# Results of Elemental and Stable Isotopic Measurements, and Dietary Composition of Arctic Grayling (*Thymallus arcticus*) Collected in 2000 and 2001 from the Fortymile River Watershed, Alaska

*by* J. G. Crock, R.R. Seal, II, L.P. Gough, and P.Weber-Scannell



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J. G. Crock[1], R.R. Seal, II[2], L.P. Gough[3], and P. Weber-Scannell[4]

## ABSTRACT

We report the results of the elemental and stable isotopic analyses, as well as the composition of stomach contents, of Arctic grayling (*Thymallus arcticus*), an ecologically important resident freshwater sport and subsistence fish in the Fortymile River Mining District of the Interior Highlands Ecoregion in eastern Alaska. These data are presented here as a data compilation with minimal interpretation or discussion. Further analyses of the data will be presented elsewhere. The study area has been mined for placer gold for over a century and is currently experiencing renewed mineral exploration activity. The results for the analysis of 40 inorganic elements are reported for grayling muscle (fillet) tissue, liver tissue, and stomach contents from 34 individuals caught at 11 sites within the watershed. The 11 sites were classified as occurring within the following lithologies: metavolcanic (7 sites), metasedimentary (3 sites), and granitic intrusion (1 site). This information (along with fish tissue stable isotope data) is critical in the assessment of the influence of regional lithology on the fish chemical composition, especially the trace metal content. We report the nitrogen, carbon, and sulfur stable isotope composition of muscle samples. Nitrogen isotopes appear homogeneous ($\delta^{15}N$ = 7.6 to 9.7 permil) whereas carbon and sulfur isotope compositions of the same samples span a range from $\delta^{13}C$ = –33.1 to –25.8 permil, and $\delta^{34}S$ = –8.4 to 8.2 permil. Stomach content material was examined for the occurrence and frequency of macroinvertebrate composition and diversity in three individual fish. Results showed a high degree of diversity with 9 to 15 invertebrate taxa; both aquatic and terrestrial forms were represented.

## INTRODUCTION

Arctic grayling (*Thymallus arcticus*) is an ecologically important non-anadromous[5] (resident), salmonid fish that inhabits streams in the subarctic and Arctic regions of North America and Europe (Reynolds, 1997). Although there are several studies that examine the effect of mining on grayling habitat and physiological health (e.g., Reynolds et al., 1989), little has been published on the major and trace element concentrations in grayling tissue nor on the possible link between regional geochemical signatures (as defined by lithologic units) and fish chemistry. Farrell et al. (2000) analyzed individual scales taken from grayling collected in eastern Alaska and correlated metal levels with those in muscle tissue; they did not, however,

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[5] Non-anadromous fish are those that do not possess a sea-run as part of their life history.

relate metal levels with the geochemistry of regional rock units. Gray et al. (1996; 2000) report on the relation between Hg levels in grayling (both inorganic and organic forms) and the chemistry of water and sediments in a region of Hg mineralization, and abandoned Hg mines, in southwestern Alaska. In addition, the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service have over ten years of data (both published and unpublished) on trace element concentrations in water, sediment, and grayling (and other fish species) from various sites in interior Alaska (Snyder-Conn et al., 1992; Mueller et al., 1996).

This study presents the inorganic element and stable isotope analyses of Arctic grayling muscle, liver, and stomach contents of fish collected within the Fortymile River in eastern Alaska whose basin has been mined for placer gold for over a century. Recently, the area has experienced renewed mineral exploration activity; however, active lode deposit mining does not currently exist in the basin.

Understanding the relation between fish chemistry and regional rock, sediment, and water chemistry is essential in the establishment of baseline biogeochemical values for this and other aquatic organisms in areas that are both mineralized and non-mineralized. Stable isotope analyses (for the elements N, C, and S) of fish muscle tissue, have been used extensively to help explain the trophic level that most closely characterizes the feeding habits of fish (DeNiro and Epstein, 1978, 1981; Minagawa and Wada, 1984; Peterson and Fry, 1987; Hobson, 1999). Questions that can be addressed with stable isotope information on fish tissue (coupled with diet information determined from stomach content analysis) include: definition of the mixture of vegetative vs. invertebrate material in the diet (trophic or feeding level within the food-web); definition of aquatic vs. terrestrial sources of the invertebrates; and definition of the source of trace elements that may be bioavailable in the diet. All of these questions are important as they assist in explaining possible relations between trace element concentrations in fish tissue and the underlying geology.

The life history and physiological ecology of grayling in North America has been extensively studied (e.g., West et al., 1992; Reynolds, 1997; Deegan et al., 1997). Grayling inhabit clear water streams where, during the short summers, they aggressively feed on both aquatic and terrestrial (accidental intruder) macroinvertebrates. Of particular interest in this study is the "residence time" individual fish might be expected to inhabit a given reach of the river during the feeding period. We are interested in how well the geochemistry of a section of the river might influence fish chemistry. Data suggest that the trace-element chemistry of resident fish is influenced more by diet than by the water column (Hershey et al., 1997). During the long Arctic winters, grayling often migrate to areas of deep water, springs, or pipe-like channels in aufeis where the water does not freeze completely. West et al. (1992) report that migration distances between summer feeding areas and ice-free winter residence sites can exceed 100 km but commonly range between 25-75 km. No studies have been conducted on the specific migratory habits of the Fortymile River grayling; however, it is speculated that most migrate downstream to large pools, or even as far as the Yukon River, a maximum of about 100 km from the furthest upstream site in this study.

Buzby and Deegan (2000) report that grayling studied along a stretch of the Kuparuk River north of the Brooks Range displayed remarkable inter-year fidelity to summer feeding sites, i.e., more than half of the fish were recaptured within 300 m of the site where they were captured in previous years. They explain this behavioral adaptation selects fish that return to productive drift-feeding sites in the river where little time is available during the short summer feeding period for the exploration of alternative feeding locations. Further, Reynolds (1997) reported that grayling appear remarkably faithful to over-wintering sites as well. Therefore for our study, it is reasonable to assume that the fish we sampled could very likely have been feeding at that particular region of the river in past years. It is possible, therefore, that geochemical signatures for the sampled sites, as defined by the chemistry of the water, sediment, and local rock unit, may influence the chemistry of fish tissue.

The purpose of this study was to: (1) establish baseline biogeochemical data for Arctic grayling fish tissue along the lower reaches of the Fortymile River within the Fortymile Mining District; (2) establish baseline biogeochemical data for fish-forage organisms as measured on whole gut content; (3) examine the biogeochemical element concentration patterns (as well as stable isotope patterns) as they possibly relate to the geochemistry of the region; i.e., related to the geochemistry of rock units, sediments, and surface waters. These data are presented here with minimal interpretation or discussion as a data compilation release.

This study presents fish tissue and stomach content data for the concentration of 40 major and trace elements for 34 individuals collected from 11 sites in the watershed. In addition, N, C, and S isotope data are presented for muscle (fillet) samples. These data are the first reported for Arctic grayling in this region of Alaska.

## METHODS

### Field

Fish were collected by using rod and lure on September 10-12, 2000. Three fish, approximately the same weight and length, were collected at each of ten sites along an 80-km stretch of the North Fork, South Fork, and main stem of the Fortymile River (fig. 1; table 1). Site localities are identified by geographic coordinates and by the name of the tributary nearest to where the fish were collected (fig. 1). In addition to the above collections, four fish were sampled on O'Brien Creek, about 13 km north of its confluence with the main stem. Thus a total of 34 fish make up the sampled population for this study (table 2).

Rock units that dominate the area of collection are listed in table 1 and displayed in figure 1. Seven sites fell within the metavolcanic (mv) unit, three within the metasedimentary (ms) unit, and one within the intrusive leucogranite (g) unit. A detailed discussion of the regional geology, soils, and biogeochemistry of the lower Fortymile River is presented in companion studies (Day et al., 2000; Gough et al., 2001).

Fish were dissected in the field and muscle (fillet), liver, and stomach contents were harvested. A stainless steel blade was used in the dissection. The blade was wiped clean and rinsed, using distilled water, prior to each organ dissection. Because of the small volume of material, the livers for the fish collected at each site were composited as were the stomach contents. Samples were individually placed in plastic bags, double-sealed, and frozen. Eleven samples each of liver and stomach contents and 34 samples of muscle tissue were thus obtained. Samples were kept frozen and shipped to laboratories of the U.S. Geological Survey, Denver, Colorado for chemical analyses. Unfortunately, due to insufficient material, the identification of the fish-forage material in the grayling gut was not performed on the 2000 material that was used for chemical analysis. A re-sampling of three of the sites was conducted in 2001 within the same timeframe as the 2000 sampling, and the stomach contents from three fish were examined (this material was not chemically analyzed). We assume that the stomach material taken 12 months later in 2001 is similar in invertebrate composition and proportion.

**Laboratory**

In the laboratory, the fish tissue was thawed, washed thoroughly in deionized water, and digested using ultra-pure nitric acid and 30% hydrogen peroxide (CEM, 1994). Sample size ranged from 2.0 g to 3.0 g (weighed to the nearest 0.001 g). All analyses of element concentrations (except for Hg) were performed using inductively coupled plasma-mass spectrometry on the acid-digested material. Mercury analyses were performed on the non-digested material using cold vapor atomic absorption (Kennedy and Crock, 1987). For quality control purposes, standard reference materials, analytical duplicates, and matrix spike samples were analyzed using the same analytical methods (Taggart, 2002).

Stable isotope measurements (N, C, and S) were made using a Thermofinnigan Delta Plus mass spectrometer coupled with a Carlo Erba NC2500 Elemental Analyzer. Sample sizes for N and C isotope measurements were approximately 0.5 mg and those for S isotope measurements were approximately 5.0 mg. Nitrogen, C, and S isotope compositions were measured on $N_2$, $CO_2$, $SO_2$ gas, respectively. Data are reported in the $\delta$ -notation relative to the references air for N, Vienna Pee Dee Belemnite (VPDB) for C, and Vienna Canyon Diablo troilite (VCDT) for S. The $\delta$ -notation for the $^{15}N/^{14}N$, $^{13}C/^{12}C$, and $^{34}S/^{32}S$ composition of a substance is defined as:

$$\delta^{15}N\ \delta^{13}C, \text{ or } \delta^{34}S = \left(\frac{R_{sample} - R_{reference}}{R_{reference}}\right) \times 1000$$

expressed in values of parts per thousand or permil (‰), where R is the ratio of interest ($^{15}N/^{14}N$, $^{13}C/^{12}C$, or $^{34}S/^{32}S$). The N and C isotopic compositions were calibrated relative to a scale based on two samples of glutamic acid selected for use as laboratory reference materials, one with $\delta^{15}N$ = -4.6 ‰ and $\delta^{13}C$ = 32.5 ‰ and the other with $\delta^{15}N$ = 49.3 ‰ and $\delta^{13}C$ = -26.2 ‰; whose compositions, in turn, are based on a scale defined by the international reference materials NBS-19 ($\delta^{13}C$ = 1.95 ‰), LSVEC ($\delta^{13}C$ = -46.48 ‰), IAEA-N1 ($\delta^{15}N$ = 0.4 ‰), and USGS-32 ($\delta^{15}N$ = 180 ‰). Sulfur isotope compositions were calibrated relative to a scale defined by NBS-123 ($\delta^{34}S$ = 17.09 ‰) and Maine Light ($\delta^{34}S$ = -30.7 ‰). The analytical uncertainty (1 $\delta$) is ± 0.3 ‰ for N isotopes, ± 0.2 ‰ for C isotopes, and ± 0.3 ‰ for S isotopes.

