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Région de l'Ouest et du Nord

REPORT ON MERCURY IN COOKSON RESERVOIR

NOVEMBER, 1985

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WATER QUALITY BRANCH
REGINA, SASKATCHEWAN

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The opinions and conclusions expressed in this report are those of the author and do not necessarily reflect those of the Water Quality Branch.

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1.0 Summary and Conclusions

Mercury content of large fish collected in Cookson Reservoir in September of 1983 show that mercury concentrations have declined significantly in the walleye population since 1979, but have not declined in the white sucker population. The decline in the mercury concentration in walleye agrees with the results of similar work conducted in other reservoirs, where it has been postulated that the increased mercury in fish of newly formed reservoirs is due to the release of methyl mercury from the inundated soils. This release of mercury decreases with the stablization of the new bottom sediments, reducing the available mercury for biological uptake. Mercury concentrations in small fish and clams from Cookson Reservoir and the East Poplar River were low.

High concentrations of mercury were found in water samples collected in September, 1983 but were not found in subsequent samples. The validity of these high results has been questioned, but no justifable reason warrants the rejection of these data. These high mercury concentrations and others found in the limited historical data base indicates the existance of periods of high mercury in Cookson Reservoir, the cause of these periods are not known.

2.0 Recommendations

1) A survey of mercury content in tissue of fish from Cookson Reservoir should be conducted again in about 1987-88 to confirm the mercury trends in the walleye and white sucker populations.

2) It is quite possible that periods of elevated levels of mercury occur in the Cookson Reservoir due to biochemical or physical processes. In order to assess the frequency of these periods, an intensive water sampling program is required. However, if the results of the above recommended survey of mercury content in fish (1), show that mercury levels remain below the 0.5 ug/g guideline for human consumption, the need for such an intensive monitoring program is of low priority for the aquatic resource management of Cookson Reservoir.

3.0 Introduction

In 1979, the Water Quality Branch conducted a baseline survey of Cookson Reservoir prior to the start up of the Saskatchewan Power Corporation coal-fired Poplar River Power Generating Station. That survey examined metals in water, sediment and fish from Cookson Reservoir and in crayfish and clams from the East Poplar River downstream from the reservoir. Mercury was present at high levels in the muscle tissue of walleye and to a lesser extent in white suckers (Water Quality Branch, 1980). Mercury was not detected in the water and the levels found in the bottom sediment were low. Waite, et al. (1980) speculated that the cause of high mercury in fish was a function of the release of methyl-mercury from the recently flooded soil during the filling of the reservoir, and that mercury levels in fish populations would decline with time. Due to the high mercury levels in the fish Cookson Reservoir was designated 'Fish for Fun' by the Saskatchewan Department of Tourism and Renewable Resources. The 'Fish for Fun' designation identifies areas in Saskatchewan from which fish should not be taken for human consumption and suggests that fishing be for fun and the fish be released. The restriction on fish from Cookson Reservoir was removed in 1985. This study was undertaken in the fall of 1983 to further characterize the presence of mercury in Cookson Reservoir and to determine trends in mercury levels in the resident fish populations.

3.1 Study Area

Cookson Reservoir is a small reservoir on the East Poplar River in south central Saskatchewan (Figure 1). At full supply level (753. metres), the reservoir is approximately 11 kilometres long, has a surface area of 736.9 hectares and a volume of 41,166 cubic decametres (International Joint Commission, 1979). It was created by the closing of Morrison Dam in 1976, and reached full supply level in the fall of 1978. Morrison Dam is located on the East Poplar River, about 3.5 kilometers north of the international boundary. The reservoir was built by the Saskatchewan Power Corporation to supply cooling water for their coal-fired Poplar River Power Generating Station. Water flows into the reservoir from the East Poplar River and from Girard Creek, both of which are small prairie streams with typical high spring flows and limited flow, if any, during the remainder of the year. Coronach Reservoir is located immediately upstream of Cookson Reservoir on Girard Creek and is the source of drinking water for the town of Coronach. Ground water pumped from the coal seams of the open pit coal mine, approximately 12 kilometres northwest of Cookson Reservoir is discharged into Girard Creek downstream of Coronach Reservoir.

4.0 Methods

Sixteen sampling sites were established on Cookson Reservoir and on the inlet and outlet streams (Figure 2). A

