Physicochemical Conditions and Larval Chironomidae (Diptera) of an Urban Pond

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Timber Ridge Pond is a eutrophic pond in a residential neighborhood of Edmond, Oklahoma. Its main source of water is surface runoff, but it is also fed by two small, intermittent creeks. This pond was studied from March 1989 to February 1990 to determine trends in water chemistry, identify chironomid larvae present, describe seasonal changes in the chironomid population, and calculate cold-season and warm-season productivity. Water samples were taken monthly to analyze physicochemical properties. Chironomids were collected seasonally and productivity studies were performed once each during the cold and the warm seasons. Certain physicochemical parameters including water temperature, dissolved oxygen, and nutrients seemed to operate on a seasonal cycle. During the annual period, a total of thirty chironomid taxa comprised of 2,871 specimens were collected. Three chironomid subfamilies were represented: Chironominae, Orthocladiinae, and Tanypodinae. Chironominae and Tanypodinae were the most abundant subfamilies in each collection.

INTRODUCTION

Studies of urban pond ecology have mostly concentrated on physicochemical characteristics as they relate to plankton populations. Studies of an urban pond in India found that phytoplankton and zooplankton populations increased as the water temperature increased from 12 °C to 18 °C (*1*). Additionally, plankton blooms coincided with the highest amount of light penetration, an increase in silicates, and an increase in alkalinity. Another study showed an increase in the plankton populations when the water temperature was between 14 °C and 19 °C (*2*). This investigation also found the number of phytoplankton was negatively correlated with increasing nitrate and carbon dioxide concentrations. However, the inverse relationships between nutrients and phytoplankton may have been a result of increased flushing rates. High flushing rates expel plankton populations and increase nutrients in the pond. A positive relationship between the abundance of phytoplankton and water temperature, and a negative relationship between the number of phytoplankton and flushing rates have been observed (*3*).

The Chironomidae has a worldwide distribution owing to its broad ecological tolerances. Larval chironomids are found in lentic and lotic environments, temporary pools, hyporheic, and terrestrial environments (*4*,-*5*). They often account for the majority of aquatic insects in a freshwater environment (*5*). Chironomids are most abundant in the Holarctic region with their diversity and numbers increasing from the poles to the equator (*6*). Although chironomid larvae have been studied in streams (*7, 8*) and lakes (*9, 10*), few investigations of the larval chironomid population in small urban ponds are recorded in the literature (*11, 12*).

Timber Ridge Pond is an urban pond located in a residential neighborhood of Edmond, Oklahoma. Its main source of water is surface runoff, but it is also fed by two small intermittent creeks. It has a surface area of approximately 5,200 m^2, and a maximum depth of almost two meters. A survey of plants on the perimeter of the pond showed the following trees to be present: *Catalpa* sp., *Celtis occidentalis, Juniperus virginiana, Populus alba, Populus deltoides, Salix nigra,* and *Ulmus americana, Salix nigra,* the black willow, was the most abundant.

The major objectives of this project were to: 1) determine monthly trends in water chemistry, 2) identify chironomid larvae present, 3) monitor seasonal trends of chironomid larvae, and 4) determine cold-season and warm-season productivity in the pond.

MATERIALS and METHODS

Water samples were obtained monthly near the outflow of Timber Ridge Pond

TABLE 1. Values of physicochemical variables for each month: March 1989→February 1990.

Parameter	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Temperature (°C)	7	12	14	21	24	17	26	19	14	4	1	7.0
pH	7.3	7.6	7.0	7.0	7.2	7.0	7.1	7.6	7.0	7.4	7.7	6.9
DO[a] (mg/l)	7.0	6.7	2.9	3.2	5.5	2.4	3.3	4.3	6.0	7.6	6.6	7.1
DO[a], % of satrn[b]	63	61	27	32	62	23	38	45	56	57	46	58
Conductivity[c]	105	210	320	135	140	95	120	120	170	160	190	200
Turbidity (FTU)	23	24	26	38	39	26	29	35	52	88	158	101
Alkalinity[d] (mg/l)	28	43	60	43	54	37	30	37	37	37	35	35
C-dioxide[e] (mg/l)	5	2	11	7	5	6	3	1	7	2	1	7
Ammonia (mg/l)	0.22	0.26	0.41	1.28	0.60	0.78	0.73	0.55	0.91	1.28	1.73	1.28
Nitrates (mg/l)	0	0	0.39	0.73	0.85	0.58	0.55	0.64	0.79	1.13	0.99	0.95
Nitrites (mg/l)	0.002	0.019	0.039	0.043	0.023	0.013	0.017	0.017	0.030	0.058	0.090	0.058
O-phsphts[f] (mg/l)	0.38	0.30	0.28	1.49	0.50	0.91	0.70	0.18	0.20	0.25	0.27	0.41

[a] DO = Dissolved oxygen; [b] DO, as percent saturated; [c] $\mu S/cm$; [d] as $CaCO_3$; [e] Carbon dioxide; [f] Orthophosphates.

from March 1989 through February 1990 (Table 1). BOD bottles were used to collect water from just below the surface of the pond. Parameters analyzed included water temperature, dissolved oxygen concentration, dissolved oxygen percent saturation, pH, alkalinity, carbon dioxide concentration, specific conductance, turbidity, and orthophosphate, ammonia nitrogen, nitrate nitrogen concentrations. All measurements were conducted in accordance with Standard Methods (*13*) and Procedures for Water and Wastewater Analysis (*14*).

