Limnology of Ponds in the Kissimmee Prairie

Tim Kozusko
Environmental Management, United Space Alliance, 8550 Astronaut Blvd., USK-T28, Cape Canaveral, FL 32920
E-mail: tkozusko@cfl.rr.com

John A. Osborne
UCF Department of Biology, 4000 Central Florida Blvd., Orlando, FL 32816-2368

Paul Gray
Audubon of Florida, 100 Riverwoods Circle, FL 33857

ABSTRACT

We studied the physicochemical features of three ponds in the Kissimmee Prairie, Okeechobee County, Florida, between January and August 1997, and May and August 1998. Data collected included pH, specific conductance, water temperature and depth, turbidity, water color, alkalinity, tannin, dissolved oxygen, and concentrations of nitrogen and phosphate. We found the ponds to be acidic, poorly buffered, moderate to high in water color, and low in mineralized nitrogen and phosphorus. There were statistically significant differences in water chemistry between the inner zones of ponds and the outermost wet prairie zones. Water in the wet prairie zones had significantly lower pH, higher specific conductivity, and greater water color and tannin concentrations than did water in the inner zones of ponds.

INTRODUCTION

The National Audubon Society's Ordway-Whittell Kissimmee Prairie Preserve (KP), now part of the Kissimmee Prairie Preserve State Park, managed by the Florida Department of Environmental Protection, is located in north-central Okeechobee County, Florida. The Sanctuary (hereafter KP) represents a portion of the lower Kissimmee River watershed that contains unaltered wetlands and numerous small ponds ranging in area from less than 1 ha to greater than 5 ha.

KP is composed of nearly level Pleistocene marine terrace deposits (Webb 1990). The substrate is of well-sorted fine quartz sands. These marine sands are drought-prone yet poorly drained due to level topography and presence of an organic and/or calcareous pan that can impede vertical water movement (Pettry et al. 1965, McCollum and Pendleton 1971).

In shallow surface waters water chemistry is strongly influenced by soil composition (Wetzel, 1983). Marine terrace deposits in Florida generally favor formation of the Spodosol soil order (Brown et al., 1990). Spodosols are typified by an illuvial soil horizon enriched in oxides of iron and aluminum, and organocomplexes that have leached down from the soil surface (Allen and Fanning 1983, Brown et al. 1990). The spodic horizon in Florida soils generally follows the contour of the ground and is related to water table depth (Pettry et al. 1965, Yuan 1966). Spodic horizon development is thought to be inhibited by conditions of permanent soil saturation (McKeague et al. 1983). The spodic horizon is not present under the ponds.

Ponds within the KP exhibit a concentric zonation of vegetation, presumably related to hydroperiod. The center of most ponds is inhabited by a monotypic stand of pickerelweed, *Pontederia cordata* L. Surrounding this zone is a dense growth of maidencane, *Panicum hemitomon* Schult. grading into a zone of St. John's-wort, *Hypericum fasciculatum* Lam. with *Utricularia*, *Eleocharis*, *Carex*, *Ranunculus*, and *Rhynchospora* species. In the wet prairie transitional zone between the pond and the wiregrass/palmetto prairie, the vegetation community is principally comprised of *Drosera* sp., *Sphagnum* sp., *Eriocaulon* spp., *Rhynchospora*, *Aristida stricta* var. *beyrichiana* (Trin. & Rupr.) D. B. Ward, *Carex* spp., and *Rhynchospora* spp.

We studied the limnological characteristics of Kissimmee Prairie ponds to determine if there were significant differences in water chemistry among the ponds and among the vegetation zones within each pond. We used monthly mean precipitation data from Fort Drum, 1961-1990 (Owenby and Ezell 1992) to characterize precipitation for the area. Fort Drum is located approximately 16 km east of KP.

METHODS AND MATERIALS

The study ponds are located at latitude 27° 33' N, longitude 81° 59' W. Surveys of the property indicate the wetlands are near the top of their watershed (P. Gray, unpub. data), thus should be unaffected by flows from off the property. Native-range cattle grazing was the previous use of the property, but cattle had been removed for 17 years at the commencement of the study.

