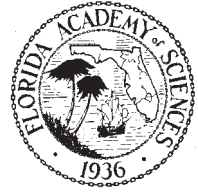


Florida Scientist



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ABSTRACT: *Lake Thonotosassa is a hypereutrophic lake in west central Florida and the largest natural freshwater lake in Hillsborough County. The Environmental Protection Agency established Total Maximum Daily Loads (TMDLs) for lead in Lake Thonotosassa in 2005. The lake was determined to be impaired for lead based on three exceedences of the EPA's chronic water quality criterion of 2.70 ppb during 2002. The EPA report suggested that a possible source for the lead was from resuspension of contaminated bottom sediments during storm events. The Environmental Protection Commission of Hillsborough County (EPCHC) conducted a study in May 2008 to test for sediment contamination from lead and other metals and to map the distribution of metals in the lake. Results from this study found that most metals, including lead, had sediment concentrations below the Florida state sediment quality guidelines. Highest concentrations for most metals were found associated with high silt/clay sediments in the deeper sites on the west end of the lake. Arsenic, tin, and antimony, however, had highest concentrations at shallow sites. This was attributed to the higher solubility of these elements under the reducing conditions found in the deeper portions of the lake and their subsequent precipitation in the more oxygen rich shallow areas. Overall, there was little evidence that sediment contamination for metals was an issue within Lake Thonotosassa.*

Key Words: Lake Thonotosassa, Hillsborough County, sediments, metals, lead

LAKE THONOTOSASSA has historically been a hypereutrophic system and the reduction of nutrient inputs has been the primary focus for the Southwest Florida Water Management District's (SWFWMD) Surface Water Improvement and Management (SWIM) plan for the lake (SWFWMD, 2003). Lake Thonotosassa is the largest natural freshwater lake in Hillsborough County covering an area of 942 acres (3.82 km²) (Harley and Eilers, 2008). The lake is fed by Baker Creek at the southeastern end of the lake and water flows out of the lake through a SWFWMD operated control structure into Flint Creek on the northeastern end to the Hillsborough River (Figure 1). Past studies on fossil diatom assemblages from sediment cores have shown that historically Lake Thonotosassa has been a eutrophic system (Brenner et al., 1996). The lake shifted from a eutrophic to a hypereutrophic system at some point in the early 1900's, presumably due to nutrient loading from surrounding agriculture and population growth, and alterations to the lakes hydrology from the channelization of Baker Creek and the construction of a weir structure on Flint

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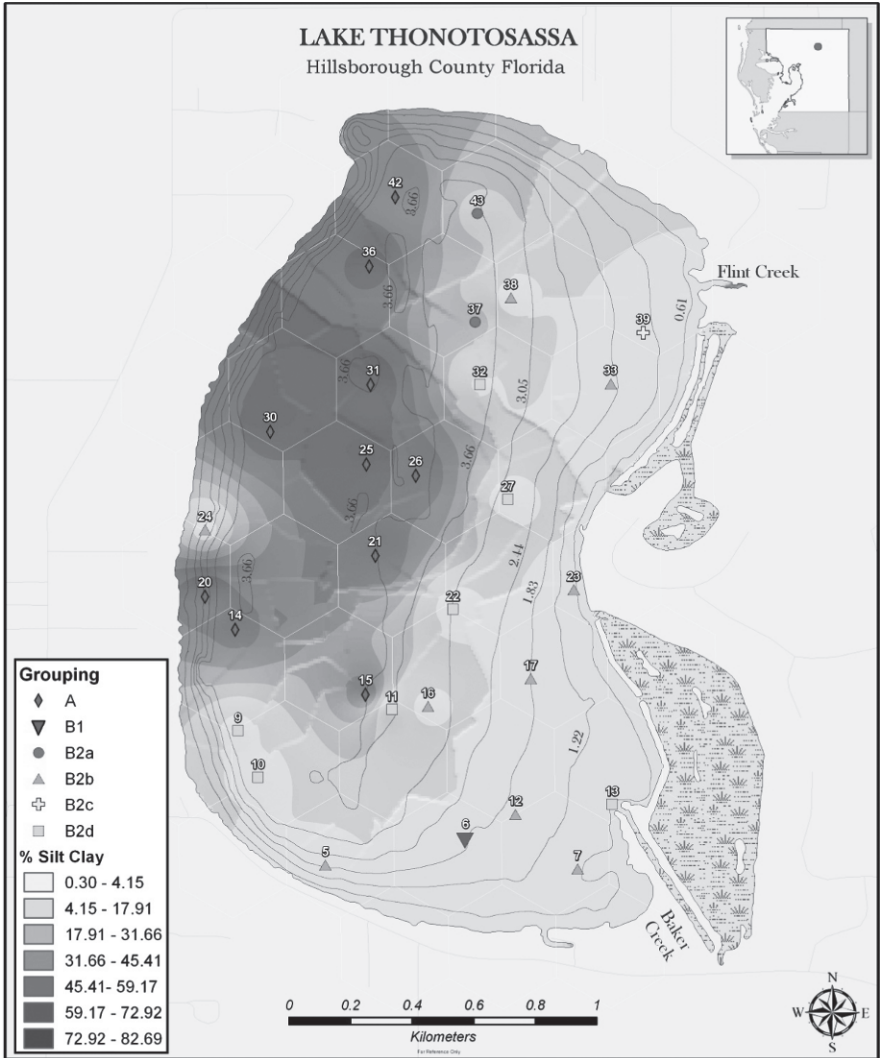