Poplar River Basin

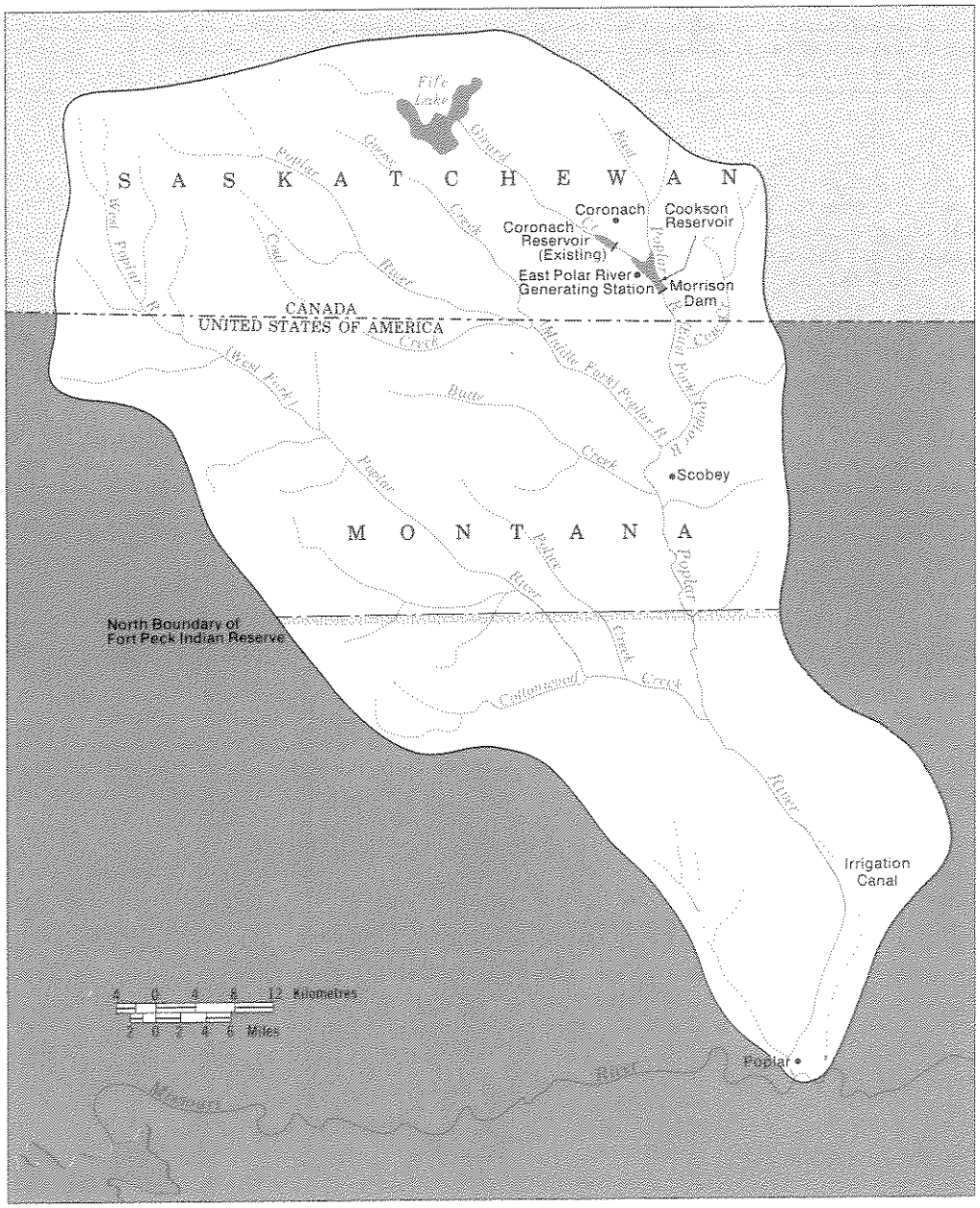

Figure 1 Map of the Poplar River Basin.

