

Seasonal changes in sediment and water chemistry of a subtropical shallow eutrophic lake*

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Abstract

A field study was conducted (May 1981 to June 1982) to develop a data-base on seasonal changes of water and sediment chemistry of Lake Monroe (4000 ha surface and ca. 2 m deep) located in central Florida, USA. This shallow eutrophic lake is a part of the St. Johns River. Quantitative samples of lake water and sediments were collected on a monthly basis from 16 stations and analyzed for various physico-chemical parameters. Relatively high levels of dissolved solids (mean electrical conductivity (EC) = 1832 $\mu\text{S cm}^{-1}$) prevailed in the lake water, and seasonal changes in EC were probably associated with hydrologic flushing from external sources, such as incoming water from upstream as well as precipitation. Average monthly levels of total N and P during the study period were 1.82 and 0.21 mg l⁻¹, respectively. Nutrient concentrations in the water did not show any strong seasonal trends. Organic matter content of lake sediments ranged from 1 to 182 g C kg⁻¹ of dry sediment, reflecting considerable spatial variability. All nutrient elements in the sediments showed highly significant ($P < 0.01$) correlations with sediment organic C, though little or no significant relationship appeared at any sampling period between water and sediment chemistry of the lake. Temporal trends in water and sediment chemical parameters may have been concealed by periodic hydrologic flushing of the St. Johns River into Lake Monroe.

Introduction

Freshwater habitats (mostly lakes and a few streams and rivers) occupy ca. 8% of the total surface area of the state of Florida. Continuous nutrient loading of many lakes in the state from urban and agricultural activities on surrounding lands has enhanced the rate of eutrophication. Discharged nutrients are generally tied up in algal cells and aquatic macrophytes (Yount and Crossman, 1970); upon death or aging, this tissue (Sonzogni *et al.*, 1982) is deposited on the lake bottom, eventually resulting in buildup

of organic matter. To assess lake eutrophication, it is a common practice to monitor lake water chemistry and that of any external nutrient sources discharged into the lake (Shannon and Brezonik, 1972; Joyner, 1974; Kaufman, 1975; Canfield, 1981), while chemistry of sediment nutrients and their roles in affecting quality of overlying water are often ignored. Presently, little or no information on the current status (nature and extent) of nutrient concentrations in lake sediments of Florida is available.

Sediment deposits of lakes can function as either a source or a sink for many of the essential nutrients

involved in the eutrophication process. Exchange of nutrients between sediments and overlying water depends upon chemical characteristics of the water and of the sediment (Mortimer, 1971; Wildung *et al.*, 1974). Therefore, to assess the nutrient status of a lake, it is essential to develop information on seasonal changes in water and sediment chemistry at the sediment-water interface.

The present study was undertaken in Lake Monroe (4000 ha surface area) located along the northern fringe of the City of Sanford in central Florida. This portion of peninsular Florida contains a large number of similar lakes often associated with intense urban development and/or agricultural activities. The purpose of study was to develop information on seasonal changes of physico-chemical parameters at the sediment-water interface, and to elucidate any relationships between chemistry of the sediments and that of overlying water.

Materials and methods

Lake Monroe is a natural lake located at approximately 28°50'N latitude and 81°15'W longitude, in Seminole and Volusia counties, Florida. It is ca. 8.5 km long and 6.0 km wide at its widest point (Fig. 1). The St. Johns River enters from the east and

flows through the lake, but water movement is hardly noticeable because of flow rates of only 10–40 cm min⁻¹. Water depth ranges from <1 m around the lake's perimeter to ca. 3 m in some of its central portions. Water is turbid, with an average Secchi disc value of 0.5 m (0.3–0.5 m) (Canfield, 1981).

Sixteen sampling stations were established in the lake, with some selected close to permanent channel markers, while others were permanently marked with buoys. Physical appearance of sediments between sampling stations ranged from clean sand to predominantly muck. Generally, the more shallow stations supported sandy substrates. There were no rooted or floating macrophytes or filamentous algae at any station. Sampling efforts were concentrated near the City of Sanford (Fig. 1) because of greater urban activity near this portion of the lake.