FIG. 1. EPCHC Lake Thonotosassa sediment sampling grid (hexagons) and sample locations, May 2008. Lake bathymetry indicated in 0.61 meter (2 feet) intervals [modified from Kenner (1964) and Harley and Eilers (2008)]. Shading represents % silt + clay distribution. Symbols represent cluster groupings from the Euclidian distance cluster analysis (see Figure 2).

Creek (Brenner et al., 1996). Degradation of the lake’s water quality continued through most of the 20th century as the area’s population grew (Dye, 1972; Cowell et al., 1975). Some improvement to Lake Thonotosassa’s water quality and biological communities were observed in the early 1970’s following improvements to wastewater treatment at several citrus processing plants and at the Plant City sewage treatment plant (Dye, 1972; Cowell et al., 1975). High nutrient effluents from these facilities ultimately reached the lake through the

Pemberton Creek – Baker Creek drainage and contributed to the hypereutrophic conditions in Lake Thonotosassa (Dye, 1972; Cowell et al., 1975). Despite the reduction from these point sources, Lake Thonotosassa still exhibited hypereutrophic conditions due in part to nitrogen inputs from storm water runoff (U.S. EPA, 2005) and most probably internal nutrient recycling.

The U.S. Environmental Protection Agency (U.S. EPA) published recommended Total Maximum Daily Loads (TMDLs) for Lake Thonotosassa for un-ionized ammonia and for lead (U.S. EPA, 2005). In the case of the lead impairment, the U.S. EPA recorded three instances of dissolved lead concentrations exceeding their chronic water quality criterion of 2.70 ppb (at a hardness of 88 mg/l CaCO₃) during 2002 (U.S. EPA, 2005). According to the U.S. EPA criteria, a water body is considered impaired for lead if the chronic water quality criterion is exceeded two or more times during a three year period. The U.S. EPA report suggested that the observed lead exceedences may be due to the re-suspension of contaminated sediments from storm events. Therefore the U.S. EPA recommended sampling the lake sediments for lead contamination. This recommendation was the primary reason for the current study.

Potential sources of lead included storm water runoff and the historic deposition of lead in lake sediments from the combustion of leaded gasoline prior to its ban in the 1980s (U.S. EPA, 2005). Lead remains a persistent contaminant in soils near roadways despite the ban of leaded gasoline (Hafen and Brinkmann, 1996; Newsome et al., 1997). The historic use of lead based paints has also resulted in high soil lead levels in older neighborhoods (Brinkmann, 1994; Brinkmann et al., 2000). Periodic flooding may act to transport and redeposit lead contaminated soils (Brinkmann et al., 2000). In rural areas, the use of lead arsenate as an agricultural pesticide in the early 1900s has contributed to elevated lead concentrations in lake sediments (Galicki et al., 2008). Lead deposited in riparian sediments can be remobilized through the decomposition of organic matter and transported to open waters where it is deposited and accumulates in bottom sediments (Galicki et al., 2008). Atmospheric deposition of lead from the combustion of wood and coal, the smelting of lead ore and the combustion of leaded gasoline are also past sources of lead found in lake sediments (Graney et al., 1995). Graney et al. (1995) studied the lead isotope records in lake sediment cores for the Great Lakes region and was able to detect changes in the isotopic signatures at different sediment levels, which corresponded to changing sources of lead pollution over the past 150 years (before 1860 to the 1980s).

MATERIAL AND METHODS—Sediment samples were collected at 30 randomly selected locations throughout the lake on May 5–6, 2008. Sampling locations were generated by superimposing a hexagonal grid over a GIS map of the lake and generating one set of random GPS coordinates within each hexagon (Figure 1). Sediment samples were collected at each location using a stainless steel Young grab sampler. The grab sampler and all sampling utensils were field cleaned with Liqui-Nox® detergent (Alconox, Inc. White Plains, NY), rinsed with ambient surface water and decontaminated with 99% pesticide grade isopropyl alcohol (2-Propanol, Fisher Chemicals,

Fisher Scientific, Fair Lawn, NJ) prior to sampling and all equipment and samples were handled wearing latex gloves. The top 2-cm layer of sediment was removed from each grab using a stainless steel or Teflon® coated spoon, placed in a stainless steel beaker, and homogenized by stirring. The homogenized sample was then split, with one fraction being placed in a pre-cleaned HDPE sample jar for metals analysis and second fraction being placed in smaller HDPE jar for silt + clay analysis.

The sediment samples were analyzed for a suite of 14 trace metals and processed using a total digestion method with hydrofluoric acid using a CEM MARS Xpress microwave digester. Analysis was performed on a Perkin Elmer Optima 2000 Optical Emission Spectrometer (EPA Method 200.7).