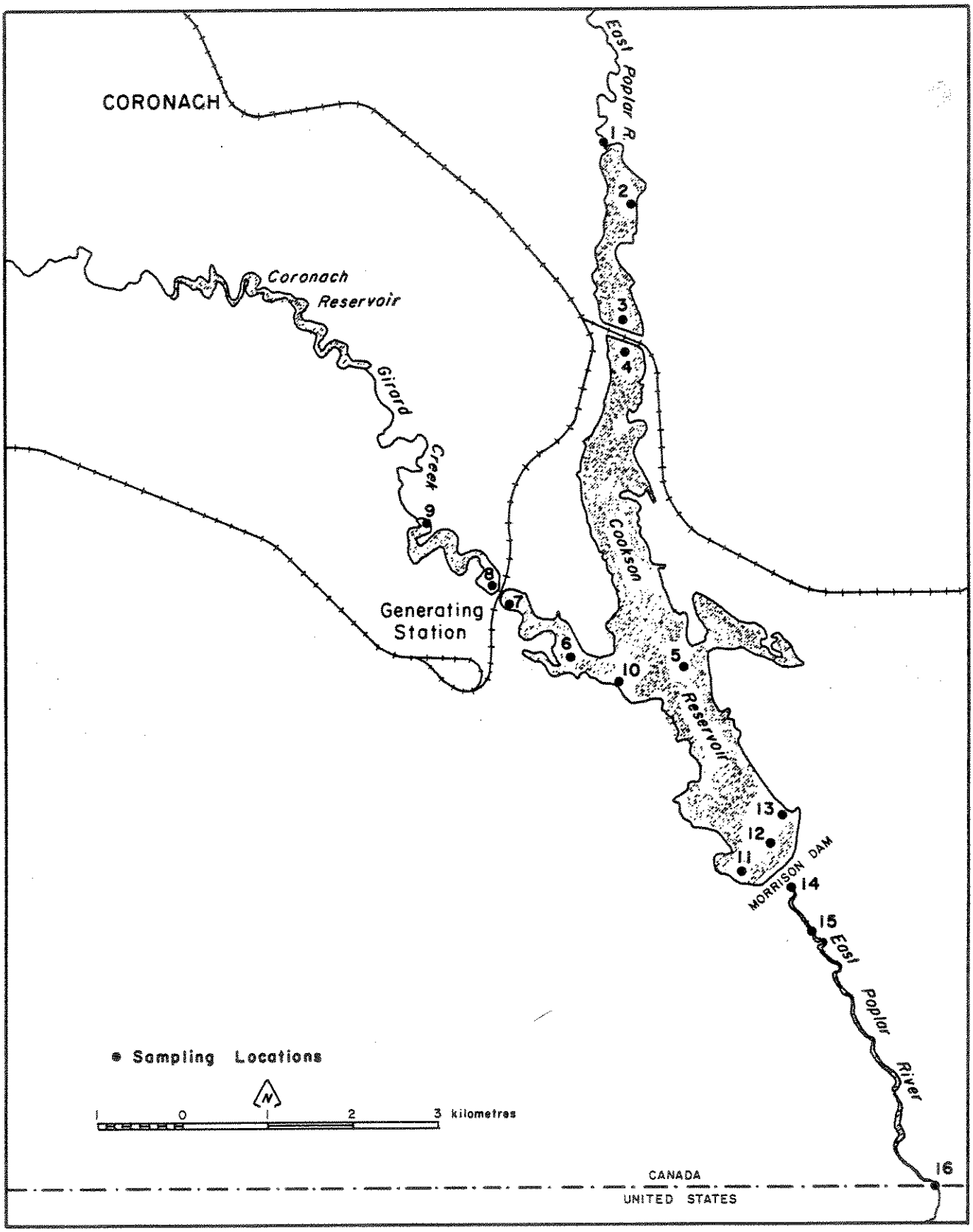

Figure 2 Map of Study Area Showing the Sampling Locations.

Table 1 List of Stations Sampled During the Study.

Map Number	Location
# 1	East Poplar River at inlet to Cookson Reservoir.
# 2	Cookson Reservoir near inlet of East Poplar River.
# 3	North End of Cookson Reservoir approximately 100 metres north of causeway.
# 4	North end of Cookson Reservoir approximately 100 metres south of causeway.
# 5	Middle of Cookson Reservoir opposite the east arm of the reservoir.
# 6	Cookson Reservoir in mouth of east arm of reservoir.
# 7	East arm of Cookson Reservoir near Water Survey of Canada gauge.
# 8	Cookson Reservoir above causeway on Girard Creek inlet.
# 9	Girard Creek at inlet to Cookson Reservoir.
# 10	Cookson Reservoir on south side of the east arm.
# 11	Cookson Reservoir approximately 300 metres east of cooling water outlet.
# 12	Cookson Reservoir approximately 300 metres from east shore opposite cooling water outlet.
# 13	Cookson Reservoir in shallow bay east of the outlet structure.
# 14	Cookson Reservoir at the control structure.
# 15	East Poplar River below the control structure.
# 16	East Polpar River at the international boundary.
N/A	Beaver River at the international boundary.

brief description of these sites is given in Table 1. One additional sampling site was established on Beaver Creek at the international boundary to provide information on mercury levels in a natural fluvial system similiar to the East Poplar River. Beaver Creek is approximately 30 kilometres east of the East Poplar River and is similar in size and drainage area. Each site was sampled during the week of September 19, 1983.

Surface water samples were collected at fifteen of the sixteen sites plus the Beaver Creek site for total mercury analysis. At the sites in the reservoir, where the water depth was greater than two metres an additional water sample was taken 0.5 metres above the bottom using an alpha bottle. Additional water samples were collected at some sites on March 14, 1984 and October 1, 1984. Poor ice conditions on Cookson Reservoir, allowed collection of water samples only from site 3 during March of 1984. All water samples were put in 250 mL teflon bottles and preserved with concentrated sulfuric acid and 5 % potassium dichromate solution (Water Quality Branch, 1983). Samples were analyzed at the Water Quality Branch National Laboratory in Burlington. Total mercury was determined by flameless atomic absorption on an autoanalyzer after wet digestion and reduction with stannous sulphate, method 80011, (Water Quality Branch, 1985).

Bottom sediments were collected at 13 sites using an ekman dredge. Samples were taken from the top two centimeters of sediment in the dredges. The samples were frozen in

polyethylene bags on the day of collection and remained frozen until analyzed at the National Water Research Institute Laboratory in Winnipeg. Total mercury was determined on 0.5 g wet sample which was digested with 10.0 mL aqua regia, volumed to 25.0 mL, and read by semi-automated flameless atomic absorption spectrophotometer.

