JOURNAL OF GEOSCIENCE EDUCATION **61**, 280–290 (2013)

Transforming a University Tradition Into a Geoscience Teaching and Learning Opportunity for the University Community

Steven T. Goldsmith,[1,a] Annette M. Trierweiler,[2,3] Susan A. Welch,[2,3] Alyssa M. Bancroft,[2]
Justin M. Von Bargen,[2,3] and Anne E. Carey[2,3]

ABSTRACT

Recent initiatives in geosciences education have focused on interactive and inquiry-based learning experiences both inside and outside of the classroom. While the concept is sound, examples and datasets seldom focus on opportunities to which the students can immediately relate. Herein we show how a university tradition has been transformed into an interactive geosciences learning opportunity for the university community. Each year during the third week of November, thousands of university students jump into an artificial pond on campus in support of the annual football rivalry game. An undergraduate student research initiative documenting the water quality of the pond before, during, and after the event clearly documents how humans can affect their environment. Use of the resulting dataset in the classroom for an entry-level geoscience laboratory exercise on water contamination has sparked student interest in the effects of anthropogenic activities on water quality and has mobilized subsequent studies to test additional hypotheses. Changes in students' attitudes on water quality were documented by significant differences in administered pre- and postexercise surveys with five-point Likert-type items, while subsequent interest in the dataset from both the university and the surrounding communities has provided additional audiences for engagement on local water contamination issues. Inclusion of the dataset into laboratory exercises is intended to lead to future research questions and promote independent research initiatives. © *2013 National Association of Geoscience Teachers*. [DOI: 10.5408/12-354.1]

Key words: biogeochemistry, university tradition

INTRODUCTION

Public understanding of environmental problems is often incomplete or nebulous (how fossil fuel emissions result in climate change, how nonpoint sources of pollution can affect local water supplies, etc.). However, this is not necessarily due to lack of interest in an issue. For example, recent Gallup polls have shown that 77% of the population polled are concerned about "pollution of drinking water" and 79% are concerned about "pollution of rivers, lakes, and reservoirs" (Saad, 2011). In an effort to bridge this disconnect between awareness and understanding of a scientific issue, there have been efforts in the geoscience community to promote active learning in the classroom (McConnell et al., 2003).

Several geoscience-based water quality courses have successfully focused on the evaluation of water bodies in the immediate campus vicinity; however, these courses are often a semester in duration and pitched at upper-level students (Kirk et al., 1997; Woltemade and Blewett, 2002; Graney et al., 2008). To address geoscience issues of relevance in a weekly breakout laboratory session for large lecture classes (150+ students) can be particularly challenging and often results in cookie-cutter format exercises in which students neither become personally invested nor feel the need to report results to the class. While interactive and inquiry-based learning techniques (McConnell et al., 2003; Apedoe et al., 2006) and concept-based learning (McConnell et al., 2006) prove effective in this particular setting, they often don't focus on an issue close to home to which students can immediately relate. Yet personal relevance has been shown to increase long-term knowledge retention (Semken and Freeman, 2008). Even rarer are watershed studies that can incorporate both teaching and research experience at a basic level (Fryar et al., 2010). This is important, because students might be particularly responsive to a dataset collected by their colleagues. One prospective methodology that appears to have been overlooked in meeting these objectives is using a university tradition to conduct a controlled experiment on campus to address issues of water quality.

Herein we chronicle how an annual university tradition involving thousands of students jumping into a man-made water body can be effectively transformed into both an undergraduate research opportunity and an introductory-level Earth Science laboratory exercise on water quality. We hypothesize that concentrating on an activity of immediate campus relevance (and in which the students may have participated) motivates students to discern the impacts of human activities on water quality and enables their ability to draw parallels to greater issues of water quality within the state. In other words, can a university tradition be truly transformed into an interactive geoscience learning opportunity? We set out to accomplish this goal in three distinct parts: (1) organization and mobilization of water sampling during a university tradition, (2) introduction of the resultant dataset in a geoscience-based, introductory-level laboratory on water quality and validation of our hypothesis, and (3)

Received 23 August 2012; revised 17 March 2013; accepted 3 April 2013; published online 27 August 2013.

[1] Department of Geography and the Environment, Villanova University, Villanova, Pennsylvania, 19085, USA
[2] School of Earth Sciences, The Ohio State University, Columbus, Ohio 43210-1398, USA
[3] Byrd Polar Research Center, The Ohio State University, Columbus, Ohio 43210-1002, USA
[a] Author to whom correspondence should be addressed. Electronic mail: steven.goldsmith@villanova.edu. Tel.: 610-519-3589. Fax: 610-519-3338.