Water and sediment samples were collected each month from May 1981 to April 1982, and also in June 1982. To determine water pH and turbidity, three separate samples were collected with a 2-l Kemmerer bottle near the bottom at each station without disturbing underlying sediments. Samples were then transferred to 1-l plastic bottles, stored in an ice chest, and analyzed the same day for pH and turbidity using an Orion research-analog pH meter (Model 301, Orion Research, Inc., Cambridge, MA) and a turbidity meter (Model DRT 1000, HF Instruments, Bolton, Ontario, Canada). Water temperature and dissolved oxygen near the bottom at each station were measured with a portable YSI meter (Model 54-A, Yellow Springs Instruments Co., Yellow Springs, OH), and a YSI conductivity/salinity meter (Model 33 SCT) was used to measure in-situ electrical conductivity. Water depth at each sampling station was measured with a graduated pole.

Quantitative samples of sediments and associated overlying water utilized for analysis of chemical characteristics, were collected with a previously-described sampler (Ali, 1984). Approximately 8-cm cores of sediment, and 250 ml of overlying water, were taken in each case. Three core samples and three water samples were collected at each station. A sediment depth of 8 cm was selected because this zone is the most actively involved in nutrient exchange at the sediment-water interface (Berner, 1977; Mortimer, 1971). A 50-ml syringe was used to retrieve the

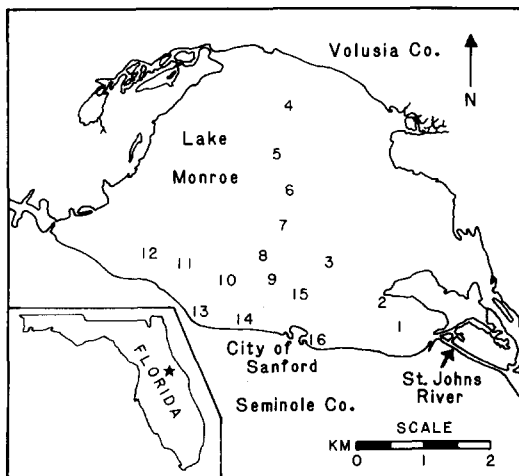


Fig. 1. Location of sampling stations for water and sediment samples in Lake Monroe, Seminole and Volusia Counties, central Florida.

required amount of water from above sediment column in core tube. Any water left after collecting water sample was siphoned off and discarded prior to extruding the desired length of sediment core into a polyethylene bag (Ali, 1984). The appropriately labeled sediment and water samples were transported to the laboratory in an ice chest and then frozen until analysis 2–8 weeks after collection. Three drops of conc. HCl were added to each water sample to stabilize its trace-metals content prior to freezing.

For water analysis, a portion of each water sample was filtered through a 0.45 μm filter into a flask containing three drops of 12 N HCl. Filtered samples were analyzed for $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, SRP (soluble reactive P), K, Ca, Na, Mg, Mn, Fe, and Zn. A portion of the unfiltered water from each sample was analyzed for Kjeldahl nitrogen (Kj-N) and total phosphorus (TP).

All sediment samples were analyzed for total elemental concentration as well as water-soluble (pore water), and extractable fractions. To determine water-soluble concentrations, a known amount of wet sediment was extracted in deionized water at a sediment-water ratio (by weight) of 1:2. After one hr of shaking, the sediment suspension was filtered through a 0.45 μm filter into a flask containing three drops of HCl. Filtered solutions were analyzed for $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, SRP, K, Ca, Na, Mg, Mn, Fe, and Zn.

Extractable $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ was analyzed by utilizing a known amount of wet sediment from each sample and extracting in 2 N KCl at a sediment-KCl ratio of 1:5. After one hr of shaking, the sediment suspension was filtered through a Whatman #42 filter paper into a flask containing three drops of HCl. The extracted solution was then analyzed.

To determine the amount of extractable P, K, Ca, Na, Mg, Mn, Fe, and Zn, a double-acid (0.05 N HCl + 0.025 N H_2SO_4) extraction (Nelson *et al.*, 1953) was used. A known amount of wet sediment from each sample was extracted in the double acid at a sediment-acid ratio of 1:5. After one hr of shaking, sediment suspension was filtered through a Whatman #42 filter paper.

For total analysis, each sediment sample was dried at 70 °C and ground to pass a 40-mesh sieve. A Kjeldahl digestion and distillation method was used to

determine the total N content (Bremner, 1965a). Dried sediment was digested with nitric-perchloric acid and analyzed for P, K, Ca, Na, Mg, Mn, Fe, and Zn. Total C was determined by a wet oxidation method (Nelson and Sommers, 1982).

