MINNESOTA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF FISH AND WILDLIFE

ECOLOGICAL SERVICES SECTION

Investigational Report No. 355

MERCURY LEVELS IN FISH FROM ELEVEN NORTHEASTERN MINNESOTA LAKES, 1977

April 1978

ABSTRACT

Following the discovery of elevated levels of mercury in fish from Crane Lake in northeastern Minnesota last year (1976), a study was made to see if the condition was widespread in the region and if a related source of mercury contamination could be identified.

In the study, a total of 451 game fish (mostly walleye and northern pike) from 11 large and important fishing lakes in the Rainy Lake Watershed District were analyzed for mercury. Only 2 lakes, Basswood and Sand Point Lakes, yielded fish with a mean mercury concentration above the 0.5 p.p.m. FDA action level.

A ranking of these lakes with respect to levels of mercury in fish was made by a length versus concentration regression analysis. This analysis showed that fish from Basswood and Sand Point Lakes contained relatively high levels of mercury while fish from Namakan, Vermilion and Kabetogama Lakes were relatively low in mercury. Trout, Fall, White Iron, Gunflint, Burntside and Pelican Lakes contained fish with mercury concentrations which fell between these two extremes.

No connection was seen between the levels of mercury in fish and the disposition of the parent lake in the watershed unit. No human related sources of major mercury discharges into the environment were identified and no link between the bedrock geology and mercury concentrations in fish were apparent. Differences in the methylation rates of mercury and subsequent mobilization into the fish food chain as a function of lake bottom productivity has been suggested as a possible explanation for the different levels found in the fish.

INTRODUCTION

Following last year's discovery of elevated mercury levels in fish from Crane Lake in northeast Minnesota, the Department of Natural Resources undertook a study to attempt to identify the origin and distribution of mercury in fish from other lakes in the Region.

As a matter of background it may be recalled from the Crane Lake and Rainy Lake Mercury Report dated March 1977 that the mean concentration for the 53 walleyes and 23 northern pike collected from Crane Lake was 0.79 p.p.m. and 1.18 p.p.m. respectively. The analysis showed that 40 walleyes over 16 inches in length from eastern Rainy Lake had a mean concentration of 0.61 p.p.m. mercury and 27 northern pike (all sizes) from eastern Rainy Lake had a mean mercury content of 0.51 p.p.m. The concentration of mercury in both walleyes and northern pike from western Rainy Lake was generally below 0.5 p.p.m.

It was difficult to explain why the fish from the eastern part of Rainy Lake were higher in mercury than those from the western part of the lake, or why the fish from Crane Lake were so high in mercury content. There were no significant man-made related sources of mercury pollution at either location, and it was theorized that the mercury probably resulted from stores in lake bottom sediments or from the bedrock formation. It was further hypothesized that the mercury from these sources was readily mobilized to the present extent up through the fish food chain because of the soft water chemistry of the lakes and the biological activity of bottom organisms in the sediments. Since it was evident that many of the other lakes in the region were similarly constituted it was concluded that additional study was needed. It was hoped that the extent of the problem in the region could be determined and the source of the mercury problem in Crane Lake could be identified. A brief discussion of the human health considerations of mercury and the rationale for FDA guidelines concerning consumption of fish containing mercury is included in the Appendix.

DESCRIPTION OF STUDY AREA AND FISH COLLECTIONS

In this present study, a total of 451 fish were collected and analyzed from the 12 bodies of water shown in Table 1a.

Table 1a

Identification Number	Name	County	Range	Township	Area	Remarks
16-356	Gunflint Lake	Cook	2,3,4W	65	2,240 (4,047)	Also in Canada
38-645	Basswood Lake	Lake	9,10	64,65	14,610 (29,400)	Mostly in Canada
38-811	Fall Lake	Lake	11.12	63,64	2,260 (2,322)	Also in St. Louis County
69-4	White Iron	St. Louis	11,12	62		Also in Lake County and Garden Lake Res.
69-118	Burntside Lake	St. Louis	12,13	63	10,236	Dam at outlet
69-378	Lake Vermilion	St. Louis	14-16	61-63	49,110	Dam at outlet
69-498	Trout Lake	St. Louis	15,16	63,64	9,237	Dam at outlet
69-580	Pike River Flowage	St. Louis	16	61	241	Reservoir
69-617	Sand Point	St. Louis	16,17	68,69	5,680 (8,890)	Also in Canada, part Namakan Res.
69-693	Namakan	St. Louis	17,19	69,70	14,050 (28,260)	Mostly in Canada
69-841	Pelican Lake	St. Louis	19,20	19,20	11,944	Dam at outlet
69-845	Kabetogama	St. Louis	19,22	69,70	24,800)25,720)	Also in Koochiching County, part of Namakan Reservoir System.

The geographic location of the 11 study lakes and the Pike River with respect to Crane Lake is shown in Figure 1. All of these water courses are included in the Rainy Lake Watershed Unit (Figure 1). The watershed unit lies north of the Mesabi Range and extends some 175 miles along the Canadian Border from International Falls to North Lake north of Grand Marais. Figure 1 indicates that the study lakes and Pike River can be grouped into 3 sub-watershed units. Each of the sub-watersheds ultimately flows north and/or west through Rainy Lake. White Iron, Burntside and Basswood Lakes group into a sub-watershed unit which does not flow through Crane Lake. They were included in the study because of their physical proximity to Crane Lake and their importance as fishing lakes. The selection of Pelican, Vermilion, Trout, Kabetogama, Sand Point and Namakan Lakes was predicated on their flow connection with Crane Lake and their importance as fishing lakes.

Sand Point and Namakan Lakes were included in the study at the request of the Minnesota Department of Health. The Health Department observed in a related study of their own that the majority of fish being consumed in the Crane Lake vicinity were actually caught in either Sand Point or Namakan Lakes.

The bedrock type in the Rainy Lake Watershed Unit is principally basalt, gabbro and diabase and the metal deposits identified with these types is quite diverse. The distribution of minerals was not, however, used as a criteria in the selection of study lakes for reasons of expediency.

METHODS

An effort was made to collect 50 game fish from each lake in the study group excepting Sand Point and Namakan Lakes. The target number of fish was scaled down considerably to 15 fish in these latter two lakes, because of the lateness of the decision to include them into the study. Wherever practical, game fish collections were confined to walleye and northern pike. This was done to facilitate comparisons of mercury levels between the study lakes.

The decision to analyze muscle tissue rather than nerve organ tissue was made to conform with Food and Drug Administration practices and rulings. The Food and Drug Administration recommends that consumption advisories be based on the total mercury content in the edible portions of the flesh. Moreover, it has been shown (R. C. Stiefel, Mercury in Bass and White Carp, Ohio Department of Natural Resources, Division of Wildlife, 1976) that mercury concentrations tend to accumulate on a long term basis to a greater extent in the muscle than in the organ or nervous system and of course it is here that we must be careful of potential hazards to man.

Fish collections were coordinated through and made by Minnesota Department of Natural Resources Fisheries personnel in Region 2. The method of collection was, for the most part, overnight gillnet sets. The length, weight and identity of each fish was recorded and a portion of the edible muscle tissue was sectioned off from an area directly behind the head and above the lateral line. The samples were wrapped in plastic wrap and quick frozen for shipment to the laboratory.

