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Old and new borrow pits in Lyon County, Kansas were compared to determine if age class has an effect on water chemistry. There were six borrow pits in the study. The new borrow pits (< 7 years old) were located along Highway 50, and the old borrow pits (> 30 years old) were located along Interstate 35. Samples were collected bi-monthly from June through October in 1998. Tests included temperature, pH, orthophosphate, nitrate, ammonium, and chlorophyll *a*, and a brief invertebrate survey was conducted. Comparisons among borrow pits were made using analysis of variance, and the results indicated that there were statistical differences ($P < 0.05$) between the two age classes of borrow pits in nitrate, ammonium, orthophosphate, and chlorophyll *a*. Variations in precipitation and land use practices influenced the nutrient load within both classes of borrow pits. Older

bodies of water generally are more stable, with less fluctuation in water chemistry. In addition, the old borrow pits had a higher diversity of invertebrates at the family level than new borrow pits.

Biotic and Abiotic Factors of Borrow Pits
in Lyon County, Kansas

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INTRODUCTION

Limnology is the study of inland waters (Schwoerbel, 1987; Wetzel, 1975). This science has been traditionally used to determine the water quality within impounded lakes. Limnologists are now studying rivers, watersheds, and entire lake systems in addition to the traditionally-studied individual lakes. The science of limnology has also branched out into the field of ecology. Biological indicator species have been used to determine the overall health of many lakes (Lonergan and Rasmussen, 1996; Shuter and Ing, 1997). The practice of using biological indicators has been in place for many years, but many recent studies, using base-line limnological data (pH, temperature, dissolved oxygen, nitrogen, phosphorus, chlorophyll, and bicarbonate), are being used to predict how well living organisms thrive within the body of water (Hanson and Butler, 1994). Information pertaining to the survivability of aquatic organisms is an important aspect of limnology, but much of this information is useless without also collecting water chemistry data within the study area.

Borrow pits are small, man-made bodies of water. They are secondary features created by road builders as they build roads. Major highways and interstates in the United

States are built on ground that has to be leveled as much as possible. As these roads are built, workers encounter uneven terrain, which requires the addition or removal of soil. If soil needs to be added, the government agency financing the project buys land near the proposed road. The workers then dig a pit and use the substrate to build a level roadbed. The resulting pit fills with water, creating a small, man-made pond. These ponds are referred to as borrow pits. One interesting aspect of borrow pits is that although the government agency purchases the substrate used to create the roadbed, the private landowner retains the rights to the borrow pit itself. Many of these borrow pits are used for irrigation and recreational activities.

Research on borrow pits has been limited. These pits resemble small, natural ponds in appearance and structure. The cumulative concentration of ions in the pits can affect plant growth, animal growth, concentration of dissolved oxygen, and many other important limnological functions (Wetzel, 1975), especially in this system. Variables examined in this study included temperature, pH, ammonium, nitrate, orthophosphate, and chlorophyll *a*. Invertebrates were also identified to family level.

Temperature is one of the most important factors governing water quality (Reid and Wood, 1976). The solubility of nutrients and major ions are affected by the temperature of a given body of water. In general, as the temperature decreases, the solubility of many nutrients also decreases (Wetzel, 1975). One important exception to this rule is dissolved oxygen; as the temperature decreases, the solubility of dissolved oxygen increases.

The difference in temperature and dissolved oxygen concentrations causes two major problems when lakes are stratified. If the hypolimnion becomes depleted of oxygen, it forces all oxygen-breathing organisms into the epilimnion. The second problem is that the hypolimnion can become a trap for nutrients. As flora and fauna die, they sink to the bottom of the lake. The nutrients become trapped there because the stratified lake waters do not mix. Decomposers break down tissue from the dead organisms, but they do not return the nutrients to the epilimnion. This sink holds nutrients until the lake "turns over." At the point of turn over, the water temperature in the epilimnion has cooled to the same temperature as the hypolimnion. The waters begin to mix, causing the lake to turnover. This event can release important nutrients trapped in the hypolimnion. After turnover, nutrients should be uniformly distributed throughout the lake (Millard et al., 1996).

The negative logarithm of the activity of hydronium ions is termed pH (Schroeder, 1992). The pH of pure water is 7 (neutral), a higher pH is basic, and a lower pH is acidic. Factors affecting pH include geology, land use, and atmospheric emissions (Locke et al., 1994). Generally, a pH between 6 and 9 is encountered in most unpolluted bodies of water (Thorton et al., 1990). This range in pH is due to naturally-occurring acids and bases; a change in pH values outside the normal range (as described above) can be an indicator of pollution.

The concentration and type of nutrients found within a body of water are in turn affected by pH. For example, at pH = 9.2, nitrogen is in equal concentrations of NH_4^+ and NH_3; as pH decreases, NH_3 concentrations increase relative to NH_4^+ (Schroeder, 1992).

Ammonium is naturally formed by the decomposition of organic matter (Wetzel, 1975). This form of nitrogen is generally not found under oxidizing conditions, but higher concentrations can indicate a source of pollution. In general, ammonium and oxygen should not be found in the same sample; however they are frequently found together. The conversion of ammonium to nitrate is slow, and takes time to reach equilibrium; therefore, ammonium and oxygen can be found in the same sample, if ammonium is entering the lake from a terrestrial source. A likely source is often anhydrous ammonia, which is used by many farmers as a fertilizer to supplement nitrogen in the soil. Ammonia, in contact with water, is converted into ammonium. The positive ion ammonium is attracted to the negatively-charged soil particles; thus, the nitrogen is not lost. Heavy rains can affect the conversion of ammonium into nitrate. As the soil becomes saturated with rainwater, the oxygen in the water is quickly used up. The process of converting ammonium into nitrite, then into nitrate requires oxygen and two different species of bacteria. If all the oxygen has been used up, ammonium can become concentrated in the runoff, which eventually spills into a lake (Schroeder, 1992). The lake can then have higher than normal concentrations of ammonium. This can be toxic to living organisms if present in high enough quantities.

Nitrate is a major nutrient for many plants (Wetzel, 1975). Ammonium is the main source of nitrate via nitrification. One species of bacteria, Nitrosomonas, in the presence of oxygen, converts ammonium to nitrite (NO_2^-). Nitrite then reacts with oxygen with the assistance of another species of bacteria (Nitrobacter) to produce nitrate (NO_3^-). This form of nitrogen (nitrate) can be used by many plants (Wetzel, 1975). As with ammonium, nitrate should not be found in large concentrations, unless there is a source of pollution.