All water samples were analyzed using standard methods (APHA, 1980). Ammonium- and $\text{NO}_3\text{-N}$ in the water and sediment samples were analyzed by a steam distillation method (Bremner, 1965b) whereas total N was determined by a Kjeldahl digestion and distillation method (Bremner, 1965a). Phosphorus was analyzed by an ammonium molybdate-ascorbic acid method (APHA, 1980). All other elements (K, Ca, Na, Mg, Mn, Fe, and Zn) were analyzed using an atomic absorption spectrophotometer.

Results and discussion

Physical and chemical characteristics of lake water at the sediment-water interface are summarized in Table 1. Mean concentrations of organic N and total

Table 1. Physical and chemical parameters of water from Lake Monroe, Seminole County, FL. Values represent overall means ($n = 208$) and range of observations for samples taken monthly at 16 stations from May 1981 to June 1982.

Parameter	Mean \pm SD	Range
Depth (m)	2.3 \pm 0.7	0.3 – 4.1
Temperature (°C)	22.6 \pm 6.1	9.9 – 31.8
Turbidity (NTU)	7.27 \pm 3.53	0.7 – 16.5
Conductivity ($\mu\text{S cm}^{-1}$)	1832 \pm 588	540 – 3130
Dissolved oxygen (mg l^{-1})	7.4 \pm 2.1	1.7 – 11.4
pH	8.1 \pm 0.7	6.4 – 9.3
Organic N (mg l^{-1})	1.61 \pm 0.62	0.28 – 3.57
$\text{NH}_4\text{-N}$ (mg l^{-1})	0.18 \pm 0.15	0.01 – 0.57
$\text{NO}_3\text{-N}$ (mg l^{-1})	0.03 \pm 0.05	0.001 – 0.43
Total P (mg l^{-1})	0.21 \pm 0.09	0.05 – 0.78
SRP (mg l^{-1})	0.06 \pm 0.05	0.002 – 0.22
K (mg l^{-1})	8.0 \pm 4.0	1.0 – 22.0
Ca (mg l^{-1})	51.5 \pm 19.9	7.0 – 98.0
Na (mg l^{-1})	194.7 \pm 77.0	18.0 – 386.0
Mg (mg l^{-1})	23.3 \pm 9.7	3.0 – 47.0
Mn (mg l^{-1})	0.027 \pm 0.018	0.001 – 0.12
Zn (mg l^{-1})	0.010 \pm 0.010	0.001 – 0.05

SRP = Soluble reactive phosphorus

P were 1.61 and 0.21 mg l⁻¹, respectively. A substantial portion of the N and P was in organic form, most likely tied up as dissolved organic compounds in microbial or algal biomass. Inorganic forms of N and P represented a relatively small fraction of the two nutrients. Average concentrations of NH₄-N and NO₃-N were 0.18 and 0.03 mg N l⁻¹, respectively, while SRP levels averaged 0.06 mg P l⁻¹.

Electrical conductivity levels of lake water were 540–3130 μs cm⁻¹, with a mean value of 1832 ± 588 μs cm⁻¹, indicating high concentrations of dissolved solids. Concentrations of Na were also somewhat elevated, averaging 195 mg l⁻¹ and ranging as high as 386 mg l⁻¹. Elevated levels of Na were probably due to marine sediments in and near the lake, and to mineralized water from salt springs located upstream of Lake Monroe (McLane, 1955). During periods of high rainfall mineral content of this lake is low, but under conditions of low rainfall, mineral content can be high (Canfield, 1981). Mean concentrations of K, Ca, Mg, Mn, and Zn in the

water column were 8.0, 51.5, 23.3, 0.03, and 0.01 mg l⁻¹, respectively.

High pH and dissolved oxygen levels (Mean = 8.1 pH units and 7.4 mg O₂ l⁻¹, respectively) measured during the daytime suggest presence of significant phytoplankton biomass at the sediment-water interface, or of good mixing of water in this shallow lake due to wind action.

