Water Resources Center
Annual Technical Report
FY 2001

Introduction

Water related issues and problems in Alaska have varied over the years. However, the one main component that keeps driving our research effort is resource development. As market prices for natural resources (gold, oil, lumber, other metals, etc.) fluctuate, so does the impact on the water resources of Alaska. In the past few years, there has been a resurgence in resource development. At present, our research is driven by needs of rural Alaska (sustainable energy, heating, air quality, water and wastewater), research related to climate change, groundwater contamination (hydrocarbons, heavy metals, radioactive material, etc.), resource development, applications of remote sensing, accurate precipitation measurement in extreme environments, sediment transport in arctic regions and permafrost geomorphology.

During 2001/2002 (March 1 to February 28), funds from the USGS Water Resources Institute Program were used to fund four projects at the Water and Environmental Research Center (WERC) at the University of Alaska Fairbanks (UAF):

i) Fingerprinting Organic Material in the Caribou-Poker Creek Watershed to Support Hydrologic Investigations (PIs: Daniel M. White and Kenji Yoshikawa)

ii) Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic (PI: Larry D. Hinzman)

iii) Compatibility Analyses of Various Snow Measurements/Data in Alaska (PI: Daqing Yang)

iv) Mercury levels in Alaskan Rivers: Relationship Between Hg Levels, Salmon and Subsistence (PI: Larry K. Duffy)

Because of the limited support afforded this program ($75,321), as Director of WERC, I encourage proposals that emphasize graduate student support. These grants are viewed as an initial investment in a research program that should lead to a larger research project.

The Water and Environmental Research Center at UAF has gone through considerable change in the past couple of years. First, we have added several new faculty members, each with a major affiliation in the Center. This past year we added Dr. Silke Schiewer, an Assistant Professor in Environmental Engineering. In September 2001, we also moved back into our facilities after major renovations. We vacated the building for 15 months; during this absence our laboratory capacity was much reduced as WERC was housed in a dormitory. Essentially, the space from the old Center was completely gutted (several code violations in the laboratories), new offices were built (where the old labs existed on the outside of the building), and new labs were constructed in the interior of the building (where offices existed previously). Our old walk-in environmental chambers (1950s and 1960s technology) were replaced with new environmental chambers. The labs are now state-of-the-art and house a wide range of analytical instruments, several of which were obtained on a large grant from a private foundation about three years ago. Within WERC, we have a Stable Isotope Mass Spectrometer Laboratory (run as a cost center) where we presently have three Isotope Ratio Mass Spectrometers (IRMS). We process about 10,000 samples per year. We can presently measure O, H, C and N stable isotope ratios; within 6 months we should be able to handle sulfur, and in the future we hope to add inorganic carbon.

Information dissemination at WERC occurs through journal publications, workshops, participation in conferences and symposiums, out-reach programs, and our extensive website (http://www.uaf.edu/water/). The website contains information on: WERC Mission, Faculty and Staff, Current Projects, Past Projects, Publications, Photo Gallery, Seminars, Student Information (New Opportunities, Current Graduate Students, Information for Potential Graduate Students, and Related Programs) and Current Data Collection. We have five research areas (Ft. Wainwright, Caribou-Poker Creeks Research Watershed, North Slope Research Watersheds, Seward Peninsula Research Watersheds, and Ester Dome) where the hydrological data we collect is posted on the internet. This past summer a workshop on The Measurement of Solid Precipitation was held on campus in June; over 60 participants from about one dozen countries were present for this 3-day workshop. Numerous outreach programs are performed by the faculty, staff, and students of WERC each year; for an example see Fairbanks Outdoor Days on the above website.

Research expenditures by WERC faculty, staff and students during the state physical year (July 1 to June 30:

Fiscal year 2001: State expenditures, $582,454

Restricted expenditures, $1,889,458

Total Expenditures, $2,471,912

Fiscal year 2002: State expenditures, $706,963

Restricted expenditures, $1,877,268

Total Expenditures, $2,584,231

Research Program

Basic Information

Title:	Fingerprinting organic material in the Caribou-Poker Creek Watershed to support hydrologic investigations
Project Number:	2001AK3461B
Start Date:	3/1/2001
End Date:	3/1/2003
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Groundwater, Water Supply
Descriptors:	permafrost, organic chemistry, hydrology
Principal Investigators:	Daniel M. White , Kenji Yoshikawa

Publication

1. White, D. K. Yoshikawa, and D. Garland, (2002), Fingerprinting dissolved organic matter to support hydrologic investigations, Cold Regions Science and Technology, Vol. 35, pp. 27-33.
2. Jaspreet Narr (2001), Disinfection By-Product Experiences in Alaskan Village Drinking Water Systems and the Caribou-Poker Creek Watershed. MS. Environmental Engineering, Thesis, University of Alaska Fairbanks.
3. Vincent Autier (2002), Predicting Contaminant Transport Pathways in the Caribou-Poker Creeks Watersheds. MS. Civil Engineering, Thesis, University of Alaska Fairbanks.

Problem and Research Objectives:

The Caribou and Poker Creek Watershed (CPCRW) is an important component of the Bonanza Creek LTER (Long Term Ecological Research) Program. The CPCRW serves as a testbed for process studies on interactions between hydrology, meteorology and permafrost. By characterizing the nature and origin of organic matter in water below or above permafrost, in interpermafrost springs, and in streams this project sought to better describe the influence of permafrost on the hydrology in this region. In addition to a better understanding of the hydrology of permafrost watersheds in general, understanding the origin of organic matter is important for studies on drinking water treatment and use. Many public drinking water systems in Alaska extract water from above or below permafrost. Depending on the origin of the organic matter, certain health risks may be present.

NOM in water from the CPCRW was collected and subjected to a suite of analytical tests including dissolved organic carbon (DOC), apparent molecular size fractionation, ultraviolet absorbance. NOM was also fingerprinted using pyrolysis-G/MS. Fingerprint analysis was used to help determine the character and origin of surface water contributing to groundwater and vice versa during different seasons.

Methodology

Site Selection

The CPCRW served as an ideal research watershed for investigation. Water samples were collected from wells, streams, and springs from three different sub-watersheds (C2, C3, and C4). Mr. Vincent Autier, the graduate student working on the project, collected and analyzed all water samples under the direction of Dr. Kenji Yoshikawa.

Pyrolysis-gas chromatography/mass spectrometry (py-GC/MS) of water samples

Py-GC/MS was conducted with a CDS Model 2500 pyrolyzer and state of the art autosampler in tandem with a gas chromatograph/mass spectrometer (GC/MS). During pyrolysis the sample was heated from a starting temperature of 25 ^{o}C to 700 ^{o}C in 0.1 seconds and held at a constant 700 ^{o}C for 9.9 seconds. The pyrolysis reactor was mounted on an HP 5890 Series II GC, with a Supelco SPB 35 (35% Ph Me silicon) column, 60 m x 0.25 m x 0.25 µm. The GC interface temperature was set at 235 ^{o}C. The GC temperature program was 45 ^{o}C for 5 minutes, 2 ^{o}C /min to 240 ^{o}C and held for 25 min. The GC was plumbed directly to an HP 5971A Series Mass Selective Detector on electron impact (EI) mode. The MS scanned mass units 45 to 650. All mass spectra were compared to the NBS54K spectral library. Helium served as a carrier gas at a flow rate of 0.5 cm^{3}/minute. Each sample was injected with a split ratio of 1:50.

The fingerprinting technique provided us with generalizations and specifics about the chemical make-up of NOM and how it changed during the course of the year. As in White and Beyer (1999), we expected to correlate the organic matter in various samples with the probable origin.

Principal findings and significance

A detailed analysis of organic matter in 33 spring, stream and groundwater samples was made. Analyses of organic matter in the water samples showed that certain waters had very similar fingerprints, indicating either a similar source, or organic matter that had undergone similar transformation processes (White et al. 2002). Further analysis of seasonal variations, however, suggested that these relationships changed during the course of the year. The results suggested that springs and streams in the watershed were fed from different sources during different seasons. One significant finding was that winter samples from springs and streams were depleted in chemical signatures known to cause adverse health effects when treated for drinking water. These signatures, derived from aromatic molecules, were abundant in the summer, suggesting that their source is soil organic matter that is transported by surface runoff or short residence time interflow. The results suggested that these organic structures are removed from the water by chemical or biological activity when subjected to substantial subsurface residence times.