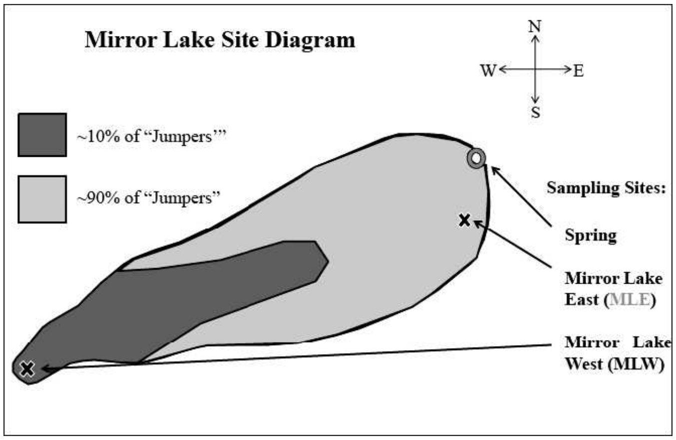

FIGURE 1: Map of Mirror Lake. The east and west sampling points are denoted by an X. More than 90% of the jumpers were observed on the east side of the lake.

assessment of the change in student attitudes on water quality issues via pre- and post exercise surveys. We show that this project provided not only an introduction to undergraduate research but also a dataset that has captured the interest of the general student population.

THE MIRROR LAKE JUMP

Background to a Campus Tradition

Located in the heart of the Ohio State University campus, Mirror Lake originally was a spring-fed natural water body (Fig. 1) (Herrick, 1984). During subsequent development of the surrounding Ohio State campus, the lake was transformed in 1935 into an engineered structure with limestone brick sides and a brick paver bottom (Herrick, 1984). Lake inflow originates from municipal water supplied through a fountain on the east of the lake, while outflow exits over a small notch and into a stream on the west side of the lake. The lake contains a total volume of ~2,600 m^3 and slopes gradually downward from east to west (fountain to stream). This graded bottom results in an average depth of 1 m on the east end increasing to approximately 3 m near the outflow point. Mirror Lake is surrounded by mixed vegetation of grass and trees with a paved sidewalk on only the eastern half. Together, the depth and sidewalk provide easy access to the lake on the east but limited access on the west. While swimming is prohibited, the lake serves as a year-round home for anywhere between two to three dozen ducks. The lake is drained approximately every 2 years in the summer by the university groundskeepers in an effort to reduce the buildup of natural and artificial debris. At this time, the sidewalls and bottom of the lake are cleaned to remove accumulated algae.

Each year on the third Thursday of November several thousand Ohio State students jump into Mirror Lake, hereafter referred to as "the event" (Fig. 2). While the origin of the event is not completely understood, its current intention is to rally support for the university football team 2 days before its annual game against the University of Michigan. Student involvement often oscillates with the importance of the game and can last several hours during the night. The event also pervades awareness of the surrounding community, because it is repeatedly covered on all local media outlets.

FIGURE 2: View of the east side of Mirror Lake during the peak hours of the event.

Project Design

In the fall of 2008, our research group was approached by an undergraduate geological sciences major who was curious about whether an anthropogenic signature could be recorded from the event. Unfortunately, this inquiry occurred 1 day before the actual event and led to a limited sampling of Mirror Lake. Initial findings included a 1°C temperature increase of the lake water observed over a 3-hour period and a distinct spike in both NH_4^+ and total nitrogen (TN) concentrations in the shallow portion of the lake over the same interval.

These initial results piqued our curiosity as to the overall potential anthropogenic signature that could be recorded during such an event. We subsequently held an open group meeting in the fall of 2009 (both undergraduate and graduate students were invited), where we brainstormed about the potential effects to water quality and subsequently developed hypotheses that could be readily tested. Testable hypotheses generated included the following: (1) the event results in a distinct human geochemical signature in the lake, and (2) lake productivity is nutrient limited and perturbation of accumulated biogenic sediment, human input, or both triggers an eutrophication event.

To test these hypotheses, both graduate and undergraduate students were assigned the responsibility of developing an appropriate sampling protocol. Hypothesis 1 would be tested by analyzing water samples collected before, during, and after the event for pH, temperature, major cations and anions, and nutrients. Hypothesis 2 would be tested by comparing dissolved oxygen (DO) concentrations, along with the speciation and concentration of nutrients N and P, before, during, and after the event. It was also agreed upon that all sampling of the lake would be carried out by an assemblage of students.

