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Analysis of Fin Clips: Evaluation as a Non-lethal Method for Monitoring Mercury in Fish

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Analysis of Fin Clips: Evaluation as a Non-lethal Method for Monitoring Mercury in Fish[1]

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EXECUTIVE SUMMARY

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Title of Project: Analysis of Fin Clips: Evaluation as a Non-lethal Method
for Monitoring Mercury in Fish

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Research Category: Program Interest Area I.B. (Mercury in Wisconsin)
Environmental Monitoring of Pollutants (Biomonitoring)

Project Period: May 15, 2003 – February 15, 2005

Objective of Research: To evaluate the analysis of mercury in fin clips as a nonlethal approach for surveying or monitoring mercury in game fish.

Summary of Results and Accomplishments:

Consumption of fish is the principal pathway of human exposure to methylmercury, a toxic compound affecting the quality of fishery resources in much of the northern Great Lakes Region. Wisconsin and other states routinely sample and analyze recreational fishes for mercury. Existing approaches for monitoring mercury in sport fish involve the dissection and subsequent analysis of axial muscle tissue or edible filets, a process requiring the removal of analyzed fish from the sampled population. Alternative approaches for non-lethal, non-invasive sampling for monitoring mercury in game fishes are desirable. We determined mercury in pelvic fins of two regionally important game fishes, northern pike (*Esox lucius*) and walleye (*Sander vitreus*), and statistically evaluated fin tissue as a bioindicator of mercury concentrations in the edible flesh of these fishes. The analysis of fin tissue could provide a non-lethal approach for surveying or monitoring mercury in game fish.

Mercury concentrations in pelvic fins were positively correlated with those in axial muscle tissue

of northern pike and walleye. Nearly 100% of the mercury in the pelvic fin was present as methylmercury. Concentrations of methylmercury and total mercury in the pelvic fins were about 4% of the concentrations of total mercury in the filet. There was a small, but statistically significant difference between northern pike and walleye in the amount of methylmercury in the pelvic fins relative to that in the filet; there was no statistical difference between the two species in the amount of total mercury in the fin relative to that in the filet.
Pelvic fin mercury was not consistently predictive of filet total mercury within a given lake (coefficient of determination (r^2) varied between 0.01 and 0.95 in 16 lakes). However, combining the data from all lakes resulted in a linear relationship with an r^2 greater than 0.65. Fin mercury concentrations less than 150 ng g^{-1} dry weight were used for additional analysis and comparison as fin-filet relations for both northern pike and walleye were fairly linear in this range.

The fin clip technique shows greater promise in identifying the position of a lake within the regional continuum of mercury concentrations, rather than for evaluation of within-lake variation in fish mercury content. We present examples of the potential use of the fin clip technique in estimating the fin mercury concentration that represents the upper bound of the 95% confidence interval of various mercury advisory limits. For example, our analysis indicates that pelvic fin mercury concentrations exceeding approximately 27 ng g^{-1} mercury (dry weight) are indicative of filet concentrations in excess of a consumption advisory guideline of 0.050 ppm wet weight.

Similarity of the results of the analyses of total mercury and methylmercury implies that the simpler and more cost-effective total mercury analysis may be the best method for utilizing the fin clip technique for fisheries managers. The technique may be incorporated as part of a routine sampling strategy, with rapid sample collection and minimal handling or processing concerns beyond wearing clean gloves and rinsing the fin with lake or tap water. However, prior to using this approach on a wide scale or with other species, the relation between fin and filet mercury concentrations should be established for a particular species of fish within a specific region as this relationship may be different for the same species among regions or for different species within the same region.

Future Directions and Activities: We plan on submitting this data, along with data on fin clip analyses from other geographic positions (Arctic Alaska, New England, and the Upper Midwest) as a manuscript to a relevant journal within the next 2-3 months. We will continue to add to our growing fin clip database as new samples are collected from future studies.

Introduction

Contamination of fishery resources with methylmercury is of widespread concern because consumption of fish is the principal pathway of human exposure to this highly toxic compound (Mahaffey 2000; NRC Committee on the Toxicological Effects of Methylmercury 2000; Clarkson 2002). The surveillance and monitoring of mercury in fish provides information for issuance of fish-consumption advice in Wisconsin and other states (USEPA 2003). Existing approaches for monitoring mercury in recreational fishes involve the dissection and subsequent analysis of axial muscle tissue or edible filets, a process requiring the removal of analyzed fish from the sampled population. Alternative approaches are needed for non-lethal sampling and monitoring of mercury in fish (Baker et al. 2004; Wiener et al. *in press*).

We evaluated the analysis of mercury in pelvic fins as a non-destructive approach for surveillance or monitoring of methylmercury in fish. The clipping of fins is a commonly used method of marking fish in scientific investigations. This procedure causes little or no harm to marked fish, and partially clipped fins usually regenerate (Guy et al. 1996). Removed fin tissue could be analyzed for mercury, potentially serving as a bioindicator of mercury concentrations in the axial muscle or edible filets of fish. Skurdal et al. (1986), for example, found that the concentrations of mercury in the axial muscle and adipose fin of brown trout (*Salmo trutta*) were highly correlated. However, few fishes (e.g., catfishes and salmonids) have adipose fins, and we are unaware of any previously published information on the statistical relation of mercury concentrations between fins and the edible flesh of fishes that bioaccumulate methylmercury to high concentrations.

Mercury concentrations in fish could be assessed without removing fish from the sampled population(s) if the measured concentration of methylmercury or total mercury in removed fins reflects the methylmercury content of edible fish flesh. We evaluated the analysis of mercury in fin clips of two regionally important sport fishes, northern pike (*Esox lucius*) and walleye (*Sander vitreus*), as a non-lethal approach for surveying or monitoring mercury in the axial muscle tissue of these fishes.

Methods

Fish were sampled from a total of 16 lakes (12 for northern pike, 5 for walleye) in northern Wisconsin and Minnesota (Table 1), states that have issued state-wide consumption advisories for mercury in lacustrine fishes. Inputs of mercury to most of the lakes are probably from direct or indirect atmospheric deposition (Swain et al. 1992; Engstrom and Swain 1997; Wiener et al. *in preparation*), and atmospheric influxes to the lakes are considered sufficient to supply the mass of mercury accumulating as methylmercury in fish (Wiener et al. 1992; Watras et al. 1994). The study lakes spanned a broad (~10 fold) range of methylmercury concentrations in resident game fish, based on prior surveys.

