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What Impact Does Sustainable Certification Have? A Comparison of Aquatic Nitrate and Phosphate Levels between Two Golf Courses in the Bloomington-Normal Community

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Abstract: Two golf courses in the Bloomington-Normal community in central Illinois were tested for nitrate and phosphate concentrations in their ponds. One golf course (The Den) is Audubon International certified while the other golf course (Ironwood) is not. This study tries to establish if differing environmental management practices can contribute to significantly different concentrations of nutrients. It was determined that the nitrate concentration was higher at the non-certified golf course, while the phosphate concentrations at both courses were essentially negligible. The implications of these findings are discussed and were presented to both golf courses. It is the hope of this paper that the non-certified golf course will seek improved management practices, with regard to environmental impact, after observing the differences in nutrient concentrations.

Introduction

Nitrates and phosphates are two of the most common chemical compounds present in fertilizer. They are applied heavily on farms and golf courses across the country to keep fields productive and golf courses green. Fertilizer is primarily applied to fairways and greens on golf courses; where it slowly leaches out of the soil and ends up in aquatic systems. High levels of nitrates and phosphates can result in aquatic algal blooms, and ultimately result in ecosystem death. These algal blooms die off in the winter, and in the process of decomposition, all of the oxygen from the water is removed. This prevents anaerobic life (fish, plants, birds) from flourishing. Without oxygen, plants and fish have no method for survival, and the birds that normally prey on fish have no source of food.

If nitrate levels are high enough in drinking water, it can lead to methemologlobinemia, a condition known as "blue baby." This disorder (caused by high nitrate levels) prevents hemoglobin in the body from adequately transporting oxygen to the limbs resulting in death if prolonged for a long enough time. Illinois has adopted an EPA standard concentration of 10-ppm nitrate in water, meaning that this is the highest allowable concentration in drinkable water (Illinois Dept of Public Health 1999). The

EPA does not currently monitor phosphate, but high concentrations of phosphate also can lead to algal growth, resulting in pond death.

While fertilizer from farming generates the largest nutrient load (nitrates and phosphates) flow from land to water, golf course management also creates a large amount of runoff into drinking waters. To counteract this, Audubon International works with individual golf courses in an effort to change the way fertilizers and pesticides are applied. Over two thousand golf courses across the country have participated in the Audubon program and, as a result, have lowered their nutrient load annually. One such golf course is in the Bloomington-Normal community.

This project examines two golf courses in an effort to determine if Audubon certification does reduce nutrient runoff into pond ecosystems. One of the courses, The Den at Fox Creek, has been certified for seven years and has taken a strong environmental stance since it was built in 1997. The other course is Ironwood Golf Course, which currently has no environmental standards for application of nutrients, but has expressed willingness to re-examine its methods. Because both golf courses reside in the same geographic area, it is assumed that the background nitrate and phosphate levels from farming and other non-golf course activities are similar. This allows us to test if the nutrient levels at the Audubon certified course are indeed lower than those at a non-certified course.

Literature Review

In order to keep golf courses green and appealing to players around the world, copious amounts of fertilizer and pesticides are applied (Davis, Lydy 2002). Extensive studies have been performed documenting the troubles associated with pesticide application, but little has been done observing the effects of nutrient runoff. These nutrients, while beneficial to encouraging plant growth, can end up in aquatic systems, promote growth of oxygen removing algae and result in ecosystem death. This phenomenon has been observed in the Gulf of Mexico where a giant “dead zone” exists. Fertilizers applied to fields in the Midwest flow down the Mississippi river and end up in the Gulf of Mexico creating a zone where no life (plant or animal) is possible.

