



Central Alaska Network Flowing Waters Monitoring Program

2007 Annual Report

Natural Resource Technical Report NPS/CAKN/NRTR—2009/218



ON THE COVER

View of the upper Copper River near its source at the Copper Glacier, Wrangell-St. Elias National Park and Preserve
Photograph by: Trey Simmons

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Trey Simmons
National Park Service
4175 Geist Road
Fairbanks, Alaska 99709

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Abstract

The 2007 field season marked the second year of development of the flowing waters portion of the Central Alaska Network (CAKN) Inventory and Monitoring Program, also known as the Vital Signs Program. Data collection occurred in both Wrangell-St. Elias National Park and Preserve (WRST) and in Denali National Park and Preserve (DENA). The purposes of the study were to 1) continue to refine field protocols and logistics related to the collection of relevant data in DENA and WRST streams and rivers; 2) determine the extent to which data collected from streams in DENA, primarily along the park road, as part of the Long-Term Ecological Monitoring Program (LTEM) are compatible with data collected using CAKN field protocols; and 3) implement the long-term flowing water monitoring program. The data collected included biological (benthic macroinvertebrate and diatom samples, fish identity and size, riparian vegetation type), physical (extensive channel geometry, substrate, etc.) and chemical (collected *in situ* as well as in water samples for later analysis) information. Data were collected from a total of 41 sites across the two park units. Initial analyses indicate that there are substantial differences between the macroinvertebrate data collected by the LTEM program and that collected by the CAKN program; however, further analyses are required before any firm conclusions can be drawn.

Acknowledgements

I would like to thank Tyler Logan for assistance in the field. I would also like to thank the staff of Wrangell-St. Elias National Park and Preserve, in particular Eric Veach, Geoff Bleakley, Beth Betts, Tom Betts and Thelma Schrank for their invaluable assistance with field logistics, and for many discussions about the park and the monitoring program. Thanks also to Pam Sousanes and Geoff Bleakly for sharing a helicopter, and to Andrew Ruth for managing it. I'd also like to thank the staff of Denali National Park and Preserve, in particular Lucy Tyrell, for lots of cheerful assistance. Finally, I'd like to thank Maggie MacCluskie for her unflagging support, intellectual, financial and moral, as I struggled through my second field season.

Introduction

This study is part of the National Park Service Vital Signs (Inventory and Monitoring) Program for the Central Alaska Network (CAKN; MacCluskie and Oakley 2005). Climate change and other anthropogenic impacts can be expected to have a dramatic effect on freshwater ecosystems in Alaskan National Parks; the streams and rivers portion of the Vital Signs program will be designed to detect trends in the status of important components of lotic ecosystems. These include hydrologic regime, geomorphology, temperature, water quality and the distribution and abundance of freshwater fish, benthic macroinvertebrate and diatom species. Fundamentally, the goal is to develop a logistically feasible, repeatable and scientifically robust monitoring program that will detect change in these systems. To the extent possible, we intend to incorporate indicators, data and methods developed as part of the Denali National Park and Preserve (DENA) Long Term Ecological Monitoring (LTEM) program, as well as utilizing other relevant data collected in network parks for a variety of purposes.

In 2007, the purposes of the program were to evaluate the comparability of invertebrate data collected by Sandy Milner for the LTEM program with data collected using the CAKN field and laboratory methodology, continue to evaluate and refine the existing field methods, maintain the continuity of existing data streams by sampling sites along the DENA park road that were part of the LTEM program, and collect data from a variety of sites in Wrangell-St. Elias National Park and Preserve (WRST) to continue characterization of the natural variability of stream ecosystems in that park unit. We were also interested in investigating the suitability of park road sites (in both WRST and DENA) for possible designation as intensively-monitored model watershed sites. We sampled a total of 41 sites in 2007, 21 in DENA and 20 in WRST, although the full suite of data was not collected at all sites. Two sites in WRST were visited twice during the year, once in the summer and once in the fall. To evaluate the comparability of LTEM invertebrate data with that collected by the CAKN, we scheduled duplicate sampling visits to 10 LTEM sites along the DENA park road. Both the CAKN crew and Dr. Milner sampled each site; visits were arranged so that no more than five days separated sampling by the two crews. After laboratory identification of the organisms (also performed separately), the two resulting datasets were compared.

The ultimate target population for the CAKN stream program is all flowing waters in the network. The sampling design, while not finalized, will be similar to the following. Parkwide inference will be established for each park unit using a set of synoptic sites selected using a Generalized Random Tessellation Stratified (GRTS) survey design, which generates a spatially-balanced, probabilistic sample (Overton and Stehman 1993, Stevens and Olsen 2004). We will use an unequal-weighting approach to specifically target Wadeable streams and stratify the sample to account for differences in the cost of access. Although the spatial variation in site characteristics and responses inherent in such designs can substantially reduce overall sensitivity to trends, explicitly incorporating revisits can effectively eliminate this effect (Urquhart *et al.* 1998, Urquhart and Kincaid 1999), assuming reasonable coherence in regional response. For this reason, we will use a panel rotation approach, in which sites are revisited periodically according to a master schedule. In addition to the synoptic site panels, we will establish a set of “sentinel sites” that will be sampled annually. Sentinel sites will be selected for ease of access, and will be

distributed as much as possible among representative stream types. Annual visitation will maximize our ability to detect trends at these sites, although inference to unsampled sites will be limited. Finally, we will establish a very small number of “intensively monitored sites”. These sites will be subject to a more intensive sampling regime than those in the other two categories, and will ideally be instrumented with continuously-recording sensors of various types (temperature, precipitation, water chemistry, stage height, soil moisture, etc.). These sites will be visited more than once per year, allowing the seasonal component of variance in the values of ecological metrics to be estimated and taken into account (*e.g.*, Larsen *et al.* 2004). The results obtained at these sites will allow us to model relevant ecological and hydrological processes that may be occurring, and thus provide a conceptual framework for interpreting the data we collect at other sites.

Methods

Study Area

Data were collected from a total of 41 sites in 2007, 21 in DENA and another 20 in WRST (Table 1). Two sites in WRST were revisited in the fall. The full suite of data was only collected from a subset of these sites, however (16 in WRST, 15 in DENA). The locations of the sites sampled are shown in Figures 1 and 2. All of the DENA sites were located along the road. These sites included ten sites that were sampled as part of the LTEM program, plus Rock Creek, which was only minnow trapped. Sampling at these sites was coordinated with Sandy Milner to ensure that both teams sampled each of the LTEM streams within a short time period (five days). The other DENA sites included seven spring-fed streams, a stream characterized by extensive deposits of travertine, two tributaries to Little Stony Creek, and Igloo Creek above the road construction. In WRST, five sites along the road system were sampled; the other 15 were remote sites accessed by fixed-wing aircraft or helicopter. 5 of these sites were coastal streams located south of the Bagley Ice Field, in a part of WRST that is rarely studied. Two sites in WRST, Chalk Creek and Willow Creek, were sampled twice during the year. This marks the second year that Chalk Creek has been sampled twice. Unfortunately, few data were recovered from either visit to Chalk Creek. The first sampling attempt occurred during a high-flow event that made it unsafe to wade. The second attempt, in mid-October, occurred on a windy day with air temperatures near -15°C. In these conditions, sampling equipment soon froze and was rendered unusable. Future cold-weather sampling attempts will require modifications to the field methods to protect equipment from freezing. One solution appropriate for site with easy road access would be to set up a wall tent or similar structure, equipped with a small woodstove or other heat source, streamside at the bottom of the reach. This would allow equipment to stay as warm as possible, and for all processing (*e.g.*, filtering of water samples) to take place in a heated environment. For air-accessed remote sites, it might be possible to use the aircraft in a similar fashion, although that would likely be somewhat awkward.