Basic Information

Title:	Final Report: Mercury Levels in Alaskan Rivers: Relationship between Hg levels and young salmon.
Project Number:	2001AK3481B
Start Date:	3/1/2000
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Toxic Substances, Education
Descriptors:	salmon, methylmercury,mercury exposure
Principal Investigators:	Lawrence Kevin Duffy , Xiaoming Zhang

Publication

1. Jewett, S.C., Zhang, X., Naidu, A.S., Kelley, J.J., Dasher, D., and Duffy, L.K. (2002) Comparison of mercury and methylmercury in Northern Pike and Arctic Grayling from Western Alaska rivers. Chemosphere, in press.
2. Rothschild, R.F.N. and Duffy, L.K. (2002) Methylmercury in the hair of subsistence food users in a rural Alaskan village. Alaska Medicine, 44:2-8.
3. Zhang, Xiaoming. M.S. Thesis, August 2001. Department of Chemistry and Biochemistry, University of Alaska Fairbanks, Fairbanks, AK. 100pp.
4. Duffy, LK., Zhang, X., Naidu, AS., Kelley, JJ., Jewett, SC., and Dasher D. (2001). Assessment of the inhaled and ingested contribution to mercury exposure in Alaskan river otters. Proceedings of the Electric Utilities Environmental Conference: Global Contaminants, Tucson, AZ. (CD-ROM format).
5. Marcy, S., Dasher, D., Deitz, R., Duffy, L., Evans, M., Juntto, S., Lindberg, S., Lockhard, L., Naidu, S., OHaro, T., Pacyna, J., Robertson, A., Ynguadottir, E., and Asmund, G. (2000) Mercury in the Arctic. In AMAP Report on Issues of concern, AMAP Report 2000:4.
6. Naidu, A.S., Kelly, J.J., Zhang, X., Jewett, S.C., Duffy, L.K., Dasher, D., and Kennish, J.M. (2001) Total and methylmercury in adult salmon and selected freshwater fish from rivers opening into the East Bering Sea, Alaska. AMAP Workshop on Heavy Metals, McLean, VA. June 2001.
7. Godduhn, A., and Duffy, L.K. 2002 Health related research in the Yukon River water-shed: a bibliography and overview of research and research needs. AMAP Meeting Tromsoe, Norway, January 2002.
8. Zhang, X., Naidu, A.S., Kelley, J.J., Jewett, S.C., Dasher, D., and Duffy, L.K. (2001) Baseline concentrations of total mercury and methylmercury in salmon returning via the Bering Sea (1999-2000). Marine Pollution Bulletin 42:993-997.

Problem and Research Objectives:

Global atmospheric cycling of mercury (Hg) and exchange at air-water, air-soil, and soil-water interfaces are major processes affecting the mobilization of Hg on earth. Once in a water system, mercury (Hg) bioaccumulation can occur. In Alaska, there is little information on processes and transport pathways related to Hg accumulation in water; however, there is major concern in relation to wildlife and human subsistence. In this project, we are continuing a long-term investigation of Hg in Alaskan rivers, focusing now on biotransport by fish to humans. For this, we measure total mercury (THg) and methylmercury (MeHg). We also provide opportunities of local residents to participate in the evaluation and to disseminate our research results by building a comprehensive education effort to inform the public of the changing levels of the mercury in their local environment. This research follows the priorities and direction set by the Arctic Council and AMAP. This project addresses a data gap in which contaminant inputs from salmon returning with MeHg are insufficiently known, as well as data gaps for freshwater fish and subsistence foods.

Methodology:

Salmon muscle and liver samples were collected from sites on four major rivers throughout western Alaska during the summers of 1999 and 2000. The sites were mainly at Bethel (Kuskokwim R.), Pilot Station (Yukon R.), Levelock (Kvichak R.), and Portage Creek (Nushagak R.). The tissue samples were dissected in the field using surgical sheets, and acid-washed titanium knife and powder free latex gloves; then they were stored frozen until analysis. In the laboratory, the tissue samples were thawed and split before analysis. Total mercury (THg) was analyzed by cold vapor fluorescence spectrophotometry (CVAF) after samples were digested with acid (Bloom, 1992; Bloom and Fitzgerald, 1998). For THg, about 1 gram of tissue was transferred to a 40mL pre-cleaned vial, to which 7mL of 70% HNO_3/30% H_2SO_2 was added. The samples were heated on a hotplate at 90^0 C for 4 hours, until all soft tissue was dissolved. After cooling, the digests were diluted to a final volume of 37mL with 10% 0.2N BrC1. For THg, aliquots of digests were reduced with $SnC1_2$, followed by CVAF detection. For MeHg analysis, 1g of tissue was transferred to a 40mL pre-cleaned vial, to which 10mL of 25% KOH/methanol was added. The sample was then heated on a hotplate at 125^0C for approximately 2 hours. After cooling, the digest was diluted to 40mL with methanol. An aliquot of the digest was analyzed for MeHg using aqueous phase ethylation, purging onto a carbotrap, isothermal GC separation, followed by CVAF detection.

To access the accuracy of THg and MeHg determinations, certified dogfish tissue (DORM-2) from the National Research Council of Canada was used. Our recovery was 100.3% for THg and 93.2% for MeHg for the published values for DORM-2. A check standard and a blank were run after every 10 samples. A duplicate and a spike of samples were performed once for each 20 samples. Additionally, selected tissue samples were sent to Frontier Geosciences (Seattle, WA.) for blind analysis. The mean relative difference between laboratories was 9.5%. Methodology for freshwater fish and subsistence foods were similar.

Principal Findings and Significance:

1. Salmon

Water samples from rivers were analyzed for mercury in order to establish baseline levels for comparison between atmospheric deposition and mineral runoff. We found that the glacial rivers averaged 26.4 ng/L of Hg while the non-glacial fed rivers mean Hg level was 10-fold lower with a Hg mean of 2.0 ng/L. During the early summer with high flow rate and runoff, mercury levels in the Yukon were fourfold higher.

The arithmetic mean concentrations of THg and MeHg in the two tissues of salmon taken at the four sites for 1999 and 2000 are summarized in Table 1. THg in salmon muscle had mean concentrations for the species ranging between 34 and 96 ng/g wet weight (ww). In 1999, THg in individual salmon muscles ranged from 25 to 137 ng/g (ww), while in 2000, THg ranged from 20 to 105 ng/g. THg concentrations in liver tissue tended to be higher than those in muscle tissue ($p < 0.001$), except in chum salmon. Mean THg in the salmon liver ranged from 54 to 112 ng/g (ww). Differences in the THg levels as well as MeHg differences between species were statistically ($p < 0.001$). Differences between species in the river systems were not significant, except for chinook. For example, the mean THg in the Kuskokwim chinook muscle tissue was 96 ng/g in 1999, which is higher than the mean of the Yukon ($p = 0.038$). In contrast, THg in Kuskokwim chinook livers in 2000 (mean 79 ng/g) was lower than the mean of those samples collected from the Yukon (mean 104 ng/g). Similar, but non-significant variations can be seen for chum, coho, and sockeye salmon for mean THg in muscle and liver tissue. Overall, the mean concentration of THg in salmon muscle was 62 ng/g (ww) (range: from 25 to 137 ng/g) while THg in salmon livers was 84.3 ng/g (range: from 32 to 172 ng/g).

In salmon muscle tissue, THg and MeHg concentrations correlated, and the MeHg levels were lower than the THg means ($p = 0.001$). This contrasts with the speciation data for freshwater fish (Duffy et al., 1999) where there was no difference between THg and MeHg. For salmon, the MeHg level was 78% THg in muscle tissue, while salmon liver tissue showed a lower relative abundance of MeHg (63%). Chinook salmon eggs have higher THg levels that those of the other salmon species sampled (Table 2).

As expected, we observed that THg levels in salmon increase with fish lengths. Only our sampling of chinook contained a sufficiently wide range of sizes (fish length ranged between 400 and 950 mm) to show a good correlation. The high mean concentrations of both forms of mercury in chinook salmon muscle are related to 1) their larger size, and thus longer ocean period, and 2) their piscivorous habitat. Both sockeye and coho are considered planktivorous and have lower mean levels of MeHg in their muscles.