Outside of agricultural and waste management causes, golf courses supply the largest nutrient load into natural drinking water sources in the United States (Wu, L et al 2007). There are thousands of golf courses across the country, each of which apply tons of fertilizer each year to keep the courses green and in good playing condition. One negative impact of great concern is that nutrient levels leaching off of golf courses are extraordinarily high. Some golf courses have tried to atone for this problem by constructing biological buffer zones (Reicher, et al 2005). These biological buffer zones are areas of natural habitat before a pond or river system that will sequester nutrients into land plants rather than allow them to flow into water. By sequestering the nitrates and phosphates into plants, algae growth is not promoted, and the overall health of the pond is improved (Reicher, et al 2005). Other courses have tried to improve ecosystem health by reducing the nutrient load caused by their fertilizer applications.

In several studies, nutrient loads have been monitored to observe and compare the increase in nitrate and phosphate concentrations in normal conditions (Winter, Dillon 2006) and after periods of heavy rain (King, Balogh, Harmel 2007; King Balogh, Hughes, Harmel 2007). High nutrient levels have been observed in all of these studies, ranging from 6-9ppm (levels just below the EPA threshold for nitrate concentration). Even though these nutrient levels are below EPA standards, the additive effect from multiple sources can be dangerous. These high values are *just* from golf course sources. When the effects of farming and waste management are added to this, the threshold level can be crossed.

Golf course management has been under research scrutiny for a while, receiving special attention in the past decade for excessive nutrient generation (see King 2007). Golf courses without stringent environmental standards generally apply a round of herbicides and fungicides twice a year with daily applications of fertilizer (Hale, 2008). These regular applications can lead to high levels of nutrients present in local drinking water. A study done in Kansas showed that the water provided for the community had nutrient levels only 20% below the EPA threshold level, due in part to farming, but also from the golf courses in the area (Davis, Lydy 2002). Even though this is within the EPA guidlines, because of all of the other sources of nutrients entering the water, the further down river the water is sampled, the more concentrated the nitrates and phosphates become. This could have deleterious implications for both livestock and human health (Illinois Dept of Public Health 1999).

There has been a push in the last 20 years to ensure that golf courses strive to be environmentally friendly. Audubon International (not to be confused with the Audubon Society) has given certification to over 2000 golf courses across the country that have cut their pesticide usage to a minimum and promised to reduce nutrient flux into aquatic systems (Ross, 2003). Audubon International has been recognized as the standard for environmental golf course management, taking into account individual quirks associated with each course (Ross, 2003). There is no set standard required to become Audubon certified: the society will work with golf courses on an individual basis to look for areas of improvement and try and implement the strategies as seen appropriate. The overall goal is to improve soil quality, reduce aquatic eutrophication, and enhance wildlife areas (Audubon 2006). No two golf courses have identical conditions so to impose blanket regulations would be unwise. By working with golf courses individually, this encourages participation by allowing the golf courses to fix *individual* problems rather than address general national trends (Audubon 2006).

One of the downsides to this certification method however is that it requires no additional testing after initial implementation (Audubon 2006). It is assumed that if the course continues to follow the application methods prescribed by the Audubon Society that the nutrient levels will subsequently fall. In voluntary studies done by the golf courses, it is generally seen that once Audubon suggestions are followed that nutrient levels fall from previously recorded amounts (Podgornik, Pastor, Pinter 2008; Rice 2004). In those specific studies, water testing ranged from months to several years after

implementation of Audubon practices. Even with these varying time frames, the results consistently showed that the Audubon practices did improve water quality. While individual golf course testing has been performed, my survey of the literature found very few studies consisting of multiple sites. A search of the literature through Cambridge Science Abstracts (CSA) found that only three such studies had been done, and they were all comparing courses with similar management style in different parts of the country.

Another potential problem associated with the Audubon implementation is that it makes comparisons between golf courses difficult due not only to differing background nutrient levels but to these differing strategies (as mentioned in the above paragraphs). By doing a study where two golf courses *in the same geographic area* are compared, we can assume that the nutrient levels to begin with are similar. This means that within a community where one course is Audubon certified and one course is not, a reasonable comparison can be made, and conclusions can be drawn about which course has better methods for management of nutrients. A study involving two courses in the same area *with different management practices* would be worth conducting. Theoretically, because the golf courses are in the same geographic area and surrounded by similar geographic features (farms, roads, suburbs) they should have approximately the same baseline levels of nutrients before fertilizer is added. The major source of nutrient difference between the two golf courses, therefore, should *only be from application differences*. This should provide an accurate test between golf course management styles to see if one method is preferable to the other.