Fish stomachs, whose contents were later used for macroinvertebrate identification, were removed from the fish, frozen, and sent to the laboratories of the Alaska Department of Fish and Game. There the material was thawed, the contents removed from both the anterior and posterior portions of each stomach, and preserved separately in 70 percent ethanol.

**Data Analysis**

Arctic grayling in our study varied in weight from 0.21 to 0.42 kg (wet weight) with total length from 275 to 358 mm (table 2). We did not determine the age of the fish collected in this study. Studies that correlate Arctic grayling age to length appear specific to a given drainage up to about age five to seven years (Merritt 1989). After age five to seven (depending on the population), the correlation between length and age is less certain. Hughes (1999) reported that Arctic grayling from the Goodpaster River, interior Alaska, with a similar size range as our fish (229 mm to 298 mm), were four to six years old, whereas Merritt (1989) found Arctic grayling from the Seward Peninsula in this size range to be 3 to 7 years old.

All fish in our study were sexually mature with 32% being female. For the purposes of this study both sexes were combined in the calculations of summary statistics (table 2). The results of the chemical analyses for major and trace element concentrations in fish muscle, liver, and stomach contents are given in tables 3, 4, and 5 (wet-weight basis), respectively. Multiplying these data by a factor four results is a good estimate of the concentration values converted to a dry-weight basis (Chen et al., 2001). Frequency diagrams of element concentrations were examined and examples of these are presented for Mg and Hg in muscle tissue in figure 2. Because, in general, log-transformed data displayed more normal distributions (as measured by skewness and kurtosis), we subsequently used the transformed data for all statistical analyses.

Most statistical analyses depend on the utilization of uncensored data (data above the lower limit of analytical determination, LLD). In cases where the censored data for a particular element in a particular tissue did not exceed 33%, we followed the convention of Miesch (1976) and substituted a value equal to 0.7 x the LLD. As long as this substitution does not exceed about one-third of the data, results from statistical tests are not appreciably affected (Miesch, 1976). For example, 12 of the 34 concentration values for Cu in muscle tissue were censored (table 3). Whenever Cu is included in a statistical test a value equal to 0.35 ppm is substituted for the censored value (0.7 x 0.5 ppm).

## ANALYTICAL RESULTS

### Inorganic chemistry of grayling tissue

We present the geometric mean (GM) and geometric deviation (GD) for the concentration of 38 elements in muscle (table 5), liver (table 6), and stomach contents (table 7). These tables also give the lower limit of determination (LLD) of the analytical method for individual elements, the detection ratio (i.e., the number of uncensored analytical values--those above the LLD--to the total number of analyses), and the observed concentration range in the data. We did not calculate the geometric mean and geometric deviation for elements with censored values; however, for these elements we do report the observed concentration ranges. The GM, GD, and observed range can be used together as an estimate of the biogeochemical baseline values for grayling in the lower reaches of the Fortymile River. A more precise definition of baseline should await additional sampling of fish from second- and third-order streams within the watershed as well as sampling at other times within the life history of grayling.

The wet-weight basis element concentration ranges for the grayling muscle and liver tissue from the Fortymile River sites are compared, in tables 5 and 6, with similar material (dry-weight basis) collected in the Koyukuk National Wildlife Refuge (KNWR), western Alaska (Mueller et al., 1996). Like the Fortymile River area, the KNWR is generally unmineralized (Mueller et al., 1996). However, unlike the Fortymile River area, KNWR is topographically flat and is dominated by Quaternary glacial and glaciolacustrine deposits (Snyder-Conn et al., 1992). In order to compare our wet-weight basis data with the Koyukuk dry-weight basis data a factor of four needs to be applied to the latter (Chen et al., 2001). Nevertheless, with a few notable exceptions (for those elements with similar analytical detection limits), the chemistry of fish muscle and liver tissue from these two regions appear very similar. Because there are few data on grayling chemistry, this comparison should serve as an initial benchmark for future assessments.

Stomach contents are of particular interest because they show the greatest among-site variability and because the normalized values are, in most cases, larger than those found in liver or muscle. This is not surprising because the ingested material contains a considerable quantity of sediment. The reason some elements have normalized values that are actually smaller than those found in liver or muscle (e.g., Hg and Se) is because the concentration of these elements in the quartz-rich sediment is low and the mass of the sediment "dilutes" the overall concentration of the trace elements that make up the invertebrates in the stomach.

**Stable isotope analyses of grayling muscle tissue**

We use stable isotope analysis to help explain (1) the trophic level that most closely characterizes the feeding habits of grayling, and (2) the possible relation between metal concentrations in fish tissue and the underlying geology. This type of approach has been used successfully to trace the flow of N, C, and S through both aquatic and terrestrial ecosystems (Kline et al., 1997; Hobson, 1999). The stable isotopic ratios of N and C have received widespread application in food web and ecosystem studies (DeNiro and Epstein, 1978, 1981; Minagawa and Wada, 1984; Peterson and Fry, 1987; Hobson, 1999). The stable isotopic ratios of S have found more limited application, but have been demonstrated to be useful for distinguishing trophic level relations and migratory habits of fish (Hesslein et al., 1991; Doucett et al., 1999). Thus, stable isotopes offer potentially important insights into the processes of bioaccumulation of metals and other constituents in Arctic grayling from the Fortymile River system. Stable isotope data from muscle tissue for the Fortymile grayling are presented in table 9. The N isotope data from the study show limited variability; the $\delta^{15}N$ values for all samples average 8.7 ± 0.5 ‰ (1 δ) and range from 7.6 to 9.7 ‰. The C isotope data are more variable; the $\delta^{13}C$ values for all samples average -29.0 ± 1.7 ‰ (1 δ) and range from -33.1 to -25.8 ‰. The S isotope data show the greatest variability; the $\delta^{34}S$ values for all samples average 1.7 ± 4.0 ‰ (1 δ) and range from -8.4 to 8.2 ‰.

**Composition of grayling stomach contents**

The stomachs and upper intestines of the three Arctic grayling analyzed were fully distended, i.e., feeding success appeared high. Invertebrates were identified from the anterior portion of the stomachs and, when key characteristics remained, from the other more digested lower stomach and intestine (table 10; appendix).

We identified 109 to 172 individual invertebrates from each of the fish and from 9 to 15 distinct taxonomic groups (usually to family level, although some specimens contained sufficient remaining characteristics to identify to genus level). The fish stomachs from Steele and Polly creeks (fig. 1) contained high proportions (47% to 69%) of Ephemeroptera – Plecoptera – Trichoptera (EPT) taxa. In contrast, the proportion of EPT taxa in the Canyon Creek (fig. 1) fish was only 19%. This difference in EPT proportions means that food sources varied somewhat with location on the river and its second order tributaries; fewer EPT is reflective of the lower proportion of aquatic taxa found in the Canyon Creek population.

Most of the invertebrates found in fish from Steele and Polly Creeks were well-developed aquatic Trichoptera larvae (table 6; appendix). Similarly, 61% of the total invertebrates identified in the Steele Creek fish stomach were Trichoptera (genus *Arctopsyche)*. In contrast, 29% of the invertebrates identified in the Polly Creek fish were Trichoptera (genus *Micrasema)*. The stomach contents contained many wings that appeared to be from emerging winter stoneflies (likely Nemouridae). These were not counted as part of the sample because a positive identification could not be made; however, we estimated about 75-100 wing pairs.

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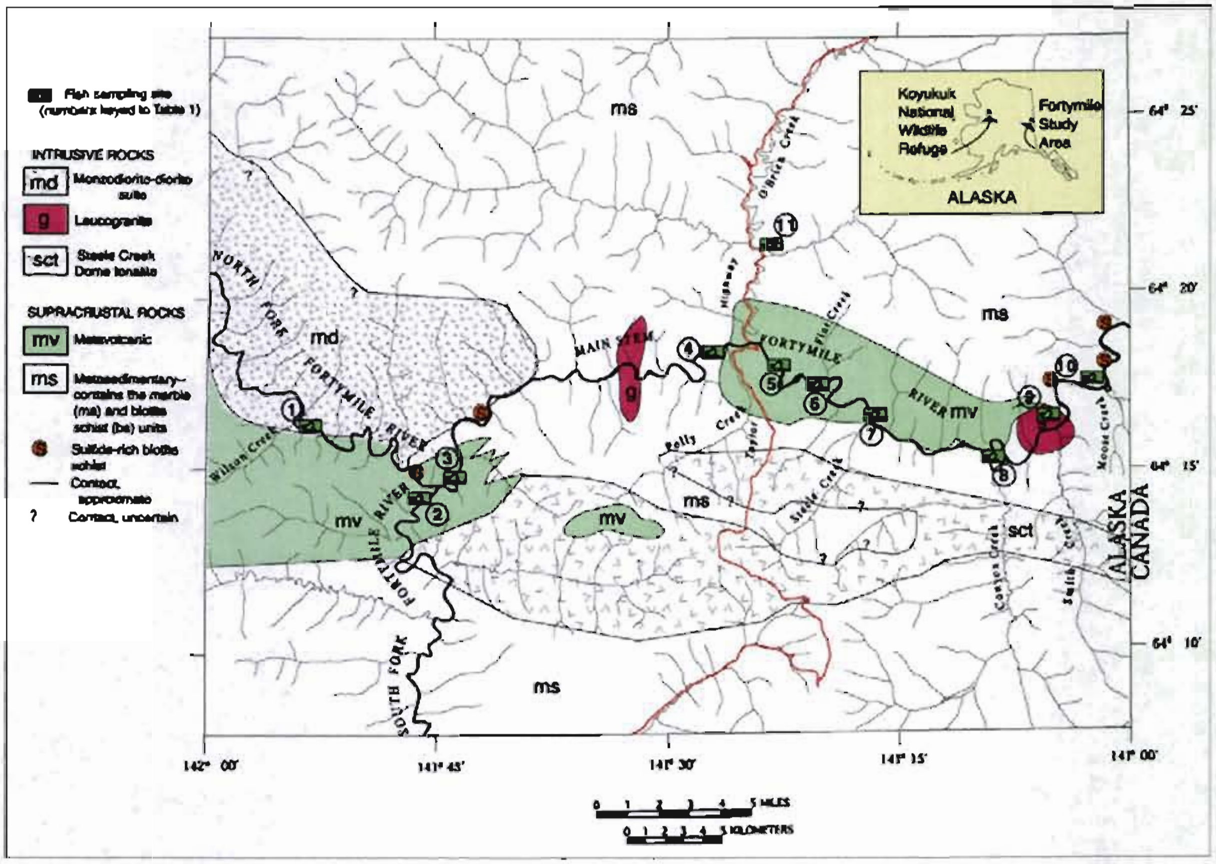


Figure 1. Map of the Fortymile River study area showing fish sampling sites and regional geology (latter from Day et al., 2000). Site numbers keyed to table 1. The location of the Koyukuk National Wildlife Refuge is shown in the inset map; fish from this area are used for comparison with those from the Fortymile River study area. Note locations of tributary creeks discussed in the text.

