

State of Alaska
Epidemiology



Bulletin

Recommendations
and
Reports

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Pike and Burbot (Lush) in Select Alaska Rivers: Mercury Exposure and Consumption Recommendations

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I. Relationship between Northern Pike Consumption and Hair Mercury Levels in Selected Rural Alaska Communities, 2007–2010

Executive Summary

Mercury is an important contaminant of concern due to its neurotoxic effects on humans, especially developing fetuses and young children. In 2004, the U.S. Fish and Wildlife Service (USFWS) began a multi-year study to evaluate mercury levels in northern pike from six National Wildlife Refuges (NWRs) in Alaska. During this time, the Alaska Section of Epidemiology (SOE) partnered with USFWS to gather hair samples for mercury testing and fish consumption histories from women who lived in villages located near the USFWS pike sampling sites. Seventeen villages participated in the project, including seven villages in the lower Yukon and lower Kuskokwim, three villages in the upper Yukon, three villages in the Northwest, and four villages in the Interior. SOE routinely conducts follow-up interviews on all persons with hair mercury levels ≥ 5 parts per million (ppm) to obtain exposure histories and provide recommendations for minimizing exposure.

Individual hair mercury levels ranged from 0.04 ppm to 4.12 ppm, with an overall mean of 0.54 ppm (data not shown). Mean hair mercury levels differed significantly by pike consumption status: 0.76 ppm for pike consumers and 0.31 ppm for non-consumers (Table 1). Mean hair mercury levels were also higher among pike consumers than non-consumers in all demographic categories (Table 1). The highest hair mercury levels were found in pike consumers who were: a) from the Yukon Delta; b) aged 40–49 years; c) Yup'ik Eskimo; and d) marine mammal consumers.

Recommendations

1. Health care providers should encourage pregnant women and women of childbearing age living in villages included in this project to follow the region-specific northern pike consumption guidance provided in this report.
2. Health care providers should encourage pregnant women and women of childbearing age to participate in the Alaska Hair Mercury Biomonitoring Program. Contact SOE's Environmental Public Health Program (907-269-8000) for information on how to collect and submit hair samples. Information is also available on the SOE Environmental Public Health Program's webpage (available at: <http://dhss.alaska.gov/dph/Epi/eph/Pages/default.aspx>).
3. Health care providers should encourage all women of childbearing age, pregnant women, and parents of young children to follow the Alaska fish consumption guidelines for themselves and their children (available at: <http://dhss.alaska.gov/dph/Epi/eph/Documents/fish/FishConsumptionCalc.pdf>).

Introduction

Mercury is an important contaminant of concern due to its neurotoxic effects on humans, especially developing fetuses and young children.¹ Mercury in Alaska comes from several sources, including natural sources such as breakdown of local bedrock into streams, forest fires, and volcanoes, and human sources such as global air pollution and mining runoff. Mercury in the environment can be converted by micro-organisms into organic methylmercury, which increases in concentration (“biomagnifies”) up the aquatic food chain. Consumption of fish and marine mammals is a common source of human methylmercury exposure worldwide. In 2007, the Alaska Section of Epidemiology (SOE) published Alaska-specific fish consumption guidelines for the general public and updated them in 2014.² These guidelines focused on consumption of selected fish species for which sufficient data existed to support statewide consumption recommendations. The recommendations were supported by human data from the statewide Hair Mercury Biomonitoring Program, which was developed in 2002 to determine mercury exposure levels in women of childbearing age (*i.e.*, women aged 15–45 years) and pregnant women living in Alaska.^{3,4} SOE routinely conducts follow-up interviews on all persons with hair mercury levels ≥ 5 parts per million (ppm) to obtain exposure histories and provide recommendations for minimizing exposure.³