Testing for Nutrients

Nitrates and phosphates have long been used in fertilizers to encourage desired plant growth, but as already mentioned, they have negative effects in aquatic ecosystems (Winter, Dillon 2006). Since the 1970's, testing methods for nitrates and phosphates have been developed. Water from ponds and streams can be obtained simply by dipping an open jar into the body of water being tested. Samples collected from the pond or stream in question must be analyzed immediately or frozen to prevent the breakdown of chemicals present in solution. These samples are then analyzed by a spectrophotometer against a known solution to determine the concentration of the unknown sample (Taras, Greenberg, Hoak, and Rand 1971). This method has been used in nearly all the previously stated articles to quantify the amount of free nitrate and phosphate present in the unknown sample.

For the methodology used in this experiment, if organic matter (such as algae and other biotic life) is present, it can interfere with the detection of nitrate, registering a higher than expected value. To account for this, the absorbance of the solution is measured at two separate wavelengths: at 220 nanometers (nm) to give a nitrate reading, and at 275nm to give an organic matter reading. The absorbance measured at 275nm is doubled and subsequently subtracted from the absorbance reading at 220nm to give the actual nitrate concentration (Taras et al, 1971). Essentially, organic matter absorbs at half the intensity of nitrate at 220nm, so doubling the value recorded and subtracting it from

the nitrate reading effectively removes any organic interference observed. If the nitrate concentration ends up being low, but a high organic matter absorbance is recorded, it is *suggested* that the high organic matter is due to originally high concentrations of nutrients, as nutrients contribute to creating organic matter (Cho et al, 2003).

Some of the potential problems associated with this type of study include date of analysis and weather patterns during analysis. As mentioned previously, golf courses apply nutrients regularly, some of them even on a daily basis (Wingate, 2008) and testing during a time immediately after application can skew the results towards a higher concentration than actually present. Also, most golf courses stop applying fertilizer towards the winter months, allowing for nutrient levels to drop considerably. Other factors such as the existence of metal ions in water can skew the results during analysis because these ions will react in a similar fashion to nutrients (Taras, Greenbert, Hoak, and Rand 1971). If the study is done after a period of heavy rain (King 2007) or during a drought, that will also affect the amount of nitrate and phosphate that flows into the water, skewing results away from the actual average. These factors must all be considered when testing water, and the researcher must do everything in his or her power to ensure constant testing methods.

Directions for Future Research

It has been found from previously done research that the ecological conditions surrounding the study play a vital part to the conclusions drawn. Some studies have focused specifically on nutrient flux after periods of heavy rain (see King 2007) and found that nutrient levels can be up to 75% higher than before periods of rain (thus sending the concentration of nitrate *above* the allowable EPA amount). Other studies have focused on urban environments (Davis, Lydy 2002) while yet other studies have looked at soil transport into water ecosystems (Wu, et al 2007). It would be beneficial to have a study that focused singularly on similar ecological conditions so that extrapolations could be made and comparative conclusions could be drawn about the effectiveness of golf course management. Since most of the previously conducted research has focused on one golf course, little has been done to try and ensure ideal conditions (that is, consistent across golf courses). Few studies have focused on testing golf courses in the same area, making this study comparing two similar golf courses particularly ideal.