Mercury was analyzed using a modification of the cold vapor technique devised by Hatch and Ott (1968). A plug of tissue was removed from the frozen filet with a steel corer. The outside ends of the plug were trimmed so that the inside remainder was approximately .6 grams. This remainder was digested overnight in 4:1 sulfuric-nitric acid at 80°C. The digestate was treated with 10 ml of 6% potassium permanganate at ice temperature. When the reaction was complete 5 ml of 20% W/V hydroxylamine hydrochloride was added to destroy any remaining potassium permaganate and the final volume of the solution brought up to 50 ml with distilled water. Immediately prior to analysis, 5 ml of 20% W/V stannous chloride in 5% sulfuric acid was added to each tube of digestate and covered with a rubber septum. The contents of the tube were shaken several times to insure complete mixing and transformation of mercury to the free and vaporizable state. The headspace over the digestate was then analyzed. To do this, mercury vapor was swept through the lightpath of our atomic absorption spectrophotometer by a purge of air through the headspace into an optical absorption cell. The internal gas flow mechanism in the spectrophotometer's (Perkin Elmer Model 603) furnace was used to regulate this air purge. By doing this, the spectrophotometer could be operated with full furnace capabilities. With the push of one button, proper gas flow, chart speed, integration, microprocessing and print-out sequencing were fully coordinated, greatly simplifying the analysis. Tissue values were compared to blanks and a series of standards and spikes prepared in the same manner. Standard concentrations were calculated to correspond to the amount of sample (about .6 grams), so instrument printout with correction to precise weight could be used directly.

RESULTS

The mean concentration of mercury in the 451 fish collected from the 11 study lakes was 0.38 p.p.m. with individual values ranging from 0.03 to 2.67 p.p.m. The mean concentration of mercury in the 213 walleyes in this collection was 0.41 p.p.m. with a range corresponding to that of the entire lake collection, or again 0.03 to 2.67 p.p.m. The mean concentration of mercury in the 200 northern pike from the lake collection was 0.34 p.p.m. with a range of 0.09 to 1.29 p.p.m.

The mean concentration of mercury in the fish (8 walleyes) from the Pike River was 0.73 p.p.m., with individual values ranging from 0.36 to 1.50 p.p.m. It may be noted that the fish collected from the Pike River were captured during the spring spawning run near its outfall into Vermilion Lake. A detailed account of these results is given in Tables 1, 2, and 3 of this report.

Table 1 details the average mercury level of the total fish collection in each lake plus the Pike River. Table 2 details the average mercury level in each fish species by lake. Table 3 (Appendix) is a listing of our individual determinations for each fish in the study with corresponding length and/or weight measurements.

In comparing mercury concentrations in fish in the 11 lakes, it was found necessary to compare levels in fish of like species and size.

Results

TABLE 1

Average Mercury Levels in All Fish for Each Lake

Lake	D.O.W. No.	No. Fish	Ave. ppm Hg	Range ppm Hg
Vermilion - Pike River	———	8	0.73	0.36 - 1.50
Vermilion	69-378	52	0.20	0.09 - 0.73
Trout	69-498	50	0.38	0.11 - 0.98
Pelican	69-841	36	0.29	0.10 - 0.87
Basswood	38-645	53	0.54	0.23 - 1.95
Sand Point	69-617	15	0.84	0.21 - 2.67
Namakan	69-693	14	0.27	0.09 - 0.58
Kabetogama	69-845	36	0.16	0.03 - 0.40
Burntside	69-118	53	0.43	0.18 - 1.01
White Iron	69-4	51	0.40	0.21 - 0.78
Fall	38-811	49	0.38	0.15 - 1.29
Gunflint	16-356	42	0.43	0.12 - 1.23

TABLE 2

Average Mercury Levels in Fish by Species for Each Lake

Lake	D.O.W. No.	Species	No. Fish	Ave. ppm Hg	Range ppm Hg
Vermilion - Pike River	———	Walleye	8	0.73	0.36 - 1.50
Vermilion	69-378	Walleye	30	0.20	0.09 - 0.73
		Northern Pike	22	0.21	0.10 - 0.47
Trout	69-498	Walleye	25	0.40	0.20 - 0.95
		Northern Pike	5	0.58	0.25 - 0.98
		Lake Trout	15	0.29	0.11 - 0.50
		Smallmouth Bass	5	0.36	0.28 - 0.42
Pelican	69-841	Walleye	6	0.40	0.10 - 0.87
		Northern Pike	25	0.27	0.13 - 0.69
		Smallmouth Bass	5	0.22	0.13 - 0.36
Basswood	38-645	Walleye	28	0.61	0.24 - 1.95
		Northern Pike	25	0.42	0.23 - 0.86
Sand Point	69-617	Walleye	8	1.21	0.25 - 2.67
		Northern Pike	7	0.43	0.21 - 0.83
Namakan	69-693	Walleye	10	0.31	0.13 - 0.58
		Northern Pike	4	0.19	0.09 - 0.28
Kabetogama	69-845	Walleye	26	0.16	0.03 - 0.40
		Northern Pike	10	0.16	0.09 - 0.24
Burntside	69-118	Walleye	6	0.42	0.18 - 0.95
		Northern Pike	34	0.42	0.19 - 1.01
		Lake Trout	4	0.56	0.37 - 0.76
		Smallmouth Bass	9	0.45	0.27 - 0.65
White Iron	69-4	Walleye	26	0.46	0.26 - 0.78
		Northern Pike	25	0.34	0.21 - 0.58

To use the mercury levels in fish presented in these tables to compare lakes with it is necessary to base the comparisons between like species of fish and then on the basis of their physical size. These comparisons are developed below in the discussion section of this report.

DISCUSSION

Data has been manipulated to relate mercury concentration to length for walleyes and northern pike in each lake. The usual positive correlation was found between size and mercury concentration in both species. No attempt was made to establish the size versus mercury correlation between dissimilar species because of their differing growth rates, differing food chains and correspondingly variant pathways for mercury accumulation.

Linear regression analysis was used to develop a relationship between length of fish and expected mercury concentration.

Table 4 details the results obtained for walleyes and Table 5 the corresponding data for northern pike. Table 6, immediately following presents the supportive statistical data and equations for the regression analysis.

The length versus concentration analysis was applied only to walleye and northern pike and not the few bass and trout collected for the study. These miscellaneous species were collected to satisfy the total game fish requirement for in some lakes and such supplementation was necessary in only a few instances.

The regression calculations were extrapolated from the available data to include 14 to 40-inch northern pike and 10 to 30-inch walleyes. These particular ranges were selected and based on what is believed might be found in the anglers creel.

The purpose of these mercury concentration to length relationships are to provide a frame of reference for comparing the mercury body burdens from one lake to another and to approximate the "expected" maximum size walleye or northern pike that might be taken with under 0.5 ppm of total mercury in its muscle tissue, assuming other things to be equal. Other things are rarely equal in the real world and hence, the regression data should be taken as an idealized expression of expectations. For instance, the fish populations sampled could be mobile but were treated as a stationary population with regard to a particular lake.

Moreover, these expectations are merely central tendencies, so that for a given mercury concentration level, individual fish may show more or less mercury in their flesh than suggested by the regression data, but as a group, there would be a clustering around the calculated values. Needless to say, it has been difficult to find a single criteria, free of ambiguity, that could be used to compare the 11 study lakes on the basis of mercury levels found in the fish populations. The relationship that has been developed by matching the length of fish to the Food and Drug Administration 0.5 ppm "mercury action level" in each of the study lakes is one attempt to satisfy this end.