Sampling and Analytical Methods

For each year of the experiment, water samples were collected by the students at two locations (east and west)

FIGURE 3: View of students sampling to the east side of Mirror Lake prior to the event.

before, during, and after the event. To determine baseline concentrations, sampling of the fountain and both ends of the lake was conducted approximately 1 week and 1 day before the event. Background samples were also collected from both the east and the west ends of the lake beginning at 8 pm on the night of the event. Sampling of the lake proceeded hourly from 8 to 10 pm and was thereafter at half-hour intervals to coincide with the peak of the event. The last sample for the evening was collected at 1 am, at which time the event was shut down by the Columbus Police Department. Additional samples were collected the following morning at 8 am and approximately 1 week after the event to document the response time of the lake returning to baseline values.

All water samples were collected using a modified lake water sampler consisting of a 1-L, low-density, polyethylene bottle attached to a 3-ft. aluminum pole. This was done to ensure samples were collected far enough into the lake to be deemed representative while trying to keep the student sampling the lake dry (Fig. 3). The sample bottle was rinsed out three times with lake water prior to the collection of the sample. The pH, temperature, and conductivity were measured in the field immediately after sampling using a Thermo Scientific Orion 5-Star multiparameter meter and the methods supplied by the manufacturer.

Water samples for major ions and nutrients were filtered the next morning and analyzed for cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions (Cl^- and SO_4^{2-}) on a Dionex DX 120 ion chromatograph using established methodology (Welch et al., 1996). Analyses of nutrients (TN, NH_4^+, NO_3^-, NO_2^-, Si, PO_4^{3-}, and total phosphorus) were made with a Skalar Sans++ nutrient analyzer using methods supplied by the manufacturer.

Observations

The first "jumper" was observed around 9 pm. While it can vary from year to year, the timing for the big "jump-in" started around 10 pm. From 10 pm to 1 am, there were dozens to hundreds of students in the lake at any time, with an estimated 5,000 total students in the lake that evening. The event was abruptly stopped at 1 am by the Columbus and university police departments, at which time all students exited the lake.

A temperature increase of 0.7°C, from 10.7°C to 11.4°C, was observed in the lake water from 8 pm to 1 am. The air temperature at the time of the event was approximately 40°F (4°C). We deemed the water–atmosphere mixing effects to be negligible and assumed that the temperature increase could be attributed directly to a release of body heat from the jumpers. This result was similar to that observed in 2008 when a lakewide 1°C temperature increase, from 3°C to 4°C, was observed over the course of the evening when the outside temperature was approximately 35°F (1°C).

Initial Findings

A brief summary of some of the more pertinent findings from this study is integral to understanding the structure of the associated laboratory exercise. Thus, we have included some highlights, along with some interpretation.

As expected from the conductivity readings, detectable increases in almost all anion and cation concentrations were observed in both sides of the lake throughout the course of the evening (Table I). However, clear spatial variability existed in the dataset, with substantial increases in several elements in the shallow, east side of the lake that correlated with the majority of the jumpers.

The results garnering the most attention were the substantial increase of NH_4^+ and TN concentrations during the sample period. TN concentrations were found to increase approximately 500% in the east side of the lake compared to an increase of 94% in the west. NH_4^+ concentrations followed a similar trend, with concentrations increasing more than 3,200% (7.5–201 parts per billion) in the east side of the lake. In both cases, these peak concentrations in the east side of the lake were observed in the samples collected at 1 am, just after the observed peak of jumpers. While this TN pulse could be attributed to the release of nutrients from perturbed lake bottom sediments (decaying algae and avian fecal matter), the lake had been drained and the base and sides pressure washed several months before the event. This meant that the brick paving stones on the bottom of the lake were clearly visible from the surface, indicating that there was little sediment in the lake. Therefore, the spikes in NH_4^+ and TN were largely attributed to direct human input during the event.

Hypothesis 2 proved more difficult to test, because a faulty DO probe prevented analysis of the lake for DO both during and after the event. While no definitive conclusions can be drawn as to whether an algal bloom had been triggered, students were readily able to observe the brick pavers on the bottom of the lake in the days following the event, suggesting a bloom had not occurred.

CLASSROOM INTEGRATION OF THE STUDY RESULTS

In addition to providing an opportunity for undergraduate research experience, this sampling exercise has presented an occasion to incorporate campus-related scientific data in the classroom. The dataset has already been utilized both qualitatively and quantitatively in an introductory geoscience course lab exercise examining human impacts on water quality at Ohio State. The lab is designed to challenge students' perceptions on water quality and to draw connections between the Mirror Lake jump and water quality issues of a larger scale. Laboratory sessions typically range from 25–30 students with a maximum of 30. Students work in small groups consisting of four or five of their peers.