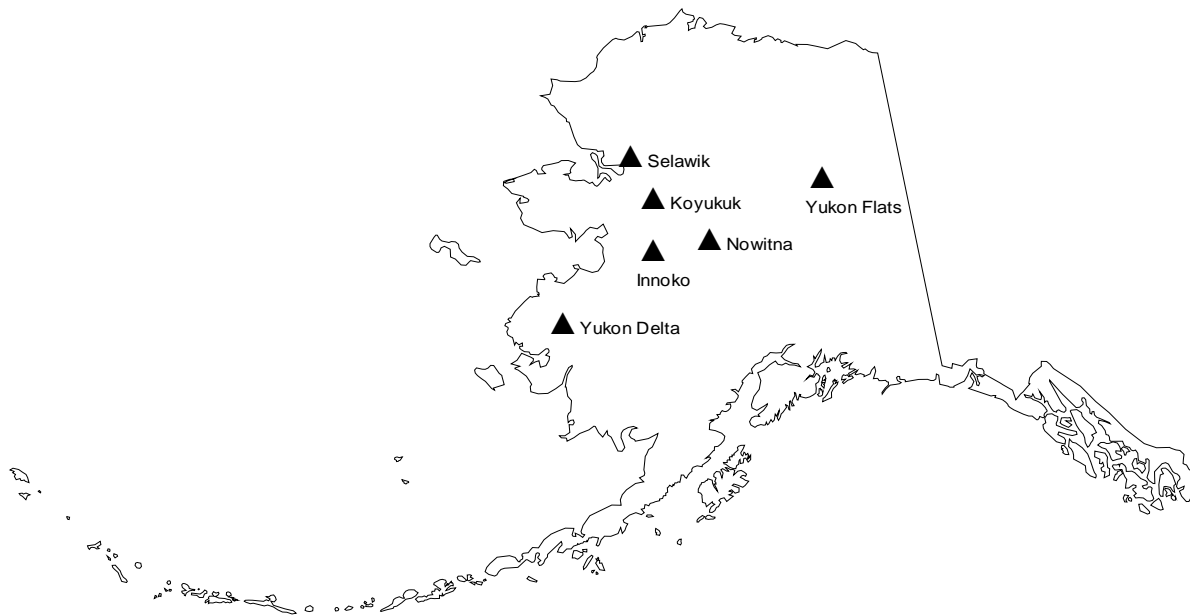
Since the release of the Alaska fish consumption guidelines, additional fish mercury data have become available that include northern pike (*Esox lucius*). A freshwater species found in many Alaska rivers and lakes, northern pike are a commonly consumed subsistence food and are known to contain elevated concentrations of mercury in their muscle tissue due to their high position on the aquatic food chain.⁵⁻¹⁰

In 2004, the U.S. Fish and Wildlife Service (USFWS) began a multi-year study to evaluate mercury levels in northern pike from six National Wildlife Refuges (NWRs) in Alaska. During this time, SOE partnered with USFWS to gather hair samples and fish consumption histories from women who lived in villages located near the USFWS pike sampling sites. The main goals of the joint project were to explore the relationship between northern pike consumption and hair mercury levels in women of childbearing age and pregnant women living near USFWS pike sampling sites, and to develop site-specific pike consumption advice for women and children living in those regions.

Methods

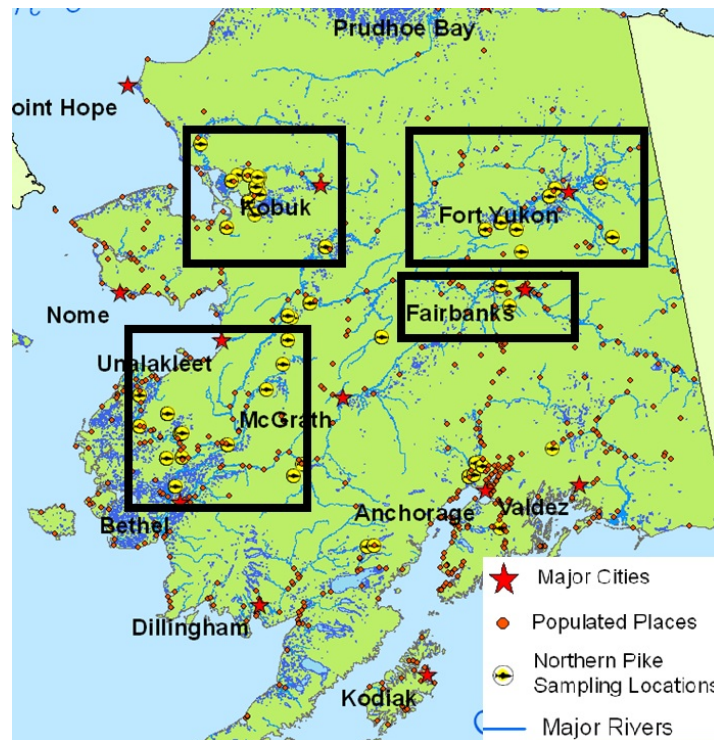
USFWS pike sampling: Pike samples were collected during 2005–2007. Pike data were grouped into four regions by watershed: 1) the lower Yukon River and lower Kuskokwim River areas (referred to as *Yukon Delta*), including the Yukon Delta NWR; 2) the upper Yukon River area, including the Yukon Flats NWR; 3) Northwest, including the Selawik NWR and surrounding subsistence fishing rivers; and 4) the mid-Yukon River area (referred to as *Interior*), including the Koyukuk, Innoko and Nowitna NWRs and surrounding subsistence fishing locations (Figure 1).