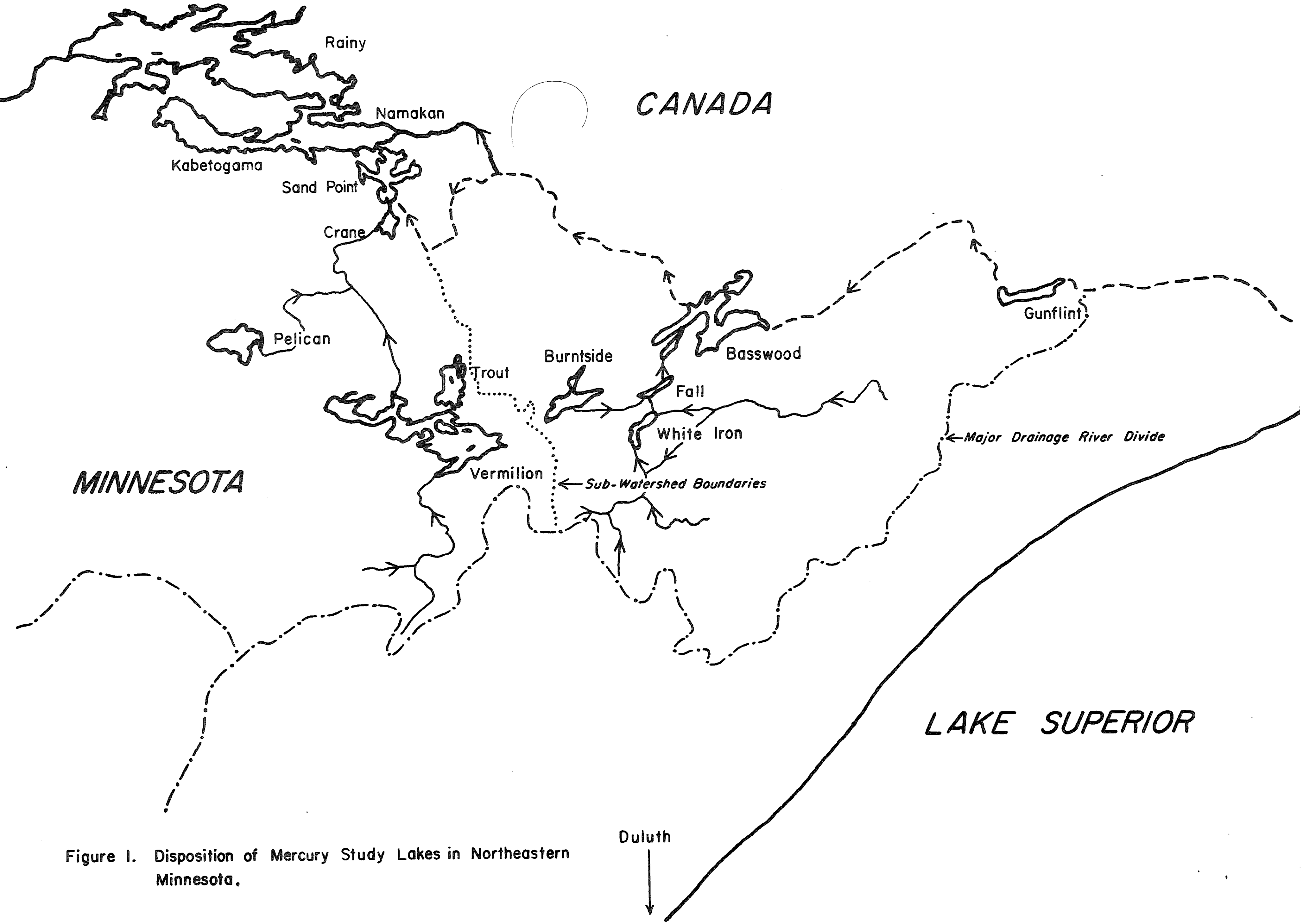
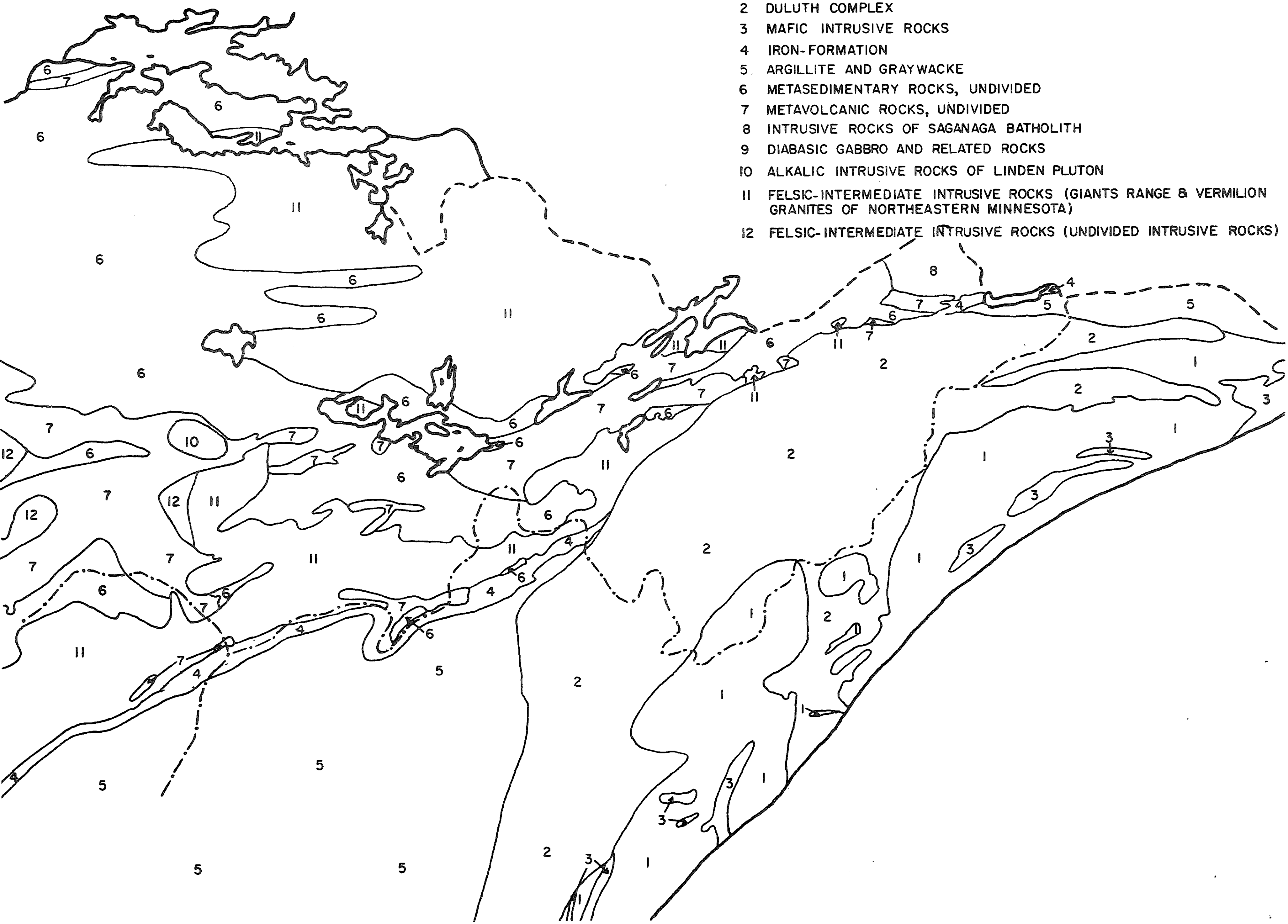


Figure 1. Disposition of Mercury Study Lakes in Northeastern Minnesota.

LEGEND

1 NORTH SHORE VOLCANIC GROUP
2 DULUTH COMPLEX
3 MAFIC INTRUSIVE ROCKS
4 IRON-FORMATION
5. ARGILLITE AND GRAYWACKE
6 METASEDIMENTARY ROCKS, UNDIVIDED
7 METAVOLCANIC ROCKS, UNDIVIDED
8 INTRUSIVE ROCKS OF SAGANAGA BATHOLITH
9 DIABASIC GABBRO AND RELATED ROCKS
10 ALKALIC INTRUSIVE ROCKS OF LINDEN PLUTON
11 FELSIC-INTERMEDIATE INTRUSIVE ROCKS (GIANTS RANGE & VERMILION GRANITES OF NORTHEASTERN MINNESOTA)
12 FELSIC-INTERMEDIATE INTRUSIVE ROCKS (UNDIVIDED INTRUSIVE ROCKS)



It may be noted that the correlation coefficient and the slope of the regression equation is negative for the Namakan Lake walleye collection. The data implies that the larger fish would tend to accumulate less mercury than the smaller fish. This trend is clearly contrary to experience and probably attributable to insufficient number of fish in the sample and insufficient spread in fish lengths.