Phosphorus is a common nutrient found in most bodies of water. However, it is found in low quantities, and can be a limiting nutrient affecting plant and algae growth (Schroeder, 1992). If high amounts of phosphorus (> 2 mg/L) are detected, it could indicate fertilizer runoff or wastewater contamination. Some fertilizers contain traces of phosphorus, and heavy rains after application can cause a rapid influx of phosphorus into bodies of water. In addition, human wastewater usually contains high concentrations of phosphorus from detergents. Phosphorus is in detergent because it forms a chelate, which helps soil molecules cling together; this suspended complex is then carried away in the wash water (Schroeder, 1996). Both fertilizer and wastewater can contribute large concentrations of phosphorus to bodies of water. This can cause massive algal blooms (if phosphorus was the limiting nutrient). At this point, photosynthesis is at its peak. Carbon dioxide is being used up and oxygen is being produced. However, as photosynthesis increases, many other nutrients are also being used. Thus, other nutrients can become depleted quickly, causing other plants to die off within the body of water. Algae can also cover the surface of the water, blocking sunlight to other plant life. Along a food web, this can have negative effects on other aquatic life (Basu and Pick, 1995).

Many nutrients can be tested to determine water quality. Additionally, organismal diversity can give an overall picture of the nutrients present in a lake (Blomqvist et al., 1995). Invertebrates are a particularly good indicator of water quality. Different species of invertebrates require different abiotic conditions. One species might not tolerate high nitrogen levels, whereas another might thrive in these conditions. If a body of water is high in nitrogen, many invertebrates that cannot tolerate these conditions are eliminated. If the diversity of invertebrates is large, it indicates there are several niches for these organisms to fill. In addition, it indicates there is not a limiting nutrient or a major source of pollution. If the diversity is low, either it can indicate presence of pollution, or that a nutrient is not present that is needed by a particular species of invertebrate (Huggins et al., 1985). Completing an invertebrate survey can give some indication of how "healthy" a body of water is by the diversity of invertebrates present in the body of water.

The purpose of this study was to compare the variables described above in old versus new borrow pits. There has been little research done on borrow pits, and a baseline limnological study needs to be done to examine the variation among borrow pits and to determine if a difference exists between old and new borrow pits. As small, man-made lakes, these pits should have the same nutrient loads as other small, man-made lakes in the area. The independent variable being tested was age of the borrow pits. The hypothesis was that the old borrow pits would be more stable and have less nutrient fluctuation then the new borrow pits. In addition, the old borrow pits should have more invertebrate diversity because the niches available to the organisms have had longer to become established.

STUDY SITES

Six borrow pits were examined in this study. Each pit has an estimated depth of three to five meters. This estimate is based on landowner information and general knowledge of borrow pits. The borrow pits were split into two categories, three new borrow pits (less than 7 years old) and three old borrow pits (greater than 30 years old). The new borrow pits are located along Highway 50 in Lyon County, Kansas (with the exception of one borrow pit that is on the Lyon/Chase county border), and the old borrow pits are in the vicinity of Interstate 35 around the city of Emporia, Kansas (Figure 1).

The new borrow pits are referred to as borrow pit 1 (T19S, R10E, S11; 3.4 miles west of Americus road), borrow pit 3 (T19S, R10E, S12; 5.0 miles west of Americus road), and borrow pit 4 (T19S, R9E, S7; 6.4 miles west of Americus road). Each of the new borrow pits is less than 100 meters from Highway 50 on the north side of the road (Figure 1). The land use in this area is dominated by row crop agriculture (corn and sorghum). Agricultural fields come within 10 m of each new borrow pit. The farmers in this area use anhydrous ammonia as a fertilizer.

The old borrow pits are referred to as King borrow pit (T19S, R11E, S10; 0.6 miles southeast of the Merchant

Street exit), Railroad borrow pit (T19S, R11E, S9; 0.2 miles east of King borrow pit), and Ski borrow pit (T19S, R12E, S12; 3.4 miles east of the Merchant street exit). Each of the old borrow pits is within 100 m of Interstate 35, with the exception of the Railroad borrow pit, which is about 500 m from Interstate 35. The land around the old borrow pits is dominated by non-native grasses. The grasses are mowed, but no fertilizer is used. Essentially, the land use pattern around the old borrow pits has less human influence than that around the new borrow pits.

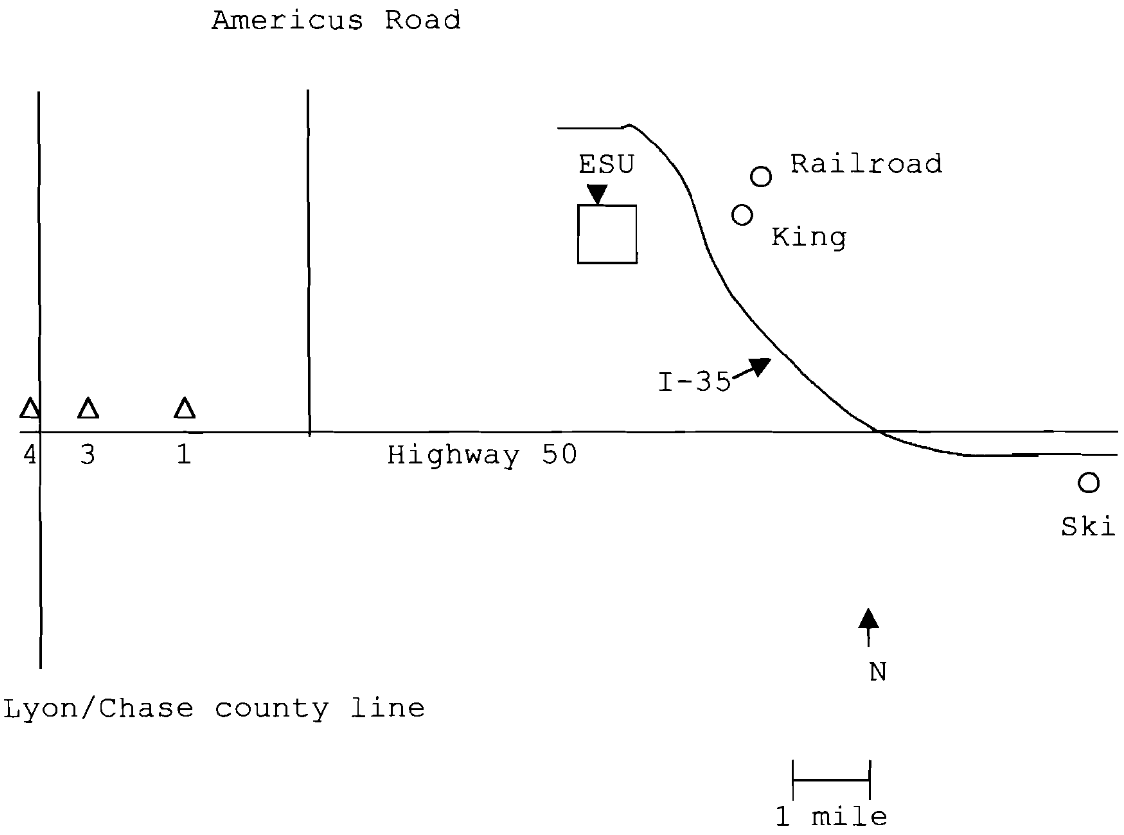

Figure 1. Locations of the old (O) and new (Δ) borrow pits.