Figure 1. Map of National Wildlife Refuge Locations Participating in USFWS Pike Project



Participating villages: Villages were invited to participate in the SOE portion of the joint project if they were located near one of the four USFWS northern pike sampling regions. Villages participated only after approval was provided by the local village council. A total of 17 villages participated in the project, including seven villages in the lower Yukon and lower Kuskokwim, three villages in the Upper Yukon, three villages in the Northwest, and four villages in the Interior. In each of these villages, a convenience sample (i.e., those persons who were convenient to reach) of pregnant women and women of childbearing age (aged 13–49 years for this project) were recruited to participate in the project. Figure 2 shows a map of fish sampling sites and hair collection areas in the USFWS Pike Project.

Figure 2. Map of Fish Sampling Sites and Hair Collection Areas in USFWS Pike Project*



**Note: Rectangles on this map indicate the approximate areas where hair samples were collected (upper left=Northwest; upper right=Upper Yukon; lower left=Lower Yukon and Kuskokwim; lower right=Interior).*

Data collection: Data collection occurred from April 2007 through April 2010. Participating women completed a 20-question in-person survey administered by SOE. In addition to basic demographic information, the survey asked questions about pregnancy and breastfeeding status, fish and marine mammal consumption, and reasons for and concerns about fish consumption. The survey was developed specifically for the project, and had not been previously validated. The quantity of pike consumed was estimated from the total ounces of pike eaten as reported by survey respondents, with one meal being roughly equal to 6 ounces of fish. Persons with a history of pike consumption were defined as those who reported eating at least one meal of pike in the past 12 months. Persons with a history of marine mammal consumption were defined as those who reported eating at least one marine mammal meal of any size in the past 12 months. Women were considered pregnant or breastfeeding if they were pregnant or breastfeeding at the time that they completed the survey. A hair sample was obtained from all study participants for mercury analysis. Hair samples were analyzed by the Alaska State Public Health Laboratory using the Milestone DMA-80 Direct Mercury Analyzer.³

Analysis: Because none of the women who participated in this project had a hair mercury level that exceeded SOE's established exposure risk level of 5 ppm, all data were compared to the mean hair mercury level for all project participants. In order to perform parametric comparison of means, hair mercury levels were transformed to natural log scale and then transformed back to mercury levels for display in tables—this method has been used in similar studies.¹² Student's t-tests were used to determine if there was a correlation between hair mercury levels and reported

pike consumption. Upper Yukon, Northwest, and Interior data points were combined into one group to allow for more detailed regional comparisons, as data from the statewide Hair Mercury Biomonitoring Program demonstrate relatively higher hair mercury levels in the Yukon Delta compared to other regions of the state.⁴ ANOVA was used to further analyze predictors of higher mean hair mercury levels. All analyses were conducted using SPSS PASW 18 software (SPSS Inc., Chicago, IL).

This project was reviewed and approved by the Alaska Area Institutional Review Board (AAIRB) on February 14, 2007.

