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Alaska State Office
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Final Operations Plan - 2011

Quantification of fish and aquatic insect tissue contaminants in the middle Kuskokwim River, Alaska

BLM

Alaska

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1.0 Introduction

The Kuskokwim River drains into a significant area of southwestern Alaska and supports a variety of resident and anadromous fish species. Subsistence uses of the land and wildlife have long sustained the peoples of the central Kuskokwim River basin in western Alaska (Brelsford et al. 1987). Within the last decade, increasing concerns associated with environmental contaminants and Alaska's fish have prompted the State of Alaska and various federal agencies to initiate monitoring programs. As a result of these efforts, an improved understanding of contaminants, such as methylmercury, within freshwater and anadromous fish species and the potential causal factors have been realized. Specifically in the Kuskokwim River basin, which is within what is often referred to as "the mercury belt" in Alaska, a number of mineral deposits have been mapped, that contain mercury (Hg), arsenic, antimony and other metals (Sainsbury and MacKevett, 1965). Some of these deposits were mined during the early and mid-20th century and remnant waste rock and processed ore from these operations are still present at some locations.

Resident fish species in the Kuskokwim and at least one tributary have been shown to contain elevated levels of mercury (Gray et. al, 2000). The relative contributions of mercury to the Kuskokwim ecosystem by abandoned mines is not well understood. The middle Kuskokwim River watershed, between Crooked Creek and Stony River runs through an area containing a number of known mercury deposits. The potential impacts of the mercury deposits on the aquatic food web, including species targeted for subsistence harvest, have not been thoroughly explored. Metals data collected from representative species at several trophic levels are needed to estimate the natural bioaccumulation metals in the aquatic ecosystem. This project seeks to collect the data needed to estimate natural levels of metals in sediments, water and levels of bioaccumulation across aquatic trophic levels. Study results will provide a more complete understanding of metals bioaccumulation in the aquatic foodweb in the middle Kuskokwim River and associated tributaries.

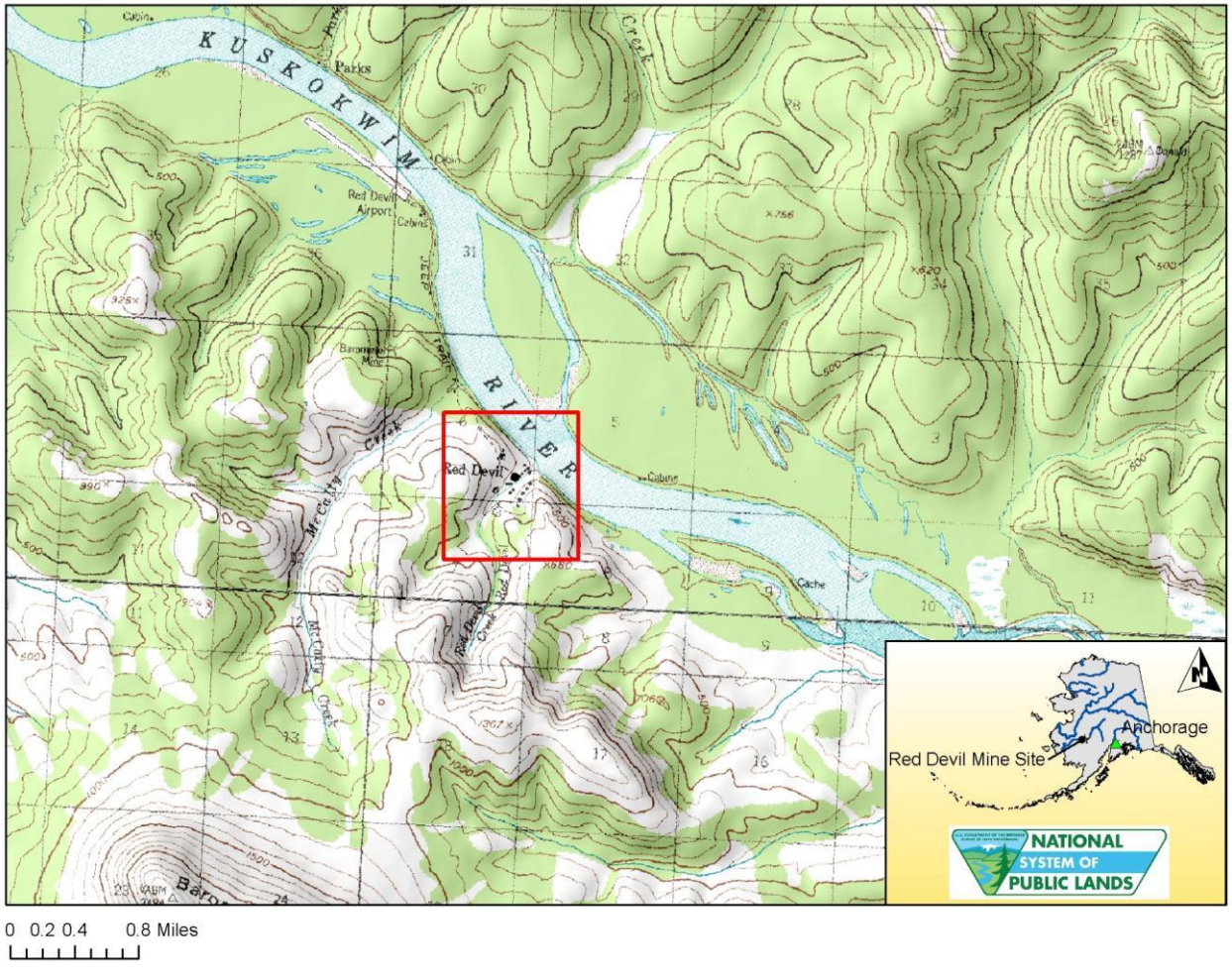
One of the largest abandoned mines in this section of the Kuskokwim River, the Red Devil Mine (RDM), is the site of an environmental investigation being conducted by the Bureau of Land Management (BLM). The data collected for this study will provide a regional context for site specific RDM data. Establishing natural background conditions is critical to assessing the RDM's relative contribution to mercury and other metals concentrations in the aquatic ecosystem of the middle Kuskokwim River. Aquatic macroinvertrebrate and fish tissue methyl-mercury and total mercury concentrations will be incorporated into the human health and ecological risk assessments to be conducted as part of the environmental investigation.