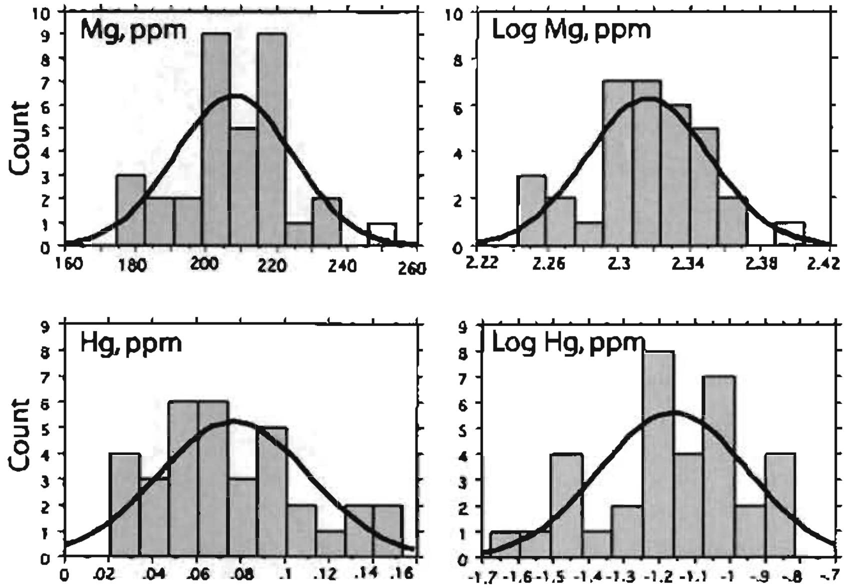


Figure 2. Examples of frequency distributions for the concentration of elements in grayling muscle tissue (wet-weight basis) where n = 34 (arithmetic data, left; log-transformed data, right).

**Appendix.**

Number of aquatic and terrestrial invertebrate taxa identified in three Arctic grayling individuals collected from sites on the main stem of the Fortymile River, Alaska

| Invertebrate Taxa | | | Anterior stomach | | Posterior stomach | | Lower intestine | |
|---|---|---|---|---|---|---|---|---|
| Order (common name) | Family | Genus | *A*[1] | *T*[1] | *A*[1] | *T*[1] | *A*[1] | *T*[1] |
| Fish sampled--male collected at the Steele Creek confluence (406 mm in length) | | | | | | | | |
| Ephemeroptera | Baetidae | *Baetis* | | | 2 | | | |
| (mayfly) | Heptageniidae | *Cinygmula* | 1 | | | | | |
| Plecoptera | unidentified | | | 1 | | | | |
| (stonefly) | | | | | | | | |
| Trichoptera | Brachycentridae | *Brachycentrus* | 2 | | 3 | | | |
| (caddisfly) | Hydropsychidae | *Arctopsyche* | 18 | | 55 | | | |
| Coleoptera | Hydrophilidae | | 1 | | | 1 | | |
| (beetle) | | | | | | | | |
| Diptera | Ceratopogonidae | | | 10 | | | | |
| (true fly) | Chironomidae | (adult) | | 8 | | | | |
| | Simuliidae | (larvae) | | 5 | | | | |
| | Tipulidae | | 1 | | | | | |
| Homoptera | Cicadellidae | | | 1 | | | | |
| (leafhopper) | | | | | | | | |
| Hemiptera | Corixidae | | | | | 1 | | |
| (water boatman) | | | | | | | | |
| Hymenoptera | unidentified | | | 1 | | | | |
| (wasp) | Ichneumonidae | | | 8 | | | | |
| Arachnida | | | | 1 | | | | |
| (spider) | | | | | | | | |

[1] A = aquatic forms; T = terrestrial forms.

**Appendix (continued).**

Number of aquatic and terrestrial invertebrate taxa identified in three Arctic grayling individuals collected from sites on the main stem of the Fortymile River, Alaska

| Invertebrate Taxa | | | Anterior stomach | | Posterior stomach | | Lower intestine | |
|---|---|---|---|---|---|---|---|---|
| Order (common name) | Family | Genus | *A*[1] | *T*[1] | *A*[1] | *T*[1] | *A*[1] | *T*[1] |
| Fish sampled–female collected at the Canyon Creek confluence (360 mm in length) | | | | | | | | |
| Ephemeroptera (mayfly) | unidentified | | 1 | | | | | |
| Trichoptera (caddisfly) | Brachycentridae | *Brachycentrus* | 18 | | | | 1 | |
| | Glossosmatidae | *Glossosoma* | | | | | 1 | |
| Diptera (true fly) | Chironomidae | (pupae) | 4 | | | | | |
| | | (adult) | | 20 | | 40 | | |
| Homoptera (leafhopper) | unidentified | | | 20 | | | | |
| | Cicadellidae | | | 1 | | | | |
| Hymenoptera (wasp) | Formicidae | Mymicinae | | 3 | | | | |
| Thysanoptera (thrip) | | | | 1 | | | | |
| Fish sampled–male collected at the Polly Creek confluence (340 mm in length) | | | | | | | | |
| Ephemeroptera (mayfly) | Baetidae | *Baetis* | 3 | | | | | |
| | Heptageniidae | *Cinygmula* | 2 | | | | | |
| Plecoptera (stonefly) | Capniidae | | 2 | | 3 | | | |
| | Nemouridae | | | | | 10 | | |
| Trichoptera (caddisfly) | Brachycentridae | *Brachycentrus* | 5 | | | | | |
| | | *Micrasema* | 10 | | 15 | | 25 | |
| | Hydropshchidae | *Arctopsyche* | 3 | | | | | |
| Coleoptera (beetle) | Staphylinidae | | | 1 | | | | |
| | Hydrophilidae | | | 3 | | | | |
| Diptera (true fly) | unidentified | | | 25 | | | | |
| | Chironomidae | (pupae) | 10 | | | | | |
| | Simuliidae | (pupae) | 15 | | 20 | | | |
| | Culicidae | | | 10 | | | | |
| Hymenoptera (wasp) | Ichneumonidae | | | 3 | | 1 | | |
| | Mymanidae | | | 5 | | 1 | | |

1

Table 1.–Description and location of fish sampling sites on the Fortymile River. Coordinates are in decimal degrees.

| ID number[1] | Site Description | N. Latitude | W. Longitude | Rock unit[2] |
|---|---|---|---|---|
| 1 | North Fork, 0.1 km upstream of confluence with Wilson Creek near right | 64.2722 | 141.9045 | mv |
| 2 | South Fork, 0.75 km upstream of confluence with the North Fork near left | 64.2381 | 141.7567 | mv |
| 3 | Main Stem, 0.75 km downstream of confluence with South and North Forks left bank | 64.2422 | 141.7406 | mv |
| 4 | Main Stem, 0.5 km downstream of confluence with Polly Creek near right | 64.3086 | 141.4292 | mv |
| 5 | Main Stem, 1.5 km below Taylor Highway bridge near left bank (no name | 64.2937 | 141.3757 | mv |
| 6 | Main Stem, 0.5 km below confluence with Flat Creek near left bank | 64.2929 | 141.3191 | mv |
| 7 | Main Stem, 0.1 km below confluence with Steele Creek near right bank | 64.2767 | 141.2857 | mv |
| 8 | Main Stem, 1.5 km below confluence with Canyon Creek near right bank | 64.2633 | 141.1443 | ms |
| 9 | Main Stem, 0.1 km below confluence with Smith Creek near right bank | 64.2683 | 141.0804 | g |
| 10 | Main Stem, 0.1 km below confluence with Moose Creek near right bank | 64.2999 | 141.0262 | ms |
| 11 | O'Brien Creek at confluence with Alder Creek | 64.4053 | 141.4050 | ms |

[1] Keyed to Figure 1.

[2] Lithology of area where fish were sampled: *ms* = metasedimentary; *mv* = metabasalt; *g* = intrusive. Keyed to Figure 1.