Productivity was determined during the cold (January 12-13) and warm (July 12-13) seasons by the light-dark bottle method over a twenty-four-hour period (*15*). The BOD bottles were suspended approximately 0.25 m beneath the surface for the duration of the diurnal study. The ratio of gross primary productivity to respiration was calculated to indicate whether the pond generated enough oxygen compared to the amount required, or whether it relied heavily on oxygen diffusing into the water from the atmosphere.

Three benthic samples were obtained from each of the five stations in the pond (Northeast, Northwest, Southeast, Southwest, Central) each season. The samples were collected using a petite Ponar grab (15.24 cm^2), washed through a 0.250-mm sieve, preserved in a mixture of formalin and Rose Bengal dye, and returned to the laboratory. In the laboratory chironomid larvae were washed, sorted, and stored in a 70% ethanol solution prior to identification.

Shannon's diversity index (*16*) was calculated for each station per collection. The indices for each collection date were averaged to compare diversity among the four seasons. Additionally, the diversity indices for each station were averaged for the entire year to compare diversity among the five stations. Sorensen's index of similarity was used to compare the similarity of species between each station for the entire year (*17*).

RESULTS AND DISCUSSION

Physicochemical Conditions

Temperature. Temperature of the water varied from 0 °C to 26 °C (Table 1). The water temperature increased from 7 °C in March to 26 °C in September, gradually decreased through the fall, and reached the lowest point during December and January when the pond became covered by ice. Generally water temperatures lagged slightly behind air temperatures and were within normal ranges for the local area.

Dissolved Oxygen. Extreme values for dissolved oxygen concentrations ranged from 2.4 mg/1 to 7.6 mg/1 (Table 1). The decrease in dissolved oxygen from 7.0 mg/1 and 60% saturation in March 1989 to 2.9 mg/1 and 27% saturation in May was most likely due to the increasing water temperature in the pond. During the period September through December the dissolved oxygen values increased as the water temperature decreased. In December the highest dissolved oxygen reading, 7.6 mg/l, was recorded.

Alkalinity, Carbon Dioxide, pH. Alkalinity values were low and remained fairly constant in the fall and winter months (Table 1). A decrease in alkalinity occurred during the autumn, probably due to the increased leaf litter present in the pond at that time. With the exception of May and

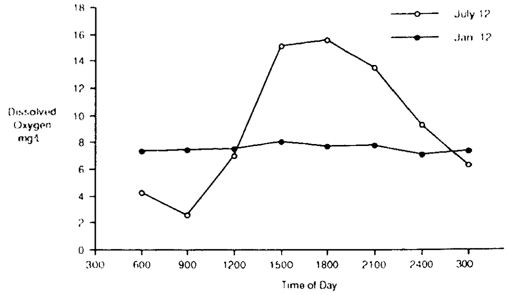

Figure 1. Diurnal oxygen pulse.

TABLE 2. Results of diurnal productivity studies using the light-dark bottle method.

	Jul 12–13[a]	Jan 12–13[b]
GPP[c], mg/l	3.1	0.2
Respiration, mg/l	5.4	0.1
NPP[c], mg/l	–2.3	0.1
GPP/respiration	0.6	2.0

[a] 1989. [b] 1990. [c] GPP/NPP = Gross/Net primary production.

July when alkalinity measured 60 mg $CaCO_3$ and 54 mg $CaCO_3$ respectively, alkalinity was less than 45 mg $CaCO_3$, indicating that Timber Ridge Pond relied on carbon dioxide diffusing from the atmosphere.

Carbon dioxide levels fluctuated widely while pH remained fairly constant during the year. The pH ranged from 6.9 to 7.7 (Table 1) which indicates the alkalinity in the pond was due mainly to bicarbonates (*15*). This is normal in central Oklahoma (*18*).

Conductivity. Conductivity ranged from 95 μS/cm to 320 μS/cm. Since conductivity reflects the amount of ionic compounds dissolved in the water (*14*), it was reasonable for conductivity to increase during the autumn when an increase in organic material, such as plant debris, entered the pond. During spring, conductivity increased to a high of 320 μS/cm. The conductivity for the year was generally too low to be stressful to organisms in the pond (*13*).