We monitored pond depth using a 2.54-cm-diameter gauging post driven into the sediment. Water depth was also determined at each sampling site. We performed water sampling along a transect with three stations in each of four vegetation zones. We withdrew water samples for laboratory analyses using PVC pipe, 1 m long and 2.5 or 5 cm in diameter (2.5 cm for deep samples, 5 cm for shallow samples). The pipe was fitted with a shut-off valve. This device was used to isolate a section of the water column. Two columns were withdrawn from each station and mixed in a larger container from which the sample bottle was filled.

Land of Fire and Water: The Florida Dry Prairie Ecosystem. Proceedings of the Florida Dry Prairie Conference. Reed F. Noss, editor. 2006.

We measured hydrogen ion concentration *in situ* with an Oakton pH Testr 2. We measured specific conductance and water temperature *in situ* with a Hach Model 150 specific conductivity meter. Water color and tannin/lignin concentrations were determined spectrophotometrically (APHA 1975). We determined dissolved carbon dioxide and alkalinity by titration (APHA 1975) and Lind (1979), respectively. Dissolved oxygen was determined using the modified Winkler method (APHA 1975).

A certified commercial laboratory performed nutrient analyses on composite samples (n = 27) using EPA laboratory procedures. These included ammonium (EPA 350.1), nitrate (EPA 353.1), total Kjeldahl nitrogen (EPA 351.2), nitrite (SM4500NO2B), orthophosphate (EPA 365.2), and total phosphorus (EPA 365.2). In 1998 the updated version (365.4) was used to determine total phosphorus. The wet prairie zone was not included in the composite samples for nutrient analysis because this would over-represent this small component of the pond volume. Beginning in July 1998, nutrient analyses included composites of the four vegetation zones.

Kruskall-Wallace analysis of variance was used to compare sample medians with a confidence level of $p = 0.05$. All calculations involving pH were performed by first converting pH to hydrogen ion concentration. We assigned the detection limit value to concentrations found to be below detection limits, allowing calculation of means and confidence limits.

RESULTS AND DISCUSSION

The study ponds had areas <1 ha, maximum depths < 60 cm, and surface area to volume ratios > 50:1. Dense vegetation shaded the water, retarded mixing, and decreased the effects of wind on the water surface. In the less-shaded areas of the ponds, heating was intensified by high water color. Water between 20 and 50 cm deep was isothermal at dawn, yet stratified by afternoon. In late spring through summer, the surface of the water column was generally 10° C warmer than the bottom, and temperatures of water less than 20 cm deep exposed to full sunlight commonly exceeded 40° C. The highest temperature recorded was 46° C.

The normal rainfall pattern for the study area is a wet summer and fall, followed by a dry winter and spring. The seasonal rainfall pattern was abnormal in 1998, with above average precipitation during February and March. This resulted in flooded conditions throughout the prairie during late winter and spring. When the normal rainy season would have begun, the area was struck by a drought that resulted in the study ponds drying out in June.

During 1997 there was no significant difference in the pH of water in the pickerelweed and maidencane zones (Table 1). However, the St. John's-wort zone pH was significantly lower than the two inner zones, and the wet prairie pH was significantly lower than the St. John's-wort zone. In 1998 the pH of each zone ranged much lower,

Table 1. Mean pH values, ranges, and sample sizes within the vegetated zones of Kissimmee Prairie study ponds between January and August 1997, and May and August 1998.

	Vegetated Zone			
	Pickerelweed	Maidencane	St. John's-wort	Wet Prairie
1997				
Pond 1				
Mean pH	4.7	4.6	4.5	4.3
Range	4.6 - 4.9	4.4 - 4.8	4.3 - 4.9	4.1 - 4.4
Sample Size	42	42	42	24
Pond 2				
Mean pH	4.5	4.5	4.4	3.7
Range	4.3 - 4.7	4.3 - 4.7	4.1 - 4.7	3.3 - 4.1
Sample Size	42	42	42	30
Pond 3				
Mean pH	4.3	4.4	4.3	4.0
Range	4.1 - 4.6	4.2 - 4.7	4.0 -4.7	3.7 - 4.2
Sample Size	42	42	42	30
1998				
Pond 1				
Mean pH	4.5	4.5	4.5	4.6
Range	4.1 - 4.9	4.1 -4.9	4.0 - 4.9	4.0 - 5.8
Sample Size	27	27	27	21
Pond 2				
Mean pH	4.3	4.3	4.2	3.8
Range	3.5 - 4.7	3.5 - 4.9	3.4 - 4.7	2.9 - 4.5
Sample Size	27	27	27	21
Pond 3				
Mean pH	4.3	4.2	4.0	3.9
Range	4.1 - 4.6	3.9 - 4.7	3.8 - 4.5	3.5 - 4.3
Sample Size	27	27	24	21

