Ecological condition of wadeable streams in the Tanana River basin, interior Alaska

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Introduction

This report summarizes field data collected during 2004 and 2005 as part of a study designed to assess the ecological condition of wadeable, perennial streams in the Tanana River basin, interior Alaska. This project was conducted as a pilot study in conjunction with the U.S. Environmental Protection Agency's (EPA) Wadeable Streams Assessment (WSA), the first nationally consistent, statistically valid assessment of the ecological condition of streams in the conterminous United States (EPA 2006). Alaska's WSA pilot study was funded by the EPA and was a cooperative effort between the EPA, the Alaska Department of Environmental Conservation (ADEC), the University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI), the University of Alaska Fairbanks' School of Fisheries and Ocean Sciences, and the U.S. Geological Survey (USGS).

The WSA used the Environmental Monitoring and Assessment Program (EMAP) methodology developed by the EPA's Office of Research and Development – this approach was designed to estimate the current status and trends of the nation's ecological resources and to examine the relationship between ecological condition and natural and human disturbances. Defining characteristics of the EMAP approach include probabilistic site selection and the use of a standardized sampling design and standardized ecological indicators. The EMAP sampling design treats stream networks as continuous entities, allowing statistically valid inferences regarding the entire population of streams in a study region (Herlihy et al. 2000). For survey sampling, sites are randomly selected utilizing a Generalized Random Tessellation Stratified Reverse Hierarchical Order method (EPA 2008). This system provides uniform spatial coverage, allows for the selection of sampling strata in proportion to their abundance, and ensures sample representativeness. The ecological indicators are quantifiable attributes of the aquatic physicochemical environment, physical habitat, periphyton standing stock, and macroinvertebrate assemblage.

Nationally, the WSA focused on assessing the biological condition of smaller streams that are shallow enough to be readily sampled by wading. In the conterminous United States, wadeable streams do not require the use of a boat and specialized sampling equipment, making field data collection relatively quick and inexpensive. This is not the case in Alaska, where long hikes or helicopters are required to access most sites. In general, relative to larger systems, wadeable streams have been thoroughly studied and their ecological indicators are well developed, but are undersampled in many traditional monitoring programs. The vast majority of streams are wadeable (> 90% of stream miles in the U.S.; EPA 2006), making them biologically and culturally important resources. Intermittently flowing streams (i.e., those that cease to flow for part of the year) were omitted from biological sampling because ecological indicators for these waterbodies have yet to be refined.

Understanding the current condition of Alaska's streams is essential for setting meaningful benchmarks to maintain their quality and for predicting and detecting changes associated with climate change and other impacts. Toward this end, this report provides a baseline assessment to track ecological status and trends in Tanana basin wadeable streams. Summaries are presented of the most important physicochemical, habitat, and biological metrics. Preliminary results of a modeling approach for helping detect and diagnose changes in ecological condition at stream sites based on deviations from predicted macroinvertebrate functional feeding group composition is discussed. Finally, two studies conducted in conjunction with this survey are presented as appendices. The first study compared macroinvertebrate assemblages collected with 350-µm mesh size (the standard for Alaska's biological monitoring program) to those collected with 500-µm mesh (the EPA EMAP standard) (Appendix G). The second study, conducted in the Tanana Basin during the summer of 2005, compares macroinvertebrate and diatom assemblages from watersheds that burned during the extensive 2004 fires to those in unburned watersheds (Appendix H).

Methods

Study area

The Tanana River watershed (Figure 1), a major tributary to the Yukon River in interior Alaska, was selected for the EMAP wadeable streams demonstration project. The basin is comprised of parts of three different level-2 ecoregions: the Tanana-Kuskokwim Lowlands flank the south side of the mainstem Tanana and contain the lower portion of the southern tributaries, the Alaska Range contains the upper portions of the southern tributaries, and the Yukon-Tanana Uplands contain the northern tributaries (Nowacki et al. 2001). Intermittent permafrost is found throughout the basin and the climate is dry continental with cold winters and relatively warm summers. In terms of elevation, terrain, glaciation, soils, and vegetation, however, the Tanana basin presents a highly variable landscape.

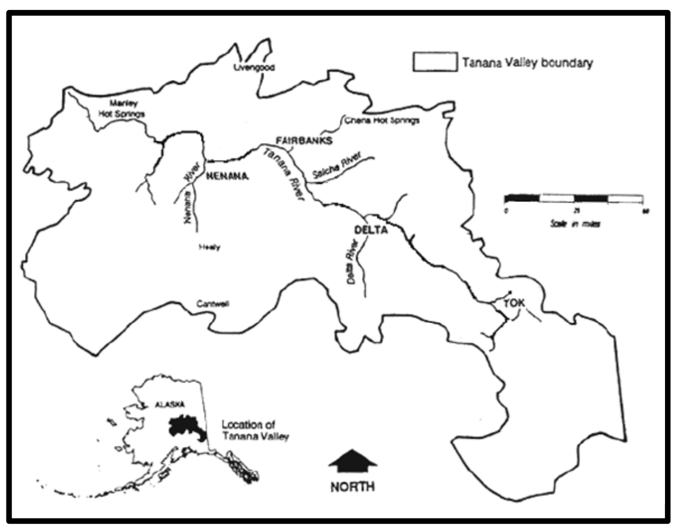


Figure 1. The Tanana River basin.

The Alaska Range (Figure 2) is an arc of high mountains that comprise the southern boundary of the Tanana basin and intercept much of the precipitation from the Gulf of Alaska. Soils are shallow and rocky. High slopes are sparsely vegetated with tundra communities or are barren; lower elevations and valley bottoms contain shrub communities of birch, willow, and alder; and forest stands occur in some of the lowest valleys. Glaciers are common along the spine of the Range, giving rise to braided streams that carry vast sediment loads northward to the Tanana River (Nowacki et al. 2001).

Tanana-Kuskikwim Lowlands (Figure 3) consist of an alluvial plane draining northward from the Alaska Range. Due to impermeable soils and intermittent permafrost, surface water is relatively common despite the dry climate. The region is dominated by boreal forests, with black spruce stands occurring in bogs and on north-facing slopes, white spruce, paper birch, and trembling aspen on south-facing slopes, and balsam poplar and white spruce in well-drained riparian soils. Permafrost areas contain dwarf birch and ericaceous shrubs with sedge tussocks (Nowacki et al. 2001). Groundwater from the Alaska Range reemerges from alluvial deposits as numerous seeps and springs, some of them being quite large (Laperriere 1994).

The Yukon-Tanana Uplands (Figure 4) are a band of rounded mountains between the Tanana and mainstem Yukon. Upland surfaces are dominated by bedrock and colluvium and the deep, narrow valleys are dominated by alluvial deposits. Low elevations are dominated by boreal forests similar to that of the Tanana-Kuskokwim Lowlands while alpine areas support dwarf birch, ericaceous shrubs, and *Dryas*-lichen tundra. Lightning strikes and associated forest fires are common. Glaciers are absent and the clear Tanana River tributaries are important for stocks of spawning chinook, coho, and chum salmon (Nowacki et al. 2001).

This basin has a wide variety of land uses, including forestry, agriculture, mining, recreation, subsistence, and national defense. Fairbanks is by far the largest community, with a 2007 population of 35,540 for the city and 82,840 for the entire North Star Borough (U.S. Census Bureau data). Suburbs (i.e., North Pole), smaller towns (e.g., Nenana, Delta Junction, Tok), and numerous villages are scattered throughout the basin. The majority of the basin is, however, uninhabited, with little or no localized human impacts. As such, any random sampling of streams is likely to yield a population of sites whose watersheds have experienced negligible human impacts.

Aside from the localized impacts mentioned above, we anticipate ecological changes stemming directly and indirectly from global climate change to occur over the upcoming years or decades. Melting permafrost and associated changes in vegetation communities will likely increase nutrient and dissolved organic carbon loads (Wrona et al. 2006). Coupled with warmer water and longer growing seasons, this may increase primary and secondary production while favoring certain macroinvertebrate and fish species over others. Due to Alaska's relatively cold water temperatures, small increases in water temperature can have a large impact on the overall heat budget of streams. A 4°C increase in water temperature over a four-month ice-free season will increase the heat budget of a waterbody by 500 degree-days, approximately a 50–100% increase (Oswood et al. 1992). Such large change in the thermal regime of streams will undoubtedly favor some taxa over others and foster changes in the composition of the region's biological communities. The intensity of spring break-up, a major disturbance in northern rivers, is expected to decrease with warming temperatures, possibly altering the diversity of stream communities (Scrimgeour et al. 1994). Changes in the period of ice cover and the timing and magnitude of snowmelt may exacerbate the above changes. Possible indirect changes linked to climatic warming include increased intensity and frequency of wildfires and insect outbreaks (National Assessment Synthesis Team 2001). Such changes can have sudden and drastic impacts on forest structure and, in turn, on stream ecosystems (Minshall et al. 1997, Zimmerman et al. 2000, Rinella et al. 2009).

Figure 2. Representative stream sites in the Alaska Range ecoregion. Clockwise from upper left: Sites 73, 122 (Big Grizzly Creek), 7 (Moose Creek), and 98 (Till Valley).

Figure 3. Representative stream sites in the Tanana-Kuskokwim Lowlands ecoregion. Sites 63 (upper panel) and 85 (lower panel).

Figure 4. Representative stream sites in the Yukon-Tanana Uplands ecoregion. Clockwise from upper left: Sites 23 (Monument Creek), 54 (Upper Boulder Creek), 17, and 147 (Chatanika River).

Site Selection

Site selection generally followed that of EPA's Wadeable Streams Assessment program (EPA 2006). Site selection was carried out by Tony Olsen at the EPA's National Health and Environmental Effects Research Lab (Corvallis, OR) with cooperation from ADEC, ENRI, and

USGS. Our target population consisted of all wadeable perennial streams within the Tanana River basin and our sampling goal was 50 sites. Site selection was based on stream attributes in the USGS National Hydrography Dataset – High Resolution Dataset for Alaska (NHD). The cataloging units (CU) 19040501 – 19040509 and 19040511 (available from the NHD ftp site as of February, 2004) were appended using the "append_NHD tool 2.27", creating continuous coverage for the Tanana basin (Figure 5). Since no coverage was available for CU 19040510 in the southwest portion of the basin, we eliminated streams in this CU from the target frame.

While EMAP protocols for probabilistic site selection use Strahler stream orders as multi-density categories to weight larger streams since their proportional abundance is low relative to headwater streams (EPA 2006), the NHD data for the Tanana basin lacked this attribute. The USGS Alaska Science Center initiated the calculation of stream order in conjunction with this project and determined that completion within the time frame was not feasible. As an alternative, other NHD attributes were used as surrogates for stream size, making the assumption that named streams tended to be larger than unnamed streams. Our multi-density categories were as follows: (1) named rivers and streams including headwater and start reaches with names ("Named Rivers"), (2) headwater and start reaches excluding any named reaches ("Headwaters"), and (3) in-network streams that were not in category 1 or 2 ("Other Network"). Non-networked and isolated reaches were excluded from the sampling frame. Twice as many sites were selected from the Named River category as from the other two categories expecting that more Headwater and Other Network streams would be non-target (e.g., intermittent flow, mis-mapped, unwadeable due to permafrost incision, etc.). From each category, index sites (i.e., points on streams) were selected at random from the NHD stream network data layer. Sites were oversampled at a rate of 300% (i.e., 150 sites) for a total of 200 potential sites (Figure 6), providing alternates for sample sites not conforming to target population rules or where access was denied by the landowner. Appendix F contains the Tanana Basin wadeable streams design metadata.

While EMAP protocol calls for sampling sites in numerical order as well as choosing alternates in numerical order, access constraints prevented us from doing so. The Tanana basin is remote and largely roadless, necessitating considerable planning and logistics prior to accessing each site. A few sites were accessible by hiking but helicopters were the only practical means of access for most sites, giving us logistical control over a limited number of sites at any given time. We staged helicopters (when available) and fuel at practical locations across the study area to access all primary sites within range. From each staging area we accessed alternate sites as needed, preferentially sampling the lowest numbered alternate sites within range. To eliminate unnecessary (and expensive) helicopter flight time, we reconnoitered many of our sites from fixed-wing aircraft, eliminating any that were obviously non-sampleable. In 2004, with over 6 million acres burning in interior Alaska, both active ground fires and smoke required day-to-day changes in the sampling logistics.

During the second year of sampling (2005) we revised our selection approach in an effort to ensure equitable distribution of sites across the study region. We divided the Tanana basin into three sub-regions (Figure 5) and allocated the remaining 24 sites evenly among them (i.e., 8 sites per sub-region). Within each region we staged at road accessible locations and sampled those sites within hiking or helicopter range, beginning with lowest numbered sites. We successfully sampled our target sites in sub-regions 1 and 2 but had difficulties accessing sites in the upper portion of sub-region 3 (CUs 19040501 and 19040502). These sites were accessible only by helicopter and low ceilings during our allocated time frame prevented us from travelling through the necessary mountain passes. We successfully accessed one site (Site 29) during 2005 and wildfire smoke and logistical difficulties (helicopter fuel transportation and storage) prevented sampling in this area during 2004. As such, we decided to eliminate these CUs from our sampling frame.

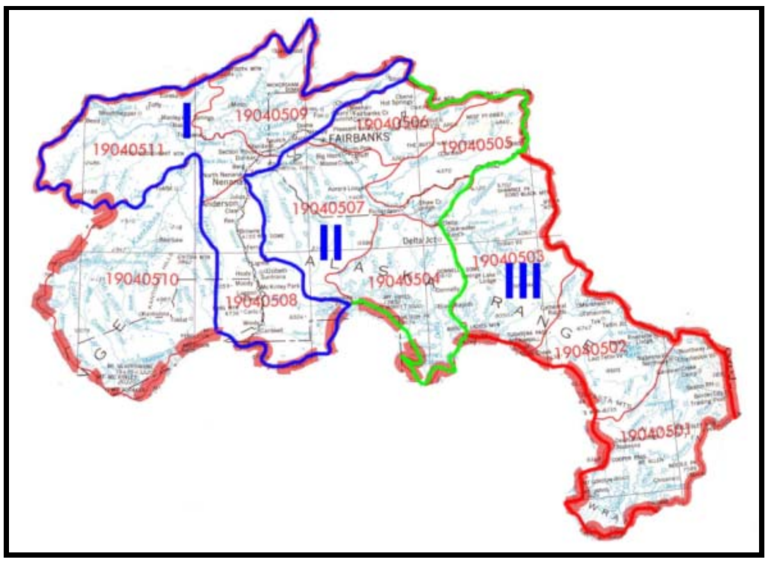


Figure 5. National Hydrography Dataset cataloging units for the Tanana River basin. Map also shows the 3 sub-regions used for sample allocation during 2005 field sampling.

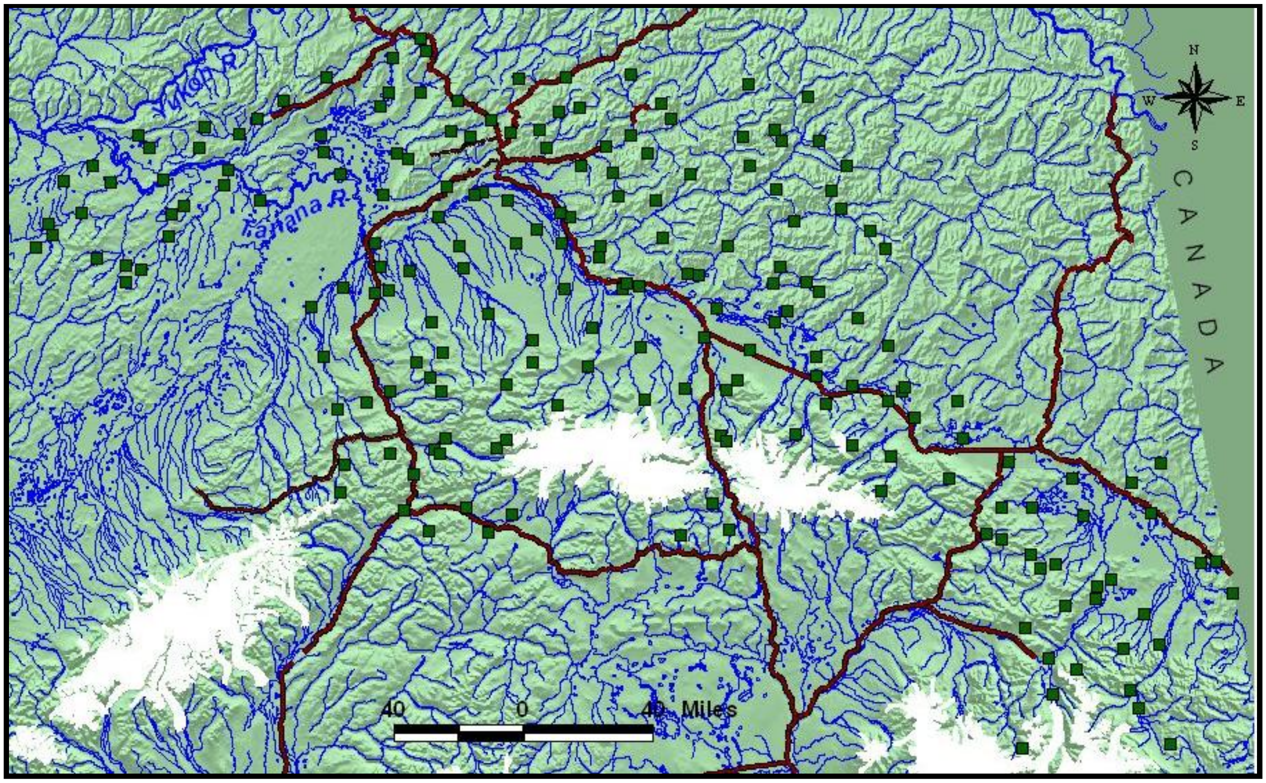


Figure 6. Probabilistic sample sites in the Tanana River basin (n=200 including oversample).

Environmental indicators

Field sampling followed the Wadeable Streams Assessment protocol; pertinent field methods are given briefly here but see EPA (2004a) for more details on field sampling, safety, equipment care and calibration, sample packing and shipping, and other quality assurance procedures. We entered the coordinates of each index site (i.e., systematic-randomly selected stream site) into a handheld GPS unit. Upon arriving at each index site we took photographs facing upstream and downstream and filled out a site verification form that detailed the location of the site, travel directions, and whether or not the site was sampleable (i.e., perennial and wadeable). At each sampleable site, we established a sampling reach with 11 transects spaced equally over a sample reach equivalent to 40 times the stream's average width (minimum reach length = 150 m). The 11 transects were marked with surveyor's flagging and labeled A through K (downstream to upstream), with the middle transect (F) located at the index site (or "X site") (Figure 7). General categories of EMAP environmental indicators and the rationale for quantifying them are given in Table 1; the methodologies for collecting the data are given below.

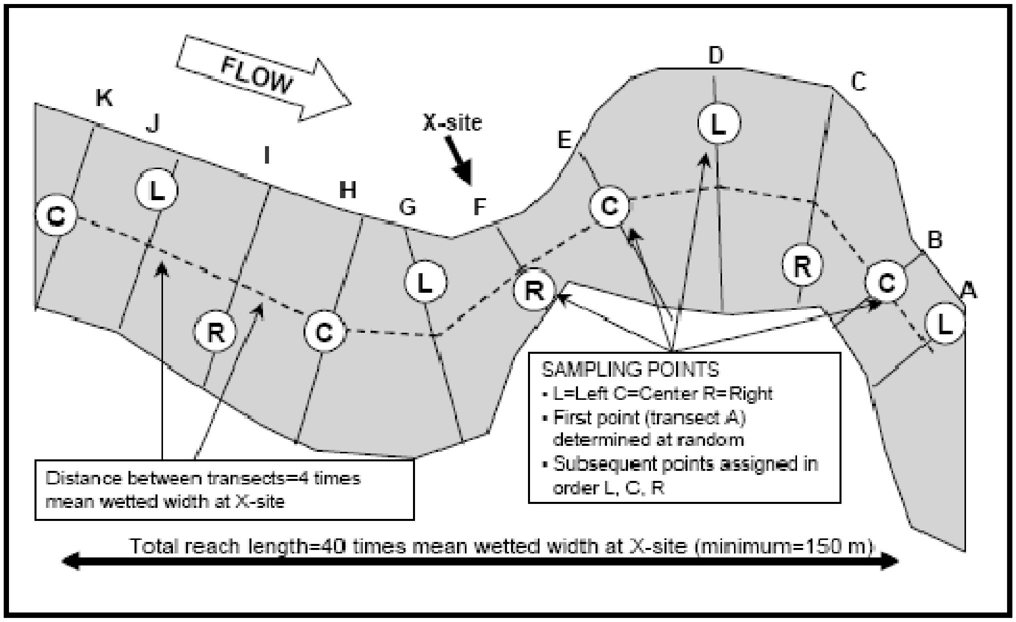


Figure 7. Schematic of hypothetical sampling reach showing transects A–K and biological sampling points (From EPA 2004a).