Conclusions:

Previous studies have demonstrated the presence of mercury in Alaskan subsistence users (Galster, 1976). As salmon is a common food for subsistence users in western Alaska (Nobmann et al, 1992), we determined the bioconcentration factor for THg and MeHg in these Bering Sea region salmon. Using a value of 1.5 ng/L Hg in seawater (Mason and Figzgerald, 1996; Nelson et al, 1977; Gray et al, 2000), our estimated bioconcentration factors ranged around 2.5×10^4 and varied twofold between species in our data set (Table 3). Despite the bioconcentration of MeHg, the levels in the Alaskan salmon do not exceed critical values (200 ng/g) for human consumption (Yeardly et al, 1998; US EPA, 1997). Therefore, these low levels do not pose a risk for salmon food consumers (Wheatley et al, 1998; Meyer et al, 2000), including wildlife such as river otters.

Lastly, these baseline data suggest that biotransport of MeHg should be incorporated in Hg transport models, since MeHg is usually completely absorbed through the gastrointestinal tract in vertebrates. Spawning salmon, which have accumulated 99% of their biomass and most of their body burden of mercury in the ocean, can return to spawning areas, notable amounts of MeHg as a readily bio-available form. Since this salmon biomass is delivered not as a dispersed source like atmospheric Hg but as a concentrate, salmon spawning areas can be a MeHg source to surface waters within the aquatic ecosystem. For example, a return of 2.25×10^6 sockeye salmon in 1980 (about 50×10^6 kg) to the Kvichak River represented an estimated input of 1kg of MeHg into surface water. This amount of MeHg is about 1/500 of the mercury reported released in the U.S. in 1996 (USEPA, 1997).

Twenty-year sockeye mean escapement data for eight rivers in the Bristol Bay region (ADF&G, 1998) were integrate with our MeHg mean value for sockeye (26 ng/g) to evaluate the magnitude of biotransport over time. Table 4 lists the estimated 20-year total mass loading for MeHg to Bristol Bay river ecosystems, showing about 16 kg MeHg transported form the ocean. Our data support the hypothesis of Ewald et al, (1998), that salmon biomass is an additional transport pathway for MeHg, in addition to atmospheric and local geological sources of Hg, to Alaska's interior fluvial waters. However, until more-detailed research is available, the biogeochemical fate and impact of such transported MeHg remain unknown.

TABLE 1: Arithmetic mean concentrations (ng/g ww) with standard deviations (1) of total mercury (THg) and methylmercury (MeHg) in muscles and livers of salmon from rivers drainage into the Eastern Bering Sea, Alaska.

MUSCLE		**1999**			**2000**		
River	**Species**	**#Fish**	**THg**	**MeHg**	**#Fish**	**THg**	**MeHg**
Yukon	Chum	6	68 (22.9)	56 (23.7)	6	84 (11.3)	64 (6.0)
	Coho	6	44 (15.6)	36 (5.9)	6	58 (11.6)	42 (10.4)
	Chinook	6	50 (35.2)	39 (27.1)	6	70 (27.0)	59 (24.3)
Kuskokwim	Chum	6	58 (14.2)	44 (12.0)	6	74 (14.9)	60 (18.2)
	Coho	6	49 (6.5)	39 (5.9)	6	57 (14.2)	38 (12.7)
	Chinook	6	96 (30.4)	78 (27.6)	6	80 (26.1)	59 (25.0)
	Sockeye	6	34 (5.8)	23 (3.2)	6	51 (5.3)	33 (6.7)
Nushagak	Chum	6	72 (17.7)	58 (18.2)	6	73 (18.3)	54 (17.7)
	Coho				6	59 (11.4)	42 (7.4)
	Chinook	6	92 (28.9)	78 (28.2)	6	60 (20.2)	43 (19.1)
	Sockeye	6	38 (7.1)	27 (12.7)	6	61. (6.0)	44 (6.4)
Kvichak	Coho	5	47 (3.7)	41 (6.2)			
	Sockeye				6	58 (11.2)	46 (12.3)

LIVER							
River	**Species**	**#Fish**	**THg**	**MeHg**	**#Fish**	**THg**	**MeHg**
Yukon	Chum	6	71 (37.1)	41 (17.3)	6	95 (16.7)	58 (10.4)
	Coho	6	87 (15.6)	50 (14.2)	6	54 (13.8)	29 (12.4)
	Chinook	6	60 (45.0)	37 (39.8)	6	103 (34.0)	68 (27.6)
Kuskokwim	Chum	6	66 (10.2)	43 (13.4)	6	72 (9.0)	47 (9.9)
	Coho	6	94 (23.6)	62 (16.9)	6	104 (31.4)	69 (34.2)
	Chinook	6	107 (36.0)	76 (27.1)	6	79 (23.2)	49 (18.7)
	Sockeye	6	58 (15.8)	36 (12.5)	6	100 (27.0)	66 (18.5)
Nushagak	Chum	6	64 (11.6)	42 (11.4)	6	69 (14.1)	46 (13.1)
	Coho				6	112 (40.3)	72 (18.6)
	Chinook	6	99 (35.4)	59 (29.2)	6	77 (24.6)	39 (16.4)
	Sockeye	6	84 (16.8)	49 (16.0)	6	105 (40.3)	69 (25.5)
Kvichak	Coho	5	75 (14.1)	36 (13.4)	6	105 (40.3)	69 (25.5)
	Sockeye	6			6	94 (15.3)	51 (16.5)

TABLE 2: Total mercury for salmon eggs collected in 1999.

Species	**Sample site**	**THg (ng/g)**
Sockeye	Kuskokwim River	4.5
Sockeye	Kuskokwim River	3.4
Sockeye	Kuskokwim River	3.8
Chum	Kuskokwim River	5.0
Chum	Kuskokwim River	5.3
Chum	Kuskokwim River	7.4
Chum	Yukon River	4.3
Chum	Yukon River	7.8
Chum	Nushagak	7.0
Chinook	Kuskokwim River	11.6
Chinook	Kuskokwim River	14.7
Chinook	Kuskokwim River	7.7
Chinook	Kuskokwim River	10.8
Chinook	Yukon River	15.3
Chinook	Nushagak	13.0
Chinook	Nushagak	6.4
Chinook	Nushagak	7.1
Coho	Kuskokwim River	8.5
Coho	Kuskokwim River	6.4
Coho	Kuskokwim River	6.7
Coho	Kuskokwim River	7.2
Coho	Yukon River	8.0
Coho	Kvichak River	5.4
Mean (± SD)		7.7 (3.30)

TABLE 3: Bioconcentration factors for average THg content in organs of salmon[a].

	Muscle	Liver
Sockeye salmon	24,600	24,173
Chinook salmon	52,386	59,006
Chum salmon	43,086	44,633
Coho salmon	31,607	57,033

[a] water level 1.5 ng/L

TABLE 4: Estimated methylmercury biotransport to 8 Bristol Bay, Alaska, rivers over a 20 year period (1979-1998).

Bristol Bay, AK **River Drainage**	Sockeye **Escapement** (1)	20 Year Total Input in grams (2) **MeHg Average**
Kvichak River	6,054,000	7,422
Naknek River	1,521,000	1,863
Egegik River	1,371,000	1,681
Ugashik River	1,303,000	1,597
Wood River	1,326,000	1,626
Igushik River	465,000	570
Nushagak River	626,000	767
Togiak River	192,000	235
Total	**12,858,000**	**15,764**

(1) Alaska Department of Fish & Game, Annual Management Report, Bristol Bay, Area, 1999 Appendix Table 1. Number of fish escaping upriver per year based on mean for 20 years of annual escapement surveys.

(2) MeHg level based on muscle average of 25 ng/g ww and average weight for the sockeye.

TABLE 5: Mercury Level in Alaskan Rivers and Lakes

Location	Hg ng/L
Glacial Rivers	
Yukon (June, High water)	28.7
Yukon (August, Low water)	6.5
Tanana	44.1
Non-Glacial Rivers	
Chena, iceburg site	1.3
Chena, power plant site	2.9
Salcha	1.1
Chatanika	2.8
Lakes	
Fairbanks Area	
Float Pond	0.3
Chena Marina	0.3
Peger Lake	0.3
Lark Lake	0.4
Delta Junction Area	
Birch Lake	4.6
Lost Lake	0.8
Harding Lake	1.9

2. Subsistence Foods:

Mercury was detected in 41 out of 45 food samples measured; their concentrations are presented in Table 6. The critical vale for human consumption established by the USEaPA is .2 μg/g (200 ng/g). The range of mercury in all food samples which mercury was detected was 1.0 – 443.8 ng/g. Concentrations in pike and mallard were higher than the EPA critical value, but lower tahna the FDA action level of 1000 ng/g. Because of the small sample sizes, levels can be strongly influenced by individual samples. The Bearded seal is an example where the mean of 140 ng/g for an *n*=4 had a standard deviation of 151 ng/g.