MATERIALS AND METHODS

Water samples were collected bi-monthly from June to October in 1998, using 1000-ml plastic containers. There were two study sites per borrow pit to account for variation within each borrow pit. The study sites were located in the northeast corner and the southwest corner of each borrow pit. Samples were collected within one meter of the shoreline at the surface of the water. Additionally, samples were collected between 1400 and 1600 hours each sampling day. The water samples were filtered, acidified, and frozen. The filter used was 7 cm in diameter with 0.45 µmpore space. The membrane filter was used to remove turbidity, as well as to extract chlorophyll from the water samples. Each 1000-ml water sample was acidified with 1000 µm H_2SO_4. The acidification process was used to stop any biological activity occurring in the sample. After filtering and acidification, the samples were frozen for later analysis. All chemical analyses were done within 12 days after collection.

Temperature and pH were determined in the field (before filtering and acidification). An alcohol thermometer was used and temperature readings were determined to the nearest tenth of a degree (Celsius).

After each sampling day, the thermometer was calibrated with ice water and a correction was used to determine the actual temperature of the water samples. An electronic pH meter was used to find the pH of each water sample. The unit was calibrated with a pH 4.0 buffer and a pH 10.0 buffer at each site. The buffers were then placed in a container filled with water from the sampling site, and the temperature was allowed to reach that of the pit, the pH meter was calibrated again. This was done because temperature can affect pH.

Ammonium, nitrate, and orthophosphate testing was all done in duplicate to assure precision. If the test results did not come within 0.1 mg/L of each other, the test was redone until this precision level was reached. I am confident that using this type of quality assurance gave accurate values for the variables tested, and decreased experimental error throughout the study.

Ammonium concentrations were analyzed using the Hach method and the packets of reagents supplied by Hach. This involves taking 5-ml of the sample and adding a packet of ammonia salicylate. This process fixes the ammonium and prevents it from reacting with oxygen, which converts the ammonium to nitrite. A packet of ammonia cyanurate is then added to induce a color change. The procedure was done in a color cube, and the color was compared with known values obtained from the cube.

Nitrate concentrations were determined using another method developed by Hach. This involved taking a 5-ml sample and adding a packet of NitraVer 6 (Copyright) reagent. This chemical contains cadmium metal that reacts with nitrate. The solution was allowed to mix and the excess cadmium metal settled to the bottom. The liquid supernatant was then added to another test tube and mixed with a reagent to obtain a pink color change. The more intense the color, the more nitrate was present in the water sample. The intensity of the color was compared to a fixed color wheel, and the concentration of nitrate in the water sample was then determined.

The filtered water sample was tested with the ascorbic acid method as described in Greenberg et al. (1992) to determine orthophosphate concentrations. This method involved mixing the sample with ammonium molybdate and potassium antimonyl in a sulfuric acid medium. This forms phosphomolybdic acid (if orthophosphate is present), which is reduced by ascorbic acid, forming a deep blue color. The blue color formed was analyzed for its intensity with a photospectrometer at 880 nm. Beer's law was used to calculate the concentration of orthophosphate present in the sample.

Chlorophyll *a* concentrations were tested by filtering a sample and analyzing the algae collected on the filter. A known volume of water was filtered, trapping algae on the filter paper. The filter paper was then dissolved in acetone and mechanically ground with a ground glass tissue grinder. This process breaks up the algae and promotes the release of chlorophyll *a*. The samples were refrigerated and stored overnight, letting the organic matter settle out of solution. The solution was then analyzed using a wavelength of 663 nm with a double-beam spectrometer. Other wavelengths (600, 630, 700, and 720 nm) were used as corrections when calculating the concentration of chlorophyll *a* (Schroeder, 1995).

Plankton were collected by the use of standard plankton nets. Each month, two plankton tows were taken of the surface water at each study site. The organisms captured were preserved in alcohol and later identified to the familial level in the lab. An additional 10 minutes following the plankton tows were spent looking for other invertebrates in the study area. The results were reported as a percent of organisms caught from each area. These data are later presented as an organismal diversity.

For each variable analyzed (except the organismal diversity), a one-way analysis of variance (ANOVA) was used to determine if there was a statistical difference between old and new borrow pits. Statistical analysis indicated there was not a significant difference within borrow pits. Therefore, I was able to pool the two samples collected at each study site for use in calculating the ANOVA for each variable. The organismal diversity was reported as a percentage of individuals within a family compared to the number of individuals captured (Huggins et al., 1985).

RESULTS

The main focus of this study was to determine if old and new borrow pits were significantly different from each other in several water chemistry variables (temperature, pH, ammonium, nitrate, orthophosphate, and chlorophyll *a*), and organismal diversity using invertebrates as the indicator. It was interesting to compare these variables between the two types of borrow pits; however, it was also beneficial to show, graphically, the variables of the two types of borrow pits across months.

The trend in temperature data does fluctuate across months (Figure 2). During the summer months (June, July, and August) the temperature stayed between 26 and 30°C. In September, a cold front moved through Emporia and the temperature dropped to 16 °C. This dramatic drop in temperature was accompanied by a week of major thunderstorms that produced large amounts of rain causing major flooding in the area.

Over the length of the study, pH stayed consistent (8.0 - 8.5) however, at the same time as the decrease in temperature, there is a significant decrease in pH (Figure 3). The trend of both the temperature and pH decrease is most likely due to changes in weather patterns in the area.