Chemical composition of sediments from the various sampling stations reflected a high degree of spatial variability (Table 2). Sediment types in Lake Monroe range from sand and shells to peat or muck. Organic sediments predominate near the littoral fringe, where plant detritus has accumulated on the lake bottom. On average, sediment contained relatively high levels of organic matter (75 mg g⁻¹ organic C), Kj-N (6.6 mg g⁻¹), P (1.4 mg g⁻¹), Ca (24.5 mg g⁻¹), and Fe (12.2 mg g⁻¹). Mean concentrations of K, Na, Mg, Mn and Zn for Lake Monroe sediments were 768, 1874, 3101, 87, and 180 mg kg⁻¹, respectively.

Table 2. Chemical composition (total) of sediments from 16 sampling stations in Lake Monroe, Seminole County, FL. Values are means (n = 208) of monthly samples taken from May 1981 to June 1982.

Station	mg g ⁻¹					mg kg ⁻¹				
	Org C	Kj-N	P	Fe	Ca	K	Na	Mg	Mn	Zn
1	87	9.9	1.5	14.3	8.1	819	2600	3728	94	220
2	1	0.2	0.1	0.3	0.6	56	323	166	15	60
3	6	0.7	0.2	2.2	1.8	151	451	665	22	83
4	102	10.8	3.1	19.3	32.7	1142	2924	4641	114	221
5	131	12.1	3.1	18.3	35.8	1281	2969	4571	113	226
6	151	13.5	2.1	19.1	20.5	1117	3164	5164	131	138
7	31	3.7	3.1	22.1	32.2	914	1918	5795	77	194
8	96	9.9	1.8	20.2	47.7	1172	2787	4559	90	145
9	182	11.9	1.0	9.2	30.1	690	2704	3433	66	203
10	89	6.7	1.8	10.8	59.3	764	2033	2831	112	224
11	65	5.6	1.0	12.4	11.6	882	1597	3230	130	210
12	53	4.4	1.0	15.4	25.1	705	1529	2273	143	403
13	3	0.2	0.2	1.8	4.7	241	439	518	24	50
14	23	1.7	0.4	2.4	32.2	150	652	1117	38	60
15	110	8.5	0.8	11.5	38.9	605	1868	2572	115	166
16	64	5.5	1.1	16.2	10.1	1603	2018	4171	113	279
Overall										
mean	75	6.6	1.4	12.2	24.5	768	1874	3101	87	180
SD	57	4.6	1.2	7.6	21.1	475	1044	1824	44	127

Kj-N = Kjeldahl nitrogen.

Table 3. Chemical composition (water-soluble and acid-extractable fractions) of sediments from 16 sampling stations in Lake Monroe, Seminole County, FL. Values are means ($n = 208$) of monthly samples taken from May 1981 to June 1982.

Station	mg kg ⁻¹											
	Water-soluble			Exchange- able NH ₄ -N	Acid-extractable							
	NH ₄ -N	NO ₃ -N	SRP		P	Ca	K	Na	Mg	Mn	Zn	Fe
1	147	11.8	7.2	200	61	5128	215	1682	1139	10.3	7.2	19.5
2	5	2.8	1.1	14	6	202	23	84	42	2.9	1.6	5.1
3	6	2.9	0.6	17	29	1643	61	117	236	4.6	2.1	34.8
4	93	10.9	2.8	133	72	5465	167	1102	1046	4.6	1.0	0.5
5	126	13.4	2.5	172	56	5316	163	1318	1027	3.9	1.1	0.6
6	144	12.1	4.0	192	61	5229	166	1421	1306	7.7	1.7	1.4
7	33	6.4	2.2	111	81	5363	121	839	758	3.4	1.3	0.3
8	116	7.7	6.4	169	55	5692	179	1341	993	5.4	1.5	0.9
9	47	16.1	2.2	84	15	5420	106	1359	1020	3.0	0.9	0.2
10	30	5.7	2.0	71	18	6030	95	839	712	2.6	0.7	0.0
11	35	6.3	1.8	78	54	5317	103	607	831	13.3	3.2	10.7
12	13	5.0	0.8	29	30	6187	66	475	481	6.2	1.8	0.2
13	5	2.4	0.3	9	25	2664	32	134	115	3.3	1.7	16.1
14	5	3.0	0.6	15	32	6105	28	333	268	2.1	1.5	1.6
15	27	6.0	2.1	49	10	5700	92	672	714	2.1	0.6	0.1
16	54	8.1	5.4	112	46	5156	152	857	830	5.6	23.9	18.0
Overall												
mean	55	7.5	2.6	91	41	4789	111	824	720	5.1	3.2	6.9
SD	65	8.3	3.2	89	32	2064	69	593	444	4.0	7.7	16.1

SRP = Soluble reactive phosphorus.