The salmon foods qaamallug and qiaganuk showed THg concentrations ranging from 10 to 225.8 ng/g. The combined means for both red salmon and king salmon Qaamalluq was 80.6 ng/g for *n*-6. These levels are higher than the boiled red salmon (36.6 ng/g). These levels are also lower that the dried Bearded seal (*Erignathus gaibatus*), whose mean concentration was 140.0 ng/g (*n*=4).

The objective of this study was to obtain preliminary data about THg levels in traditional Yup'ik foods. Because of limited resources, only one or a few samples of each food item were collected and analyzed in this study. Relatively high values of standard deviation (1-105%; Table 6) were observed, which suggests that there is a high level of intra-food type variation in mercury concentrations. Any dietary intake estimates based on low numbers of samples should be interpreted with caution.

Methylmercury (MeHg) concentrations in fish tissues are of special concern because of the potential of MeHg to biomagnify through out the food web in aquatic ecosystems. MeHg is generally accumulated more efficiently from food than Hg in an inorganic form such as Hg^{2+}. The biological half-life of MeHg in fish is longer than that of inorganic Hg and MeHg is the major form of THg in fish muscle. As THg accumulates in the edible portions of fish, primarily as the MeHg, MeHg will be biomagnified up the food chain. Because of the importance of fishing, both commercial and subsistence, to Alaska's Yup'ik economy, the Hg in fish has become a focus of research interest. The concentrations of mercury in salmon derived foods are comparable to those reported in the literature (Table 7). For example, both smoked King Salmon and Red Salmon Qiaganuk have higher levels that the wild fish. Similar results were reported for Arctic char, where food preparation increased the concentration of THg in the fish muscle. There is a general trend that the prepared food items have higher THg concentrations than the raw samples. Red and King salmon feed at different trophic levels and King salmon generally have higher THg levels than Red salmon.

Marine mammals are usually on a higher trophic level than the terrestrial mammals used for subsistence so we expected to see differences between seal meat and caribou or moose meat. As seen in Table 7, we observed no difference in either THg in stews but the dried meat from seal was higher than caribou. These levels are comparable with reported values for THg in the tissue and hair of these species. Lastly, plants and treats showed very low levels and should contribute little THg to a consumer total mercury burden.

The samples in this study were contributed by the Napakiak community and they may better represent the typical levels of mercury in the Yup'ik diet than samples of fish and wildlife collected for environmental studies. The low levels reported here are consistent with the low levels found in Yup'ik hair, however, monitoring programs to assess the changes in body burden with time should be considered. Our results suggest that mercury exposure is low but the small sample size and high variation warrants larger scale studies to increase confidence.

Table 6: Mercury (THg) concentrations in Yup'ik food (ng/g)

Food Source	THg	Mean (S.D.)
Red Salmon (*O. nerka*)		
Qaamalluq		
Half dried, fermented	36.9	
	109.8	
	145.0	
	66.2	
	10.0	73.6 (54.4)
Qiaganuk		
Half dried	97.9	
	95.0	
	64.2	
	225.8	120.7 (71.7)
Red Roe	3.3	
Stinkhead (fermented)	337.7	
Head	40.8	
Boiled	36.3	
King Salmon (*O. tshawytsha*)		
Qaamalluq		
Half dried, fermented	115.6	
Qiaganuk		
Half dried	72.8	
	57.1	64.9 (11.1)
King Roe	6.6	
King Roe	7.7	7.2 (0.8)
Smoked King	113.2	
King Salmon with Seal Oil	117.4	
Pike (*Esox lucius*)		
Dried with Skin	443.8	
Blackfish (*Dallia pectoralis*)		
Dried	155.2	

Whitefish (*Coregonus nelsoni*)		
Dried	55.5	
½ Dried with Potatoes	33.6	
Meat		
Reindeer Stew (*Rangifer tarandus*)	11.5	
Moose Stew (*Alces alces*)	12.3	
Dried Caribou (*Rangifer tarandus*)	55.8	
Marine Mammal		
Dried Seal (*Erignathus gaibatus*)	347.1	
	149.9	
	62.9	
	0	140.0 (151.1)
Seal Stew	6.0	
Birds		
Lesser Canadian Goose	6.2	
Dried Ptarmigan (*Lagopus lagopus*)	11.5	
Mallard Stew	357.2	
Plants		
Buttercup Greens	8.5	
Sourdough, Seal Oil and Sugar	3.9	
Tundra Tea	0	
Greens and Fish Stew	0	
Greens, Raw	3.1	
Wild Celery	0	
Boiled Fiddlehead	4.3	
Treats		
Aqutug	1.0	
	0	
	4.2	1.7 (2.2)

Table 7: Comparison of THg in traditionally prepared foods with raw foods (ng/g).

Qaamalluq		Wild (ref.)
Red Salmon	73.6	51 (15)
King Salmon	115.6	80(15)
Qiaganuk		
Red Salmon	120.7	51(15)
King Salmon	57.1	80(15)
Stews		
Seal	6.0	17,200(18)
Reindeer	11.5	4.1(24)
Moose	12.3	135(25)
Dried Meat		
Seal	140.0	17,200(18) 90-530(26)
Caribou	55.8	47.1(24)
Other Dried Fish		
Pike	443.8	823(11)
Whitefish	55.5	163(1)

3. Freshwater Fish assessment

Northern pike from the Yukon River exceeded the FDA action level of 1.0 mg/kg; mean MeHg in muscle and liver was 1.560 mg/kg and 1.200 mg/kg, respectively. If the EPA guidelines are used, there is little exposure from ingestion of grayling or whitefish. The ingestion level from a 100% pike diet (48 meals per year) would be 18 X 10^4 mg/kg/d MeHg or a hazard index of 18 for an average child, while grayling have a hazard index of 3 for children. Salmon and whitefish have a hazard index around 1 and below for both children and adults. The hazard index for pike and grayling may indicate that pike and grayling consumption should be kept at a minimum for children. Based on the estimated consumption of pike, the EPA guidelines would indicate that children should consume only about 2 meals of pike per year.

Numerous investigations over the past 15 years have demonstrated that mean concentrations of mercury in northern pike from western Alaska freshwater streams are highly variable, fluctuating nearly an order of magnitude. Pike from certain tributaries contain particularly high mercury content. In general, the data available do not support any increase or decrease in mercury in pike over time. When 13 pike-Hg data sets between 1987 and 2000 were compared, excluding the 2000 Andreafsky River pike, there was no significant ($p > 0.01$) correlation ($r = 0.18$) between mean THg concentrations and year of collection, signifying no trend for mercury in pike over time. However, the interpretation changed when the 2000 Andreafsky pike was added to the other data sets; a weak trend ($r = 0.39$; $p < 0.01$) of increasing mercury in pike over time was evident. The high values from Andreafsky River (this study and Duffy et al., 1999), eight had concentrations of THg in muscle tissues that are greater than the FDA action level of

1mg/kg. This high incidence of high muscle mercury in pike should cause heightened concern to those who utilize pike for human consumption from the Andreafsky River, particularly residents of the village of St. Marys at the mouth of the Andreafsky River. However, no fish consumption advisory has been issued for pike on this river or any other river in Alaska.

Little is known about the source of mercury from the Andreafsky River. Possible sources include: 1) runoff from cinnabar (HgS) ore deposits in the vicinity of Wolf Creek Mountain, approximately 40 km west of the east fork of the Andreafsky (Keith and Miller, 1996); and 2) hydrothermal fluids with elevated mercury seeping from the Andreafsky Fault (Szumigala, D., State of Alaska, Division of Geological and Geophysical Surveys, Personal Communication, 2002). No mining activity is known to have occurred within the Andreafsky watershed.

High mercury concentrations in pike were also observed in 1987 upstream on the Yukon River, within the Nowitna National Wildlife Refuge (Snyder-Conn et al., 1992). Pike ($n = 5$) taken form that Refuge at the mouth of the Sulukna River had a mean THg in muscle of 1.515 (0.843)(Snyder-Conn et al., 1992), demonstrating that fish from certain drainages are prone to have higher mercury concentrations than in fish from other nearby drainages.