In summary, although a few research studies have examined the benefits of applying more stringent environmental standards, little has been done to try and convince other golf courses to change their land treatment practice based on previous local success stories. Research has shown the benefits of lowering pesticide and nutrient levels, but not on a comparative basis (between golf courses). Three factors are constantly noted in literature on golf course grounds: (1) that pesticide residues wipe out desired species; (2) that nutrient levels leaching off of golf courses are extraordinarily high (up to 75% of allowable amount for drinking); and (3) that excessive nutrient levels can lead to pond death if left unchecked. The last two points are of particular interest because of the relatively small body of research done on nutrients. Pesticides have always been seen as

the more hazardous material to deal with, thus most of the research pre-2000 was conducted on that topic. The purpose of this study is to show the need for competitive studies between golf courses *in the same community* to show the benefits of reducing the amount of nutrients applied to not only to keep the course healthy but the surrounding ecosystem. Courses can be successful and healthy at the same time without dumping thousands of pounds of fertilizer each year.

Methodology:

This study focuses on two golf courses in the Bloomington-Normal community (population 120,000) located in central Illinois, two hours south of Chicago. Both golf courses have similar geographic features (nearby corn farms, surrounded by houses and major roads) and both have ponds completely influenced by golf course treatment. As a basis for this study, these ponds were tested for nitrates and phosphates using standard testing methods discussed below. Water samples were drawn at least 3 weeks after the last application of fertilizer to ensure that the nutrient levels were not erratically changing day to day from application differences. This would allow for a good determination of whether or not the Audubon certified golf course (The Den) had lower nutrient levels than the non-certified course. The details of data collection and analysis are described below.

Sample Collection. Six samples of water were collected from select, geographically similar ponds from each golf course. At Ironwood golf course, the pond on hole 16 was sampled, and at the Den, the pond on hole 11 was sampled. These ponds were used because they displayed many similar features to each other that should ensure consistency; both are relatively large and have a major road that borders one side of the pond. Shallow water was collected using 250ml bottles submerged in the pond at a specified depth (one foot below surface). Samples were collected at both courses at least three weeks after the last application of fertilizer and during a period of little rain. If samples are collected after heavy rainfall (or for that matter, drought), the results of the nitrate and phosphate tests will be skewed towards values not representative of the actual golf course levels. Samples collected must be analyzed immediately to avoid the breakdown of nitrate and phosphate in solution. Because immediate analysis was not possible, the solutions were frozen and re-thawed. When a small amount of acid is added before freezing, nitrate is preserved without breaking down.

Nitrate Sample Preparation. After sample collection, the samples were filtered so that the biological matter was removed. This solution was then treated with 1 milliliter of hydrochloric acid (a weak solution of acid) to allow for color analysis to take place, which allow for measurement of nitrate concentration.

Nitrate Analysis. Once the samples were purified, a standard calibration curve was created using different known nitrate concentrations measured against an absorbance value taken at a wavelength of 220nm. As mentioned previously, a spectrophotometer was used to create a beam of light at 220nm that will pass through the sample (or

standard) and give an absorbance reading between zero and two. If the reading is zero, then all the light will pass through, indicating no nitrate is present. With these known nitrate standards, a linear plot was arranged on a graph relating absorbance with concentration. Thus, when the samples were analyzed, the concentrations were derived from the absorbance value measured. The values taken from each pond (one pond from each course) were then averaged to provide a golf course nitrate concentration level.

Phosphate Sample Preparation. After sample collection, the pH of the solution was recorded. If the pH is above 10 or below 4, then it must be altered using either acid or base to get the solution within the desired range. The samples collected had a desirable pH so no alteration was necessary. The solutions were then shaken with activated carbon to remove any organic matter in solution. The samples were then filtered and analyzed.

Phosphate Analysis. Phosphate analysis was similar to nitrate analysis where a calibration curve was created using known concentrations of phosphate. Phosphate has the highest absorbance reading at 470nm so the spectrophotometer was set to send out a wavelength of light at that desired level. A caveat to this system is that the color analysis is not stable over time. Before the analysis began, a vanadate-molybdate solution was added to the sample, reacting with the phosphate in solution to create a yellow color. This solution must then be read *exactly* 10 minutes after it is added. The color will continue to intensify if left alone for a longer period of time and will skew results towards higher levels of phosphate than actually present. Once the absorbance has been recorded for the unknown sample, the concentration was determined based on the calibration curve created with known phosphate standards.