Inspection of the regression lines shows that when matching northern pike body burdens of mercury at the 0.5 ppm "action level" threshold to length, the following order of mercury pollution in lakes is suggested:

Name of Lake	Expected length at the 0.50 ppm threshold
Basswood	21 inches
Sand Point	22
Fall	23
Trout	24
White Iron	25
Gunflint	28
Burntside	28
Pelican	30
Namakan	31
Vermilion	over 40
Kabetogama	over 40

It must be remembered that we are looking at an inverse relationship in this table, as fish length increases from lake to lake at the 0.5 ppm threshold level the corresponding mercury hazard decreases. This rationale is based on the fact that mercury in fish accumulates with growth and the rate of accumulation is governed by the amount of available mercury in their environment.

Inspection of corresponding data for walleyes shows the following ranking of lakes:

Name of Lake	Expected size (inches) of walleyes at the 0.5 ppm threshold
Sand Point	13
Basswood	15
White Iron	15
Gunflint	16
Burntside	17
Trout	18
Pelican	20

Name of Lake	Expected size (inches) of walleyes at the 0.5 ppm threshold
Fall	25
Vermilion	25
Namakan	>30
Kabetogama	>30

It can be seen that these rankings of lakes that although they do not correspond exactly, they are quite similar. If the data were combined one could expect to find highest mercury levels in fish at Sand Point and Basswood Lakes and the least in Kabetogama.

It has not been possible to determine any direct cause or to identify any point source of mercury pollution which might relate to the concentrations of mercury in fish from the eleven study lakes or Crane Lake.

In the search for a pattern, consideration was given to the disposition of lakes in the watershed, the bedrock geology of the region and the proximity of the lakes to possible sources of mercury from man related activities. None of these avenues of investigation gave an obvious pattern of mercury distribution within the study area or one which could be tied in with the results of the study.

As far as our consideration of watersheds was concerned, the ordering of lakes with respect to mercury contamination within three sub-watershed units in the Rainy Lake Watershed was tried. Making a simplistic assumption that the network of lakes in each sub-watershed could be treated as a sprawled river system which ultimately flowed into Rainy Lake, a relationship between mercury levels in fish and the disposition of the corresponding lake in the watershed unit was investigated. Working tables constructed from the data failed to show any support for this hypothesis. A limited literature search was made of the bedrock geology information in our files. Although this information was quite broad, it did not suggest any direct link of mineral deposits with the levels of mercury in the fish samples. As a matter of fact, no reported analysis of mercury deposits in the study area was found. This may be more a lack of information than an absence of mercury. Despite the inability to correlate mineral deposits with the study results, a map of the bedrock geology of the area for the general interest of the reader and for the sake of reporting completeness is included (Figure 2).

There apparently are no known major industrial discharges of mercury wastes into the study lakes, nor does there appear to be experimental data available to confirm or reject the theory of mercury fall-out from power plants. This question will probably remain moot until additional data becomes available.

A plausible explanation for the varying levels of mercury in the study lakes was offered by Mr. Russell Frazier, Head of the Minnesota Department of Health Chemistry Laboratory. Mr. Frazier suggested that the variations in mercury levels were probably associated with the productivity of the lake bottoms.

It was speculated that more mineral lake bottoms are better substrates for mercury methylating organisms than organic, "mucky bottoms", and thus effective vehicles for mercury escalations into the fish food chain.

This hypothesis is not inconsistent with the seemingly random patterns or mercury contamination seen in the study and could be reinforced by consideration of the production proclivity of organic bottoms to generate hydrogen sulfide by decay mechanisms. It has been shown that hydrogen sulfide immobilizes mercury from the biological environment by formation of a stable relatively water insoluble sulfide. Thus by comparision to the organic bottom alternative, the more mineralized bottom appears to be the better substrate for mercury enhancement in fish.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations for additional work are presented together for reporting convenience.

The present study like so many other initial surveys, will probably provoke as many questions as it will answer. To date there is only an inkling of what the total mercury problem in the region might be. However, the results of the study do suggest that only a minority of the lakes in the region are apt to have fish with elevated levels of mercury and that these problem lakes may not be necessarily connected directly to one another or even roughly grouped together. In short, the data thus far indicates that mercury may be a problem in a small percentage of selected lakes scattered throughout the region.

No pattern of mercury contamination has, thus far, been identified that can be related directly to the bedrock geology, or to man's activities. It is strongly recommended that the study project be continued to further address these considerations and to better understand the mercury situation in northeastern Minnesota for reasons of human safeguards. Moreover, additional data could lay the groundwork for an eventual relaxation or modification of the existing advisory for the northeastern lakes, especially if it is shown that only a small percentage of the lakes have high mercury fish.

In consideration of this possibility and the many unanswered questions surrounding the origin and distribution of mercury in the region it is suggested that additional fish be collected for mercury analysis from a minimum of 10 additional fishing lakes in northeastern Minnesota during the summer of 1978. The criteria of 50 game fish established in this study should be carried on into the future work. It is presumed that the specific study plan will be devised and administered by the Department of Natural Resources in cooperation with other state and federal regulatory agencies.

During this study a similar positive correlation between size and mercury concentration for both walleyes and northern pike was substantiated within individual collections. This relationship was used as a common denominator in comparing the mercury problem from one lake to the next. The question of age was not reckoned in with the size, despite the possibility that growth rates could have been different from lake to lake and thus, like size fish from different habitats could have been quite different in age. There is a possibility that rates of mercury elimination may be impaired by age. This fact could partially explain why the mercury levels were so high in the smaller walleye collected from the Pike River during their spawning run, postulating that the small fish were old males.

It is suggested that the relationship between age and mercury levels in fish be investigated. This could be done by aging the fish collections covered by this report. Scales from these fish have been saved for this contingency.

Although it has not been possible to establish any immediate connection between the distribution of fish with high levels of mercury and man related activities, additional work should be undertaken before this possibility is dismissed. In particular, it is suggested that core samples be taken and analyzed from those lakes which had fish with high mercury levels in their systems.

Knowing that the strata in the lake bottoms are built up over time, sections from a core sample can be analyzed for dating mercury accumulations historically. Analysis of the core sample can thus be used to see if any significant increase in the rate of mercury accumulations in the sediments has occurred since the beginning of industrial activity in the region. Negative findings could be testimony that the mercury problem in the study lake has been of natural origin and thus narrow the field of speculation.

It is suggested that provision be made to analyze core samples from a sampling of our study lakes, preferably those which have been shown to be problem lakes, such as Crane, Sand Point and Basswood Lakes.

Finally, it is suggested that water from the study lakes be analyzed for mercury, total alkalinity and ph. These three parameters can greatly influence the mercury levels in fish and little work has been reported on their present levels.

Discussion

TABLE 4

Walleyes

"Expected" Mercury Levels (in p.p.m.) at Different Lengths (in inches)

Length (inches)	Basswood	Burntside	Crane	Fall	Gunflint	Kabetogama	*Namakan	Pelican	Sand Point	Trout	Vermilion	White Iron
10	.04	.07	.47	.29	.11	.06	.50	.00	.00	.00	.01	.29
11	.12	.15	.58	.31	.17	.07	.46	.02	.00	.04	.04	.32
12	.21	.19	.69	.32	.23	.09	.42	.07	.12	.11	.07	.36
13	.29	.24	.80	.33	.29	.11	.38	.12	.34	.17	.10	.40
14	.38	.30	.91	.35	.35	.12	.34	.17	.57	.23	.13	.44
15	.46	.35	1.02	.36	.41	.14	.29	.22	.80	.30	.17	.48
16	.55	.41	1.13	.37	.48	.16	.25	.27	1.02	.36	.20	.52
17	.63	.47	1.24	.38	.54	.17	.21	.32	1.25	.42	.23	.56
18	.72	.53	1.35	.40	.60	.19	.17	.37	1.48	.49	.26	.60
19	.81	.58	1.46	.41	.66	.21	.13	.42	1.70	.55	.29	.64
20	.89	.64	1.57	.42	.72	.22	.09	.47	1.93	.62	.33	.68
21	.98	.75	1.68	.43	.78	.24	.05	.52	2.16	.68	.36	.72
22	1.06	.81	1.79	.45	.84	.26	.01	.57	2.38	.75	.39	.76
23	1.13	.87	1.90	.46	.91	.27	0	.62	2.61	.81	.42	.79
24	1.23	.92	2.01	.47	.97	.29		.67	2.84	.87	.45	.83
25	1.32	.98	2.12	.49	1.03	.31		.72	3.06	.94	.49	.87
26	1.40	1.03	2.23	.50	1.09	.32		.77	3.29	1.00	.52	.91
27	1.49	1.09	2.34	.51	1.15	.34		.82	3.52	1.07	.55	.95
28	1.57	1.15	2.45	.52	1.21	.36		.87	3.74	1.13	.58	.99
29	1.66	1.21	2.56	.54	1.27	.37		.92	3.97	1.20	.61	1.03
30	1.75	1.27	2.67	.55	1.33	.39		.97	4.20	1.26	.65	1.07