Large fish species were collected at site 10 on Cookson Reservoir using a gill net. The fish were identified, weighed, measured and scales taken for aging before a sample of dorsal skeletal muscle was taken for mercury analysis. Small fish samples were collected at seven sites including the Beaver Creek site using a beach seine. These fish were identified and divided by species into samples for mercury analysis. Each sample consisted of a group of whole fish with minimum combined weight of five grams. Clams were collected from the East Poplar River at the international boundary and at the Beaver Creek site. Clams were identified and the foot muscle removed for mercury analysis. All biological samples were frozen in polyethylene bags on the day of collection and remained frozen until analyzed for mercury by the Department of Fisheries and Oceans at the Freshwater Institute in Winnipeg. Total mercury in biological samples was determined by semi-automated atomic absorption spectrophotometer after digestion in concentrated sulfuric and nitric acid (Hendzel and Jamieson, 1976).

5.0 Results and Discussion

5.1 Water

Mercury was found in all water samples collected in September, 1983 (ranging from 0.02 to 0.19 ug/L) but was below the analytical detection limit in all samples collected in March and October of 1984 (Table 2). The detection of mercury in September water samples was not anticipated and there is some question as to the confidence that should be placed in these results. However, after investigating the possibility of contamination, no justification could be found to discard the results as being invalid. In part, the validity of the results is substantiated by the presence of a pattern. The samples from the two inlet streams had the highest mercury concentration (0.19 and 0.16 ug/L). Within the reservoir, bottom samples were greater than surface samples at all but site 5 where the concentrations were equal and the sample from Beaver Creek was the lowest, 0.02 ug/L, the analytical detection limit. Repeat analysis conducted on seven samples confirmed the high mercury results. Unfortunately, blank samples were not submitted for mercury analysis with these samples with high mercury. Blank samples submitted later using the same preservatives and alpha bottle all had non-detectable mercury concentrations.

Total mercury concentration in the leachates of soils to be flooded by the creation of Cookson Reservoir ranged from less than 0.05 to 1.28 ug/L (International Joint Commission, 1979).

Table 2. Mercury Results for Water and Bottom Sediment Samples.

Map Number	Date Sampled	Total Mercury in Water (ug/L) Surface	Bottom	Bottom Sediment Mercury (ug/g)	Moisture (%)
# 1	Sept 20,1983	0.19		0.02	24.5
	Oct 1,1984	L0.02			
# 2	Sept 20,1983	0.12		0.03	48.6
# 3	Sept 20,1983	0.08	0.11	0.03	67.5
	Mar 14,1984	L0.02	L0.02		
	Oct 1,1984	L0.02	L0.02		
# 4	Sept 20,1983	0.09	0.17	0.03	47.6
	Oct 1,1984	L0.02	L0.02		
# 5	Sept 21,1983	0.07	0.07	0.01	36.2
# 6	Sept 20,1983	0.05	0.10	0.01	57.7
	Oct 1,1984	L0.02	L0.02		
# 8	Sept 20,1983	0.06		0.02	31.8
# 9	Sept 19,1983	0.16		0.01	35.6
	Oct 1,1984	L0.02			
# 11	Sept 21,1983	0.04	0.13	0.03	52.8
	Oct 1,1984	L0.02	L0.02		
# 12	Sept 21,1983	0.08	0.14	0.02	62.0
	Oct 1,1984	L0.02	L0.02		
# 13	Sept 21,1983	0.13		0.01	27.0
# 15	Sept 22,1983	0.07		0.01	24.1
# 16	Sept 22,1983	0.10		L0.01	30.7
	Mar 14,1984	L0.02			
	Oct 1,1984	L0.02			
Beaver Creek	Sept 22,1983	0.02			

Note: Mercury in sediment is total mercury based on wet weight

On the basis of these studies mercury concentration in Cookson Reservoir water were predicted to reach 0.62 ug/L. Elevated mercury has been detected sporadically, occuring in 18 of 66 water samples from Cookson Reservoir and in 21 of 108 samples from the East Poplar River at the international boundary (Table 3). Only one sample from Cookson Reservoir has been equal to or greater than the concentration predicted by the International Joint Commission and no extended periods of elevated mercury has been recorded. The recognized potential of mercury leaching from the soil and positive mercury results on numerous occasions help substantiate the validity of the high mercury levels observed in the September 1983 samples.

The processes causing these high mercury concentrations in the reservoir are not known. The Canada-Ontario Steering Committee, (1983) report on studies conducted on the Wabigoon-English River System described seasonal trends in mercury concentration in water from that system. Maximum mercury concentration occurred at different times of the year in different locations in the system. A variety of reasons for the occurrence of these peaks were suggested: dieoff of algal populations in the fall resulting in the release of mercury; biological activity in the bottom sediment which is greater at higher temperatures causing higher mercury concentration when the water is warmer; and seasonal lake turnover which causes movement of mercury from the sediment/water interface to move into the water column. Any or all of these factors may

Table 3. Historical Mercury Concentrations in the Water of Cookson Reservoir and the Inlet and Outlet Streams

Location	Collection Agency	Sampling Period	No. of Samples	No. of Detections	Highest Conc. (ug/L)	Date of Highest Conc.
Girard Creek upstream of Cookson Reservoir.	SPC	1980-1983	4	1	0.3	12/81
North end of Cookson Reservoir south of causeway.	WQB	1977-1979	30	5	0.09	05/04/77
	SPC	1980-1983	4	1	0.3	12/81
South end of Cookson Reservoir.	WBQ	1977-1979	28	9	0.21	06/07/79
	SPC	1980-1983	4	3	0.9	11/82
Outlet from Cookson Reservoir.	SPC	1980-1983	4	1	0.3	11/83
East Poplar River at the international boundary.	WQB	1974-1984	108	21	0.15	22/03/76

Note: - WQB denotes the Water Quality Branch, Environment Canada
- SPC denotes the Saskatchewan Power Corperation
- Mercury results are for total mercury

contribute to the high level of mercury found in Cookson Reservoir in September of 1983 and the occurrence of high mercury concentrations on occasion throughout the historical data base. Intensive sampling designed to determine fluctuations such as these, would be required to confirm the validity of these high concentrations.