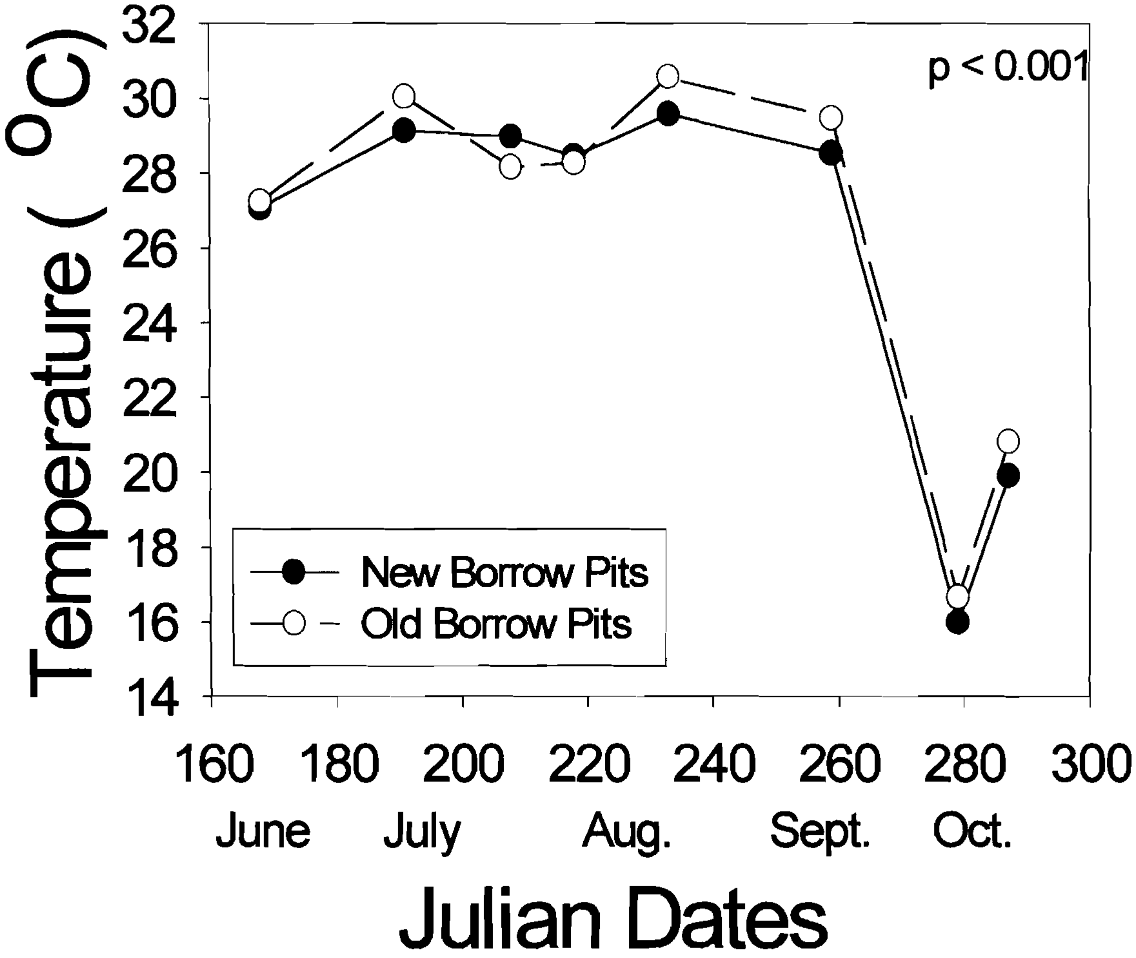

Figure 2. Average temperature (^{o}C) of borrow pits across months in Lyon County, Kansas between June and October 1998.

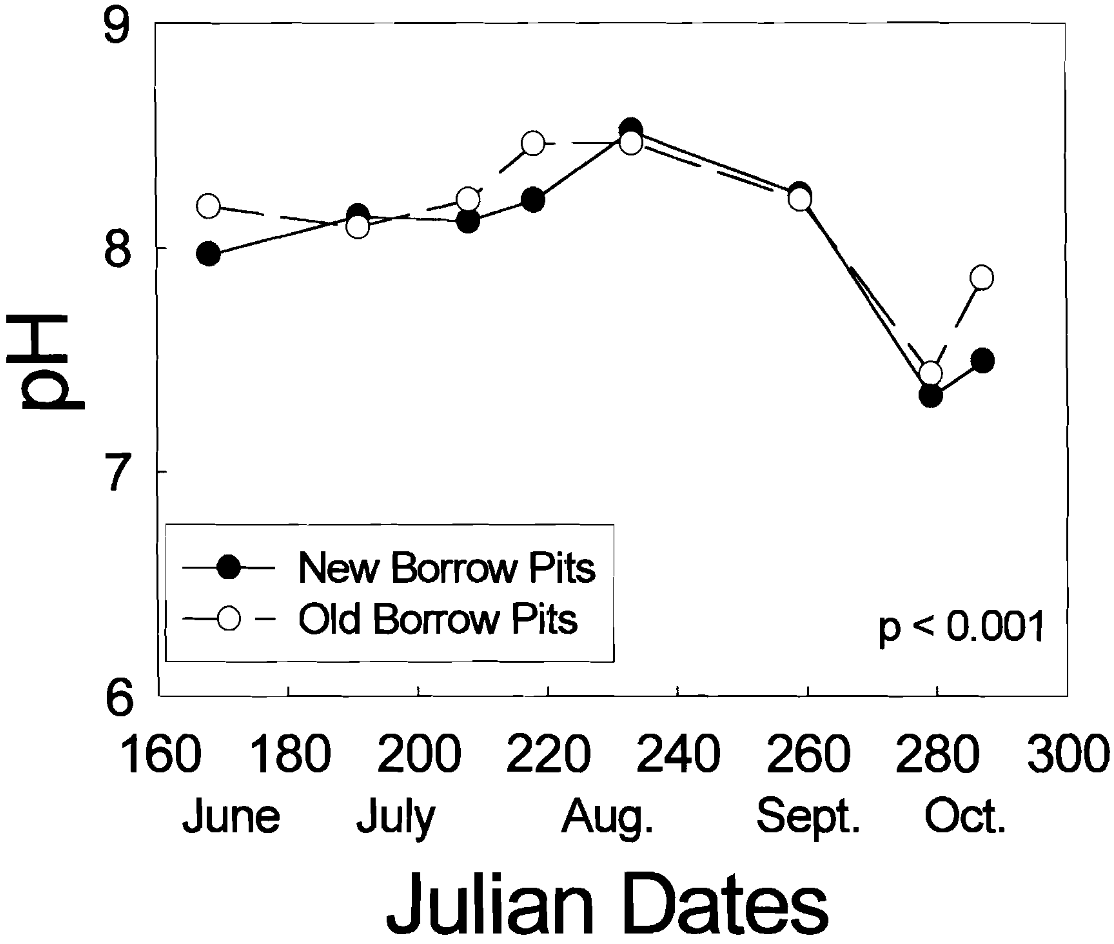

Figure 3. Average pH of borrow pits across months in Lyon County, Kansas between June and October 1998.

Temperature (P = 0.647; df = 1,94; F = 0.211) and pH (P = 0.216; df = 1,94; F = 1.552) were not significantly different (Table 1) between old and new borrow pits. The borrow pits in this study are all located in the vicinity of Emporia. Both of these variables are affected by regional geology and weather patterns and were not expected to be significantly different from each other. However, there was a significant difference between June and October for both temperature (Figure 2) and pH (Figure 3).

Ammonium was found in low concentrations throughout the study; however there was a significant difference (P < 0.001; df = 1,94; F = 11.625) in ammonium concentrations between types of borrow pits (Table 1). At the beginning of the study, ammonium concentration in the old borrow pits was at its highest point during the study (Figure 4). The ammonium concentrations taper off in the old borrow pits throughout the study, until late September during the heavy rains. At that time, the ammonium concentration increased drastically in both the new and old borrow pits.

Nitrate was the predominant form of nitrogen in the study. Nitrate was found in higher concentrations than ammonium. Similar to ammonium, nitrate was significantly different (P < 0.001; df = 1,94; F = 13.135) between old and new borrow pits; however, the new borrow pits had

Table 1. Mean and range values of chemical parameters in old and new borrow pits in Lyon County, Kansas between June and October 1998. Significant differences (one-way ANOVA) are indicated by * ($p<0.05$) and ** ($p<0.001$).