Table 1. General EMAP environmental indicators (adapted from Hayslip et al. 2004).

Indicator	Rationale
physicochemical	The physical and chemical properties of water directly affect aquatic biota, making them important indicators of environmental conditions. Alaska's water quality standards dictate maximum (and/or minimum) values for some physicochemical parameters.
physical habitat	Physical habitat includes all physical attributes that influence organisms. Instream and riparian alterations affect stream biota and water quality.
periphyton standing stock	Reflects the biomass of aquatic primary production. Related to the nutrient status and hydrologic stability of streams.
macroinveretebrate assemblage	Benthic macroinvertebrates live on the bottom of streams and reflect the overall biological integrity of the stream. They are direct measures of aquatic life uses.

Physicochemical parameters

At the index site we collected water samples for chemical analyses and measured dissolved oxygen, specific conductance and temperature with a Hydrolab Surveyor unit and MiniSonde. Water samples were sent to Dynamac, Inc. in Corvallis, Oregon for analyses following EPA's WSA protocols (EPA 2004c). The samples were analyzed for an extensive suite of constituents including pH, specific conductance, alkalinity, turbidity, total solids, total suspended solids, color, dissolved inorganic and organic carbon, primary nutrients (i.e., various species of nitrogen and phosphorus), and metals. In this report we give data for those parameters that we expect to have the greatest ecological importance and/or that we anticipate being most susceptible to human watershed impacts or global climate change (Table 2).

Table 2. Selected physicochemical indicators for Tanana basin wadeable streams.

Physicochemical indicator	Rationale
pH	Measure of acidity or alkalinity; pH can decrease as organic acids are released from thawing permafrost or from mining waste.
conductivity	Measure of dissolved ions; can be influenced by groundwater or contaminated runoff.
dissolved organic carbon	Increases are associated with thawing permafrost.
nutrients (total nitrogen, total phosphorus, ammonium, nitrate)	Limit primary production; can be increase through contaminated runoff or from thawing permafrost.
total suspended solids	Highest loads are found in glacial streams; may change as glaciers recede or disappear. In clearwater streams, high loads are associated with watershed erosion.

<u>Physical habitat</u>

At each of the 11 transects we measured water depth (at 5 equally-spaced points along each transect) and the height, angle, and undercut distance of each stream bank (Figures 7, 8). We took 6 densiometer readings across the stream channel to measure riparian canopy coverage. We measured the channel width and categorized substrate size and embeddedness at 5 points along each transect and, additionally, we measured width and categorized substrate size along supplemental transects between each of the 11 transects (total of 21 transects, 105 particles). We categorized the areal extent of fish cover, aquatic macrophytes, and filamentous algae. We categorized riparian vegetation coverage and type (separately for canopy, understory, and ground cover) and recorded the presence and proximity of any human influences (e.g., revetments, buildings, roads, etc.).

Figure 8. Measuring depth and substrates along a channel transect.

From each transect (except for the A transect) we recorded the compass azimuth and channel slope to the next downstream transect. Between each of the 11 transects, we counted pieces of large woody debris within and above the bankfull channel according to several length and diameter classes. At 10 or 15 equal intervals between each of the transects (depending on stream size), we recorded the thalweg depth, noted the presence/absence of soft sediment within the thalweg, classified the dominant habitat type, classified any pool forming features, and noted the presence of backwaters and side channels. At the index site, we measured stream discharge using the velocity-area method and a Marsh-McBirney model 2000 flow meter (Figure 9). In this document we report metrics that summarize the channel form, substrates, riparian vegetation, fish habitat, and riparian disturbance of Tanana basin wadeable streams (Table 3).

Figure 9. Measuring stream discharge.

Table 3. Selected physical habitat indicators for Tanana basin wadeable streams.

Physical habitat category	Rationale	Physical habitat indicator
channel form	The physical structure of stream channels determine suitability for many organisms.	channel slope wetted width thalweg depth
substrates	Substrate size is important for fish spawning and invertebrate production.	% sand or fines log mean substrate diameter
riparian vegetation	Important for streambank stability, shade, and inputs of food and LWD.	riparian woody cover (sum of all layers) mid-channel canopy shade
fish habitat	Fish habitat, especially cover, dictates the abundance and diversity of fish present.	LWD volume in bankfull channel (m^3/m^2) fish cover all types pools (% of reach)
riparian disturbance	Riparian disturbance can influence the above habitat categories.	riparian disturbance (proximity weighted)

Periphyton standing stock

We sampled periphyton at each of the 11 transects, alternating from the left, center, and right side of the stream channel (Figure 7). We used two different periphyton sampling methods depending on the habitat encountered at a given transect. In both methods, periphyton was sampled from a 12-cm^2 area as delineated by a short length of PVC tubing. In erosional areas, we removed a rock from the stream, held the delimiter against the rock, used a toothbrush to dislodge periphyton, and rinsed the periphyton into the sample container. In depositional areas, we placed the delimiter on top of streambed sediments, drew the periphyton layer into a syringe, and emptied the syringe into the sample container. Periphyton samples from the 11 transects were combined into a single composite sample. We ran two 25-mL aliquots of each composite sample through flass-fiber filters, froze the filters, and shipped them to Dynamac, Inc. in Corvallis, Oregon for chlorophyll a and ash-free dry mass analyses following EPA (2004c). Ash-free dry mass is a measure to total benthic biofilm biomass and chlorophyll a is a measure of benthic algal biomass.

Macroinvertebrate assemblages

We used a D-frame kick net (500-µm mesh) to sample macroinvertebrates over a 1 ft^2 area at each of the 11 transects, alternating from the left, center, and right side of the stream channel (Figures 7, 10). Use of the 500-µm mesh maintained WSA national consistency, but is of a larger size than recommended for Alaska stream macroinvertebrates (350-µm), many which are small (i.e., chironomid midges) and may be underrepresented in samples collected with larger mesh (Major and Barbour 2001). The sampling point along each transect alternated among the left side, center, and right side of the stream channel. After positioning the D-frame net on the substrate facing upstream, we picked any heavy organisms (i.e., snails, mussels) from the sampling quadrat into the net. We then picked up any loose rocks and, with a gloved hand, scrubbed any attached macroinvertebrates into the net. From here, the sampling methods differed depending on the habitat type of the sampling point. In riffle/run habitats, we kicked or manually disturbed the remaining substrates for 30 seconds to dislodge any remaining organisms downstream into the net. In glide/pool habitats, we kicked or manually disturbed the remaining substrates for 30 seconds to suspend any remaining macroinvertebrates while repeatedly sweeping the net through the disturbed area. The predominant substrate size and habitat type at each sampling point was recorded. We combined the 11 samples into a reachwide composite sample and preserved it with denatured alcohol. Laboratory processing

Figure 10. Sampling benthic macroinvertebrates.

and identification followed EPA (2004b). We subsampled each macroinvertebrate sample to a fixed count of 500 organisms to standardize the taxonomic effort across all sites. In addition, we conducted a 5–10-minute search through the remaining sample to select any large and/or rare taxa that may have been missed during subsampling. We identified all insects to genus (or lowest taxon practical) and non-insects generally to higher taxa (usually family or order) using standard taxonomic keys (Weiderholm 1983, Pennak 1989, Merritt and Cummins 1996, Wiggins 1996, Thorpe and Covich 2001, Stewart and Stark 2002). In this document we report metrics that describe the richness, density, and taxonomic composition of macroinvertebrate assemblages.

Data analysis

<u>Cumulative distribution frequencies</u>

We used plots of cumulative distribution functions (CDFs) as our primary method for summarizing environmental indicator data. A CDF plot shows the cumulative value of an indicator in relation to stream length for the entire population of sites. Since our sample sites were drawn randomly from a population of known size, the CDF plots are scaled to indicate the linear distance of Tanana basin wadeable streams corresponding to each percentage. For example, Figure 11 shows that 80% of the target population (or 10,129 km of streams) has an indicator value of less than 700 while 20% (or 2532 km of streams) have an indicator value less than 700.

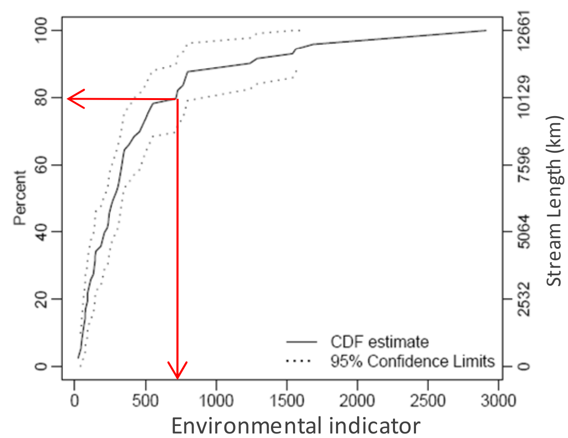


Figure 11. Hypothetical cumulative distribution frequency plot.

<u>Predictive modeling</u>

We used data from 40 sites with no detectable human watershed impacts or recent wildfires to model the expected macroinvertebrate functional feeding group (FFG) composition of stream reaches based on environmental characteristics. We considered 5 standard and commonly used FFGs in this analysis: collectors feed on streambed detritus, filterers sieve and consume suspended particles, predators feed on other invertebrates, scrapers feed on streambed algal matter, and shredders consume leaves fallen into the stream from riparian plants. Streams have a somewhat predictable FFG composition based on stream size, riparian vegetation type, etc. (Vannote et al. 1980) and, in application of this monitoring application, ecological impacts will be indicated by deviation from a stream site's expected FFG composition. This methodology is conceptually similar to the River Invertebrate Prediction and Classification System methodology (RIVPACS; Norris and Hawkins 2000) that predicts the expected taxonomic richness at stream sites, with the possible advantages of increased sensitivity to species replacements and greater ability to diagnose specific impairment sources.

Environmental assessments, like WSA and other EMAP efforts, often use sampling schemes where fixed numbers of organisms are identified; this sampling generates data that follow the multinomial distribution, yet this distribution is rarely invoked in environmental data analysis. To better match our data analysis to our data collection scheme, we developed a generalized linear model based on the multinomial distribution. Hierarchical Bayesian methods were used to estimate the parameters of this model because these methods were ideally suited for handling our data's nested structure (i.e. multinomial data points within sites within regions). The use of link function hierarchical generalized linear models provided a natural means for predicting discrete outcomes (e.g. FFG identity) as functions of continuous and categorical environmental covariates (e.g. elevation, vegetation type, etc.).

Development of this model is ongoing, but as a first effort we used the dominant vegetation type (Viereck et al. 1992) as a predictor variable since many other environmental variables (e.g., elevation, channel slope, etc.) co-vary with vegetation. Vegetation types represented by out Tanana River basin wadeable sites were dry alpine, scrubland, coniferous forest, and mixed forest. We withheld three sites from the model development: (1) Monument Creek, a coniferous forest site burned by wildfire in 2004; (2) McAdam Creek, a scrubland stream whose headwaters were hydraulically placer mined; and (3) Piledriver Slough, a mixed forest site near Fairbanks and the only watershed in our survey with urban development. We used these three sites to test the model's ability to detect changes in FFG composition under different scenarios of landscape alteration.

Results and discussion

Probabilistic survey

We visited 103 of the 200 potential sites (i.e., 50 target sites plus 150-site oversample). Of these, 46 were sampled while the others were unsampleable due to various reasons: 30 sites were unwadeable, 11 had dry channels, 7 were impounded (i.e., beneath a lake or pond), landowner access was denied for 5 sites, 3 sites were wetlands (i.e., no defined stream channel), and 1 site was a map error (i.e., no evidence of a channel was present). We were unable to visit 97 of the 200 potential sites, primarily due to wildfire smoke and aircraft logistical problems. See Table 4 for sampling dates, coordinates, and elevation of sampled sites and Figure 12 for a map of sampled sites. See Moran (2007) for additional site characteristics including physiography, climate, land use, and permafrost data.

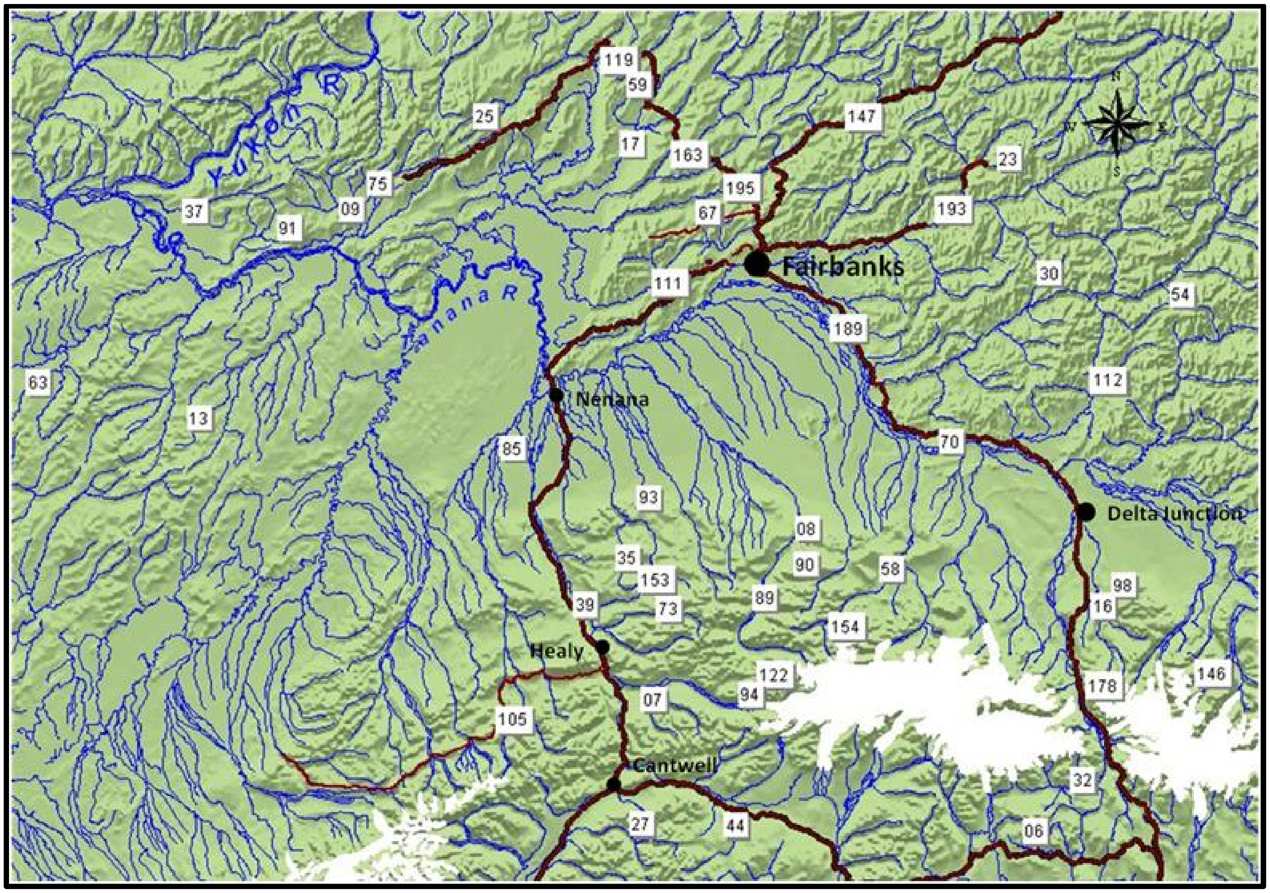


Figure 12. Tanana River basin wadeable stream sites that were successfully sampled.

Table 4. Sample date, coordinates, and elevation for the 46 Tanana Basin wadeable streams.

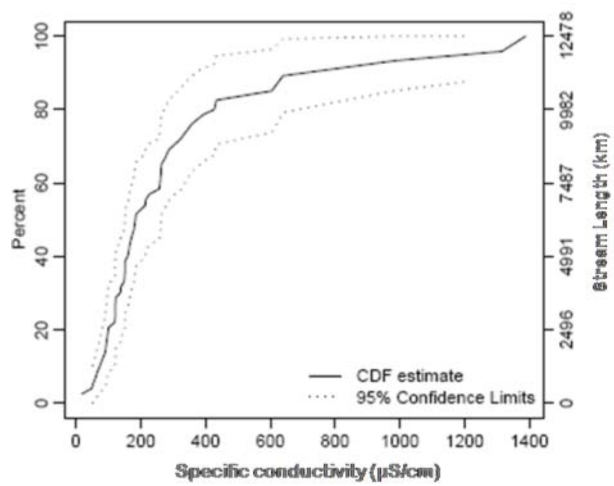
Site ID	Stream name	Date sampled	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
6		7/30/2004	63º 9' 14"	146º 14' 14"	1204
7	Moose Creek	7/14/2004	63º 38' 20"	148º 34' 47"	686
8	Snow Mountain Gulch	7/16/2004	64º 4' 53"	147º 29' 37"	600
9	Baker Creek	7/20/2004	65º 5' 40"	150º 21' 8"	146
13		7/25/2004	64º 30' 40"	151º 26' 6"	226
16	Granite Creek	7/29/2004	63º 46' 9"	145º 37' 1"	661
17		7/28/2004	65º 13' 15"	148º 24' 49"	110
23	Monument Creek	7/11/2005	65º 3' 52"	145º 54' 2"	503
25	Starvation Creek	7/25/2004	65º 19' 20"	149º 24' 5"	396
27		7/14/2004	63º 16' 53"	148º 42' 00"	899
30	Butte Creek	8/15/2004	64º 44' 5"	145º 41' 52"	543
32		7/30/2004	63º 16 45	145º 53' 31"	1006
35	McAdam Creek	7/15/2004	64º 2' 6"	143º 41' 22"	564
37	Boulder Creek	7/26/2004	65º 6' 25"	151º 24' 57"	85
39	Terrace Creek	7/13/2004	63º 54' 39"	148º 58' 31"	457
42		7/26/2005	62 0' 35"	143º 15' 33"	2039
44		7/13/2004	63º 15' 22"	148º 6' 57"	846
54	Upper Boulder Creek	8/15/2004	64º 37' 11"	144º 50' 33"	823
58		7/29/2004	63º 56' 36"	146º 58' 3"	671
59	Slate Creek	7/19/2004	65º 24' 8"	148º 19' 35"	320
63		7/26/2004	64º 37' 41"	152º 30' 51"	168
67	Hastings Creek	7/11/2004	65º 00' 34"	147º 56' 16"	192
70	Canyon Creek	7/8/2004	64º 17' 32"	146º 29' 10"	305
73		8/7/2004	63º 53' 51"	148º 28' 00"	1295
75	Hutlinana Creek	7/20/2004	65º 9' 25"	150º 9' 27"	183
85		8/8/2004	64º 23' 2"	149º 22' 27"	143
89		8/3/2004	63º 53' 52"	147º 48' 7"	945
90	Glacier Creek	8/3/2004	63º 59' 2"	147º 31' 4"	1158
91	Little Denver Creek	8/14/2004	65º 2' 42"	150º 46' 23"	396
93		7/15/2005	64º 12' 15"	148º 30' 21"	390
94		7/14/2005	63º 37' 23"	147º 57' 14"	1152
98	Till Valley	7/27/2005	63º 48' 18"	145º 29' 35"	756
105		7/13/2005	63º 36' 24"	149º 29' 30"	1189
111	Ohio Creek	7/8/2005	64º 47' 46"	148º 14' 8"	207
112	Shaw Creek	7/19/2005	64º 24' 1"	145º 24' 43"	347
119	Tolovana River	7/9/2005	65º 27' 42"	148º 22' 17"	174
122	Big Grizzly Creek	7/14/2005	63º 39' 16"	147º 51' 12"	1335
146		7/27/2005	63º 31' 58"	144º 58' 48"	985
147	Chatanika River	8/2/2005	65º 13' 44"	146º 52' 49"	320
153	Platt Creek	7/13/2005	63º 57' 36"	148º 33' 42"	899
154		7/15/2005	63º 47' 22"	147º 18' 13"	1399
163		7/8/2005	65º 10' 23"	148º 1' 52"	418
178		7/27/2005	63º 32' 35"	145º 41' 5"	1158
189	Piledriver Slough	7/22/2005	64º 37' 58"	147º 4' 39"	171
193	Stiles Creek	7/21/2005	64º 56' 22"	146º 15' 51"	259
195	Dome Creek	7/18/2005	65º 4' 23"	147º 42' 12"	174

Environmental indicators

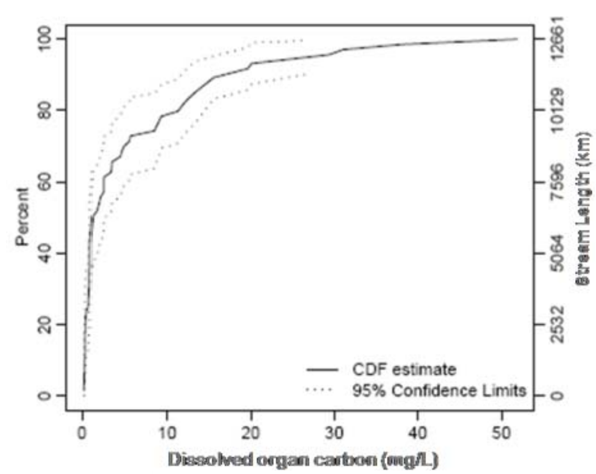
Physicochemical parameters

We present CDF plots for selected physicochemical parameters below. See Appendix A for raw physicochemical data on a larger suite of parameters and see Moran (2007) for additional water quality parameters including trace metals.