Mercury content in pike from the Kuskokwim River in 2000 did not differ appreciably from pike previously examined from the Kuskokwim. Gray et al. (2000) examined mercury concentrations in pike, as well as grayling, Dolly Varden (*Salvelinus malma*), and Pacific salmon (*Oncorhynus* spp.) down steam from abandoned mercury mines on a tributary of the Kuskokwim River. A comparable sample of these fishes was also taken nearby but away from the influence of the mines. While mercury concentrations in fishes down stream of the mines were elevated in comparison to the baseline, none, including pike, had mercury concentrations that approached the FDA action level of 1 mg/kg. The THg values in muscle tissues of pike ($n = 8$) and grayling ($n = 47$) downstream of the mines were < 0.310 and < 0.420 mg/kg, respectively (Gray et al., 2000). No sizes of fish were noted.

The examination of grayling for mercury in 2000 revealed values comparatively low to those of pike but similar to values found in grayling from other studies. The database on grayling containing THg from western Alaska spans approximately 15 years (Table 3). When eight data sets were analyzed, there was no significant ($p > 0.01$) correlation ($r = 0.04$) between mean THg in muscle and year sampled, indicating no increasing or decreasing trend.

The bioaccumulation of mercury in fish is generally size dependent (Jackson, 1990). Because of the accumulation of MeHg is related to the time of exposure and accumulation kinetics, Hg concentrations in fish tend to rise with an increase in age, and therefore, with the fish size as well (Johnels et al., 1967; Scott and Armstrong 1972). The age is the more preferred parameter (Derkson and Green 1987), but since in our study the age was not available, the fish length or body weight can be used for an approximation of age. Norstrom et al., (1976) showed that the body weight was a suitable parameter because MeHg concentrations and accumulation kinetics varied as a function of weight. In a study of several species from lakes in Manitoba and northwestern Ontario, Scott and Armstrong (1972) considered length more reliable because it is less prone to major short-term fluctuations (weight being strongly affected by feeding). In a study of fish in northern Manitoba, Derksen and Green (1987) showed that the Hg concentrations in walleye (*Stizostedion vitreum*) and pike correlated with length more significantly than with the body weight. The Product-Moment correlation (r) values from this study (pike: 0.66; grayling 0.93; whitefish: 0.64) show that length is sufficiently reliable to predict size-related bioaccumulation. Comparatively, the correlation between pike size and muscle THg from the Innoko National Wildlife Refuge in western Alaska was 0.82 (n = 48; Headlee, 1996).

Our data revealed no difference in mercury concentration between sexes of similar sized pike; however, female grayling had higher mercury content than male grayling. Presumably, the higher mercury value in females was because females were larger than males. Data from another study showed significantly more mercury in female pike, however, the females (n = 25) were significantly larger than the males (n = 23)(Headlee, 1996).

Ratios of mean concentrations of MeHg to THg in fish muscles and livers can be calculated. The proportion of MeHg to THg in pike muscle had a mean value of 0.94 (1.04 for Yukon; 0.92 for Kuskokwim), which was similar to 0.86 reported by Jackson (1990), 1.03 reported by Bloom (1992), and 1.02 reported by Duffy et al., (1999). For whitefish, MeHg in muscle comprised 81% of THg, similar to 84% reported by Jackson (1990), but lower than 100% reported by Duffy et al. (1999). These MeHg to THg ratios were higher in muscle than in liver, possibly indicating demethylation in the latter tissue. This ratio difference was most dramatic in pike and supports Jackson's (1990) observations for both whitefish and pike. Perhaps the greatest reason why pike have grater concentrations of mercury than grayling or most other fishes from the same watershed is because MeHg bioaccumulates in fish tissue and is biomagnified throughout the food chain, with piscivorous fish like pike having higher MeHg concentrations than non-piscivorous fish like grayling. The predominance of mercury in pike muscle versus liver tissue from the Yukon and Kuskokwim rivers suggests steady-state conditions in pike in these drainages, whereas much lower liver to muscle ratios would probably indicate ongoing depuration (Jernelöv and Lann, 1971).

Consuming 100% grayling is only hazardous for children while it is hazardous for all groups to consume large amounts of northern pike. Because of children's size, it is more hazardous for them to consume pike and grayling than for the adults. Consumption limits for adults show that 16 chinook salmon (*Oncorhynchus tshawytscha*) meals or 31 sockeye salmon (*Oncorhynchus nerka*) meals bay be eaten per month, while 1 pike or 6 grayling meals may be eater per month. Children have a consumption limit of 3 chinook salmon or 6 sockeye salmon meals per month; 0.2 pike meals per month (2 meals per year) or 1 grayling meal per month. Subsistence harvests of resident freshwater fishes, like pike and grayling, may increase if Pacific salmon catches continue to decline in the Yukon and Kuskokwim rivers (e.g. McNair and Geiger, 2001).

The EPA current RfD or reference dose is an estimate (with a large uncertainty) of the daily exposure to the human population that will likely not cause appreciable risk of deleterious effects during a lifetime. With an RfD of 1.1 μg/kg of body weight per day, a 70kg person could ingest 0.07 mg a day without risk. There are different risk indicators used by other government agencies. ATSDR uses a minimum risk level (MRL) of 0.3 μg/kg/d, but ATSDR has stated that MRL's are not intended to be used in developing fish advisories. The FDA level of 1mg/kg (1 ppm) is an action level calculated from an RfD of 0.5 μg/kg/d. The National Academy of Science has found the EPA levels to be justifiable based on the latest evidence, but also notes the need for further research to understand potential risk to a fetus.

The uncertainties in the EPA equations become apparent when applying this methodology to Alaska, especially to subsistence food users. While certain areas of the U.S. show high levels of mercury in the human hair (Fleming et al., 1995; Harnly et al., 1997), Alaska natives on the Kuskokwim do not (Rothschild and Duffy, 2002). Further, the actual amount of each species consumed is needed to develop a more complete exposure assessment. At this time, such data are not available in Alaska.

Literature Cited:

Alaska Department of Fish and Game. 2001. Alaska subsistence fisheries—1999 annual report. Division of Subsistence. Alaska Department of Fish and Game, Juneau, AK. 154pp.

Bilby, R.E., Fransen, B.R., Bisson, P.A. 1996. Incorporation of nitrogen and carbon from spawning Coho salmon into the trophic system of small streams: evidence from stalbe isotopes. Can. J. Fish. Aquat. Sci. 53:164-173.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 49:1010-1017.

Bloom N.S., and Fitzgerald W.F. 1998. Determination of volatile mercury species at the picogram level by low temperative gas chromatorgrphy with cold vapor atomic fluorescence detection. Anal. Chem. Acta. 208:151-159.

Boening, D.W. 2000. Ecological effects, transport, and fate of mercury; a general review. Chemosphere. 40:1335-1351.

Braune, B., Muir, D., Demarch, B., Gamberg, M., Poole, K., Currie, R., Dodd, M., Duschenko, W., Eamer, J., Elkin, B., Evans, M., Grundy, S., Hewbert, C., Johnstone, R., Kidd, K., Koeneg, B., Lochhart, Marshall, H., Shutt, L. 1999. Spatial and temporal trends of contaminants in Canadian Arctic freshwater and terrestrial ecosystems: a review. Sci. Total Environ. 230:145-208.

Derksen, A.J., and Green, D.J. 1987. Total mercury concentrations in large fishes from lakes on the Churchill River Diversion and Nelson River. In: Technical Appendices to the Summary Report. Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion. Vol. 4. Chap. 17. Published by the Governments of Canada and Manitoba.

Duffy, LK., Rodgers, T., Patton, M., Scofield, E., and Bowyer, RT. (1999) Baseline levels of mercury, Hsp 70 and Hsp 60 in subsistence fish from the Yukon-Kuskokwim Delta Region of Alaska. Comp. Biochem. Physiol. 124C:181-186.

Ewald, G., Larsson, P., Linge, H., Okla, L., Szarzi, N. 1998. Biotransport of organic pollutants to an inland Alaska lake by migrating sockeye salmon (*O. nerka*). Arctic 51:40-47.

Egland, G.M., Feyk, L.A., and Middaugh, J.P. 1998. Use of Traditional Foods in a healthy diet in Alaska: risks in perspective. State of Alaska Epidemiology Bulletin—Recommendations and Reports 2(1), 140 pp.

Egland, G.M., and Middaugh, J.P. 1997. Balancing fish consumption benefits with mercury exposure. Science 278:1904-1905.