Results

Of the 144 women who provided both a hair sample and a completed survey, 142 were included in the analysis because they indicated on the survey whether or not they consumed pike in the past year. Individual hair mercury levels ranged from 0.04 ppm to 4.12 ppm, with an overall mean of 0.54 ppm (data not shown). Mean hair mercury levels differed significantly by pike consumption status: 0.76 ppm for pike consumers and 0.31 ppm for non-consumers (Table 1). Mean hair mercury levels were higher among pike consumers than non-consumers in all demographic categories; the highest hair mercury levels were found in pike consumers who were: a) from the Yukon Delta; b) aged 40–49 years; c) Yup'ik Eskimo; and d) marine mammal consumers (Table 1). The mean hair mercury level among women who consumed pike and lived in the Yukon Delta was higher than the mean hair mercury level among women who consumed pike and lived in the Upper Yukon, Northwest, and Interior regions combined (1.00 ppm vs. 0.46 ppm, respectively; $p < 0.0001$; data not shown).

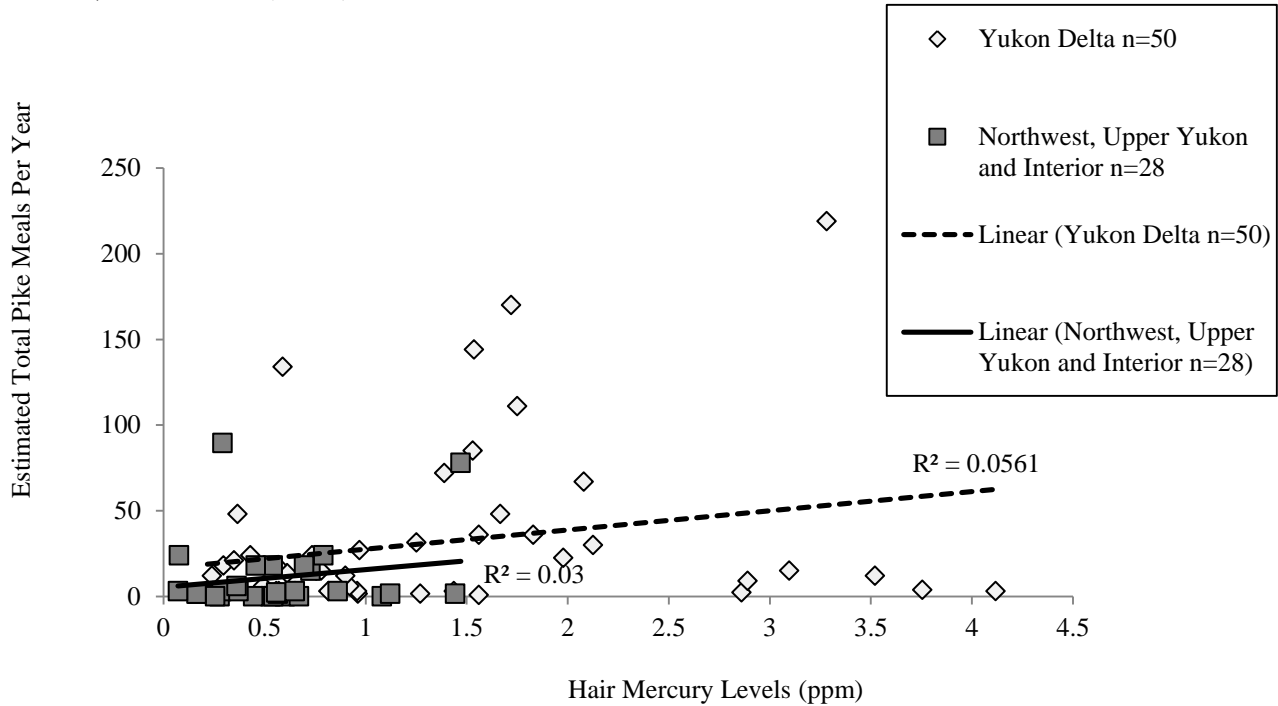
Table 1. Comparison of Mean Hair Mercury Levels among Groups of Women by Self-Reported Pike Consumption—Rural Alaska, 2007–2010 (N=142)