though there were no significant differences in any zone from 1997 to 1998. The extremely low values are from the one sampling period right after the ponds had re-filled. In 1998 the inner three zones had no significant differences in pH, but the wet prairie zone had a significantly lower pH than did the rest of the pond. All study ponds had this general trend of decreasing pH towards the shore.

Riekerk and Korhnak (1992) report that the pH values of runoff water from undisturbed pine flatwoods were nearly one pH unit less than the pH of rainfall, and these authors attributed the lower pH of runoff to organic acids leached from soil humus. Specific conductivity increased from the center of the ponds towards the shore (Table 2). The wet prairie zone in the study ponds had significantly

Table 2. Mean specific conductance (Sp. Cond.), water color, tannin, and dissolved oxygen concentrations within the vegetated zones of Kissimmee Prairie study ponds between January and August 1997, and May and August 1998. Ninety-five percent confidence interval in parentheses.

	Vegetated Zone			
	Pickerelweed	Maidencane	St. John's-wort	Wet Prairie
1997				
Pond 1				
Sp. Cond.	55.2	56.2	58.2	99.8
(µS/cm @ 25 C)	(2.8)	(3.1)	(3.4)	(8.6)
Water Color	66.1	63.2	74.3	165
(Pt-Co Units)	(4.6)	(4.0)	(9.6)	(57)
Tannin (µg/l)	4.41	4.29	4.70	7.02
	(0.29)	(0.26)	(0.62)	1.07)
Pond 2				
Sp. Cond.	51.2	50.0	52.1	113
(µS/cm @ 25 C)	(2.1)	(1.9)	(2.2)	(7)
Water Color	72.4	68.0	68.8	275
(Pt-Co Units)	(2.2)	(2.6)	(6.2)	(51)
Tannin (µg/l)	4.82	4.26	4.20	11.9
	(0.20)	(0.26)	(0.35)	(1.9)
Pond 3				
Sp. Cond.	53.8	52.7	57.3	91.6
(µS/cm @ 25 C)	(2.5)	(2.1)	(2.8)	(7.1)
Water Color	93.3	88.8	92.3	151
(Pt-Co Units)	(4.5)	(4.1)	(6.4)	(20)
Tannin (µg/l)	5.89	5.70	5.78	9.24
	(0.37)	(0.34)	(0.33)	(1.80)
1998				
Pond 1				
Sp. Cond.	24.2	23.9	23.0	28.4
(µS/cm @ 25 C)	(2.4)	(2.2)	(2.7)	(7.1)
Water Color	98.8	108	109	174
(Pt-Co Units)	(8.4)	(7)	(9)	(26)
Tannin (µg/l)	8.24	8.17	8.32	10.3
	(1.60)	(1.47)	(1.87)	(3.0)
Dissolved Oxygen (mg/l)	2.29	2.40	3.48	3.84
	(0.24)	(0.17)	(0.28)	(0.32)
Pond 2				
Sp. Cond.	17.8	18.8	20.7	38.5
µS/cm @ 25 C	(1.5)	(1.4)	(2.6)	(13.9)
Water Color	96.9	98.7	102	254
(Pt-Co Units)	(8.7)	(9.3)	(9)	(53)
Tannin (µg/l)	7.72	7.53	7.54	13.4
	(1.68)	(1.59)	(1.64)	(4.8)
Dissolved Oxygen (mg/l)	2.09	2.61	3.59	3.51
	(0.17)	(0.20)	(0.25)	(0.22)
Pond 3				
Sp. Cond.	23.7	25.1	26.9	36.9
(µS/cm @ 25 C)	(3.6)	(4.2)	(2.8)	(5.6)
Water Color	124	118	138	222
(Pt-Co Units)	(9)	(11)	(14)	(39)
Tannin (µg/l)	10.4	8.84	9.42	12.3
	(2.0)	(1.9)	(2.17)	(3.6)
Dissolved Oxygen (mg/l)	2.02	2.56	3.44	3.54
	(0.22)	(0.19)	(0.31)	(0.20)

greater values than did the three inner zones. Specific conductivity in all zones was significantly lower in 1998 than in 1997. Conductivity was not well correlated with pH. In the ponds conductivity increased with acidity, but when pond acidity increased in 1998, conductivity decreased. The lower conductivity values in 1998 might have resulted from the rapid filling of the ponds after the drought.