Linear regressions of the sediment metal concentrations against corresponding *in situ* aluminum values were done in order to detect possible sediment enrichment and graphed using SigmaPlot® 10 software (SYSTAT, 2006a). The Florida Department of Environmental Protection's interpretive tool for assessment of metal enrichment in Florida freshwater sediment (Carvalho et al., 2002) was used to compare selected 2 metals: aluminum values in Lake Thonotosassa with Florida state reference sites.

The sediment quality assessment guidelines (SQAGs) developed for freshwater ecosystems were used to evaluate the potential levels of sediment toxicity for specific metals (MacDonald et al., 2000; Ingersoll et al., 2001; MacDonald et al., 2003). These are defined as the Threshold Effect Concentration (TEC), the value below which toxic effects to aquatic organisms would be unlikely, and the Probable Effect Concentration (PEC), the value above which toxic effects to aquatic organisms would be likely to occur (MacDonald et al., 2003). The percent silt + clay was determined following the methods developed for the U.S. EPA Environmental Monitoring and Assessment Program for Estuaries (EMAP-Estuaries) as outlined in Versar (1993).

Summary statistics were calculated using SYSTAT® 11 software (SYSTAT Software, Inc., 2004) or SigmaStat® 3.5 (SYSTAT, 2006b). PRIMER® v6 software was used for multivariate statistical analysis including principle components analysis (PCA) and cluster analysis on the sediment metals (PRIMER-E, Ltd., 2006; Clarke and Gorley, 2006). Values for aluminum and iron were excluded from analysis since these two metals were measured as background parameters. Where measured values were below the minimum detectable level (MDL) for a given metal, ½ the MDL value was substituted for purposes of statistical analysis. The metals data were normalized and log (n+1) transformed prior to analysis, and the Euclidian distance was used as the measure of resemblance for the cluster analysis. The spatial distribution of the sampling locations and the silt + clay content were mapped using ArcGIS® 9.2 software (ESRI, 2006).

RESULTS—The sample depth and percent silt + clay summary statistics for all 30 sampling sites are presented in Table 1. Depths ranged from 0.54 m to 3.78 m with a median sample depth of 3.27 m. Over half of the sites (60%) had depths greater than 3 m, while only 10% (3 sites) were shallower than 1 m. The silt + clay content ranged from 0.3% to 82.7% with a median value of only 1% and one-third of the samples had silt + clay contents > 50%. Higher silt + clay values tended to be concentrated at the deeper sites on the west and central areas of the lake (Figure 1).

The sites clustered into six distinct groups based on their sediment metals composition (Figure 2). The first group designated as “A” split off from the other sites at a Euclidian distance of six and was composed of ten sites. Group “A” sites were generally located in the deeper, western portion of the lake (Figure 1) and were characterized by high (> 50%) silt + clay content (Table 2). The remaining 20 sites (group “B”) were further subdivided into groups “B1” and “B2”. Group “B1” consisted of a single site (08LTH06) on the southern end of the lake at a depth of 2 m (Figure 1; Table 2). This site

TABLE 1. Lake Thonotosassa sample depth (meters), % silt + clay and metal concentrations (mg/kg).