Water-soluble and extractable fractions from the sediment also exhibited a high degree of spatial variability (Table 3). Most of the interstitial (water-soluble) sediment N was present as NH₄-N, with an average concentration of 55 mg N kg⁻¹ sediment, whereas the average interstitial concentration of NO₃-N was only 7.5 mg kg⁻¹. Concentration of sediment-bound (exchangeable) NH₄-N was roughly twice the concentration of interstitial NH₄-N, with the former averaging about 91 mg kg⁻¹. Similarly, levels of acid-extractable P were substantially higher than levels of water-soluble P, indicative of the P-retention capacity of the sediment, such capacity is enhanced by organic matter content and by cations such as Ca and Fe. Mean water-soluble P in the sediment was 2.6 mg P kg⁻¹, compared with an average acid-extractable P concentration of 41 mg kg⁻¹. Concentrations of metals bound by sediment's cation exchange complex generally varied with sediment organic C content. Average concen-

trations of extractable Fe, Ca, K, Na, Mg, Mn, and Zn were 6.9, 4789, 111, 824, 720, 5.1, and 3.2 mg kg⁻¹, respectively.

Seasonal trends of pH, conductivity, dissolved O₂ and turbidity levels during the period May 1981 to June 1982 are shown in Fig. 2. Dissolved O₂ levels displayed a discernible seasonal pattern due to the dependence of O₂ solubility on temperature. Water pH, conductivity, and turbidity followed no particular trend with respect to season; however, there was a general decline in levels of these parameters between February and June of 1982. This was probably due to excessive rainfall during the period, resulting in increases in lake-water elevations of up to 1.1 m during that period. The influx of a large volume of relatively acidic rainfall (pH of ca. 4.5) may have effected a decrease in water pH, while simultaneously depressing conductivity levels by dilution of dissolved salts. Since the St. Johns River flows through Lake Monroe, mineral inputs to the

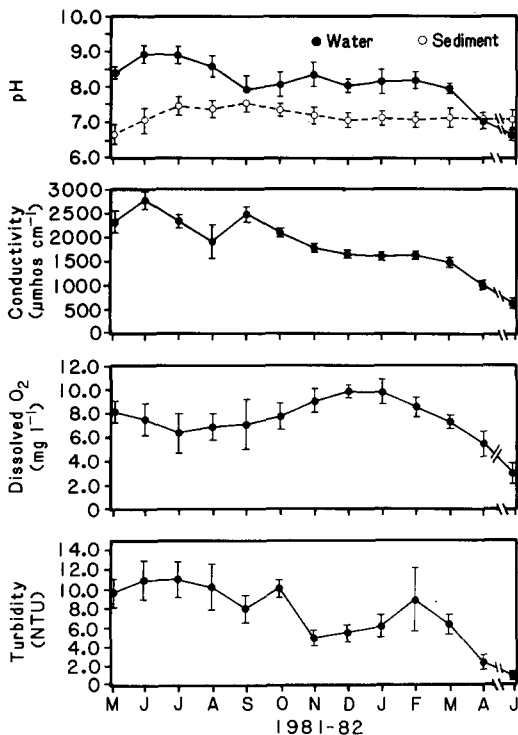


Fig. 2. Seasonal changes in selected physico-chemical parameters for water and sediments from Lake Monroe, central Florida.

river also affect the mineral content of the lake. Dissolved O_2 and turbidity levels may have declined during this period because of the considerable increase in water depth, reducing the degree of water mixing and turbulence. Sediment pH fluctuated only slightly during the study period, with pH levels generally lower than those of the overlying water. The lower levels for sediment pH were probably due to the presence of substantial amounts of organic matter, with associated CO_2 production and nitrogen mineralization.