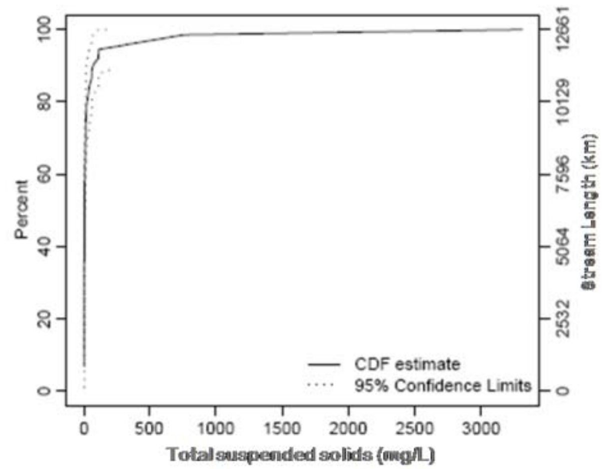
Specific conductivity is a measure of water's ability to conduct an electric current and can be used as an indication of its ion content or dissolved solids concentration. The 42 streams analyzed, representing 12,478 km of stream, showed high variation in specific conductivity, with a low of 18 and a high of 1388µs/cm, and a median value of 180µs/cm. Typical specific conductivity measures were notably higher than those of wadeable streams from Southcentral Alaska (Rinella and Bogan 2007).



Dissolved Organic Carbon (DOC) is often a major component of the organic matter in freshwater systems. Typical measures for streams range from 1 mg/l for pristine, clear streams to 30 mg/l for blackwater streams (Thurman 1985). Of the 45 streams where DOC was measured, 18 had concentration less than 1 mg/L and three had concentrations over 30 mg/L. The two streams with highest DOC concentrations, sites 59 and 67 with DOC of 38.2 and 51.9 respectively, were not flowing during sampling (i.e., water was present in stagnant pools), which probably contributed to the elevated DOC levels.

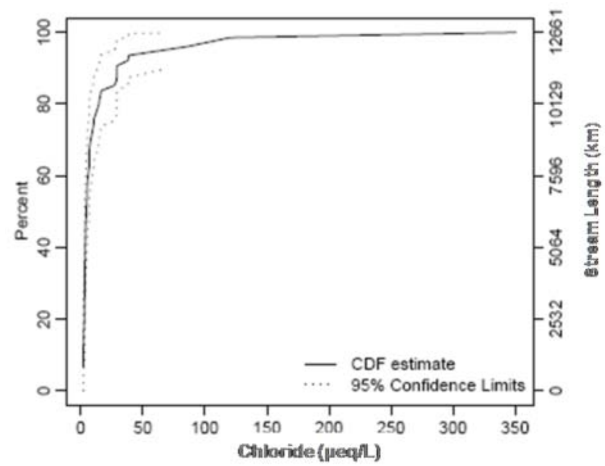


Total Suspended Solids (TSS) is a measure of the concentration of suspended particles in a waterbody and is often closely correlated with turbidity. TSS ranged from 0 to 3307 mg/L, with a median value of 3.6mg/L. Most streams had low TSS loads, as indicated by the steepness of the CDF. Two non-glacial, silt-laden streams drove the plateau of the CDF (Sites 105 and 111, Ohio Creek). Site 105 was cutting through a steep gully with recent deposition from mass wasting while site 111 was cutting through extensive silt deposits. They accounted for only an estimated 184 stream km, while 11,466 estimated

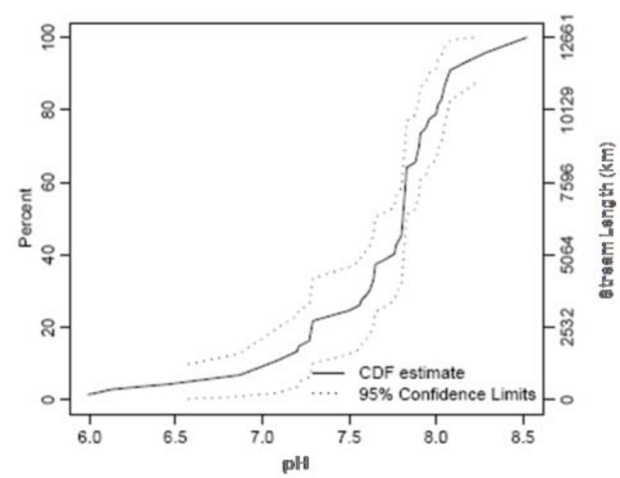


stream km had a TSS of less than 100mg/L.

Chloride is one of the main dissolved inorganic anions present in surface water, originating from parent rock and soil. It occurs usually occurs in low concentrations, with an estimated worldwide mean in rivers at 220µeq/L (8.7mg/L) (Hem 1985). In coastal areas, chloride can be transported through the atmosphere from ocean spray, but this was an unlikely source for Tanana basin streams. The range for Tanana basin dataset was 2.0 to 350.6 µeq/L, with most streams having less than 50 µeq/L. The highest concentration was at Site 35 (McAdam Creek), a stream with substantial placer mining impacts upstream.

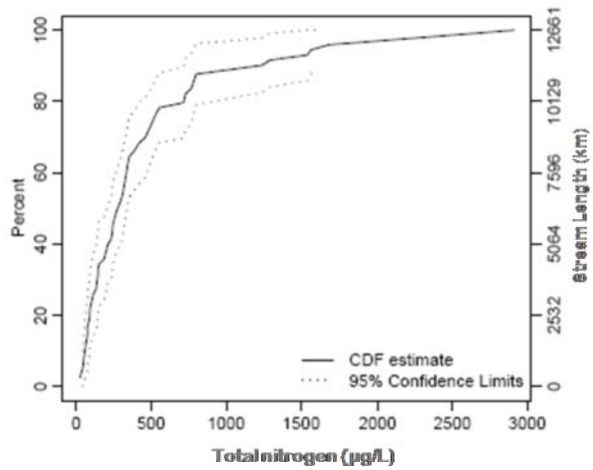


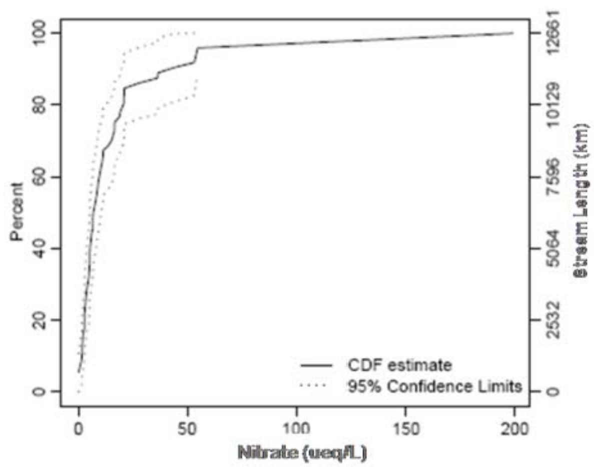
A measure of water's hydrogen ion activity, pH is based on a logarithmic scale ranging from 0 (acidic) to 14 (alkaline). The pH of natural water typically ranges from 6.5 to 8.0 (Hem 1985). Alaska state standards for aquatic life call for surface water to have a pH between 6.5 and 8.5. The pH of Tanana basin streams ranged from 6.0 to 8.5, with a mean of 7.7. Of the 46 streams surveyed, two had pH values less than 6.5, representing an estimated 366 stream km. These sites were 59 and 67 (pH of 6.1 and 6.0 respectively), intermittent streams that also had

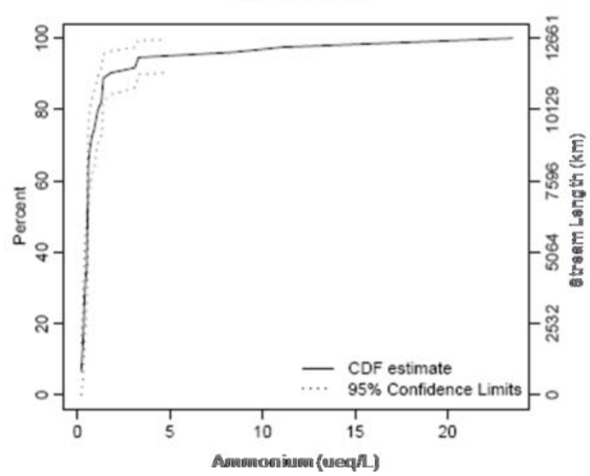


elevated DOC concentrations (see above).

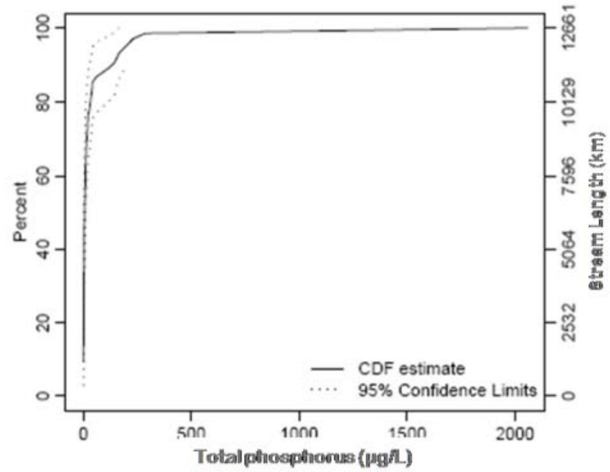
Nitrogen is a nutrient that often limits primary production in freshwater systems. It occurs at relatively low concentrations in water although it is abundant in the atmosphere and rocks. It is reduced to organic forms of nitrite (NO_2) and nitrate (NO_3) through microbial activity. There is no state or national standard for nitrate-nitrogen, although concentrations of less than 300µeq/L probably prevent eutrophication (MacDonald et al. 1991). All estimated stream km were well below that level, with nitrate concentrations ranging from non-detect to 199µeq/L. Ammonium (NH_4) is another constituent of nitrogen in freshwater systems, often as a byproduct of biological activity. Due to its toxicity to freshwater organisms, the EPA recommends an upper limit of 20µeq/L ammonium for fish-bearing waters. Only one stream had an ammonium concentration above this level (Site 63); this concentration was probably natural since this watershed showed no obvious signs of human disturbance.







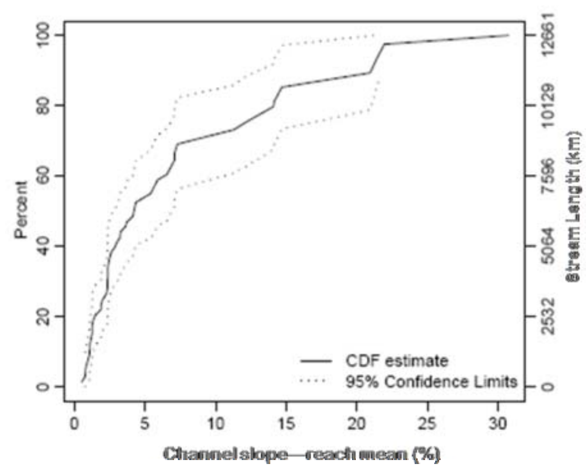
Phosphorus is another nutrient that often limits primary production in freshwater systems. Phosphorus is a common element in igneous rock and, while it is often abundant in sediments, its dissolved concentrations are typically low. Most Tanana basin streams have low phosphorus concentrations, but the plateau of the CDF plot is driven by the relatively high concentration of one sediment-laden stream (Site 111, Ohio Creek) with a concentration of 2058µg/L. The next highest total phosphorus concentration was 286 µg/L, also in a sediment-rich stream (Site 122, Big Grizzly Creek). There are currently no state standards for nutrients in surface water. EPA (1986) recommends <50 µg/L for streams that empty into lakes and <100µg/L for streams that do not deliver to lakes. Total phosphorus was estimated to exceeded 50µg/L in 13.4% of stream km and to exceed 100µg/L in 11% of stream km.



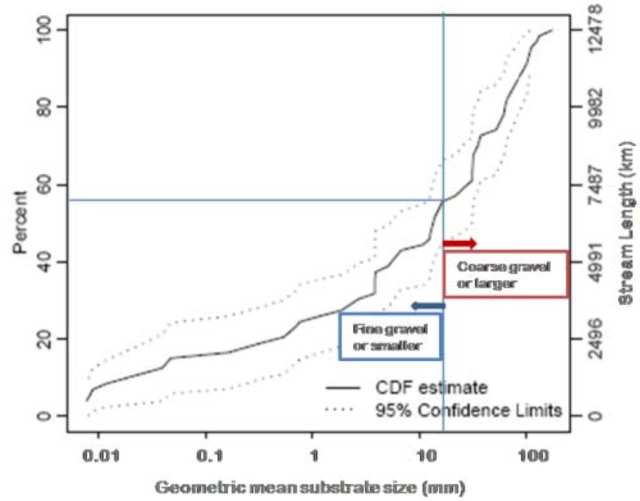
Physical habitat

We present CDF plots for selected physical habitat parameters below. We summarized raw data for these and additional pertinent physical habitat parameters in Appendix B; contact the authors for additional data.

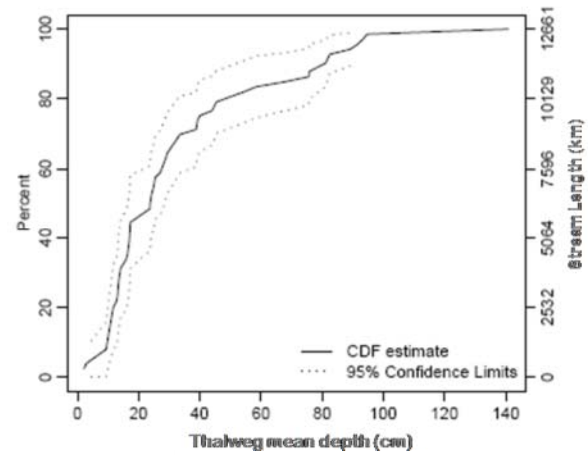
Mean channel slope of streams sampled in the Tanana basin ranged from 0.5 to 30.8%, with a median of 2.9%.



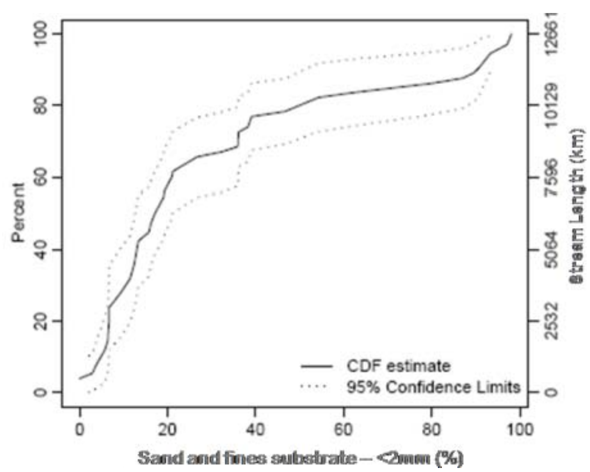
Streams ranged in mean wetted width from 0.4 to 19.8 m, with a median of 4.0 m. Sixty-two percent (9156 estimated stream km) had mean wetted widths less than 5m.



Streams had a mean thalweg depth of 33.2 cm and ranged from 2.1 to 140.8 cm.

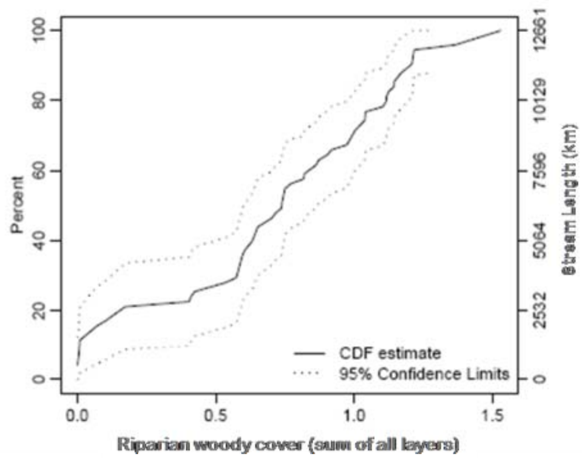


Substrate size is an important habitat variable for all aquatic biota. Fine sediment (<2mm) can fill in spaces between rocks in the streambed and reduce the quantity and quality of habitat available for macroinvertebrates and spawning fish. Streams ranged from 0 to 98% sand and fines, with a median of 18%. Twenty percent of stream km were estimated to have at least 50% sand and fines.

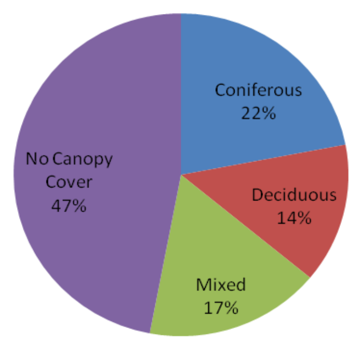


The geometric mean of substrate size, typically plotted on a log scale, is a relatively comprehensive metric of substrate size. For 56% of Tanana basin streams, the mean substrate size was coarse gravel or larger (i.e., >16 mm). Approximately 20% of sites had mean substrate size less than 2 mm (i.e., sand). More than 80% of sites had mean substrate size less than 100 mm.

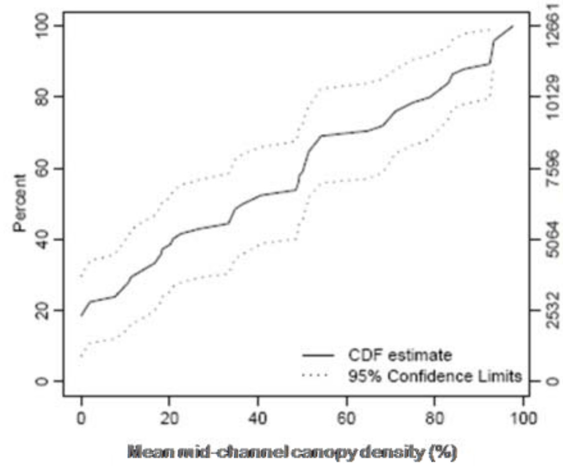
We recorded visual estimates of the areal cover of woody vegetation in each of three layers: canopy (>5 m above ground), understory (0.5 – 5 m), and ground cover (<0.5 m). The highest possible value is 3.0, which would represent 100% woody vegetation cover in each of the three layers. The mean estimated woody cover score for all three layers was 0.7. About 70% of estimated stream km had a combined woody riparian vegetation score of less than 1.0.