Group	Sample	Depth	silt+clay	Al	Sb	As	Cd	Cr	Cu
A	08LTH14	3.48	63.5	38648	4.05	<MDL	1.85	42.97	15.03
A	08LTH15	3.45	56.9	32444	3.88	<MDL	1.73	35.89	15.47
A	08LTH20	3.39	71.8	45096	<MDL	<MDL	1.80	49.05	15.90
A	08LTH21	ND	70.6	41116	2.69	<MDL	1.84	46.77	16.86
A	08LTH25	3.48	80.7	43678	<MDL	<MDL	1.71	43.93	15.52
A	08LTH26	3.54	69.2	42013	<MDL	<MDL	1.75	43.36	14.16
A	08LTH30	3.27	77.8	46634	<MDL	<MDL	1.58	42.51	13.10
A	08LTH31	3.42	82.7	41015	<MDL	<MDL	1.75	42.89	15.86
A	08LTH36	3.27	77.2	48906	<MDL	<MDL	1.82	46.88	13.69
A	08LTH42	3.30	58.6	37568	<MDL	<MDL	1.62	38.59	12.10
B1	08LTH06	2.01	0.3	507	14.44	7.35	2.52	3.75	0.53
B2a	08LTH37	3.60	20.6	8367	7.75	<MDL	1.48	17.33	5.68
B2a	08LTH43	3.51	13.5	5921	8.02	<MDL	1.23	12.30	4.25
B2b	08LTH05	1.86	0.7	515	10.91	5.24	1.24	3.02	1.01
B2b	08LTH07	0.81	0.6	834	11.26	5.77	1.57	2.74	0.63
B2b	08LTH12	1.65	0.5	568	10.10	5.78	1.21	2.23	0.50
B2b	08LTH16	3.27	0.7	731	10.52	5.64	1.11	3.99	1.13
B2b	08LTH17	1.77	0.5	611	10.48	5.06	1.26	2.93	0.57
B2b	08LTH23	0.75	0.3	667	10.22	6.98	1.31	2.07	0.37
B2b	08LTH24	1.17	0.3	640	10.24	4.98	1.34	2.75	0.46
B2b	08LTH33	1.95	0.5	570	10.36	5.41	1.07	2.92	0.79
B2b	08LTH38	3.36	0.6	631	9.95	5.02	0.99	3.60	0.52
B2c	08LTH39	1.41	0.3	546	9.44	<MDL	1.07	2.40	<MDL
B2d	08LTH09	3.48	0.6	891	10.76	<MDL	1.40	3.65	1.24
B2d	08LTH10	3.39	0.7	932	9.79	<MDL	1.32	3.68	1.10
B2d	08LTH11	3.60	2.9	1575	10.24	<MDL	1.52	5.43	1.55
B2d	08LTH13	0.54	1.3	2248	9.68	<MDL	1.55	6.12	0.81
B2d	08LTH22	2.94	0.3	572	9.46	<MDL	1.48	2.56	0.70
B2d	08LTH27	2.79	0.6	602	10.19	<MDL	1.46	3.08	0.69
B2d	08LTH32	3.78	2.9	1551	10.29	<MDL	1.19	4.64	1.59
Group	Sample	Fe	Pb	Mn	Ni	Se	Ag	Sn	Zn
A	08LTH14	6259	27.36	49.47	10.90	50.85	<MDL	<MDL	55.62
A	08LTH15	5407	32.14	41.81	9.42	44.13	<MDL	2.44	44.21
A	08LTH20	6758	30.02	52.46	11.59	55.16	<MDL	<MDL	61.17
A	08LTH21	6810	30.83	53.79	11.43	56.15	<MDL	<MDL	66.38
A	08LTH25	6420	29.40	49.20	10.77	51.44	<MDL	<MDL	60.16
A	08LTH26	6171	28.24	50.15	10.39	51.43	<MDL	<MDL	52.82
A	08LTH30	5913	25.97	45.22	10.49	47.42	<MDL	<MDL	46.13
A	08LTH31	6216	27.52	48.29	10.74	51.48	<MDL	<MDL	59.02
A	08LTH36	6252	30.48	50.51	11.91	52.10	<MDL	<MDL	54.10
A	08LTH42	5463	26.83	46.74	9.87	44.63	<MDL	<MDL	43.78
B1	08LTH06	343	10.24	<MDL	3.83	<MDL	<MDL	10.85	<MDL
B2a	08LTH37	2834	16.06	28.48	6.29	21.76	<MDL	5.36	17.83
B2a	08LTH43	2372	13.96	23.44	5.45	16.23	<MDL	5.32	13.49
B2b	08LTH05	340	11.36	<MDL	3.39	<MDL	<MDL	8.72	<MDL
B2b	08LTH07	355	10.63	<MDL	3.82	<MDL	<MDL	7.44	<MDL
B2b	08LTH12	289	10.28	<MDL	3.62	<MDL	<MDL	6.81	<MDL
B2b	08LTH16	654	11.07	14.18	3.87	<MDL	<MDL	8.04	3.00
B2b	08LTH17	368	11.18	<MDL	3.85	<MDL	<MDL	6.54	<MDL

TABLE 1. Continued.

Group	Sample	Fe	Pb	Mn	Ni	Se	Ag	Sn	Zn
B2b	08LTH23	321	13.30	<MDL	3.75	<MDL	<MDL	6.63	<MDL
B2b	08LTH24	441	14.33	<MDL	3.79	<MDL	<MDL	7.30	<MDL
B2b	08LTH33	352	12.84	<MDL	3.43	<MDL	<MDL	8.73	<MDL
B2b	08LTH38	580	8.04	<MDL	3.26	<MDL	<MDL	6.79	<MDL
B2c	08LTH39	336	6.56	<MDL	3.24	<MDL	<MDL	6.50	<MDL
B2d	08LTH09	631	11.70	<MDL	3.88	<MDL	<MDL	7.53	4.27
B2d	08LTH10	574	12.62	<MDL	3.85	<MDL	<MDL	6.83	3.21
B2d	08LTH11	826	13.01	16.44	4.07	<MDL	<MDL	6.60	4.27
B2d	08LTH13	602	12.59	13.25	3.62	<MDL	<MDL	6.53	<MDL
B2d	08LTH22	436	14.30	<MDL	3.65	<MDL	<MDL	6.86	<MDL
B2d	08LTH27	438	12.99	<MDL	3.64	<MDL	<MDL	8.13	<MDL
B2d	08LTH32	841	11.52	13.32	4.33	<MDL	<MDL	6.70	5.23

