Figure 6-10. Mercury Concentrations (mg/kg) in 1969-1970 Lake Michigan Surficial Sediments

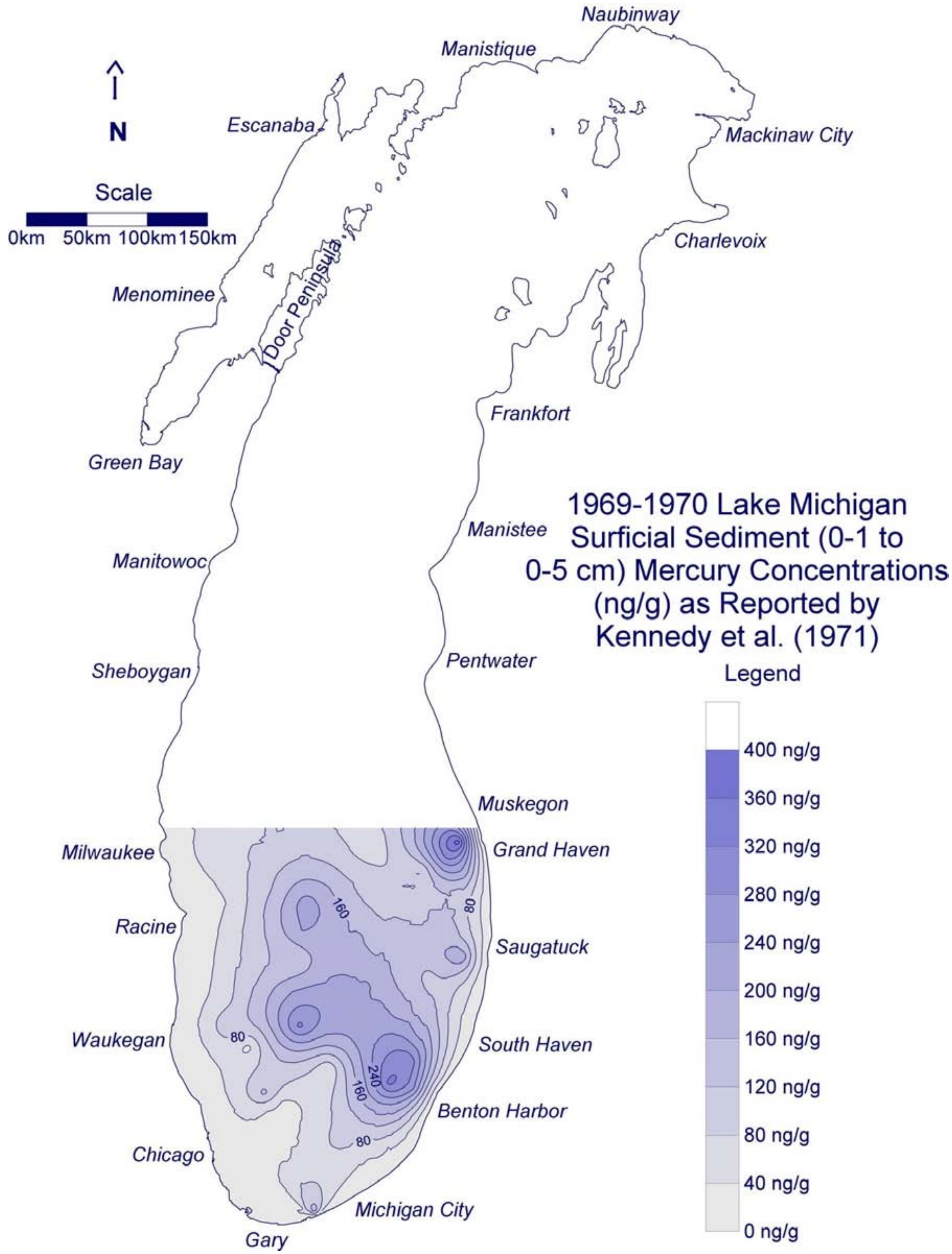
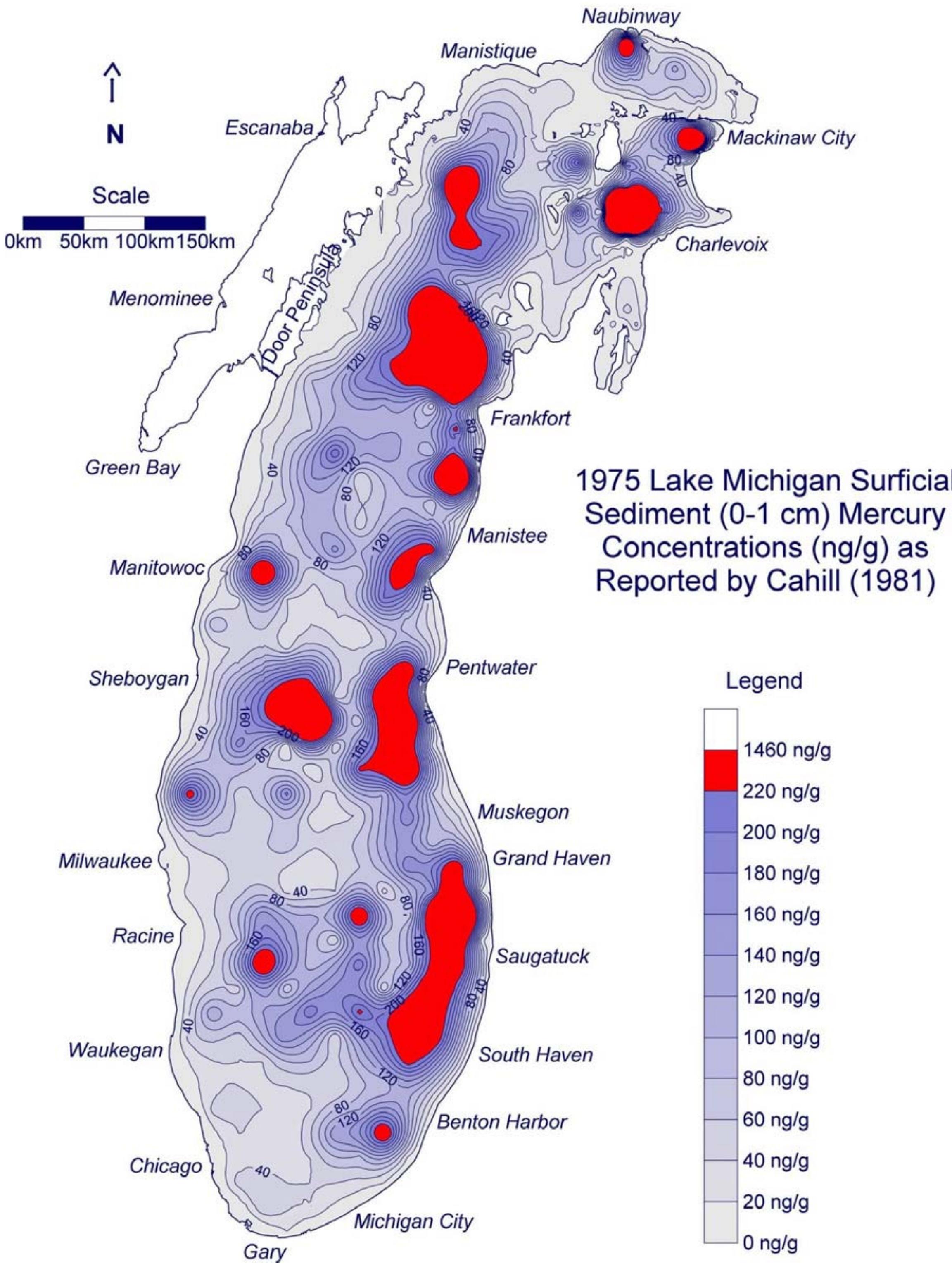