**Table 2.**–Summary statistics (arithmetic mean and standard deviation) for the weight and total length of Arctic grayling sampled at various distances from the confluence of the North and South Forks of the Fortymile River, Alaska.

| Sample ID | Sex | Wet weight (kg) | Length (cm) | Distance (km)[1] |
|---|---|---|---|---|
| Wilson Cr.-1 | F | 0.47 | 330 | -15 |
| Wilson Cr.-2 | M | 0.19 | 292 | -15 |
| Wilson Cr.-3 | M | 0.14 | 260 | -15 |
| mean | | 0.27 | 294 | |
| SD | | 0.18 | 35 | |
| So. Fork-1 | M | 0.42 | 356 | -0.3 |
| So. Fork-2 | M | 0.24 | 305 | -0.3 |
| So. Fork-3 | F | 0.39 | 356 | -0.3 |
| mean | | 0.35 | 339 | |
| SD | | 0.10 | 29 | |
| No. Fork-1 | M | 0.39 | 356 | 0.3 |
| No. Fork-2 | M | 0.42 | 357 | 0.3 |
| No. Fork-3 | M | 0.46 | 362 | 0.3 |
| mean | | 0.42 | 358 | |
| SD | | 0.04 | 3.2 | |
| Polly Cr.-1 | M | 0.34 | 356 | 27 |
| Polly Cr.-2 | F | 0.44 | 357 | 27 |
| Polly Cr.-3 | M | 0.38 | 343 | 27 |
| mean | | 0.39 | 351 | |
| SD | | 0.05 | 7.8 | |
| no name cr.-1 | M | 0.16 | 273 | 31 |
| no name cr.-2 | M | 0.34 | 342 | 31 |
| no name cr.-3 | M | 0.19 | 279 | 31 |
| mean | | 0.23 | 299 | |
| SD | | 0.10 | 38 | |
| Flat Cr.-1 | F | 0.32 | 318 | 35 |
| Flat Cr.-2 | F | 0.14 | 241 | 35 |
| Flat Cr.-3 | M | 0.18 | 267 | 35 |
| mean | | 0.21 | 275 | |
| SD | | 0.09 | 39 | |
| Steele Cr.-1 | M | 0.52 | 394 | 41 |
| Steele Cr.-2 | M | 0.18 | 267 | 41 |
| Steele Cr.-3 | M | 0.22 | 304 | 41 |
| mean | | 0.31 | 322 | |
| SD | | 0.04 | 18 | |

**Table 2.**--Summary statistics (arithmetic mean and standard deviation) for the weight and total length of Arctic grayling sampled at various distances from the confluence of the North and South Forks of the Fortymile River, Alaska (continued).

| Sample ID | Sex | Wet weight (kg) | Length (cm) | Distance (km)[1] |
|---|---|---|---|---|
| Canyon Cr.-1 | F | 0.31 | 318 | 50 |
| Canyon Cr.-2 | M | 0.20 | 279 | 50 |
| Canyon Cr.-3 | M | 0.23 | 292 | 50 |
| mean | | 0.25 | 296 | |
| SD | | 0.06 | 20 | |
| Smith Cr.-1 | M | 0.38 | 356 | 58 |
| Smith Cr.-2 | M | 0.42 | 343 | 58 |
| Smith Cr.-3 | F | 0.29 | 318 | 58 |
| mean | | 0.36 | 339 | |
| SD | | 0.07 | 19 | |
| Moose Cr.-1 | M | 0.36 | 356 | 64 |
| Moose Cr.-2 | F | 0.38 | 349 | 64 |
| Moose Cr.-3 | F | 0.32 | 311 | 64 |
| mean | | 0.35 | 339 | |
| SD | | 0.03 | 24 | |
| O'Brien Cr.-1 | M | 0.34 | 318 | --[2] |
| O'Brien Cr.-2 | M | 0.48 | 368 | --[2] |
| O'Brien Cr.-3 | F | 0.34 | 330 | --[2] |
| O'Brien Cr.-4 | F | 0.35 | 330 | --[2] |
| mean | | 0.38 | 337 | |
| SD | | 0.07 | 22 | |

[1] Kilometers from the confluence of the North and South Forks that form the Main Stem of the Fortymile River; negative values = upstream (on the North Fork), positive values = downstream (on the Main Stem).

[2] Site upstream on O'Brien Cr. 13 km from its confluence with the Main Stem of the Fortymile River.

**Table 3.**–Analytical results (wet-weight basis) for grayling muscle tissue. Except were note, all fish were collected along the main stem of the Fortymile River. Table 3

| Site Identifier | Sample Description | Ag ppm | Al ppm | As ppm | Ba ppm | Be ppm | Bi ppm | Ca ppm | Cd ppm | Ce ppm | Co ppm | Cr ppm | Cs ppm | Cu ppm | Fe ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 159 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | <0.50 | < 50 |
| Wilson-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | 0.001 | < 0.005 | 27 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.01 | 0.50 | < 50 |
| Wilson-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 67 | < 0.003 | < 0.5 | < 0.1 | 0.3 | 0.02 | <0.50 | < 50 |
| S. Fork-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 2280 | < 0.003 | < 0.5 | < 0.1 | 0.5 | 0.008 | <0.50 | < 50 |
| S. Fork-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 27 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.004 | 0.55 | < 50 |
| S. Fork-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 69 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.007 | <0.50 | < 50 |
| N. Fork-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 103 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | <0.50 | < 50 |
| N. Fork-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 65 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | 0.60 | < 50 |
| N. Fork-3- | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 69 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.05 | <0.50 | < 50 |
| Polly-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 73 | 0.005 | < 0.5 | < 0.1 | 0.4 | 0.02 | <0.50 | < 50 |
| Polly-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 40 | 0.005 | < 0.5 | < 0.1 | 0.4 | 0.01 | 0.69 | < 50 |
| Polly-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 91 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.01 | <0.50 | < 50 |
| no name-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 27 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | 0.56 | < 50 |
| no name-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 540 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.01 | <0.50 | < 50 |
| no name-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 27 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | 0.55 | < 50 |
| Flat-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 23 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.04 | 0.53 | < 50 |
| Flat-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 29 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.01 | 0.68 | < 50 |
| Flat-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 26 | 0.004 | < 0.5 | < 0.1 | 0.3 | 0.02 | 0.69 | < 50 |
| Steele-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 25 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.04 | 0.64 | < 50 |
| Steele-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | 0.001 | < 0.005 | 35 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | <0.50 | < 50 |
| Steele-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 33 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | 0.65 | < 50 |
| Canyon-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 48 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | <0.50 | < 50 |
| Canyon-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | 0.001 | < 0.005 | 20 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | 1.20 | < 50 |
| Canyon-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 33 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | <0.50 | < 50 |
| Smith-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 20 | < 0.003 | < 0.5 | < 0.1 | 0.5 | 0.05 | 0.87 | < 50 |
| Smith-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 14 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.009 | 1.00 | < 50 |
| Smith-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 21 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | 0.61 | < 50 |
| Moose-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 21 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.007 | 0.98 | < 50 |
| Moose-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 20 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.02 | 1.30 | < 50 |
| Moose-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 26 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | 0.52 | < 50 |
| [1]O'Brien-1 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | 0.001 | < 0.005 | <20 | 0.004 | < 0.5 | < 0.1 | 0.4 | 0.02 | 0.78 | < 50 |
| [1]O'Brien-2 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 21 | < 0.003 | < 0.6 | < 0.1 | 0.4 | 0.16 | 0.92 | < 50 |
| [1]O'Brien-3 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 172 | 0.003 | < 0.5 | < 0.1 | 0.4 | 0.01 | 0.50 | < 50 |
| [1]O'Brien-4 | Grayling Muscle | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | < 0.005 | 61 | < 0.003 | < 0.5 | < 0.1 | 0.4 | 0.03 | 0.70 | < 50 |

[1] Fish from the O'Brien site were collected 13 km north of the main stem of the Fortymile River.

wet-weight basis) for grayling muscle tissue. Except were note, all fish were collected along the
f the Fortymile River (continued).

Table 3.--Analytical results (wet-weight basis) for gr
main stem of the Fortymile River (co