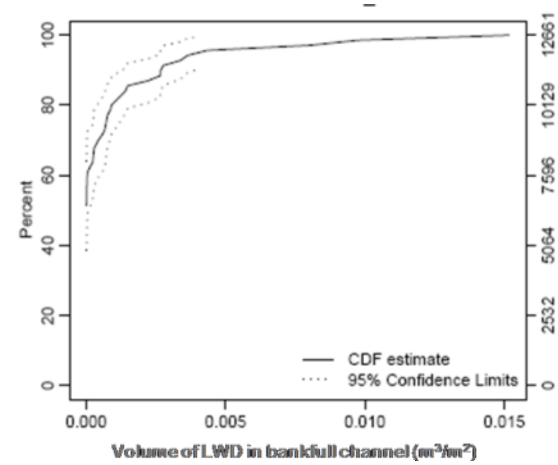
Riparian canopy (riparian vegetation >5m) was classified into four different cover types: coniferous, deciduous, mixed, and none. Typical coniferous species included both white spruce (*Picea glauca*) and black spruce (*P. mariana*), whereas typical deciduous species included birch (*Betula paperifera*), cottonwood (*Populus* sp.), and alder (*Alnus* sp.). An estimated 47% of the stream km had no riparian vegetation over five meters.



Mid-channel stream shading was evenly distributed across the range of 0 to 100%. An estimated 19% of stream km had no mid-channel shading. The mean mid-channel shading was estimated at 41%.

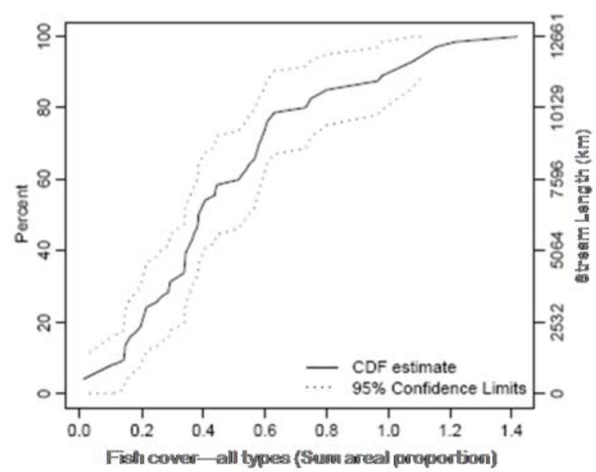


Large woody debris (LWD) in streams can serve many vital functions, including retention of organic matter, stable substrate for macroinvertebrates, cover for fish, and pool formation and maintenance. In this study, LWD was defined as any piece of wood within the bankfull channel at least 1.5m long, with a large end diameter of at least 0.1m. The volume of LWD in northern streams is less than that found in temperate streams due to a decrease in the size of trees in the riparian area.



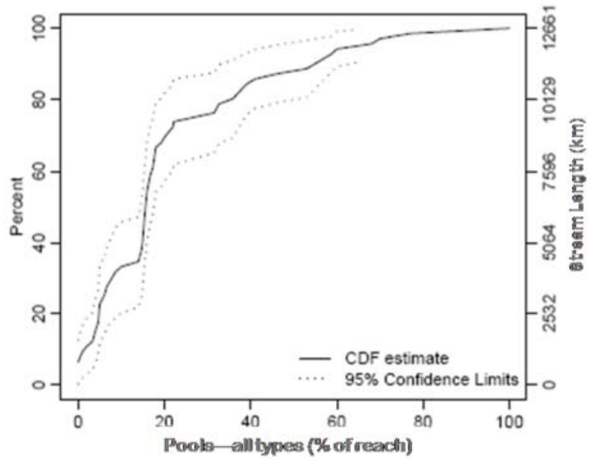
Twenty of the 45 streams surveyed (an estimated 51.3% of the total stream km) contained no LWD. The mean volume of LWD was $0.001 m^3/m^2$.

Fish cover estimates were based on several features present in and along the stream channel including filamentous algae, aquatic macrophytes, LWD, brush/small woody debris, in-channel live trees/roots, overhanging vegetation, undercut banks, boulders, and artificial substrates. Areal cover estimates were recorded for each feature at each of the 11 transects within the sample reach. The mean index score for all types of fish cover in the

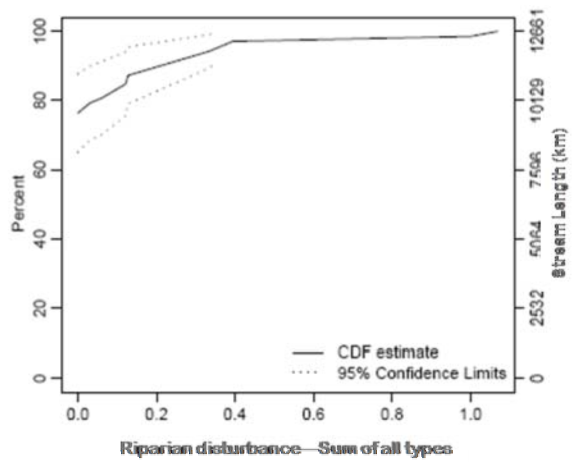


Tanana basin was 0.5.

Pools are created by any of a number of geomorphological processes and provide important habitat for fish at various life stages. The average stream reach had a pool channel type along 22% of the reach. Reaches with less than 10% pool accounted for an estimated 31% of stream km, while only 5% of estimated stream km had more than 64% pool composition.



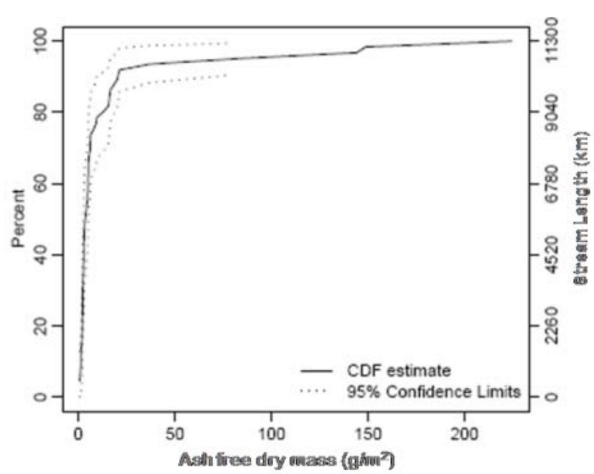
Riparian disturbance data were collected by visual examination of stream channel, banks and riparian area at each of the 11 transects. Several disturbance categories were considered (including roads, buildings, and trash) and disturbances were weighted according to their proximity to the stream. An estimated 76% of stream km had no detectable signs of human disturbance present.



Periphyton standing stock

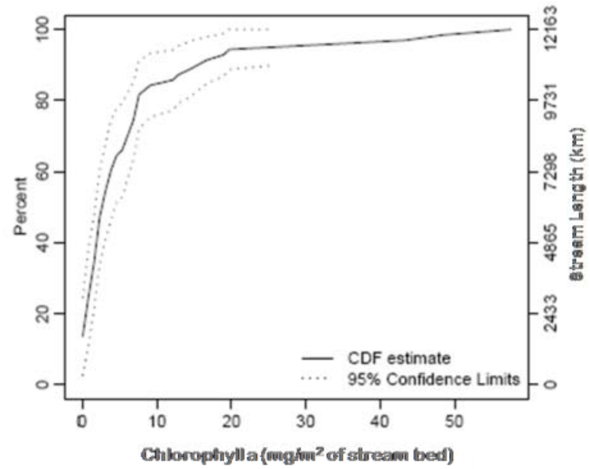
We present CDF plots for periphyton ash-free dry mass and chlorophyll a below; see Appendix C for raw data.

Ash fee dry mass (AFDM) is a measure of the standing crop of periphyton in a stream. It does not distinguish between algal biomass and other organic material (e.g., fungi, bacteria) and can therefore only be used as a coarse indicator of stream productivity. AFDM varied from 0.6 to 224.2 g/m^2, with a mean value of 15.4 g/m^2, yet 90% of



estimated stream km had an AFDM of 20.4 g/m^2 or less.

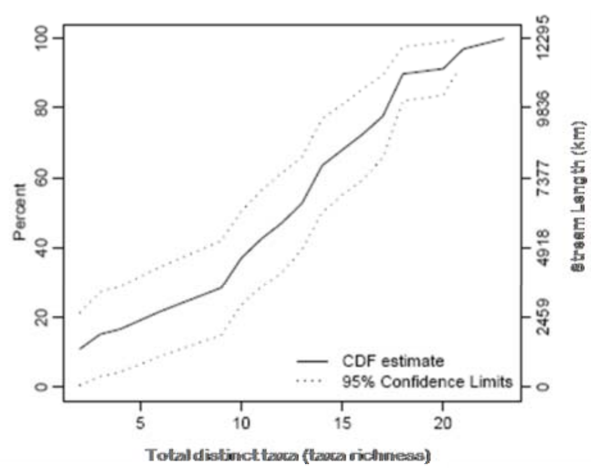
Chlorophyll a, a photosynthetic pigment found in producers, is used as another measure of algal growth in streams. Chlorophyll a levels increase with the biomass of photosynthetic algae. Chlorophyll a values ranged from 0 to 57.6 mg/m^2, with a mean value of 15.4 mg/m^2.



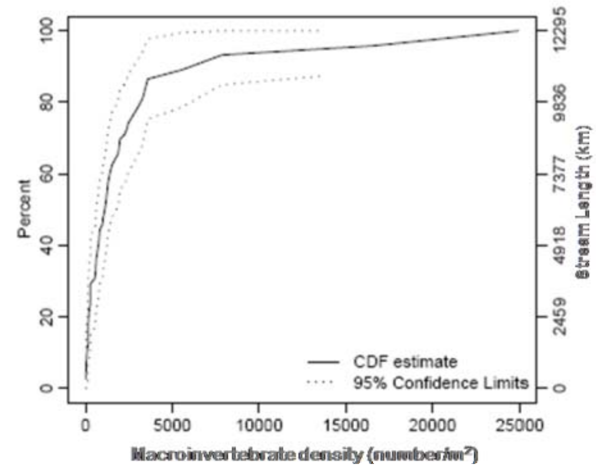
Macroinvertebrate assemblages

We present CDF plots for selected macroinvertebrate assemblage metrics below. See Appendix D for raw data on a larger set of metrics and see Appendix E for a macroinvertebrate taxa list. This survey produced a notable range extension for the caddisfly *Phanocelia canadensis* (Rinella and Bogan 2008). This rare species, found at Site 13, is known mainly from eastern North America; our collection represents a range extension of more than 1500 km and is the first record west of the continental divide.

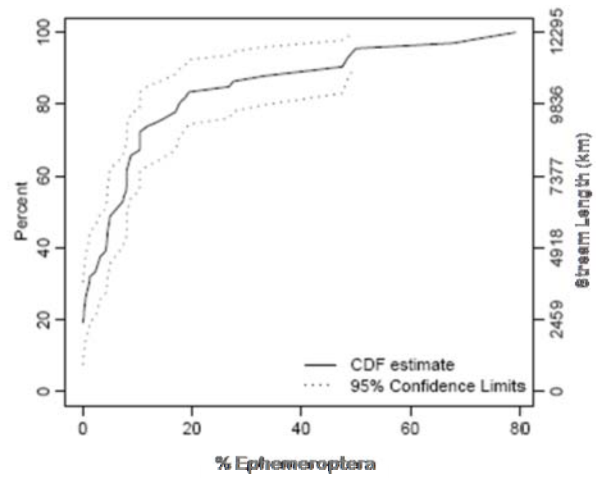
Taxa richness (i.e., the number of different types of macroinvertebrates) depicts the overall diversity of the macroinvertebrate assemblages in Tanana basin wadeable streams. Taxa richness ranged from 2 to 23, with a mean of 12.2. Individuals in the family Chironomidae, a diverse group of midges, were identified to tribe or sub-family (as opposed to genus for other insects), which likely underestimated the taxa richness at some sites.



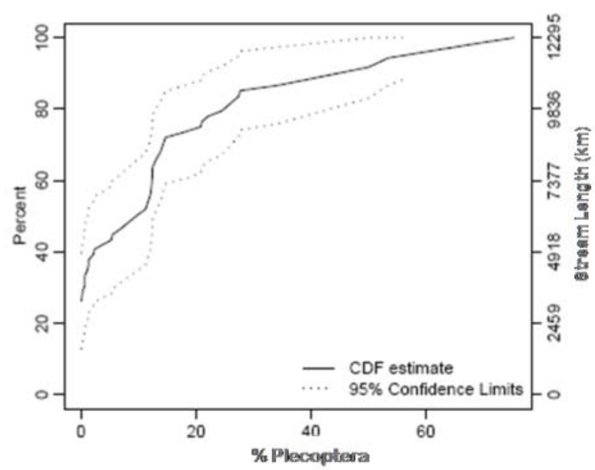
Macroinvertebrate density represents the number of individuals per unit area of streambed. High macroinvertebrate densities are often associated with stable streamflows and/or high nutrient concentrations. Macroinvertebrates are the primary food source for juvenile fish. Macroinvertebrate densities showed high variability ranging from 2 to 24,949 individuals/m^2, with a mean of 2945 individuals/m^2.



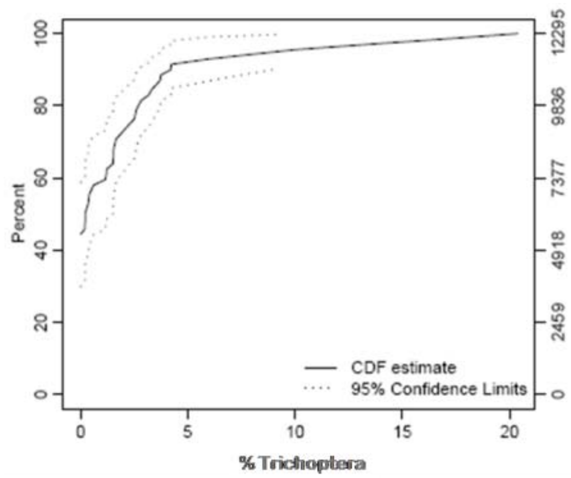
Mayflies (order Ephemeroptera) are well-known for their general sensitivity to sedimentation and toxic runoff. The percent of the macroinvertebrate assemblage comprised of mayflies was found to be a good indicator of polluted streams in Southcentral Alaska (Rinella and Bogan 2007). In Tanana basin streams, mayflies were estimated to be present in 80% of stream km and to comprise at least 5.7% of the assemblage in half of the stream km. The mean percent Ephemeroptera was 13%, notably higher than the 7.6% reported by Oswood (1989) for streams of interior Alaska. In our survey, sites lacking mayflies were typically high gradient alpine streams in the Alaska Range.



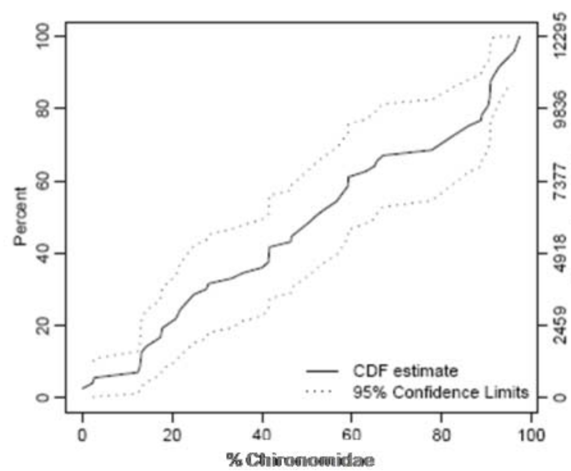
Stoneflies (order Plecoptera) are another group of organisms that are sensitive to human disturbances. Stoneflies were present in 73% of estimated Tanana basin stream km, and comprised at least 9.5% of the macroinvertebrate assemblage in half of the estimated stream km. The mean percent Plecoptera was 15.2%, corresponding closely with the 17.2% reported by Oswood (1989) for this region.



Another group of insects that are sensitive to human disturbance are the caddisflies (order Trichoptera). Trichoptera were estimated to be present in only 55% of stream km, with a mean assemblage composition of 2.0%. This corresponds closely with the low abundance of caddisflies (2.9%) reported by Oswood (1989) for this region.



True flies (order Diptera) dominate the macroinvertebrate assemblage in most Alaskan streams. Of the dipterans, midges (family Chironomidae) comprised the overwhelming majority. Chironomidae tend to be more tolerant of human disturbance, but actual sensitivities vary greatly among the different genera. Chironomidae were found in all but one stream reach, representing an estimated 11,980 stream km, and ranged up to 96% of the BMI assemblage, with a mean of 53.2%. This followed closely with Oswood's (1989) reported 62% dipterans for this region.



Predictive model

Our lone categorical variable (dominant vegetation type) resulted in relatively narrow expected ranges (i.e., 95% credibility intervals) for most combinations of vegetation type and FFG (Table 5). Figure 13 graphically displays the expected FFG composition for streams in the different vegetation types; comparing these figures to those for a mined, a burned, and an urbanized site (Figures 14, 15, and 16) shows that FFG composition changed substantially and intuitively at these impacted sites relative to reference sites .

At Site 35, a scrubland site with severe sedimentation impacts from an upstream placer mine, filterers were absent and populations of scrapers and shredders were severely diminished relative to the expected FFG composition (0.4% and 1.5% of the macroinvertebrate assemblage, respectively). At Site 23, a coniferous forest site that experienced an intensive wildfire in 2004, filterers and scrapers were more abundant than expected (38% and 19% of the assemblage, respectively) while collectors and shredders were less abundant than expected (38% and 0.8% of the assemblage, respectively). At Site 189, a mixed forest site with a modest amount of suburban development in the watershed, filterers were rarer than expected (0.2% of the assemblage) and shredders were absent.

Our results indicate that this methodology holds promise for monitoring applications. Our next step is to include additional model parameters; promising candidates include specific conductance, substrate composition, discharge, gradient, and pool depth. We expect that further model parameterization will further narrow credibility intervals and lead to more precise estimates of the expected FFG composition of Alaska's streams.

Table 5. 95% credibility intervals for functional feeding group composition in Tanana basin wadeable streams based on dominant vegetation type.