Figure 6-11. Mercury Concentrations (mg/kg) in 1975 Lake Michigan Surficial Sediments



6.4.4 Regional Lake Michigan Comparisons

Because bathymetry and currents control observed mercury distributions in surficial sediments, it is important to compare regional mercury concentrations for only the depositional basins of the lake (Table 6-15). When this is done, it becomes apparent that the mean mercury concentration varies very little between basins. Mean mercury concentrations range between 120 and 160 ng/g, within the observed standard deviations (Table 6-15). Two anomalies are noteworthy. First, the minimum concentration in the Southern Basin is substantially lower than those for the other basins. The reason for this is unknown. Second, the maximum concentration for the Waukegan Basin is considerably higher than those for the other basins, suggesting a historic or current source, containing high mercury concentrations, to that basin. Other than these noted differences, the sediments in the lake's depositional basins are amazingly similar, suggesting either a similar regional source of mercury to the lake most likely delivered through atmospheric pathways, or a well-mixed lake that redistributes inputs extremely well prior to sedimentation to the lake bottom.

Table 6-15. Comparison of Mercury Concentrations in Various Basins of Lake Michigan for Box Cores Only

Basin	N	Mean (ng/g)	Standard Deviation (ng/g)	Median (ng/g)	Minimum (ng/g)	Maximum (ng/g)
Southern	15	120	31	130	72	180
Waukegan	11	160	65	130	100	320
Grand Haven	6	150	19	150	120	170
Milwaukee	3	130	15	130	110	140
Sarian	1	160	—	—	—	—
Algoma South	8	140	17	140	120	180
Algoma Central	7	130	15	130	100	150
Algoma North	2	130	—	—	110	150
Traverse	1	160	—	—	—	—

6.4.5 Mercury Fluxes

The amount of material available in trap samples limited the number of samples available for mercury analyses. This limitation translates to a data bias because trap samples having enough material available for mercury analysis represent relatively high sediment flux periods. As a result, mercury fluxes to traps (0.049 to 3.7 $ng/cm^2/d$) are always higher than fluxes to the sediment (0.0055 to 0.063 $ng/cm^2/d$) at the trap locations. Therefore, further discussion of mercury concentrations in and fluxes to sediment traps is not warranted due to the bias.

As with mercury concentrations, mean mercury fluxes did not significantly vary from basin to basin of the lake (Table 6-16). All fluxes were within one standard deviation of one another. Of interest are the considerably higher minimum fluxes to the Algoma Basin relative to the other basins. In general, basins that are towards the west side of the lake have lower mean and median fluxes than those on the east side of the lake. Of significant note are the relatively high maximum mercury fluxes to the Southern and Grand Haven Basins. Both of these basins are on the east side of the lake. These high fluxes could be related to the transport of materials from the southwestern and southern shore of the lake to the eastern shore, especially in the spring. This event occurs annually and the resulting plume has suspended particulate matter concentrations 4 to 10 times that of the lake (Eadie *et al*., 1996). A large amount of particulate matter, with its associated contaminants, is transported along the eastern shore, where it settles to the lake floor and accumulates in the Southern and Grand Haven deposition basins (Figure 6-5).

Table 6-16. Comparison of Total Mercury Fluxes to Various Basins of Lake Michigan for Box Cores Only

Basin	N	Mean (ng/cm²/y)	Standard Deviation (ng/cm²/y)	Median (ng/cm²/y)	Minimum (ng/cm²/y)	Maximum (ng/cm²/y)
Southern	15	10	8.7	6.5	0.85	32
Waukegan	11	3.4	1.9	2.9	1.4	8.5
Grand Haven	6	10	12	4.0	0.94	31
Milwaukee	3	3.3	1.9	4.0	1.1	4.8
Sarian	1	14	—	—	—	—
Algoma South	8	6.9	4.9	5.1	2.8	16
Algoma Central	7	5.2	2.5	5.2	2.6	9.5
Algoma North	2	7.6	—	—	7.1	8.0
Traverse	1	8.0	—	—	—	—