Northern pike were sampled in May and June of 2002 in 11 lakes of the Voyageurs National Park in north-central Minnesota. Northern pike and walleye were sampled in April and May of 2004 from 5 lakes in Minnesota and Wisconsin; both species were collected only from Mille Lacs Lake, Minnesota. Fish were sampled with gill nets, hook and line, and electroshocker and held on ice until placed into a conventional freezer. In the laboratory, each fish was thawed, weighed to the nearest 0.01 kg, measured (maximum total length) to the nearest millimeter, and dissected to remove pelvic fins, pectoral fins, caudal fins, and a sample of axial muscle tissue. The axial muscle tissue and fins were stored at -30°C until lyophilization at -90°C to a constant dry weight.

We analyzed a total of 200 northern pike and 90 walleyes. Samples were collected, processed with trace element "clean techniques" to reduce handling contamination, and immediately placed on ice. For total-mercury determinations, lyophilized samples of axial muscle tissue and pelvic fins were pulverized and homogenized with a mortar and pestle. A 50- to 250-mg sample of axial muscle from each fish collected in 2002 was acid digested and analyzed by flow-injection cold-vapor atomic absorption spectrophotometry with a Perkin-Elmer FIMS 100, as described by Hammerschmidt et al. (1999).

We digested 100-mg samples of axial muscle from each fish collected in 2004 and digested 20- to 100-mg samples of pelvic fin homogenate (fish from both years of sampling) in acid and bromine monochloride by modification of EPA Method 1631 (US Environmental Protection Agency 2001). Samples were digested with 10 mL of a 3:7 (v/v) solution of 16M HNO_3 and 18M H_2SO_4 in 50-mL polypropylene digestion cups (Environmental Express) for 2 to 6 h at 90^{o}C in a Teflon$^{®}$-coated graphite block followed by oxidation with 40 mL of 0.02M BrCl for 8 h at 40^{o}C in a laboratory oven. After cooling, 2 mL of 12% (w/v) hydroxylamine hydrochloride were added to each digestate, and total mercury was determined by cold vapor atomic fluorescence spectroscopy with a Leeman Labs Hydra AF Gold Plus analyzer. Methylmercury was determined by cold-vapor atomic fluorescence spectrophotometry in samples of lyophilized fin clips after extraction in 4.5M HNO_3, digestion at 60^{o}C for 12 h, derivitization to volatile ethylmethylmercury, GC column separation, and thermal decomposition to Hg^0 (Hammerschmidt and Fitzgerald 2001; Liang et al. 1994; Olson et al. 1997).

The accuracy and precision of mercury determinations were estimated by analyses of (1) procedural blanks and calibration standards, (2) triplicate subsamples, (3) spiked subsamples, and (4) certified reference materials from the National Research Council of Canada and the National Institute of Standards and Technology. Quality-assurance results are summarized in Table 2. Concentrations in all samples analyzed substantially exceeded our method detection limits, which were below 2 ng g^{-1} dry weight for total mercury and 3 ng g^{-1} for methylmercury.

Statistical analyses were conducted with SPSS software on a microcomputer. Linear regression was used to determine the relation between concentrations of mercury in axial muscle and pelvic fins from fish within each lake. The slopes of the regression equations were compared to determine if the relations were constant between species and to evaluate the utility of pelvic fins as indicators of mercury in axial muscle.

Results and Discussion

Mercury in the pelvic fins was nearly 100% methylmercury (Figure 1). This percentage is similar to that observed in axial muscle (Bloom 1992) and was unexpected given the amount of non-proteinaceous (calcified) material present in the fin rays. The coefficient of determination ($r^2 = 0.75$) indicated a strong linear relation between concentrations of total mercury and methylmercury in the pelvic fins of fish analyzed. Although significantly different from zero ($p<0.001$), the small value of the regression intercept suggests that contamination of fin samples during handling and processing is minimal. The fin samples in the present study were not “washed” of surficial contamination by any means other than a deionized water rinse, and measurable contamination of biological samples with methylmercury during handling in the field is unlikely.

Concentrations of both methylmercury (Figure 2) and total mercury (Figure 3) in pelvic fins were positively correlated with the concentration of total mercury in the axial muscle of northern pike and walleye. Fin and muscle data for all fish are shown in Figures 2a and 3a, whereas fin and muscle data for fish with fins containing less than 150 ng g^{-1} dry weight of methylmercury and total mercury are shown in Figures 2b and 3b, respectively (all walleye fins were less than this methylmercury concentration). These plots show that mercury concentrations in many northern pike in our samples were greater than those in walleyes and that the relation in northern pike was somewhat curvilinear above a fin-mercury concentration of 150 ng g^{-1}. The processes causing this curvilinear relation evident in larger fish may be physiological (e.g., more methylmercury is distributed to the fin as the fish ages) or methodological (e.g., methylmercury is somehow more extractable in larger fins). We speculate that the former explanation is the more likely scenario.

Statistical results for all linear regression statistics are provided in Table 3. For individual lakes, correlations between fin mercury and filet mercury ranged from weak to very strong (range of r^2: 0.01-0.95; median r^2: 0.39). Coefficients of determination for the combined data set for all lakes, presented in Table 3, ranged from 0.57 to 0.74. As noted, correlations were stronger and regression intercepts smaller for northern pike when only fish with fin mercury concentrations less than 150 ng g^{-1} were included in the analysis.

Concentrations of mercury were much lower in fin clips than in axial muscle, a consistent pattern observed in both species across all study sites. In northern pike, the concentration of methylmercury in fins < 150 ng g^{-1} averaged 3.4% of the concentration of total mercury in axial muscle, and the concentration of total mercury in fins averaged 3.6% of that in axial muscle. In walleye, the concentration of methylmercury in fins < 150 ng g^{-1} averaged 2.4% of the concentration of total mercury in axial muscle, and the concentration of total mercury in fins averaged 3.2% of that in axial muscle. The regression slopes in Figure 2b differed ($p<0.001$) between northern pike and walleyes, whereas the slopes in Figure 3b did not. Analysis of the data from Lake Mille Lacs, where both walleye and northern pike were analyzed, suggests a slight difference in the ratio of mercury concentrations between fin clips and axial muscle tissue between the two species, with northern pike having a greater percent methylmercury in fins (11%) than the walleye (3%).