FDA Action Level at 0.5 ppm

* See Text

Range of Sizes of fish in sample

Discussion

TABLE 5

Northern Pike

"Expected" Mercury Levels (in p.p.m.) at Different Lengths (in inches)

Length (inches)	Basswood	Burntside	Crane	Fall	Gunflint	Kabetogama	Namakan	Pelican	Sand Point	Trout	Vermilion	White Iron
14	.22	.06	.28	.18	.13	.12	.08	.13	0	0	.15	.19
15	.26	.09	.36	.22	.16	.13	.10	.15	.02	0	.16	.22
16	.30	.12	.45	.25	.18	.13	.13	.17	.08	0	.16	.24
17	.33	.15	.53	.28	.20	.14	.15	.19	.15	0	.17	.27
18	.37	.18	.62	.32	.23	.14	.17	.22	.22	.03	.18	.29
19	.41	.22	.70	.35	.25	.15	.20	.24	.28	.11	.18	.32
20	.45	.25	.79	.38	.28	.15	.22	.26	.34	.18	.19	.35
21	.49	.28	.87	.42	.30	.15	.24	.28	.41	.25	.19	.37
22	.52	.31	.96	.45	.33	.16	.27	.31	.47	.32	.20	.40
23	.56	.34	1.05	.48	.35	.16	.29	.33	.54	.40	.21	.43
24	.60	.37	1.13	.52	.38	.17	.31	.35	.60	.47	.21	.45
25	.64	.40	1.22	.55	.40	.17	.33	.37	.67	.54	.22	.48
26	.68	.43	1.30	.58	.43	.18	.36	.39	.73	.61	.22	.51
27	.71	.46	1.39	.62	.45	.18	.38	.42	.80	.69	.23	.53
28	.75	.49	1.47	.65	.48	.18	.41	.44	.86	.76	.24	.56
29	.79	.52	1.56	.68	.50	.19	.43	.46	.93	.83	.24	.59
30	.83	.55	1.64	.72	.53	.19	.45	.48	.99	.90	.25	.61
31	.87	.58	1.73	.75	.55	.20	.48	.51	1.06	.98	.26	.64
32	.90	.61	1.81	.78	.58	.20	.50	.53	1.12	1.05	.26	.66
33	.94	.64	1.90	.82	.60	.21	.52	.55	1.19	1.12	.27	.69
34	.98	.67	1.99	.85	.63	.21	.55	.58	1.25	1.19	.27	.72
35	1.02	.70	2.07	.88	.65	.21	.57	.60	1.32	1.27	.28	.74
36	1.06	.73	2.16	.92	.67	.22	.60	.62	1.38	1.34	.29	.77
37	1.09	.76	2.24	.95	.70	.22	.62	.64	1.44	1.41	.29	.80

Discussion

TABLE 5

(Continued)

Length (inches)	Basswood	Burntside	Crane	Fall	Gunflint	Kabetogama	Namakan	Pelican	Sand Point	Trout	Vermilion	White Iron
38	1.13	.80	2.33	.98	.72	.22	.64	.67	1.51	1.48	.30	.82
39	1.17	.83	2.41	1.01	.75	.23	.67	.69	1.57	1.55	.30	.85
40	1.21	.86	2.50	1.05	.77	.23	.69	.71	1.64	1.63	.31	.88

FDA Action Level at 0.5 p.p.m.

Range of sizes of fish in sample.

TABLE 6

Linear Regression Equations, Correlation Coefficient (r) and Standard Deviation (sd) of Length versus Mercury Concentration (p.p.m. Hg vs. L) in Walleyes and Northern Pike in Study Lakes.

	Walleye	Northern Pike
Basswood	p.p.m. Hg = .08L-.81 r = .81 sd = .39 n = 6	p.p.m. Hg = .03L-.31 r = .57 sd = .16 n = 25
Burntside	p.p.m. Hg = .06L-.50 r = .95 sd = .3 n = 28	p.p.m. Hg = .03L+.30L r = .47 sd = .17 n = 33
Crane	p.p.m. Hg = .11L-.63 r = .80 sd = .32 n = 53	p.p.m. Hg = .09L-.92 r = .83 sd = .59 n = 23
Fall	p.p.m. Hg = .01L+.16 r = .42 sd = .08 n = 24	p.p.m. Hg = .03L+.28 r = .88 sd = .25 n = 25
Gunflint	p.p.m. Hg = .06L-.5 r = .82 sd = .79 n = 24	p.p.m. Hg = .026L-.21 r = .80 sd = .10 n = 18
Kabetogama	p.p.m. Hg = .01L-.07 r = .54 sd = .08 n = 26	p.p.m. Hg = .004L-.05 r = .36 sd = .05 n = 10
Namakan	p.p.m. Hg = .04L+.9 r = -.54 sd = .15 n = 10	p.p.m. Hg = .02L+.25 r = .95 sd = .08 n = 4
Pelican	p.p.m. Hg = .05L-.49 r = .97 sd = .15 n = 6	p.p.m. Hg = .02L+.19 r = .78 sd = .13 n = 25

TABLE 6
(continued)

	Walleye	Northern Pike
Sand Point	p.p.m. Hg = .22L-2.6 r = .86 sd = .87 n = 8	p.p.m. Hg = .06L-.95 r = .54 sd = .21 n = 7
Trout	p.p.m. Hg = .06L-.66 r = .77 sd = .20 n = 25	p.p.m. Hg = .07L-1.27 r = .74 sd = .35 n = 5
Vermilion	p.p.m. Hg = .03L-.31 r = .6 sd = .14 n = 30	p.p.m. Hg = .006L-.06 r = .23 sd = .098 n = 22
White Iron	p.p.m. Hg = .03L-.10 r = .50 sd = .15 n = 26	p.p.m. Hg = .02L+.13 r = .72 sd = .08 n = 25

r = Correlation Coefficient
sd = Standard deviation
n = Number of fish

APPENDIX

BACKGROUND OF TOLERANCE GUIDELINES FOR CONSUMPTION OF FISH WITH MERCURY RESIDUES

General awareness of the health hazards of mercury has been a comparatively recent event. The severity of the problem was underscored in the early 1950's when Japanese Fishermen and their families around Minimata Bay were stricken with an unexplained neurological illness.

This illness was linked to the consumption of fish and other seafood products which were derived from the bay. The fish showed accumulations of up to 50 parts per million of mercury in their flesh which is 100 times the concentration currently considered safe in the United States and Canada. The source of mercury was traced to the effluent from a factory. The neurological illness caused by this mercury contamination produced weakening of the muscles, loss of vision, impairment of other cerebral functions, eventual paralysis and death.

The Minimata Bay experience cited above is an extreme case of mercury pollution and one which can hardly be extrapolated to Minnesota. For one thing the affected people had subsisted on a seafood diet derived almost entirely from the contaminated bay. Moreover, the large quantities of mercury that had been discharged into the bay came from chemical wastes in the form of highly toxic methylmercury. Ordinarily some methylmercury is formed from the general store of less toxic mercury compounds in the environment by biochemical processes, but the quantilies involved are minute by comparison.

As a matter of fact, the overall rate of methylation of mercury in the environment is so low that the amount likely to be solubilized from the sediments and then methylated according to a Swedish Study is generally below 1% per year.