Demographic (Number of Participants)	Pike Consumption in Past Year	N	Mean Hair Mercury Level in ppm (range)	Significance
<i>All participants (n=142)</i>				
	Yes	87	0.76 (0.07–4.12)	p<0.001
	No	55	0.31 (0.04–1.69)	
<i>Location (n=142)</i>				
Yukon Delta (n=76)	Yes	57	1.00 (0.22–4.12)	p<0.001
	No	19	0.45 (0.13–1.62)	
Upper Yukon (n=19)	Yes	6	0.35 (0.08–0.73)	p=0.5
	No	13	0.26 (0.04–0.51)	
Northwest (n=17)	Yes	8	0.57 (0.17–1.47)	p=0.07
	No	9	0.26 (0.04–0.71)	
Interior (n=30)	Yes	16	0.45 (0.07–1.44)	p<0.05

	No	14	0.26 (0.11–0.76)	
<u>Age (n=142)</u>				
13–29 years (n=65)	Yes	37	0.56 (0.07–3.52)	p<0.001
	No	28	0.30 (0.04–1.22)	
30–39 years (n=39)	Yes	22	0.78 (0.07–2.89)	p<0.01
	No	17	0.37 (0.13–1.62)	
40–49 years (n=38)	Yes	28	1.14 (0.29–4.12)	p<0.001
	No	10	0.31 (0.04–0.69)	
<u>Pregnancy/breastfeeding status (n=137)</u>				
Pregnant or breastfeeding (n=39)	Yes	20	0.73 (0.17–3.76)	p<0.001
	No	19	0.26 (0.04–1.62)	
Not pregnant or breastfeeding (n=98)	Yes	64	0.79 (0.07–4.12)	p<0.001
	No	34	0.34 (0.04–1.57)	
<u>Ethnicity (n=142)</u>				
Athabaskan (n=41)	Yes	16	0.60 (0.07–2.86)	p<0.01
	No	25	0.26 (0.04–0.76)	
Inupiaq (n=17)	Yes	9	0.38 (0.08–1.47)	p=0.6
	No	8	0.31 (0.10–0.71)	
Yup'ik/Cup'ik (n=59)	Yes	47	1.01 (0.22–4.12)	p<0.05
	No	12	0.57 (0.20–1.62)	
White/other/mixed (n=25)	Yes	15	0.63 (0.23–1.75)	p<0.05
	No	10	0.27 (0.04–0.78)	
<u>Ate marine mammals (n=117)</u>				
Ate marine mammals (n=43)	Yes	36	0.93 (0.08–4.12)	p=0.2
	No	7	0.52 (0.20–1.62)	
Did not eat marine mammals (n=74)	Yes	41	0.70 (0.07–3.10)	p<0.001
	No	33	0.27 (0.04–1.22)	

Of the 78 women who reported consuming pike in the past year and provided a consumption estimate, hair mercury levels generally increased with increasing pike consumption when stratified by geographic region (Yukon Delta, $R^2=0.06$; Northwest, Upper Yukon, and Interior combined, $R^2=0.03$; Figure 3); however, neither correlation was statistically significant.

Figure 3. Hair Mercury Levels in Women Who Ate Northern Pike, by Location—Rural Alaska, 2007–2010 (n=78)



Discussion

The results of this evaluation show that while the mean hair mercury levels of participants in each of the four locations were higher among those who reported consuming pike than those who reported not consuming pike, none of the participants had hair mercury levels that exceeded SOE's 5 ppm threshold level of concern.^{2,4} Among women who reported consuming pike during the past year, hair mercury levels increased slightly as the number of pike meals consumed increased; however, the trends were not statistically significant. A possible explanation for the relatively “weak” dose response curve found here is that pike did not make up a substantial percentage of the diet of the project participants. Participants were asked to recall if they had eaten pike during the previous 12 months, then to estimate a typical number of pike meals per week, similar to completion of a food frequency questionnaire (FFQ). While FFQs are an important method for assessing consumption in populations, they are subject to recall bias, and may result in an inaccurate estimation of actual consumption.^{13,14} In addition, pike is not the highest contributor to the total fish diet among Alaska Native people in most settings;¹³ therefore, low consumption rates of fish high in mercury, such as pike, may not result in substantially higher hair mercury levels.