These results suggest that data on mercury concentrations in fins are more useful as a predictor of mercury contamination of fishes on a regional, multi-lake scale than in assessing the relative mercury contamination of fish within a single lake. Fins with lower concentrations (< 150 ng g^{-1} in our samples) may provide the most reliable indicator of mercury in edible axial muscle tissue.

Concentrations of total mercury in fins may be used to indicate whether concentrations of mercury in the filet exceed a consumption advisory limit. For example, for a predetermined filet advisory concentration, mean fin concentrations above the upper bound of the 95% confidence interval of a regression of fin (Y-axis) and filet concentration (X-axis) would indicate that the fish from the lake should be considered for the consumption advisory (Figure 4). Similarly, fin concentrations below the lower bound of the confidence limit would indicate that filet concentrations probably are less than the consumption advisory concentration. The 95% confidence interval about the fin concentration is calculated by (Zar, 1996):

$$s_Y = \sqrt{s^2_{Y \cdot X}\left[\frac{1}{n} + \frac{(X_{ADV} - \bar{X})^2}{\sum x^2}\right]} \qquad \text{and} \qquad 95\%\ \text{CI} = \text{Fin Total Hg} \pm (t_{0.05(2),\ df=n-2})(s_Y)$$

where n = # paired samples

X = individual filet total Hg concentration data point

Y = individual fin total Hg concentration data point

X_{ADV} = advisory threshold filet total Hg concentration to be tested

$\bar{X}$ = mean filet total Hg concentration

$$s^2_{Y \cdot X} = \frac{\text{residual sum of squares (SS)}}{\text{residual degrees of freedom (DF)}}$$

Residual Sum of Squares = $a - \left[\frac{b}{c}\right]$

Residual Degrees of Freedom = n-2

$$a = \sum Y^2 - \frac{(\sum Y)^2}{n}$$

$$b = \sum XY - \frac{(\sum X)(\sum Y)}{n}$$

$$c = \sum X^2 - \frac{(\sum X)^2}{n}$$

For example, if we apply this approach to the regression of total Hg in fins and total Hg in filets (all fish with fins < 150 ng g^{-1}), measurements most commonly made by monitoring agencies due to their simplicity and cost relative to that of methylmercury analysis:

n = 141

X = filet total Hg concentrations, ng g^{-1} dw

Y = fin total Hg concentrations, ng g^{-1}

X_{ADV} = 250 ng g^{-1} dw (approx. 0.050 ppm ww)

$\bar{X}$ = 1668

$\sum X$ = 235138

$\sum Y$ = 7464

a = 185957

b = 4575365

c = 179517450

Residual SS = 185957

Residual DF = 139
$s^2_{Y\cdot X}$ = 1337.8
s_Y = 4.946
$t_{0.05(2),\ df=139}$ = 1.977
95% Confidence Interval = 9.778

The equation of our regression line: fin=0.0255(filet) + 10.4
Substituting 250 ng g^{-1} for the filet advisory level produces a fin concentration = 16.81 ng g^{-1} dw.

Thus, fin concentrations of 16.8 ± 9.8 ng g^{-1} represent the 95% confidence interval for our data set, given an advisory threshold of 0.250 ppm dry weight (approximately 0.050 ppm wet weight) in the filet. In other words, fish with fin concentrations greater than 27 ng g^{-1} would be expected to exceed the filet consumption advisory of 0.050 ppm wet weight and those with fin concentrations less then 17 ng g^{-1} would not. The results of similar calculations for other filet advisory limits are presented in Table 4.

The data generated by total mercury determinations were comparable to that generated by the more expensive and labor-intensive methylmercury determination. Thus, the analysis of fin clips for total mercury can provide a useful alternative or supplement to sampling approaches that require the dissection and removal of fish from the sampled populations. Although the mercury content of fin clips may not be reliably predictive for some individual lakes, it appears useful in assessing contamination among lakes that vary widely in the mercury content of fish. Moreover, this approach may be highly useful in situations requiring non-intrusive sampling, which may be required when sampling protected populations (e.g., endangered species) or when sampling in protected environments (e.g., national parks). However, prior to using this approach on a wide scale or with other species, the relation between fin and filet mercury concentrations should be established for a particular species of fish within a specific region as this relationship may be different for the same species among regions or for different species within the same region.

Acknowledgments

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Table 1. Sources, species, numbers, and size of fish analyzed for total mercury and/or methylmercury.

		Total length (mm)			Weight (g)		
Lake	n	median	minimum	maximum	median	minimum	maximum
				Northern pike			
Net, MN	33	485	367	582	670	330	1090
Ryan, MN	11	451	417	557	460	410	1060
Tooth, MN	19	440	337	529	460	240	680
Little Trout, MN	22	709	620	844	2340	1490	3720
Jorgens, MN	8	539	482	626	940	590	1240
Locator, MN	14	513	384	693	840	340	2010
Brown, MN	10	543	458	596	920	520	1130
Ek, MN	6	559	510	607	970	720	1350
Oslo, MN	25	492	363	583	670	210	1040
Mukooda, MN	24	493	461	560	810	640	1280
Agnes, MN	12	584	296	774	1365	136	3790
Mille Lacs, MN	20	741	519	974	3165	970	8130
				Walleye			
Squaw, WI	20	366	300	474	460	230	1130
Bearskin, WI	19	399	302	487	580	230	1160
Franklin, WI	12	439	306	625	880	280	3080
Tomahawk, WI	20	426	319	588	685	310	2150
Mille Lacs, MN	19	446	346	608	825	400	2440

Table 2. Results of quality-assurance analyses during determination of total mercury (THg) and methylmercury (MeHg) in fish.