Turbidity. Turbidity in the pond seemed to be correlated with local rainfall and the introduction of materials into the pond. During the study period, turbidity values ranged from 23 FTU to 158 FTU (Table 1). Turbidity was highest following heavy rainfall during late spring and following leaf fall during late autumn. Some increases in turbidity during warmer periods were probably also related to increases in planktonic populations (*1*). Turbidity decreased as materials were flushed from the pond or settled toward the bottom.

Nutrients. Ammonia, nitrite, and nitrate concentrations generally peaked during the autumn and winter months. This was attributed to increased decomposition of organic material in the pond and concurrent decreases in algal and bacterial populations which normally absorbed those nutrients. In late spring and early summer urban runoff into the pond from precipitation increased the concentrations of those nutrients. By the end of summer ammonia, nitrite, and nitrate concentrations had decreased.

The concentration of orthophosphate remained high throughout most of the study (Table 1), indicating the eutrophic condition of this pond (*19*). Slight increases occurred during early summer, probably due to lawn fertilizers present in surface runoff.

Productivity

The ratio of gross primary productivity to respiration for the warm season was 0.6 (Table 2), which indicated that not enough oxygen was being produced in the pond to meet the demands of organisms there. Therefore, the inhabitants of the pond relied on additional oxygen diffusing from the atmosphere. The diurnal oxygen pulse in July shows high dissolved oxygen concentrations during daylight hours while photosynthesis was occurring and gradually decreasing oxygen concentrations during the night (Figure 1). During this productivity study, a film of algae was present on the surface of the pond. While the algal populations produced oxygen during the daylight, photosynthesis did not occur during the night and respiration in the pond used the oxygen that accumulated during the daylight hours. The amount of oxygen required during darkness exceeded the amount present during the daylight, so that the pond was operating under an oxygen deficit. This warm-season diurnal pulse was normal and expected, particularly in a eutrophic pond (*15*).

The ratio of gross primary productivity to respiration for the cool season had a value of 2.0 (Table 2). This indicated the pond was not operating under an oxygen deficit during the cool months. The diurnal oxygen pulse in January showed little fluctuation compared to that in summer (Figure 1). Very little photosynthesis occurred during daylight in winter because the photosynthetic populations were too small or inactive. The observed cool-season diurnal pulse also was normal and expected (*15*).

Biological Conditions

A total of 30 chironomid taxa comprised of 2,871 individuals were collected in Timber Ridge Pond during the study (Table 3). The most abundant taxa were *Procladius* sp., *Chironomus* sp. A, and *Cladopelma* sp., comprising 48.1%, 13.4%, and 10.3% of the total specimens, respectively. Members of the genus *Chironomus* are often abundant in eutrophic aquatic ecosystems *(20)*. *Procladius* sp. dominated each collection except in October when *Chironomus* sp. A and *Cladopelma* sp. were more abundant. *Procladius* sp. adults probably emerged between July and October, explaining their decrease in the October collection.

In July and October the Chironominae was the most abundant subfamily forming 50.7% and 80.6%, respectively, of the chironomid population in those collections (Table 4). The Tanypodinae composed 66.5% of the individuals collected in January, and 58.0% of those collected in April (Table 4). The high percentage of Tanypodinae in January and April are due to the large populations of *Procladius* sp., which comprised 66.2% and 55.4% of the total midge larvae collected during those months. In the October collection, it appeared the Chironominae became more abundant while the number of *Procladius* sp., a predator, decreased in the pond as adults emerged. The Orthocladiinae comprised only 0.4% of the chironomids in April, and were not found during the three other seasons.

Species diversity for the entire pond was highest during the October collection (Table 3). This highest value of 2.31 can be attributed to the increase in organic material, primarily twigs and leaves, in the pond. This material increased the amount of benthic surface area by increasing the three-dimensional aspect of the pond bottom and by providing an increase in the food supply for the chironomids. Furthermore, since Shannon's index of species diversity measures the uncertainty of encountering a taxon, it became less likely that *Procladius* sp. would be encountered as

TABLE 3. Species list and numbers of chironomid larvae in collections from Timber Ridge Pond: April, July, Oct 1989 and Jan 1990.