Functional feeding group	Dry alpine	Scrubland	Coniferous forest	Mixed forest
collector	98.8 – 99.9%	89.7 – 97.3%	79.3 – 94.9%	88.9 – 96.3%
filterer	–	0.6 – 3.8%	1.3 – 9.7%	0.7 – 3.1%
predator	1 – 1.2%	1.5 – 8.3%	2.3 – 16%	2.4 – 9.4%
scraper	0.5 – 6%	2.3 – 14.4%	1 – 8.7%	0.8 – 3.9%
shredder	0 – 0.7%	8.3 – 47.3%	2 – 17%	3 – 13.2%

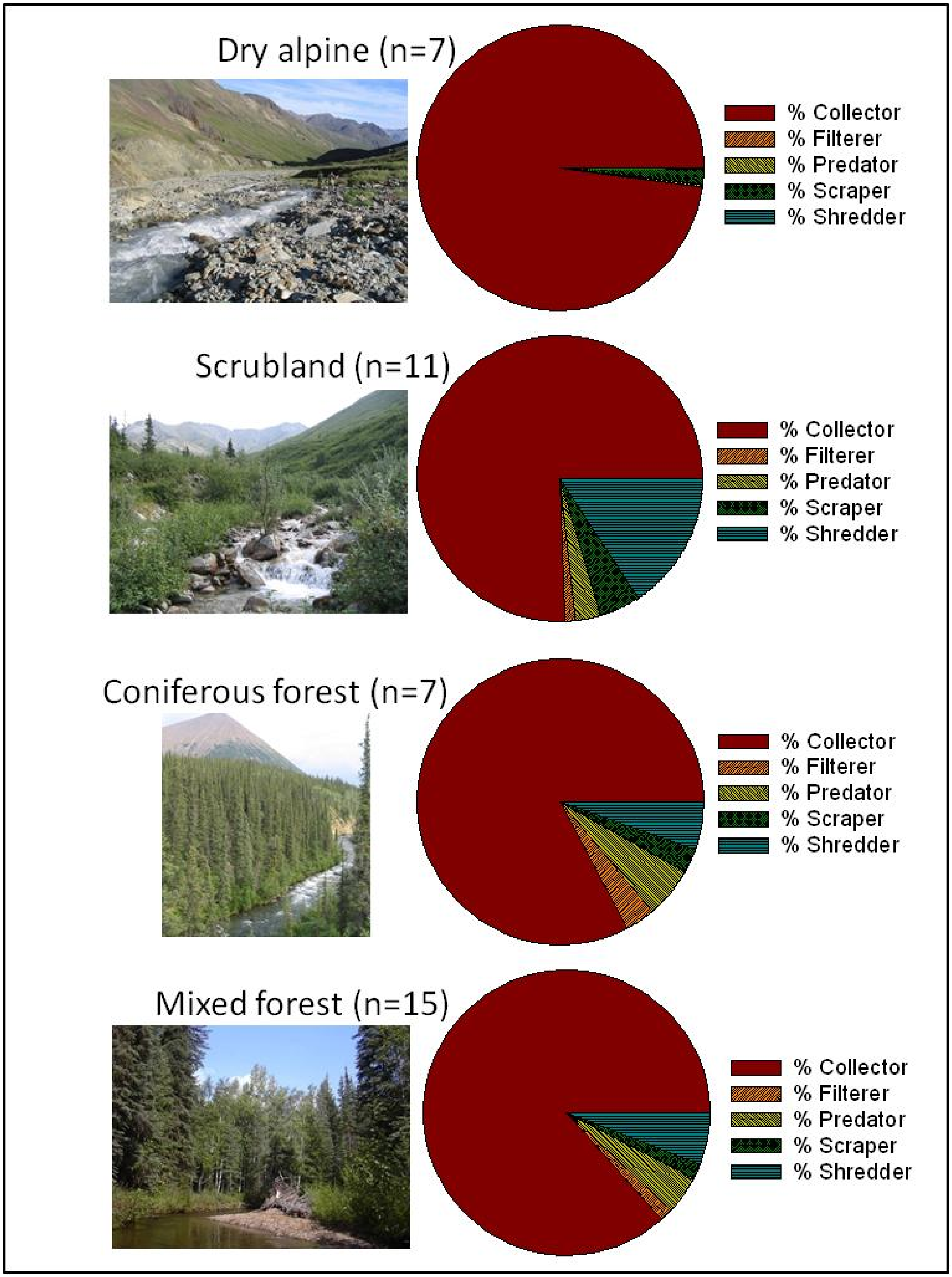

Dry alpine (n=7)
% Collector
% Filterer
% Predator
% Scraper
% Shredder
Scrubland (n=11)
% Collector
% Filterer
% Predator
% Scraper
% Shredder
Coniferous forest (n=7)
% Collector
% Filterer
% Predator
% Scraper
% Shredder
Mixed forest (n=15)
% Collector
% Filterer
% Predator
% Scraper
% Shredder

Figure 13. Expected functional feeding group composition (50% credibility interval) for wadeable streams in the 4 dominant vegetation types of the Tanana River basin.

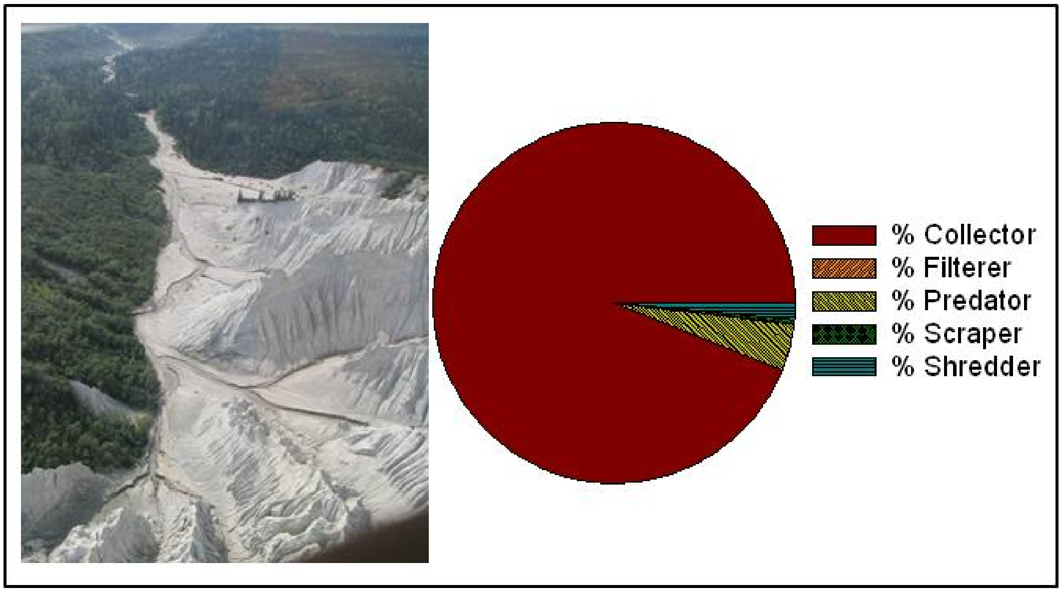


Figure 14. Observed macroinvertebrate functional feeding group composition at Site 35 (McAdam Creek), a placer mined scrubland site.

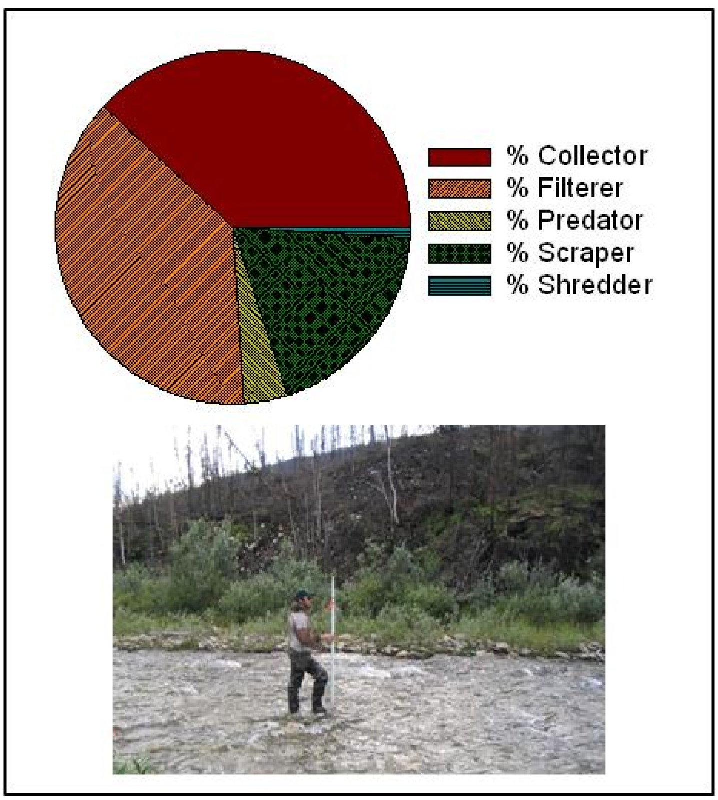


Figure 15. Observed functional feeding group composition at Site 23 (Monument Creek), a burned coniferous forest site.

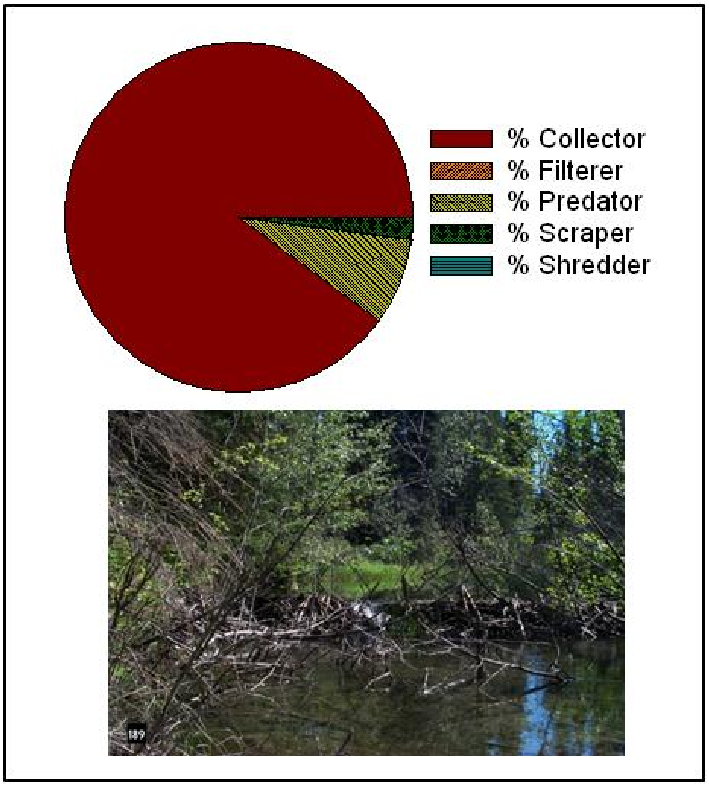


Figure 16. Observed functional feeding group composition at Site 189 (Piledriver Slough), a mixed forest site with some suburban development.

Acknowledgments

We thank the U.S. Environmental Protection Agency's Wadeable Streams Assessment Program for funding this work and the Alaska Department of Environmental Conservation for supplemental funding. We thank Mike Booz, Jodi McClory, Matt Drost, Keiko Kishaba, Joel Gottschalk, Skip Call, Allison Butler, Calvin Sweeney, Camille Camay, and Margaret Cysewski for help with fieldwork and logistics. Thanks also to Lil Herger and Phil Kaufman (EPA) for expert training on field methodology.

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Appendix A. Physicochemical parameters measured in Tanana basin wadeable streams.

Site ID	pH	Conductivity (µs/cm)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Dissolved organic carbon (mg/L)	Dissolved inorganic carbon (mg/L)	Total nitrogen (µg/L)	Nitrate (µeq/L)	Ammonium (µeq/L)	Total phosphorus (µg/L)	Ionic strength (M)	Chloride (µeq/L)
6	7.2	17	2.1	1	0.5	2.1	50	2	0	2	0	2
7	7.8	408	1.7	2.3	0.8	10.8	34	3	0	1	0.011	15
8	7.9	816	3.4	3.4	3.4	32.6	150	7	1	6	0.022	4
9	8.0	320	4.2	3.9	5.5	32.6	245	0	1	41	0.008	27
13	6.9	128	2.9	4.4	29.4	15.6	729	4	1	10	0.003	16
16	7.8	145	1.0	0	0.8	10.3	185	11	0	0	0.004	3
17	7.8	295	5.3	9	12.1	27.7	420	3	1	22	0.007	5
23	7.3	65	0.2	0.5	2.1	3.3	554	37	1	8	0.002	4
25	7.6	181	1.2	16.3	11.3	17.8	459	9	1	9	0.005	3
27	8.0	370	0.1	1.2	0.8	14.5	24	2	0	1	0.01	3
30	7.6	181	0.1	0	1.2	13.7	535	36	0	1	0.005	4
32	7.9	189	0.2	0.6	0.8	21.2	90	5	0	3	0.004	14
35	7.6	180	12.5	14.3	4.8	8.4	145	3	1	13	0.004	351
37	7.8	236	0.8	5.1	4.4	21.0	231	5	0	7	0.006	5
39	7.9	303	0.2	1.5	2.4	31.7	345	21	0	5	0.007	7
42	7.1	7	3.5	18.7	0.4	0.8	102	6	1	10	0	2
44	7.8	107	0.3	0.8	1.9	8.0	91	0	1	9	0.002	120
54	7.5	50	0.1	0.2	0.9	4.2	306	19	0	0	0.001	3
58	7.1	86	1.1	1.3	9.3	10.1	330	5	1	4	0.002	11
59	6.1	57	22.9	72.9	38.2	10.1	1565	2	3	144	0.002	11
63	7.8	234	18.6	57.4	19.6	24.4	1240	17	23	118	0.006	5
67	6.0	74	12.7	16.5	51.9	16.8	1291	2	8	59	0.002	7
70	7.6	172	0.3	0	31.1	12.3	1688	53	2	7	0.004	6

Site ID	pH	Conductivity (µs/cm)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Dissolved organic carbon (mg/L)	Dissolved inorganic carbon (mg/L)	Total nitrogen (µg/L)	Nitrate (µeq/L)	Ammonium (µeq/L)	Total phosphorus (µg/L)	Ionic strength (M)	Chloride (µeq/L)
73	8.1	2161	0.1	3.7	0.3	39.7	64	6	0	2	0.061	3
75	7.8	279	0.9	4.5	3.4	28.7	271	10	0	3	0.007	29
85	7.8	439	0.1	0.8	0.9	44.7	295	21	0	0	0.011	86
89	8.1	844	0.1	0.7	0.9	22.2	210	11	0	2	0.024	2
90	8.0	2004	28.4	109.3	0.3	16.9	74	9	0	164	0.057	3
91	7.3	201	0.3	0.6	1.6	12.6	241	14	0	2	0.005	7
93	7.3	108	6.9	12.7	15.6	10.2	504	3	1	18	0.003	3
94	7.8	469	0.9	2.1	0.2	9.6	144	8	1	3	0.013	3
98	7.9	131	0.5	1.3	0.7	11.1	313	19	1	0	0.003	3
105	8.5	1187	555.0	761.3	0.8	69.4	2911	199	1	231	0.021	4
111	7.2	160	716.0	3307.4	20.1	17.3	1542	11	11	2058	0.004	5
112	7.8	211	2.6	7.8	5.6	18.4	766	44	1	11	0.005	8
119	7.5	204	1.7	2	13.4	13.7	352	2	1	12	0.005	38
122	7.6	172	60.5	107.2	0.2	4.4	44	5	0	286	0.005	2
146	8.2	810	0.2	0	0.4	23.8	260	16	1	0	0.023	5
147	7.7	193	3.7	12.6	3.3	14.9	518	28	1	5	0.005	8
153	6.5	50	29.6	38	8.5	9.2	383	2	3	28	0.001	2
154	7.7	176	30.7	34.1	0.3	6.1	114	7	1	37	0.005	2
163	7.8	137	0.4	0.8	1.1	12.9	799	55	1	3	0.003	29
178	8.3	535	36.0	59.4	0.3	31.0	75	5	1	22	0.014	2
189	8.0	372	1.9	9.2	2.4	34.1	132	0	1	5	0.009	39
193	7.6	276	0.8	1.5	4.6	26.7	238	8	1	4	0.007	4
195	7.9	549	9.7	9.8	12.7	37.7	716	15	3	42	0.014	12

Appendix A continued

Site ID	Color (PCU)	Alkalinity (μeq/L)	Calculated bicarbonate (μeq/L)	Calculated carbonate (μeq/L)	Sum of cations (μeq/L)	Sum of anions (μeq/L)	Anion deficit [C-A] (μeq/L)	Sum of base cations (μeq/L)	Ion balance [C-A]/[C+A/2] (%)	Estimated organic ion (μeq/L)	Selenium (μg/L)
6	10	151	150	0	161	161	0	160	-0.11	4.73	-1.315
7	5	872	866	5	3189	3217	-27	3189	-0.43	8.39	-0.876
8	10	2656	2633	22	6405	6727	-322	6404	-2.45	33.67	-1.837
9	25	2670	2643	27	3058	3007	51	3057	0.84	54.61	-0.310
13	90	999	998	1	1425	1029	396	1423	16.12	286.04	-1.176
16	5	833	827	5	1292	1257	35	1292	1.38	8.24	-1.258
17	40	2233	2219	13	2780	2709	71	2779	1.30	120.18	-1.127
23	10	248	247	0	542	532	9	541	0.88	20.24	
25	65	1403	1398	5	1775	1617	158	1774	4.66	111.79	-1.389
27	10	1182	1171	10	2954	3014	-61	2954	-1.01	8.20	-0.318
30	15	1089	1084	4	1592	1601	-9	1592	-0.28	11.47	1.009
32	10	1723	1709	13	1785	1851	-66	1785	-1.81	8.22	-0.793
35	25	662	659	2	1549	1497	52	1548	1.70	47.95	-1.636
37	20	1696	1685	10	2163	2156	8	2163	0.17	43.80	-1.010
39	5	2577	2558	19	2828	2945	-116	2828	-2.02	24.25	-0.603
42	3	56	56	0	57	71	-14	57	-10.60	3.64	
44	10	643	639	4	974	931	44	974	2.29	18.88	-0.920
54	15	324	323	1	438	449	-11	438	-1.24	9.06	-0.353
58	20	709	708	1	883	769	114	882	6.90	91.09	-1.196
59	150	318	319	0	720	335	385	716	36.44	355.30	0.073
63	100	1975	1963	12	2316	2144	171	2293	3.84	195.12	-1.067
67	200	422	423	0	947	434	512	937	37.08	475.20	-0.027
70	90	977	973	4	1721	1359	362	1719	11.75	308.24	-0.727
73	5	3256	3222	34	15890	17307	-1417	15890	-4.27	3.40	1.698

Site ID	Color (PCU)	Alkalinity (µeq/L)	Calculated bicarbonate (µeq/L)	Calculated carbonate (µeq/L)	Sum of cations (µeq/L)	Sum of anions (µeq/L)	Anion deficit [C-A] (µeq/L)	Sum of base cations (µeq/L)	Ion balance [C-A]/[C+A/2] (%)	Estimated organic ion (µeq/L)	Selenium (µg/L)
75	10	2320	2305	15	2520	2721	-201	2520	-3.84	33.89	0.008
85	0	3611	3588	22	4048	4186	-137	4048	-1.67	8.76	0.799
89	15	1824	1802	20	6453	6839	-386	6453	-2.90	8.80	-1.624
90	5	1385	1371	13	14330	15326	-996	14330	-3.36	2.92	-2.530
91	10	935	933	2	1705	1709	-4	1704	-0.12	15.85	-0.290
93	38	761	759	1	1101	920	182	1100	8.99	153.48	
94	8	773	768	5	3624	3588	37	3624	0.51	2.28	
98	4	898	891	6	1190	1160	30	1190	1.28	6.91	
105	13	5828	5650	175	10545	10587	-41	10545	-0.20	7.55	
111	83	1270	1268	2	1574	1440	134	1563	4.45	197.76	
112	24	1481	1472	8	1937	1919	18	1936	0.46	55.56	
119	37	1069	1066	3	1846	1729	116	1844	3.25	132.57	
122	2	346	344	1	1340	1334	6	1340	0.23	1.83	
146	4	1970	1941	28	6524	6386	138	6524	1.07	3.66	
147	14	1191	1185	6	1743	1707	36	1742	1.04	32.79	
153	33	436	436	0	504	466	37	500	3.86	80.84	
154	4	481	479	2	1408	1390	18	1407	0.65	3.21	
163	4	1046	1039	6	1254	1288	-34	1253	-1.35	11.15	
178	10	2576	2528	46	4510	4678	-168	4509	-1.83	2.70	
189	12	2791	2765	26	3356	3457	-102	3355	-1.49	24.18	
193	16	2101	2094	7	2528	2545	-16	2528	-0.32	45.18	
195	31	3068	3044	23	4980	4671	309	4977	3.20	126.41	

Appendix A continued

Site ID	Calcium (µeq/L)	Magnesium (µeq/L)	Sodium (µeq/L)	Potassium (µeq/L)	Sulfate (µeq/L)
6	91	51	17	1	6
7	1956	1065	157	11	2326
8	4886	1265	218	35	4061
9	1790	1045	199	23	309
13	807	510	91	15	10
16	799	302	153	39	409
17	1594	981	193	11	468
23	413	71	47	10	244
25	1068	630	69	7	202
27	2167	606	167	13	1827
30	1048	461	53	29	472
32	1193	399	186	7	108
35	549	418	549	32	482
37	1393	667	88	15	449
39	1414	1062	322	29	339
42	19	11	22	5	7
44	644	136	173	22	168
54	319	59	53	6	103
58	476	304	82	19	45
59	396	274	31	15	4
63	1469	716	92	16	148
67	555	312	63	8	3
70	1030	541	121	27	322
73	7487	8299	52	51	14041

Site ID	Calcium (µeq/L)	Magnesium (µeq/L)	Sodium (µeq/L)	Potassium (µeq/L)	Sulfate (µeq/L)
75	1521	698	276	24	362
85	2733	1080	195	40	468
89	2892	3523	30	8	5002
90	10261	3969	59	40	13929
91	1138	394	148	24	754
93	475	435	166	24	153
94	2614	963	40	7	2803
98	963	107	97	23	240
105	1159	1206	8112	68	4555
111	983	483	81	17	153
112	1176	635	99	26	386
119	868	790	170	17	620
122	1077	226	33	3	980
146	3493	2808	183	40	4394
147	975	685	65	17	481
153	256	156	85	3	26
154	1102	279	17	9	900
163	738	456	51	9	158
178	1740	2703	48	17	2095
189	2385	734	165	71	627
193	2001	461	49	17	431
195	2959	1842	129	47	1575

Appendix B. Selected physical habitat data from Tanana basin wadeable streams.