At the beginning of the exercise, students were provided with a brief introduction on the physiographic setting of Mirror Lake and details on its transformation from a natural water body to its present-day confined impoundment. (See the supplemental laboratory exercise available at http://dx.doi.org/10.5408/12-354s1.) During this time, they were also shown a brief YouTube video documenting the annual Mirror Lake jump. While many students had heard of, if not participated in, the jump, the video proved to be a useful visual, particularly for first-year students who were not yet familiar with the event. The humor lightened the atmosphere of the lab and let the students know that this session's exercise was directly relevant to an ongoing student tradition on their campus. The students were also purposefully informed that the authentic dataset they would be interpreting was the direct result of the collaborative efforts among their fellow undergraduate students.

Establishing the Link Between Human Activities and Water Quality Impacts

To place the data in a scientific context, students were provided with explanatory information concerning both the mechanism of delivery and the cycling of nutrients in streams and lakes. With dissolved nitrogen as an example, students were informed that ammonium is often found in the bottom sediments of lakes due to the decay of organic matter (both micro- and macrofauna and fecal matter), because the lack of oxygen in bottom sediments prevents ammonium from mineralizing to nitrate. Second, ammonium spikes can also be observed in rivers and streams downstream of sewage treatment facilities, particularly after storm events, when capacity of these facilities is often exceeded. Finally, nitrate in water bodies is typically sourced from surface runoff of fertilizer applied to the surrounding landscape, such as agricultural land, golf courses, and even household lawns. Supplied with this background information, along with selected data from the conducted experiments, students were asked to address several questions. These, some with an author's response and further information about the question, are provided here.

1. In 2009, nitrate concentrations in Mirror Lake were found almost to double from a background concentration of 0.04 mg/L to a peak value of 0.07 mg/L during the event. How do you think the nitrate entered the lake? Are the concentrations of nitrate observed in Mirror Lake during the event safe for human consumption?
2. Shocking increases in both NH_4^+ and TN concentrations were observed, particularly on the east side of Mirror Lake, throughout the course of the night. If the observed increase in TN concentrations on the eastern side of the lake is representative of the average value for this half of the lake and the flux is attributed solely to human-introduced NH_4^+, what would be the quantity of urine required to increase the TN concentration by 867 μg/L? Information provided: 1,300 m^3 = volume of the east side of the lake; 1,000 L = 1 m^3; average human urine contains 9,000 mg of N per liter (Udert et al., 2006).

Author Response: Based on the above assumptions, it would require about 125 L of urine to produce the observed increase in TN. Yuck! This is not an unreasonable value given the fact that over 5,000 students participated in the event, many of whom were inebriated.

While the humor of the event helps attract initial student interest to these specific exercises, it has also facilitated qualitative discussion in the classroom. After witnessing how humans can directly affect the quality of water in a specific body of water, parallels can be drawn to anthropogenic processes at increasing levels of scale. For example, assuming the NO_3^- flux to Mirror Lake is the result of students creating localized runoff during the event; parallels can be drawn with runoff originating from road salt, agricultural fields, and golf courses. If the NH_4^+ flux is largely due to direct human input, a corresponding connection can be drawn to how N input from septic systems can cause impairment of water quality in lakes and reservoirs. If some of the observed N pulse is due to the perturbation of lake sediments entrained with biogenic sediments and fecal matter, students can see how extensive lawns and golf courses can indirectly change the water quality of suburban lakes and ponds through the alteration of migratory bird behavior.

This discussion of modes of delivery of an element into water systems allows further expansion into other elemental cycles, thus providing the opportunity to introduce and discuss additional anthropogenic impacts on water bodies.

3. As part of the 2009 Mirror Lake jump, concentrations of K^+ were found to range from a pre-event average concentration of 5.1 mg L^{-1} to a postevent average value of 5.8 mg L^{-1}. What is the total flux of K^+ (in kilograms) introduced to Mirror Lake during the event? Information provided: 2,600 m^3 = volume of lake; 1,000 L = 1 m^3.

Author Response: A total of 1.8 kg of K^+ was introduced to the lake during the 2009 event. This question can be easily modified for the other elements analyzed.