	Borrow Pits	
	New	Old
Temperature (Celsius)		
mean	25.9	26.4
range	15.0-30.0	16.0-31.1
n	6	6
pH		
mean	8.00	8.12
range	7.16-8.78	7.31-9.12
n	6	6
Ammonium (mg/L)**		
mean	0.1	0.2
range	0-0.4	0-0.6
n	6	6
Nitrate (mg/L)**		
mean	0.32	0.09
range	0.02-1.40	0.02-0.26
n	6	6
Orthophosphate (mg/L)*		
mean	0.062	0.042
range	0.002-0.163	0.003-0.155
n	6	6
Chlorophyll *a* (µg/L)*		
mean	14.001	32.729
range	0.436-71.720	1.415-163.152
n	6	6

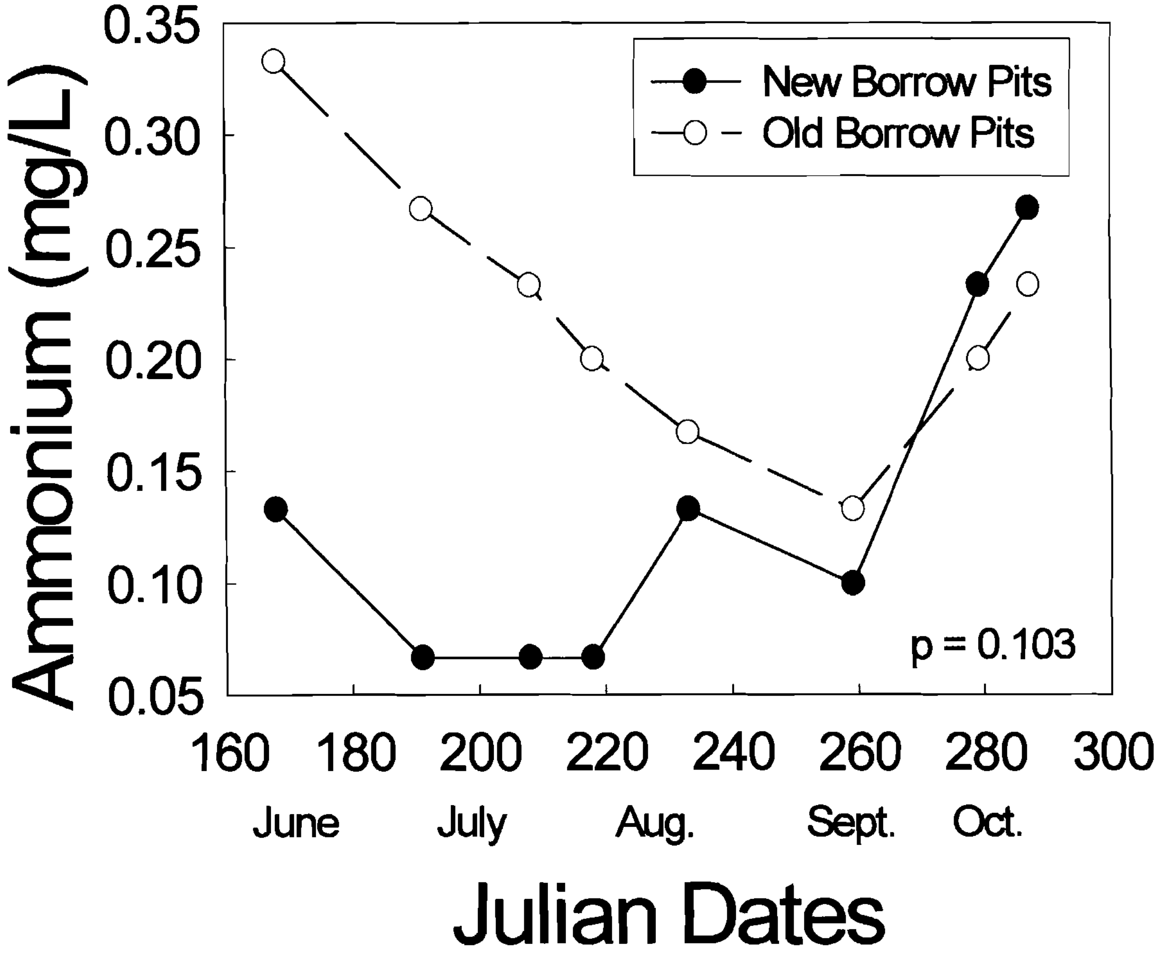

Figure 4. Average ammonium concentrations (mg/L) of borrow pits across months in Lyon County, Kansas between June and October 1998.

higher concentrations of nitrate than ammonium, whereas the old borrow pits had higher concentrations of ammonium than nitrate (Table 1). When comparing nitrate across months, the new borrow pits had decreasing amounts of nitrate, but the old borrow pits stayed constant in nitrate concentrations (Figure 5). This general trend was disrupted in late September during the heavy rains. In both types of borrow pits, the nitrate concentration increased after the large amounts of precipitation that fell in late September.

Orthophosphate concentrations were significantly different ($P = 0.042$; df = 1,91; $F = 4.236$) between the two sites in this study, with the new borrow pits having higher concentrations of orthophosphate than the old borrow pits (Table 1). When comparing orthophosphate across months, both the new and old borrow pits were constant until early September (Figure 6). At that point, orthophosphate dropped in concentration. During this time, there was no precipitation in the area. In late September after the heavy rains, the orthophosphate concentrations increased rapidly.

Chlorophyll *a* concentrations were also found to be significantly different between old and new borrow pits ($P = 0.015$; df = 1,79; $F = 6.176$); the old borrow pits had a