5.2 Bottom Sediment

The mercury concentrations found in the bottom sediment samples from Cookson Reservoir in 1983 ranged from less than 0.01 to 0.03 ug/g (Table 2) and are similar to the concentrations found in 1979, which range from 0.008 to 0.056 ug/g. Sherbin (1979) reports that cultivated and uncultivated soils in Saskatchewan have mercury concentrations ranging from 0.01 to 0.06 ug/g. Considering this information and unpublished data from Saskatchewan Environment suggest the bottom sediment mercury concentration in this range are typical of background concentrations found in unpolluted prairie systems.

5.3 Large Fish Species

Mercury concentration in the dorsal muscle of large fish collected from Cookson Reservoir on September 21, 1983 are presented in Table 4. These data are also shown in Figures 3 and 4 with 1979 (Water Quality Branch, 1980) and 1980 data (unpublished data) from Saskatchewan Power Corporation for the

Table 4 Mercury and Physical Data for Large Fish Collections from Cookson Revervoir, September 21, 1983.

Species	Collection Site	Fork Length (cm)	Weight (g)	Age	Mercury (ug/g)
Walleye	# 10	23.5	112.0	3+	0.110
Walleye	# 10	22.5	112.0	3+	0.110
Walleye	# 10	23.0	112.0	3+	0.120
Walleye	# 10	23.0	112.0	4+	0.100
Walleye	# 10	23.0	112.0	3+	0.070
Walleye	# 10	23.0	112.0	4+	0.080
Walleye	# 10	22.5	112.0	4+	0.070
Walleye	# 10	23.0	112.0	4+	0.100
Walleye	# 10	23.5	112.0	4+	0.070
Walleye	# 10	15.5	56.0	2+	0.070
Walleye	# 10	26.0	168.0	4+	0.130
Walleye	# 10	25.0	140.0	4+	0.090
Walleye	# 10	25.5	140.0	4+	0.070
Walleye	# 10	27.0	224.0	5+	0.150
Walleye	# 10	26.0	168.0	4+	0.090
Walleye	# 10	43.5	728.0	8+	0.440
Walleye	# 10	40.5	672.0	7+	0.560
Walleye	# 10	39.0	616.0	6+	0.410
Walleye	# 10	43.0	840.0	6+	0.860
Walleye	# 10	33.0	364.0	5+	0.290
Walleye	# 10	29.0	252.0	5+	0.140
Walleye	# 10	35.0	420.0	5+	0.290
Walleye	# 10	36.5	504.0	6+	0.240
Walleye	# 10	40.5	728.0	8+	0.650
Walleye	# 10	35.5	392.0	5+	0.240
Walleye	# 10	40.5	616.0	8+	0.330
Walleye	# 10	33.5	392.0	6+	0.240
W. Sucker	# 10	34.0	616.0	4+	0.250
W. Sucker	# 10	34.0	588.0	4+	0.290
W. Sucker	# 10	35.5	616.0	4+	0.270
W. Sucker	# 10	34.5	560.0	4+	0.190
W. Sucker	# 10	35.0	672.0	4+	0.410
W. Sucker	# 10	34.0	588.0	4+	0.160
W. Sucker	# 10	34.0	588.0	4+	0.170
W. Sucker	# 10	33.5	560.0	4+	0.300
W. Sucker	# 10	34.5	532.0	3+	0.320
W. Sucker	# 10	35.0	700.0	4+	0.330
W. Sucker	# 10	40.0	868.0	5+	0.290
W. Sucker	# 10	37.5	728.0	4+	0.250
W. Sucker	# 10	41.0	952.0	5+	0.240
W. Sucker	# 10	37.5	756.0	4+	0.560
W. Sucker	# 10	39.5	896.0	4+	0.200
W. Sucker	# 10	36.0	728.0	4+	0.300
W. Sucker	# 10	39.5	952.0	5+	0.333
W. Sucker	# 10	36.0	728.0	4+	0.360
W. Sucker	# 10	41.0	1064.0	5+	0.240
W. Sucker	# 10	41.0	980.0	5+	0.260