was characterized by low silt + clay content (0.3%) and had the highest concentrations for antimony, arsenic, cadmium, and tin (Table 2). Group “B2” was further split into four distinct subgroups designated as groups “B2a”, “B2b”, “B2c” and “B2d” (Figure 2). Group “B2a” consisted of two sites located in the north-central portion of the lake (Figure 1). These two sites were among the deepest with a median depth of 3.56 m and had a median silt + clay content of 17% (Table 2). Group “B2b” was composed of nine sites located primarily along the eastern side of the lake with a couple of sites scattered along the southern and western shorelines (Figure 1). The “B2b” sites varied widely in depth but all had very low silt + clay contents (median = 0.5%; Table 2). Group “B2c” consisted of a single site (08LTH39), which was located on the northeastern side of the lake near the Flint Creek outfall (Figure 1). This site was characterized by a relatively shallow depth and low silt + clay content (Table 2). Group “B2d” was composed of seven sites primarily on the eastern side of the lake; however, two sites were along the southwestern shore and a single station (08LTH13) was located at the mouth of Baker Creek on the southeastern corner of the lake (Figure 1). The median depth for the “B2d” sites was 3.39 m although station 08LTH13 was only 0.5 m deep (Table 2). These sites were also characterized by their low silt + clay composition (Table 2).

The principle components analysis (PCA) showed the same grouping of sites as the cluster analysis (Figure 3). The first two principle components (PC1 and PC2) explained over 92% of the variation among the sites (Table 3). PC1 accounted for 85% of the variation and was nearly equally weighted by all of the metals except arsenic and cadmium while PC2 accounted for 7.2% of the variation and was heavily weighted by arsenic and cadmium (Tables 3 & 4). Since silver was below its MDL at all sites it had a coefficient of 0 across all PC axes (Table 4).

Figure 4 shows the depth, % silt + clay, and the concentrations of the individual metals superimposed on the PCA plot. The “group A” sites had the highest concentrations for all of the metals with the notable exception of

**Lake Thonotosassa
EPCHC 2008 Sediment Metals Study**

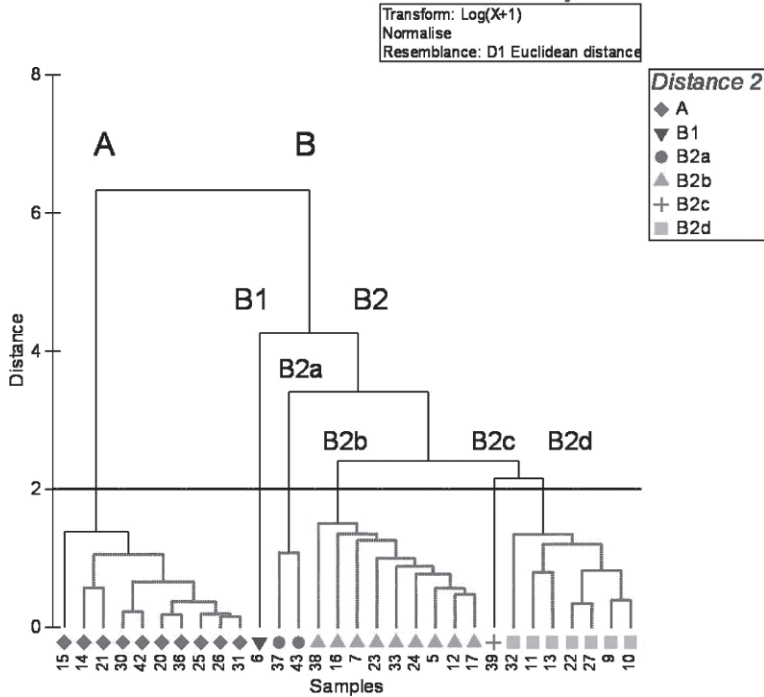


FIG. 2. Euclidian distance cluster analysis of Lake Thonotosassa sediment metals (excluding Al and Fe). Data log (n+1) transformed and normalized for analysis.

TABLE 2. Number of samples, median depth (meters), % silt/clay and metal concentrations (mg/kg) by Euclidian distance groups.

Group	Samples	Depth	silt+clay	Al	Sb	As	Cd	Cr	Cu
A	10	3.42	71.2	41564	<MDL	<MDL	1.75	43.17	15.25
B1	1	2.01	0.3	507	14.44	7.35	2.52	3.75	0.53
B2a	2	3.56	17.1	7144	7.89	<MDL	1.36	14.82	4.97
B2b	9	1.77	0.5	631	10.36	5.41	1.24	2.92	0.57
B2c	1	1.41	0.3	546	9.44	<MDL	1.07	2.40	<MDL
B2d	7	3.39	0.7	932	10.19	<MDL	1.46	3.68	1.10
Group	Samples	Fe	Pb	Mn	Ni	Se	Ag	Sn	Zn
A	10	6234	28.82	49.34	10.76	51.44	<MDL	<MDL	54.86
B1	1	343	10.24	<MDL	3.83	<MDL	<MDL	10.85	<MDL
B2a	2	2603	15.01	25.96	5.87	19.00	<MDL	5.34	15.66
B2b	9	355	11.18	<MDL	3.75	<MDL	<MDL	7.30	<MDL
B2c	1	336	6.56	<MDL	3.24	<MDL	<MDL	6.50	<MDL
B2d	7	602	12.62	<MDL	3.85	<MDL	<MDL	6.83	3.21