Site ID	Channel slope, mean (%)	Wetted width, mean (m)	Discharge (cfs)	Thalweg depth, mean (cm)	Channel sinuosity (m/m)	Width:depth ratio (m/m)	Fast water [riffle & faster] (%)	Slow water [glide, pool] (%)	Pools (%)	Riparian canopy cover	Riparian ground layer cover
6	5.4	5.6	3.76	24.2	1.0	24	78	22	15	0.00	0.73
7	3.0	11.7	115.82	67.8	1.0	18	98	2	2	0.10	0.91
8	3.7	6.5	0.99	17.1	1.2	40	97	3	1	0.12	0.55
9	1.1	10.1	41.59	94.7	1.7	12	3	97	41	0.01	0.76
13	2.6	1.6	0.02	15.9	1.1	10	31	69	5	0.07	0.78
16	2.3	19.8	43.14	44.0	1.4	47	100	0	0	0.01	0.46
17	1.3	1.8	0.56	39.2		5	16	84	33	0.04	0.68
23	2.9	8.1	39.06	40.0	1.2	21	77	23	4	0.01	0.64
25	1.5	5.2	15.98	49.8	1.1	11	50	50	4	0.12	0.59
27	5.7	5.0	9.73	32.4	1.1	16	94	6	6	0.01	0.76
30	1.9	3.5	9.45	30.4	1.5	15	55	45	22	0.24	0.91
32	7.1	0.4	< 0.01	2.2	1.1	19	9	19	7	0.00	0.82
35	3.2	5.2	6.16	16.3	1.2	39	99	1	1	0.01	0.43
37	1.1	9.6	38.16	54.4	1.2	20	33	67	14	0.58	0.60
39	14.7	0.9	0.19	10.1	1.1	11	82	18	15	0.35	0.98
42	6.0	12.2	13.99	21.4		56	96	4	1	0.00	0.04
44	2.4	16.6	76.08	45.4	1.0	44	90	10	0	0.03	0.82
54	5.9	4.8	5.23	27.1	1.1	18	59	41	18	0.12	0.81
58	4.4	0.9	0.04	13.4	1.1	9	47	53	16	0.03	0.77
59	1.9	0.5	0	12.7	1.1	4	0	46	46	0.05	0.80
63	0.8	6.1	26.26	82.4		8	4	96	0	0.38	0.71
67	3.6	3.3	0	2.9	1.0	86	0	22	22	0.02	1.02

Site ID	Channel slope, mean (%)	Wetted width, mean (m)	Discharge (cfs)	Thalweg depth, mean (cm)	Channel sinuosity (m/m)	Width:depth ratio (m/m)	Fast water [riffle & faster] (%)	Slow water [glide, pool] (%)	Pools (%)	Riparian canopy cover	Riparian ground layer cover
70	1.3	1.2	0.24	13.1	1.2	10	51	49	19	0.31	1.01
73	21.4	2.0	0.45	10.9		28	77	23	17	0.00	0.00
75	1.1	9.6	51.38	75.6	2.0	14	37	63	10	0.25	0.34
85	1.0	4.4	15.76	81.2	1.1	6	0	100	5	0.08	0.95
89	22.0	2.9	0.30	11.8		31	56	44	39	0.07	0.20
90	12.3	2.7	6.43	21.3	1.0	14	83	17	17	0.00	0.03
91	4.1	1.0	0.40	23.7	1.2	5	40	60	36	0.04	0.87
93	7.1	0.6	0.02	17.3	1.1	6	3	96	59	0.16	0.92
94	11.3	4.0	8.84	28.9	1.2	15	81	19	18	0.02	0.75
98	14.2	3.7	8.00	33.5	1.1	14	55	45	20	0.06	0.55
105	21.0	1.5	0.25	9.4	1.0	18	71	29	15	0.00	0.11
111	3.3	2.5	0.36	23.7		13	4	96	15	0.08	0.94
112	2.0	8.9	96.00	93.3	3.3	10	2	98	77	0.30	0.72
119	1.2	10.5	18.86	89.1	2.3	18	0	100	70	0.14	0.51
122	6.5	4.0	13.64	38.8	1.0	11	95	5	3	0.00	0.24
146	30.8	3.3	1.12	24.9	1.0	14	63	37	32	0.00	0.05
147	2.4	6.3	35.17	58.4	1.9	13	15	85	60	0.18	0.60
153	2.3	3.0	0.33	29.3	1.2	14	7	93	22	0.00	0.85
154	14.1	4.9	1.97	16.9	1.1	30	73	27	9	0.00	0.16
163	2.4	1.0	0.84	14.1	1.2	6	10	90	16	0.08	1.06
178	7.3	3.7	8.56	25.4	1.1	16	91	9	5	0.00	0.01
189	0.8	9.4	4.31	91.6	1.3	13	0	100	53	0.56	0.69
193	1.2	5.5	16.78	75.7	1.1	8	3	97	68	0.54	0.84
195	0.5	4.4	< 0.01	140.8	1.0	3	0	100	100	0.30	0.69

Appendix B continued

Site ID	Riparian canopy, mid layer & ground woody cover	Bank canopy density, mean (%)	Mid-channel canopy density, mean (%)	Riparian disturbance,total (proximity weighted)	Fish cover all types (sum areal proportion)	Large woody debris in bankfull channel (m^3/m^2)	Side channel present (%)	Substrate mean log10 (diameter class mm)	Substrate, sand & fines (%)	Substrate ≤ fine gravel (%)	Substrate ≥ fine gravel (%)
6	0.53	73	18	0.0	0.38	0	6	1.80	6	14	84
7	1.13	84	18	0.0	0.38	0	36	2.10	11	11	89
8	0.82	75	27	0.0	0.18	0	81	1.03	21	32	68
9	0.92	69	11	0.0	0.26	0	0	-0.12	39	94	6
13	0.63	91	84	0.0	0.97	0	12	-2.11	7	7	0
16	0.74	24	1	0.0	0.57	0	51	1.71	17	22	78
17	0.58	97	93	0.0	0.63	0	12	-1.33	80	80	0
23	0.82	28	0	0.4	0.20	0	22	1.49	17	25	75
25	0.57	94	65	0.0	0.44	0	10	1.09	19	40	45
27	1.04	85	41	0.1	0.75	0	71	1.57	16	31	69
30	1.14	97	68	0.0	0.37	0	2	1.33	19	24	75
32	0.70	94	49	0.0	0.61	0	0	1.96	0	5	95
35	0.41	27	8	0.0	0.14	0	41	0.07	54	69	31
37	1.04	87	53	0.0	0.38	0.0019	7	0.27	32	60	34
39	1.00	89	83	0.0	0.36	0	32	1.14	21	41	57
42	0.00	34	0	0.0	0.12	0	0	1.86	5	10	90
44	1.21	73	0	0.0	0.34	0	14	1.49	16	26	68
54	0.90	92	49	0.0	0.53	0	60	1.82	6	11	87
58	0.75	65	51	0.0	0.34	0	17	0.58	36	52	46
59	0.61	91	87	0.0	1.22	0	1	-1.93	90	90	0
63	0.86	95	75	0.0	0.21	0	0	-0.47	97	97	1
67	0.74	70	54	0.0	0.98	0	100		0	0	0
70	1.12	89	79	0.0	0.29	0	1	0.42	47	68	29

Site ID	Riparian canopy, mid layer & ground woody cover	Bank canopy density, mean (%)	Mid-channel canopy density, mean (%)	Riparian disturbance,total (proximity weighted)	Fish cover all types (sum areal proportion)	Large woody debris in bankfull channel (m^3/m^2)	Side channel present (%)	Substrate mean log10 (diameter class mm)	Substrate, sand & fines (%)	Substrate ≤ fine gravel (%)	Substrate ≥ fine gravel (%)
73	0.00	28	11	0.0	0.40	0	41	2.05	6	14	86
75	0.87	68	50	0.0	0.54	0.0016	20	0.58	38	53	37
85	1.17	66	15	0.0	0.29	0	2	-0.17	54	54	11
89	0.60	82	71	0.0	0.58	0	6	1.78	7	28	70
90	0.01	0	0	0.0	0.10	0	49	1.54	13	16	84
91	1.15	95	92	0.0	1.42	0	4	0.35	39	39	54
93	1.22	98	98	0.0	1.08	0	3	-1.40	93	93	0
94	0.65	63	35	0.0	0.60	0	56	1.90	9	16	84
98	0.77	78	17	0.0	0.73	0	14	2.25	7	15	85
105	0.07	11	0	0.1	0.01	0	14	1.21	13	33	67
111	1.10	50	22	0.0	0.55	0	46	-2.11	98	98	0
112	0.97	78	21	0.1	0.44	0	0	0.59	36	53	45
119	0.40	65	33	1.1	0.21	0.0003	1	0.70	19	41	56
122	0.10	4	0	0.0	0.10	0	0	2.13	3	7	93
146	0.00	1	2	0.0	0.80	0	0	2.01	4	8	92
147	0.72	79	50	0.0	0.20	0	0	1.10	19	29	70
153	0.42	57	20	0.3	0.25	0	43	-0.79	91	91	5
154	0.17	1	0	0.0	0.15	0	7	1.50	12	25	75
163	1.53	99	93	0.3	1.15	0	0	0.82	27	46	49
178	0.01	2	0	0.0	0.16	0	0	1.43	11	26	74
189	1.37	78	36	1.0	0.51	0	1	-2.05	87	87	0
193	1.12	89	52	0.3	0.34	0	0	-0.27	63	76	17
195	1.02	84	49	0.4	0.44	0	0	-2.08	98	98	0

Appendix C. Periphyton biomass data from Tanana basin wadeable streams

Site ID	Ash-free dry mass (g/m^2)	Chlorophyll a (mg/m^2)	Notes
6	0.98	0.76	
7	2.8	2.27	
8	12.88	48.48	
9	143.94	12.88	
13		1.52	AFDM sample lost
16		1.52	AFDM sample lost
17	21.14	9.09	
23	2.95	1.52	
25	2.65	2.27	
27	2.5	2.27	
30	15.45	57.58	
32	20	43.33	
35	2.05	2.27	
37		7.58	AFDM sample lost
39	1.29	2.27	
42	0.23	0.76	
44	5.3	16.67	
54	9.17	14.39	
58	6.29	6.82	
59			Not sampled - intermittent flow
63		0.76	AFDM sample lost
67	5.98	2.27	Suspect sample - intermittent flow
70	3.03	3.79	
73	0.61	0.76	

Site ID	Ash-free dry mass (g/m^2)	Chlorophyll a (mg/m^2)	Notes
75		5.3	AFDM sample lost
85	2.42		Chlorophyll a sample lost
89	1.97	3.03	
90	2.2	0	
91	3.11	3.79	
93	16.52	4.55	
94	4.7	6.82	
98	1.21	0.76	
105	4.92	0	
111	224.24	3.79	
112	2.8	3.03	
119	7.88	12.12	
122	1.67	3.03	
146	2.8	1.52	
147	2.12	3.79	
153	36.74	1.52	
154	2.12	0	
163	5.08	7.58	
178	4.7	0	
189	9.47	7.58	
193	83.94	19.7	
195	148.64	18.94	

Appendix D. Selected macroinvertebrate assemblage metric data from Tanana basin wadeable streams.

Site ID	Richness	Density (no./m^2)	Chironomidae (% individuals)	Ephameroptera richness	Ephemeroptera (% individuals)	Plecoptera richness	Plecoptera (% individuals)	Trichoptera richness	Trichoptera (% individuals)
6	18	1520	17.4	5	47.5	2	12.4	2	2.6
7	15	736	65.0	4	8.0	3	21.0	1	0.2
8	10	976	91.6	1	0.2	2	1.0	0	0.0
9	20	1323	66.9	2	4.3	1	1.3	3	3.3
13	17	1139	59.2	1	10.5	1	12.2	2	0.4
16	15	1263	2.6	4	79.2	3	5.4	3	4.2
17	14	1960	20.8	1	4.8	1	50.0	2	2.8
23	16	2367	12.3	5	27.6	1	2.1	2	2.5
25	15	1863	2.2	2	73.4	2	11.2	1	0.2
27	14	3252	17.8	4	48.5	2	13.2	2	0.6
30	18	3346	46.4	4	7.9	3	20.8	1	1.5
32	11	5533	90.4	3	1.2	4	5.2	1	0.4
35	10	265	88.9	2	2.3	2	2.3	1	1.1
37	11	135	14.2	4	67.9	2	6.7	1	6.0
39	18	7860	41.6	3	7.3	2	14.6	2	1.5
42	5	1848	83.1	0	0.0	0	0.0	0	0.0
44	17	803	56.6	6	17.0	3	12.4	3	10.0
54	16	966	28.0	2	26.8	4	27.6	1	0.2
58	13	3573	50.7	2	3.2	2	27.4	0	0.0
59*									
63	9	569	86.1	2	10.5	0	0.0	0	0.0
67*									
70	12	1690	12.7	1	0.2	2	75.3	2	0.2

Site ID	Richness	Density (no./m^2)	Chironomidae (% individuals)	Ephameroptera richness	Ephemeroptera (% individuals)	Plecoptera richness	Plecoptera (% individuals)	Trichoptera richness	Trichoptera (% individuals)
73	3	130	96.1	0	0.0	0	0.0	0	0.0
75	23	642	33.3	5	4.9	3	13.7	3	17.0
85	18	16592	21.8	3	17.7	2	53.4	2	1.6
89	9	24949	13.2	0	0.0	2	69.2	0	0.0
90	6	55	90.7	0	0.0	0	0.0	2	3.7
91	10	2441	46.6	1	1.2	1	34.2	1	1.2
93	14	2963	59.1	1	8.8	0	0.0	0	0.0
94	10	194	82.8	1	0.5	3	9.9	0	0.0
98	13	687	41.4	4	11.8	3	22.1	1	20.4
105	2	22	90.9	1	4.5	0	0.0	0	0.0
111	12	760	63.0	2	18.8	1	0.6	0	0.0
112	14	271	27.6	4	19.4	3	17.9	2	3.7
119	21	1380	35.7	6	33.1	2	0.6	3	1.2
122	4	81	88.8	0	0.0	1	1.3	0	0.0
146	5	589	92.8	0	0.0	1	0.2	0	0.0
147	18	524	40.0	4	14.0	4	24.4	3	4.2
153	12	126	52.0	1	10.4	0	0.0	0	0.0
154	2	270	97.4	0	0.0	0	0.0	0	0.0
163	21	1240	24.8	3	8.0	4	12.0	2	2.3
178	2	2	0.0	1	50.0	1	50.0	0	0.0
189	23	1052	65.6	2	4.1	0	0.0	2	13.4
193	16	2256	53.6	3	0.8	2	0.6	1	0.0
195	11	1909	77.8	2	7.5	0	0.0	1	3.2

*Not sampled due to intermittent flow

Appendix D continued

Site ID	Collector-filterer (% individuals)	Collector-gatherer (% individuals)	Predator (% individuals)	Scraper (% individuals)	Shredder (% individuals)	Dominant taxon	Shannon's diversity	Hilsenhoff biotic index
6	5.6	49.9	16.4	15.8	12.4	*Baetis bicaudatus*	2.21	3.86
7	3.9	70.8	19.3	2.7	2.9	Chironomidae	1.08	4.69
8	1.0	93.4	2.1	0.0	3.4	Chironomidae	0.43	5.86
9	1.8	76.8	7.6	0.3	13.5	Chironomidae	1.38	5.38
13	7.3	73.8	5.7	0.7	12.4	Chironomidae	1.43	5.36
16	0.0	11.4	5.0	80.8	2.8	*Epeorus*	1.54	2.22
17	5.2	29.2	40.5	0.0	24.8	*Nemoura*	1.86	3.25
23	37.8	37.8	4.2	19.4	0.8	*Prosimilium*	1.99	3.92
25	3.9	57.1	3.5	24.4	11.2	*Baetis bicaudatus*	1.53	4.44
27	16.4	26.7	5.0	39.7	12.2	*Epeorus*	1.85	2.81
30	5.1	66.8	4.9	5.8	17.4	Chironomidae	1.62	4.53
32	0.0	91.0	3.0	0.8	5.2	Chironomidae	0.46	5.67
35	0.0	93.5	4.2	0.4	1.5	Chironomidae	0.52	5.73
37	0.0	40.3	6.0	44.8	9.0	*Cinygmula*	1.91	3.30
39	9.2	65.7	6.9	1.2	16.4	Chironomidae	1.77	4.67
42	0.0	83.6	0.4	16.0	0.0	Chironomidae	0.50	5.99
44	0.8	61.2	12.4	23.5	2.2	Chironomidae	1.64	4.11
54	0.2	43.3	7.9	25.5	22.8	Chironomidae	1.84	4.37
58	5.6	61.9	3.0	1.9	27.1	Chironomidae	1.39	4.66
59*								
63	1.0	95.7	3.1	0.2	0.0	Chironomidae	0.64	5.85
67*								
70	2.8	20.1	5.2	0.2	71.1	*Nemoura*	1.18	2.65
73	0.0	97.7	1.6	0.0	0.0	Chironomidae	0.13	5.97

Site ID	Collector-filterer (% individuals)	Collector-gatherer (% individuals)	Predator (% individuals)	Scraper (% individuals)	Shredder (% individuals)	Dominant taxon	Shannon's diversity	Hilsenhoff biotic index
75	1.3	60.5	12.7	12.0	13.1	Chironomidae	2.11	4.18
85	0.7	41.9	3.5	0.5	53.2	*Zapada*	1.42	3.49
89	2.2	21.5	0.8	6.5	69.0	*Nemoura*	1.14	3.08
90	0.0	94.4	0.0	3.7	1.9	Chironomidae	0.46	5.83
91	0.2	58.3	0.4	4.3	35.0	Chironomidae	1.28	4.26
93	1.8	87.7	6.1	0.0	0.6	Chironomidae	1.35	5.53
94	0.0	84.4	1.6	0.0	10.4	Chironomidae	0.65	5.41
98	2.1	51.1	1.9	7.6	36.8	Chironomidae	1.37	4.24
105	0.0	100.0	0.0	0.0	0.0	Chironomidae	0.19	6.14
111	3.4	91.1	1.7	0.0	1.1	Chironomidae	1.11	5.65
112	0.0	60.4	13.1	16.0	9.7	Chironomidae	1.84	4.34
119	15.6	67.5	7.2	7.4	2.2	Chironomidae	2.03	5.40
122	0.0	88.8	3.8	6.3	1.3	Chironomidae	0.42	5.86
146	0.0	98.8	0.0	0.2	0.2	Chironomidae	0.30	5.94
147	10.2	46.0	8.7	12.4	22.2	Chironomidae	1.83	3.99
153	0.8	82.4	8.8	0.0	3.2	Chironomidae	1.51	5.45
154	0.0	97.4	0.0	2.6	0.0	Chironomidae	0.12	6.00
163	2.4	78.5	4.9	3.8	8.7	Oligochaeta	1.61	4.71
178	0.0	0.0	0.0	50.0	50.0	Heptageniidae	0.69	3.00
189	0.2	77.0	7.0	2.1	0.0	Chironomidae	1.52	5.64
193	1.3	95.2	0.6	0.4	0.4	Chironomidae	0.98	5.50
195	0.0	96.0	3.2	0.0	0.2	Chironomidae	0.89	5.55

*Not sampled due to intermittent flow

Appendix E. List of macroinvertebrate taxa (and associated relative abundance) collected in Tanana basin wadeable streams.