Reach definition

Sampling reaches were defined using guidelines from the EPA's EMAP Wadeable Streams Assessment (USEPA 2004), and modified as necessary. A sampling reach was defined as 40 times the mean wetted width of the stream, based on five equally spaced measurements at the bottom of the proposed reach. Although this length was initially chosen as the minimum sufficient to adequately capture fish community composition in wadeable streams (Reynolds *et al.* 2003), it is also generally long enough to include a complete meander bend, which is a fundamental unit of stream geomorphology. Hence, a reach sufficiently long to encompass a meander bend should adequately capture the habitat complexity of that section of stream (Kaufmann *et al.* 1999). The minimum sampling reach length was set at 150 meters, and the maximum at 500 meters (the latter for feasibility and safety reasons). Reaches were selected to be as representative as possible of the stream section in which they were embedded; in addition, major tributary junctions were avoided and reaches near road crossings were located so as to begin at least 50 meters upstream. Once defined, the reach was subdivided into ten equally spaced sections by the placement of 11 cross-sectional transects (A – K). These transects formed the framework around which the bulk of biological and physical sampling occurred. For 2007, we dispensed with the requirement to measure and flag the transects. This procedure can take

Table 1. List of sites sampled in 2007 with location and brief description

Site	Park	Description
Chalk Creek	WRST	clearwater stream along Nabesna Road (sampled twice)
Rock Creek	WRST	clearwater stream along Nabesna Road
Rock Creek tributary	WRST	small tannic tributary to Rock Creek
Gilahina River	WRST	clearwater river along McCarthy Road
Nizina River tributary	WRST	clearwater tributary to Nizina River
Lake Creek	WRST	clearwater tributary to Nizina River
Young Creek	WRST	high-elevation tundra stream
Willow Creek	WRST	clearwater tributary to the Tana River (sampled twice)
Skolai Pass stream	WRST	small high-elevation tundra stream
Moonshine Creek	WRST	small braided turbid glacial stream
4th of July Creek	WRST	clearwater tributary to Kennicott glacier
Bear Creek	WRST	small forest stream north of McCarthy Road
Amy Creek	WRST	high-elevation tundra stream in the Chugach Mtns.
May Creek	WRST	small forest stream
Galiano West stream	WRST	clearwater coastal stream west of Galiano Glacier
Icy Bay stream	WRST	small clearwater stream flowing into Icy Bay
Independence Creek	WRST	turbid glacial coastal stream west of Icy Bay
Little Esker creek	WRST	clearwater coastal stream near Little Esker public use cabin
Little Esker Creek trib	WRST	turbid tributary to Little Esker creek
Jack Creek	WRST	large stream along Nabesna Road
Rock Creek	DENA	small steep forested clearwater stream (LTEM study site)
E. Savage River spring	DENA	small springfed stream on terrace east of Savage River
E. branch Toklat spring	DENA	large spring complex on terrace east of Toklat River
Travertine stream	DENA	small travertine-like stream near Stony Creek
Sanctuary River	DENA	large glacially-influenced river (LTEM site)
Moose Creek	DENA	large clearwater river in Kantishna Hills (LTEM site)
Highway Pass Creek	DENA	small dynamic braided stream (LTEM site)
Little Stony Creek	DENA	high-elevation tundra stream (LTEM site)
Little Stony trib center	DENA	small trib of Little Stony Creek located east of Little Stony
Little Stony trib east	DENA	small trib of Little Stony Creek – farthest east
Gorge Creek spring	DENA	small spring-fed tundra stream below Gorge Creek overlook
McKinley Bar spring	DENA	springfed stream on terrace at end of McKinley Bar trail
McKinley Bar creek S	DENA	southernmost small stream along McKinley Bar trail
McKinley Bar creek C	DENA	“center” small stream along McKinley Bar trail
McKinley Bar creek N	DENA	northernmost small stream along McKinley Bar trail
Igloo Creek	DENA	large forested stream (LTEM site)
Tattler Creek	DENA	small steep braided stream (LTEM site)
Igloo Cr. above Tattler	DENA	Igloo Creek sampled above the road construction
E.F. Toklat River	DENA	Large turbid braided glacial river (LTEM site)
E.F. Toklat tributary	DENA	clearwater tributary to E.F. Toklat River (LTEM site)
Hogan Creek	DENA	small groundwater-fed stream (LTEM site)
Savage River	DENA	large clearwater river with some glacial input (LTEM site)

upwards of 30 minutes, which is a substantial portion of the time spent at each site. Instead, we elected to estimate the inter-transect distance by stepping it off in approximately 1-meter intervals. Although this results in some variability in transect location between different sampling efforts (*e.g.*, macroinvertebrates vs. channel geometry), we feel the loss of accuracy is minimal. The goal of the program is to characterize the reach, rather than to establish

monumented cross sections; therefore, the exact locations at which data are collected should not matter.

Biological sampling

Biological sampling protocols were largely adopted from the EMAP WSA Field Protocols (USEPA 2004) and from methods developed at the Western Center for Monitoring and Assessment of Freshwater Ecosystems at Utah State University (Hawkins *et al.* 2003).

Macroinvertebrate samples were collected as follows: a modified net that combines elements of Surber and D-net samplers with a 500 μm mesh was used. At each transect, the net was placed in the stream either on either the left, center or right (haphazardly), 1 meter upstream of the first transect. The position of the first placement was determined by rolling a die, and net placements at subsequent transects followed the pattern left-center-right-left...*etc.* An area of 0.09 m^2 in

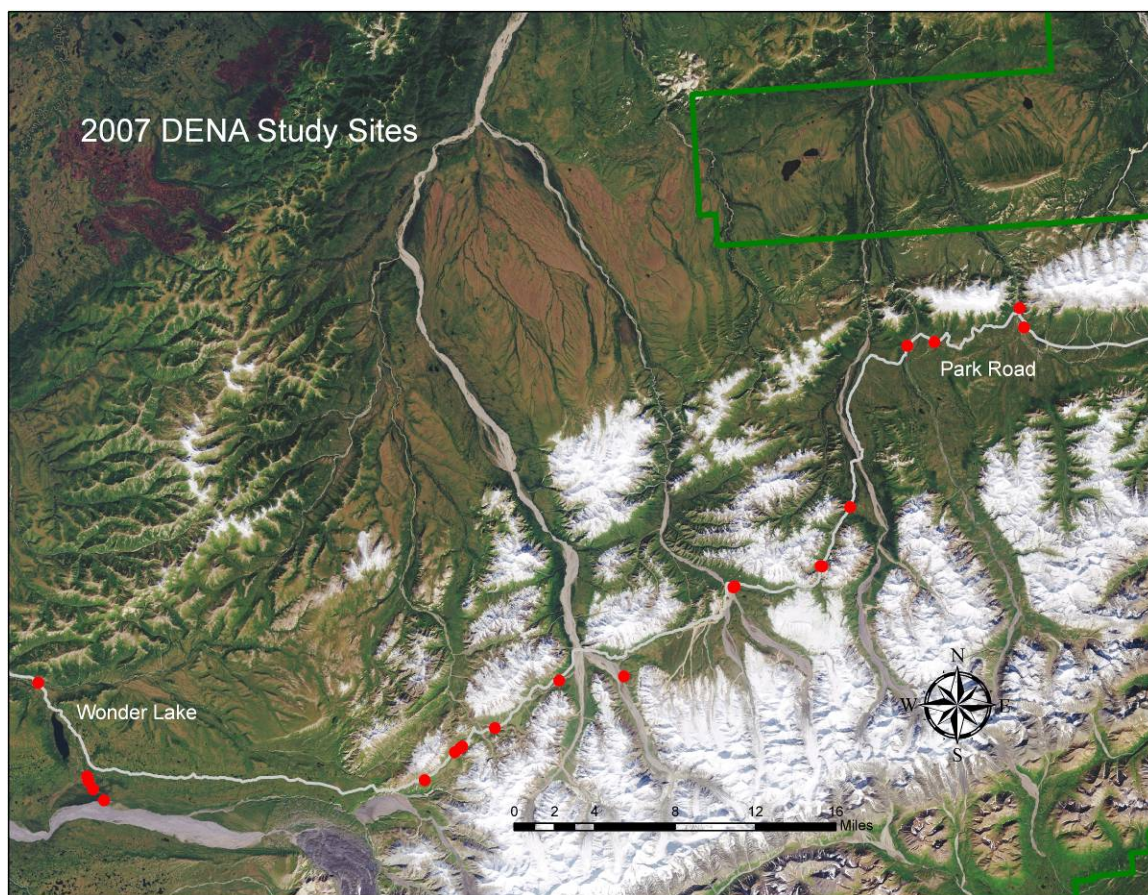


Figure 1. Locations of 2007 study sites in DENA. The easternmost sites are at Savage River; the westernmost is Moose Creek at the Kantishna Bridge.