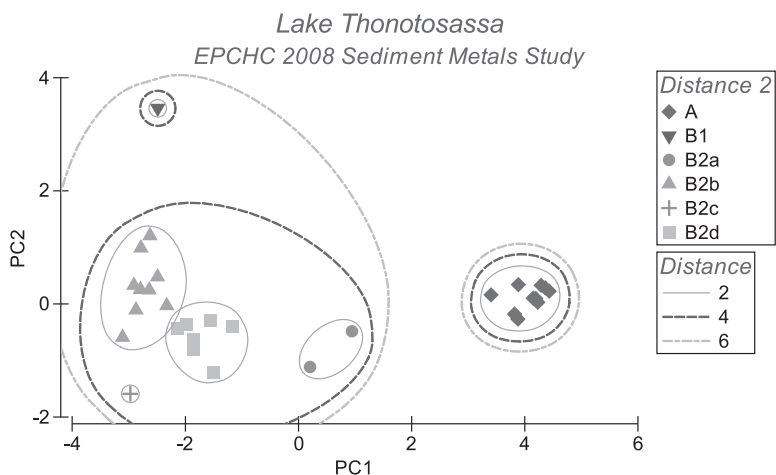


FIG. 3. PCA plot of Lake Thonotosassa sediment metals with Euclidian distance groups.

antimony, arsenic, and tin (Table 2; Figure 4). Cadmium generally was higher at the “group A” sites but the highest value for cadmium was at the “group B1” site (08LTH06), which is represented by the upper left data point on the PCA plots (Figures 3 & 4).

Sediment metals data for all 30 sites are presented in Table 1. All of the metals were below their established threshold effects concentrations with the exception of cadmium and chromium, and no metals exceeded their potential effects concentrations. MacDonald et al. (2003) did not establish SQAGs for aluminum, antimony, iron, manganese, selenium, or tin. A large percentage of the sites were below their MDLs for most of the metals, and silver was below the MDL at all sites (Table 1).

Aluminum concentrations were measured as a background element to detect possible metal enrichment relative to local levels and for comparing the metal:aluminum ratios from these sites to the FDEP reference sites (Carvalho et al., 2002). The metal:aluminum ratios for most of the metals did not indicate elevated concentrations above local background levels except for at a few sites for cadmium and manganese. Compared to the FDEP reference sites used by Carvalho et al. (2002), a few sites did show elevated levels for arsenic, lead and nickel. Generally, metals concentrations were directly related to the silt + clay

TABLE 3. Lake Thonotosassa sediment metals Principle Components eigenvalues.

PC	Eigenvalues	%Variation	Cumulative %Variation
1	9.35	85.0	85.0
2	0.79	7.2	92.2
3	0.53	4.8	97.0
4	0.15	1.4	98.3
5	0.09	0.8	99.2

TABLE 4. Lake Thonotosassa sediment metals Principle Components eigenvectors.

Variable	PC1	PC2	PC3	PC4	PC5
Sb	-0.310	0.035	0.224	-0.644	-0.200
As	-0.203	0.684	-0.683	-0.130	0.030
Cd	0.202	0.710	0.645	0.093	0.149
Cr	0.325	0.000	-0.033	-0.193	0.167
Cu	0.324	-0.015	-0.064	-0.262	-0.105
Pb	0.312	0.113	-0.031	0.114	-0.903
Mn	0.318	-0.059	-0.052	-0.402	0.188
Ni	0.325	0.065	-0.090	-0.001	0.016
Se	0.322	0.019	-0.126	-0.128	0.096
Ag	0.000	0.000	0.000	0.000	0.000
Sn	-0.317	0.033	0.179	-0.418	-0.183
Zn	0.322	-0.071	-0.046	-0.297	0.067

and tended to be highest at the deepest sites. Arsenic, antimony and tin, however, showed an inverse relationship with the percent silt + clay content and were highest at the shallower sites (Table 1; Figure 4).

DISCUSSION—Several physical and chemical factors influence the flux of metals between aquatic sediments and the overlying water column. These include the grain size, organic content of the sediments, pH, oxidation-reduction (redox) potential, dissolved oxygen conditions, and the salinity/conductivity of the surrounding waters (de Groot, 1995). Of the physical factors mentioned, sediment grain size and corresponding surface area are the most important in affecting trace metal concentrations (Horowitz, 1991). In general, smaller grain sized sediments provide larger surface area per mass for the adsorption of trace metals and for chemical reactions (Horowitz, 1991). The redox potential and pH are among the most important factors in influencing the chemical speciation and solubility of metals in aquatic environments (Pardue and Patrick, 1995; Miao et al., 2006).