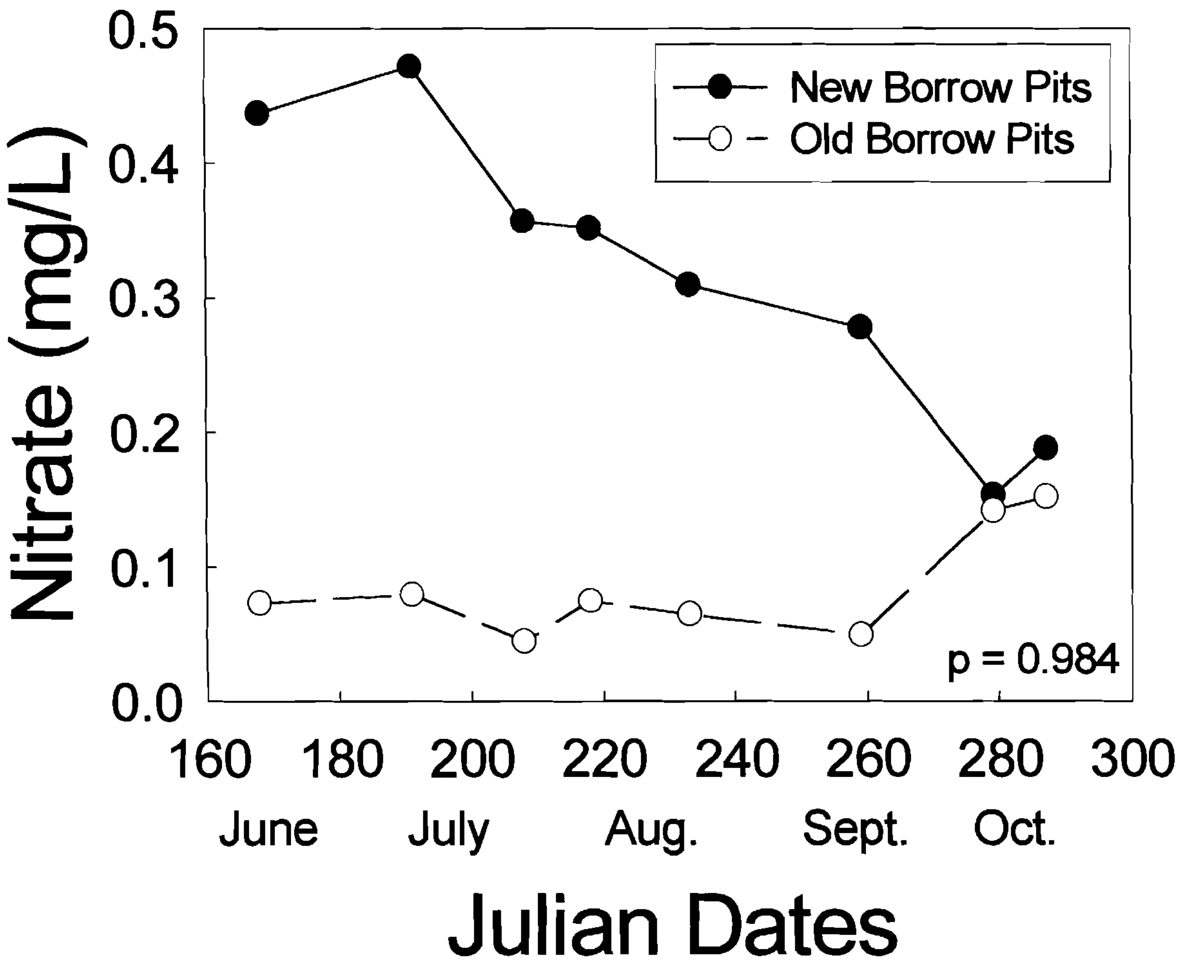

Figure 5. Average nitrate concentrations (mg/L) of borrow pits across months in Lyon County, Kansas between June and October 1998.

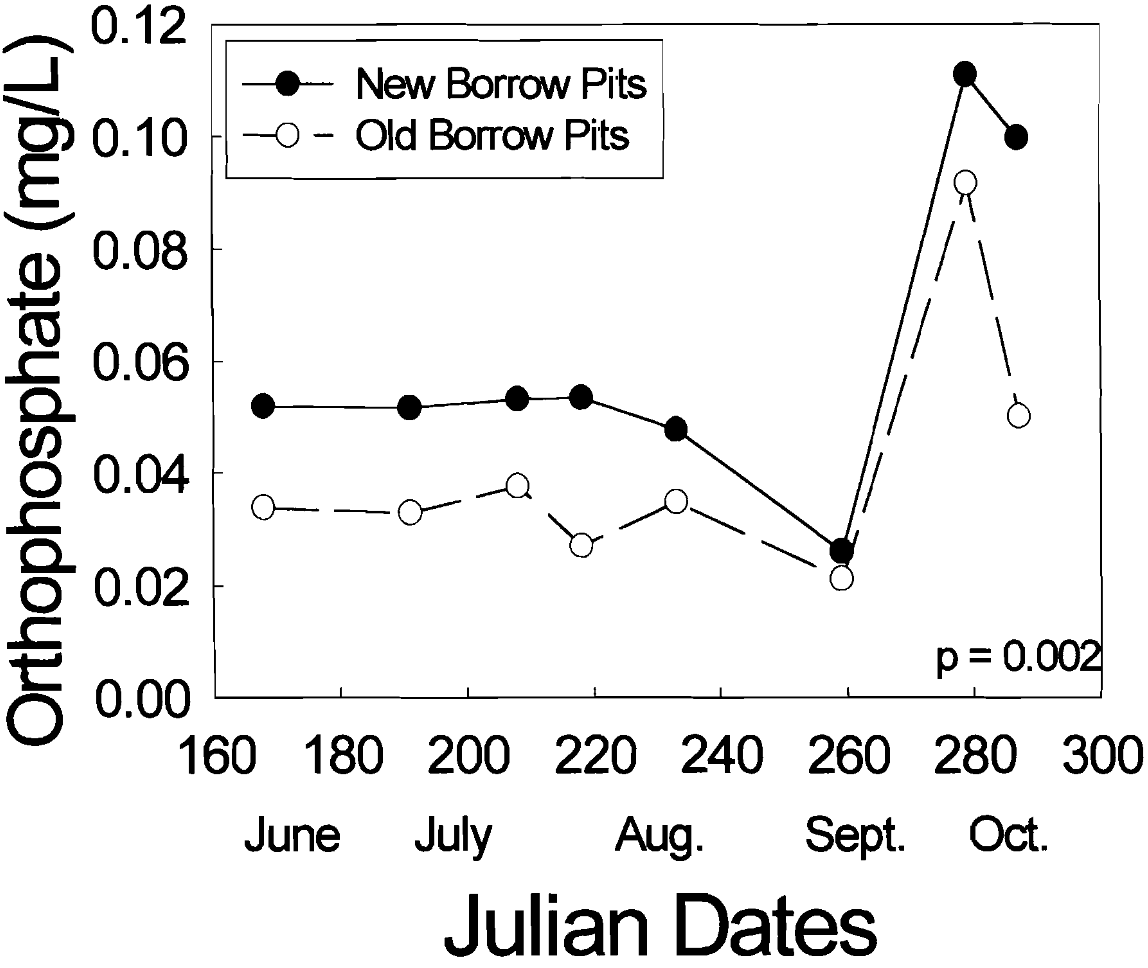

Figure 6. Average orthophosphate concentrations (mg/L) of borrow pits across months in Lyon County, Kansas between June and October 1998.

higher average concentration of chlorophyll *a* than did the new borrow pits (Table 1). Figure 7 shows chlorophyll *a* concentrations across months. Each spike on the graph indicates an algal bloom. Each type of borrow pit had two algal blooms during the study. However, the first algal bloom in each type of borrow pit occurred at different times. The second algal bloom in both types of borrow pits occurred in late September after the large amount of precipitation in the study area.

The organismal diversity samples showed that old borrow pits have a more diverse invertebrate population than the new borrow pits (Table 2). The total number of organisms collected was about the same, but the old borrow pits had more orders and families of organisms represented in the samples.