Inorganic N concentrations of the water fluctuated considerably during the study period, with a trend toward an increase in NH_4 -N concentration, while NO_3 -N showed little net change (Fig. 3). Increase in NH_4 -N may have been associated in part with the concurrent decrease in pH. Lower pH in this pH range causes a shift toward NH_4 over NH_3 as the predominant inorganic N form ($pK=9.3$) and this results in reduced loss of N by ammonia volatiliza-

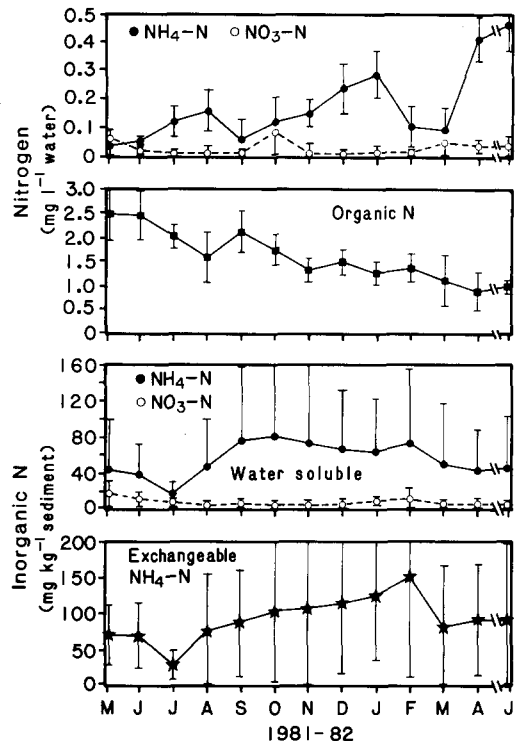


Fig. 3. Seasonal changes in organic and inorganic N concentrations for water and sediments from Lake Monroe, central Florida.

tion (Bouldin *et al.*, 1974). Organic N concentration of the water followed a generally decreasing trend concurrently, with a corresponding decrease in turbidity. This suggests that resuspension of sediment organic matter was a major cause of high organic N values early in the study period. Water-soluble (interstitial) and exchangeable N displayed a similar pattern of fluctuation. Although it appeared that these changes may have been seasonal (i.e., lower in summer months and higher during winter), there was no significant correlation with water N concentration near the sediment-water interface. The large standard deviation values for sediment N fractions reflect the extreme heterogeneity of sediments among the sampling stations.

Phosphorus concentration of the lake water generally decreased during the fall and winter months (Fig. 4). The cause of this fluctuation is not clear, though it could be related to the temperature dependence of phosphate-mineral solubility for the

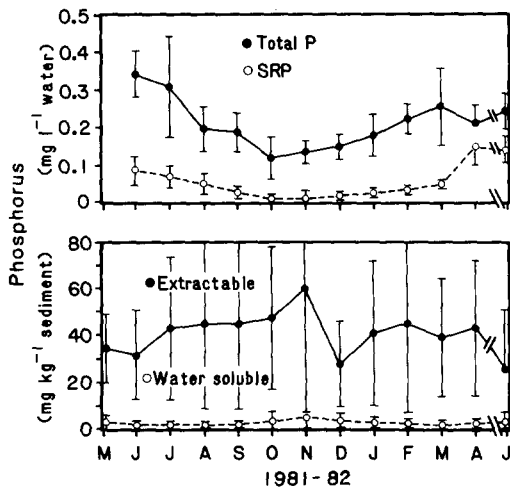


Fig. 4. Seasonal changes in phosphorus concentrations for water and sediments from Lake Monroe, central Florida. SRP = Soluble reactive phosphorus.

underlying sediments. In addition, phytoplankton populations in the lake during the winter months declined (Ali, unpublished data), which could also cause a decrease in TP concentration of the water. The proportion of SRP to total P remained essentially constant throughout the study period, except for an anomalous increase in SRP during March of 1982. Average levels of sediment-bound P did not fluctuate significantly, though values for the standard deviation were high due to the aforementioned spatial variability between sediment sites. Concen-

tration of SRP in the sediment was considerably less variable, and generally averaged less than 6 mg kg⁻¹.

Data analyses indicated few significant relationships between water chemistry and corresponding sediment chemistry. This is probably due to hydrologic flushing during flow of the St. Johns River through the lake. Under such conditions, detection of elemental fluxes and interactions across the sediment-water interface were not possible; however, many significant relationships were observed among various sediment-associated parameters as well as among certain parameters of samples from the water column (Tables 4, 5).