As noted earlier, a parallel can be drawn with runoff events, in this case with the direct application of road salts. Further inquiries into the introduction of this material facilitated student recollection of university vehicles applying a liquid spray (KCl) to sidewalks prior to forecasted winter storms and application of solid salt pellets ($CaCl_2$) afterward. There was no snow or evidence of salt on the ground at the time of the event, which created a segue for the introduction of elemental residence times in a surface environment. More importantly, students can calculate an actual physical quantity of an introduced material and develop ideas on to how to limit its introduction into water bodies.

4. During the Mirror Lake jump, the temperature of the lake increased (1°C in 2008) largely as function of heat transfer from the students. Using the volume of

TABLE I: Concentrations of dissolved ions and nutrients in mirror lake.[1,2]

Sample No.	Sampling Date	Sampling Time	Temp (°C)	pH	Cond (μs/L)	Na^+ (ppm)	K^+ (ppm)	Mg^{2+} (ppm)	Ca^{2+} (ppm)	Si (ppm)	F^- (ppm)	Cl^- (ppm)	SO_4^{2-} (ppm)	NH_4^+ (ppb)	TN (as ppb N)	Total P (as ppb P)
Mirror Lake Spring (MLS)																
MLS 1	11/12/2009	18:11	13.6	7.56	260	15	5.1	12	26	3.6	0.8	32	67	10	1033	1638
MLS 2	11/18/2009	18:10	12.8	6.51	247	15	5.4	12	25	3.9	0.6	31	68	4.2	1091	1681
Mirror Lake East (MLE)																
MLE 1	9/29/2009					15	4.7	10	26	3.7	0.8	33	63	40	532	1352
MLE 2	10/6/2009					16	4.8	10	26	4.0	0.6	32	62	55	568	1561
MLE 3	11/12/2009	18:32	10.6	8.29	262	16	5.2	11	27	5.1	0.9	33	66	6.9	428	1334
MLE 4	11/18/2009	18:20	11.3	7.42	261	15	5.1	11	27	4.3	0.8	31	68	6.1	385	1360
MLE 5	11/19/2009	20:00	10.7	7.84	270	16	5.1	11	27	4.4	0.6	32	66	7.5	491	1320
MLE 6	11/19/2009	21:00	10.8	7.83	284	16	5.1	12	27	4.4	0.7	31	66	6.5	444	1333
MLE 7	11/19/2009	22:00	10.8	7.86	283	16	5.1	12	27	4.4	0.8	33	66	6.4	404	1317
MLE 8	11/19/2009	22:30	10.9	7.03	281	16	5.1	11	27	4.3	0.7	32	67	8.6	424	1317
MLE 9	11/19/2009	23:00	11.0	7.01	285	16	5.2	12	27	4.4	0.7	33	67	8.4	417	1303
MLE 10	11/19/2009	23:30	11.2	6.87	292	17	6.0	12	28	4.4	0.9	35	67	37	1415	1367
MLE 11	11/20/2009	00:00	11.3	7.90	310	17	6.4	12	28	4.4	0.7	35	67	76	1462	1350
MLE 12	11/20/2009	00:30	11.3	8.24	311	17	6.2	12	28	4.4	1.0	36	68	72	1627	1412
MLE 13	11/20/2009	01:00	11.4	7.49	315	18	6.5	13	28	4.4	0.8	36	68	201	2256	1430
MLE 14	11/20/2009	08:01	10.5	8.07	276	17	5.9	12	28	4.4	0.8	35	69	145	1358	1413
MLE 16	11/22/2009	14:45	10.6	7.57	308	17	6.0	13	28	4.6	0.8	35	69	42	1206	1382
Mirror Lake West (MLW)																
MLW 1	9/29/2009					15	4.7	10	26	3.7	0.7	32	63	42	366	1365
MLW 2	10/6/2009					16	4.7	10	26	4.0	0.8	32	62	41	476	1536
MLW 3	11/12/2009	18:40	10.3	7.92	272	16	5.1	11	27	4.5	1.2	33	67	4.9	488	1363
MLW 4	11/18/2009	18:30	11.2	7.92	262	16	5.1	11	27	4.4	0.6	33	68	4.7	319	1373
MLW 5	11/19/2009	20:10	11.0	8.01	274	16	5.1	12	27	4.4	0.6	32	65	3.9	574	1349
MLW 6	11/19/2009	21:10	11.0	7.89	284	16	5.1	12	27	4.4	0.8	32	66	4.8	378	1340
MLW 7	11/19/2009	22:05	11.0	7.80	284	16	5.1	12	27	4.4	0.7	32	67	3.2	390	1338
MLW 8	11/19/2009	22:30	11.0	7.16	283	16	5.1	12	27	4.4	0.9	33	66	4.2	378	1329
MLW 9	11/19/2009	23:00	11.0	7.04	283	16	5.1	12	27	4.4	0.8	32	68	4.4	401	1339
MLW 10	11/19/2009	23:30	11.0	6.89	288	16	5.1	12	27	4.4	0.9	32	65	5.8	354	1339
MLW 11	11/20/2009	00:00	10.1	8.10	303	16	5.1	12	27	4.4	0.8	32	67	2.2	545	1340
MLW 12	11/20/2009	00:30	11.0	8.14	311	16	5.2	11	27	4.4	0.7	33	67	1.3	656	1340
MLW 13	11/20/2009	1:00	11.0	7.80	303	16	5.3	12	27	4.4	0.8	33	68	5.5	619	1344