At low concentrations methylmercury toxication can produce the following symptoms; headaches, inability to concentrate and memory impairment, but these symptoms are generally reversible.

Despite the fact that there may be an understanding concern about the hazards of mercury in the environment, there should be no cause for alarm. It should be remembered that mercury compounds have been used safely for years and in fact many of these mercury compounds are still prescribed as medicines for humans. It has even been alleged by one literature citation that mercury in its metallic inorganic form, may be innocuous.

However, in a aquatic environment, biochemical transformations do occur, putting relatively insoluble mercury salts into the fish food chain. Mobilization into the food chain is accomplished by a resulting conversion of inorganic mercury salts and certain organic mercury compounds to a methylated form which is not only more soluable to fish and mammals but also more toxic.

The Food and Drug Administration (FDA) "action level" is a term used throughout this report which deserves some brief explanation. The "action level" was derived from studies conducted in Sweden in the 1960's. These studies suggested that a daily intake of 0.06 mg per day, or 0.42 mg of methylmercury per week could be safely tolerated by humans. This level would permit a daily intake of 120 grams of fish containing 0.5 parts per million of methylmercury. A safety factor of 10 was figured into this calculation. The action level may be looked at as an administrative guideline promulgated by the FDA which may prompt the federal authorities to sieze and this prevent the sale of fish in interstate commerce. In the United States and Canada, this level has been 0.5 *parts per million (milligrams of mercury per kilogram of raw, undried fish flesh) of total mercury in the edible filet. (Not should be made of the term "total mercury" for it includes all mercury residues, regardless of form or toxic potential. This may be somewhat academic since studies have shown that mercury residues in fish are almost entirely methylmercury.)

The 0.5 parts per million action level is not being applied as an enforcement tool by the State of Minnesota for fish taken by the sportsman but is rather used as a flexible guideline for the issuance of consumption advisories.

An excellent summary of the FDA Rational and Proposal is given in "Quantitative Assessment of Human Health Risk Associated with Mercury Contamination of Fish in Northern Minnesota", Minnesota Department of Health Division of Environmental Health Section of Health Risk Assessment, December 1977.

It is hoped that the very brief explanation of the health considerations of mercury in fish given above might serve to keep the results of the attached report in perspective.

*The Food and Drug Administration's Bureau of Foods recently advised its field offices that mercury in fish violations should not be reported to Washington for enforcement unless the level is above 1 p.p.m. The Bureau explained that it is reevaluating its position on mercury as a result of the recent decision of a Florida court (Food Chemical News, page 2, March 27, 1978).

APPENDIX

TABLE 3a

Mercury Levels in Individual Fish from Basswood Lake (D.O.W. No. 38-645)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)	Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	12.5	0.5	0.30	Northern Pike	15.5	0.5	0.23
Walleye	12.5	0.5	0.46	Northern Pike	16.5	1.0	0.23
Walleye	12.5	0.75	0.24	Northern Pike	16.5	1.0	0.33
Walleye	13.5	0.5	0.52	Northern Pike	17.5	1.0	0.36
Walleye	13.5	0.75	0.34	Northern Pike	17.5	1.0	0.55
Walleye	14.0	1.0	0.46	Northern Pike	19.0	1.5	0.33
Walleye	14.0	1.0	0.52	Northern Pike	19.	1.5	0.38
Walleye	14.5	0.75	0.32	Northern Pike	19.5	1.0	0.34
Walleye	14.5	1.0	0.33	Northern Pike	19.5	1.0	0.38
Walleye	15.0	1.0	0.26	Northern Pike	19.5	2.0	0.24
Walleye	15.0	1.0	0.27	Northern Pike	20.0	1.5	0.54
Walleye	15.0	1.0	0.36	Northern Pike	20.0	1.5	0.58
Walleye	15.0	1.0	0.52	Northern Pike	20.0	2.0	0.44
Walleye	15.0	1.0	0.68	Northern Pike	21.0	1.5	0.37
Walleye	15.5	1.0	0.35	Northern Pike	21.	2.0	0.42
Walleye	15.5	1.0	0.72	Northern Pike	21.0	2.0	0.42
Walleye	16.5	1.0	0.43	Northern Pike	21.0	2.0	0.51
Walleye	16.5	1.0	0.50	Northern Pike	21.5	2.0	0.72
Walleye	17.0	1.5	0.53	Northern Pike	22.0	2.0	0.44
Walleye	18.0	2.0	0.84	Northern Pike	22.0	3.0	0.84
Walleye	18.5	2.0	0.82	Northern Pike	22.5	2.5	0.61
Walleye	18.5	2.5	0.75	Northern Pike	24.0	3.5	0.52
Walleye	19.0	2.0	0.72	Northern Pike	24.0	3.5	0.55
Walleye	20.0	2.0	0.56	Northern Pike	24.0	4.0	0.86
Walleye	20.5	3.0	1.65	Northern Pike	25.5	4.5	0.39
Walleye	21.5	3.0	0.50				
Walleye	24.	4.0	1.06				
Walleye	29.0	9.0	1.95				

TABLE 3b

Mercury Levels in Individual Fish from Burntside Lake (D.O.W. No. 69-118)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	11.2	0.5	0.21
Walleye	11.5	0.5	0.18
Walleye	13.	0.75	0.26
Walleye	16.5	1.25	0.27
Walleye	20.	4.1	0.62
Walleye	24.	9.9	0.95
Northern Pike	19.5	1.5	0.25
Northern Pike	20.	3.5	0.38
Northern Pike	22.	4.	0.55
Northern Pike	22.	5.	0.26
Northern Pike	23.	2.5	0.27
Northern Pike	23.	3.8	0.35
Northern Pike	24.	3.0	0.34
Northern Pike	24.	4.0	0.23
Northern Pike	24.	4.5	0.42
Northern Pike	25.	4.5	0.65
Northern Pike	25.	5.0	0.25
Northern Pike	25.	5.0	0.36
Northern Pike	25.	5.0	0.40
Northern Pike	25.	5.0	0.45
Northern Pike	25.	5.0	0.51
Northern Pike	25.	6.1	0.31
Northern Pike	26.	4.1	0.30
Northern Pike	26.	4.2	0.38
Northern Pike	26.	4.5	0.41
Northern Pike	26.	4.5	0.42
Northern Pike	26.	4.5	0.46
Northern Pike	26.	5.5	0.32
Northern Pike	26.	5.5	0.34
Northern Pike	26.	6.0	0.31
Northern Pike	27.	6.0	0.19
Northern Pike	27.	6.0	0.37
Northern Pike	27.	6.5	0.80
Northern Pike	28.	6.0	0.68
Northern Pike	28.	7.2	0.55
Northern Pike	28.	7.5	0.38
Northern Pike	29.	7.1	0.40
Northern Pike	30.	8.0	0.28
Northern Pike	30.	9.	0.62
Northern Pike	32.	8.5	1.01
Lake Trout	21.	3.75	0.47
Lake Trout	22.	4.5	0.37
Lake Trout	25.5	6.75	0.76
Lake Trout	28.0	8.75	0.65
Smallmouth Bass	9.	0.5	0.27
Smallmouth Bass	11.5	1.	0.27
Smallmouth Bass	12.6	1.	0.52
Smallmouth Bass	13.	1.5	0.40
Smallmouth Bass	14.	1.0	0.43
Smallmouth Bass	14.	1.1	0.43
Smallmouth Bass	15.5	1.5	0.51
Smallmouth Bass	16.	3.0	0.60
Smallmouth Bass	18.0	4.5	0.65