Note: - Mercury results are total mercury based on wet weight

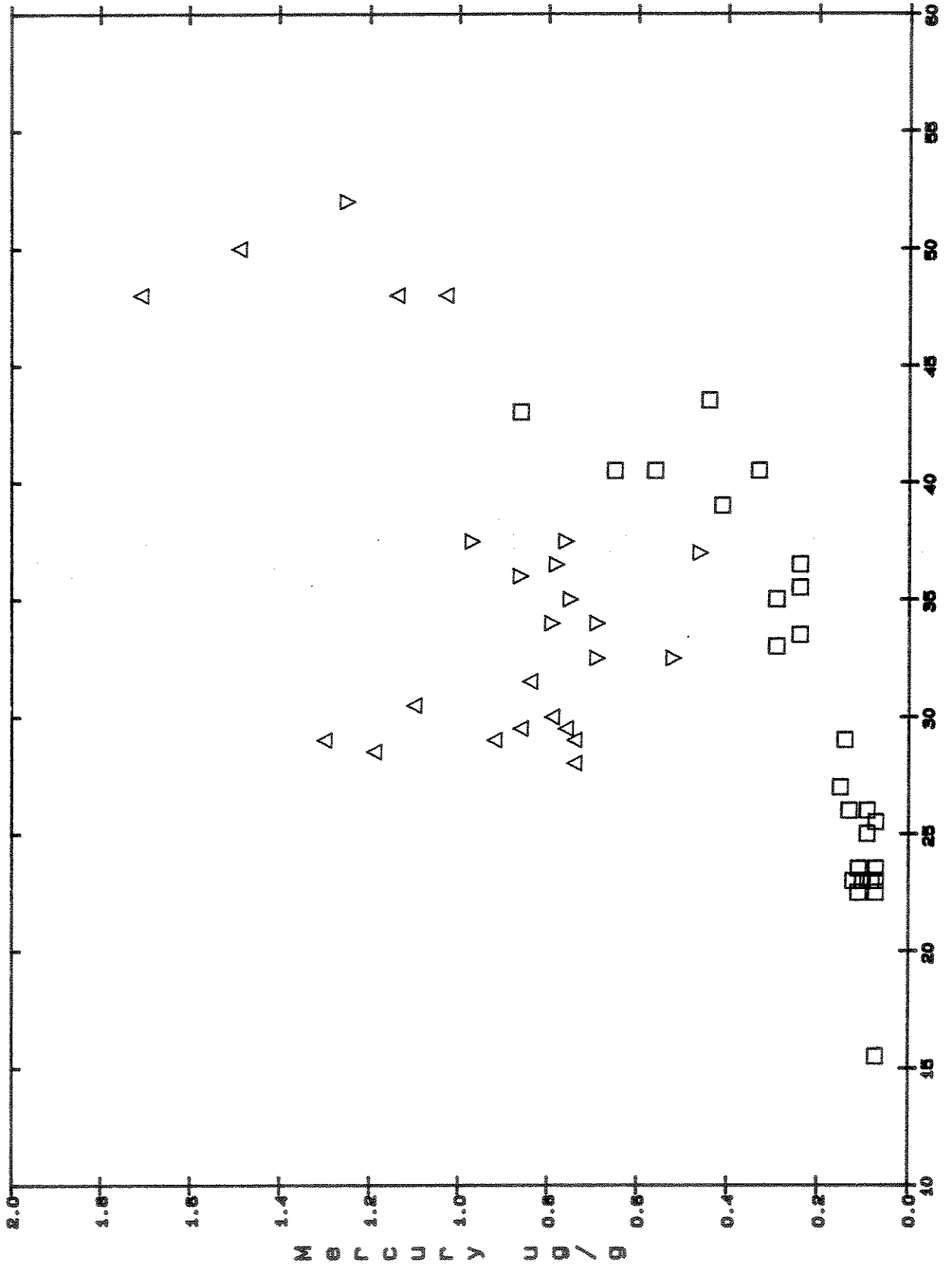

Figure 3. Mercury Concentration vs Fork Length in Walleye.