the lake and the observed change in temperature, what was the amount of heat (in calories) required to cause the observed change in temperature? Information provided: 2,600 m^3 = volume of lake; 1,000 L = 1 m^3; 1 L of H_2O = 1,000 g; 1 calorie of energy = Δ1°C per gram of H_2O.

Author Response: Approximately 2,600,000,000 calories of energy were required to raise the temperature of Mirror Lake by 1°C!

5. A pound of body fat equates to approximately 3,500 kilo calories. Use the answer from the preceding question and assume 5,000 students participated in the event. Calculate how many pounds of weight loss per person was achieved from the event. Information provided: 1 kilo calorie (aka food calorie) = 1,000 calories.

Author Response: Assuming 5,000 students participated in the event, each student lost on average 0.15 pounds of fat during the course of the evening. The answer to this question would surely pique the interest of a fitness-conscious college student!

Between the temperature change and the introduction of NH_4^+, students were surprised that the event has such an immediate impact on the water quality of Mirror Lake. More importantly, a general level of enthusiasm and natural inquiry occurred throughout this portion of the exercise. It was particularly encouraging to observe positive change in the level of the interaction among members of the individual lab groups within the classroom. While students typically work in groups of four or five individuals, communication is generally limited to the minimum needed to complete the required task or tasks for the session. Students were now actively communicating their personal observations from their participation in the event and relating stories about subsequent health impacts experienced by their friends (stomach ailments, etc.). Several students inquired whether bacterial measurements have been collected, suggesting gained understanding on contaminant sources. It was also interesting to observe students draw connections to previous observations made while traversing this portion of campus, such as the brine mixture applied to sidewalks before winter storm events and how it can contribute to runoff.

Furthermore, many students were surprised by their calculated inputs of contaminants into Mirror Lake. When asked why the contribution of nutrients, such as nitrates, might be so high, several students responded that the grass areas immediately surrounding the lake transforms to mud during the event, some of which was observed to be running into the lake. This interest into the magnitude of fluxes entering the lake was exciting to observe, because almost all questions included a quantitative component, which has been a particular initiative for geoscience laboratory exercises (McDonald et al., 2000). Although not discussed here, additional questions have been derived from the dataset, including those related to contaminant diffusion and recovery of the system to its background state.

TABLE I: continued.

Sample No.	Sampling Date	Sampling Time	Temp (°C)	pH	Cond (μs/L)	Na^+ (ppm)	K^+ (ppm)	Mg^{2+} (ppm)	Ca^{2+} (ppm)	Si (ppm)	F^- (ppm)	Cl^- (ppm)	SO_4^{2-} (ppm)	NH_4^+ (ppb)	TN (as ppb N)	Total P (as ppb P)
MLW 14	11/20/2009	08:05	10.6	7.98	276	16	5.7	13	28	4.5	0.9	34	69	35	1067	1386
MLW 15	11/22/2009	14:45	11.0	7.74	310	17	5.9	13	28	4.6	0.9	34	68			

[1] Empty cells indicate that geochemical data were not collected.

[2] Cond = concentration; ppb = parts per billion; ppm = parts per million.

SCALING UP THE RESULTS—TELECONNECTIONS WITHIN WATERSHEDS

The aforementioned series of questions provided evidence for both direct (human waste) and indirect (fertilizers, salt, etc.) introduction of contaminants into Mirror Lake. A classroom summary of the findings provided the opportunity to reinforce the concepts of both point and nonpoint sources of water pollution, respectively. Building upon this acquired knowledge base, students were asked to take what they learned from the first part of the exercise and apply it toward a specific problem of immediate concern to residents of the state of Ohio.