Statistical Analysis. After each of the concentrations was determined, they were pooled to give an average concentration for both nitrate and phosphate from each course. These concentrations were then compared to each other via a two sample T-test, a statistical analysis that compares two means. This test determines whether or not the two averages are close enough to each other to warrant a "no difference" finding or if they are far enough apart to warrant a "significant difference" finding. If the final result of a T-test is is lower than 0.05, then there is a significant difference between the two samples (so if the T-test > 0.05, then a "no difference" result is recorded). This method was then applied to the study to determine if the nitrate and phosphate concentrations from each of the ponds were in fact statistically different from one another.

Methodology note. These quantitative methods were selected based on the accessibility of the instrumentation needed and the consistency of the results obtained. These procedures have been in use for over 35 years and have accurately determined the levels of phosphates and nitrates in aquatic ecosystems across the country (Taras et al, 1971).

This study has serious implications for future golf course management issues. If it can be shown that Audubon International regulations are beneficial to reducing nitrate and phosphate levels in golf course ponds, it could cause other golf courses considering adopting tighter standards to take the steps towards certification. Proof of environmental standards being successful has always been the biggest factor in getting other institutions

to change their methods. Especially important here is that both golf courses, having come from the same geographic area, should have similar nutrient background levels. It is the hope of this study that if The Den shows significantly lower levels of nutrient runoff that Ironwood Golf Course would seriously consider adopting more stringent environmental application methods.

Results:

Calibration Curves. As mentioned in the methodology section, nitrate and phosphate calibration curves (Figures 1 and 2 respectively), were created using known concentration. From these graphs the concentrations of the unknown pond samples were then determined.

Figure 1:

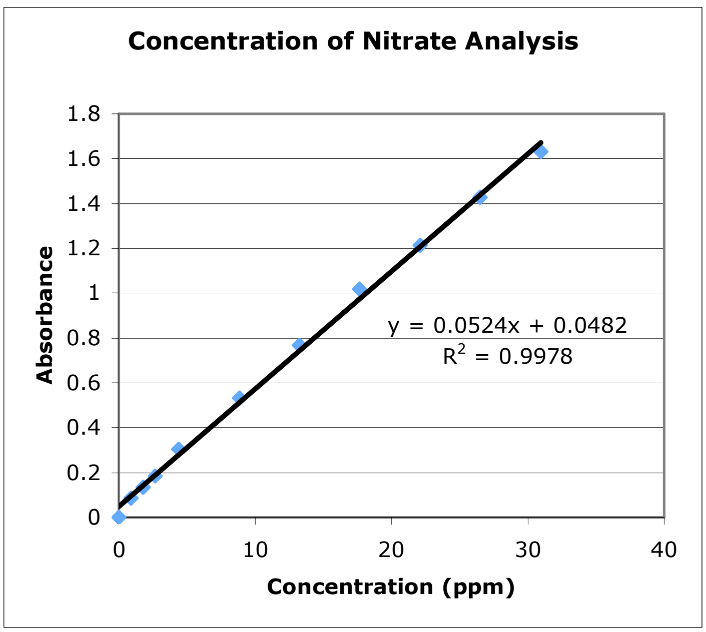
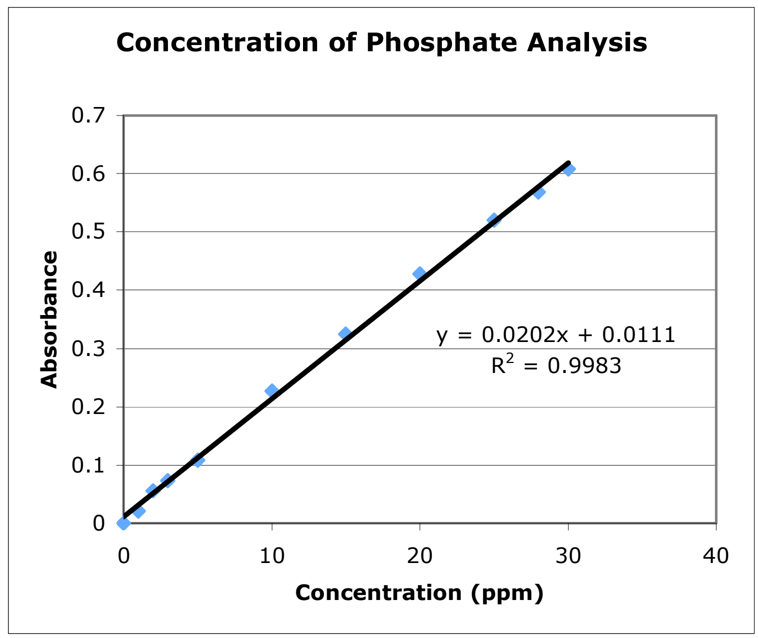