The food consumption survey was developed specifically for the project and was not pre-tested or pre-validated. The survey did not include questions about preparation methods of the fish they reported eating. Food preparation methods are known to potentially impact mercury concentration in traditional foods.¹³ For example, mercury concentrations are greater in dried fish as compared to raw or cooked fish because drying concentrates the mercury in proportion to weight. Consequently, a meal (defined by weight) of dried pike will have more mercury relative to a meal of fresh pike. Dried pike is commonly eaten in the Yukon Delta region, but

consumption rates for dried pike could not be quantified in this project. As such, while providing recommendations based on a 6-ounce dried fish meal size might not correctly approximate a person's actual meal size, it will at least serve as a reference point that consumers can follow. Consumption recommendations for this region included both fresh and dried pike.

Consumption of marine mammal tissue has previously been linked to higher than average hair mercury levels in Alaska, particularly in communities from the Yukon Kuskokwim River Delta area and the Aleutian Islands.^{4,18} In this project, when the data were stratified by marine mammal consumption, pike consumption was a significant predictor of higher mean hair mercury levels in women who did not report marine mammal consumption, but was not a significant predictor of higher mean hair mercury levels in women who also reported eating marine mammals. This was likely due to the low number of women (n=7) who reported eating marine mammals but not eating pike, as compared to the number of women who reported consuming both marine mammals and pike (n=36).

Previous studies have found substantial variability in mercury concentrations in watersheds for northern pike.⁵⁻¹⁰ Pike mercury data collected for this joint project reflect similar variability by watershed and region (Table 2, USFWS unpublished data). In this project, hair mercury levels were generally higher among women who lived in the Yukon Delta compared to women who lived in the other regions.

Table 2. Calculated Methylmercury Concentrations (parts per million) in Northern Pike from Alaska, by Region, Fish Length, and Preparation Method, 2005-2007.

Region	Fish Length ^a	Preparation Method ^b	Mean Concentration, ± Standard Deviation (Sample Size) ^c
Yukon Delta, Lower Kuskokwim River	Less than 2 ft	Fresh fish (ww)	0.22 ± 0.18 (71)
		Dried fish (dw)	1.01 ± 0.82 (71)
	More than 2 ft	Fresh fish (ww)	0.53 ± 0.32 ww (6)
		Dried fish (dw)	2.44 ± 1.44 dw (6)
Yukon Delta, Lower Yukon River	Less than 2 ft	Fresh fish (ww)	0.44 ± 0.21 ww (27)
		Dried fish (dw)	2.09 ± 1.01 dw (27)
	More than 2 ft	Fresh fish (ww)	0.61 ± 0.20 (59)
		Dried fish (dw)	2.90 ± 0.95 (59)
Interior Alaska	Less than 2 ft	Fresh fish (ww)	0.37 ± 0.22 (21)
	More than 2 ft	Fresh fish (ww)	0.53 ± 0.20 (56)
Upper Yukon River	Less than 2 ft	Fresh fish (ww)	0.35 ± 0.17 (39)
	More than 2 ft	Fresh fish (ww)	0.59 ± 0.16 (29)
Northwest, Selawik River	All lengths	Fresh fish (ww)	0.11 ± 0.05 (43)
Northwest, Buckland River	All lengths	Fresh fish (ww)	0.17 ± 0.11 (15)
Northwest, Noatak River	All lengths	Fresh fish (ww)	0.27 ± 0.11 (17)
Northwest, Kobuk River	All lengths	Fresh fish (ww)	0.29 ± 0.10 (29)

^a Due to significant differences in mean methylmercury concentrations by length, pike from the Yukon Delta, Interior, and Upper Yukon regions were divided into two length categories (under 2 feet in length vs. 2 feet or more). Pike from the Northwest region did not differ significantly in methylmercury levels by length.

^b Preparation method is either fresh (with concentrations in wet weight) or dried (with concentrations given in dry weight, dw). Dried pike is commonly consumed in the Yukon Delta region.

^c USFWS, unpublished data.