1.1 Background

The presence of mercury deposits in the Kuskokwim River water is well documented and several of the larger deposits, including Red Devil (see Figure 1), have been extensively mined. The presence of methylmercury (MeHg) in resident fish in the lower and middle Kuskokwim has been the subject of study over the last 15 years.

The Alaska Department of Fish and Game (ADF&G) (2007) reported from a 2001-2003 survey of two villages on the middle Kuskokwim River within the area near Red Devil Mine, that households consumed 101-425 lbs of non-salmon fish on average annually. Non-salmon species typically are more susceptible to methylmercury bioaccumulation because they reside entirely within the freshwater system, as such these species have a higher risk of bioaccumulation through the aquatic food web (Hanisch 1998, Wolfe et al. 1998). This MeHg accumulation is especially evident in predatory, piscivorous (fish-eating) fishes (Lepak et al. 2009a), since bioaccumulation in fish tends to rise with an increase in age and fish sizes (Johnels et al. 1967; Jewett et al. 2003).

Figure 1. Map of the Red Devil Mine Area



Large, long-lived, resident species, such as burbot (*Lota lota*) and northern pike (*Esox lucius*) will be used to determine methylmercury bioaccumulation. Burbot and northern pikecomprised 30-51% of the household fish consumption in villages near the Red Devil Mine site from 2001-2003 (ADF&G 2007). Additional sampling of lower trophic levels targeted at forage (prey) fish species and benthic aquatic macroinvertebrates will provide information methylmercury bioaccumulation in the aquatic foodweb. Wiener et al (2007) noted that top predators and 1-year old forage fish are the preferred indicators for monitoring trends in methylmercury

bioaccumulation in freshwater ecosystems. Several studies in western Alaska have examined contaminants in fish species within the last 20 years. Within the last decade, the USFWS completed extensive sampling of the lowermost segment of the Kuskokwim and Yukon Rivers to determine methylmercury levels in northern pike (personal comm. A. Matz, USFWS 2010). Additionally, limited contaminant sampling of slimy sculpin in the Crooked Creek drainage, which joins the Kuskokwim River at the lowermost extent of the study area for this project, have occurred since 2004 (personal comm. E. Fleming, OtterTail Environmental 2010).

Jewett et al. (2003) summarized the results from 1987-2000 regarding methylmercury in select fish species in western Alaska rivers. The authors concluded that "further studies are needed to determine the environmental and human health impacts associated with mercury concentrations in western Alaska, especially in the context of potentially increased consumption of resident fishes when anadromous salmon catches are reduced" which have steadily occurred since 1998 (e.g., McNair and Geiger 2001). Gray et al. (2000) conducted a study near the RDM site to evaluate the effects of abandoned mercury mines on fish and the aquatic ecosystem. Fish tissue samples from Arctic grayling (*Thymallus arcticus*) and Dolly Varden (*Salvelinus malma*) collected downstream from mercury mines, including RDM, on the Kuskokwim River contained as much as 420 and 620 ng/g Hg (wet wt. muscle). These concentrations were several times higher than that in fish collected from regional baseline sites. Gray et al. (2000) concluded that elevated mercury concentrations in freshwater fish collected near abandoned Hg mines indicate that some biologically available mercury is bioaccumulated; however the sample size (n=8) was limited and did not include top-predatory species more susceptible to methylmercury bioaccumulation, such as northern pike.

In 2010, the BLM and ADF&G sampled several hundred fish from the middle Kuskokwim River and eight tributaries. Sampling included both forage fish species and top-predatory fish, such as northern pike and burbot. These samples were analyzed for 19 metals, including mercury, and the data are currently being analyzed by a USFWS Toxicologist. Preliminary results indicate a similar pattern of contamination as samples collected in the lower Kuskokwim and Yukon Rivers during the last decade with larger, older fish exhibiting higher concentrations than smaller, younger fish. The data also indicated that top- predatory fish species had higher concentrations in the two major tributaries, the Holitna and George Rivers, compared to the middle Kuskokwim River samples. Preliminary results also indicated that forage fish collected from Red Devil Creek had increased concentrations of mercury compared to other sampled tributaries. Based on the preliminary results and the seasonal movements of fish in the Kuskokwim, George, and Holitna Rivers, additional sampling coupled with radio telemetry of northern pike and burbot is proposed for 2011-13. Additional tributary sampling is also proposed for Red Devil Creek, Egnaty Creek, and Cinnabar Creek, which is located in the upper Holitna River system and had a small historic mercury mining operation in its headwaters several decades ago.

1.2 Study Objectives

This study is designed to build upon the work completed in 2010 by addressing data gaps related to seasonal fish movements and increasing fish tissue samples throughout the study areas. The key elements of this study will:

- focus on all trophic levels from benthic macroinvertebrates to top-predatory fish species;
- target priority subsistence fish species;
- provide data on tributary fish community composition;
- provide insight into tributary watershed health using metric analysis of benthic macroinvertebrates for two tributaries;
- describe the seasonal distributions of two top-predatory fish species; and,
- include surface waters and streambed sediments sampling for contaminants, including Total Hg and MeHg, at the mouth of the Holitna River.

The goal of this study is establish a baseline condition of several metals species, including mercury and methylmercury, in the Kuskokwim River and tributaries between Stony River and Crooked Creek. Surface water and streambed sediment contaminant sampling coupled with the fish tissue and macroinvertebrate contaminant data and seasonal fish movement data will yield information about the potential sources and relative bioavailability of mercury in the Kuskokwim and sampled tributaries. Specific objectives and associated tasks for this project are:

1. Estimate the levels of metal bioaccumulation within the aquatic food web in the middle Kuskokwim River and associated tributaries.
    a. Collect 180 northern pike and 120 burbot non-lethal tissue (biopsy) samples for contaminants analysis during two distinct sampling events. Analyze fish biopsy samples for MeHg and Total Hg.
    b. Collect two composite benthic macroinvertebrate samples from Cinnabar Creek and Egnaty Creek.
    c. Collect nine macroinvertebrate samples from three tributaries (Cinnabar Creek, Red Devil Creek, and Egnaty Creek). Analyze samples for the full suite of metals.
    d. Collect streambed sediments and water samples from the Holitna River.
    e. Collect 24 whole fish samples comprising at least two species of forage fish from Red Devil Creek, Egnaty Creek, and Cinnabar Creek during two distinct sampling periods (144 total fish collected).
    f. Collect fork length (FL) and/or total length (TL) and weight of lower trophic fish species. If possible determine age-length relationships.
    g. Document instream habitat conditions and water chemistry at macroinvertebrate and fish sample sites.

