik River were above the probable effect concentration.

- Benthic macroinvertebrate QMH samples were collected from two sites on the Little Kijik River and two sites on the main stem of the Kijik River. A total of 69 taxa were found among the 4 sites. The class *Insecta* made up the largest percentage of macroinvertebrates, totaling 70 percent of the families found. The insects were comprised of four orders; Diptera (flies and midges), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The Little Kijik River basin sites were richer taxonomically; 49 more taxa than the sites within the Kijik River basin which had a total of 36 taxa. The Little Kijik River sites differed from the Kijik River sites primarily by the number of non-insectan taxa and the number of midges. The Little Kijik River sites were inhabited by 9 non-insectans and 22 midges, whereas the Kijik River sites had 3 non-insectans and 11 midges. Thirty taxa were collected in the Little Kijik River basin that were not found in the Kijik basin.

- Periphytic algae QMH samples also were collected at the four surface sites. One hundred twenty-two algal taxa were found among the four sites. The Little Kijik River basin was represented by 110 algal taxa, whereas the Kijik River basin had only 50 taxa. As with the macroinvertebrates, proximity to lakes appears to be the most readily apparent factor contributing to the greater taxa richness for the Little Kijik basin. Eight taxa, all diatoms, were identified in samples from all four sites. These eight taxa are all non-motile, suggesting that the areas from which they were collected are relatively stable. Diatoms at both sites were, by far, the most dominant class of algae, followed by green and blue-green algae.

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