Taxa	Apr	Jul	Oct	Jan	Total
Ablabesmyia mallochi	–	1	1	–	2
Chironomus sp. A	25	14	240	107	386
Chironomus sp. B	159	16	14	24	213
Cladopelma sp.	6	51	149	91	297
Cladotanytarsus sp. A	–	–	1	–	1
Cladotanytarsus sp. B	8	–	2	1	11
Clinotanypus sp.	1	–	–	–	1
Cryptochironomus blarina	–	3	–	–	3
Cryptochironomus fulvus	4	6	12	12	34
Cryptotendipes sp.	4	1	–	–	5
Dicrotendipes leucoscelis	–	5	2	2	9
Dicrotendipes sp. A	7	37	2	3	49
Dicrotendipes modestus	12	15	–	3	30
Dicrotendipes neomodestus	6	90	8	7	111
Dicrotendipes nervosus	1	–	–	–	1
Djalmabatista sp.	3	4	3	1	11
Einfeldia sp.	1	–	–	–	1
Eukiefferiella sp.	1	–	–	–	1
Glyptotendipes sp.	18	3	3	2	26
Kiefferulus sp.	1	–	–	–	1
Macropelopia sp.	2	–	–	–	2
Microchironomus sp.	11	40	7	–	58
Parachironomus monochromus	1	2	7	3	13
Polypedilum halterale	17	1	1	3	22
Procladius sp.	428	294	127	533	1382
Psectrocladius sp.	1	–	–	–	1
Tanypus carinatus	3	–	2	1	6
Tanypus neopunctipennis	5	–	–	–	5
Tanytarsus sp.	46	24	106	12	188
Orthocladiinae unknown	1	–	–	–	1
Number of individuals	772	607	687	805	2871
Number of taxa	26	18	18	16	30
Species diversity	1.71	2.14	2.31	1.59	2.66

TABLE 4. Subfamily composition of the four collections.

	Percent of collection			
Taxa	Apr 7[a]	Jul 10[a]	Oct 13[a]	Jan 12[b]
Chironominae	42.5	50.7	80.6	33.5
Tanypodinae	57.1	49.3	19.4	66.5
Orthocladinae	0.4			

[a] 1989. [b] 1990.

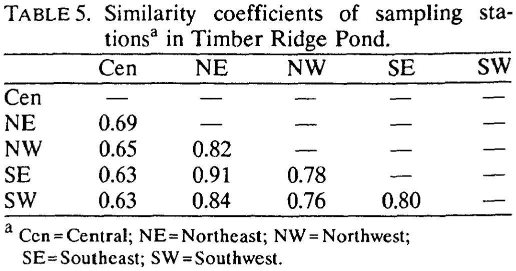

TABLE 5. Similarity coefficients of sampling stations[a] in Timber Ridge Pond.

	Cen	NE	NW	SE	SW
Cen	—	—	—	—	—
NE	0.69	—	—	—	—
NW	0.65	0.82	—	—	—
SE	0.63	0.91	0.78	—	—
SW	0.63	0.84	0.76	0.80	—

[a] Cen = Central; NE = Northeast; NW = Northwest; SE = Southeast; SW = Southwest.

its numbers decreased, so species diversity values increased.

The four stations, sampled at depths of less than one meter, along the perimeter of the pond (northeast, northwest, southeast, southwest) had higher species diversity values than the site in the middle of the pond (central). The northeast site had the greatest species diversity value followed by the southwest and southeast sites with annual species diversity values of 2.07, 2.06, and 2.03, respectively. The northwest site had a species diversity value of 1.88. The central site was the least diverse with a species diversity index of 1.66. The northeast, southwest, and southeast sites have nearly identical diversity values. This was probably because all three locations are on the perimeter of the pond and therefore contain a large amount of branches, twigs, and leaves to add spatial dimension to the benthic environment. The central location probably was the least diverse because most of the coarse particulate organic matter remained closer to the shore, therefore reducing the amount of suitable microhabitats in the middle of the pond. Additionally, there was a much greater quantity of silt in the center of the pond as compared to the other sampling sites. Since bottom waters in the center of the pond are probably not mixed as frequently as shallower waters near the shore, nutrients and other particles, particularly silt, tend to accumulate. An accumulation of silt is detrimental to some midge larvae since it packs so densely that the oxygen in the sediments is limited (*20*).

Sorensen's similarity coefficient was highest between the northeast and southeast sampling locations with a value of 0.91 (Table 5). As noted above these locations were similar physically. The northeast and southwest locations have a similarity coefficient of 0.84. These two locations were also similar not only for the presence of organic debris, but also because intermittent creeks draining the surrounding housing addition entered the pond at the northeast and southwest sampling sites. These two sites were exposed to the influence of a lotic environment during periods of increased flow following precipitation. All the sampling sites located near the perimeter of the pond were more similar to each other than to the central sampling site. The central location differs from the other locations because the water is deeper (approximately 2 m), thus it may be slightly cooler and possibly hold less oxygen during some periods.

CONCLUSIONS

Timber Ridge Pond is a eutrophic pond which experiences seasonal fluctuations in physicochemical and biological conditions. As urbanization increases around the world, many of these urban ponds are being created to assist in controlling runoff. There is considerable need for additional quantitative data and a better understanding of these small impoundments so they may be managed more effectively.

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