Material analyzed	Performance measure	Our results	
		Thg in axial muscle and pelvic fin	MeHg in pelvic fins
Standard reference materials	Measured concentrations within the certified range	32 of 48 analyses	18 of 27 analyses
Fish tissue spiked before digestion	Percent recovery		
	mean	95.6%	92.7%
	range	87.0-102.0%	68.9% - 121.1%
Triplicate subsamples of fish	Method precision (coefficient of variation)		
	mean	6.1%	10.5%
	range	4.3 – 9.1%	4.0 – 20.9%

Table 3. Results of linear regression between concentrations of mercury in pelvic fins and axial muscle of fish (y=filet [THg], x=fin [MeHg] or [THg]). All Walleye fins were < 150 ng g^{-1} dry weight.

Fish	Data set	Fin MeHg vs. Filet	r^2	Fin THg vs. Filet	r^2
All Fish	All Data	y=18.6x + 1120	0.72	y=14.4x + 972	0.66
	Fins < 150 ng g^{-1}	y=28.9x + 566	0.74	y=24.6x + 365	0.63
Northern Pike	All Data	y=17.4x + 1369	0.67	y=13.2x + 1176	0.57
	Fins < 150 ng g^{-1}	y=29.0x + 518	0.71	y=28.0x - 113	0.69
Walleye	All Data	y=41.8x + 322	0.61	y=31.6x + 317	0.61

Table 4. Summary of 95% Confidence Intervals of fin total Hg concentrations at select filet total Hg advisory concentrations.

Filet Advisory Level ($ng\ g^{-1}$ dry weight)	Fin 95% Confidence Interval ($ng\ g^{-1}$ dry weight)
250 (0.050 ppm wet)*	16.81 ± 9.78
500 (0.100 ppm wet)	23.18 ± 8.76
1000 (0.200 ppm wet)	35.93 ± 7.08
2500 (0.500 ppm wet)	74.18 ± 7.57
5000 (1.000 ppm wet)	137.9 ± 19.0

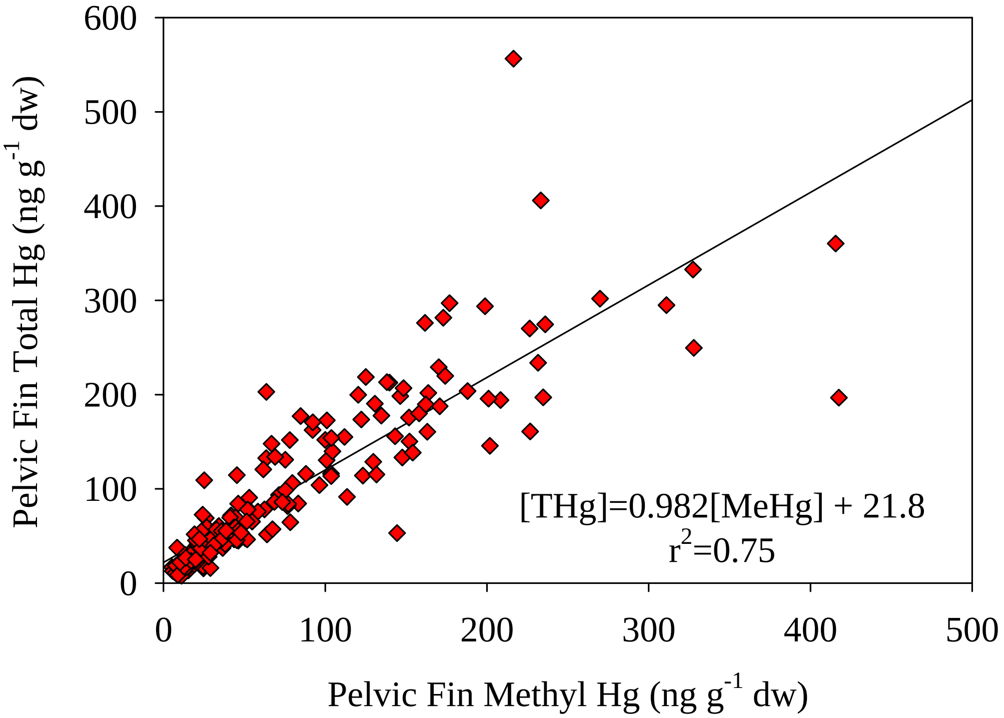
Figure Captions

Figure 1. Relation between total mercury (THg) and methylmercury (MeHg) in pelvic fins of fish.

Figure 2. (a) Relation between total mercury (THg) in axial muscle and methylmercury (MeHg) in pelvic fins of northern pike and walleye. (b) Data less than 150 ng g^{-1} fin MeHg.

Figure 3. (a) Relation between total mercury (THg) in axial muscle tissue and total mercury in pelvic fins of northern pike and walleye. (b) Data less than 150 ng g^{-1} fin THg.

Figure 4. Schematic depicting statistical application of fin clip data to consumption advisory thresholds.



600
500
400
300
200
100
0
Pelvic Fin Total Hg (ng g^{-1} dw)
0
100
200
300
400
500
Pelvic Fin Methyl Hg (ng g^{-1} dw)
[THg]=0.982[MeHg] + 21.8
r^2=0.75

Figure 1.