| Site Identifier | K ppm | La ppm | Li ppm | Mg ppm | Mn ppm | Mo ppm | Na ppm | Nb ppm | Ni ppm | Pb ppm | P ppm | Rb ppm | Sb ppm | Sc ppm | Se ppm | Sr ppm | Ta ppm | T pp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson-1 | 3970 | < 0.3 | < 0.2 | 231 | 0.3 | < 0.1 | 216 | < 2 | < 1 | < 0.2 | 2100 | 9.1 | < 0.02 | < 0.3 | 0.4 | 0.5 | < 0.2 | < 0 |
| Wilson-2 | 4080 | < 0.3 | < 0.2 | 222 | < 0.2 | < 0.1 | 214 | < 2 | < 1 | < 0.2 | 2000 | 3.6 | < 0.02 | < 0.3 | 0.7 | < 0.05 | < 0.2 | < 0 |
| Wilson-3 | 3910 | < 0.3 | < 0.2 | 217 | < 0.2 | < 0.1 | 225 | < 2 | < 1 | < 0.2 | 2000 | 4.6 | < 0.02 | < 0.3 | 1.3 | 0.1 | < 0.2 | < 0 |
| S. Fork-1 | 3480 | < 0.3 | < 0.2 | 254 | 2.8 | < 0.1 | 344 | < 2 | < 1 | < 0.2 | 3700 | 3.2 | < 0.02 | < 0.3 | 0.6 | 5.9 | < 0.2 | < 0 |
| S. Fork-2 | 3640 | < 0.3 | < 0.2 | 208 | < 0.2 | < 0.1 | 220 | < 2 | < 1 | < 0.2 | 1900 | 5.0 | < 0.02 | < 0.3 | <0.2 | < 0.05 | < 0.2 | < 0 |
| S. Fork-3 | 3570 | < 0.3 | < 0.2 | 206 | 0.2 | < 0.1 | 246 | < 2 | < 1 | < 0.2 | 1800 | 6.4 | < 0.02 | < 0.3 | 0.14 | 0.1 | < 0.2 | < 0 |
| N. Fork-1 | 3890 | < 0.3 | < 0.2 | 207 | 0.4 | < 0.1 | 239 | < 2 | < 1 | < 0.2 | 1900 | 4.5 | < 0.02 | < 0.3 | 0.6 | 0.3 | < 0.2 | < 0 |
| N. Fork-2 | 3530 | < 0.3 | < 0.2 | 183 | 0.2 | < 0.1 | 235 | < 2 | < 1 | < 0.2 | 1800 | 4.2 | < 0.02 | < 0.3 | 0.8 | 0.2 | < 0.2 | < 0 |
| N. Fork-3- | 3860 | < 0.3 | < 0.2 | 200 | 0.2 | < 0.1 | 280 | < 2 | < 1 | < 0.2 | 1900 | 6.2 | < 0.02 | < 0.3 | 1.0 | 0.1 | < 0.2 | < 0 |
| Polly-1 | 3980 | < 0.3 | < 0.2 | 196 | 0.2 | < 0.1 | 277 | < 2 | < 1 | < 0.2 | 1800 | 3.2 | < 0.02 | < 0.3 | 0.6 | 0.1 | < 0.2 | < 0 |
| Polly-3 | 3320 | < 0.3 | < 0.2 | 175 | < 0.2 | < 0.1 | 244 | < 2 | < 1 | < 0.2 | 1700 | 2.4 | < 0.02 | < 0.3 | 0.9 | 0.1 | < 0.2 | < 0 |
| Polly-3 | 3980 | < 0.3 | < 0.2 | 226 | 0.2 | < 0.1 | 219 | < 2 | < 1 | < 0.2 | 2000 | 9.9 | < 0.02 | < 0.3 | 0.3 | 0.2 | < 0.2 | < 0 |
| no name-1 | 4050 | < 0.3 | < 0.2 | 222 | < 0.2 | < 0.1 | 186 | < 2 | < 1 | < 0.2 | 2000 | 4.8 | < 0.02 | < 0.3 | 0.8 | < 0.05 | < 0.2 | < 0 |
| no name-2 | 3840 | < 0.3 | < 0.2 | 218 | 0.4 | < 0.1 | 241 | < 2 | < 1 | < 0.2 | 2200 | 3.9 | < 0.02 | < 0.3 | 1.1 | 0.9 | < 0.2 | < 0 |
| no name-3 | 3890 | < 0.3 | < 0.2 | 213 | < 0.2 | < 0.1 | 219 | < 2 | < 1 | < 0.2 | 1900 | 3.2 | < 0.02 | < 0.3 | 1.5 | < 0.05 | < 0.2 | < 0 |
| Flat-1 | 3680 | < 0.3 | < 0.2 | 199 | < 0.2 | < 0.1 | 205 | < 2 | < 1 | < 0.2 | 1800 | 4.7 | < 0.02 | < 0.3 | 0.9 | < 0.05 | < 0.2 | < 0 |
| Flat-2 | 3770 | < 0.3 | < 0.2 | 217 | < 0.2 | < 0.1 | 193 | < 2 | < 1 | < 0.2 | 1900 | 4.2 | < 0.02 | < 0.3 | 0.8 | < 0.05 | < 0.2 | < 0 |
| Flat-3 | 3980 | < 0.3 | < 0.2 | 216 | < 0.2 | < 0.1 | 217 | < 2 | < 1 | < 0.2 | 1900 | 4.7 | < 0.02 | < 0.3 | 1.2 | < 0.05 | < 0.2 | < 0 |
| Steele-1 | 4110 | < 0.3 | < 0.2 | 221 | < 0.2 | < 0.1 | 191 | < 2 | < 1 | < 0.2 | 2000 | 5.3 | < 0.02 | < 0.3 | 0.9 | < 0.05 | < 0.2 | < 0 |
| Steele-2 | 3960 | < 0.3 | < 0.2 | 210 | < 0.2 | < 0.1 | 197 | < 2 | < 1 | < 0.2 | 1800 | 3.5 | < 0.02 | < 0.3 | 1.1 | < 0.05 | < 0.2 | < 0 |
| Steele-3 | 3660 | < 0.3 | < 0.2 | 201 | 0.2 | < 0.1 | 188 | < 2 | < 1 | < 0.2 | 1600 | 4.7 | < 0.02 | < 0.3 | 0.5 | 0.1 | < 0.2 | < 0 |
| Canyon-1 | 3620 | < 0.3 | < 0.2 | 216 | 0.2 | < 0.1 | 223 | < 2 | < 1 | < 0.2 | 1800 | 3.4 | < 0.02 | < 0.3 | 1.3 | 0.1 | < 0.2 | < 0 |
| Canyon-2 | 3750 | < 0.3 | < 0.2 | 200 | < 0.2 | < 0.1 | 242 | < 2 | < 1 | < 0.2 | 2000 | 3.0 | < 0.02 | < 0.3 | 1.3 | < 0.05 | < 0.2 | < 0 |
| Canyon-3 | 3950 | < 0.3 | < 0.2 | 233 | < 0.2 | < 0.1 | 182 | < 2 | < 1 | < 0.2 | 2000 | 4.3 | < 0.02 | < 0.3 | 0.4 | < 0.05 | < 0.2 | < 0 |
| Smith-1 | 3800 | < 0.3 | < 0.2 | 202 | < 0.2 | < 0.1 | 198 | < 2 | < 1 | < 0.2 | 1900 | 5.1 | < 0.02 | < 0.3 | 1.2 | < 0.05 | < 0.2 | < 0 |
| Smith-2 | 3460 | < 0.3 | < 0.2 | 186 | < 0.2 | < 0.1 | 258 | < 2 | < 1 | < 0.2 | 1800 | 5.4 | < 0.02 | < 0.3 | 0.5 | < 0.05 | < 0.2 | < 0 |
| Smith-3 | 3340 | < 0.3 | < 0.2 | 191 | < 0.2 | < 0.1 | 222 | < 2 | < 1 | < 0.2 | 1700 | 2.3 | < 0.02 | < 0.3 | 0.7 | < 0.05 | < 0.2 | < 0 |
| Moose-1 | 3240 | < 0.3 | < 0.2 | 181 | < 0.2 | < 0.1 | 206 | < 2 | < 1 | < 0.2 | 1800 | 5.5 | < 0.02 | < 0.3 | 0.2 | < 0.05 | < 0.2 | < 0 |
| Moose-2 | 3340 | < 0.3 | < 0.2 | 178 | < 0.2 | < 0.1 | 277 | < 2 | < 1 | < 0.2 | 1900 | 3.5 | < 0.02 | < 0.3 | 0.4 | < 0.05 | < 0.2 | < 0 |
| Moose-3 | 3890 | < 0.3 | < 0.2 | 219 | < 0.2 | < 0.1 | 208 | < 2 | < 1 | < 0.2 | 1800 | 3.5 | < 0.02 | < 0.3 | 0.8 | < 0.05 | < 0.2 | < 0 |
| [1]O'Brien-1 | 3950 | < 0.3 | < 0.2 | 206 | < 0.2 | < 0.1 | 194 | < 2 | < 1 | < 0.2 | 2000 | 2.8 | < 0.02 | < 0.3 | 0.9 | < 0.05 | < 0.2 | < 0 |
| [1]O'Brien-2 | 3860 | < 0.3 | < 0.2 | 205 | < 0.2 | < 0.1 | 248 | < 2 | < 1 | < 0.2 | 2000 | 8.1 | < 0.02 | < 0.3 | 0.6 | < 0.05 | < 0.2 | < 0 |
| [1]O'Brien-3 | 3950 | < 0.3 | < 0.2 | 209 | 0.2 | < 0.1 | 251 | < 2 | < 1 | < 0.2 | 2200 | 2.2 | < 0.02 | < 0.3 | 0.6 | 0.3 | < 0.2 | < 0 |
| [1]O'Brien-4 | 3570 | < 0.3 | < 0.2 | 201 | < 0.2 | < 0.1 | 214 | < 2 | < 1 | < 0.2 | 1900 | 2.3 | < 0.02 | < 0.3 | 0.6 | 0.1 | < 0.2 | < 0 |

g muscle tissue. Except were note, all fish were collected along the
ued).

| Site Identifier | Ti ppm | Tl ppm | U ppm | V ppm | Y ppm | Zn ppm |
|---|---|---|---|---|---|---|
| Wilson-1 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Wilson-2 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Wilson-3 | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| S. Fork-1 | < 40 | < 0.003 | < 0.02 | < 0.4 | < 0.3 | 6 |
| S. Fork-2 | < 40 | < 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| S. Fork-3 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| N. Fork-1 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| N. Fork-2 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| N. Fork-3- | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Polly-1 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Polly-3 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Polly-3 | < 40 | < 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| no name-1 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| no name-2 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| no name-3 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Flat-1 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Flat-2 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Flat-3 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Steele-1 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Steele-2 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Steele-3 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Canyon-1 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Canyon-2 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Canyon-3 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Smith-1 | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Smith-2 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Smith-3 | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Moose-1 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Moose-2 | < 40 | 0.009 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| Moose-3 | < 40 | 0.004 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| [1]O'Brien-1 | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| [1]O'Brien-2 | < 40 | 0.006 | < 0.02 | < 0.4 | < 0.3 | < 5 |
| [1]O'Brien-3 | < 40 | 0.005 | < 0.02 | < 0.4 | < 0.3 | 6 |
| [1]O'Brien-4 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | < 5 |

Table 4.--Analytical results (wet-weight basis) for composited grayling liver tissue. Except were noted, all fish were collected along the main stem of the Fortymile River.

| Site Identifier | Sample Description | Ag ppm | Al ppm | As ppm | Ba ppm | Be ppm | Bi ppm | Ca ppm | Cd ppm | Ce ppm | Co ppm | Cr ppm | Cs ppm | Cu ppm | Fe ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Grayling Liver | < 0.02 | < 8 | 0.1 | < 0.5 | 0.001 | 0.005 | 19 | 0.22 | < 0.5 | 0.2 | 0.4 | 0.01 | 1.5 | < 50 |
| S. Fork (n=3) | Grayling Liver | < 0.02 | < 8 | 0.1 | < 0.5 | < 0.001 | < 0.005 | < 20 | 0.31 | < 0.5 | 0.2 | 0.3 | 0.006 | 1.0 | < 50 |
| N. Fork (n=3) | Grayling Liver | < 0.02 | < 8 | 0.1 | < 0.5 | < 0.001 | < 0.005 | < 20 | 0.63 | < 0.5 | 0.3 | 0.4 | 0.03 | 2.1 | 60 |
| Polly Creek (n=3) | Grayling Liver | < 0.02 | < 8 | 0.1 | < 0.5 | < 0.001 | < 0.005 | 40 | 0.62 | < 0.5 | 0.2 | 0.4 | 0.01 | 2.0 | 70 |
| no name (n=3) | Grayling Liver | < 0.02 | < 8 | 0.2 | < 0.5 | 0.001 | 0.006 | < 20 | 0.24 | < 0.5 | 0.2 | 0.4 | 0.03 | 2.6 | < 50 |
| Flat (n=3) | Grayling Liver | < 0.02 | < 8 | 0.2 | < 0.5 | < 0.001 | < 0.005 | 27 | 0.12 | < 0.5 | 0.1 | 0.3 | 0.02 | 1.3 | < 50 |
| Steele (n=3) | Grayling Liver | < 0.02 | < 8 | 0.2 | < 0.5 | < 0.001 | 0.01 | 22 | 0.22 | < 0.5 | 0.2 | 0.5 | 0.01 | 2.3 | 70 |
| Canyon (n=3) | Grayling Liver | < 0.02 | < 8 | 0.2 | < 0.5 | 0.001 | 0.007 | < 20 | 0.09 | < 0.5 | 0.2 | 0.4 | 0.03 | 1.4 | < 50 |
| Smith (n=3) | Grayling Liver | < 0.02 | < 8 | < 0.1 | < 0.5 | < 0.001 | 0.005 | 55 | 0.37 | < 0.5 | 0.4 | 0.6 | 0.01 | 1.7 | 60 |
| Moose (n=3) | Grayling Liver | < 0.02 | < 8 | < 0.1 | < 0.5 | 0.001 | < 0.005 | < 20 | 0.20 | < 0.5 | 0.2 | 0.4 | 0.01 | 1.7 | < 50 |
| O'Brien (n=4) | Grayling Liver | < 0.02 | < 8 | 0.1 | < 0.5 | 0.001 | 0.007 | < 20 | 0.42 | < 0.5 | 0.1 | 0.4 | 0.03 | 1.6 | < 50 |