front of the net opening (as defined by a hinged frame that could be lowered to the stream bed) was thoroughly searched for macroinvertebrates by individually rubbing cobbles in front of the net opening and subsequently disturbing the remaining substrate by raking to a depth of approximately 10 cm. A total of eight macroinvertebrate samples were collected and composited

into a single reachwide sample. This sample represents a total of 0.72 m² of streambed. Macroinvertebrates and organic detritus were separated from cobble and gravel and preserved in 70% ethanol. Macroinvertebrates were sorted and identified to the lowest practical taxonomic level, generally genus, by Mike Cole, a taxonomist for ABR, Inc.

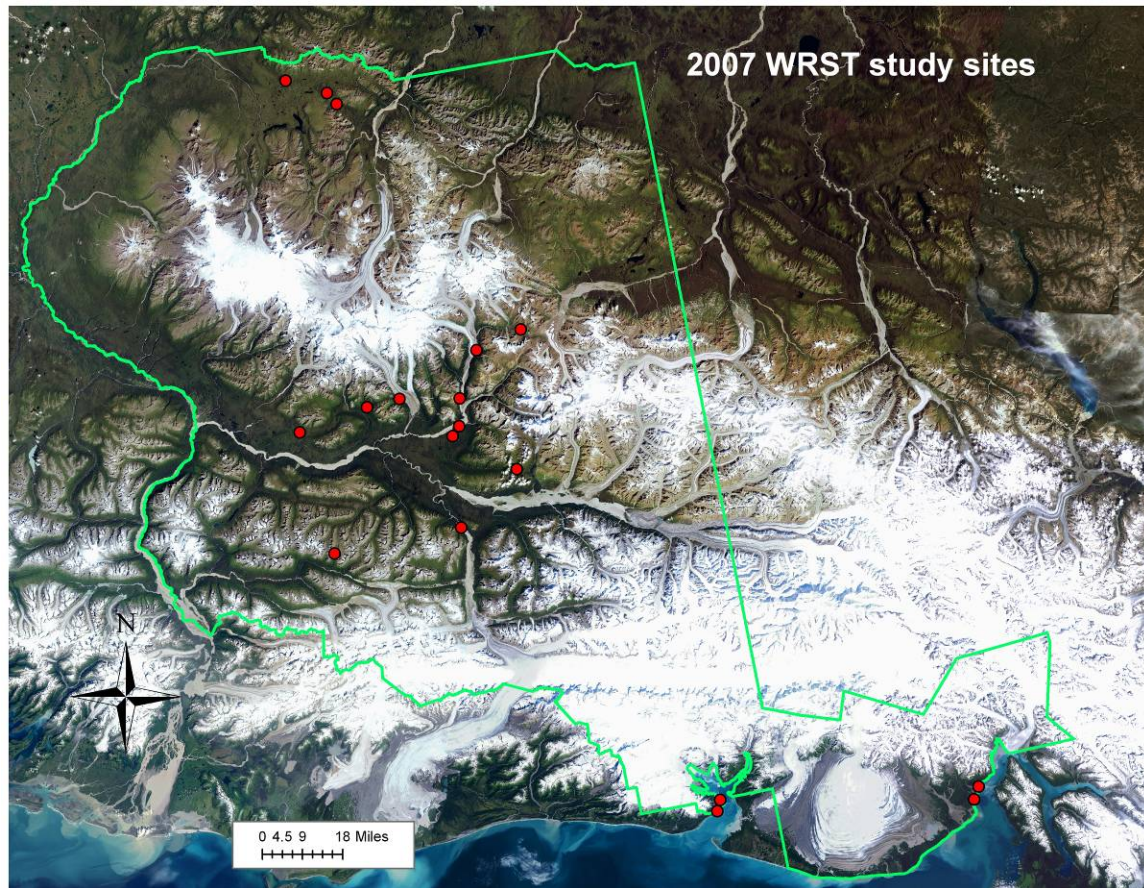


Figure 2. Location of 2007 study sites in WRST. Several sites are not visible at this scale due to their close proximity to other sites.

Benthic diatoms were collected as follows. At each of the eight transects where macroinvertebrates were collected, an appropriate cobble was haphazardly selected along the same cross section used for macroinvertebrate sampling (1 meter upstream of the transect itself). Cobble selection was shifted one “unit” to the right (*i.e.*, if macroinvertebrates were collected in the center of a given transect, a cobble was selected on the right). A defined area (12 cm²) of each cobble was scrubbed and scraped to remove diatoms and the material collected was composited into a single reachwide sample. The total volume (diatoms plus rinse water) was recorded and a 40 mL subsample was removed and preserved with 2 mL Lugol’s solution. Benthic diatoms were identified to the lowest practical taxonomic level, generally species, by Julia Eichmann, a diatom taxonomist for Ecoanalysts, Inc.

Fish were captured by a combination of electrofishing, minnow trapping and angling. We used a Smith-Root Model 15 backpack electrofisher powered by a gas generator. All likely habitats

were fished, and we generally had two netters attempting to collect stunned fish. Wherever possible, these fish were identified and recorded. Captured fish were anesthetized with a mixture of clove oil and ethanol, identified and fork lengths were recorded.

Physical and chemical data collection

We used a HACH Hydrolab sonde to collect temperature, specific conductivity, pH and dissolved oxygen *in situ*. Data were collected in riffles and generally in midstream at the bottom of the reach. *In situ* alkalinity was measured using a HACH field titration kit. In addition, water chemistry samples were collected for later laboratory analysis. The samples included an unfiltered sample for total nitrogen and total phosphorous and a filtered sample for nitrate, ammonium, phosphate and common ions. These samples were frozen at the site using a cooler supplied with dry ice. A third filtered sample, collected for dissolved organic carbon and silicon analysis, was kept cool to prevent the formation of irreversible silicon aggregates.

Physical data collection protocols were largely based on EMAP WSA protocols (USEPA 2004). At each transect, we measured depth (five measurements), width (wetted and bankfull), channel height (bankfull and incised), undercut banks, canopy cover (six measurements) and substrate size class (using a gravelometer – five measurements at depth locations). In intertransect segments, we measured thalweg depth and habitat type (ten measurements), width (one measurement), substrate (five cobbles along width measurement cross-section), woody debris (by size class) and fish cover (macrophytes, filamentous algae, boulders and undercut banks (qualitative estimate of extent)). We measured reach slope using a transit level at some sites. We also measured discharge at a subset of sites using a Marsh-McBirney flowmeter and a topsetting wading rod.