Figure 2:



Nitrate findings. Six samples from each pond were taken from the golf courses on Thursday October 30th 2008. These samples were frozen at –20°C and preserved in acidic conditions until testing the following week. Using the procedure described above, Table 1 was constructed detailing the findings for nitrate concentration from the study.

Table 1: Determining the concentration of Nitrate each pond

	The Den at Fox Creek	Ironwood
Average Absorbencies	.2705	.3235
Concentration (ppm)	4.242	5.254

Using the equation given by the calibration line, the concentration of nitrate was able to be determined for both golf courses. To see if the difference between the two golf courses was of any significance, a 2-sample T-test was used. Again, the purpose of this study was to test whether the differences in fertilizer application lead to any significant difference in nitrate and phosphate concentrations between the two courses. When the t-test was run for these two values, the p-value calculated was 0.00033, far lower than the required .05 threshold for a 95% confidence of significance. Because this p-value is so small, it suggests that the nitrate concentration at Ironwood is significantly higher than the nitrate concentration at The Den. Another confirmation factor in this process was the level of organic matter present in the samples themselves. When the samples were analyzed to measure organic interference, the Ironwood golf course also showed a significantly higher level of organic matter than The Den ($A_{Ironwood} = 0.158$, $A_{Den} = 0.123$; $p = 0.001$). High levels of organic matter indicate the *former* presence of nitrate in solution. This suggests that there was originally a larger difference in nitrate levels before some of it was sequestered away in organic material.

Phosphate Findings. Phosphate analysis was conducted in the same manner as nitrate and the concentrations of both courses are summarized based on absorbencies in Table 2.

Table 2: Determining phosphate concentration at each pond

	The Den at Fox Creek	Ironwood
Average Absorbance	.007	.01
Concentration	Negligible (< 1ppm)	Negligible (<1ppm)

From the analysis, it was determined that both ponds had such a small concentration of phosphate, that the difference between the two was insignificant.

Fertilizer differences and effects. One of the unique aspects of this study is that both of the golf courses use fertilizers with remarkably similar nutrient compositions. As stated previously, it is *essential* that all other variables besides management practices remain constant. Because the fertilizer composition (fertilizer made up of roughly 19% nitrate and 4% phosphate the remaining percentage accounted for by other solids not important in analysis) is similar, that means that the findings above should be due to *just* fertilizer application differences. By standardizing this important variable, the data above can be summarized and some interesting conclusions can be drawn.

One area of interest remains: and that deals with they specific method used by both courses to apply fertilizer. The Den at Fox Creek applies their fertilizer through the sprinkler system, meaning that the water used to irrigate the course *already contains* all the nutrients the course will apply. Ironwood, on the other hand, applies a solid fertilizer to their course, which could have interesting impacts. A liquid is *generally* much more readily absorbed into soil than a solid, which could explain the results, found in this study. By doing future work with both courses, observing the effects of runoff into ponds hours after the application, a definitive conclusion could be drawn about how the differing application methods contribute to nutrient level differences.