Fitzgerald, W.F., Engstrom, D.R., Mason, R.P., Nater, E.A. 1998. The case of atmospheric mercury contamination in remote areas. Envionr. Sci. Technol. 32:1-10.
Fleming, L.E., Watkins, S., Kaderman, R., Levin, B., Ayyar, D.R., Bizzio, M., Stephens, D., Bean, J.A. 1995. Mercury exposure in humans though food consumption form the Everglades of Florida. Water, Air, and Soil Pollution 80:41-48.
Frery N, Maury-Brachet R, Maillot E, Dehaeger M, deMerone B, Boudou A. 2001. Gold-mining activities and mercury contamination of native American communities in French Guiana: Key of fish in dietary uptake. Environ. Health Perspect. 109:449-456.
Galster, W.A. 1976. Mercury in Alaskan Eskimo mothers and infants. Environ. Health Perspect. 15:135-140.
Gray, J.E., Theoorados, P.M., Bailey, E.A. and Turner, R.R. 2000. Distribution, speciation and transport of mercury in steam-sediment, stream-water and fish collected near abandoned mercury mines in South Western Alaska. Sci. Total Envion. 260:21-34.
Hanisch C. 1998. Where is mercury deposition coming from? Environ. Sci. Technol. 32,176A-179A.
Harnly, M., Seidel, S., Rojas, P., Fornes, R., Flessel, P., Smith, D., Kreutzer, R., Goldman, L. 1997. Biological monitoring for mercury within a community with soil and fish contamination. Environmental Health Perspectives 105:424-429.
Headlee, P.G. 1996. Mercury and selenium concentrations in fish tissue and surface waters of the Northern Unit of the Innoko National Wildlife Refuge (Kaiyuh Flats), west central Alaska. 1993 Tanana Chiefs Conference, Inc. Fairbanks, AK. Water Resources Report 96-3. 24pp.
Huggett, D.B., Steevens, J.A., Allgood, J.C., Lutken, C.B., Brance, C.A., Benson, W.H. 2001. Mercury in sediment and fish from North Mississippi Lakes. Chemosphere. 42:923-929.
Jackson, T.A. 1990. Biological and environmental control of mercury accumulation by fish in lakes and reservoirs of Northern Manitoba, Canada. Canadian Journal of Fisheries and Aquatic Sciences 48:2449-2470.
Jernelöv, A., Lann, H. 1971. Mercury accumulation in food chains. Oikos. 22:403-406.
Johnels, A.G., Westermark, T., Berg, W., Persson, P.I., Sjostrand, B. 1967. Pike (*Esox lucius L.*) and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment. Oikos 18:323-333.
Keith, W.J., Miller, M.L. 1996. Holy Cross Quadrangle. U.S. Geological Survey Open-File Report 96-685, 4pp.
Kline, T.C., Goering, J.J., Mathisen, O.A., Poe, P.H., Parker, P.L., Scalan, R.S. 1993. Recycling of elements transported upstream by runs of Pacific salmon: δ15 N and δ13 C evidence in the Kvichak river watershed, Bristol Bay, southwestern Alaska. Can. J. Fish. Aquat. Sci. 50:2350-2365.
Laskowski, R. 1991. Are the top carnivores endangered by heavy metal biomagnification? Oikos 70:387-390.
Mason, R.P., Fitzgerald, W.F., Moral, M.M. 1994. The biogeochemical cycling of elemental mercury: anthropogenic influences. Geochem. Cosmochem Acta. 58: 3191-3198.

Mason, R.P., Fitzgerald, W.F. 1996. Sources, sinks and biogeochemical cycling of mercury in the ocean. In Bayens W. (ed), Global and Regional Mercury Cycles: Sources, Fluxes and Mass Balances, Kluwer Academic Publishers. Netherlands. pp 249-285.

McNair, M., Geiger, H.J. 2001. Run forecasts and harvest projections for 2001 Alaska salmon fisheries and review of the 2000 season: the short version. Alaska Department of Fish and Game. Division of Commercial Fisheries. Juneau, AK. Regional Information Report No. 5J01-02, 12 pp.

Meyer, G.J., Davidson, P.W., Cox, C., Shamlaye, C., Cernichiari, E., and Clarkson, T.W. 2000. Twenty-seven years studying the human neurotoxicity of methylmercury exposure. Eviron. Res. 83:275-285.

Mueller, K.A., Snyder-Conn, E., Bertram, M. 1996. Water quality, and metal and metalloid contaminants in sediments and fish of Koyukuk, Nowitna, and the northern unit of Innoko National Wildlife Refuges, Alaska 1991. U.S. Fish and Wildlife Service, Northern Alaska Ecological Services. Technical Report NAES-TR-96-01. 79pp.

Mueller, K.A., Snyder-Conn, E., Doyle T. 1993. Contaminant baseline data for water, sediments, and fish of Selawik National Wildlife Refuge, Alaska 1987-1988. U.S. Fish and Wildlife Service, Northern Alaska Ecological Services, Technical Report NAES-TR-93-02. 84pp.

Nelson, H., Larsen, B.R., Jenne, E.A., Sorg, D.H. 1998. Mercury dispersal from lode sources in the Kuskokwim River drainage, Alaska. Science. 820-824.

Newman, M.C. 1998. Fundamentals of Ecotoxicology. Ann Arbor Press, Chelsa, MI. 402pp.

Nobmann, E.D., Boyers, T., Lanier, A.P., et al. 1992. The diet of Alaskan native adults: 1987-1988. Am. J. Clin. Nutr. 55:1024-1032.

Norstrom, R.J., Mckinnon, A.E., De freitas, A.S.W. 1976. A bioenergetics-based model for pollutant accumulation by fish; simulation of PCB and Methylmercury residue levels in Ottawa River yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 33:248-276.

Pentreath, R.J. 1976. The accumulation of mercury from food by the plaice. *Pleuronectes platessa.* L. Journal of Experimental Marine Biology and Ecology 25:51-65.

Ribeiro, C.A.O., Rouleau, C., Pelletier, E., Audet, C., Tjalve. 1999. Distribution kinetics of dietary Methylmercury in the Arctic charr (*Salvelinus alpinus*). Environmental Science and Technology 33:902-907.

Rothschild, R.F.N. and Duffy, L.K. 2002. Methylmercury in the hair of subsistence food users in a rural Alaskan village. Alaskan Medicine 44:2-7.

Scott, D.P., Armstrong, F.A. 1972. Mercury concentration in relation to size in several species of freshwater fishes form Manitoba and north-western Ontario. Journal of Fisheries Research Board of Canada. 39:1685-1690.

Snyder-Conn, E., Patton, T., Bertram, M., Scannell, P., Anthony, C. 1992. Contaminant baseline data for water, sediments, and fish of the Nowitna National Wildlife Refuge, 1985-1988. U.S. Fish and Wildlife Service, Northern Alaska Ecological Services, Technical Report NAES-TR-92-02, 69pp +appendices.

StatSoft, Inc. 1999 STATISTICA for Windows, Tulsa, OK. StatSoft, Inc.

Stopford, W., Goldwater, L.J. 1975. Methylmercury in the environment: a review of current understanding. Environmental Health Perspectives. 12:115-118.

USEPA 1989. Risk assessment guidance for superfund: Volume I, human health evaluation manual. EPA/540/1-89/002. Washington D.C.

USEPA 1997. Guidance for assessing chemical contaminant data for use in fish advisories. Vol II—Risk assessment and fish and fish consumption limits. EPA/823/b-97/009. Washington D.C.

USEPA 1998. Guidelines for ecological risk assessment. EPA/630/R-95/002F. Washington D.C.

Watkinson, S. 2000. Life after death: the importance of salmon carcasses to British Columbia's watersheds. Arctic 53:92-99.

Wheatley, B, and Paradis, S. 1996. Balancing human exposure. risk and reality: questions raised by the Canadian Aboriginal methylmercury program. Neurotoxicology 17:251-256.

Wolfe, M.F., Schwarzbach, S., and Sulaiman, R.A. 1998. Effects of mercury on wildlife: A comprehensive review. Environmental Toxicology and Chemistry 17:146-160.

Yardley, R.B., Lazorchak, J.M. and Paulsen, S.O. 1998. Elemental fish tissue contamination in northeastern U.S. lakes: evaluation of an approach to regional assessment. Environ. Toxicol. Chem. 17:1874-1884.

Zhang, X., Naidu, A.S., Kelley, J.J., Jewett, S.C., Dasher, D., and Duffy, L.K. 2001. Baseline concentrations of total mercury and methylmercury in salmon returning via the Bering Sea (1999-2000). Marine Pollution Bulletin 42:993-997.