II. Fish Consumption Recommendations

The consumption recommendations presented here are based on USFWS fish mercury data collected during 2005–2007 (USFWS, unpublished data; Tables 3a–3d) and Bureau of Land Management fish mercury data collected during 2010–2012 (Table 3e),^{19,20} as interpreted following the methods used in developing the SOE 2014 fish consumption guidance.²

1. Health care providers should encourage pregnant women and women of childbearing age who consume pike from the Kuskokwim and Yukon rivers to follow the region- and fish species-specific consumption guidance as follows:

Table 3a. Pike Consumption Guidance for the Yukon Delta Region, including the lower Yukon and Kuskokwim Rivers in the Yukon Delta National Wildlife Refuge.

Preparation, location, and length of sampled pike	Methylmercury concentration (average, mg/kg) ^{2*}	Recommended meals per month ^{2†}
Fresh lower Kuskokwim River area pike <2 feet long	>0.20–0.34	Up to 16
Fresh lower Yukon River area pike, any length	>0.46–0.68	Up to 8
Fresh lower Kuskokwim River area pike ≥2 feet long	>0.46–0.68	Up to 8
Dried lower Kuskokwim River area pike <2 feet long	>0.68–1.63	Up to 4
Dried lower Kuskokwim River area pike ≥2 feet long	>2.0–3.40	Up to 1
Dried lower Yukon River area pike, any length	>2.0–3.40	Up to 1

Table 3b. Pike Consumption Guidance for the Northwest Region, including the Selawik National Wildlife Refuge and surrounding subsistence fishing rivers.

Preparation, location, and length of sampled pike	Methylmercury concentration (average, mg/kg) ^{2*}	Recommended meals per month ^{2†}
Fresh Selawik River and Buckland pike, any length	0–0.20	Unrestricted
Kobuk and Noatak River pike any length	>0.20–0.34	Up to 16

Table 3c. Pike Consumption Guidance for the Upper Yukon River Region, including the Yukon Flats National Wildlife Refuge.

Preparation, location, and length of sampled pike	Methylmercury concentration (average, mg/kg) ^{2*}	Recommended meals per month ^{2†}
Fresh upper Yukon River area pike <2 feet long	>0.34–0.46	Up to 12
Fresh upper Yukon River area pike ≥2 feet long	>0.46–0.68	Up to 8

Table 3d. Pike Consumption Guidance for the Mid-Yukon/Interior River Region, including the Koyukuk, Innoko and Nowitna National Wildlife Refuge, and surrounding subsistence fishing locations.

Preparation, location, and length of sampled pike	Methylmercury concentration (average, mg/kg) ^{2*}	Recommended meals per month ^{2†}
Fresh mid-Yukon River area pike <2 feet long	>0.34–0.46	Up to 12
Fresh mid-Yukon River area pike ≥2 feet long	>0.46–0.68	Up to 8

Table 3e. Pike, Burbot (Lush), and Arctic Grayling Consumption Guidance for the Middle Kuskokwim, George, Hoholitna, Holitna, and Takotna Rivers.

Location of sampled pike and burbot (lush)	Mercury concentration (average, mg/kg) ^{2*}	Recommended meals per month ^{2†}
Middle Kuskokwim River (Burbot liver)	0–0.2	Unrestricted
George River (Burbot liver) Middle Kuskokwim River (Burbot meat and Pike meat)	>0.20–0.34	16
Hoholitna River (Pike meat)	>0.34–0.46	12
Holitna River (Pike meat) George River (Burbot meat and Pike meat)	>0.46–0.68	8
George River (Arctic grayling meat) Takotna River (Pike meat)	>0.68–1.36	4

**This column denotes the fish consumption guideline methylmercury concentration range corresponding to the average concentration in pike*

†A meal is 6 ounces of fresh fish.

- Health care providers should encourage pregnant women and women of childbearing age to participate in the Alaska Hair Mercury Biomonitoring Program. Contact SOE's Environmental Public Health Program (907-269-8000) for information on how to collect and submit hair samples. Information is also available on the SOE Environmental Public Health Program's webpage (available at: <http://dhss.alaska.gov/dph/Epi/eph/Pages/default.aspx>).
- Health care providers should encourage all women of childbearing age, pregnant women, and parents of children to follow the State of Alaska fish consumption guidelines (available at: <http://dhss.alaska.gov/dph/Epi/eph/Documents/fish/FishConsumptionCalc.pdf>).

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The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.