2. Describe the seasonal distributions of northern pike and burbot.

    a. Describe the seasonal distributions of northern pike radio-tagged during summer 2011 within two geographic sections, upper Kuskokwim and Holitna.

    b. Describe the seasonal distributions of burbot radio-tagged during the fall of 2011 within two geographic sections, the lower and upper Kuskokwim River (excluding the George River).

    c. For each aerial tracking survey, estimate the proportion of northern pike that moved out of the geographic section where they were tagged. For the Holitna section, each estimated proportion will be within 10 percentage points of the true value 90% of the time. For the upper Kuskokwim River section, each estimated proportion will be within 25 percentage points of the true value 90% of the time.

    d. For each aerial tracking survey, estimate the proportion of burbot that moved out of the geographic section where they were tagged such that each estimated proportion will be within 10 percentage points of the true value 95% of the time.

    e. Test the hypothesis that the proportion of burbot radio-tagged during fall in the lower Kuskokwim section that are present in the Kuskokwim River upstream of the George River during at least one winter (November – March) tracking event is greater than or equal to 0.10 with $\alpha = 0.15$ such that $\beta = 0.10$ if the true proportion is 0.25;

3. Describe the length composition of all northern pike and burbot captured.

2.0 Sampling Locations

2.1 Biological Sampling

Radio tags and biopsy samples will be apportioned among three geographic sections and eight subsections demarcated by river kilometers (rkm) or major features (Table 2, Figures 4 and 5). Within a subsection, the radio telemetry tags and biopsy samples will be apportioned among length strata (Table 2).

Lower trophic level fish and macroinvertebrate samples will be collected from Red Devil Creek, Cinnabar Creek, and Egnaty Creek. The locations of the proposed sampling areas are shown in Figure 2.

2.2 Surface Water and Sediment Sampling

Surface water and sediment samples will be collected from the mouth of the Holinta River.

3.0 Sample Methods

3.1 Biological Sampling

All sampling will be conducted from June through October of 2011. Study design for fish and macroinvertebrate sampling for metals analysis will be based upon Scudder et al. (2008).

Northern Pike will be captured primarily with hook-and-line gear and artificial lures. If needed, fyke nets and small mesh (i.e. 19-mm or ¾-in) gill nets of varying lengths and depths will be

used. Sloughs and mouths of connecting streams and side channels will be targeted. Gillnets will be set opportunistically when angling and will be checked at regular intervals (< 10 min) to minimize stress or mortality from released fishes. Four fyke traps will be available and will be used near the entrances of sloughs and fished overnight. These are composed of 10-mm mesh, have ~1 x 1-m frames, and have shore leads of varying lengths (10-30-m).

Burbot will be captured in commercially available hoop traps. The hoop traps are 3-m long with seven 6-mm steel hoops. Hoop diameters taper from 0.6-m at the entrance to 0.5-m at the cod end. Each trap has a double throat (tied to the second and fourth hoops) which narrows to an opening 10-cm in diameter. All netting is knotted nylon woven into 25-mm bar mesh, bound with no. 15-cotton twine, and treated with an asphaltic compound. Traps will be kept stretched with two sections of 19-mm polyvinyl chloride (PVC) pipe attached by snap clips to the end hoops. In general, burbot do not fully recruit to this gear until 450-mm TL and efficiency for fish ≥ 800-mm and larger decreases slightly, but is still effective.

During fall, each crew will fish 25 – 40 hoop traps. Hoop traps will be set in a sampling subsection and be allowed to fish overnight. Hoop traps will be baited with cut Pacific herring *Clupea harengus* placed in perforated plastic containers. One end of a 5 to 10m section of polypropylene rope will be tied to the cod end of each trap, while the other end is tied off to shore. The traps will fish on the river bottom near shore with the opening facing downstream.

Forage fish will be collected using backpack electrofishing techniques within the lower segment (100-m) of the sampled tributaries. All sampled fish and macroinvertebrate for contaminant analysis will be uniquely identified within individual plastic resealable bags and placed on ice. Macroinvertebrate sampling for benthic diversity analysis would be collected based upon guidance provided by the BLM BugLab for Fixed Area Quantitative or Qualitative Invertebrate collection will take place upstream of the riffle(s) used for collection of macroinvertebrate samples for metals analysis. Samples will be labeled internally and externally and stored in ethanol within 1-quart collapsible containers. Data sheets will be completed at each sampling location for both the BLM BugLab and contaminant samples, which will include unique identification information, length (mm), weight (g), and GPS spatial location of the collection in NAD 83.

Biopsy samples will be taken from all radio-tagged fish and analyzed for mercury. The biopsy sample will be taken following the procedures detailed by Baker et al. (2004). The sample will be taken using a commercially available dermal punch 5 mm in diameter. The dermal punch will be inserted or twisted 6 mm into the musculature of the fish approximately 1.5 cm below the insertion of the dorsal fin - for northern pike, scales will first be removed from the punch site. The punch is rotated downward parallel to the fish and twisted to sever and capture the sample. The tissue sample will be placed into a sterilized vial, weighed, and placed into a portable mini-freezer. Samples will be temporarily held in a chest freezer in Sleetemute until they can be express shipped to a laboratory for analysis.

The punch and incision sites will be treated with an antibiotic and released. Baker et al. (2004) observed that punch sites for northern pike were completely healed over after a year and could not detect a significant difference in survival a year after tagging compared to a control group. It is anticipated that no significant mortality (i.e. ≥5%) for northern pike sampled in the Kuksokwim River will be incurred because of the dermal punch.