Basic Information

Title:	Compatibility analyses of various snow measurements/data in Alaska
Project Number:	2001AK3501B
Start Date:	3/1/2000
End Date:	5/30/2002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Surface Water
Descriptors:	Alaska, snowcover,snowfall, compatibility, accuracy, observation
Principal Investigators:	Daqing Yang

Publication

1. Yang, D., D.L. Kane, L.D. Hinzman, B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, G.H. Leavesley, D.G. Emerson, C.L. Hanson, 2000: An evaluation of the Wyoming gauge system for snowfall measurement. Water Resources Research, 36(9), 2665-2678.
2. Yang, D., B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, E. Elomaa, C.L. Hanson, V.S. Golubev, Th. Gunther, J. Fullwood, R. Johnson, J. Milkovic, M. Lapin, 2001: Compatibility evaluation of national precipitation gauge measurements. Journal of Geophysical Research-Atmospheres, Vol 106, No. D2, 1481-1491.
3. Yang, D., B. E. Goodison, P. Y.T. Louie, and T. Ohata, Bias correction of gauge-measured precipitation data in the northern regions: applications of WMO methods, (Abstract) Proceedings of WCRP Workshop on Determination of Solid Precipitation in Cold Climate Regions, Fairbanks, Ak, June 9-14, 2002.
4. Benning, J.L., D. Yang, and D. L. Kane, Adjustment of daily precipitation data at Barrow Alaska for 1995-2000. (Abstract) Proceedings of WCRP Workshop on Determination of Solid Precipitation in Cold Climate Regions, Fairbanks, Ak, June 9-14, 2002.

Problem and Research Objectives

Snow is one of the key components in cold region hydrology and climate systems. It is also the most important variable in global change analyses, as changes of snowfall amount, snowcover extent and mass will have a major impact on hydrology, climate and ecosystems of the Earth. Long-term snow (i.e. snowfall and snowcover) data have been collected at observational networks and in some research watersheds in Alaska. These data, quality-controlled and archived by various organizations, have been widely used in climatic and hydrologic applications. Proper utilization and interpretation of these data in Alaska is extremely important and largely depends on the user's knowledge of the observational methods and data processing and archiving procedures.

Studies have shown that the accuracy and compatibility of snow measurements in cold regions including Alaska are generally very poor mainly due to the following factors: 1) precipitation gauge undercatch of snowfall by up to 50-70% at high wind conditions (Black 1954; Benson, 1983; Goodison et al., 1998; Yang et al., 1998a,b, 1999; Yang 1999); 2) poor spatial representativeness of point snow data (Benson, 1983; Woo et al., 1983; Yang and Woo, 1999); 3) incompatibility of various snowfall and snowcover observation methods and instruments (Woo et al., 1983; Yang et al., 2001). In order to better understand the limitation of various types of snow data and make a better use of them for climate, water resources and hydrology applications, this project compiled and analyzed all available snow data collected in Alaska to focus our research on the following key aspects:

- Quantify the accuracy of the National Weather Service (NWS) gauge measured precipitation data.
- Evaluate the performance of the Wyoming gauge system in Alaska.
- Define the compatibility of various snow measuremnts/data.

Methodology

The following methods have been used in data analyses for this research project:

a) Bias correction of the NWS gauge snowfall measurements: Bias correction of the NWS gauge snowfall data was based on the methodology derived from the World Meteorological Organization (WMO) gauge intercomparison project (Goodison et al., 1998). A correction procedure, developed by Yang et al. (1998b), has been applied on a daily basis to selected NWS climate stations. Daily records of air temperature, wind speed, gauge measured precipitation were needed for this analysis. Long-term data in difference climate regimes in Alaska were used for this study and reliable daily snowfall data were generated. A comparison between the measured and bias-corrected daily snowfall data was also conducted in order to assess the impact of bias-correction on climate change/variation analysis.

b) Compatibility analysis of bias-corrected gauge data vs. Wyoming gauge observations: Recently Yang et al (2000), using the WMO gauge intercomparison data, has reported that the Wyoming gauge system performed as well as the WMO reference (a Russian double fence system) and it can measure snowfall accurately in windy and cold conditions. To evaluate the bias-correction procedures and results, a comparison of bias-corrected snowfall data (daily and seasonal totals) with the Wyoming gauge measurements has been carried out at selected locations in Alaska.

c) Compatibility of the NWS snow depth observation with Natural Resources Conservation Service (NRCS) snow survey and SnowTel data: Snow depth data can be used to estimate the SWE by assigning a snow density to the measured snowpack or new snowfall. Snow density exhibits wide temporal and spatial variations, mainly due to variations of upper air temperature, wind speed and direction near the surface, the elapsed time of measurement of snowfall after the beginning or end of the storm, the siting of the measurement station and the observer bias. It is difficult to apply universal corrections to daily snow depth data. However, intercomparisons of these measurements will crosscheck the data quality, quantify the systematic differences (if they exist), and lead to an establishment of transfer functions between these data/measurements.

Principal Findings and Significance

We have focused our effort on assessment of Wyoming gauge performance for snowfall observations and bias-correction of gauge measured data at selected climate stations in Alaska.

Analysis of Wyoming gauge data show that, in comparison with the DFIR (a Russian snow fence system), the mean snow catch efficiency of the Wyoming gauge was about 80– 90%. We found a close linear relation between the measurements of the two gauge systems and this relation may serve as a transfer function to adjust the Wyoming gauge records to obtain an estimate of the true snowfall amount. We also found that catch efficiency of the Wyoming gauge did not change with wind speed and temperature, and that Wyoming gauge measurements were generally compatible to the snowpack water equivalent measured at selected locations in northern Alaska. These results are important to our ongoing efforts to better quantify the water and energy balances in the research basins located on the North Slope of Alaska (Kane et al., 1999; Hinzman et al., 1998; Zhang et al., 2000). They are also useful for regional hydrologic and climatic analyses.

We found that daily adjustment for observational biases increased the gauge-measured annual precipitation by 65–800 mm (about 10–140% of the gauge-measured yearly total) at selected climate stations in Alaska (Yang et al., 2002; Benning et al., 2002). The NWS 8-inch standard gauges with an Alter wind shield have a much lower adjustment for wind-induced undercatch than the unshielded gauges. Monthly adjustment factors (adjusted/measured precipitation) differ by station, and at an individual station by type of precipitation. We identified considerable intra-annual variation of the magnitude of the adjustments in Alaska owing to the fluctuation of wind speed, air temperature, and frequency of snowfall (Benning et al., 2002). We confirmed that the adjustments of gauge observational errors significantly impact climate monitoring and change analysis.

References Cited

Benson, C.S., Reassessment of winter precipitation on Alaska's Arctic slope and measurement on the flux of wind blown snow, Geophysical Institute, University of Alaska, Fairbanks, Alaska, 26pp, 1982.

Black, R.F., Precipitation at Barrow, Alaska, greater than recorded, *American Geophysical Union Transactions*, 35(2), 203-206, 1954

Goodison, B.E., P.Y.T. Louie, and D. Yang, WMO solid precipitation measurement intercomparison, final report, WMO/TD-No. 872, WMO, Geneva, 212pp, 1998.

Hinzman, L.D., D.J. Goering and D.L. Kane, A distributed thermal model for calculating temperature profiles and depth of thaw in permafrost regions, *J. Geophys. Res.,* Vol. 103, D22, 28975-28991, 1998.

Kane D.L., L.D. Hinzman, J.P. McNamara, Z. Zhang and C.S. Benson, Nested watershed study in the Kuparuk river basin, arctic Alaska. Proc. of 12th Northern Research Basin Symposium and Workshop, 181-196, 1999.

Woo, M., R. Heron, P. Marsh and P. Steer, Comparison of weather station snowfall with winter snow accumulation in high Arctic basins. *Atmosphere-Ocean*, 21, 312-322, 1983.

Yang, D., B.E. Goodison, J.R. Metcalfe, V.S. Golubev, R. Bates, T. Pangburn, and C.L. Hanson, Accuracy of NWS 8-inch standard non-recording precipitation gauge: result and application of WMO Intercomparison, *Journal of Atmospheric and Oceanic Technology,* 15(2), 54-68, 1998a.