Conductivity and pH of the water showed significant correlations with many water-chemistry parameters (Table 4). Similarly, with the exception of NO₃-N and P, Na also showed significant relationships with all water chemistry parameters. Such results suggest the significance of external inputs of Na-rich water, from either natural or anthropogenic sources, with respect to many lake-water chemical characteristics. Similarly, Na content of the sediments showed highly significant correlations with all other elements studied, with the exception of Ca (Table 5). Sediments of many lakes in this physiographic zone are dominated by deposits of peat, alluvium, freshwater marl, and marine sediments (White, 1970). Only the latter is a likely potential source of the Na.

Table 4. Matrix of correlation coefficients (n = 208) between selected physico-chemical parameters of water from Lake Monroe, Sanford, FL. Values >0.181 are significant at the 0.01 probability level.

Parameter	EC	NO ₃ -N	NH ₄ -N	Kj-N	SRP	TP	K	Ca	Mg	Na	Cl
pH	0.765	-0.152	-0.687	0.398	0.001	0.096	0.450	0.633	0.592	0.743	0.563
EC	-	0.662	-0.732	0.672	0.138	0.222	0.528	0.640	0.604	0.846	0.655
NO ₃ -N	-	-	0.117	0.050	0.187	0.186	0.118	0.032	0.036	-0.045	-0.058
NH ₄ -N	-	-	-	-0.352	-0.149	0.226	-0.497	-0.597	-0.569	-0.750	-0.444
Kj-N	-	-	-	-	0.245	0.308	0.402	0.378	0.389	0.483	0.415
SRP	-	-	-	-	-	0.980	0.610	0.272	0.335	0.119	0.044
TP	-	-	-	-	-	-	0.658	0.346	0.404	0.192	0.104
K	-	-	-	-	-	-	-	0.839	0.897	0.547	0.579
Ca	-	-	-	-	-	-	-	-	0.928	0.689	0.677
Mg	-	-	-	-	-	-	-	-	-	0.638	0.619
Na	-	-	-	-	-	-	-	-	-	-	0.700

SRP = Soluble reactive phosphorus, KJ-N = Kjeldahl nitrogen.

Table 5. Simple correlation coefficients ($n = 208$) between selected elements in sediments from Lake Monroe, Sanford, FL. Values > 0.181 are significant at the 0.01 probability level.

Parameter	Total							
	Kj-N	TP	K	Ca	Mg	Fe	Mn	Na
TOC	0.916	0.367	0.479	0.322	0.555	0.414	0.537	0.745
Kj-N	-	0.503	0.652	0.241	0.711	0.617	0.584	0.904
TP	-	-	0.551	0.410	0.657	0.642	0.472	0.588
K	-	-	-	0.141	0.850	0.844	0.652	0.792
Ca	-	-	-	-	0.212	0.264	0.364	0.231
Mg	-	-	-	-	-	0.921	0.602	0.844
Fe	-	-	-	-	-	-	0.682	0.786
Mn	-	-	-	-	-	-	-	0.594

Ej-N = Kjeldahl nitrogen.

It was apparent, as previously discussed, that pH affected the concentration of $\text{NH}_4\text{-N}$ in the overlying water column. Regression analysis showed a significant relationship between pH and $\text{NH}_4\text{-N}$ (Fig. 5). Sediment Kj-N was found to be positively

correlated with both interstitial and exchangeable $\text{NH}_4\text{-N}$ of the sediment. The latter two parameters are shown as functions of pH and Kj-N in Fig. 5. Similarly, acid-extractable P proved related to total sediment P concentration (Fig. 6). The considerable