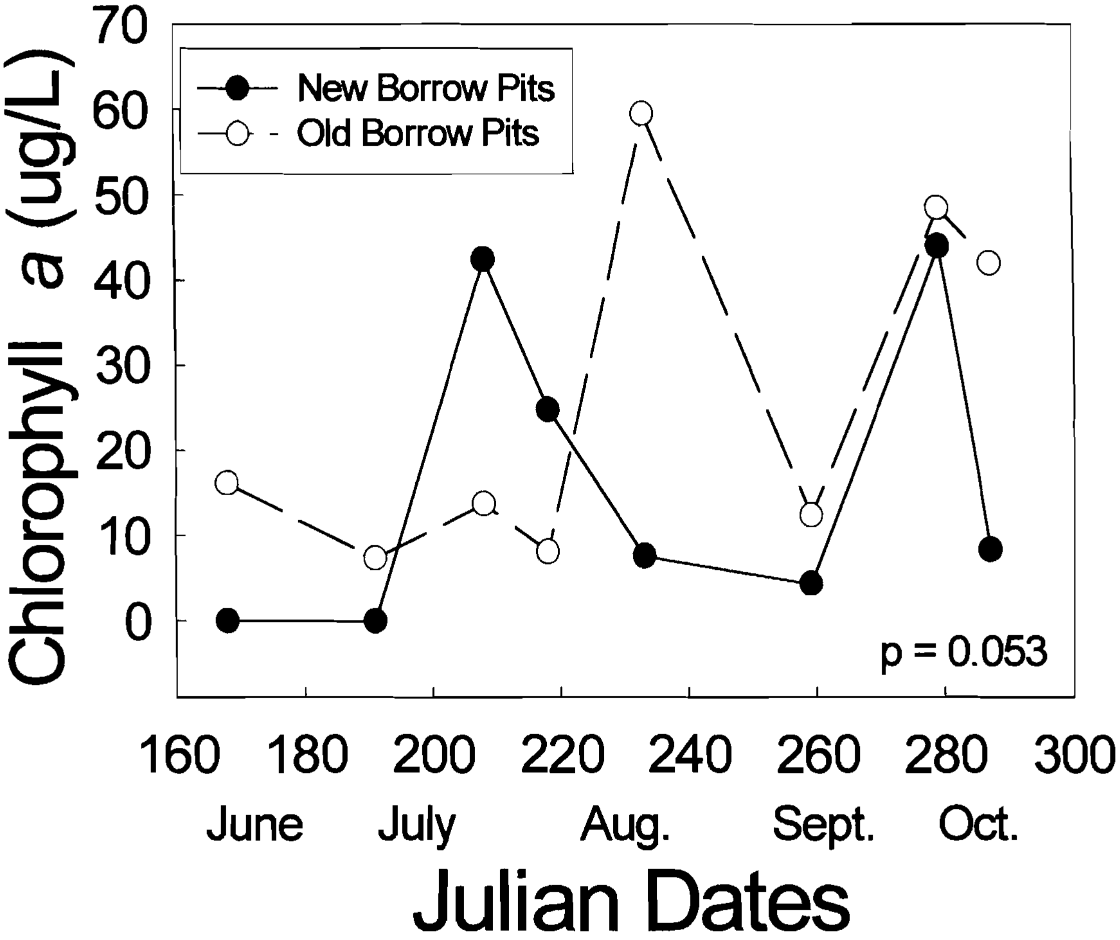

Figure 7. Average chlorophyll *a* concentrations (µg/L) of borrow pits across months in Lyon County, Kansas between June and October 1998.

Table 2. Diversity of invertebrates in old and new borrow pits in Lyon County, Kansas between June and October 1998.

Order	Family	Common name	# of individuals	% of total
Old borrow pits				
Decapoda	Astacidae	crayfish	12	1.66
Coleoptera	Gyrinidae	whirligig beetle	241	33.24
Coleoptera	Dytiscidae	predaceous water beetle	2	0.28
Diptera	Culidae	mosquitoes (larve)	112	15.45
Diptera	Dixidae	meniscus midge	250	34.48
Diptera	unknown	unknown	30	4.14
Ephemeroptera	Ephemerellidae	none	3	0.41
Hemiptera	Gerridae	water striders	75	10.34
			Total 725	100.00
New borrow pits				
Decapoda	Astacidae	crayfish	5	0.71
Diptera	Culidae	mosquitoes (larve)	312	44.32
Diptera	Dixidae	meniscus midge	387	54.97
			Total 704	100.00

DISCUSSION

Temperature between old and new borrow pits was not significantly different in the study. All of the study sites are located around Emporia, therefore all study sites were affected by the same weather changes. The small changes in temperature might result from micro weather patterns.

The borrow pits in the study had a pH range from 7.16 to 9.12. The reason the pH was slightly basic in the pits is related to the geology of Kansas. Limestone rock contains bicarbonate, which is a natural base in waters (Schroeder, 1992). The limestone rock weathers away, carrying bicarbonate into the borrow pit, and causes the water to be slightly basic.

The comparison of pH for old and new borrow pits showed there was not a significant difference between them. Again, all the borrow pits are located in the same geographic region. If present, air pollution might have caused a difference by supplying a large amount of acid or base, but this condition was not found in the study.

Precipitation might have lowered pH in the study. Acid deposition is caused when sulfur and nitrogen oxides react with oxygen and water (Schroeder, 1995). The resulting precipitation is acidic. After the heavy rains, average pH in both types of borrow pits dropped from a little over eight to about 7.2. The drop in pH was probably caused by the slightly acidic rain water. Another factor that might be contributing to the drop in pH includes, water falling on land would filter to the lowest point (the borrow pits), and along the way it could have picked up ions causing the runoff to be acidic. In early October, the flooding subsided and the pH of the water in the borrow pits started to increase. If the study had continued through November, I hypothesize that the pH would have returned to baseline levels of around eight.

The old borrow pits had significantly higher average ammonium concentrations than the new borrow pits (Table 1). Land use practices around the area can have a major influence on ammonium and nitrate concentrations in the borrow pits. This factor was not controlled for in the study, but might be playing a role in the amount and form of nitrogen found in the borrow pits. The new borrow pits are surrounded by agricultural fields. The fields are located within 10 m of the borrow pits and are fertilized annually. Farmers reported using anhydrous ammonia in the spring to add nitrogen content to the soil. I hypothesized the fertilizer would run off into the borrow pits. Thus, the new borrow pits should have higher ammonium concentrations than the old borrow pits; however, the data showed this was not true (Figure 4). One explanation for the contradiction might be that the anhydrous ammonia might have been converted to another form of nitrogen before it leached into the pit, or the anhydrous ammonia was used by the crops in the agricultural fields before it had time to run off. In either case, the application of anhydrous ammonia was not directly reflected in the high ammonium concentrations in the new borrow pits.