| Site Identifier | Sample Description | K ppm | La ppm | Li ppm | Mg ppm | Mn ppm | Mo ppm | Na ppm | Nb ppm | Ni ppm | Pb ppm | P ppm | Rb ppm | Sb ppm | Sc ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Grayling Liver | 2520 | < 0.3 | < 0.2 | 137 | 1.6 | < 0.1 | 724 | < 2 | < 1 | < 0.2 | 2400 | 6.8 | < 0.02 | < 0.3 |
| S. Fork (n=3) | Grayling Liver | 2110 | < 0.3 | < 0.2 | 102 | 1.2 | 0.4 | 562 | < 2 | < 1 | < 0.2 | 1800 | 5.4 | < 0.02 | < 0.3 |
| N. Fork (n=3) | Grayling Liver | 2580 | < 0.3 | < 0.2 | 120 | 1.1 | < 0.1 | 600 | < 2 | < 1 | < 0.2 | 2100 | 6.1 | < 0.02 | < 0.3 |
| Polly Creek (n=3) | Grayling Liver | 3240 | < 0.3 | < 0.2 | 155 | 1.9 | 0.1 | 469 | < 2 | < 1 | < 0.2 | 2800 | 9.5 | < 0.02 | < 0.3 |
| no name (n=3) | Grayling Liver | 2670 | < 0.3 | < 0.2 | 131 | 1.3 | < 0.1 | 675 | < 2 | < 1 | < 0.2 | 2300 | 4.4 | < 0.02 | < 0.3 |
| Flat (n=3) | Grayling Liver | 2700 | < 0.3 | < 0.2 | 140 | 1.4 | < 0.1 | 681 | < 2 | < 1 | < 0.2 | 2500 | 4.8 | < 0.02 | < 0.3 |
| Steele (n=3) | Grayling Liver | 2940 | < 0.3 | < 0.2 | 152 | 1.8 | 0.2 | 494 | < 2 | < 1 | < 0.2 | 2700 | 5.7 | < 0.02 | < 0.3 |
| Canyon (n=3) | Grayling Liver | 2680 | < 0.3 | < 0.2 | 143 | 1.5 | 0.1 | 830 | < 2 | < 1 | < 0.2 | 2500 | 4.7 | < 0.02 | < 0.3 |
| Smith (n=3) | Grayling Liver | 2340 | < 0.3 | < 0.2 | 112 | 1.3 | 0.1 | 738 | < 2 | < 1 | < 0.2 | 2100 | 4.9 | < 0.02 | < 0.3 |
| Moose (n=3) | Grayling Liver | 2580 | < 0.3 | < 0.2 | 138 | 1.9 | 0.1 | 767 | < 2 | < 1 | < 0.2 | 2400 | 5.9 | < 0.02 | < 0.3 |
| O'Brien (n=4) | Grayling Liver | 2440 | < 0.3 | < 0.2 | 133 | 1.5 | < 0.1 | 601 | < 2 | < 1 | < 0.2 | 2400 | 5.2 | < 0.02 | < 0.3 |

| Site Identifier | Sample Description | Ta ppm | Th ppm | Ti ppm | Tl ppm | U ppm | V ppm | Y ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 17 |
| S. Fork (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.01 | < 0.02 | < 0.4 | < 0.3 | 13 |
| N. Fork (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 17 |
| Polly Creek (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 19 |
| no name (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.03 | < 0.02 | < 0.4 | < 0.3 | 17 |
| Flat (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 17 |
| Steele (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 22 |
| Canyon (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 17 |
| Smith (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.01 | < 0.02 | < 0.4 | < 0.3 | 16 |
| Moose (n=3) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.01 | < 0.02 | < 0.4 | < 0.3 | 17 |
| O'Brien (n=4) | Grayling Liver | < 0.2 | < 0.03 | < 40 | 0.02 | < 0.02 | < 0.4 | < 0.3 | 15 |

[1] Fish from the O'Brien site were collected 13 km north of the main stem of the Fortymile river.

**Table 5.**–Analytical results (wet-weight basis) for composited grayling stomach contents. Except were noted, all fish were collected along the main stem of the Fortymile River.

| Site Identifier | Sample Description | Ag ppm | Al ppm | As ppm | Ba ppm | Be ppm | Bi ppm | Ca ppm | Cd ppm | Ce ppm | Co ppm | Cr ppm | Cs ppm | Cu ppm | Fe ppm | Ga ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Stomach Contents | < 0.02 | 62 | 0.2 | 3.7 | 0.003 | 0.006 | 180 | 0.17 | < 0.5 | < 0.1 | 0.8 | 0.01 | 8.2 | 150 | 0.04 |
| S. Fork (n=3) | Stomach Contents | < 0.02 | 20 | 0.1 | 0.8 | 0.001 | < 0.005 | 71 | 0.07 | < 0.5 | < 0.1 | 0.4 | 0.008 | 5.4 | 60 | 0.02 |
| N. Fork (n=3) | Stomach Contents | < 0.02 | 191 | 0.4 | 4.2 | 0.01 | 0.007 | 212 | 0.09 | 1.0 | 0.3 | 0.9 | 0.02 | 7.0 | 490 | 0.08 |
| Polly (n=3) | Stomach Contents | < 0.02 | 183 | 0.3 | 1.9 | 0.009 | < 0.005 | 87 | 0.18 | 0.70 | 0.3 | 1.0 | 0.02 | 9.1 | 420 | 0.09 |
| no name (n=3) | Stomach Contents | < 0.02 | 116 | 0.3 | 5.2 | 0.004 | < 0.005 | 222 | 0.29 | < 0.5 | 0.1 | 0.9 | 0.02 | 7.7 | 300 | 0.07 |
| Flat (n=3) | Stomach Contents | < 0.02 | 44 | 0.2 | 1.6 | 0.008 | < 0.005 | 198 | 0.10 | < 0.5 | 0.1 | 0.4 | 0.01 | 3.9 | 140 | 0.02 |
| Steele (n=3) | Stomach Contents | < 0.02 | 70 | 0.2 | 1.3 | 0.005 | < 0.005 | 70 | 0.13 | < 0.5 | 0.1 | 0.6 | 0.01 | 6.2 | 140 | 0.04 |
| Canyon (n=3) | Stomach Contents | < 0.02 | 24 | < 0.1 | 1.2 | 0.002 | 0.01 | 514 | 0.06 | < 0.5 | < 0.1 | 0.4 | 0.008 | 2.4 | 50 | 0.02 |
| Smith (n=3) | Stomach Contents | < 0.02 | 58 | 0.2 | 1.6 | 0.002 | < 0.005 | 59 | 0.08 | < 0.5 | < 0.1 | 0.6 | 0.01 | 5.4 | 110 | 0.03 |
| Moose (n=3) | Stomach Contents | 0.02 | 26 | 0.1 | 1.5 | 0.002 | 0.009 | 100 | 0.24 | < 0.5 | < 0.1 | 0.6 | 0.009 | 6.3 | 80 | 0.02 |
| O'Brien (n=4) | Stomach Contents | < 0.02 | 323 | 0.6 | 4.4 | 0.01 | 0.006 | 140 | 0.18 | 0.72 | 0.4 | 3.1 | 0.06 | 4.3 | 710 | 0.10 |

| Site Identifier | Sample Description | K ppm | La ppm | Li ppm | Mg ppm | Mn ppm | Mo ppm | Na ppm | Nb ppm | Ni ppm | P ppm | Pb ppm | Rb ppm | Sb ppm | Sc ppm | Se ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Stomach Contents | 925 | < 0.3 | < 0.2 | 80 | 9.4 | 0.2 | 349 | < 2 | < 1 | 2400 | < 0.2 | 1.4 | < 0.02 | < 0.3 | 1.9 |
| S. Fork (n=3) | Stomach Contents | 433 | < 0.3 | < 0.2 | 33 | 2.0 | 0.2 | 118 | < 2 | < 1 | 1400 | < 0.2 | 0.95 | < 0.02 | < 0.3 | 0.8 |
| N. Fork (n=3) | Stomach Contents | 768 | 0.5 | < 0.2 | 103 | 19 | 0.2 | 208 | < 2 | < 1 | 2200 | < 0.2 | 1.8 | < 0.02 | < 0.3 | 1.4 |
| Polly (n=3) | Stomach Contents | 611 | 0.4 | 0.2 | 122 | 10 | 0.3 | 286 | < 2 | < 1 | 2000 | < 0.2 | 1.2 | < 0.02 | < 0.3 | 1.4 |
| no name (n=3) | Stomach Contents | 773 | < 0.3 | < 0.2 | 120 | 14 | 0.2 | 243 | < 2 | < 1 | 2600 | < 0.2 | 1.0 | < 0.02 | < 0.3 | 1.6 |
| Flat (n=3) | Stomach Contents | 576 | < 0.3 | < 0.2 | 69 | 16 | 0.1 | 306 | < 2 | < 1 | 1100 | < 0.2 | 1.0 | < 0.02 | < 0.3 | 1.3 |
| Steele (n=3) | Stomach Contents | 891 | < 0.3 | < 0.2 | 72 | 5.7 | 0.2 | 246 | < 2 | < 1 | 1800 | < 0.2 | 1.7 | < 0.02 | < 0.3 | 1.4 |
| Canyon (n=3) | Stomach Contents | 724 | < 0.3 | < 0.2 | 67 | 5.4 | 0.1 | 289 | < 2 | < 1 | 1400 | < 0.2 | 0.94 | < 0.02 | < 0.3 | 0.8 |
| Smith (n=3) | Stomach Contents | 861 | < 0.3 | < 0.2 | 80 | 7.3 | 0.2 | 288 | < 2 | < 1 | 1400 | < 0.2 | 1.3 | < 0.02 | < 0.3 | 1.0 |
| Moose (n=3) | Stomach Contents | 899 | < 0.3 | < 0.2 | 90 | 17 | 0.2 | 373 | < 2 | < 1 | 1900 | < 0.2 | 1.6 | < 0.02 | < 0.3 | 1.3 |
| O'Brien (n=4) | Stomach Contents | 1110 | 0.4 | 0.4 | 350 | 18 | 0.2 | 285 | < 2 | 2 | 2000 | 0.2 | 1.6 | < 0.02 | < 0.3 | 1.4 |