Results and Discussion

Water Chemistry

The water chemistry results (Table 2) revealed a very wide range of conditions across the 2 parks. The exception was pH, which normally does not vary much between unpolluted streams, and is typically in the range of 7.5 – 8.5. For example, sulfate concentrations varied some 600-fold among the sites. By far the highest sulfate levels (>84 mg/L) were observed in the “Travertine stream”, a small, unusual-looking stream that crosses the DENA park road near Stony Creek. It is characterized by extensive deposition of a travertine-like precipitate and water with a slight yellowish cast. This stream was quite alkaline (bicarbonate-carbon = 60 mg/L, vs. a mean value of 25.7 for all streams), with high levels of dissolved minerals such as calcium and magnesium. During high flows the water is actually slightly milky (P. Brease, Denali National Park, personal communication), suggesting that very high levels of minerals may be transported. The origin of this unusual stream has yet to be fully investigated; interestingly, the stream has an above average diversity of aquatic insects (see Macroinvertebrate section below). One possible natural source of elevated sulfate in streamwater is anoxic oxidation of FeS_2 in groundwater by denitrifying bacteria (*e.g.*, Kölle *et al.* 1985), although the presence of elevated calcium and magnesium as well suggests that calcium and magnesium sulfate minerals may be contributing the bulk of the sulfate.

Table 2. Summary water chemistry statistics from 2007 samples.

	Minimum	Mean	Maximum
Temperature	1.8°C	6.9°C	11.9°C
Specific Conductance	61 $\mu\text{S}/\text{cm}$	350 $\mu\text{S}/\text{cm}$	936 $\mu\text{S}/\text{cm}$
pH	7.52	8.02	8.38
Alkalinity ($\text{HCO}_3\text{-C}$)	6 mg/L	25.2 mg/L	60 mg/L
Total nitrogen	40 $\mu\text{g}/\text{L}$	229 $\mu\text{g}/\text{L}$	950 $\mu\text{g}/\text{L}$
Nitrate-N	< 1 $\mu\text{g}/\text{L}$	108 $\mu\text{g}/\text{L}$	372 $\mu\text{g}/\text{L}$
Total phosphorous	3 $\mu\text{g}/\text{L}$	78 $\mu\text{g}/\text{L}$	1546 $\mu\text{g}/\text{L}$
Phosphate-P	< 1 $\mu\text{g}/\text{L}$	4 $\mu\text{g}/\text{L}$	37 $\mu\text{g}/\text{L}$
Sulfate-S	0.14 mg/L	19.9 mg/L	84.9 mg/L
Dissolved organic carbon	0.42 mg/L	2.77 mg/L	40.5 mg/L

Another feature of these streams is the generally low levels of phosphate-P. The mean concentration among all streams was only 4 $\mu\text{g}/\text{L}$, and 20% of samples had undetectable levels (<1 $\mu\text{g}/\text{L}$). Total phosphorus (TP) was also generally low, with a few exceptions. While the mean TP concentration in these streams (78 $\mu\text{g}/\text{L}$) is comparable to the average value (90 $\mu\text{g}/\text{L}$) for wadeable streams in the lower 48 (USEPA 2006), the mean for these streams is driven by a single outlier – Chalk Creek, which in July exhibited a TP concentration of 1546 $\mu\text{g}/\text{L}$. The median concentration for CAKN streams is only 11 $\mu\text{g}/\text{L}$, which is strikingly low. In fact, only a handful of streams had TP concentrations higher than 50 $\mu\text{g}/\text{L}$ – all of these except one were glacial streams with high sediment loads and very low levels of dissolved phosphate. This

suggests that suspended sediment was the source of the high TP levels and that much of it is not biologically available. The one exception was the small tundra stream at Skolai Pass, which had moderately high levels of both TP (58 $\mu\text{g/L}$) and dissolved phosphate (37 $\mu\text{g/L}$). This stream also had very low nitrate (10 $\mu\text{g/L}$) and so is likely to be strongly nitrogen limited, which is unusual for freshwater systems.

The anomalously high TP value at Chalk Creek illustrates an important point about nutrient export in streams in general. Chalk Creek was sampled at high flow in July, following a severe rainstorm. The levels of dissolved nutrients measured that day were very high. For example, the TP measured that day was nearly 100 times higher than it was at the same site three months later. The total nitrogen concentration was only three times higher than at low flow, but still quite elevated (950 $\mu\text{g/L}$) for an unpolluted stream. In combination with the greatly increased flow, it is clear that large quantities of dissolved nutrients can be exported in a very short time during and after high rainfall events. This phenomenon has been observed many times in other systems, and is also typically true of spring runoff. Hence, in order to get an accurate idea of how much nitrate or phosphate is exported from a watershed on an annual basis, it would be necessary to install a flow-triggered continuous sampler and a stream gage.

Finally, one other stream with unusual chemistry was sampled in 2007. This is a small tributary to Rock Creek, located along the Nabesna Road in WRST. It is a brownwater stream, with very high levels of dissolved organic carbon (at 40 mg/L , nearly 40 times higher than the median concentration among all sampled streams). Dissolved organic carbon concentrations in CAKN streams in general (median = 1.03 mg/L) are substantially lower than reported for streams worldwide (median = 5 mg/L ; Wetzel 2001). The stream had very high total nitrogen (550 $\mu\text{g/L}$), but undetectable nitrate, suggesting high levels of organic nitrogen. It also had very low levels of dissolved minerals, consistent with its flowing through highly organic soil.

Macroinvertebrates

Macroinvertebrates were collected from 15 DENA streams and 16 WRST streams in 2007. Observed taxa richness varied tremendously among the sampled sites. The mean richness across all sites was 17 taxa, which is comparable to that observed in 2006 at a different but partially overlapping set of streams. Chironomid midges accounted for approximately 37% of taxa richness across all sites, and 44% of individuals. This is substantially lower than reported by Oswood (1989), who found that chironomids constituted on average 59% of individuals in Alaskan streams.

The lowest richness (a single unique taxon) among the 2007 streams was found in Independence Creek. This site also had very low abundance (8.3/ m^2). While this is in itself not particularly surprising given the dynamic, turbid nature of this glacial stream, it is surprising in light of the large numbers of fish that were captured here (discussed below). The other turbid, braided glacial streams were similarly depauperate, consistent with other studies (*e.g.*, Milner *et al.* 2003, 2006). The highest richness was found in Moose Creek (29 unique taxa) and Savage River (28 unique taxa). Densities varied from a low of 4 individuals/ m^2 at East Fork Toklat River to a high of nearly 8000 per m^2 at Igloo Creek above Tattler. Interestingly, the observed density at the lower Igloo Creek site was less than 3% of this value (275 per m^2). It is not yet clear whether this is a result of the ongoing road construction along Igloo Creek.

A total of 15 aquatic insect taxa not reported by Milner *et al.* (2003) or by Conn (1998) were collected in DENA by the CAKN crew in 2007. These are listed in Table 3, and include both a family not previously reported (Muscidae, also known as muscoid flies), and an unidentified chironomid taxon collected in Hogan Creek. The true total may be higher, as we were able to identify to the species level seven taxa from three genera reported by Milner *et al.* as well as 14 genera from taxa identified only to the family level by Milner *et al.* This serves to illustrate that the streams and rivers of DENA remain woefully understudied, despite nearly two decades of research.

Table 3. List of aquatic insect taxa identified from 2007 CAKN Denali samples and not reported in Milner *et al.* (2003) or Conn (1998). Milner *et al.* sampled 45 streams parkwide.

Ephemeroptera (mayflies)

Acentrella lapponica

Drunella doddsii

Plecoptera (stoneflies)

Capnia spp.

Isocapnia spp.

Prostoia spp.

Arcynopteryx spp.

Diura spp.

Taenionema spp.

Trichoptera (caddisflies)

Apatania spp.