Lake Thonotosassa's bathymetry strongly influences the distribution of fine sediments on the lake bottom. Previously published maps of the lake's bathymetry indicate a broad, gradual slope on the eastern side of the lake ending in a deep trough of around 4.5 meters near the west side of the lake and with a steep slope along the western shoreline that borders the trough (Kenner, 1964; Harley and Eilers, 2008). Whitmore et al. (1996) surveyed the distribution of soft sediments in Lake Thonotosassa and found little or no deposition on the eastern side of the lake while the deeper western sites had soft sediment deposits as thick as 1.5 meters. The percent silt + clay results from this study corroborate the results from Whitmore et al. (1996). Most of the shallow eastern sites had silt + clay values <1% while the deeper western sites all had values in excess of 50%. Whitmore et al. (1996) hypothesized that the sediment distribution in Lake Thonotosassa was due to the resuspension of the sediments from the shallow areas by wind mixing the overlying water column. These

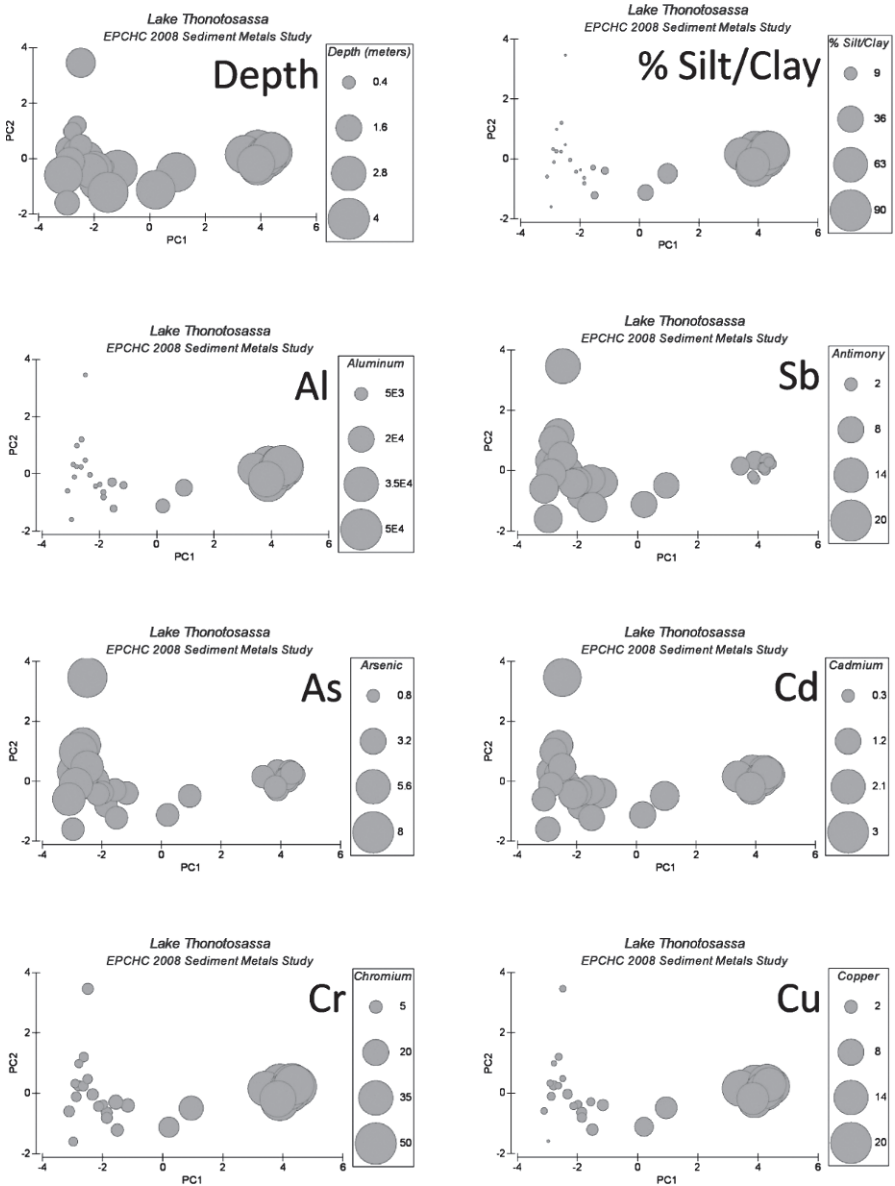


FIG. 4. PCA bubble plots for depth (m), silt + clay (%), and individual metals (mg/kg).

suspended sediments then would be deposited into the deeper parts of the lake. The steep slope along the western shoreline also causes slumping of the fine sediments focusing their deposition into the deep trough on the western side of the lake (Whitmore et al., 1996). The warm shallow areas of the lake and well mixed water column results in the rapid breakdown of organic