Comparing average ammonium concentrations across months reveals a steady decrease in ammonium concentrations from June to September in the old borrow pits (Figure 4). There are no agricultural fields around this area; however, there is a baseball field complex located within 20 m of King Lake and the Railroad Borrow Pit. These two borrow pits, on average, had higher ammonium concentrations than Ski Lake. A form of liquid nitrogen has been used on the baseball field in past years, but was not used during this study. The increase in ammonium concentrations found in the old borrow pits might result from the use of nitrogen fertilizers in past years.

Weather also seemed to play an important role in average ammonium concentrations. In late September, the ammonium concentrations for both new and old borrow pits increased at a rapid rate. Heavy rains occurred in the Emporia area during this period. The rains probably carried large influxes of ammonium from the land surrounding the borrow pits.

Nitrate concentrations better fit the land use practice hypothesis. The new borrow pits were significantly higher in nitrate than the old borrow pits (Table 1). The new borrow pits, located near the agricultural fields, probably had higher nitrate concentrations because of the fertilizer applied to the land around the pits. The anhydrous ammonia could have been converted to nitrate through the nitrogen cycle, and the nitrate slowly leaked into the new borrow pits as might be indicated in Figure 5.

The nitrogen concentrations in old borrow pits were below 0.1 mg/L. Nitrate remained constant throughout the study, indicating there was not a significant source of nitrate input around the old borrow pits. The fertilizer used on the baseball fields was different than the anhydrous ammonia used in the agricultural fields. This could explain why ammonium is found in higher concentrations and that nitrate is found in lower concentrations in the old borrow pits. Adjacent land use practices might be more important than age class differences as a correlative factor in these borrow pits. A more comprehensive study needs to be done to determine how land use practices are affecting water chemistry variables in these systems.

The data indicate the same phenomenon happening in late September with nitrate concentrations as ammonium concentrations. The increase in nitrate most likely resulted from heavy rains flushing nitrates into the borrow pit systems.

The new borrow pits had significantly higher orthophosphate concentrations than the old borrow pits in the study (Table 1). In the case of the old borrow pits, farmers reported that they do not add any supplemental phosphorus to the soil. In addition, phosphorus fertilizer was not added to the baseball fields. It appears orthophosphate is naturally higher in the new borrow pits than the old borrow pits (Figure 6). This could indicate there is less primary productivity in the new borrow pits because phosphorus has been shown to be a limiting nutrient in many aquatic systems (Wetzel, 1975). On the other hand, the flora located in the old borrow pits might have been using more phosphorus; therefore the old borrow pits should have less orthophosphate than new borrow pits.

Chlorophyll *a* concentrations can be used as an indicator of primary productivity. Results show the old borrow pits did have significantly higher chlorophyll *a* concentrations than new borrow pits (Table 1). This might indirectly indicate that phosphorus, specifically orthophosphate, was the limiting nutrient in these aquatic systems, but the data do not support this conclusion. In Figure 7, the spikes in the chlorophyll *a* graph indicate algal blooms. If orthophosphate was the limiting nutrient affecting plant growth, there should have been a decrease in orthophosphate at the peak of the algal blooms. The first algal blooms in the new and old borrow pits occur at different times, but there is no corresponding decrease in orthophosphate. This indicates orthophosphate is not the limiting nutrient in these aquatic systems.

At the peak of the second algal blooms in the borrow pits, there was a corresponding decrease in orthophosphate, but this can be explained by the large amount of precipitation that fell in the area at that time. Orthophosphate concentrations increased greatly after the heavy rains, but the concentrations were beginning to decrease back to the baseline levels. This event has been shown for other variables in the study, so the assumption was made that orthophosphate was acting in the same manner.

Other variables included in the study (nitrate and ammonium) also do not seem to be limiting nutrients. Nitrogen is frequently a limiting nutrient in terrestrial systems and occasionally in aquatic systems. However, along with orthophosphate there is no corresponding decrease in ammonium and nitrate as the chlorophyll *a* decreases (Figures 4 and 5). There is a steady decrease in nitrate in the new borrow pits, and a steady decrease in ammonium in the old borrow pits. If nitrogen, in either form, was the limiting nutrient, there should have been sharp decrease at the end of the algal blooms. It appears that there was some other limiting nutrient or physical characteristic governing primary productivity in the borrow pits.

The diversity of invertebrate organisms is shown in Table 2. There was not an apparent difference in either number of individuals captured or different families captured at any given time throughout the study, so the data were pooled together for the entire study. Interestingly, the same families of organisms were found at both types of borrow pits, but the new borrow pits lacked the families Gyrinidae, Dytiscidae, Ephemerellidae, and Gerridae. The data indicate that old borrow pits have more diversity, hence they are likely to have more niches available than the new borrow pits. One problem in making this assumption was that these data were not complete. Many invertebrates live on the substrate, a complete comprehensive study was not done on the substrate of the borrow pits. A substrate dredge should be used in future studies when completing a diversity survey of invertebrates.

FUTURE STUDIES

Old and new borrow pits differ when comparing water chemistry variables except pH and temperature. Each water chemistry parameter tested was significantly different when comparing borrow pits with respect to age class. One variable not controlled, land-use around the borrow pits, might have the most influence on the water chemistry of the borrow pits. The new borrow pits, located near agricultural fields, were significantly higher in nitrate concentrations than old borrow pits; however they were lower in ammonium concentrations. If the fertilizer from the agricultural fields is running off into the new borrow pits, these new borrow pits should have higher concentrations of ammonium and nitrate. The ammonium might be converted to nitrate through the nitrogen cycle before leaching into the borrow pit. I believe this is the case when comparing nitrogen (both nitrate and ammonium) concentrations between old and new borrow pits.

Examining orthophosphate and chlorophyll *a* concentrations showed that there was a significant difference between old and new borrow pits. Land-use practices should not have an effect on these nutrients, because fertilizers were not used on or near either type of borrow pit. Another year of data might have showed different results when testing concentrations for these two variables. Wetzel (1975) commented that older bodies of water are more stable and generally have less fluctuation of nutrients from year to year. Another year of data might have shown the new borrow pits to have major increases or decreases in nutrient concentrations. I might have tested during a year with extreme nutrient loads in the new borrow pits.

Many inland bodies of water are vegetatively limited by phosphorus. This study showed orthophosphate is not the limiting nutrient in either type of borrow pit. After algal blooms, there was not a decrease in orthophosphate, thus some other factor is limiting plant growth in these systems.

Finally, weather patterns, specifically precipitation, have a major influence on nutrient concentrations. Heavy storms flush a large amount of nutrients into the borrow pits. Following these nutrient influxes, algal blooms can occur, causing the body of water to become eutrophic. This can have a devastating effect on the fauna within the body of water because eutrophication can cause the body of water to become depleted of oxygen.

The study performed provides baseline limnological data on borrow pits in Lyon County, Kansas. A more comprehensive, long-term study needs to be done. Many of the conclusions in the study are incomplete because there were no previous data with which to compare the results from the study. A complete analysis of the water chemistry variables needs to be compiled over several years. Also, land use studies and possible locations of point source pollution need to be obtained to accurately explain the water chemistry variables within the borrow pits.

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