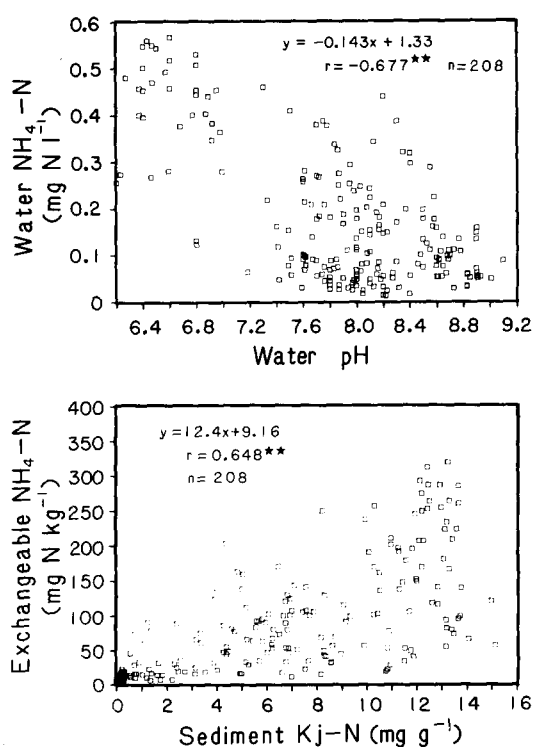


Fig. 5. Relationship between pH and ammonium N concentration of water (5a), and between Kjeldahl-N and exchangeable ammonium N of sediment (5b), for Lake Monroe, central Florida, May 1981 to June 1982.

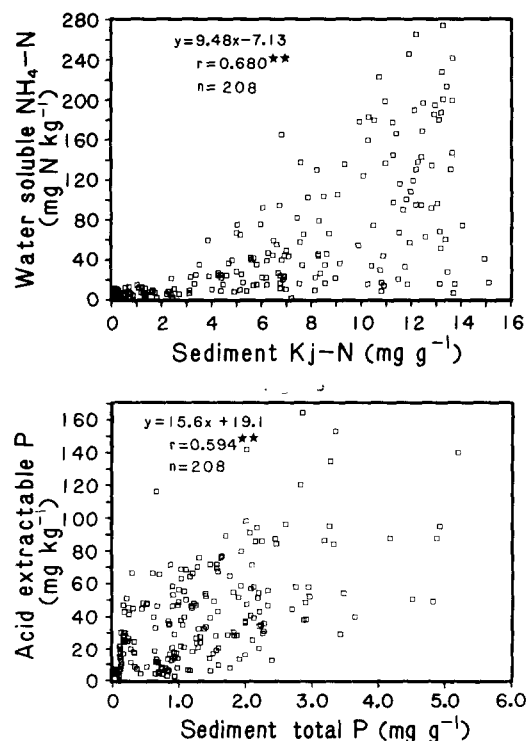


Fig. 6. Relationship between sediment Kjeldahl-N and water soluble ammonium N (6a), and between sediment total P and extractable P (6b) for Lake Monroe, central Florida, May 1981 to June 1982.

scatter in data points of Figs. 5 and 6 was due to the spatial and temporal variability of these parameters between sampling sites.

The study reported here presents an initial database on nutrient status, and a comprehensive characterization of water and sediment chemistry for Lake Monroe, one of the larger lakes of Florida. Such information, presently not available for most Florida lakes, is necessary for defining water-quality trends and future research needs concerning specific water quality related problems of such lakes.

Sediments in Lake Monroe showed a high degree of spatial variability, specifically with respect to physical composition and chemical characteristics. This indicates that areas of the lake bottom support high levels ($>100 \text{ mg kg}^{-1}$), medium levels ($50\text{--}100 \text{ mg kg}^{-1}$), and low levels ($<50 \text{ mg kg}^{-1}$) or organic C content. This type of variability is to be expected for larger lakes such as Lake Monroe. Temporal variation of sediment chemistry at any particular sampling station was minimal. Generally, chemical composition of sediment does not change significantly in a relatively short time-span such as 1–2 years unless large quantities of anthropogenic sources of pollutants are discharged into the lake.

Little or no hydrologic information on Lake Monroe is presently available to quantify the residence time and flushing rates. However, some other Florida lakes such as Lake Apopka (12 500 ha surface area) and Lake Okeechobee (292 000 ha surface area) considered to be having lower flushing rates than Lake Monroe, have hydraulic residence times of about 6 months to one year (Pollman, 1983). It is estimated that hydraulic retention time in Lake Monroe is much less than 6 months.

A much lesser degree of variability was observed for water chemistry, but the water was apparently greatly influenced in turn by regular and continued hydrologic flushing of the lake. For lakes with high rates of hydrologic flushing, sediment characteristics are poor indicators of overlying water chemistry. Any nutrients released from the sediments can be rapidly assimilated by phytoplankton, and also are liable to be flushed away by water movement in the lake. Further long-term studies on Lake Monroe are needed to understand the influence of sediment nutrients on overlying water and the eventual impact on trophic structure of the lake.

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