The specific example provided focused on Grand Lake St. Marys, Ohio's largest inland lake, which has been in the news because nitrate concentrations in the lake have increased to the point of triggering toxic algal blooms. During the summer of 2010, the Ohio Environmental Protection Agency (EPA) deemed the lake unsafe for swimming and fishing because of the high concentrations of liver and nerve toxins released by the algae and several reported illnesses from swimmers. This has had a negative impact on the $150 million a year tourism industry for the surrounding area (Hunt, 2010).

After being informed that the area immediately surrounding Grand Lake St. Marys is predominantly agricultural, students were asked to state what they believe is the source of this nitrogen contamination. Most students were able to draw the connection from, the first portion of the lab, that runoff of fertilizers was the dominant mechanism of delivery to the lake. This led to student inquiries as to what could be done to ameliorate the issue. Expanding on this idea, students were subsequently asked to imagine themselves as a resident or an owner of a tourist-related industry in the Grand Lake St. Marys area and address how they would want their local government to respond in an effort to lower the concentration of nitrate in the lake. Responses varied, with the most common theme focused on the limitation of agricultural development close to watersheds that feed inland water bodies, such as lakes or reservoirs. Several other comments focused on the possible mandate for greenways within a certain radius of streams that feed the lake.

This line of questioning allowed the introduction of methodologies to reduce the influx of nitrate into water bodies. Students were informed of the characteristics and use of riparian buffers and of how they have been shown to dramatically reduce the amount of nitrate entering streams from both farmland and golf courses. They were also informed that the only known downside to these buffers is the slight loss of arable land to farmers or the loss of what are deemed aesthetic views of water bodies at golf courses. Students were then asked whether the use of riparian buffers should be enforced to improve Ohio's water quality and were asked to provide reasoning for their responses. The majority of students were in favor of the use of riparian buffers despite the potential drawbacks. In addition, several students expressed surprise that riparian buffers were not necessarily required under law, particularly in areas prone to high fertilizer use.

In a final effort to scale up the issue, the students were provided with the results of a 2010 Integrated Water Quality Monitoring and Assessment Report released by the Ohio EPA, which indicates that while the overall quality of Ohio's water resources is improving, only 13% of the water bodies sampled meet the minimum requirement for recreational use. Students were also informed that elevated levels of nitrate were reported as the major cause of impairment to these systems. The information provided ample background for questions seeking students' thoughts on what Ohioans can do better to improve the quality of their water resources. Students were again able to draw correlations between agriculture and general level of water quality within the state. Many students commented on the brownish-green appearance of streams in the surrounding campus area, their place of origin within the state, or both during spring and summer runoff events. These observations ultimately facilitated discussion of how overland flow can operate as a mode of delivery for contaminants to a watershed.

Several of questions were specifically designed to allow students to draw parallels between Mirror Lake and water contamination issues at increasing levels of scale within the state of Ohio. The questions also offered the opportunity to address a variety of mechanisms that could reduce anthropogenic influence on water bodies, including riparian buffers and the role of government in the protection of water quality. While the examples were written predominately from an agricultural runoff perspective, they can be readily expanded upon to address additional contaminants, such as the introduction of salts from road runoff or the direct introduction of raw or partially treated sewage.

Additional Avenues for Discussion

Students were surprised that humans could cause such a noticeable impact upon a sizable water body during the course of an evening simply through direct contact. This realization led to an organic discussion about other ways in which students might affect the water quality of Mirror Lake or even the groundwater on Ohio State's campus. These classroom discussions have also identified several other areas of inquiry, along with corresponding testing methodologies (Table II). For example, additional analytical techniques such as N isotopes or sampling for bacteria can be used to discern whether the observed NH_4^+ and TN peaks originate from human input or perturbed bottom sediments. Other students have inquired whether additional parameters such as deodorant and pharmaceuticals (i.e., antibiotics and birth control) can be sampled to identify an anthropogenic signature. Furthermore, several of these proposed areas of inquiry allow the direct participation of students from other departments (i.e., chemistry and microbiology). It is our hope that continued and expanded monitoring of the event will encourage the involvement of a more diverse group of undergraduate scientific disciplines to become involved in the sampling and laboratory analytical techniques and provide a bridge to unrelated projects.