Diptera (true flies)

Limnophora spp. (family Muscidae)

Heterotrissocladius spp.

Micropsectra spp.

Pseudosmittia spp.

Sympotthastia spp.

unknown Orthoclaadiinae

A total of 125 unique macroinvertebrate taxa have now been identified in the two years of the CAKN program. 84 of these first were identified in the 2006 samples, while another 41 were unique to the 2007 samples. It is likely that we will continue to add to this total for a number of years given the relative paucity of stream macroinvertebrate data from these parks, particularly from WRST. One interesting observation was made at the “Travertine stream” in DENA, which has unusual water chemistry and extensive deposition of a travertine-like precipitate (see above in “Water Chemistry” section). As a result of the deposition, the stream contains little in the way of traditional stream habitat for invertebrates; there are only a few small areas of apparent upwelling that remain partially precipitate-free. These areas also accumulate small amounts of particulate organic matter. Despite these seemingly hostile conditions, numerous taxa of

macroinvertebrates were found by informal inspection. Formal sampling for macroinvertebrates did not occur until 2008, when a surprisingly high diversity was observed (discussed in the CAKN Flowing Waters 2008 Annual Report).

Benthic Diatoms

Diatoms were also collected from the same 31 sites. Observed species richness for diatoms was higher than for macroinvertebrates, and varied from a low of two species (Bear Creek in WRST) to a high of 56 species (McKinley Bar spring creek in DENA), with a mean of 28 species per site. A total of 234 diatom species have now been identified through the CAKN program. 166 of these were first identified in samples collected in 2006, while another 68 species were identified in the 2007 samples. To my knowledge, this work represents the first survey for benthic diatoms in DENA attempted to date (*e.g.*, diatoms are not mentioned in either Mangi Environmental Group 2005 or Karle 2006). Prior to the CAKN pilot survey in 2006, there were no extant diatom data from WRST either. To get an idea of how complete or incomplete these data might be as an inventory of CAKN diatoms, I compared our 2007 DENA data to work conducted in 15 streams in the Cook Inlet basin in 2002 (Rinella and Bogan 2004). The total taxonomic richness in the Cook Inlet streams (140 species) was similar to what we found in 15 streams in DENA (129 species); however, only 48 species were common to both data sets. Clearly, much work remains to be done. In general, the lowest species richness and density were found in unstable braided systems, and the highest in stable spring-fed creeks. Although the finding that species richness and densities were lowest in turbid and unstable streams was expected, species richness in some of these systems was remarkably high. For example, the East Fork of the Toklat River had 21 species of diatoms, as opposed to only three macroinvertebrate taxa. Similarly, Independence Creek had 18 diatom species but only 1 macroinvertebrate taxon. The true taxonomic richness in the spring-fed creeks is likely even higher than observed in 2007, as epiphytic diatoms were not collected, and these systems tend to be dominated by moss cover. *Didymosphenia geminata*, an emerging invasive species with a number of unusual properties, is native to boreal streams, but has been observed recently to cause problematic blooms even within its native range. *D. geminata* was identified in 11 of the 31 sites sampled, albeit at low densities. The CAKN program will continue to monitor the distribution and abundance of this species, and we are developing a set of procedures to allow other field personnel in the parks to recognize and collect samples of suspected *D. geminata* blooms.

Fish

Sampling for fish took place in 36 streams. Fish were successfully captured at 24 of these sites (listed in Table 4) using a combination of electrofishing, minnow traps and angling. Electrofishing was conducted at only a handful of sites. Because different capture methods are biased toward different species, these results are illustrative rather than definitive. For example, both slimy sculpin and arctic grayling tend to be poorly represented in minnow trap samples, whereas grayling are easily captured by angling. In contrast, juvenile salmonids are highly susceptible to minnow traps. Several results of the 2007 fish survey are of potential importance. First, we were able to extend the documented distributions of four anadromous salmon species. These species were captured at nine sites where they have not until now been formally reported (Table 4). For example, the capture of juvenile chinook salmon at the Moose Creek site in DENA constitutes a substantial expansion of its known range in the drainage (some 40 km upstream of its previously documented extent). Formal application to add these nine sites (a total

of 12 species range extensions because at least two different species were verified at two of the nine sites) to the State of Alaska's Anadromous Waters Catalog (AWC) was made in 2007. These changes were accepted by the Alaska Department of Fish and Game in 2008 and will be included in the 2009 version of the AWC. Second, the high concentrations of juvenile Arctic grayling observed in the spring-fed creeks along the McKinley Bar trail (the only places in DENA we observed large numbers of juveniles) suggests that these sites may be important rearing areas. Accordingly, we will continue to monitor spring creeks on McKinley Bar in 2008 and beyond. Third, we found surprisingly high numbers of fish in two glacial streams. Both Moonshine Creek and Independence Creek are dynamic, turbid, glacial streams. Moonshine Creek is extensively braided as well. We captured eight Dolly Varden in minnow traps in Moonshine Creek. In Independence Creek, we captured seven Dolly Varden, 17 coho salmon

Table 4. Summary of 2007 fish data.

Site name	Species identified (number)
DENA	
Savage River	Arctic grayling (5) ^b
Sanctuary River	Slimy sculpin (11), Arctic grayling (2) ^a
E.F. Toklat River	Arctic grayling (15) ^a
E.F. Toklat tributary	Arctic grayling (10) ^a
Igloo Creek	Arctic grayling (1) ^a
Igloo Creek above Tattler	Arctic grayling (10) ^a
Little Stony Creek	Arctic grayling (10) ^a
Moose Creek	Chinook salmon (3) ^j , slimy sculpin (1)
McKinley Bar spring	Arctic grayling (~25) ^b
McKinley Bar south creek	Arctic grayling (~11) ^b
McKinley Bar center creek	Arctic grayling (~10) ^b
McKinley Bar north creek	Arctic grayling (~40) ^b
WRST	
Gilahina River	Rainbow trout (3) ^b , Dolly Varden (5) ^b , sockeye salmon (6) ^a
Nizina River tributary	Dolly Varden (4) ^j , coho salmon (16) ^j
Lake Creek	Coho salmon (~50) ^{j, #}
Young Creek	Dolly Varden (29) ^b
Willow Creek (July)	Dolly Varden (6) ^b , chinook salmon (2) ^a
Willow Creek (September)	Dolly Varden (12) ^b , coho salmon (2) ^a
Moonshine Creek	Dolly Varden (8) ^b
May Creek	Dolly Varden (51) ^b
Galiano West stream	Dolly Varden (5) ^b , coho salmon (28) ^j , chinook salmon (3) ^j , pink salmon (1) ^a
Icy Bay stream	Coastrange sculpin (8), coho salmon (3) ^j
Independence Creek	Dolly Varden (7) ^b , coho salmon (17) ^j , coastrange sculpin (13)
Little Esker stream	Dolly Varden (2) ^a , coastrange sculpin (2), pink salmon (8) ^a

^j Juvenile fish only

^a Adult fish only

^b Both juveniles and adults present

bold indicates an extension of the Alaska Anadromous Waters Catalog for this species

[#] Identification was by visual observation and was tentative; however, the presence of coho salmon at this site was confirmed in 2008.

and 13 coastrange sculpin in minnow traps in less than an hour. What makes this so surprising is the very low density of macroinvertebrates in both of these streams, especially Independence Creek (8.3 invertebrates per m²). It is not clear what these fish are eating. Further research may be warranted to address this question. One possibility is that flow was temporarily higher than normal due to recent precipitation; this might have led both to increased turbidity and to anomalous macroinvertebrate data (macroinvertebrates tend to seek refuge deep in the hyporheos during high flow events).