3.2 Sediment Sampling

Stream sediment will be collected from surface-layer, bedload alluvium at the mouth of the Holitna River. Sample collection and preservation will follow accepted USEPA protocols (EPA 2001). Each single sediment sample will represent a separate composite. Sediment will be field sieved to <63-um in accordance with USGS protocol and spilt in the field into a mercury and trace element samples (Radke, 2005). Solid samples for trace element analysis are to be collected in triplicate, using amber glass vessels with Teflon lined lids, and then frozen until analyzed. Samples for Hg methylation and demethylation rate measurements also will be collected in amber glass vessels and then refrigerated until analysis. Prior to analysis, the stream-sediment samples would be air dried and pulverized to less than 100 mesh (0.15-mm).

3.3 Water Sampling

Unfiltered water samples for Hg and methyl-Hg analysis will be collected in triplicate. Water samples will be depth and width integrated samples collected according to USGS protocol (U.S. Geological Survey, variously dated) in teflon bottles pre-cleaned by boiling in concentrated nitric acid (HNO3) for 48 hours. Within eight hours of collection, these water samples will be acidified with ultra-pure HCl using a final acid concentration of 0.5% (v/v). Unfiltered water samples collected for cation analysis will be collected in polypropylene bottles pre-cleaned in 10% HCl and these water samples are acidified on-site with ultra-pure HNO3. Water samples for anion analysis are collected in clean, polypropylene bottles.

Discharge measurement will be made at the collection site either by hand held flow meters or Doppler measurements.

4.0 Sample Analysis

4.1 Biological Samples

Laboratory sample processing and analysis will be completed by a contract laboratory and follow protocols outlined in EPA method 6020 and 7473 for metals and high-performance liquid chromatography (HPLC) coupled to inductively coupled plasma mass spectrometry (ICP-MS) technique for MeHg analysis.

The BLM BugLab would process the benthic diversity macroinvertebrate samples using the procedures recommended by the United States Geological Survey (Cuffney et al. 1993), which is described in greater detail in Vinson and Hawkins (1996).

4.2 Sediment and Water Samples

Concentrations of Hg and methyl-Hg will be determined using cold-vapor atomic fluorescence spectrometry (CVAFS). Measurement of total Hg follows protocols established in EPA Method 1631 (EPA 1996; 2002). Solid samples are digested using aqua regia (3 parts HCl: 1 part HNO3) and the Hg ions in the digestate are reduced by acidic SnCl2 to elemental Hg and purged from the sample with argon. The released Hg is then measured by CVAFS as outlined in EPA Method 1631. Methyl-Hg determinations follow EPA Method 1630 (Bloom 1989). During methyl-Hg analysis and sediment samples must be extracted into methylene chloride following digestion to avoid possible methylation artifact effects (Bloom et al. 1997). An ethylating agent is added to

the extract to form a volatile methyl-ethylmercury derivative, and then purged onto graphitized carbon traps as a means of pre-concentration and interference removal. The samples are then isothermally chromatographed, pyrolitically broken down to elemental Hg and detected using CVAFS following the method of Bloom (1989).

Sediment and water samples will be sent to the USGS laboratory for determination of total Hg and methyl-Hg concentrations. Quality control for geochemical analyses, including Hg and methyl-Hg determinations, would be addressed with method blanks, blank spikes, matrix spikes, certified reference materials, and blind duplicates. Major and trace elements would be measured in sediment and water by inductively coupled plasma-mass spectrometry (ICP-MS) using techniques developed by Lamothe et al. (1999). Anions in water will be determined using ion chromatography. Water measurements such as temperature, conductivity, oxidation-reduction potential, dissolved oxygen, total dissolved solids, pH, and salinity will be made on-site with a Hydrolab instrument. Measurements will also be made on-site in water for concentrations of alkalinity, total Fe, reduced Fe (Fe2+), phosphate, ammonia, and sulfide using chemical test kits (manufactured by Chemetrics).

4.3 Sample Size

The number of fish and macroinvertebrate samples for metals analysis dictated by Scudder et al. (2008), the number of sampling areas being targeted, and environmental conditions. Table 1 outlines the targeted sample sizes for each of the two sampling events. Benthic diversity sampling would include the collection of one sample within each tributary targeted for metals analysis.

The number of radio-tagged northern pike and burbot required to meet the precision criteria specified was estimated to be 180 northern pike and 120 burbot in two distinct sampling events (Cochran 1977). This sample size calculation assumed a 20% annual tag loss. It is expected that ~5% of fish will not be found in a given survey and will be assumed to be a random occurrence. Using these assumption, the number of viable tags by survey has been constructed (Table 4). Biopsy samples will be taken from all radio-tagged fish and analyzed for mercury, 180 northern pike and 120 burbot.

5.0 Data Analysis and Reporting

5.1 Metals analysis of biological, sediment, and water samples

The intent of the biological sample analysis is to provide additional baseline data on the bioaccumulation of metals, including MeHg, in the middle Kuskokwim River and associated tributaries. Processed sample data by the contracted laboratory will be submitted for a third party quality assurance review before being considered complete.

Results from the metals analysis of biological, sediment, and water samples collected in the tributaries will be summarized in a separate spreadsheet. These spreadsheets will serve as the basis for analysis by US DOI contaminants experts. Contaminant levels noted within fish and macroinvertebrates tissue, in addition to various macroinvertebrate diversity metrics and sediment/water quality data, would be compared across sites and to existing datasets in the region.

5.2 Schedules and Reports

A draft project report for BLM sampling will be compiled by May 2012 and finalized by August 2012. Telemetry data would be summarized in a final report in 2015.