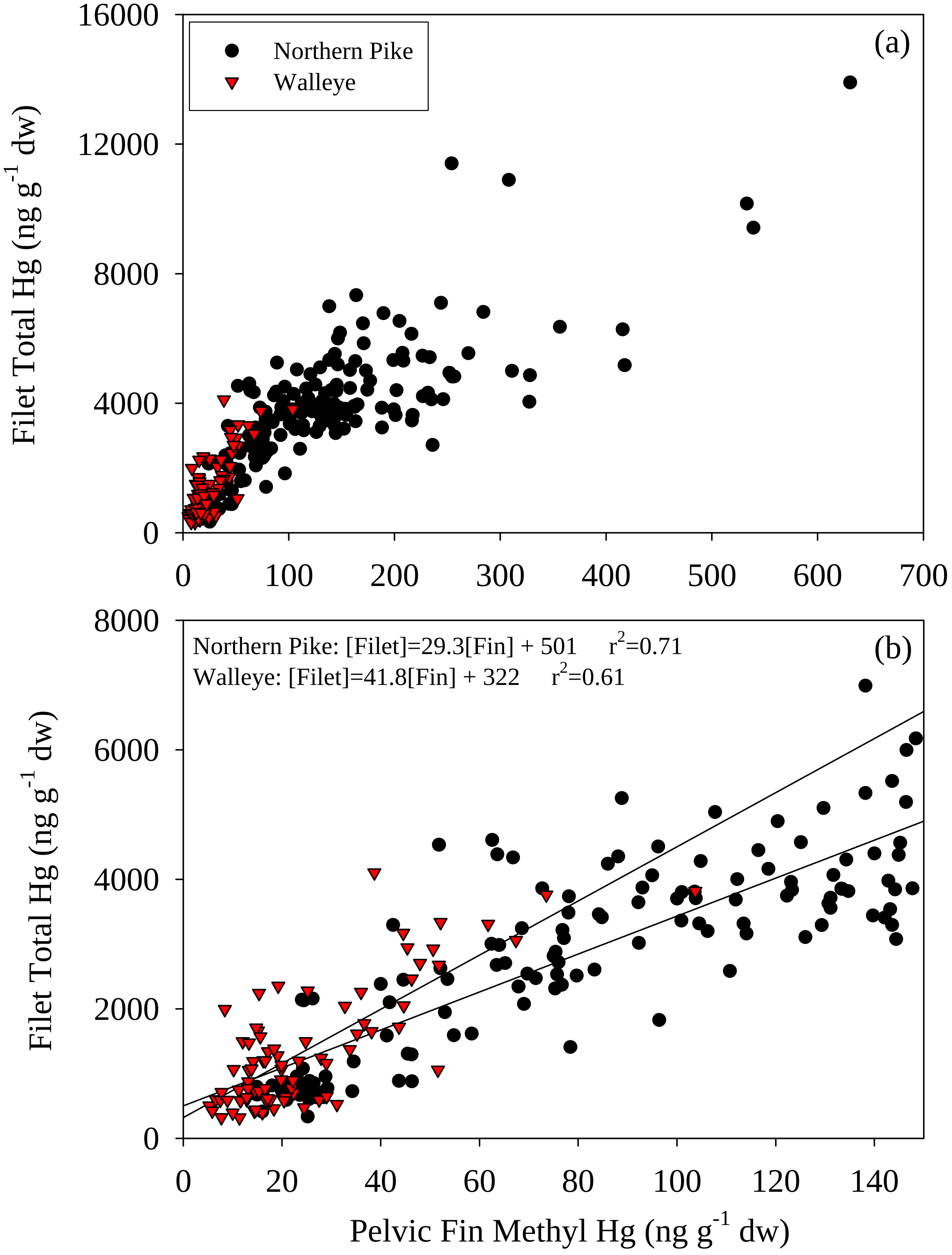

16000
12000
8000
4000
0
Filet Total Hg (ng g^{-1} dw)
Northern Pike
Walleye
(a)
0
100
200
300
400
500
600
700
8000
6000
4000
2000
0
Filet Total Hg (ng g^{-1} dw)
Northern Pike: [Filet]=29.3[Fin] + 501 r^2=0.71
Walleye: [Filet]=41.8[Fin] + 322 r^2=0.61
(b)
0
20
40
60
80
100
120
140
Pelvic Fin Methyl Hg (ng g^{-1} dw)

Figure 2.