A final note is that while the methods we employed cannot be used to generate population estimates, there was a clear, if anecdotal, difference in grayling numbers above and below the road construction on Igloo Creek. The lower site appears to be excellent grayling habitat, yet we captured no grayling by angling, and only a single juvenile by minnow trapping. Above the construction area, we easily and rapidly captured ten grayling by angling (minnow traps were not deployed at this site). This is consistent with the difference in macroinvertebrate densities we observed, but cannot be confidently attributed to the construction based on the evidence we have at present.

Comparison between LTEM and CAKN macroinvertebrate data

An important focus for the 2007 field season was to test whether legacy invertebrate data collected in Denali National Park and Preserve (DNA) as part of the Long Term Ecological Monitoring Program (LTEM) would be compatible with data collected using the Central Alaska Network (CAKN) stream monitoring protocols. Under the direction of Sandy Milner, invertebrate samples have been collected annually since 1994 at 14 sites along the Park Road. Furthermore, the program collected macroinvertebrate data in 1994-1996 from a total of 58 streams located throughout DNA. These data provide an invaluable starting point for the determination of long-term trends in the ecology of DNA streams; however, differences in the field methods used by Milner and the CAKN program have the potential to complicate efforts to synthesize these two data streams. To determine the degree to which the two datasets are compatible, each group sampled the same ten streams along the park road within a relatively brief time period (in all cases less than five days separated visits by the two groups). There are several differences in field and laboratory methodology that might be expected to lead to differences in the resulting macroinvertebrate samples.

First, the CAKN protocol calls for establishing a sampling reach that varies in length according to the average width of the stream. The standard sampling reach for the CAKN program is 40 times the mean wetted width, with a minimum of 150 meters and a maximum of 500 meters; this proportion is based on studies conducted for the Environmental Protection Agency's Ecological Monitoring and Assessment Program (EMAP – see Reynolds *et al.* 2003, USEPA 2004). The idea behind this approach is to ensure that the sampling reach encompasses a representative set of habitat units in each stream regardless of its size. In contrast, the LTEM program uses a standard reach length of approximately 10 meters for all stream sizes (Milner *et al.* 2003). Table 5 lists the 10 sites that were sampled by both groups, along with the reach length for the CAKN sampling visit and the approximate location of the CAKN sampling reach.

Secondly, there are differences between the two programs in the sampling approach within each reach. The CAKN program establishes a set of 11 equally spaced transects in the reach that serve

as the basis for all further data collection. Macroinvertebrates are collected from a 0.09 m² area at each of the first eight transects using a systematic sampling approach with a random start (total area sampled = 0.72 m²). The LTEM protocol calls for the collection of 0.09 m² samples from each of five haphazardly selected locations (total area sampled = 0.45 m²). To account for this difference in sampling effort, abundances were converted to densities (organisms/m²).

Third, the LTEM collection net has a mesh size of 343 µm, whereas the CAKN program uses a collection net with a 500 µm mesh size. While this probably has some effect in terms of differential retention of smaller organisms, especially chironomidae, a recent study comparing samples collected with these mesh sizes found that the differences were relatively minor (Rinella and Bogan 2006). This study found no significant difference in taxa richness among the two

Table 5. Streams sampled by both CAKN and S. Milner in 2007 for comparative data analysis.

Stream name (reach length in meters)	Description of CAKN sampling reach
Savage River (400 m)	Top of reach ~200 m downstream of bridge
Hogan Creek (150 m)	Reach starts ~50 m above road
Sanctuary River (500 m)	Reach starts opposite pullout ~1/4 mile past bridge
Igloo Creek (250 m)	Reach starts ~100 m above bridge
Tattler Creek (150 m)	Reach starts ~50 m above road
East Fork Toklat River *	Reach starts ~50 m above tributary confluence
East Fork Toklat tributary (150 m)	Reach starts ~200 m above confluence
Highway Pass Creek (150 m)	Reach located ~1500 m above Toklat confluence
Little Stony Creek (150 m)	Reach starts ~50 m above road
Moose Creek (500 m)	Top of reach at Kantishna bridge

*The E.F. Toklat is a dynamic braided river. For this type of system, we use a “transverse” reach across the floodplain and sample all braids.

mesh sizes. Although there was a statistically significant difference in %chironomidae, the effect size was small (41% vs. 35%). An evaluation using the classification strength-sample method comparability index (CS-SMC; Cao *et al.* 2005) revealed that within- and between-method variability was identical. This indicates that data collected using either mesh size are fully comparable with data collected using the other mesh size.

Finally, macroinvertebrates collected by the CAKN program and the LTEM program are identified by different experts. The CAKN samples are analyzed by a professional taxonomist (albeit with limited experience with Alaskan stream fauna prior to this project). Samples collected by the LTEM program are analyzed by students working under the direction of Dr. Milner, who has years of experience working with Alaskan stream fauna. Aquatic macroinvertebrate taxonomy is challenging and dynamic, and some specimens may be interpreted differently by different practitioners. This has the potential to introduce another source of variability when comparing data sets. Differences in the level of taxonomic resolution between the two programs complicate direct comparison of the datasets somewhat. To bring the datasets into taxonomic agreement required a number of adjustments. Most of these involved

collapsing taxa in the CAKN dataset back to a lower level of taxonomic resolution to match that found in Milner's dataset (see Table 6).

However, there were also two cases of clear disagreement on the identities of particular taxa. One such case involves the perlodid stonefly genera *Isoperla* and *Arcynopteryx*. In six instances, the CAKN taxonomist identified no *Isoperla* and multiple *Arcynopteryx* while Milner's group identified the opposite pattern (and in fact has never reported *Arcynopteryx* from any sample collected in DENA). In one other instance, the CAKN taxonomist identified both genera while Milner's group again identified only *Isoperla*. I requested that our taxonomist re-examine the

Table 6. Taxa identified to a higher level of resolution by CAKN than reported by Milner in 2007 or listed in Conn (1998) or Milner *et al.* (2003).

Taxa identified to species by CAKN rather than genus

Ephemerella excrucians
Epeorus grandis
Epeorus deceptivus
Zapada cinctipes
Zapada Oregonensis
Isoperla petersoni
Isoperla sobria

Taxa identified to genus or species by CAKN rather than family

Chelifera/Metachela spp.
Clinocera spp.
Dixa spp.
Neoplasta spp.
Oreogoton spp.
Wiedemannia spp.
Pericoma spp.
Metacnephia spp.
Prosimulium spp.
Simulium spp.
Twinnia spp.
Arctotipula spp.
Dicranota spp.
Rhabdomastix spp.

specimens in light of this disagreement. He confirmed the identification of the specimens in the CAKN samples as *Arcynopteryx* and provided the following likely explanation for the discrepancy:

“The abdomen lacks any striping and submental gills (while small) are present - this combination of characters can be used to separate the Perlodinae (including Arcynopteryx) from

the Isoperlinae (including Isoperla). Arcynopteryx actually closely resemble Skwala, but mature specimens of the former are larger, pleural folds occur on abdominal segments 1-3, and they lack the mesal hair tufts on the head that occur on Skwala. I've seen some Arcynopteryx with faint patterns on the abdomen that almost resemble stripes and the submental gills can be very small. I suspect this is why Sandy Milner's lab has not been able to distinguish them from Isoperla (if they have sampled both)."

Although it is possible that the two groups actually collected organisms from different genera in every case, it is unlikely. Therefore, we have assumed for comparative purposes that the specimens identified as *Isoperla* by Milner's group are in fact *Arcynopteryx*. In the second case, the CAKN identified *Drunella doddsii* from two streams where Milner's group reported *Drunella grandis* instead. I again requested that the taxonomist re-examine the CAKN samples and he confirmed that the specimens in question are definitely *D. doddsii*:

"D. doddsi vs. D. grandis - the ventral setal disk is obvious in these specimens. They're undoubtedly D. doddsi."