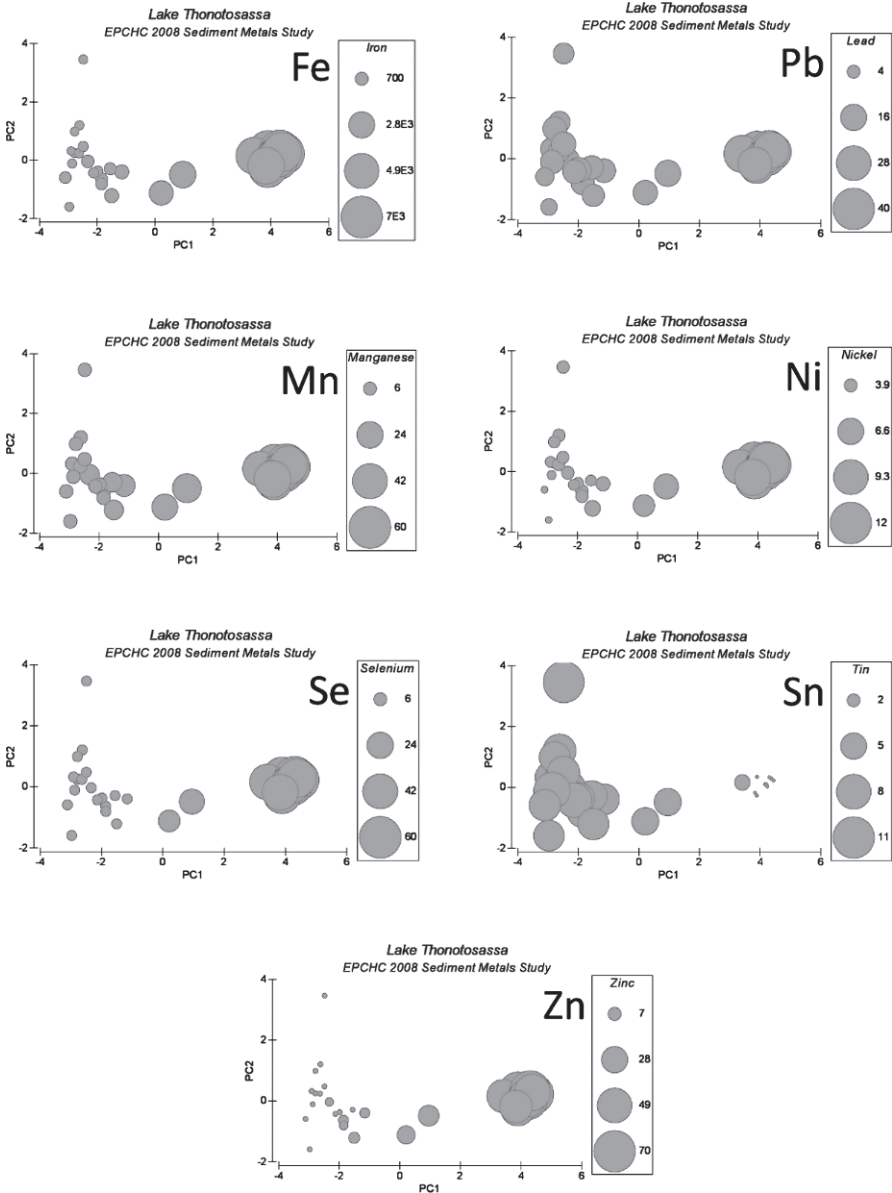


FIG. 4. Continued.

material which also prevents the accumulation of fine sediments (Whitmore et al., 1996).

Metals tend to adsorb onto finer grained sediments and the distribution of most of the metals in Lake Thonotosassa closely followed the distribution of fine sediments. The concentrations of antimony, arsenic and tin however were

highest in the shallow areas of the lake, which were characterized by sandy sediments with low % silt + clay values. These shallower sites tend to have better mixing of the overlying water column and higher dissolved oxygen levels which results in an oxidizing environment. One possible explanation for this distribution is that the oxidized states of these three metals are less soluble than their reduced forms (Chen et al., 2003; Whitmore et al., 2008) and therefore they precipitate into the sediments in the shallow oxygenated areas of the lake. Arsenic and antimony bind and precipitate with iron and manganese compounds under oxic conditions and are released under anoxic conditions into their dissolved states (Chen et al., 2003; Whitmore et al., 2008; Pichler et al., 2008). Conversely, the heavier metals are more soluble in their oxidized forms and precipitate in their reduced forms. The deeper areas of the lake are more anoxic forming reducing environments and hence these metals were found in higher concentrations at the deeper sites (Miao et al., 2006).

Overall, the sediment metals concentrations in Lake Thonotosassa were better than the established Florida state sediment quality guidelines (MacDonald et al., 2003). Exceptions were cadmium, which exceeded its TEC level at all 30 sites; and chromium which was above its TEC level at four sites. The chromium concentrations were not enriched relative to the FDEP reference sites (Carvalho et al., 2002) although cadmium levels were. The metal:aluminum ratios for both of these metals however suggest that they were not elevated above local background levels.

Lead was of particular interest in this study due to the establishment of the TMDL for lead in Lake Thonotosassa surface waters (U.S. EPA, 2005). The TMDL report for Lake Thonotosassa suggested that the observed lead exceedences may have been due to the resuspension of contaminated sediments during storm events (U.S. EPA, 2005). Lead levels in the lake sediments were highest at the deeper sites and associated with fine sediments. All the sites were below the established TEC for lead (35.8 mg/kg; MacDonald et al., 2003) although several sites did approach this threshold. These results are consistent with the assumption that deeper areas of the lake act as a sink for lead entering the lake.

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