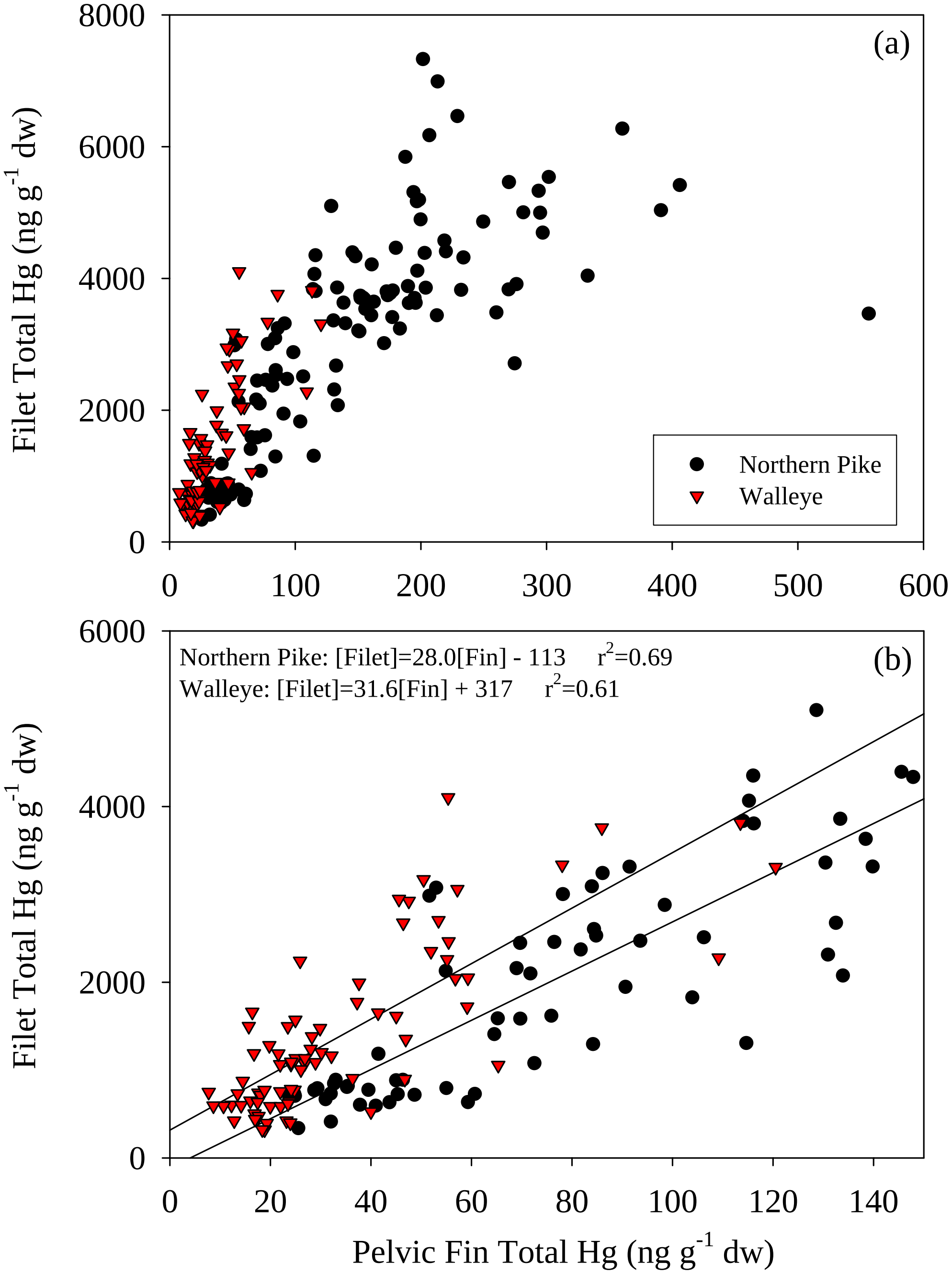

(a)
Filet Total Hg (ng g-1 dw)
8000
6000
4000
2000
0
0
100
200
300
400
500
600
Northern Pike
Walleye
(b)
Northern Pike: [Filet]=28.0[Fin] - 113 r2=0.69
Walleye: [Filet]=31.6[Fin] + 317 r2=0.61
Filet Total Hg (ng g-1 dw)
6000
4000
2000
0
0
20
40
60
80
100
120
140
Pelvic Fin Total Hg (ng g-1 dw)

Figure 3.

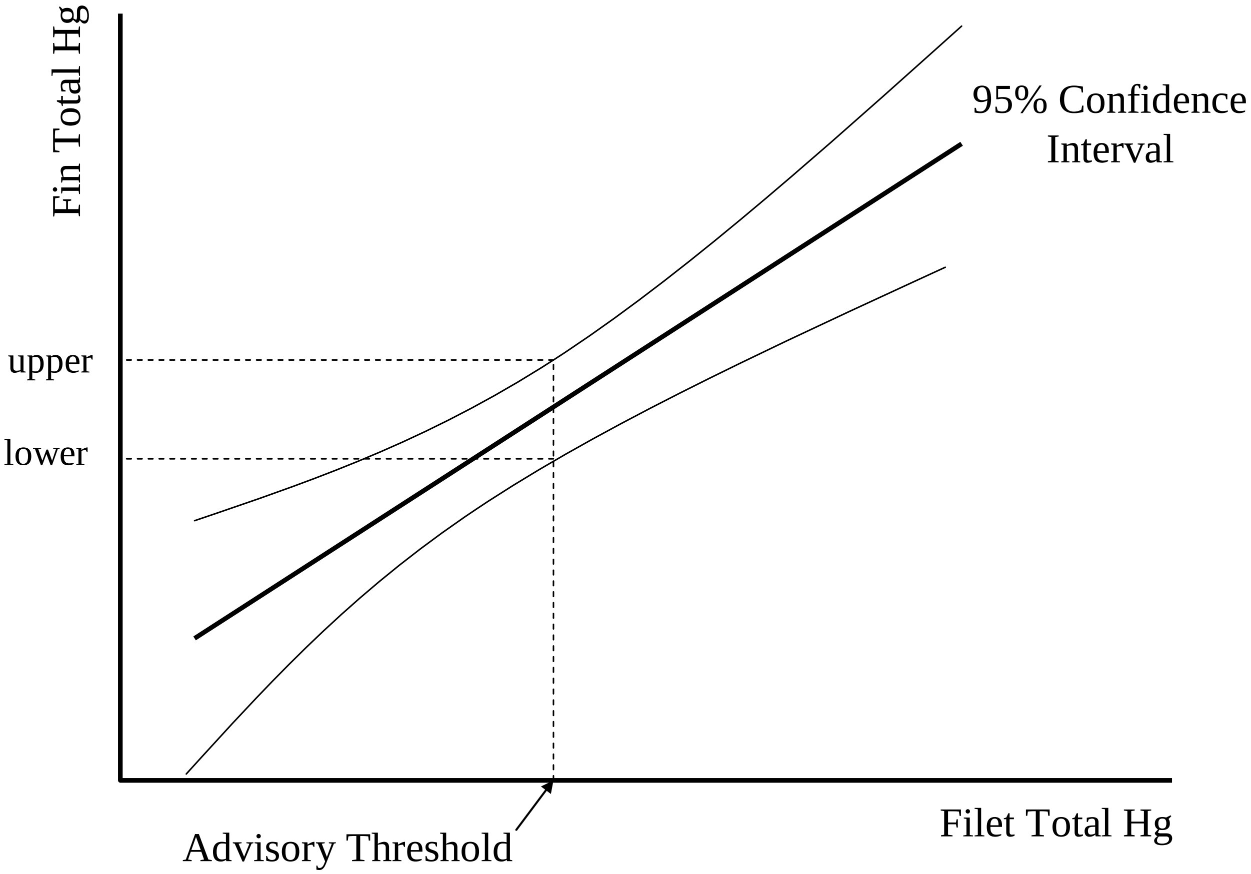

Fin Total Hg
95% Confidence Interval
upper
lower
Filet Total Hg
Advisory Threshold

Figure 4.

Appendix 1. Total and methylmercury concentrations in pelvic fins and axial muscle from the study lakes. NP=northern pike, WE=walleye, 02=2002 collection, 04=2004 collection. Missing data for fin MeHg or Fin HgT indicates that sufficient sample mass was not available for analysis of fins for both methyl and total mercury.