While again, it is possible that the two groups actually collected different genera from these streams, the more likely explanation is a potential misidentification; therefore, for the purposes of comparison I have assumed that specimens reported as *D. grandis* by Milner's group are actually *D. doddsii*. We hope to resolve these discrepancies soon, preferably by a reciprocal exchange of samples. It is important to note that taxonomic discrepancies between datasets developed by different programs, and generally using different taxonomists, are a common challenge in stream ecology in general, and for large-scale monitoring programs in particular. Stribling *et al.* (2003) showed that in one test, the mean percent disagreement between two taxonomy labs given the same 54 samples was 17%; in other words, taxonomy can often be a substantial source of error. It is therefore critical that we develop taxonomic standards for the CAKN monitoring program.

After making the taxonomic adjustments listed in Table 7, there are 40 unique taxa among the among datasets. Mean taxa richness for the CAKN samples was 35% higher (13.9 taxa/site) than for the LTEM samples (10.8 taxa/site). Mean density (organisms/m²) was 31% higher in the CAKN samples. These differences are potentially problematic; however, since most of the analyses CAKN will use to examine status and trends in macroinvertebrate communities use either presence-absence data or log-transformed abundances, only the difference in taxa richness is likely to have a substantial impact.

At nine of the ten sites, taxa richness was higher in the CAKN sample. At Savage River, the difference was nearly two-fold (23 vs. 12). The next two largest differences (excluding the East Fork Toklat River, which has very low abundance and richness and hence would be expected to vary tremendously between any two samples) were also observed in large, wide rivers. At Sanctuary River, the CAKN sample had 25% higher richness (16 vs. 12), and at Moose Creek the difference was 39% (25 vs. 18). It is at these sites, which are more than 20 meters wide, that the difference in reach length may be most affecting the results, since the Milner group is sampling a reach that is less than ½ of the width, whereas the CAKN group is sampling 500 meters of

stream. It is likely that this difference in sampling methodology accounts for most of the discrepancies in taxa richness. Further analyses, currently underway in collaboration with Dr. Milner and the CAKN data analyst, should shed some light on the degree to which these differences will impact our ability to combine the 2 data streams.

Table 7. Taxonomic adjustments made to 2007 CAKN and Milner macroinvertebrate data sets to allow direct comparison.

Collapse all chironomidae to family
 Collapse *Epeorus* *deceptivus* to genus
 Collapse *Ephemerella* *excrucians* to genus
 Collapse all Capniidae to family
 Collapse *Podmosta* and *Prostoia* to *Podmosta/Prostoia*
 Collapse all *Zapada* species to *Zapada*
 Collapse *Ecclisomyia* to Limnephilidae
 Delete small Chloroperlidae
 Delete small Perlodidae
 Delete Empididae pupae
 Delete small Tipulidae
 Change Milner's *Isoperla* to *Arcynopteryx*
 Change Milner's *Drunella grandis* to *Drunella doddsi*

We also looked at differences in species composition between the two sets of samples. Natural variability (spatial and temporal) in macroinvertebrate community composition presents a major challenge for the detection of trends in stream ecosystems. This variability can be substantial; hence, it is critical that other sources of variability, such as those due to sampling error, be minimized.

We have so far used several approaches to attempt to address the degree of variation in composition between the two data sets. We calculated Bray-Curtis distance among all sets of sites, using log-transformed density data to minimize the effects of extremes in abundance. Bray-Curtis distance is a measure of the degree to which the taxa lists of two samples overlap. It varies from zero to one, with a value of zero indicating that two samples are identical, and a one indicating that they share no taxa in common. The mean Bray-Curtis distance among all streams was 0.63, meaning that on average a given DENA LTEM stream shares 37% of its taxa with any other DENA LTEM stream. The mean Bray-Curtis distance between pairs of samples from the same stream was 0.38, meaning that on average, a sample taken by CAKN and a sample taken by Milner's group from the same site share 62% of their taxa. The East Fork Toklat River samples are outliers in this analysis, because they have so few taxa that any difference, even the absence of a single taxon, between the two samples is exaggerated. If the East Fork Toklat samples are removed from the analysis, the mean between-sample distance falls to 0.34. In most cases the between-sample distance for a given site is less than the distance between either sample (CAKN or Milner) and a sample from any other stream. Exceptions (again ignoring the East Fork of the Toklat River) included Igloo Creek and Sanctuary River, where both CAKN and Milner samples were more similar to at least one other sample than they were to the

corresponding same-site sample. Milner's Igloo Creek sample was more similar to either Tattler Creek sample (0.30, 0.30) than to the CAKN Igloo Creek sample (0.38). The CAKN Igloo Creek sample was more similar to the CAKN Tattler Creek sample (0.35) than to the Milner Igloo Creek sample (0.38). The CAKN Sanctuary River sample was slightly more similar to the Savage River CAKN sample (0.44) than to the Milner Sanctuary River sample, while the Milner sample was more similar to the Milner Little Stony Creek sample (0.42) than to the CAKN sample.