Water color was correlated with pH, suggesting that the high acidity of the pond water resulted from organic acids transported from the spodic horizon. Water color increased towards the shore, though some color is contributed by organic material in the pond centers (Table 2). Water color was significantly greater in 1998 in all but the wet prairie zone.

Tannin concentrations were closely related to water color values in 1997 (Table 2). The pickerelweed, maidencane, and St. John's-wort zones within the study ponds were not significantly different (except the pickerelweed and St. John's-wort zones of pond 2) in water color and tannin concentration; however, the wet prairie zone had a significantly greater water color and tannin concentration. Tannin concentration was significantly greater in 1998 over 1997 in the pickerelweed, maidencane, and St. John's-wort zones of all three ponds. When the pond depths were low, 1 cm of rain increased the depth by nearly 2 cm. When the ponds were near their maximum depths, the increase was 1 to 1. The spodic horizon has been shown to affect soil permeability when it is dry (Pettry et al. 1965).

Additionally, the water table rose higher from rainfall than the pond depths did because the rainwater only had to fill the interstitial spaces. When the ponds were low this created a hydraulic head resulting in subsurface flow towards the ponds. This probably resulted in transport of soluble material from the adjacent prairie soils into the ponds, particularly when the ponds began to fill. When the ponds were continuously deep, less water entered from subsurface flow. There was also some surface sheet flow into the ponds. Soaking of surface humus in distilled water did not duplicate the increased acidity, conductivity, and water color that were observed in the shallow pond zones. Spodic horizon material placed in distilled water added color and acidity, and increased specific conductivity of the water.

Dissolved oxygen concentrations were typically less than 5 mg/l, and increased from the center of the ponds towards the shore (Table 2). The ponds were inhabited by fish that are able to gulp air, such as *Fundulus* sp. and *Gambusia affinis*. The first few cm of surface water probably had greater dissolved oxygen concentrations, but due to sampling techniques this layer was not represented in the data.

Ecosystems subject to frequent fire are often low in nitrogen due to loss by volatilization. The presence of carnivorous plants such as *Drosera* and *Utricularia* often indicates nitrogen deficient soils. All but one nitrate value was below the detection limit of 0.020 mg/l (Table 3). Ammonium was below the detection limit of 0.030 mg/l in 6 of 12 measurements but was more variable, ranging to greater than 0.1 mg/l. Nitrite was below the detection limit of 0.005 mg/l in all samples. Total Kjeldahl Nitrogen (TKN) values were rather high, generally between 1 and 2.5 mg/l. The pattern that emerged was low concentrations of mineralized nitrogen while total nitrogen, which includes the organic fraction, was higher.

Orthophosphate was generally near or below the detection limit of 0.005 mg/l. Total phosphorus was 1 or 2 orders of magnitude greater (Table 3). The low concentrations of mineralized nutrients and moderate to high concentrations of total N and P suggest that the system used the nutrients as they were supplied, cycling them quickly into biomass. At several times during the study orthophosphate concentrations were of the same order of magnitude as mineralized nitrogen, suggesting that either N or P could be limiting at various times.

Table 3. Mean nitrogen and phosphorus concentrations within the Kissimmee Prairie study ponds between January and August 1997, and May and August 1998. Ninety-five percent confidence interval in parentheses.