Lake, Sample ID	Fin MeHg (ng/g)	Fin HgT (ng/g)	Filet HgT (ng/g)
Net, MN			
NE02NP001	134.3		4304
NE02NP002	145.2		4563
NE02NP003	104.8		4281
NE02NP004	251.8		4933
NE02NP005	69.7		2543
NE02NP006	78.0		3484
NE02NP007	95.0		4060
NE02NP008	93.0		3871
NE02NP009	76.0		2718
NE02NP010	42.5		3294
NE02NP011	140.0		4400
NE02NP012	84.2		3459
NE02NP013	107.7		5036
NE02NP014	112.2		4000
NE02NP015	118.5		4159
NE02NP016	131.1		3713
NE02NP017	114.1		3163
NE02NP018	144.9		4376
NE02NP019	131.1		3559
NE02NP020	24.0		2139
NE02NP021	96.2		4504
NE02NP022	110.7		2585
NE02NP023	123.1		3957
NE02NP024	133.3		3855
NE02NP025	144.2		3844
NE02NP026	133.5		3851
NE02NP027	143.6		5515
NE02NP028	72.7		3859
NE02NP029	65.2		2704
NE02NP030	52.1		2625
NE02NP031	88.8		5250
NE02NP032	142.8		3976
Ryan, MN			
RY02NP013	204.8		6533
RY02NP014	162.9		5298
RY02NP015	533.1		10159
RY02NP016	253.9		11399
RY02NP017	630.8		13899

RY02NP018	157.9		5020
RY02NP019	308.1		10892
RY02NP020	244.0		7099
RY02NP021	189.5		6779
RY02NP022	284.0		6815
RY02NP023	207.6		5547
Tooth, MN			
TO02NP001	208.4	194.1	5309
TO02NP002	170.2	229.1	6463
TO02NP003	153.6		3825
TO02NP004	78.1	151.8	3736
TO02NP005	163.7	201.7	7330
TO02NP006	100.0	151.9	3703
TO02NP007	146.4	198.5	5192
TO02NP008	125.1	218.7	4572
TO02NP009	88.1	116.1	4351
TO02NP010	62.6		4607
TO02NP011	126.0		3109
TO02NP012	51.8		4532
TO02NP013	138.2		5332
TO02NP014	170.8	187.6	5843
TO02NP015	148.4	206.7	6173
TO02NP016	63.5	132.5	2675
TO02NP017	111.9	155.1	3686
TO02NP018	86.0		4239
TO02NP019	101.0	172.7	3799
Little Trout, MN			
LT02NP001		269.9	3831
LT02NP002	152.1	150.2	3208
LT02NP003	201.0	195.7	3628
LT02NP004	134.7	177.7	3816
LT02NP005	122.3	173.6	3745
LT02NP006		151.0	3194
LT02NP007	92.2	162.5	3645
LT02NP008	188.0	203.8	3857
LT02NP009	84.8	177.2	3411
LT02NP010		391.0	5033
LT02NP011		194.9	3703
LT02NP012		183.3	3238
LT02NP013	139.7	212.7	3440
LT02NP014		232.0	3825
LT02NP015	151.8	175.6	3774
LT02NP016	100.9	130.4	3361
LT02NP017	158.0	180.0	4463
LT02NP018	161.7	276.1	3911
LT02NP020	130.7	190.4	3626
LT02NP021	104.5	139.8	3317
LT02NP022		260.1	3482
Jorgens, MN			

JO02NP001	41.8	71.7	2099
JO02NP002	24.4	54.9	2129
JO02NP003	75.7	84.8	2531
JO02NP004	53.0	90.7	1947
JO02NP005	44.6	69.7	2448
JO02NP006	66.8	147.9	4336
JO02NP007	71.4	93.6	2472
JO02NP008	26.2	69.0	2159
Locator, MN			
LR02NP001	539.2		9417
LR02NP002	356.3		6356
LR02NP004	165.0		3958
LR02NP005	129.3		3292
LR02NP006	142.1		3408
LR02NP007			
LR02NP008	40.0		2382
LR02NP009	106.2		3200
LR02NP010	143.6		3296
LR02NP011	217.1		3632
LR02NP012	254.6		4818
LR02NP013	215.9		6137
LR02NP014	75.0		2816
LR02NP015	67.9		2345
Brown, MN			
BR02NP001	123.3	114.0	3836
BR02NP002	83.3	84.4	2605
BR02NP003	327.4	332.7	4040
BR02NP004	147.7	133.4	3860
BR02NP005	113.5	91.5	3315
BR02NP006	79.7	106.3	2510
BR02NP007	129.7	128.6	5098
BR02NP008	201.8	145.5	4395
BR02NP009	62.4	78.2	3003
BR02NP010	143.2	155.8	3538
Ek, MN			
EK02NP001	96.4	103.9	1827
EK02NP002	78.4	64.6	1409
EK02NP003	76.7	81.7	2371
EK02NP004	68.6	86.1	3242
EK02NP005	77.1	84.0	3091
EK02NP006	53.5	76.5	2458
Oslo, MN			
OS02NP001	76.8		3214
OS02NP002	116.5		4449
OS02NP003	173.0	281.5	5003
OS02NP004	199.3		3805
OS02NP005	103.6	116.2	3807
OS02NP006	327.9	249.6	4860
OS02NP007	146.5		5993

OS02NP008	311.0	294.9	4995
OS02NP009	246.1		4121
OS02NP010	269.9	301.8	5539
OS02NP011	256.5		4819
OS02NP012	226.7	160.9	4211
OS02NP013	188.1		3243
OS02NP014	138.2	213.2	6988
OS02NP015	162.2	189.7	3881
OS02NP016	154.1	138.4	3631
OS02NP017	176.9	296.9	4693
OS02NP018	144.4	53.0	3075
OS02NP020	103.8	154.0	3706
OS02NP021	226.4	270.0	5463
OS02NP022	234.8	197.1	4115
OS02NP023	63.6	202.9	4385
OS02NP024	231.6	233.8	4316
OS02NP025	417.6	196.8	5170
Mukooda, MN			
MU02NP001	75.3	130.9	2313
MU02NP002	34.5	41.5	1184
MU02NP003	23.4	32.6	846
MU02NP004	22.4	28.7	771
MU02NP005	23.6	31.0	668
MU02NP006	26.0	32.0	732
MU02NP007	16.1	23.7	713
MU02NP008	14.9	24.9	706
MU02NP009	21.0	35.4	818
MU02NP010	14.9	29.3	793
MU02NP011	40.3	45.2	
MU02NP012	26.4		852
MU02NP013	28.8		954
MU02NP014	23.0		955
MU02NP015	29.2	39.5	775
MU02NP017	14.8		680
MU02NP018	15.0		674
MU02NP019	18.0		815
MU02NP020	25.6		886
MU02NP021	22.3		773
MU02NP022	46.3	45.0	882
MU02NP023	23.0	33.0	889
MU02NP024	22.5		846
Agnes, MN			
AG02NP001	69.0	133.9	2075
AG02NP002	174.2	219.9	4410
AG02NP003	131.7	115.2	4066
AG02NP004	163.1	160.6	3440
AG02NP005	92.3	170.7	3016
AG02NP006	198.8	293.7	5330
AG02NP007	216.4	556.3	3464