TABLE 3c

Mercury Levels in Individual Fish from Fall Lake (D.O.W. No. 38-811)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	9.3	0.3	0.42
Walleye	9.4	0.3	0.26
Walleye	9.6	0.3	0.21
Walleye	10.2	0.3	0.26
Walleye	10.5	0.4	0.45
Walleye	10.8	0.4	0.24
Walleye	11.1	0.4	0.27
Walleye	11.3	0.5	0.25
Walleye	11.5	0.5	0.42
Walleye	11.7	0.5	0.27
Walleye	11.9	0.6	0.38
Walleye	13.2	0.7	0.28
Walleye	13.8	0.8	0.32
Walleye	13.8	0.9	0.31
Walleye	14.0	0.9	0.32
Walleye	14.3	1.0	0.33
Walleye	14.6	1.1	0.36
Walleye	15.0	1.0	0.23
Walleye	15.2	1.1	0.36
Walleye	16.3	1.4	0.52
Walleye	17.1	1.5	0.32
Walleye	17.5	1.7	0.53
Walleye	18.7	2.2	0.38
Walleye	18.8	2.1	0.39
Northern Pike	14.0	0.6	0.26
Northern Pike	14.6	0.7	0.24
Northern Pike	15.4	0.7	0.32
Northern Pike	15.4	0.8	0.15
Northern Pike	15.6	0.7	0.20
Northern Pike	15.8	0.7	0.30
Northern Pike	16.0	0.8	0.17
Northern Pike	17.2	1.1	0.28
Northern Pike	17.4	1.1	0.28
Northern Pike	17.9	1.3	0.29
Northern Pike	18.6	1.3	0.26
Northern Pike	18.7	1.4	0.33
Northern Pike	18.9	1.5	0.27
Northern Pike	19.9	1.6	0.43
Northern Pike	20.4	1.9	0.39
Northern Pike	20.7	2.0	0.54
Northern Pike	20.8	1.9	0.38
Northern Pike	21.7	2.4	0.51
Northern Pike	24.7	3.4	0.65
Northern Pike	25.9	3.9	0.61
Northern Pike	26.3	4.0	0.52
Northern Pike	27.5	5.3	0.63
Northern Pike	32.3	9.9	0.87
Northern Pike	33.7	10.4	0.42
Northern Pike	40.7	19.4	1.29

TABLE 3d

Mercury Levels in Individual Fish from Kabetogama Lake (D.O.W. No. 69-845)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	9.4	No data	0.10
Walleye	11.4	"	0.12
Walleye	12.4	"	0.15
Walleye	12.5	"	0.03
Walleye	12.5	"	0.10
Walleye	12.8	"	0.27
Walleye	13.4	"	0.14
Walleye	13.5	"	0.09
Walleye	15.3	"	0.04
Walleye	15.5	"	0.10
Walleye	15.6	"	0.11
Walleye	15.6	"	0.13
Walleye	15.8	"	0.13
Walleye	16.2	"	0.09
Walleye	17.4	"	0.23
Walleye	17.5	"	0.13
Walleye	18.2	"	0.33
Walleye	18.4	"	0.15
Walleye	18.5	"	0.21
Walleye	18.5	"	0.23
Walleye	19.0	"	0.15
Walleye	19.1	"	0.11
Walleye	19.4	"	0.23
Walleye	21.0	"	0.20
Walleye	21.0	"	0.21

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	21.3	No data	0.40
Northern Pike	15.8	"	0.11
Northern Pike	17.2	"	0.09
Northern Pike	18.0	"	0.11
Northern Pike	19.6	"	0.24
Northern Pike	23.0	"	0.12
Northern Pike	23.0	"	0.22
Northern Pike	23.4	"	0.22
Northern Pike	23.5	"	0.14
Northern Pike	24.1	"	0.17
Northern Pike	30.5	"	0.16

TABLE 3e

Mercury Levels in Individual Fish from Gunflint Lake (D.O.W. No. 16-356)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	10.	0.25	0.21
Walleye	11.5	0.5	0.36
Walleye	12.0	0.50	0.20
Walleye	12.0	0.6	0.29
Walleye	13.0	0.75	0.35
Walleye	13.0	0.8	0.28
Walleye	14.	1.0	0.37
Walleye	14.0	1.0	0.44
Walleye	15.	1.7	0.45
Walleye	16.	1.6	0.32
Walleye	16.0	2.25	0.63
Walleye	17.0	2.0	0.37
Walleye	17.0	2.75	0.37
Walleye	18.0	2.25	0.38
Walleye	18.0	2.25	0.51
Walleye	19.0	2.7	0.35
Walleye	19.	2.75	0.53
Walleye	20.0	3.1	0.54
Walleye	20.0	3.5	0.66
Walleye	21.0	3.7	0.74
Walleye	21.0	3.75	1.10
Walleye	21.0	4.75	1.18
Walleye	23.0	5.0	0.95
Walleye	26.0	5.75	1.23
Northern Pike	14.0	0.7	0.12
Northern Pike	17.0	1.0	0.27
Northern Pike	17.0	1.0	0.36
Northern Pike	17.	1.4	0.14
Northern Pike	18.	1.3	0.20
Northern Pike	18.0	1.4	0.17
Northern Pike	18.0	1.4	0.23
Northern Pike	19.0	1.6	0.24
Northern Pike	19.0	1.75	0.26
Northern Pike	20.0	1.7	0.22
Northern Pike	20.0	1.75	0.30
Northern Pike	20.0	2.0	0.29
Northern Pike	21.0	2.25	0.39
Northern Pike	22.0	2.6	0.28
Northern Pike	24.0	3.1	0.34
Northern Pike	24.0	3.25	0.35
Northern Pike	26.0	3.7	0.56
Northern Pike	28.0	6.5	0.44

TABLE 3f

Mercury Levels in Individual Fish from Namakan Lake (D.O.W. No. 69-693)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	11.5	No data	0.58
Walleye	12.5	"	0.13
Walleye	13.2	"	0.32
Walleye	13.5	"	0.35
Walleye	13.6	"	0.53
Walleye	15.4	"	0.22
Walleye	16.0	"	0.21
Walleye	16.2	"	0.40
Walleye	17.5	"	0.14
Walleye	17.5	"	0.19
Northern Pike	15.5	"	0.09
Northern Pike	16.4	"	0.15
Northern Pike	20.1	"	0.25
Northern Pike	23.3	"	0.28

TABLE 3g

Mercury Levels in Individual Fish from Sand Point Lake (D.O.W. No. 69-617)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	11.8	No data	0.31
Walleye	13.5	"	0.50
Walleye	15.1	"	0.25
Walleye	15.3	"	1.20
Walleye	18.2	"	1.46
Walleye	19.5	"	1.11
Walleye	20.1	"	2.17
Walleye	21.0	"	2.67
Northern Pike	19.2	"	0.24
Northern Pike	20.1	"	0.21
Northern Pike	20.2	"	0.37
Northern Pike	20.6	"	0.37
Northern Pike	21.5	"	0.83
Northern Pike	22.8	"	0.37
Northern Pike	24.5	"	0.60

TABLE 3h

Mercury Levels in Individual Fish from Pelican Lake (D.O.W. No. 69-841)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	9.5	No data	0.10
Walleye	13.2	No data	0.18
Walleye	16.0	"	0.18
Walleye	16.1	"	0.27
Walleye	25.4	"	0.81
Walleye	25.9	"	0.87
Northern Pike	10.8	"	0.17
Northern Pike	14.8	"	0.22
Northern Pike	15.4	"	0.16
Northern Pike	15.6	"	0.13
Northern Pike	15.8	"	0.19
Northern Pike	16.6	"	0.21
Northern Pike	18.2	"	0.18
Northern Pike	18.3	"	0.20
Northern Pike	18.5	"	0.23
Northern Pike	19.2	"	0.18
Northern Pike	19.3	"	0.19
Northern Pike	19.4	"	0.13
Northern Pike	20.2	"	0.27
Northern Pike	20.5	"	0.23
Northern Pike	21.3	"	0.22
Northern Pike	22.2	"	0.38
Northern Pike	22.5	"	0.37
Northern Pike	23.5	"	0.26
Northern Pike	23.5	"	0.30

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Northern Pike	24.1	No data	0.25
Northern Pike	25.8	No data	0.50
Northern Pike	27.0	"	0.39
Northern Pike	27.1	"	0.69
Northern Pike	27.4	"	0.41
Northern Pike	28.2	"	0.41
Smallmouth Bass	13.1	"	0.13
Smallmouth Bass	14.0	"	0.21
Smallmouth Bass	14.0	"	0.24
Smallmouth Bass	14.6	"	0.16
Smallmouth Bass	15.4	"	0.36