Phylum	Class	Order	Family	Final ID	% of total
Annelida	Hirudinea			Hirudinea	0.02
Annelida	Oligochaeta			Oligochaeta	15.10
Arthropoda	Arachnoidea	Acari (Hydracarina)		Hydracarina	0.21
Arthropoda	Arachnoidea	Acari (Hydracarina)	Eremaeidae	Hydrozytes (near)	0.24
Arthropoda	Arachnoidea	Acari (Hydracarina)	Lebertiidae	*Lebertia*	0.61
Arthropoda	Arachnoidea	Acari (Hydracarina)	Sperchonidae	*Sperchon*	0.59
Arthropoda	Crustacea	Amphipoda		Amphipoda	0.65
Arthropoda	Crustacea	Amphipoda	Hyalellidae	*Hyalella*	0.36
Arthropoda	Crustacea	Podocopa		Ostracoda	0.23
Arthropoda	Insecta	Coleoptera		Coleoptera	0.07
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Agabinus*	0.02
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Dytiscidae*	0.05
Arthropoda	Insecta	Collembola		Collembola	0.10
Arthropoda	Insecta	Diptera		Diptera	0.35
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Bezzia*	0.07
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Ceratopogon*	0.12
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogonidae	0.12
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Culicoides*	0.04
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Probezzia*	0.03
Arthropoda	Insecta	Diptera	Chironomidae	*Odontomesa*	0.04
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	1.19
Arthropoda	Insecta	Diptera	Culicidae	Culicidae	0.04
Arthropoda	Insecta	Diptera	Dixidae	*Dixa*	0.02
Arthropoda	Insecta	Diptera	Dixidae	*Dixella*	0.06
Arthropoda	Insecta	Diptera	Dolichopodidae	Dolichopodidae	0.11
Arthropoda	Insecta	Diptera	Empididae	*Chelifera*	1.23
Arthropoda	Insecta	Diptera	Empididae	*Clinocera*	0.26
Arthropoda	Insecta	Diptera	Empididae	Empididae	0.08
Arthropoda	Insecta	Diptera	Empididae	*Oreogeton*	0.68
Arthropoda	Insecta	Diptera	Empididae	*Trichoclinocera*	0.07
Arthropoda	Insecta	Diptera	Muscidae	Muscidae	0.11
Arthropoda	Insecta	Diptera	Phoridae	Phoridae	0.02
Arthropoda	Insecta	Diptera	Psychodidae	*Pericoma*	1.04
Arthropoda	Insecta	Diptera	Simuliidae	*Cnephia*	0.03

Phylum	Class	Order	Family	Final ID	% of total
Arthropoda	Insecta	Diptera	Simuliidae	*Gymnopais*	1.82
Arthropoda	Insecta	Diptera	Simuliidae	*Helodon*	0.52
Arthropoda	Insecta	Diptera	Simuliidae	*Metacnephia*	0.01
Arthropoda	Insecta	Diptera	Simuliidae	*Prosimulium*	3.95
Arthropoda	Insecta	Diptera	Simuliidae	Simuliidae	0.88
Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	2.19
Arthropoda	Insecta	Diptera	Tabanidae	Tabanidae	0.04
Arthropoda	Insecta	Diptera	Tipulidae	*Dicranota*	0.85
Arthropoda	Insecta	Diptera	Tipulidae	*Hesperoconopa*	0.10
Arthropoda	Insecta	Diptera	Tipulidae	*Holorusia*	0.01
Arthropoda	Insecta	Diptera	Tipulidae	*Molophilus*	0.01
Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	0.94
Arthropoda	Insecta	Diptera	Tipulidae	Tipulidae	0.03
Arthropoda	Insecta	Ephemeroptera		Ephemeroptera	0.06
Arthropoda	Insecta	Ephemeroptera	Ameletidae	*Ameletus*	0.95
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetidae	0.40
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	1.15
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis bicaudatus*	6.57
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis tricaudatus*	4.13
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Drunella coloradensis*	0.01
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Drunella doddsi*	0.22
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Ephemerella*	0.03
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerellidae	0.08
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Serratella*	0.51
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Cinygmula*	6.49
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Epeorus*	2.76
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Epeorus iron*	2.90
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptageniidae*	2.11
Arthropoda	Insecta	Hemiptera		Hemiptera	0.18
Arthropoda	Insecta	Lepidoptera		Lepidoptera	0.03
Arthropoda	Insecta	Lepidoptera	Noctuidae	Noctuidae	0.01
Arthropoda	Insecta	Odonata	Aeshnidae	*Aeshna*	0.04
Arthropoda	Insecta	Plecoptera		Plecoptera	1.79
Arthropoda	Insecta	Plecoptera	Capniidae	*Capnia*	0.60
Arthropoda	Insecta	Plecoptera	Capniidae	Capniidae	0.54
Arthropoda	Insecta	Plecoptera	Capniidae/Leuctridae	Capniidae/Leuctridae	0.13
Arthropoda	Insecta	Plecoptera	Chloroperlidae	*Alaskaperla*	0.01
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Chloroperlidae	0.62
Arthropoda	Insecta	Plecoptera	Chloroperlidae	*Plumiperla*	0.14

Phylum	Class	Order	Family	Final ID	% of total
Arthropoda	Insecta	Plecoptera	Chloroperlidae	*Suwallia*	2.34
Arthropoda	Insecta	Plecoptera	Leuctridae	*Despaxia*	0.11
Arthropoda	Insecta	Plecoptera	Nemouridae	*Nemoura*	11.72
Arthropoda	Insecta	Plecoptera	Nemouridae	Nemouridae	2.19
Arthropoda	Insecta	Plecoptera	Nemouridae	*Podmosta*	0.06
Arthropoda	Insecta	Plecoptera	Nemouridae	*Zapada*	8.98
Arthropoda	Insecta	Plecoptera	Perlodidae	*Isoperla*	0.25
Arthropoda	Insecta	Plecoptera	Perlodidae	*Kogotus*	0.10
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlodidae	0.10
Arthropoda	Insecta	Plecoptera	Perlodidae	*Skwala*	0.04
Arthropoda	Insecta	Plecoptera	Taeniopterygidae	*Taenionema*	0.01
Arthropoda	Insecta	Trichoptera		Trichoptera	0.17
Arthropoda	Insecta	Trichoptera	Apataniidae	*Allomyia*	0.07
Arthropoda	Insecta	Trichoptera	Apataniidae	*Apatania*	0.42
Arthropoda	Insecta	Trichoptera	Apataniidae	Apataniidae	0.01
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentridae	0.03
Arthropoda	Insecta	Trichoptera	Brachycentridae	*Brachycentrus*	0.03
Arthropoda	Insecta	Trichoptera	Glossosomatidae	*Glossosoma*	0.53
Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Agraylea*	0.01
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilidae	0.02
Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Oxyethira*	0.66
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Dicosmoecus*	0.00
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Ecclisomyia*	0.39
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Hydatophylax*	0.25
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilidae	1.66
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Onocosmoecus*	0.02
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Phanocelia canadensis*	0.02
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Psychoglypha*	0.21
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	*Rhyacophila*	0.45
Mollusca	Bivalvia	Veneroida	Sphaeriidae	Sphaeriidae	0.22
Mollusca	Gastropoda			Gastropoda	0.05
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbidae	0.12
Mollusca	Gastropoda	Basommatophora	Planorbiidae	*Planorbula*	0.02
Nematoda				Nematoda	0.24
Platyhelminthes	Turbellaria			Turbellaria	0.68

Appendix F.

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Alaska Tanana Basin Wadeable Streams Design

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Description of Sample Design

Target population: All wadeable perennial streams within the Tannana Basin in Alaska.

Sampling Frame: National Hydrologic Dataset (NHD) for the Tannana Basin in Alaska. NHD for this basin has not yet undergone the process of updating and review that has been completed for most of the United States. It does not have Strahler order available as an attribute. USGS in Alaska initiated the calculation of Strahler order and determined that sufficient problems were present that it was not feasible to complete within the time frame required. Other attributes in NHD will be used as surrogates for stream size and importance. The categories will be: (1)Named rivers and streams including headwater and start reaches that are named, (2) Headwater and Start reaches excluding any named reaches , (3) In network streams (0 and 1) that are not in either category 1 or 2, and (4) other reaches, non-networked and isolated reaches. In the documentation please explicitly describe the NHD codes used to create these categories. Note the fourth category will be excluded from the frame for sampling purposes.

Survey Design: GRTS survey design for a linear network with RHO. GRTS: Generalized Random Tessellation Stratified. RHO: Reverse Hierarchical Order.

Stratification: None
Panels: None

Multi-Density Categories: Use the first 3 categories described under the sample frame. For convenience refer to them as: Headwater, Named River, and Other Network reaches. The fourth category will not be included.

Sample size: 50 total base samples. Allocate to Multi-Density Categories as follows:

Headwater - 12, Named River - 25, Other Network - 13. Expectation is that more Headwater streams will be replaced due to being non-perennial (NonTarget) than streams in the other categories and that more Other network streams will be non target than named rivers. If this is the case, then more than 50% of the sites will be on Named
Rivers and less than 25% will be in the other two categories. Rationale for assigning more sites to Named Rivers is that they are most likely to be streams and rivers that are of interest.

Over sample: 300% (150 sites) for a total of 200 sites.

Sample Frame Description (USGS National Hydrography Dataset – High Resolution data for Alaska)

The Cataloging Units 19040501 – 19040509 and 19040511 (available from the NHD ftp site as of February, 2004) were appended using the "append_NHD tool 2.27". This created one coverage for the Tanana Basin. An attribute for the sample categories listed above was added to the coverage. No coverage was available for CU 19040510 in the southwest portion of the Tanana River Basin, therefore, no streamsin this CU were used for selection.

The attributes were assigned to the reach (RCH) route in the following order:

1. Named routes were selected (variable "NAME" contained any character string) and assigned sample category 1.
2. From the remaining reaches, using the related NHD.rflow table (rch2tflw relate), routes where "delta_lvl" = -9999 were assigned sample category 2.
3. From the remaining reaches, routes where "delta_lvl" is greater or equal to 0 were assigned sample category 3.
4. All remaining reaches were assigned sample category 4.

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Description of Sample Design Output:

To achieve an expected sample size of sites in the target population, an appropriate sample size was selected for each separate study area. The extra/reserve samples are to provide alternate sites for sample sites not conforming to target population rules (e.g. non-wadeable, mis-mapped features) or being inaccessible due to safety concerns or denied access by landowners. The design has a base set of 50 samples spread over a single panel. The design has a 300% oversample, i.e. 150 reserve sites, for a total of 200 potential sample sites. The oversample sites should be added, as needed, in numerical order.

The following tables show the distribution of the frame information, as well as the sample sites, for each separate design (stratum).

Sums of Multipliers for Sample Design
AK Tanana Basin streams 2004

sampclass	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	55323.61	50.00	55323.61	50.00
2	26555.97	24.00	81879.57	74.00
3	28774.57	26.00	110654.1	100.00

clasmult	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	26555.97	24.00	26555.97	24.00
1.571	28774.57	26.00	55330.54	50.00
3.262	55323.61	50.00	110654.1	100.00

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MD_CATY values for AK Tanana Basin streams 2004
sums are in meters

md_caty	numbering scheme for design strata	clasmult	sampclass	sum of units	sum of weighted units
1	1	1.000	2	26555965.52	26555965.52
2	1	1.571	3	18316088.14	28774574.47
3	1	3.262	1	16960026.48	55323606.37

Selected Sites for AK Tanana Basin streams 2004

Table of nest_id by oversamp

nest_id
oversamp(If 0: routine site; Else a reserve site)

Frequency	0	1	Total
1	50	150	200
Total	50	150	200

Table of sampclass by oversamp

sampclass
oversamp(If 0: routine site; Else a reserve site)

Frequency	0	1	Total
1	24	68	92
2	11	41	52
3	15	41	56
Total	50	150	200

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The attached comma-delimited, ASCII file (akw04450.csv) has the following variable definitions:

Site_ID	Sample Identifier assigned to each site 14 characters
Site Name	Name (if provided) 30 characters
Long-DD	Longitude, Decimal Degrees 12.6 numeric
Lat-DD	Latitude, Decimal Degrees 12.6 numeric
Stratum	Stratum (1 stratum defined in this design) 2 integer
Panel	Used if Multiple years/seasons/etc. sample 1 integer
Oversamp	Defines “backup” or “oversample” sites. 1 = oversample site, 0 = expected sample site 1 integer
Division	Division breaks down panels and expected/replicate sites. 1 integer
MD_Caty	Multi-Density weight category - defined above. 2 integer
Nest_ID	More than one if multiple levels/classes of samples drawn. 1 integer
Nest1	Defines sites within this nest class (1 = within, 0 = not in) 1 integer
Nest1_N	Expected number of samples for initial design categories. 2 integer
Nest1_wt	Initial Design weight for the site. 12.7 numeric
Long-DMS	Longitude, Degrees Minutes Seconds 20 characters
Lat-DMS	Latitude, Degrees Minutes Seconds 20 characters

The location information (if provided) is based on the 1927 North American Datum for projection. The Arc/INFO export files, if delivered with these data, have the following projection parameters:

Projection	Albers
Datum	NAD27
Spheroid	Clarke 1866
Units	Meters

1st projection parallel	55.0
2nd projection parallel	65.0
central meridian	-154
projection origin	50
false easting	0.0
false northing	0.0

Description of Statistical Analysis:

The statistical analysis of the data requires the weighting and stratification variables be used, even if computation of descriptive statistics (means, medians, standard errors, etc.) is all that is desired. After fieldwork and sampling, information on sampled and unsampled sites, along with reasons for non-sampling, need to be used to adjust sample weights. Otherwise, incorrect estimates for the target population will occur. See references for estimation procedures, or contact emapdesign@mail.cor.epa.gov.

For any questions about these data, please contact:

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Appendix G.

COMPARISON OF MACROINVERTEBRATE SAMPLES COLLECTED BY TWO DIFFERENT MESH SIZES – EMAP *vs*. ENRI Methods

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INTRODUCTION

The goal of this study is to compare the macroinvertebrate assemblages collected using the 500-µm mesh used in the U.S. EPA's Environmental Monitoring and Assessment Program protocols (EMAP; Peck et al. 2001) to those collected using the 350-µm mesh called for in the standard methodology for Alaska streams developed by the Environment and Natural Resources Institute (ENRI; Major and Barbour 2001). A large number of stream macroinvertebrate samples have been collected from various regions of Alaska over the past eight years using the ENRI methodology, and this methodology will continue to be used for stream surveys and restoration effectiveness monitoring. EMAP methodology is currently being used to guide data collection in the EPA-funded Tanana Basin probabilistic stream survey project and will likely be used for future projects of this nature. These are the two primary methodologies currently in use for stream macroinvertebrate surveys in Alaska and it is important to know the extent to which resulting data are comparable. If major systematic errors are detected, it will be advisable to refine one or both methods to increase the level of compatibility.

There are several differences between these methods. The ENRI method employs a 350-µm-mesh net while the EMAP method uses 500-µm. The ENRI method calls for sampling at 20 locations across a 100-meter study reach, where each available stream habitat (i.e., rocky substrate, submerged wood and vegetation, undercut banks) is sampled in proportion to its abundance. The EMAP method calls for systematic sampling on 11 equally spaced transects on a study reach equal to 40x the mean channel width that is centered on a randomly selected point. The ENRI method calls for a standardized count of 300 organisms to be identified whereas the EMAP protocol calls for 500 organisms. Taxonomic resolution is similar between the methods except for the Chironomidae (a very common and diverse family of midges): the ENRI method calls for genus-level identification while the EMAP method does not identify them beyond family.

This study addresses only the different mesh sizes employed by the two methods as this seems to be the most fundamental difference. The other differences in sampling methodology – 20 sample locations in proportion to habitat abundance for the ENRI method vs. 11 systematically chosen locations for the EMAP method – yield samples that should theoretically have similar taxonomic composition. The differences in taxonomic effort (300- *vs*. 500-organism counts) can by overcome by rarefaction (Hurlbert 1971, Heck et al. 1975) or by autosimilarity analyisis (Cao et al. 2002), methods that statistically scale the taxonomic effort of large samples to that of smaller samples. The increased Chironomidae taxonomic resolution of the ENRI samples can be reconciled by combining Chironomidae genera at the family level when comparing across the two methods.

ENRI has collected an additional set of side-by-side samples from streams in the Cook Inlet Basin ecoregion during the spring of 2006 for a complete comparison of the two methodologies. We will proceed with the analysis of these samples once funding is identified.

METHODS

We collected side-by-side macroinvertebrate samples using both 350-µm and 500-µm-mesh D-frame nets at 8 stream sites (4 in Cripple Creek, 4 in Caribou Creek) during the summer of 2005. Aside from mesh size, we used EMAP protocols for all of the field sampling and laboratory processing (see Introduction).

For each sample we calculated the number of taxa (i.e., taxa richness) and the percent of the individuals belonging to the family Chironomidae (i.e., % Chironomidae). We chose these response variables because we hypothesized that they would be among the most vulnerable to the differential capture efficiencies offered by the two mesh sizes. Taxa richness is a ubiquitous measure of species diversity that could potentially be influenced by mesh size if small taxa were being missed by the 500-µm mesh. Since Chironomidae are very common and are among the smallest of the macroinvertebrates, it is conceivable that the 500-µm mesh is less efficient at capturing them. We used paired-samples *t*-tests to compare the two mesh sizes according to these two response variables. We also used regression analysis to test the relationship between the mesh sizes according to these response variables.

In separate multivariate analyses, we used cluster analysis (PC-ORD with system defaults) to hierarchically aggregate the samples according to their multivariate similarity. This analysis simultaneously considered the abundance of each taxon in each sample.

We also calculated the classification strength sampling-method comparability index (CS-SMC) described in Cao et al. (2005). This method calculates the pairwise multivariate similarity between all possible combinations of samples (i.e., a similarity matrix) and then divides the average between-method similarity by the average within-method similarity. Scores can range from 0% (when the samples collected by the two methods share no species) to 100% (when the within-method similarity equals the between-method similarity). We quantified sample similarity by the Jaccard coefficient, which considers only the presence/absence of taxa in each sample, as well as the Bray-Curtis index which considers the abundance of each taxon in each sample (Krebs 1999).

RESULTS AND DISCUSSION

In total, 65 macroinvertebrate taxa were collected from the 8 sites (Table 1). Paired-samples *t*-tests indicated that taxa richness did not differ between samples collected with the different mesh sizes ($P = 0.35$). Conversely, % Chironomidae was higher in the 350-µm-mesh samples ($P = 0.02$). However, the effect size was relatively small, with Chironomidae comprising 41% of the 350-µm-mesh samples and 35% of the 500-µm-mesh samples. Correlation analysis showed that, for both response variables, the data from the two mesh sizes correlated significantly ($P < 0.05$) and that, when forced through the origin, the slope of each line was close to 1 (Figures 1 and 2).

Cluster analysis revealed that, in almost every case, the 350-µm and 500-µm samples from a given site were more similar to each other than to any sample from another site (Figure 3). This is remarkable considering the fact that these sampling sites were located entirely on two small watersheds where the among-site similarity was expected to be high. The only exceptions to this pattern were sites 2 and 4 on Cripple Creek, where the 350-µm-mesh samples were more similar to each other than to their respective 500-µm-mesh samples (Figure 3). However, the macroinvertebrate communities at these sites were very similar (more similar than any other two sites, Figure 3), so this result does not necessarily indicate a fundamental difference between samples collected by the two mesh sizes.