AG02NP008	64.0	51.6	2983
AG02NP009	233.3	406.0	5416
AG02NP010	415.6	360.3	6274
AG02NP011	120.4	199.7	4896
AG02NP012	75.4	98.4	2879
Mille Lacs, MN			
ML04NP001	20.9	41.0	594
ML04NP002	58.4	75.9	1617
ML04NP003	22.5	24.7	727
ML04NP004	46.2	84.2	1296
ML04NP005	25.2	25.5	338
ML04NP006	20.0	45.3	724
ML04NP007	24.2	72.5	1077
ML04NP008	16.0	32.0	413
ML04NP009	28.5	43.7	634
ML04NP010	28.5	48.7	718
ML04NP011	25.5	37.8	604
ML04NP012	43.7	46.4	889
ML04NP013	22.2	35.2	807
ML04NP014	26.8	59.3	635
ML04NP015	54.8	65.2	1589
ML04NP016	41.2	69.7	1585
ML04NP017	23.4	55.0	795
ML04NP018	236.0	274.6	2710
ML04NP019	45.5	114.7	1307
ML04NP020	34.2	60.7	728
ML04WE001	24.8	15.7	1497
ML04WE002	24.5	17.7	474
ML04WE003	12.9	14.2	598
ML04WE004	29.1	16.0	649
ML04WE005	11.2	7.7	748
ML04WE006	16.6	18.8	771
ML04WE007	9.0	8.7	592
ML04WE008	11.6	20.0	585
ML04WE009	13.1	24.8	772
ML04WE010	20.8	23.8	639
ML04WE011	15.6	25.0	1570
ML04WE012	19.1	19.8	1279
ML04WE013	8.4	37.6	1992
ML04WE014	13.3	29.9	1475
ML04WE015	18.4	28.3	1381
ML04WE016	16.0	24.0	399
ML04WE018	14.7	17.0	439
ML04WE019	20.4	22.0	585
ML04WE020	12.9	17.5	633
Franklin, WI			
FR04NP001	25.8		
FR04NP002	8.9		
FR04NP003	10.3		

FR04NP004	31.5		
FR04NP005	31.0		
FR04NP006	6.1		
FR04NP007	17.7		
FR04NP008	19.5		
FR04NP009	16.7		
FR04NP010	12.7		
FR04NP011	27.6		
FR04NP012	15.1		
FR04NP013	24.2		
FR04NP014	25.1		
FR04NP015	19.5		
FR04WE001	15.3	25.9	2242
FR04WE002	14.8		1707
FR04WE003	12.0	23.5	1496
FR04WE004	14.4	23.2	422
FR04WE005	10.0	19.3	394
FR04WE006	5.3	16.9	502
FR04WE007	6.6	12.3	601
FR04WE008	5.9	12.8	423
FR04WE009	7.5	10.7	590
FR04WE010	15.3	13.5	731
FR04WE011	7.7	18.0	713
FR04WE012	7.7	18.4	321
Squaw, WI			
SQ04WE001	50.6	47.5	2924
SQ04WE002	103.7	113.5	3816
SQ04WE003	61.8	120.5	3308
SQ04WE004	51.8	46.4	2676
SQ04WE005	25.2	109.2	2278
SQ04WE006	19.2	51.9	2351
SQ04WE007	52.1	78.0	3335
SQ04WE008	44.6	50.5	3169
SQ04WE009	43.7	59.1	1721
SQ04WE010	44.7	59.3	2049
SQ04WE011	51.6	65.3	1056
SQ04WE012	46.3	55.5	2463
SQ04WE013	32.8	56.8	2042
SQ04WE014	36.7	37.3	1772
SQ04WE016	38.1	41.4	1652
SQ04WE018	36.0	55.2	2258
SQ04WE019	73.5	85.9	3758
SQ04WE020	45.4	45.6	2946
SQ04WE021	48.0	53.4	2703
SQ04WE022	35.2	45.0	1613
Bearskin, WI			
BS04WE001	13.3		1050
BS04WE002	33.7		1372
BS04WE003	17.2		1340

BS04WE004	27.5		595
BS04WE005	14.2	16.7	1187
BS04WE006	13.2	14.5	874
BS04WE007	23.4		1195
BS04WE008	22.4		703
BS04WE009	16.8		586
BS04WE010	18.4		458
BS04WE011	31.1	40.0	526
BS04WE012	17.7		600
BS04WE013	11.4	18.9	320
BS04WE014	15.4		752
BS04WE015	21.9		779
BS04WE016	16.2		1201
BS04WE017	19.8		906
BS04WE018	14.5	17.6	740
BS04WE019	15.1	16.4	1660
Tomahawk, WI			
TH04WE001	27.9	28.0	1239
TH04WE002	19.9	24.1	1068
TH04WE003	38.7	55.4	4101
TH04WE004	16.6	30.2	1200
TH04WE005	10.2	21.9	1063
TH04WE006	17.1	23.5	616
TH04WE007	67.4	57.2	3057
TH04WE008	13.8	26.8	1074
TH04WE009	19.9	25.0	1132
TH04WE010		26.1	1003
TH04WE011	22.2	46.7	895
TH04WE012	29	32.1	1161
TH04WE013		24.1	1091
TH04WE014		36.4	904
TH04WE015		21.6	1186
TH04WE016		22.0	756
TH04WE017		26.9	1133
TH04WE018		24.1	781
TH04WE019		29.0	1086
TH04WE020		46.9	1352