TABLE 3i

Mercury Levels in Individual Fish from Lake Vermillion (D.O.W. No. 69-378)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)	Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	12.4	0.75	0.20	Walleye	19.4	2.5	0.31
Walleye	12.8	0.75	0.18	Walleye	19.7	2.5	0.21
Walleye	13.	0.75	0.24	Walleye	22.2	3.	0.28
Walleye	13.4	0.75	0.17	Walleye	23.0	4.0	0.59
Walleye	13.6	0.75	0.12	Northern Pike	17.6	1.5	0.12
Walleye	14.	0.8	0.11	Northern Pike	17.8	1.5	0.17
Walleye	14.	0.8	0.15	Northern Pike	19.2	2.0	0.38
Walleye	14.1	0.75	0.12	Northern Pike	19.6	1.5	0.14
Walleye	14.4	0.9	0.13	Northern Pike	20.2	2.	0.11
Walleye	14.6	0.9	0.12	Northern Pike	21.6	2.5	0.14
Walleye	14.	1.	0.09	Northern Pike	22.4	2.5	0.14
Walleye	14.6	1.	0.22	Northern Pike	22.6	2.5	0.22
Walleye	15.0	1.	0.12	Northern Pike	23.6	2.5	0.41
Walleye	15.	1.	0.12	Northern Pike	23.8	2.5	0.21
Walleye	15.	1.	0.13	Northern Pike	24.4	3.5	0.15
Walleye	15.	1.	0.22	Northern Pike	24.4	3.5	0.23
Walleye	15.2	1.	0.12	Northern Pike	24.6	3.5	0.22
Walleye	15.4	1.	0.10	Northern Pike	25.	3.5	0.16
Walleye	15.4	1.	0.11	Northern Pike	25.	4.	0.10
Walleye	16.4	1.	0.14	Northern Pike	26.	4.	0.22
Walleye	16.4	1.	0.17	Northern Pike	26.2	4.	0.16
Walleye	17.2	1.5	0.12	Northern Pike	26.4	3.5	0.47
Walleye	17.6	2.	0.09	Northern Pike	26.6	4.	0.16
Walleye	18.2	2.	0.17	Northern Pike	27.	5.25	0.20
Walleye	18.8	2.5	0.36	Northern Pike	27.	5.25	0.28
Walleye	19.0	1.75	0.73	Northern Pike	33.	11.5	0.25

TABLE 3j

Mercury Levels in Individual Fish from Trout Lake (D.O.W. No. 69-498)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)	Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	14.0	0.8	0.25	Northern Pike	20.	1.5	0.25
Walleye	14.2	0.8	0.23	Northern Pike	25.4	4.	0.33
Walleye	14.3	1.	0.38	Northern Pike	26.	4.	0.41
Walleye	14.3	1.	0.51	Northern Pike	26.4	3.	0.98
Walleye	14.4	0.8	0.21	Northern Pike	30.	5.	0.94
Walleye	14.6	1.	0.22	Lake Trout	15.	1.	0.11
Walleye	14.6	1.0	0.26	Lake Trout	15.2	1.5	0.27
Walleye	14.8	1.	0.42	Lake Trout	16.8	1.25	0.18
Walleye	14.9	1.	0.26	Lake Trout	17.2	1.5	0.28
Walleye	15.2	1.	0.27	Lake Trout	18.0	2.	0.23
Walleye	15.6	1.25	0.21	Lake Trout	18.0	2.	0.24
Walleye	15.8	1.	0.28	Lake Trout	18.0	2.	0.25
Walleye	15.8	1.25	0.35	Lake Trout	18.4	2.25	0.31
Walleye	15.8	1.25	0.35	Lake Trout	19.4	2.0	0.36
Walleye	16.	1.	0.25	Lake Trout	19.4	2.5	0.37
Walleye	16.	1.25	0.20	Lake Trout	19.6	2.5	0.29
Walleye	17.0	2.0	0.49	Lake Trout	20.	2.	0.26
Walleye	18.3	2.25	0.62	Lake Trout	24.	4.75	0.50
Walleye	18.6	2.	0.46	Lake Trout	24.0	5.	0.36
Walleye	19.6	2.5	0.50	Lake Trout	24.8	5.5	0.28
Walleye	19.6	3.	0.63	Smallmouth Bass	11.3	0.75	0.38
Walleye	20.0	2.5	0.46	Smallmouth Bass	13.6	1.25	0.36
Walleye	20.0	3.	0.84	Smallmouth Bass	13.8	1.75	0.28
Walleye	20.3	3.	0.41	Smallmouth Bass	14.8	1.5	0.42
Walleye	21.4	3.25	0.95	Smallmouth Bass	14.8	1.75	0.36

TABLE 3k

Mercury Levels in Individual Fish from Lake Vermillion-Pike River collected during Spring Spawning Run

Species	Sex	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	M	14.2	1.	0.49
Walleye	M	15.5	1.5	0.46
Walleye	F	18.2	2.	0.77
Walleye	F	21.	4.5	0.64
Walleye	F	23.	5.5	0.36
Walleye	F	27.	7.	0.62
Walleye	F	28.5	7.	1.02
Walleye	F	29.	7.5	1.50

MERCURY LEVELS IN FISH FROM ELEVEN NORTHEASTERN MINNESOTA LAKES, 1977

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Ron Lawrenz, Dale Christensen and Howard Krosch for their assistance in laboratory analyses and in the preparation of this report.

TABLE 31

Mercury Levels in Individual Fish from White Iron Lake (D.O.W. No. 69-4)

Species	Length (inches)	Weight (lbs.)	Mercury (ppm)	Species	Length (inches)	Weight (lbs.)	Mercury (ppm)
Walleye	11.	0.6	0.37	Northern Pike	15.2	0.4	0.34
Walleye	11.5	0.75	0.33	Northern Pike	15.3	0.7	0.21
Walleye	12.	0.75	0.26	Northern Pike	16.0	0.8	0.22
Walleye	12.0	0.75	0.31	Northern Pike	16.5	0.9	0.23
Walleye	12.	0.75	0.45	Northern Pike	17.1	1.1	0.35
Walleye	13.	0.75	0.33	Northern Pike	17.4	1.0	0.25
Walleye	13.	0.75	0.46	Northern Pike	17.6	1.0	0.22
Walleye	13.5	1.	0.72	Northern Pike	18.4	0.9	0.27
Walleye	14.	1.	0.56	Northern Pike	18.9	1.2	0.29
Walleye	14.5	1.	0.26	Northern Pike	19.0	1.2	0.24
Walleye	14.5	1.	0.29	Northern Pike	19.4	1.4	0.34
Walleye	14.5	1.	0.30	Northern Pike	19.6	1.8	0.47
Walleye	14.5	1.	0.34	Northern Pike	20.1	1.6	0.27
Walleye	14.5	1.	0.42	Northern Pike	20.3	1.6	0.35
Walleye	14.5	1.	0.44	Northern Pike	20.6	2.0	0.38
Walleye	14.5	1.	0.46	Northern Pike	20.8	1.9	0.40
Walleye	14.5	1.	0.50	Northern Pike	20.9	1.9	0.37
Walleye	15.	1.	0.46	Northern Pike	20.9	2.1	0.37
Walleye	15.	1.	0.73	Northern Pike	21.0	2.0	0.36
Walleye	15.	1.	0.78	Northern Pike	21.4	2.1	0.33
Walleye	15.5	1.5	0.35	Northern Pike	21.8	2.2	0.37
Walleye	16.	1.3	0.56	Northern Pike	22.2	2.4	0.38
Walleye	16.	1.5	0.62	Northern Pike	22.6	2.8	0.47
Walleye	16.	1.75	0.37	Northern Pike	23.7	2.8	0.38
Walleye	16.5	2.	0.64	Northern Pike	23.7	3.2	0.58
Walleye	21.5	3.	0.73				