CS-SMC using the Jaccard coefficient was 100%, indicating that the amount of within-method sample variability was identical to the average between-sample variability. Likewise, CS-SMC using the Bray-Curtis index was 99.9%.

Taken together, our data indicate that 350-µm mesh and 500-µm mesh were collecting samples with very similar taxonomic composition. Although the smaller mesh appears to be more efficient at collecting the small and abundant Chironomidae, this had no perceptible effect on taxa richness, the cluster analysis, or CS-SMC which simultaneously considered the abundance of each taxon. While we recommend to avoid comparing metrics that are vulnerable to this Chironomidae bias (e.g., % Chironomidae, % Diptera), the high correlation between % Chironomidae collected by the two mesh sizes (r^2 = 0.88) makes it possible to correct for the difference in capture efficiency.

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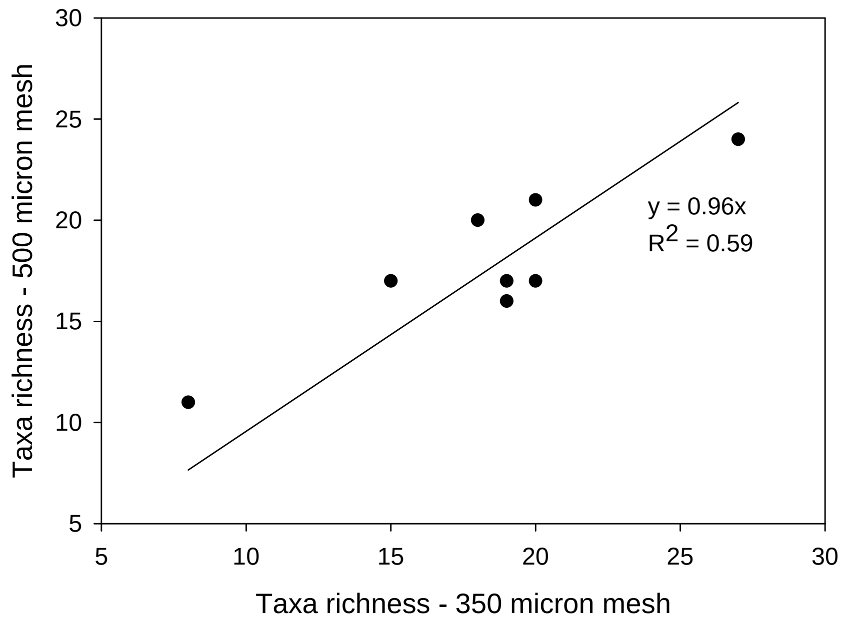

Figure 1. Correlation between taxa richness in macroinvertebrate samples collected by the two different mesh sizes.

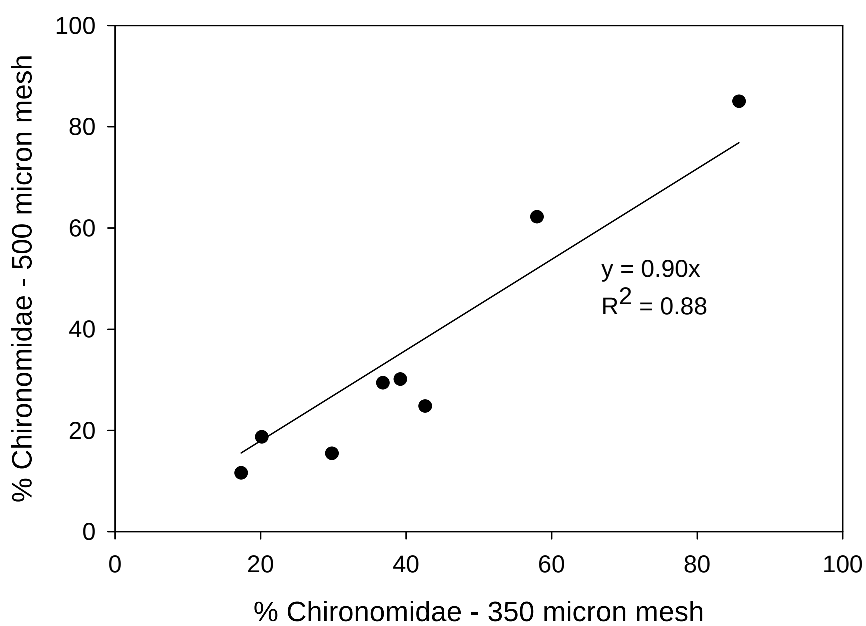

Figure 2. Correlation between % Chironomidae in macroinvertebrate samples collected by the two different mesh sizes.

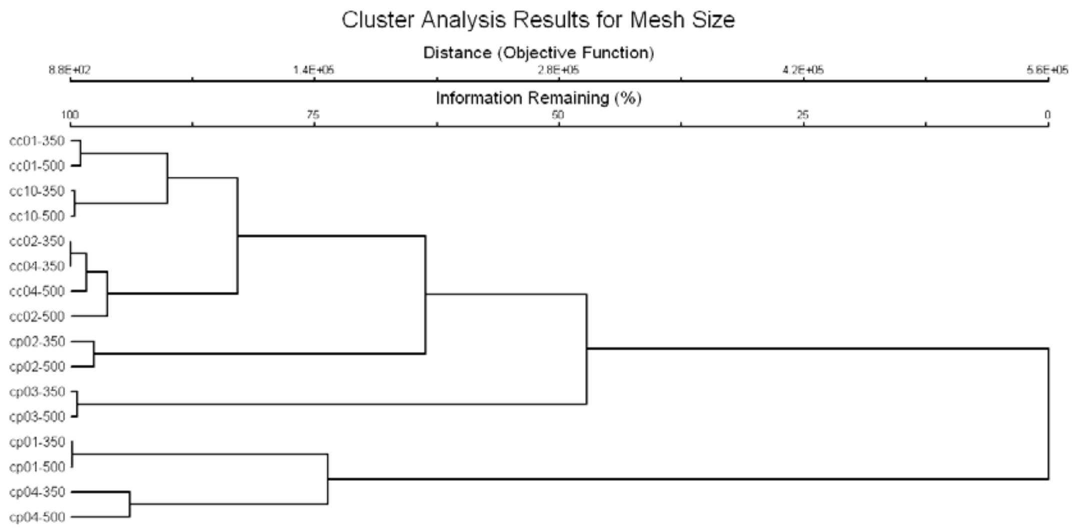

Figure 3. Dendrogram showing the hierarchical relationship between the multivariate taxonomic composition of the macroinvertebrate samples. cc = Cripple Creek, cp = Caribou Creek.

Table 1. Macroinvertebrate taxa (and associated abundances) collected by the two mesh sizes.

Site	Cripple Cr-01		Cripple Cr-02		Cripple Cr-04		Cripple Cr-010		Poker Cr-01		Poker Cr-02		Poker Cr-03		Poker Cr-04	
Mesh size	350	500	350	500	350	500	350	500	350	500	350	500	350	500	350	500
TAXON																
Allomyia							20	36								
Ameletus	1	8	5	14	19	13	7	7			1		18	22		
Amphipoda			1				8	6			3					
Apatania																2
Baetidae		1														
Baetis			3	8	3	12	5	5			1			2		1
Baetis bicaudatus	24	23	127	166	147	129	132	114	1		10	13	16	6	5	5
Bivalvia							1									
Canace										1						
Capniidae					1		4	6								
Ceratopogon										3				1		
Ceratopogonidae			1	1												
Chelifera	8	3	1		4	1					21	17	11	18	20	12
Chironomidae	104	94	208	95	191	139	79	54	294	314	144	77	196	152	403	562
Chloroperlidae							1									
Cinygmula	82	80	33	29	35	33	59	78			25	51	1		8	5
Clinocera					2											
Coleoptera			1	1												
Collembola	1		4	3	3	2	1						1			
Dicranota	3		4			1			5	1	1	2			10	8
Diptera										1					2	1
Drunella doddsi	4	7													2	5
Ecclisomyia		3	2	2	5	6	2	3				6		2		7
Epeorus	15	22	1	2	1						2	2				1
Gastropoda		1	1	2												
Glossosoma															1	
Gymnopais			1	4		1	8	6								
Helodon							1									
Hemiptera		1	2	3	2	1			9	17	2	1	1			1
Heptageniidae	4	22	13	52	7	6	25	15			1	5		1	2	
Hydatophylax			1												1	
Hydracarina			1							1						6
Hydrozytes			3	1						1		1	1	3	1	1
Isoperla				6	2	1					1	1			4	
Lebertia	1					1						1	3	1	6	9
Lepidoptera			1	1		1					1					
Limnephilidae	1		4	15	1		9	6			4	14	4	4		
Metacnephia				1	3	2					143	118	1			
Molophilus							1	1								
Muscidae												1				
Nematoda												1				2
Nemoura				1					4	12						
Nemouridae		1					2									1
Oligochaeta	137	91	29		22	47	85	108	37	39	7	16	13	32	5	23
Oreogeton	1		3	2	1	2	4	8					2	2		
Pericoma	1		1	1			6	6			3	1	5	2		
Perlodidae				2		2										
Planorbidae													1	1		
Plecoptera	1		2	1												
Plumiperla	27	7					5	7					1			
Prosimulium	73	111	35	15	32	33	8				80	124	1			
Psychoglypha															1	0
Rhyacophila	13	16			27	28					3	6	18	24	2	0
Simuliidae	1	2				1		2	1		7		1		1	
Simulium	14	24	2													
Sperchon														2		
Staphylinidae					1	1										
Stegopterna									156	116					1	
Suwallia			1		2	5										
Syrphidae										0						
Tipulidae			1	2												
Trichoclinocera								1								
Trichoptera		1		2									2	1		
Turbellaria	4	6										1				
Zapada	2	6	15	14	19	26	25	24	1		32	59	206	232	22	18

Appendix H.

PROVISIONAL COMPARISON OF MACROINVERTEBRATE AND DIATOM COMMUNITIES AT BURNED AND UNBURNED SITES IN INTERIOR ALASKA

Daniel Rinella and Daniel Bogan
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University of Alaska Anchroage

Wildfires burned millions of acres of interior Alaska boreal forest during the summer of 2004. The goal of this project is to compare the macroinvertebrate and diatom taxonomic composition in streams draining burned and unburned watersheds in interior Alaska.

METHODS

We used the US E.P.A.'s Ecological Monitoring and Assessment Program methodology for all field data collection (Peck et al. 2001). We collected composite macroinvertebrate and diatom samples at 11 evenly-spaced transects over a stream reach equal to 40 channel widths (with a minimum reach length of 150 m). We collected macroinvertebrates with a 500-µm-mesh D-frame net (one subsamples from each transect); in the lab, we identified a standard-count subsample of 500 organisms from each sample to the lowest practical taxon. We collected diatoms by scrubbing a standard area on each of 11 rocks (i.e., one from each transect); in the lab, we identified a standard-count subsample of 600 valves from each sample to species.

We sampled 10 sites in the extensively-burned Cripple Creek watershed during August of 2004, just days after the fires extinguished (sites denoted as CC01 – CC04 and CC06 – CC11). During July and early August of 2005, we sampled four of these sites for a second time (CC01, CC02, CC04, and CC10) and sampled four sites in the mostly unburned Caribou-Poker Creek watershed. Of the Caribou-Poker sites, 3 were in unburned watersheds (CP1, CP2, and CP4) while CP3 was in a watershed that burned only on one side of the stream. To bolster the sample size and broaden the geographical focus of this analysis, we added three sites that we sampled with identical methodology as part of regional water quality assessment (the Wadeable Streams Assessment). One of these stream sites (WSA23) was draining an extensively-burned watershed and two were draining unburned watersheds (WSA27 and WSA147). The three treatments were denoted as follows: burned sites sampled in 2004 are "year of burn," burned sites sampled in 2005 are "year after burn," and unburned sites, regardless of date, are "unburned". Table 1 gives the sampling date and treatment for each site.

We analyzed the diatom and invertebrate data separately following similar procedures. For both diatoms and invertebrates, we compared abundance and taxa richness among the three treatments (i.e., unburned, 1 year after burn, 2 years after burn) using one-way ANOVA. To compare whole-community structure we used multi-response permutation procedures (MRPP; PC-ORD 4), a non-parametric multivariate test for differences among treatments. We then used indicator species analysis (PC-ORD 4) to identify taxa that were faithful and exclusive to the treatments. One additional analysis, conducted for invertebrates but not diatoms, was to compare the functional feeding group composition (i.e., the proportion of filter feeders, collectors, predators, scrapers, and shredders) across the treatments using a non-parametric MANOVA (Statistica 6).

Table 1. Study site and sampling information. For data collected column, I=invertebrate and D=diatom, *indicates diatom samples that have yet to be included in the analysis.

Site ID	Watershed	Sample date	Treatment	Data collected
CC01	Cripple Cr	08-11-2004	year of burn	I,D
CC02	Cripple Cr	08-12-2004	year of burn	I,D
CC03	Cripple Cr	08-10-2004	year of burn	I
CC04	Cripple Cr	08-10-2004	year of burn	I,D
CC06	Cripple Cr	08-12-2004	year of burn	I
CC07	Cripple Cr	08-17-2004	year of burn	I
CC08	Cripple Cr	08-16-2004	year of burn	I
CC09	Cripple Cr	08-16-2004	year of burn	I
CC10	Cripple Cr	08-14-2004	year of burn	I,D
CC11	Cripple Cr	08-12-2004	year of burn	I
CC01	Cripple Cr	07-21-2005	year after burn	I,D
CC02	Cripple Cr	07-23-2005	year after burn	I,D
CC04	Cripple Cr	07-22-2005	year after burn	I,D
CC10	Cripple Cr	02-03-2005	year after burn	I,D
CP3	Caribou-Poker Cr	08-01-2005	year after burn	I,D
WSA23	Monument Cr	07-11-2005	year after burn	I,D*
CP1	Caribou-Poker Cr	07-31-2005	unburned	I,D
CP2	Caribou-Poker Cr	07-31-2005	unburned	I,D
CP4	Caribou-Poker Cr	08-01-2005	unburned	I,D
WSA25	Starvation Cr	07-25-2004	unburned	I,D*
WSA147		08-02-2005	unburned	I,D*

RESULTS

Invertebrates

Invertebrate abundance and species richness were highly variable and did not significantly differ among the three treatments. Likewise, Minshall et al. (1997) found no effect of burn treatments on these measures following Yellowstone wildfires. MRPP indicated significant differences in community composition among the three treatments. The test statistic was highly significant (*p*=0.001) although the effect size was modest (A=0.11), indicating that the within-treatment similarity was only slightly higher than the overall among-sample similarity. Of the 28 common invertebrate taxa collected in this study, 3 were identified as significant indicator taxa. The mayfly *Ameletus* was essentially absent from the unburned sites, was common in burned stream during the year of the burn, and was very common one year after the burn (Table 2). Likewise, the mayfly *Baetis* spiked in abundance at burned sited during the year of the burn (Table 2). Both *Ameletus* and *Baetis* are trophic generalists (Mihuc and Minshall 1995) and, as such, are expected to be good competitors in disturbed stream reaches (Minshall et al. 1997). *Dicranota* is a predaceous cranefly that inhabits detritus deposits (Merritt and Cummins 1996) and its decline in the burned sites may be linked to decreased leaf litter inputs.

Functional feeding group composition did not differ between the reference and burned sites (α=0.05), but the proportion of predators and scrapers differed between sites sampled the year of burn and the year after burn (Figure 1). These data may indicate rapid recovery of the trophic base in these streams, but more years of data are required to address this.

Table 2. Indicator values (% of perfect indication, based on combining the above values for relative abundance and relative frequency) for macroinvertebrate taxa.

	Indicator values			
Taxon	Year of burn	Year after burn	Unburned	*p*
Ameletus (Ephemeroptera: Ameletidae)	31	63	1	0.003
Baetis (Ephemeroptera: Baetidae)	63	22	14	0.002
Dicranota (Diptera: Tipulidae)	14	2	67	0.017

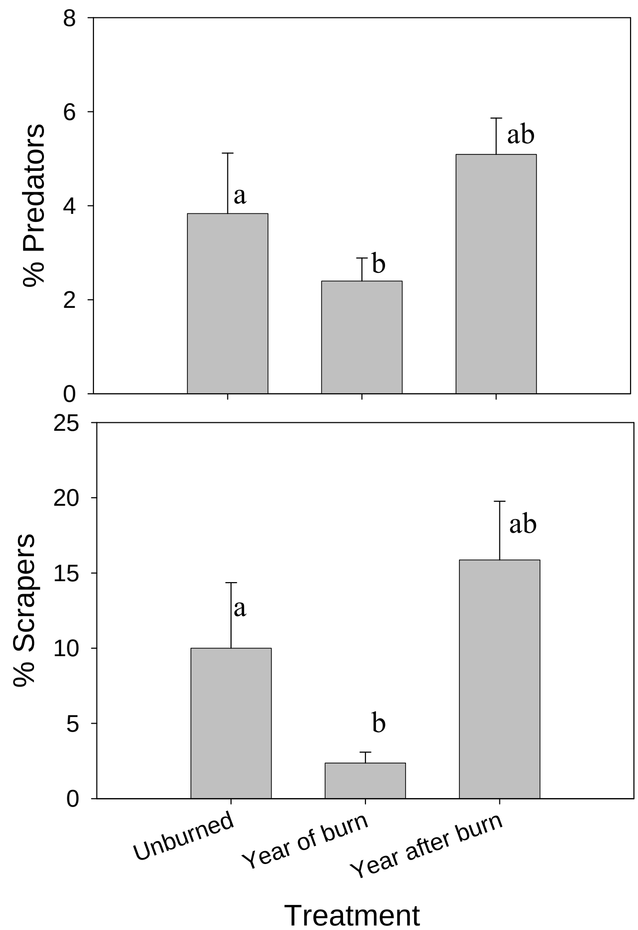

Figure 1. The proportion of predators (top panel) and scrapers (bottom panel) within the three treatments. Within a panel, bars with different lower-case letters are significantly different (nonparametric MANOVA, α=0.05). Other functional feeding groups (filterers, collectors, shredders) did not differ significantly among the treatments.

Diatoms

We are still in the process of identifying and entering the diatom data from the Wadeable Streams Assessment sites (WSA 23, 25, 147), so the analyses given here apply only to the Cripple Creek and Caribou-Poker watersheds. Diatom abundance and species richness were highly variable and did not significantly differ among the three treatments. MRPP failed to detect a significant treatment effect when the burned treatments (i.e, year of burn and year after burn) were analyzed separately. When the burned treatments were pooled, burned and unburned sites were significantly different (p=0.028). As with the invertebrates, the effect size was small (A=0.06) indicating that within-treatment similarity was only slightly higher than the overall among-sample similarity. Of the 66 common diatom species collected in this study, 15 were identified as significant indicator taxa (Table 3). Of these, 14 species were common in and faithful to unburned sites but uncommon in burned sites, indicating that many diatom populations were negatively impacted by fires. Only one species, *Diatoma mesodon*, showed the opposite pattern, being common in and faithful to burned sites. A more complete analysis of diatom autecological data will follow once the Wadeable Streams Assessment diatoms have been identified and added to this data set.

Table 3. Indicator values (% of perfect indication, based on combining the above values for relative abundance and relative frequency) for diatom taxa.

	Indicator values		
Taxon	Burned	Unburned	*p*
Achnanthes biasolettiana	9	86	0.019
Psammothidum chlidanos	3	90	0.018
Achnanthes pusilla	1	95	0.007
Cymbella gracilis	1	90	0.015
Cymbella naviculiformes	0	99	0.020
Diatoma mesodon	100	0	0.003
Eunotia exigua	0	67	0.048
Fragilaria capucina var. rumpens	1	64	0.029
Fragilaria capucina var. Desmazieres	9	83	0.027
Fragilaria construens var. venter	3	86	0.024
Frustulia cf. *rhomboides*	3	70	0.015
Navicula gregaria	1	98	0.003
Navicula rhynchocephala	0	100	0.003
Pinnularia microstauron	0	99	0.012
Tabellaria fenestra	1	97	0.003

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