	Nitrite (mg/l)	Nitrate (mg/l)	Ammonium (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Ortho-Phosphate (mg/l)	Total Phosphate (mg/l)
1997						
Pond 1	<0.005 *	<0.03 (0.01)	<0.10 (0.07)	2.41 (0.78)	<0.015 (0.014)	0.112 (0.061)
Pond 2	<0.005 *	<0.02 *	<0.04 (0.02)	2.00 (0.34)	<0.010 (0.008)	0.073 (0.038)
Pond 3	<0.005 *	<0.02 (0.00)	<0.09 (0.04)	2.35 (0.80)	<0.014 (0.012)	0.148 (0.105)
1998						
Pond 1	<0.005 *	<0.02 *	0.05 (0.03)	1.07 (0.20)	<0.011 (0.007)	<0.05 (0.00)
Pond 2	<0.005 *	<0.02 (0.00)	<0.05 (0.02)	1.19 (0.43)	<0.007 (0.002)	<0.06 (0.01)
Pond 3	<0.019 (0.027)	<0.02 *	<0.06 (0.04)	3.08 (3.74)	<0.009 (0.004)	<0.13 (0.15)

*All measurements less than the detection limit.

CONCLUSIONS

There was a statistically significant difference in the water chemistry between the inner zones of the ponds and the surrounding wet prairie zone. Water in the wet prairie zones had significantly lower pH, higher specific conductance, and greater water color and tannin concentrations than water in the inner zones of ponds. Water chemistry of the wet prairie zones was probably affected by transport of organic compounds from the soil surrounding the ponds, particularly the spodic horizon.

The pH of water in these ponds was <5 and at times <4 in the shallowest zone. The combination of low pH and low alkalinity resulted in nearly all inorganic carbon being present in the water as dissolved carbon dioxide. During the spring and summer months, surface temperatures of shallow water exposed to sunlight commonly exceeded 40° C. Water <50 cm deep was isothermal at dawn, yet thermally stratified by afternoon. Despite these conditions, KP ponds support populations of fish (centrarchids, cyprinodontids, and poeciliids), frogs (hylids and ranids), snakes (colubrids and crotalids), and many birds.

ACKNOWLEDGMENTS

This study was conducted in partial fulfillment for the requirements of the University of Central Florida for the Master of Science in Biology, and was funded by grants from the Florida Center for Environmental Studies to I. J. Stout and J. A. Osborne. Thesis committee at the University of Central Florida: Drs. C. de la Rosa, I. J. Stout, W. K. Taylor, and chair J. Osborne. Thanks to the National Audubon Society for preserving a beautiful piece of Florida's landscape.

LITERATURE CITED

Allen, B. L. and D. S. Fanning. 1983. Composition and soil genesis. Pages 141-186 *in* L. P. Wilding, N. E. Smeck, and G. F. Hall, editors, Pedogenesis and Soil Taxonomy I. Concepts and Interactions.

APHA. 1975. Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF, 14th ed.

Brown, R. B., E. L. Stone, and V. W. Carlisle. 1990. Soils. Pages 35-69 *in* R. L. Myers and J. J. Ewel, editors, Ecosystems of Florida. University of Central Florida Press, Orlando.

Lind, O. T. 1979. Handbook of Common Methods in Limnology. 2nd ed. St. Louis: Mosby Co.

McCollum, S. H. and R. F. Pendleton. 1971. Soil survey of Okeechobee County. U.S. Department of Agriculture. Gainesville, FL.

McKeague, J. A., F. DeConinck, and D. P. Franzmeier. 1983. Spodosols. Pages 217-247 *in* L. P. Wilding, N. E. Smeck, and G. F. Hall, editors, Pedogenesis and Soil Taxonomy II. The Soil Orders.

Owenby, J. R., and D. S. Ezell. 1992. Monthly station normals of temperature, precipitation, and heating and cooling days in Florida, 1961-1990. N.O A.A. Bulletin 81.

Pettry, D. E., V. W. Carlisle, and R. E. Caldwell. 1965. Spodic horizons in selected Leon and Immokalee soils. Soil and Crop Science Society of Florida 25:160-172.

Riekerk, H., and L. V. Korhnak. 1992. Rainfall and runoff chemistry of Florida pine flatwoods. Water, Air and Soil Pollution 65:59-68.

Webb, D. S. 1990. Historical Biogeography. Pages 70-100 *in* R. L. Myers and J. J. Ewel, editors, Ecosystems of Florida. University of Central Florida Press, Orlando.

Wetzel, R. G. 1983. Limnology. 2nd ed. Saunders College Publishing, NY.

Yuan, T. L. 1966. Characteristics of surface and spodic horizons of some spodosols. Soil and Crop Science Society of Florida 26:163-171.