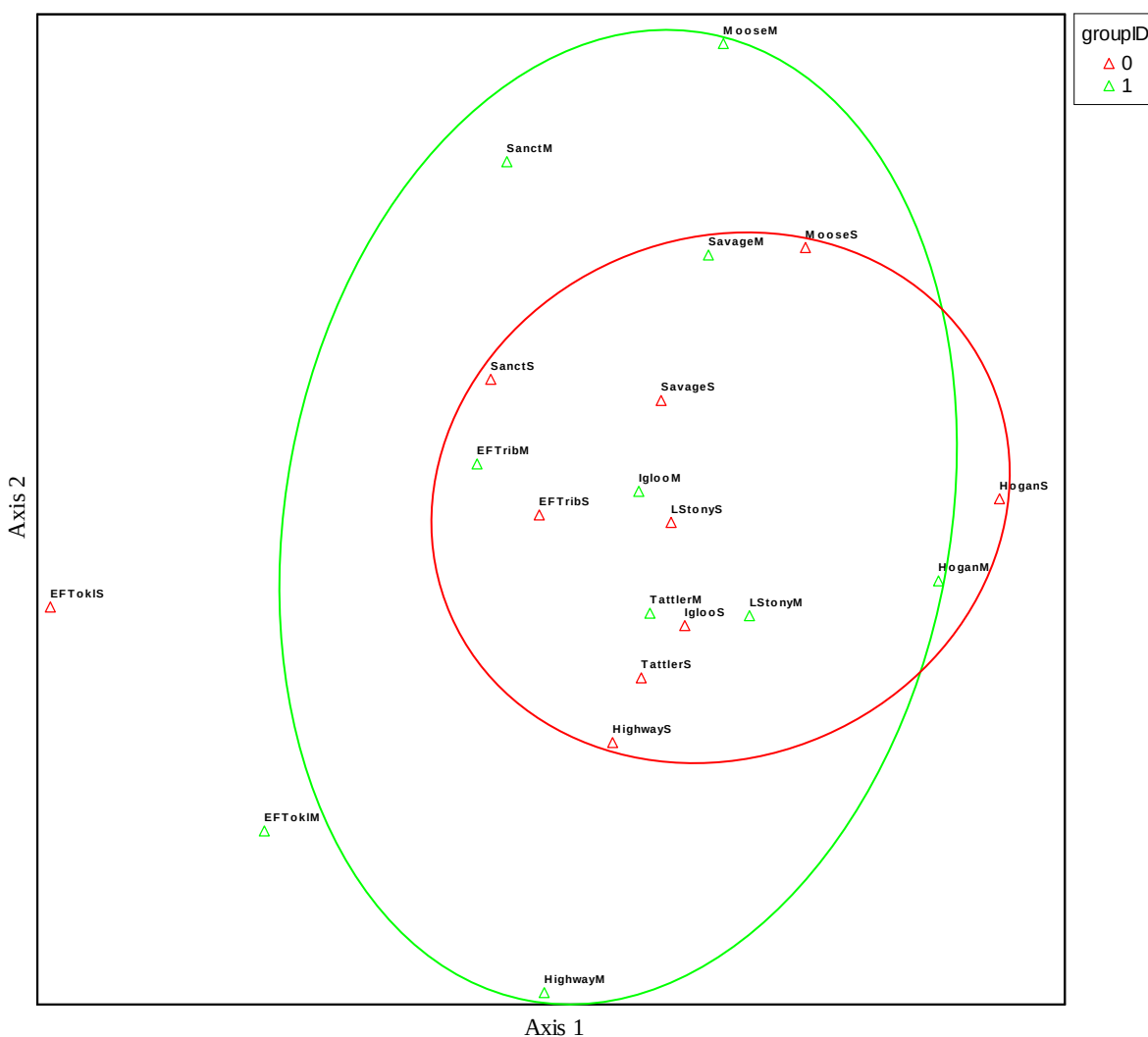


Figure 3. Non-metric Multidimensional Scaling (NMDS) ordination of combined 2007 macroinvertebrate data. Abundances were log-transformed prior to calculation of Bray-Curtis distance. Names ending in “S” (shown in red) refer to samples collected by Sandy Milner’s group; those ending in “M” (shown in green) refer to samples collected by CAKN. The ellipses were constructed to contain all samples except the East Fork Toklat River samples. Orientation of axes is arbitrary. Abbreviations: Moose = Moose Creek, Savage = Savage River, Sanct = Sanctuary River, Igloo = Igloo Creek, Hogan = Hogan Creek, LStony = Little Stony Creek, Tattler = Tattler Creek, EFTrib = East Fork Toklat tributary, EFTokl = East Fork Toklat River.

Although the mean between-sample distance is about ½ of the mean between-stream distance, it is still higher than it should be. In 2006, the CAKN program resampled a single reach (Chalk Creek in WRST) 5 times in one day. The mean Bray-Curtis distance among these replicate macroinvertebrate samples was 0.14, meaning that they shared 86% of their taxa lists on average. The mean distance among all WRST streams sampled in 2006 was 0.66, which is comparable to the mean for these Denali streams. The remaining variability between the two data sets could result largely from taxonomic differences we have not yet identified (Stribling *et al.* 2003) or may stem from the differences in field methodology or from a combination of both. On the other hand, the mean between-sample distance among the Chalk Creek replicate samples was 0.33 for diatoms (compared to 0.66 for all streams). Hence, the 2 macroinvertebrate sampling methodologies are at least as comparable as replicate diatom samples. However, diatoms are generally more spatially variable within habitats than macroinvertebrates.

We also used two multivariate techniques to compare the 2 methodologies. Non-metric Multidimensional Scaling (NMDS) is an ordination technique that reduces the dimensionality of a dataset while maintaining the rank order of intersite Bray-Curtis distances. This allows us to “visualize” the distance matrix in 2 or 3 dimensions. The NMDS ordination is shown in Figure 3. The distances between sites in the ordination are related to the relative similarity of the species

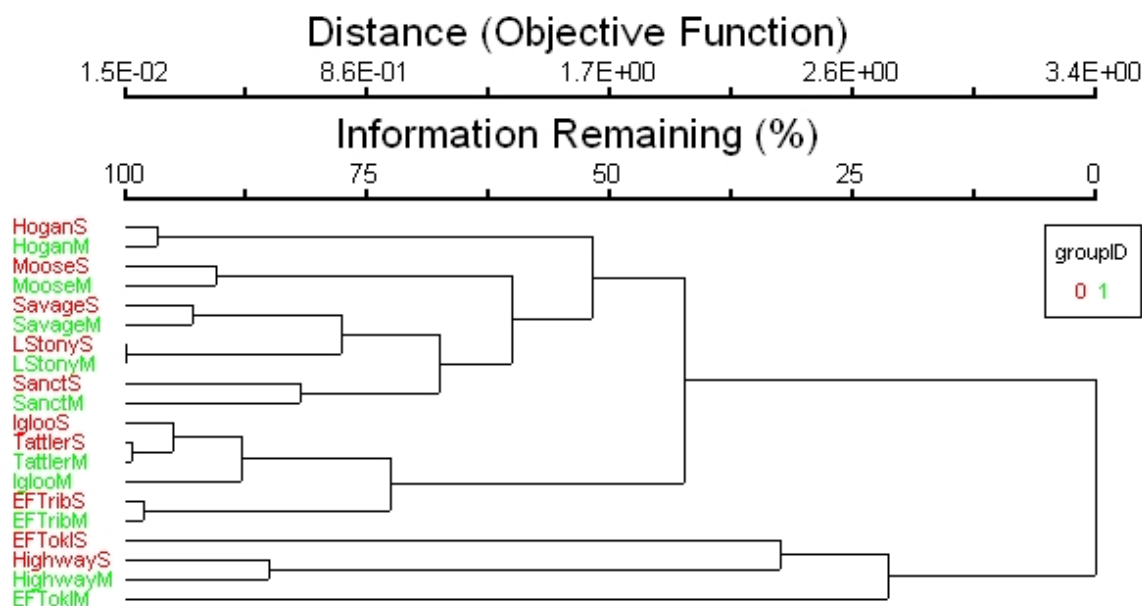


Figure 4. Dendrogram of a flexible- β cluster analysis ($\beta = -0.25$) of the combined 2007 DENA macroinvertebrate data. Abundances were log-transformed prior to calculation of Bray-Curtis distance. Names ending in “S” refer to samples collected by Sandy Milner’s group (shown in green); those ending in “M” refer to samples collected by CAKN (shown in red). The path length between any two sites represents how similar they are in terms of species composition (longer paths indicate more difference). Site name abbreviations are the same as in Figure 3.

compositions at those sites, although because the figure only shows 2 dimensions of a 3-dimensional ordination, the perceived distance between sites depends to some extent on the orientation of the axes, which is arbitrary. Nevertheless, the ordination reveals that as a group the Milner samples are substantially more similar to each other than the CAKN samples are (the CAKN samples are more “spread out” in ordination space). Compare the size of the ellipses marked on Figure 3 to see this. This discrepancy could be a consequence of the systematic absence of species from the LTEM samples that are important determinants of between-site differences, although there are other possibilities, which we are actively investigating. It also suggests that there is no systematic bias in the observed differences in species composition (which would lead to a coherent displacement of one point cloud relative to the other), although this is complicated by the dependence on perspective discussed above.

Figure 4 shows another way of looking at the same data, using cluster analysis. Cluster analysis recursively partitions the data into groups in such a way that the members of a group are more similar to each other than to members of other groups. The path length between any two sites in the figure is related to the difference in species composition, with longer paths indicating greater difference. The cluster analysis shows that some pairs of samples are quite similar to each other (Hogan Creek, Little Stony Creek and Tattler Creek, East Fork Toklat tributary), whereas others are moderately different (Moose Creek, Savage River, Igloo Creek, Sanctuary River, Highway Pass Creek). While all sample pairs (except East Fork Toklat River) cluster together at standard information cutoff levels (50-75%), the differences are in many cases substantial enough that they may be problematic for change detection and other types of analyses. We are currently in the process of subjecting these data to more sophisticated analyses to determine in a more quantitative way how comparable the two methodologies will be for the types of analyses we are interested in using in the CAKN monitoring program. As part of this process, we will in 2009 be maintaining each individual subsample from the composite reach sample separately at these sites (using the CAKN methodology). Milner’s group already maintains subsamples separately. This will allow us to account for imperfect detectability of taxa, and generate more accurate estimates of species richness.

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Fort Collins, CO 80525

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