| Site Identifier | Sample Description | Ta ppm | Th ppm | Ti ppm | Tl ppm | U ppm | V ppm | Y ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|
| Wilson (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.005 | 0.04 | 0.4 | < 0.3 | 16 |
| S. Fork (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | < 0.003 | < 0.02 | < 0.4 | < 0.3 | 8 |
| N. Fork (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.004 | 0.16 | 1.1 | 0.4 | 14 |
| Polly (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.003 | 0.27 | 1.1 | 0.3 | 10 |
| no name (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.003 | 0.05 | 0.6 | < 0.3 | 22 |
| Flat (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.003 | 0.08 | < 0.4 | < 0.3 | 11 |
| Steele (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.004 | 0.14 | < 0.4 | < 0.3 | 13 |
| Canyon (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.003 | < 0.02 | < 0.4 | < 0.3 | 9 |
| Smith (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | < 0.003 | < 0.02 | < 0.4 | < 0.3 | 11 |
| Moose (n=3) | Stomach Contents | < 0.2 | < 0.03 | < 40 | 0.003 | 0.03 | < 0.4 | < 0.3 | 13 |
| O'Brien (n=4) | Stomach Contents | < 0.2 | 0.06 | < 40 | 0.005 | 0.05 | 1.0 | < 0.3 | 17 |

[1] Fish from the O'Brien site were collected 13 km north of the main stem of the Fortymile river.

Table 6.--Summary statistics for element concentrations in Arctic grayling muscle (fillet) tissue, Fortymile River study area compared to muscle tissue from grayling collected in the Koyukuk National Wildlife Refuge (Meuller et al., 1996)

[Fortymile data expressed as ppm wet weight; Koyukuk data expressed as ppm dry weight]

| | Fortymile samples | | | | Observed range (ppm) | |
|---|---|---|---|---|---|---|
| Element | Lower limit of analytical determination (LLD) | Analytical detection ratio[1] | Geometric mean (ppm) | Geometric deviation | Fortymile (n=34) | Koyukuk (n=8) |
| Ag | 0.02 | 0:34 | --[2] | -- | <0.02 - <0.02 | <0.4 - <0.4 |
| Al | 8 | 0:34 | -- | -- | <8 - <8 | <1.9 - 2.9 |
| As | 0.1 | 0:34 | -- | -- | <0.1 - <0.1 | <0.5 - <0.5 |
| Ba | 0.5 | 0:34 | -- | -- | <0.5 - <0.5 | <0.1 - 0.65 |
| Be | 0.001 | 4:34 | -- | -- | <0.001 - 0.001 | <0.1 - <0.1 |
| Bi | 0.005 | 0:34 | -- | -- | <0.005 - <0.005 | nd[3] |
| Ca | 20 | 33:34 | -- | -- | <20 - 2280 | nd |
| Cd | 0.003 | 5:34 | -- | -- | <0.003 - 1.2 | <0.5 - <0.5 |
| Ce | 0.5 | 0:34 | -- | -- | <0.5 - <0.5 | nd |
| Co | 0.1 | 0:34 | -- | -- | <0.1 - <0.1 | nd |
| Cr | 0.2 | 34:34 | 0.4 | 1.09 | 0.3 - 0.5 | <0.3 - <0.3 |
| Cs | 0.003 | 34:34 | 0.019 | 2.05 | 0.004 - 0.016 | nd |
| Cu | 0.5 | 22:34 | -- | -- | <0.5 - 1.3 | 1.6 - 2.7 |
| Fe | 50 | 0:34 | -- | -- | <50 - <50 | 21 - 40 |
| Ga | 0.006 | 34:34 | 0.02 | 1.32 | 0.01 - 0.03 | nd |
| Hg (total) | 0.004 | 34:34 | 0.069 | 1.62 | 0.021 - 0.15 | 0.22 - 0.66 |
| K | 20 | 34:34 | 3750 | 1.07 | 3240 - 4110 | nd |
| La | 0.3 | 0:34 | -- | -- | <0.3 - <0.3 | nd |
| Li | 0.2 | 0:34 | -- | -- | <0.2 - <0.2 | nd |
| Mg | 0.3 | 34:34 | 210 | 1.08 | 175 - 254 | 1000 - 1200 |
| Mn | 0.2 | 12:22 | -- | -- | <0.2 - 2.8 | 1.1 - 1.8 |
| Mo | 0.1 | 0:34 | -- | -- | <0.1 - <0.1 | <0.30 - 0.33 |
| Na | 6 | 34:34 | 220 | 1.15 | 182 - 344 | nd |
| Nb | 2 | 0:34 | -- | -- | <2 - <2 | nd |
| Ni | 1 | 0:34 | -- | -- | <1 - <1 | <1.0 - <1.0 |
| Pb | 0.2 | 0:34 | -- | -- | <0.2 - <0.2 | <3.0 - <3.0 |
| P | 8 | 34:34 | -- | -- | <8 - <8 | nd |
| Rb | 0.01 | 34:34 | 4.1 | 1.44 | 2.2 - 9.9 | nd |
| Sb | 0.02 | 0:34 | -- | -- | <0.02 - <0.02 | <3.0 - <3.0 |
| Sc | 0.3 | 0:34 | -- | -- | <0.3 - <0.3 | nd |
| Se | 0.2 | 33:34 | -- | -- | <0.2 - 1.5 | 1.5 - 2.3 |
| Sr | 0.05 | 15:34 | -- | -- | <0.05 - 5.9 | <1.5 - 4.7 |
| Th | 0.03 | 0:34 | -- | -- | <0.03 - <0.03 | nd |
| Ti | 40 | 0:34 | -- | -- | <40 - <40 | nd |
| Tl | 0.003 | 31:34 | -- | -- | <0.003 - 0.009 | <11 - <11 |
| U | 0.02 | 0:34 | -- | -- | <0.02 - <0.02 | nd |
| V | 0.4 | 0:34 | -- | -- | <0.4 - <0.4 | <0.3 - <0.3 |
| Zn | 5 | 2:34 | -- | -- | <5 - 6 | 11 - 16 |

**Table 7.**--Summary statistics for element concentrations in Arctic grayling liver tissue, Fortymile River study area, compared to liver tissue from grayling collected in the Koyukuk National Wildlife Refuge (Mueller et al., 1996)

[Fortymile data expressed as ppm wet weight; Koyukuk data expressed as ppm dry weight]

| | Fortymile samples | | | | | |
|---|---|---|---|---|---|---|
| | Lower limit of analytical determination | Analytical detection | Geometric | Geometric | Observed range (ppm) | |
| Element | (LLD) | ratio[1] | mean (ppm) | deviation | Fortymile (n=11) | Koyukuk (n=8) |
| Ag | 0.02 | 0:11 | --[2] | --[2] | <0.02 - <0.02 | <0.4 - <0.4 |
| Al | 8 | 0:11 | -- | -- | <8 - <8 | 21 - 37 |
| As | 0.1 | 9:11 | -- | -- | <0.1 - 0.2 | nd[3] |
| Ba | 0.5 | 0:11 | -- | -- | <0.5 - <0.5 | <0.1 - 0.29 |
| Be | 0.001 | 5:11 | -- | -- | <0.001 - 0.001 | <0.1 - <0.1 |
| Bi | 0.005 | 6:11 | -- | -- | <0.005 - 0.01 | nd |
| Ca | 20 | 5:11 | -- | -- | <20 - 55 | nd |
| Cd | 0.003 | 11:11 | 0.27 | 1.85 | 0.09 - 0.63 | <0.1 - 1.1 |
| Ce | 0.5 | 0:11 | -- | -- | <0.5 - <0.5 | nd |
| Co | 0.1 | 11:11 | 0.19 | 1.36 | 0.13 - 0.35 | nd |
| Cr | 0.2 | 11:11 | 0.4 | 1.20 | 0.3 - 0.6 | <0.7 - 0.85 |
| Cs | 0.003 | 11:11 | 0.015 | 1.83 | 0.006 - 0.030 | nd |
| Cu | 0.5 | 11:11 | 1.7 | 1.32 | 1.0 - 2.6 | 7.8 - 27 |
| Fe | 50 | 4:11 | -- | -- | <50 - 70 | 270 - 320 |
| Ga | 0.006 | 11:11 | 0.02 | 0.0 | 0.02 - 0.02 | nd |
| Hg (total) | 0.004 | 11:11 | 0.062 | 1.53 | 0.031 - 0.10 | 0.2 - 0.9 |
| K | 20 | 11:11 | 2600 | 1.12 | 2100 - 3240 | nd |
| La | 0.3 | 0:11 | -- | -- | <0.3 - <0.3 | nd |
| Li | 0.2 | 0:11 | -- | -- | <0.2 - <0.2 | nd |
| Mg | 0.3 | 11:11 | 130 | 1.16 | 100 - 160 | 630 - 700 |
| Mn | 0.2 | 11:11 | 1.5 | 1.2 | 1.1 - 1.9 | 7.4 - 11 |
| Mo | 0.1 | 6:11 | -- | -- | <0.1 - 0.4 | <0.4 - 0.84 |
| Na | 6 | 11:11 | 640 | 1.2 | 470 - 830 | nd |
| Nb | 2 | 0:11 | -- | -- | <2 - <2 | nd |
| Ni | 1 | 0:11 | -- | -- | <1 - <1 | <1.0 - <1.0 |
| Pb | 0.2 | 0:11 | -- | -- | <0.2 - <0.2 | <3.0 - <3.0 |
| P | 8 | 11:11 | 2350 | 1.13 | 1800 - 2800 | nd |
| Rb | 0.01 | 11:11 | 5.6 | 1.24 | 4.4 - 9.5 | nd |
| Sb | 0.02 | 0:11 | -- | -- | <0.02 - <0.02 | <3.0 - <3.0 |
| Sc | 0.3 | 0:11 | -- | -- | <0.3 - <0.3 | nd |
| Se | 0.2 | 0:11 | 0.67 | 1.73 | 0.2 - 1.5 | nd |
| Sr | 0.05 | 0:11 | -- | -- | <0.05 - 5.9 | <1.5 - <1.5 |
| Th | 0.03 | 0:11 | -- | -- | <0.03 - <0.03 | nd |
| Ti | 40 | 0:11 | -- | -- | <40 - <40 | nd |
| Tl | 0.003 | 0:11 | -- | -- | <0.003 - 0.009 | <15 - <15 |
| U | 0.02 | 0:11 | -- | -- | <0.02 - <0.02 | nd |
| V | 0.4 | 0:11 | -- | -- | <0.4 - <0.4 | 0.7 - 1.9 |
| Zn | 5 | 0:11 | -- | -- | <5 - 6 | 87 - 94 |

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**Table 8.**–Summary statistics for element concentrations in Arctic grayling stomach contents, Fortymile River study area.