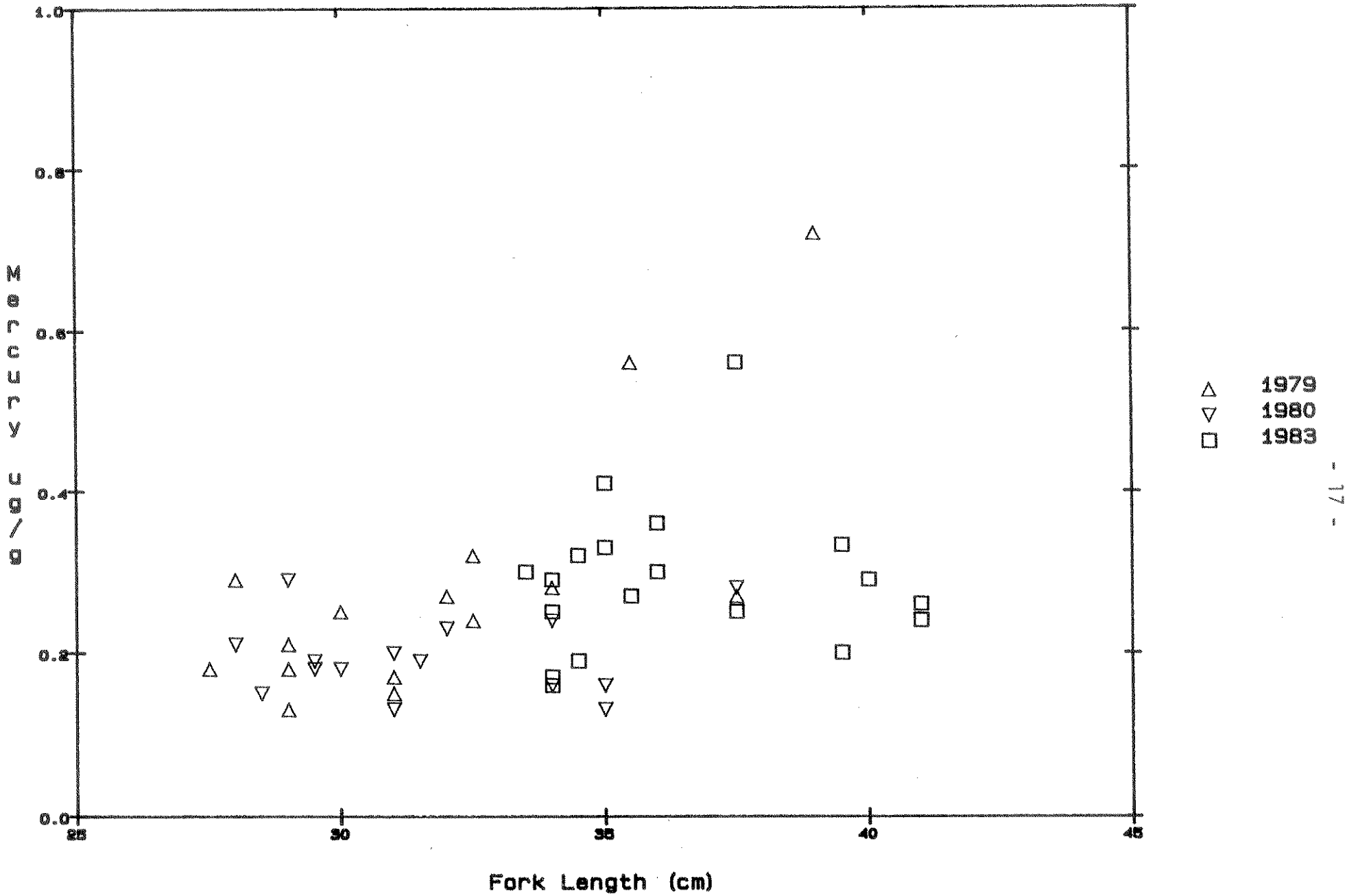

Figure 4. Mercury Concentration vs Fork Length in White Sucker.

same species. All samples were analyzed at the Freshwater Institute using the same methods. Mercury concentrations in walleye (Stizostedion vitreum), show the typical positive correlation of mercury concentration to size (Figure 3). The correlation is best in the 1983 sample ($r = 0.86$) which included the widest range in fish size. Comparision of the mercury concentration in fish of comparable size shows a significant ($p > 0.001$) decline from 1979 to 1983 and from 1980 to 1983. In 1979, the mean mercury concentration in walleye with fork lengths between 25 and 33.5 cm was 0.92 ug/g, compared to 1983 when the mean concentration in the same size class was 0.17 ug/g. The mercury concentration in the walleye collected by Saskatchewan Power Corporation in 1980 were only slightly lower than that found in walleye in 1979 but the fish were from a slightly larger size class. The mercury concentration in the fish collected in 1980 were also significantly ($p > 0.001$) greater than in similar size fish collected in 1983 (0.73 ug/g versus 0.29 ug/g, respectively).

In contrast to the walleye, the white sucker (Catostomus commersoni) mercury concentrations declined from 0.28 to 0.19 ug/g between 1979 to 1980, for the two collections of 15 fish from approximately the same size class. In 1983, however, the mean mercury concentration of the sample of 20 fish was 0.29 ug/g. The size of the fish in the 1983 sample were slightly larger than in the 1979 and 1980 samples and this may have contributed in part to the higher mercury concentration in 1983.

The occurrence of elevated mercury concentrations in fish from recently flooded reservoirs is widespread in North America. Bodlay, et al. (1984) reported increased levels of mercury in fish, particularly in predatory fish species, from a number of lakes, flooded by the Churchill Diversion in Northern Manitoba. They found that mercury levels in the fish increased quickly after impoundment with noticeable increases occurring within 2 to 3 years. With the exception of whitefish from Southern Indian Lake the high levels had not declined 5 to 8 years after impoundment. Whitefish showed a steady decline after peak levels were reached 2 years after impoundment. They hypothesized that the increase in mercury in fish was due to the bacterial methylation of naturally occurring mercury found in flooded soils. Similar hypotheses have been put forth by Meister, et al. (1979); Abernathy and Cumbie, (1977); and Bruce and Spencer, (1979). Potter, et al. (1975) suggested the source of mercury in fish from Lake Powell, Arizona was the increased availability of naturally transported mercury due to increased retention of inflowing material.