Yang, D., Goodison, B.E., Benson, C.B. and Ishida, S., Adjustment of daily precipitation at 10 climate stations in Alaska: application of WMO Intercomparison results. *Water Resources Research*, 34(2), 241-256, 1998b.

Yang, D., An improved precipitation climatology for the Arctic Ocean. *Geophysical Research Letters*, 26(11), 1625-1628, 1999.

Yang, D., S. Ishida, B.E. Goodison, T. Gunther, Bias correction of daily precipitation measurements for Greenland. *J. Geophys. Res.,* 105(D6), 6171-6182, 1999.

Yang, D., M.K. Woo, Representativeness of local snow data for large-scale hydrological investigations. *Hydrological Processes*, Vol.13, 12-13, 1977-1988, 1999.

Yang, D., D. L. Kane, L. D. Hinzman, B. E. Goodison, J. R. Metcalfe, P. Y. T. Louie, G. H. Leavesley, C. S. Benson, D. G. Emerson, C. L. Hanson, An evaluation of Wyoming gauge system for snowfall measurement, *Water Resources Research,* 36 (9), 2665-2678, 2000.

Yang, D., B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, E. Elomaa, C.L. Hanson, V.S. Golubev, Th. Gunther, J. Fullwood, R. Johnson, J. Milkovic, M. Lapin, Compatibility evaluation of national precipitation gauge measurements. *J. Geophys. Res.,* 106 (D2), 1481-1492, 2001.

Zhang,Z, D.L. Kane and L.D. Hinzman, Spatially distributed arctic thermal and hydrologic model, *Hydrological Processes , 14(6), 1017-1044, 2000*.

Basic Information

Title:	Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic
Project Number:	2001AK3521B
Start Date:	3/1/2002
End Date:	2/28/2003
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Geomorphological Processes
Descriptors:	channel networks, Arctic, permafrost, erosion, sedimentation
Principal Investigators:	Larry D. Hinzman

Publication

1. Oatley, Jeffrey (2002), Ice, Bedload Transport, and Channel Morphology on the Upper Kuparuk River. MS Water Resources Engineering, Thesis, University of Alaska Fairbanks.

Problem and Research Objectives

The objective of this research is to develop a better understanding of watershed morphology and to elucidate how a basin structure may evolve with the onset of climatic warming. Over the past several years, river morphology studies performed in the Kuparuk River have documented some of the changes that have occurred as a result of bedload transport. This study will provide insight into the nature of the bedload transport process. The study is being conducted in the upper Kuparuk River, near the intersection of the river and the Dalton Highway.

Objective

There are three primary goals for this study:

1) Use predictive methods to determine the total sediment load in the river for a given flow rate.
2) Compare the bedload material movement that occurs during the spring snowmelt to that which occurs in response to significant rainfall events during the summer.
3) Compare features of three arctic rivers to identify characteristics that may be symptomatic of the role of ice in arctic river morphology.

Methodology

Several field measurement methods have been, and will continue to be, used to quantify the total amount of sediment transport.

Suspended sediment is being measured directly by using an auto-sampler to collect one-liter samples at regular time intervals during the summer months. These samples will be filtered and weighed to determine the mass of solid material in each sample.

Bedload material movement is being monitored by two different methods. One method is tracer rocks; the other method is sediment traps. Scour chains, located throughout the study reach are also being used.

A total of 400 Tracer rocks are being used to study the movement of specific pieces of cobble. Both active and passive tracer rocks have been placed in the channel. The passive tracers are painted rocks. The active tracers are rocks that have a small radio transmitter implanted in them. These transmitters emit a different pulse rate at rest than during movement. This feature allows knowledge of incipient motion.

Sediment traps are being used to capture particles (greater than 3mm diameter) during motion. These traps will be fixed to the riverbed and the current will carry particles into the traps.

Extensive survey data has been gathered for the Kuparuk River, the Toolik Lake inlet stream, and Oksrukuyik Creek and these data will be used to define and compare the three stream characteristics.

Principal Findings and Significance

During the summer of 2001 the study reach was fully surveyed and field measurements of the channel material grain size distribution were made in the form of Wohlman pebble counts. This information has been used to perform the modeling task of predicting the bedload rating curve for the study reach. This prediction is shown in Figure 1 below.

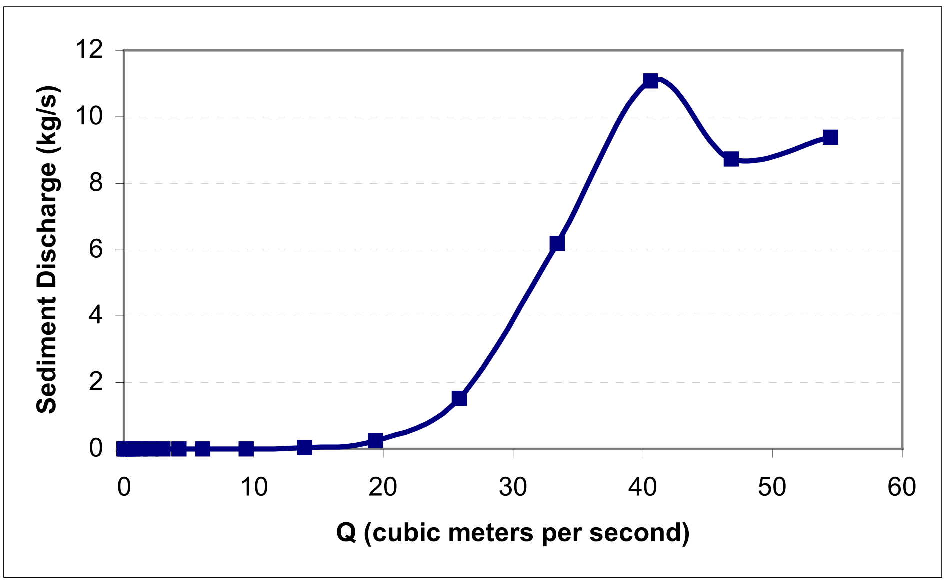

Figure 1. Bedload rating curve.

The bedload rating curve shows that the competent flow threshold for this channel is approximately 20 m^3/s. Since this study began the peak flow volume has been 16.4 m^3/s, so there has not been a significant amount of bedload movement to this point. Of the 201 tracers that were in place during the snowmelt period of 2001, 14 tracers moved a measurable distance and another 12 tracers were not recovered. The measured tracer movement is summarized in Figure 2.

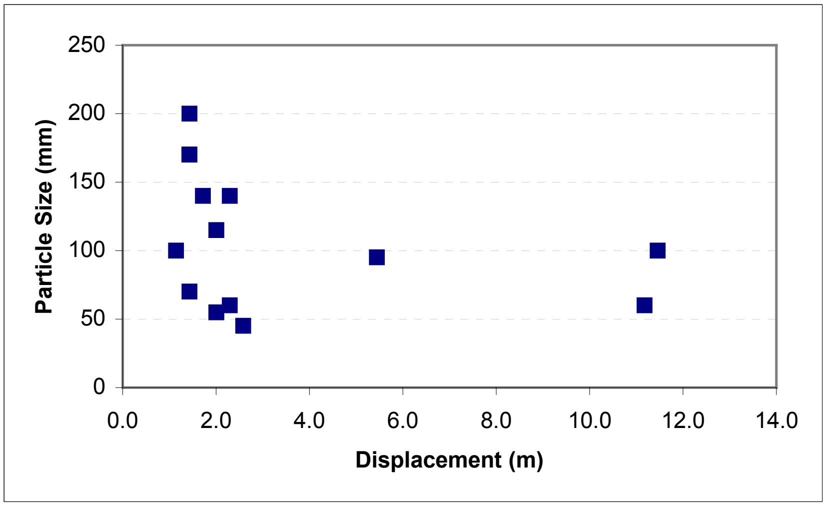

Figure 2. Particle size versus distance traveled.

Eleven of the twenty radio transmitter tracers are still functional and may provide incipient motion data in the event of a major rainfall event during the summer of 2002.

During the snowmelt period of 2002 there was an excessive amount of ice in the channel of the Kuparuk River, forcing much of the snowmelt runoff onto the floodplain. This resulted in ice remaining in the channel until well after the snowmelt peak, which prevented any movement of the tracer rocks.

In June of 2002 the Kuparuk River and the Toolik Lake inlet stream were surveyed. This data will be used to compare the morphologies of these rivers. In July of 2002 Oksrukuyik Creek will also be surveyed.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	4	0	0	0	0

Notable Awards and Achievements

Publications from Prior Projects