5.3 Responsibilities

Project Leader: Matthew Varner, Fisheries Program Lead, BLM – AK State Office
Duties: Coordinate sampling effort, contract oversight, lead tributary sampling of biological resources, compile data, and author project report

Table 1. Sample Size for Metals and Benthic Diversity Sampling

Macroinvertebrate Sampling (Per Round)	
Metals - 3 tributaries (Target: 3 replicate composite samples)	9
Diversity Samples - 3 tributaries	3
Radio Telemetry Tags and Biospy Sampling (2011)	
Reaches	6
Species (Target: N. Pike and Burbot)	2
Number of radio telemetry tags and biopsy samples per species	180 - northern pike 120 - burbot
Total Number of Fish Sampled in 2011	**300**
Number of muscle samples analyzed for Hg and other metals per round	300
Forage Fish Sampling (Each Round) - BLM sampling	
Species (Target: S. Sculpin and Dolly Varden, Arctic Grayling, or LN Sucker)	2
# Samples per Tributary	24
Total Samples (3 Tributaries)	72
Total Number of Fish Sampled per round	**72**
Total Number of Whole Body Fish Sampled (Two Rounds)	**144**

Table 2. Allocation of radio tags by species, and geographic, and length strata in the Middle Kuskokwim study area, 2011. Geographic strata are defined parenthetically.

Species	Study section	Subsection	Length strata (mm FL)	Number of tags
Pike	Holitna River (H)			
		Mouth to rkm 25 (A)	550-649	8
			650-749	12
			>750	10
		rkm 25 to Hoholitna (rkm 50; B)	550- 649	8
			> 650	12
			>750	10
		Lower 20-km of Hoholitna (C)	550- 649	8
			> 650	12
			>750	10
		Hoholitna to rkm 75 (D)	550- 649	8
			650-750	12
			>750	10
				120
	Upper mainstem Kuskokwim (UMK)			
		Lower 20-km of the George River (E)	500 - 599	10
			600-650	5
			>650	5
		George to Holitna Mouth (27-km; F)	500 - 599	10
			600-650	5
			>650	5
		Holitna R. to Stoney R. (28-km; G)	500 - 599	10
			600-650	5
			>650	5
				60
Burbot	Lower mainstem Kuskokwim (LMK)	George to Holitna Mouth (27km)	500 - 599	20
			> 600	20
		Holitna R. to Stoney R. (28-km)	500 - 599	20
			> 600	20
	Aniak	40 km reach centered on Aniak (H)	500 - 599	20
			> 600	20
				120

Table 3. Predicted number of viable radio tags for northern pike and burbot in the middle Kuskokwim River study area after 1 and 2 years of tagging.

Species	Section	Start	Number of viable tags located at the end of year 1	Number of viable tags located at the end of year 2
Pike	UKR	80	60	48
	H	120	90	64
Burbot				
	UKR	80	60	48
	LKR	40	30	28