[Concentrations are expressed as ppm wet weight]

| Element | Lower limit of analytical determination (LLD) | Analytical detection ratio[1] | Geometric mean (ppm) | Geometric deviation | Observed range (ppm) |
|---|---|---|---|---|---|
| Ag | 0.02 | 0:11 | --[2] | --[2] | <0.02 - <0.02 |
| Al | 8 | 0:11 | -- | -- | <8 - <8 |
| As | 0.1 | 10:11 | -- | -- | <0.1 - 0.6 |
| Ba | 0.5 | 11:11 | 2.1 | 1.86 | 0.84 - 5.2 |
| Be | 0.001 | 11:11 | 0.004 | 2.21 | 0.003 - 0.01 |
| Bi | 0.005 | 5:11 | -- | -- | <0.005 - 0.01 |
| Ca | 20 | 11:11 | 140 | 1.92 | 59 - 510 |
| Cd | 0.003 | 11:11 | 0.13 | 1.68 | 0.06 - 0.29 |
| Ce | 0.5 | 3:11 | -- | -- | <0.5 - 1.0 |
| Co | 0.1 | 6:11 | -- | -- | <0.1 - 0.37 |
| Cr | 0.2 | 11:11 | 0.72 | 1.79 | 0.4 - 3.1 |
| Cs | 0.003 | 11:11 | 0.02 | 1.84 | 0.008 - 0.06 |
| Cu | 0.5 | 11:11 | 5.6 | 1.47 | 2.4 - 9.1 |
| Fe | 50 | 11:11 | 170 | 2.41 | 50 - 710 |
| Ga | 0.006 | 11:11 | 0.04 | 1.9 | 0.02 - 0.1 |
| Hg (total) | 0.004 | 11:11 | 0.0097 | 1.31 | 0.0063 - 0.014 |
| K | 20 | 11:11 | 760 | 1.3 | 430 - 1110 |
| La | 0.3 | 3:11 | -- | -- | <0.3 - 0.5 |
| Li | 0.2 | 2:11 | -- | -- | <0.2 - 0.4 |
| Mg | 0.3 | 11:11 | 90 | 1.77 | 33 - 350 |
| Mn | 0.2 | 11:11 | 9.5 | 1.99 | 2.0 - 19 |
| Mo | 0.1 | 11:11 | 0.19 | 1.4 | 0.1 - 0.29 |
| Na | 6 | 11:11 | 260 | 1.36 | 120 - 370 |
| Nb | 2 | 0:11 | -- | -- | <2 - <2 |
| Ni | 1 | 0:11 | -- | -- | <1 - <1 |
| Pb | 0.2 | 0:11 | -- | -- | <0.2 - <0.2 |
| P | 8 | 11:11 | 1780 | 1.31 | 1100 - 2600 |
| Rb | 0.01 | 11:11 | 1.3 | 1.28 | 0.9 - 1.8 |
| Sb | 0.02 | 0:11 | -- | -- | <0.02 - <0.02 |
| Sc | 0.3 | 0:11 | -- | -- | <0.3 - <0.3 |
| Se | 0.2 | 11:11 | 1.3 | 1.31 | 0.8 - 1.9 |
| Sr | 0.05 | 11:11 | 1.6 | 1.97 | 0.6 - 5.1 |
| Th | 0.03 | 0:11 | -- | -- | <0.03 - <0.03 |
| Ti | 40 | 0:11 | -- | -- | <40 - <40 |
| Tl | 0.003 | 9:11 | -- | -- | <0.003 - 0.005 |
| U | 0.02 | 8:11 | -- | -- | <0.02 - 0.27 |
| V | 0.4 | 5:11 | -- | -- | <0.4 - 0.4 |
| Zn | 5 | 11:11 | 12 | 1.36 | 7.8 - 22 |

**Table 9.**--Summary of nitrogen, carbon, and sulfur isotopic data for Arctic grayling in the Fortymile River, Alaska.

| Sample ID | $d^{15}N$ permil | $d^{13}C$ permil | $d^{34}S$ permil |
|---|---|---|---|
| Wilson Cr.-1 | 8.2 | -30.1 | 5.5 |
| Wilson Cr.-2 | 8.6 | -31.4 | -0.2 |
| Wilson Cr.-3 | 8.3 | -27.4 | 0.9 |
| mean | 8.3 | -29.6 | 2.1 |
| SD | 0.2 | 2.0 | 3.0 |
| So. Fork-1 | 8.4 | -28.9 | 6.8 |
| So. Fork-2 | 7.9 | -29.9 | 8.2 |
| So. Fork-3 | 8.9 | -30.7 | 4.1 |
| mean | 8.4 | -29.8 | 6.4 |
| SD | 0.5 | 0.9 | 2.1 |
| No. Fork-1 | 9.4 | -28.1 | 3.3 |
| No. Fork-2 | 9.3 | -28.4 | 6.2 |
| No. Fork-3 | 9.3 | -26.5 | 3.3 |
| mean | 9.4 | -27.7 | 4.3 |
| SD | 0.0 | 1.0 | 1.7 |
| Polly Cr.-1 | 9.7 | -26.5 | 0.5 |
| Polly Cr.-2 | 8.8 | -31.7 | 6.1 |
| Polly Cr.-3 | 9.0 | -29.2 | -3.3 |
| mean | 9.2 | -29.1 | 1.1 |
| SD | 0.5 | 2.6 | 4.7 |
| no name cr.-1 | 7.7 | -27.4 | 2.1 |
| no name cr.-2 | 8.0 | -31.1 | -8.4 |
| no name cr.-3 | 8.2 | -27.6 | -2.4 |
| mean | 8.0 | -28.7 | -2.9 |
| SD | 0.2 | 2.1 | 5.3 |
| Flat Cr.-1 | 9.2 | -26.9 | 3.3 |
| Flat Cr.-2 | 8.7 | -29.1 | 4.0 |
| Flat Cr.-3 | 8.9 | -28.0 | 1.8 |
| mean | 8.9 | -28.0 | 3.0 |
| SD | 0.2 | 1.1 | 1.1 |

| Sample ID | $d^{15}N$ permil | $d^{13}C$ permil | $d^{34}S$ permil |
|---|---|---|---|
| Steele Cr.-1 | 7.9 | -28.7 | 0.5 |
| Steele Cr.-2 | 9.2 | -29.5 | -3.8 |
| Steele Cr.-3 | 8.9 | -29.3 | 4.9 |
| mean | 8.6 | -29.2 | 0.5 |
| SD | 0.7 | 0.4 | 4.4 |
| Canyon Cr.-1 | 8.7 | -29.2 | -2.5 |
| Canyon Cr.-2 | 8.8 | -28.5 | -2.8 |
| Canyon Cr.-3 | 7.6 | -31.5 | -1.3 |
| mean | 8.4 | -29.7 | -2.2 |
| SD | 0.6 | 1.6 | 0.8 |
| Smith Cr.-1 | 8.9 | -25.8 | 2.5 |
| Smith Cr.-2 | 8.6 | -29.0 | 6.4 |
| Smith Cr.-3 | 8.9 | -28.7 | 0.0 |
| mean | 8.8 | -27.8 | 2.9 |
| SD | 0.2 | 1.8 | 3.2 |
| Moose Cr.-1 | 9.4 | -29.8 | 6.7 |
| Moose Cr.-2 | 8.9 | -27.9 | 3.9 |
| Moose Cr.-3 | 9.1 | -27.9 | 3.4 |
| mean | 9.1 | -28.6 | 4.6 |
| SD | 0.3 | 1.1 | 1.8 |
| O'Brien Cr.-1 | 8.3 | -27.9 | 2.2 |
| O'Brien Cr.-2 | 8.7 | -33.1 | 3.0 |
| O'Brien Cr.-3 | 9.3 | -30.1 | -6.9 |
| O'Brien Cr.-4 | 9.0 | -30.8 | 0.8 |
| mean | 8.8 | -30.5 | -0.2 |
| SD | 0.5 | 2.2 | 4.5 |

| | | | |
|---|---|---|---|
| **Mean-All** | 8.7 | -29.0 | 1.7 |
| **SD-All** | 0.5 | 1.7 | 4.0 |

**Table 10.**–Summary of the dominant invertebrate taxa found in the stomach contents of three Arctic grayling from sites along the main stem of the Fortymile River.

[": the same as]

| Parameter: | Invertebrate common name | Steele Creek | Canyon Creek | Polly Creek |
|---|---|---|---|---|
| Total individual invertebrates counted | | 120 | 109 | 172 |
| total aquatic invertebrates | | 83 | 25 | 113 |
| total terrestrial invertebrates | | 37 | 84 | 59 |
| Total taxa found | | 15 | 9 | 15 |
| | | | | |
| Total Ephemeroptera[1] | mayfly | 3 | 1 | 5 |
| Percent Ephemeroptera[1] | " | 3 | 1 | 3 |
| Total Plecoptera[1] | stonefly | 1 | 0 | 15 |
| Percent Plecoptera[1] | " | 1 | 0 | 9 |
| Total Trichoptera[1] | caddisfly | 78 | 20 | 58 |
| Percent Trichoptera[1] | " | 65 | 18 | 34 |
| Total aquatic Diptera[1] | true fly | 1 | 4 | 45 |
| Percent aquatic Diptera[1] | " | 1 | 4 | 26 |
| Miscellaneous aquatic species | | 8 | 0 | 10 |
| Percent miscellaneous aquatic species | | 9 | 0 | 6 |
| | | | | |
| Percent EPT[2] | | 69 | 19 | 47 |
| Percent Chironomidae[3] (Diptera) | true fly | 0 | 4 | 9 |
| TOTALS: | | | | |
| Percent dominant taxa | | 61 | 55 | 29 |
| Percent aquatic | | 69 | 23 | 66 |
| Percent terrestrial | | 31 | 77 | 34 |

[1] Insect order

[2] Combination of the orders Ephemeroptera-Plecoptera-Trichoptera

[3] Insect family