Discussion

Significance of findings. From the data presented above, it can be suggested that the better fertilizer management practices at the Den contribute to lower nutrient levels and thus better overall water quality. The analysis of the samples gives a strong indication that there was a significant difference in nitrate concentration but not phosphate concentration between the two golf courses.

The phosphate analysis did not prove significantly that there was a difference in application methods in relation to concentration. From the analysis, the concentration values were so low, that a difference could not be determined. It is possible that phosphate is sequestered at a faster rate into sediments and plants than nitrate, and thus it is harder to quantify after application has been cut off.

There were some inherent problems associated with testing that could have contributed to some of the inconsistencies in the findings. As a result of the testing occurring so late in the year, an accurate determination of nutrient levels was not possible because fertilizer applications had been stopped for the year. Still, Ironwood cut off its fertilizer application nearly two weeks before The Den did. This means that the pond being tested at Ironwood had additional time for nitrate to filter out (either through algae or sequestering into sediment) yet a higher value at Ironwood than at the Den was still recorded. Because of the late time of year and how it might skew readings, every possible effort was made to ensure that all other variables were kept constant. Also, because both ponds were relatively shallow (a couple of meters in depth), it was assumed that the concentration of nutrients was constant throughout the strata. In deeper ponds, stratification can occur (where concentrations can vary with pond depth) causing skewed data. The assumption that the strata were homogeneous may not be a safe assumption to make, but because of time constraints, it was adopted into the methodology.

Due to the timing of this study, accurate representations of nutrient levels during golf season could not be quantified. Both golf courses registered a low value for nitrate concentration, but whether this is a good reading for general conditions is questionable. This could be due to end of the season fertilizer cutoff more than anything else. It would be beneficial to a future study to try and test both golf courses (in the Bloomington-Normal community or elsewhere) during times of heavy application to see if there still is this significant difference. It would also be beneficial to do water sampling throughout the year to observe changes in nutrient levels due to varying weather patterns, differences in applications, and general changes as time progresses. Again, because of time constraints, these issues were not pursued, but such additional studies would be needed to suggest a trend.

Future Work. The results shown above were presented to members of both golf courses and the community with suggestions for both future work and beneficial changes. Both courses showed relatively low concentrations of both nutrients, suggesting after fertilization has been cut off, the ponds will return to normal baseline levels over time.

To counteract this, more testing will occur during the spring of 2009 after application has started again. Hopefully, the values taken from the spring sampling will confirm the findings of this study and will be more representative of the actual conditions. Without a good comparison at peak golfing season (during periods of heavy fertilizer application), the results as presented above do not have the same significance.

After talking with members of the golf courses, it was determined that small steps could be taken to ensure that water quality remains good. Ironwood has expressed willingness to seek environmental certification, but wants to see more results before any serious action is taken. Both courses have seemed receptive to the idea of placing biological buffer zones around their ponds to ensure that the water remains in good health and that eutrophication does not occur on a massive scale. The management understands the potential ecological and health risks that could come with having poor water quality and will address the issues once more confirmatory results have been produced. Again, the community of Normal has recently stressed the importance of "going green" and the town seems receptive to the idea of pursuing certification for their course. Not only would this be beneficial ecologically, but it could also serve as a good working educational model to the community for how an environmental upgrade could be accomplished. Change is often caused when people witness success. Ironwood could be an environmental success if changes are adopted, and the educational benefits to the community would be extremely useful.

Summary:

In summary, it has been shown that The Den, after three weeks without fertilizer, has a lower nitrate concentration than Ironwood. The same cannot be said for phosphate, the concentrations of which were too low to quantify and determine a significant difference. There is a slight suggestion from this study that because of Audubon certification, The Den exhibits lower concentration of nutrients, but because an extensive study could not be carried out, that suggestion cannot be backed up strongly.

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