Figure 2. Map Depicting Cinnabar Creek Watershed

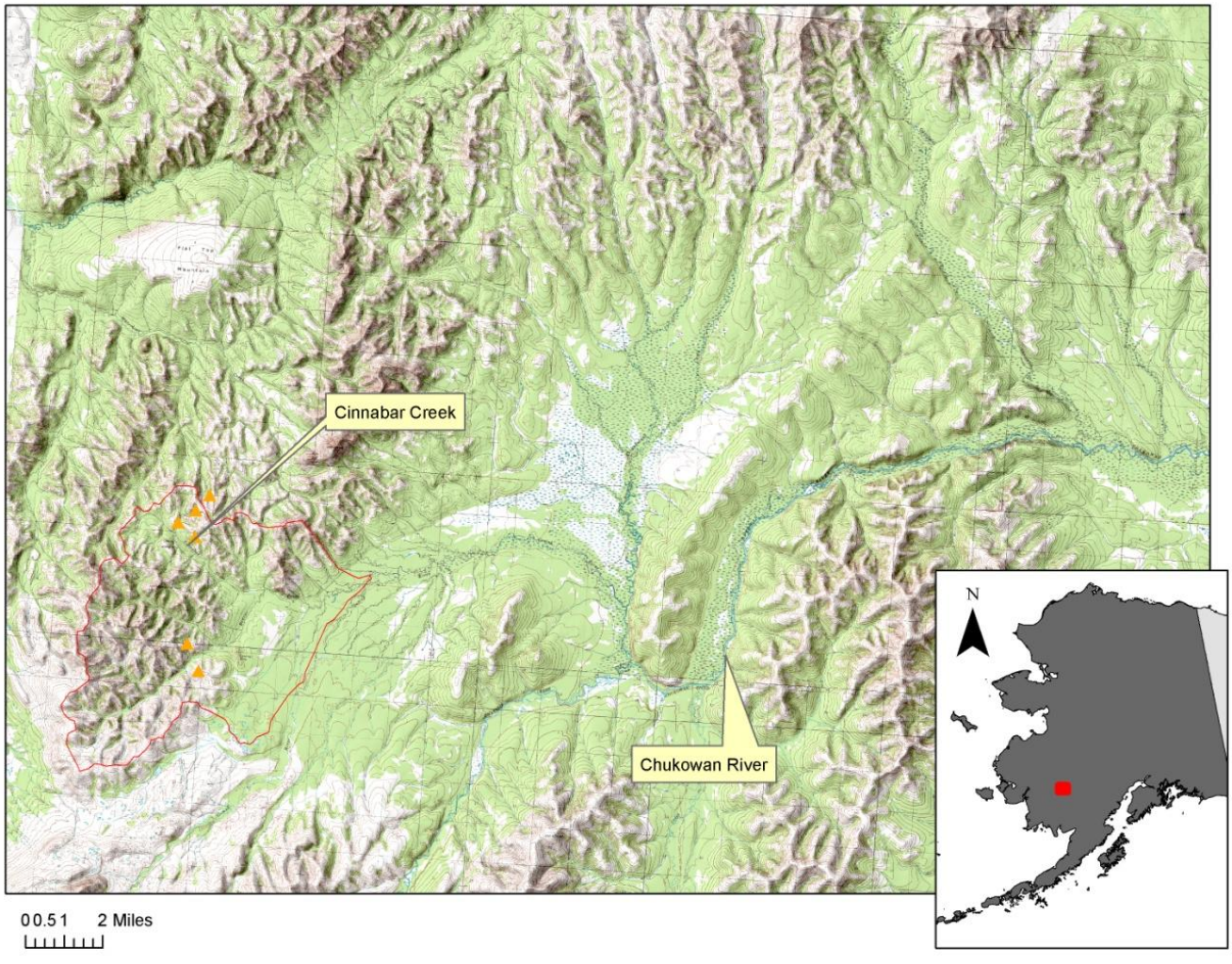


Figure 3. Map Depicting Red Devil Creek Watershed

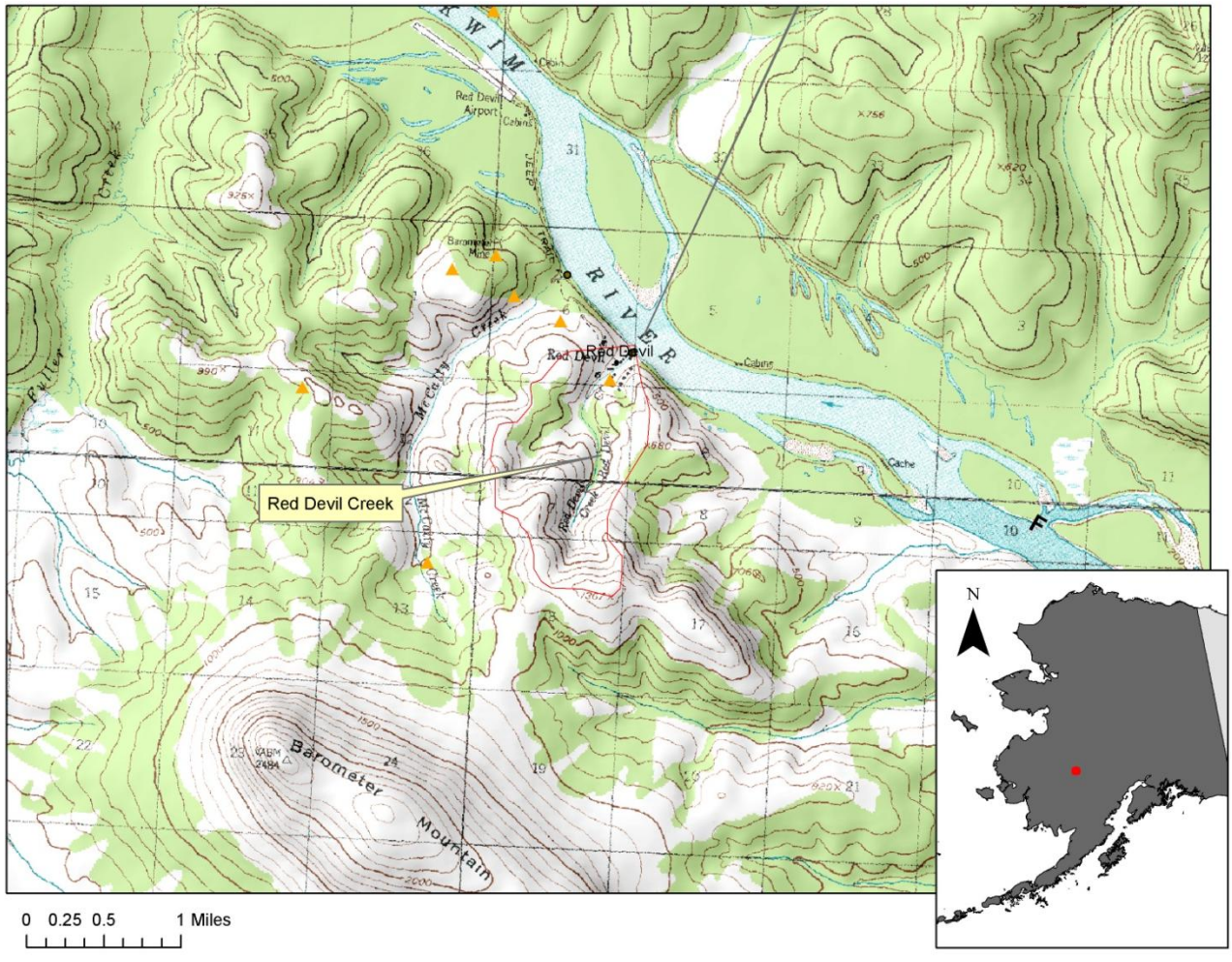


Figure 4. Map Depicting Egnaty Creek Watershed

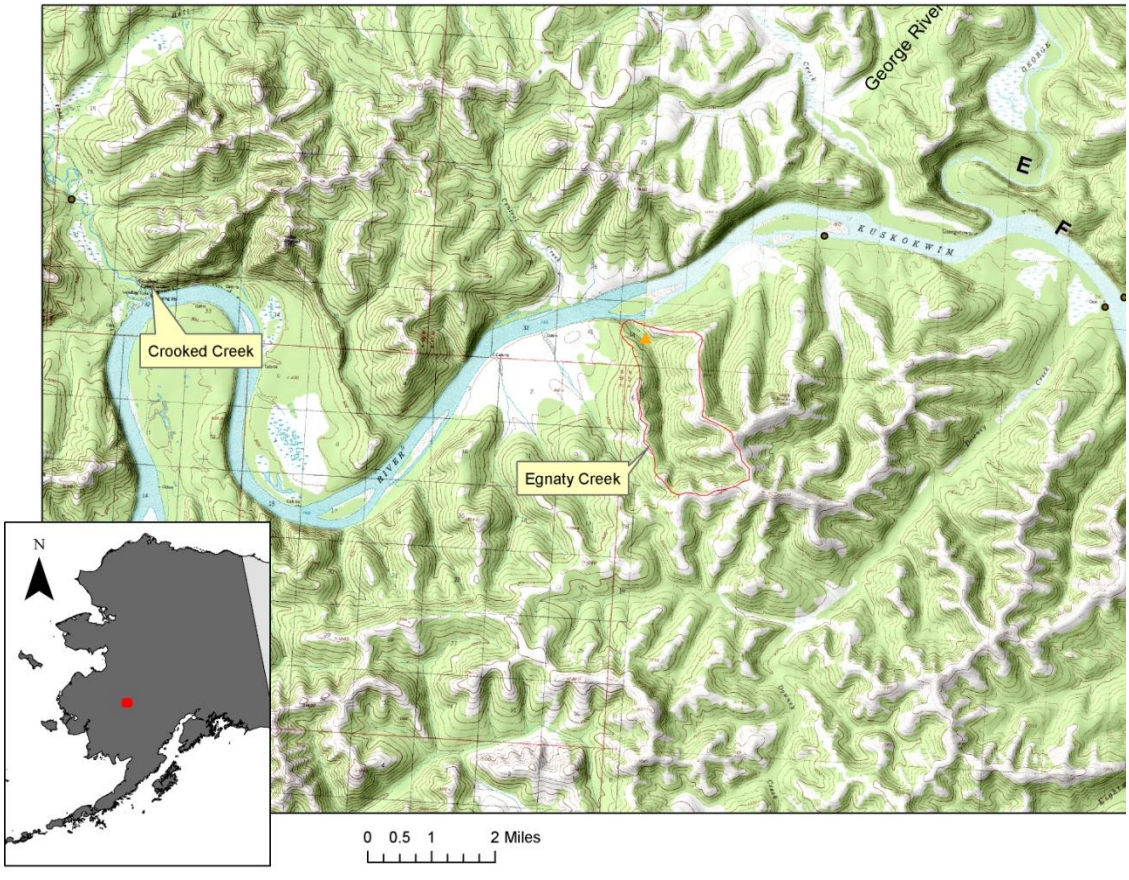


Figure 5. Kuskokwim River with locations of tracking stations and subsection H of the study area demarcated.

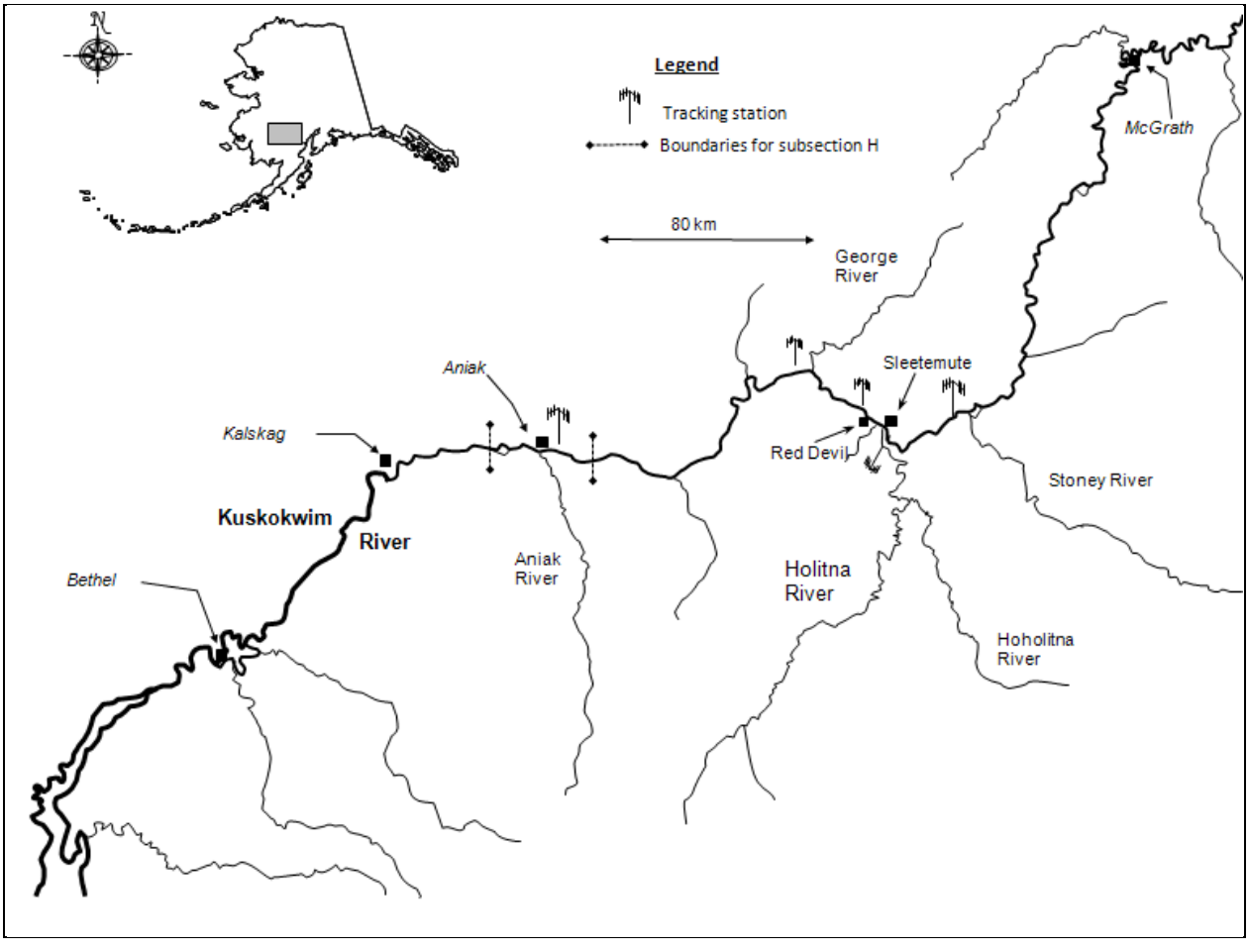


Figure 6. Study area with subsections demarcated.

Literature Cited

Alaska Department of Fish and Game. 2007. The Harvest of Non-salmon Fish by Residents of Aniak and Chuathbaluk, Alaska, 2001-2003. Technical Paper No. 299. 115pp.

Bernard, D. R., G. A. Pearse, and R. H. Conrad. 1991. Hoop traps as a means to capture burbot. North American Journal of Fisheries Management 11:91–104.

Bloom, N., Colman, J., and Barber, L., 1997. Artifact Formation of Methylmercury during Aqueous Distillation and Alternative Techniques for the Extraction of Methylmercury from Environmental Samples. Fresenius J. Anal. Chem. 358:371-377.