Fluxes to Lake Michigan in the vicinity of Station 15 (Figure 6-1) have decreased since 1981. In order to compare fluxes between the two years, it is necessary to correct fluxes for sediment focusing. Sediment focusing is the process by which fine-grained particles and their associated contaminants are winnowed from the coarser fraction of sediments by wave and current action. Winnowing and resuspension occurs in regions that are shallow enough to have wave and current velocities high enough to initiate sediment grain movement. The resuspended materials are transported until they settle from the water column. For each particle and associated contaminants, the process is repeated until the particle settles in a region where winnowing and resuspension no longer occur. These regions are the depositional basins. For the contaminants that are preferentially associated with fine-grained sediment particles, the resuspension/transport process can result in a depletion or enhancement of a contaminant's net flux to any one location. For sedimentary basins, the result is an enhancement of contaminate concentrations and fluxes called sediment focusing. Sediment focusing can be estimated using parameters whose fluxes to a lake's surface are equal at all locations. This is true for historically bomb-generated Cs-137 whose fluxes to the region are well documented, and naturally derived Pb-210, whose flux is well known. Both of these are mixed well in the atmosphere and were deposited to the lake's basin as a uniform flux from the atmosphere. Because they, like contaminants, are associated with the fine-grained components of sediment, they also are subject to sediment focusing. Because their fluxes are known, the degree of sediment focusing can be calculated for them and then applied to observed contaminant fluxes. When there is an excess of either of these radionuclides, the focusing factor is greater than one (depositional basins). In regions of active winnowing and resuspension, the focusing factor may be less than one, indicating depletion.

The Pb-210 and Cs-137 focusing factors are not always equal. The reason for this is unknown, but it is reasoned to be related to each radionuclide associating with a different particle type. Because we do not always know which focusing factor to apply to a particular contaminant, an average of the two focusing factors can be used. For this study, however, the Cs-137 focusing factor will be used for the purpose of comparison of Lake Michigan mercury fluxes to those of Green Bay and Lake Superior. For both those locations, the Cs-137 focusing factor was used because only the Cs-137 factor was available for Lake Superior. Mercury fluxes to Lake Michigan are very similar to those for the open waters of Lake Superior, but are considerably lower than those to Green Bay (Table 6-17).

Table 6-17. Comparison of Total Mercury Fluxes for Lake Michigan Corrected for Cs-137 Focusing Factors to Fluxes for other Locations

Location	Mean ($ng/cm^2/y$)	Standard Deviation ($ng/cm^2/y$)	Median ($ng/cm^2/y$)	Reference
Lake Michigan	3.4	1.8	3.2	this study
Lake Superior	3.2	1.1	2.8	Rossmann (1999)
Green Bay	19	30	14	Rossmann and Edgington (2000)

A good illustration of the use of a sediment focusing factor is the region of the lake around Station 15. Total uncorrected mercury fluxes to the surficial 1 cm of sediment are very similar in magnitude (Table 6-18). When corrected for sediment focusing, it becomes apparent that the flux of mercury to this region of the lake has decreased from 13 $ng/cm^2/y$ in surficial sediments collected in 1981, to 4.1 $ng/cm^2/y$ for surficial sediments collected in 1994. This is consistent with the observed trend of decreasing mercury concentrations in surficial sediments.

Table 6-18. Comparison of Mercury Fluxes to Lake Michigan Surficial Sediments at Station 15 in 1981 and 1994

Year	Total Mercury Flux ($ng/cm^2/y$)	Total Mercury Flux Corrected for Focusing Factor ($ng/cm^2/y$)
1981	22	13
1994	23	4.1

6.4.6 Relative Importance of Regional Atmospheric Sources and Point Sources of Mercury

To estimate the relative contribution of regional atmospheric and local point-source mercury fluxes to measured total mercury fluxes, the total mercury fluxes were corrected with the Cs-137 focusing factor. For Lake Michigan, atmospheric mercury fluxes account for 50% of the total mercury flux. This is higher than that for Lake Superior (38%) and Green Bay (15%). Fluxes of mercury to Green Bay are dominated by point sources derived from historic industrial use of mercury within the region (Rossmann and Edgington, 2000).

6.5 Conclusions

Lake Michigan surficial sediments have low mercury concentrations relative to Green Bay. The mean concentration was 0.078 mg/kg. The mean net total mercury flux to the depositional basins was 7.2 $ng/cm^2/y$. Mercury fluxes to Lake Michigan sediments were similar to those for Lake Superior open-water sediments and considerably lower than those to Green Bay sediments. There was little variation in mercury concentration or fluxes from basin to basin of the lake. Mercury concentration distribution patterns in surficial sediments are similar to historic patterns and conform to the bathymetry. Fluxes do not conform to the bathymetry and are elevated along the eastern shore of the lake. Regional atmospheric fluxes of mercury account for 50% of the total mercury flux to recent surficial sediments. Both mercury concentrations in, and fluxes to, surficial sediments have decreased since the 1970s.