The decline in mercury concentrations in the walleye from Cookson Reservoir from 1979 to 1983 differs with the Southern Indian Lake reported by Bodlay, et al. (1984) but is similar to what has occurred in other reservoirs. Abernathy and Cumbie (1977) found mercury levels in fish declined within 3 to 5 years of impoundment. Meister, et al. (1979) reported a similar finding and suggested the reason for the decline was the

depletion of available mercury in the bottom sediment due to constant removal of water, fish harvest and the volatillity of organic mercury. Although mercury concentrations appear to be high in the water in Cookson Reservoir from time to time, the mercury levels in walleye have declined from 1979 to 1983 suggesting a general decrease in biologically available mercury.

5.4 Small Fish Species and Clams

Three species of small fish were collected by beach seine, brassy minnows (Hybognathus hankinsoni), young of the year carp (Cyprinus carpio) and white sucker. The results of the mercury analysis of the small fish samples and the physical data for the samples are presented in Table 5. For the most part the mercury concentration in these small fish was low. The mercury concentration ranged from 0.03 to 0.14 ug/g in brassy minnows and from 0.07 to 0.25 ug/g in white sucker fry from Cookson Reservoir and the East Poplar River. The higher mercury concentrations for both these species occurred in the larger fish collected in the East Poplar River below the reservoir. Comparison of mercury results for fish from the East Poplar River and Cookson Reservoir with the same fish species from Beaver Creek show that the mercury concentrations are similar in both systems. Thus, relative to the fish from Beaver Creek there is no evidence to suggest that mercury levels are elevated in these species in the East Poplar River System. The carp fry collected in Cookson Reservoir had mercury concentration ranging

Table 5 Mercury and Physical Data for the Small Fish Collections.

Species	Map Number	Mean Length (cm)	Mean Weight (gm)	No. of Fish	Mercury (ug/g)
Brassy Minnow	2	3.4	0.44	11	0.04
Brassy Minnow	2	3.8	0.68	8	0.07
Brassy Minnow	7	3.8	0.68	6	0.09
Brassy Minnow	9	4.0	0.71	6	0.05
Brassy Minnow	9	3.0	0.30	10	0.05
Brassy Minnow	13	3.6	0.65	10	0.07
Brassy Minnow	13	4.7	1.30	7	0.08
Brassy Minnow	13	4.3	0.86	7	0.06
Brassy Minnow	14	4.6	1.30	5	0.08
Brassy Minnow	14	3.8	0.66	7	0.08
Brassy Minnow	15	9.8	11.6	1	0.14
Brassy Minnow	15	7.3	4.60	1	0.11
Brassy Minnow	15	3.7	0.76	7	0.05
Brassy Minnow	15	3.0	0.33	17	0.03
Brassy Minnow	16	3.9	0.73	10	0.03
Brassy Minnow	16	3.4	0.44	11	0.03
Brassy Minnow	N/A	7.9	6.10	2	0.11
Brassy Minnow	N/A	7.4	4.70	2	0.10
Brassy Minnow	N/A	7.0	4.00	2	0.10
Brassy Minnow	N/A	6.8	3.90	2	0.08
Brassy Minnow	N/A	7.9	5.80	2	0.09
Carp	2	5.1	2.90	2	0.05
Carp	13	3.7	1.10	3	0.04
Carp	16	4.3	1.40	5	0.04
Carp	16	4.2	1.30	5	0.02
Carp	16	3.5	0.87	7	0.04
Carp	16	2.9	0.47	7	0.01
Carp	16	4.2	1.30	5	0.01
W.Sucker	15	10.3	10.0	1	0.10
W.Sucker	15	8.5	7.6	1	0.10
W.Sucker	15	10.3	13.8	1	0.09
W.Sucker	15	5.3	1.5	5	0.04
W.Sucker	16	18.5	80.	1	0.25
W.Sucker	16	11.5	18.4	1	0.03
W.Sucker	N/A	10.0	13.3	1	0.19
W.Sucker	N/A	8.0	8.7	1	0.23
W.Sucker	N/A	6.4	3.5	3	0.07

Note: - N/A is the site on Beaver Creek at the International Boundary
- Mercury results are total mercury based on wet weight

from 0.01 to 0.05 ug/g. Carp were not collected in Beaver Creek.

The results of the analysis of mercury in the foot muscles of clams (Anodonta sp) and the physical data for the clams are presented in Table 6. Mercury concentrations in the clams ranged from 0.02 to 0.04 ug/g which is similar to that found in clams in 1979 (range 0.01 to 0.04 ug/g). No apparent difference exists between the mercury concentration in clams from Beaver Creek and East Poplar River downstream from Cookson Reservoir.

Table 6. Mercury and Physical Data for the Clam Samples.

Map Number	Weight (gm)	Length (cm)	Width (cm)	Mercury (ug/g)
15	104	11.0	5.8	0.04
15	91	10.0	5.5	0.02
15	131	12.0	6.0	0.03
15	112	11.0	5.8	0.03
16	216	13.5	7.0	0.02
16	132	12.0	6.0	0.02
16	149	12.5	6.8	0.02
16	221	13.5	7.0	0.03
16	163	13.0	6.8	0.02
N/A.	108	10.8	5.6	0.04
N/A	40	8.5	4.5	0.02

Note: N/A is Beaver Creek at the International Boundary
Mercury results are total mercury based on wet weight

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