Bloom, N.S., 1989. Determination of Picogram Levels of Methylmercury by Aqueous Phase Ethylation, Followed by Cryogenic Gas Chromatography with Cold Vapor Atomic Fluorescence Detection. Can. J. Fish. Aquat, Sci. 46, 1989.

Bloom N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Canadian Journal of Fisheries and Aquatic Sciences 46: 1010–1017

Clements, W.H., D.M. Carlisle, J. M. Lazorchak, P. C. Johnson. 2000. Heavy Metals Structure Benthic Communities in Colorado Mountain Streams. Ecological Applications, Vol. 10 (2) 626-638

Cuffney, T.F., M. E. Gurtz, and M.R. Meador. 1993. Methods for Collecting Benthic Invertebrate Samples as a Part of the National Water-Quality Assessment Program. U.S. Geological Survey, Open File Report 93-406.

EPA, 2001. Appendix to Method 1631: Total mercury in tissue, sludge, sediment, and soil by acid digestion and BrCl oxidation. U.S. Environmental Protection Agency, EPA 821-R-01-013, 13 p.

Gray, J.E., Theodorakos, P.M., Bailey, E.A., and Turner, R.R., 2000. Distribution, speciation, and transport of mercury in stream-sediment, stream-water, and fish collected near abandoned mercury mines in southwestern Alaska, USA. Sci. Total Environ. 260, 21-33.

Hanisch C. 1998. Where is mercury deposition coming from? Environ Sci Technol 32:176A–9A.

Jewett S.C., Zhang X., Naidu S.A., Kelly J.K., Dasher D., Duffy L.K. 2003. Comparison of mercury and methylmercury in northern pike and Arctic grayling from western Alaska rivers. Chemospere 50: 383–92.

Johnels A.G., Westermark T., Berg W., Person P.I., Sjostrand B. 1967. Pike and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment. Oikos 18:323–33.

Kannen K., Smith R.G. Jr., Lee R.F., Windom H.L., Heitmuller P.T., Macauley J.M., Summers J.K. 1998. Distribution of total mercury and methyl mercury in water, sediment, and fish from South Florida estuaries. Archives of Environmental Contamination and Toxicology 34: 109–118.

Lamothe, P.J., Meier, A.L. and Wilson, S., 1999. The determination of forty four elements in aqueous samples by inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 99-151, 14 p.

Lawler, G. H. 1963. The biology and taxonomy of the burbot, *Lota lota*, in Heming Lake, Manitoba. Journal of the Fisheries Research Board of Canada 20:417-433.

Lepak, J. M., J. M. Robinson, C. E. Kraft, and D. C. Josephson. 2009a. Changes in mercury bioaccumulation in an apex predator in response to removal of an introduced competitor. Ecotoxicology 18:488–498.

Lepak, J. M., H.A. Shayler, C. E. Kraft, and B. A. Knuth. 2009b. Mercury Contamination in Sport Fish in the Northeastern United States: Considerations for Future Data Collection. BioScience. Vol 59 (2): 174-181

McCrimmon, H. R., and O. E. Devitt. 1954. Winter studies on the burbot, Lota lota lacustris, of Lake Simcoe, Ontario. Canadian Fish Culturist 16:34-41.

McNair, M. and H.J. Geiger, 2001. Run forcasts 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, 12pp.

Maret, T.R., D.J. Cain, D. E. MacCoy, and T. M. Short. 2003. Response of Benthic Invertebrate Assemblages to Metal Exposure and Bioaccumulation Associated with Hard-Rock Mining in Northwestern Streams, USA. Journal of the North American Benthological Society, Vol. 22 (4), 598-620

Radtke, D. B., Revised 2005, Bottom-material samples:U. S. Geological Survey Techniques of Water-Resources Investigations, book 9, chapter A8, June, accessed August 9, 2010 at http://pubs.water.usgs.gov/twri9A8/

Sainsbury, C.L. and MacKevett, E.M., 1965, Qicksilver Deposits of Southwestern Alaska, U.S. Geological Survey Bulletin 1187, 84p.

Scudder, B.C., Chasar, L.C., DeWeese, L.R., Brigham, M.E., Wentz, D.A., and Brumbaugh, W.G., 2008, Procedures for collecting and processing aquatic invertebrates and fish for analysis of mercury as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 2008-1208, 34 p.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at http://pubs.water.usgs.gov/twri9A

Wiener, J.G., Bodaly, R.A., Brown, S.S., Lucotte, M., Newman, M.C., Porcella, D.B., Reash, R.J., and Swain, E.B., 2007, Monitoring and evaluating trends in methylmercury accumulation in aquatic biota, Chapter 4 in Harris, R.C.; Krabbenhoft, D.P.; Mason, R.P.; Murray, M.W.; Reash, R.J.; Saltman, T., Eds., Ecosystem Responses to Mercury Contamination – Indicators of Change: Pensacola, FL, CRC Press and Society of Environmental Toxicology and Chemistry, pp. 87-122.

Wolfe MF, Schwarzbach S, Sulaiman RA. Effects of mercury on wildlife: a comprehensive review. Environ Toxicol Chem 1998;17: 146–60.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. Journal of the North American Benthological Society 15:392-399.

Appendix 1. Field Forms

Macroinvertebrate Sampling Form (Metals)	
Stream Name:	**Sample Date:**
Site ID:	
Time Range (24h), HHMM-HHMM	
Sample Type:	
Field Crew:	
Field Comments:	
Species Common Name:	**Latin Name:**
Stream Habitat Sampled: **Riffle** **Pool** **Run** **Margin**	

Composite #	**Sample time (24h)**	**# Individuals in Composite**	**Sample wet wt, field, g**	**Sample ID**
1				
2				
3				

Fish and Macroinvertebrate Sampling Form (Metals)				
Stream Name:			**Sample Dates (YYYYMMDD)**	
Site ID:				
Time Range (24h), HHMM-HHMM				
Gear Types:				
Field Crew:				
Field Comments:				
Species Common Name:			**Latin Name:**	
Stream Habitat Sampled:	**Riffle**	**Pool**	**Run**	**Margin**
Fish #	**Sample time (24h)**	**Fork Length, total, mm**	**Fish wt, g**	**Sample ID**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				