The dataset has lent itself to additional endeavors. The Ohio State University Department of Chemistry has recently utilized the data in an introductory lab on data management. As part of their first lab for the quarter, students are required to enter the existing data in their laboratory notebooks. The students are then brought to the lake to take additional measurements of pH, temperature conductivity, and DO. Throughout the course of the lab, students are required to determine the clearest and most efficient manner in which to enter data into their lab notebooks. This exercise has provided the opportunity to teach an important lesson in

TABLE II: Future areas of inquiry and proposed testing methodology.[1]

Area of Inquiry	Proposed Testing Method
Discern whether NH_4^+ and TN peaks are from human waste or disturbed bottom sediments	Analyze samples for bacteria (*Escherichia coli*) and N isotopes
Determine whether the Mirror Lake jump triggered an anoxia event	Sample for DO in the hours and days immediately following the event, and hold similar event in the spring or summer to see whether this outcome is temperature limited
Identify additional evidence of a human geochemical signature	Sample for pharmaceuticals and determine whether human-sourced bacteria was introduced
Better determine spatial variability in observed changes	Increase sample points to better document variability
Determine the carbon budget of the lake for the event	Characterize C pools in the immediate vicinity of the lake and analyze for $^{13/12}C$ of DOC and POC before, during, and after the event

[1] DOC = dissolved organic carbon; POC = particulate organic carbon.

notebook-keeping while using a dataset of immediate relevance to the students.

DETERMINING THE EFFECTIVENESS OF OUR EXERCISE

The introductory-level Earth Sciences course and the associated laboratory sessions are specifically designed to provide entry-level understanding to an array of geoscience-related topics. Classes typically consist of a common lecture class containing approximately 200 students, with several associated breakout laboratory sections with a typical enrollment of 22 students. While a small fraction of the students may go on to pursue to a degree in Earth Sciences, the course primarily serves as the base for a two-course sequence of general education curriculum requirements students can take to meet a physical sciences requirement. The course enrollment demographics for calendar year 2012 was 35% seniors, 27% juniors, 30% sophomores, and 7% freshmen. According to the common dataset provided by the Ohio State University Office of Enrollment Services, student demographics for degree-seeking undergraduates during the 2011–2012 academic year were approximately 52% male and 48% female with an average student age of 20.7; 8% of the students were age 25 years or older. The Enrollment Services report also showed the following racial or ethnic identities for undergraduate students: 76% white, non-Hispanic; 6% black or African American; 6% nonresident aliens; 5% Asian, non-Hispanic; 3% Hispanic; 1% two or more races, non-Hispanic; 1% race and/or ethnicity unknown, 0.2% American Indian or Alaska Native, non-Hispanic; and 0.03% Native Hawaiian or other Pacific Islander, non-Hispanic.

Survey Results

An attitudinal survey conducted before and after the laboratory students completed the exercise presented an opportunity to determine whether this lab using student-generated, quantitative data of water quality in Mirror Lake played a role in students' opinions about water quality and the event. The prelaboratory survey was administered 1 week before the actual laboratory exercise and was coupled with a brief introduction in which students were notified that their participation was voluntary and anonymous and therefore was not going to be reflected in their grade. Ohio State Institutional Review Board approval for the survey was received beforehand, and appropriate consent procedures were followed.

The description of the research conveyed orally to the students in the laboratory sections was as follows:

You are being asked to participate in a study on how knowledge of water quality might affect one's attitude toward some regular, everyday activities. Your part will be to fill out a survey containing only a few questions. There will be one survey today, and there will be another, similar survey next week. It should only take you a few minutes to complete each of the surveys.

For the past 3 years, some of the students in the School of Earth Sciences have been conducting a study of the water quality in Mirror Lake, on the South Oval. Those students have sampled and analyzed the water in the lake before, during, and after the Mirror Lake jump in November 2008, 2009, and 2010. The Earth Sciences students are interested in learning whether your own analysis, in this lab section of 100, of data they have generated on Mirror Lake, affects your attitude about human activities and anthropogenic effects on water quality. So far, this study has involved about 40 students majoring in Earth Sciences, from first-quarter freshmen to ready-to-graduate PhD students. These Earth Sciences students have planned, coordinated, carried out, and written up this research. You will learn about the results of their study when you carry out the Mirror Lake lab in this class.

All survey questions, except the open-ended questions, utilized five-point Likert-type items: strongly disagree (1), disagree (2), undecided (3), agree (4), and strongly agree (5). The prelab items were as follows:

1. Water quality is a major issue facing the citizens of Ohio.
2. Routine human activities (lawn care, snow removal, etc.) have an impact on the quality of groundwater beneath the South Oval.
3. Students affect the water quality of Mirror Lake during the annual jump.
4. What parameters would you test for to provide or disprove your viewpoint from question 3?

Postlab items were as follows:

5. Water quality is a major issue facing the citizens of Ohio.

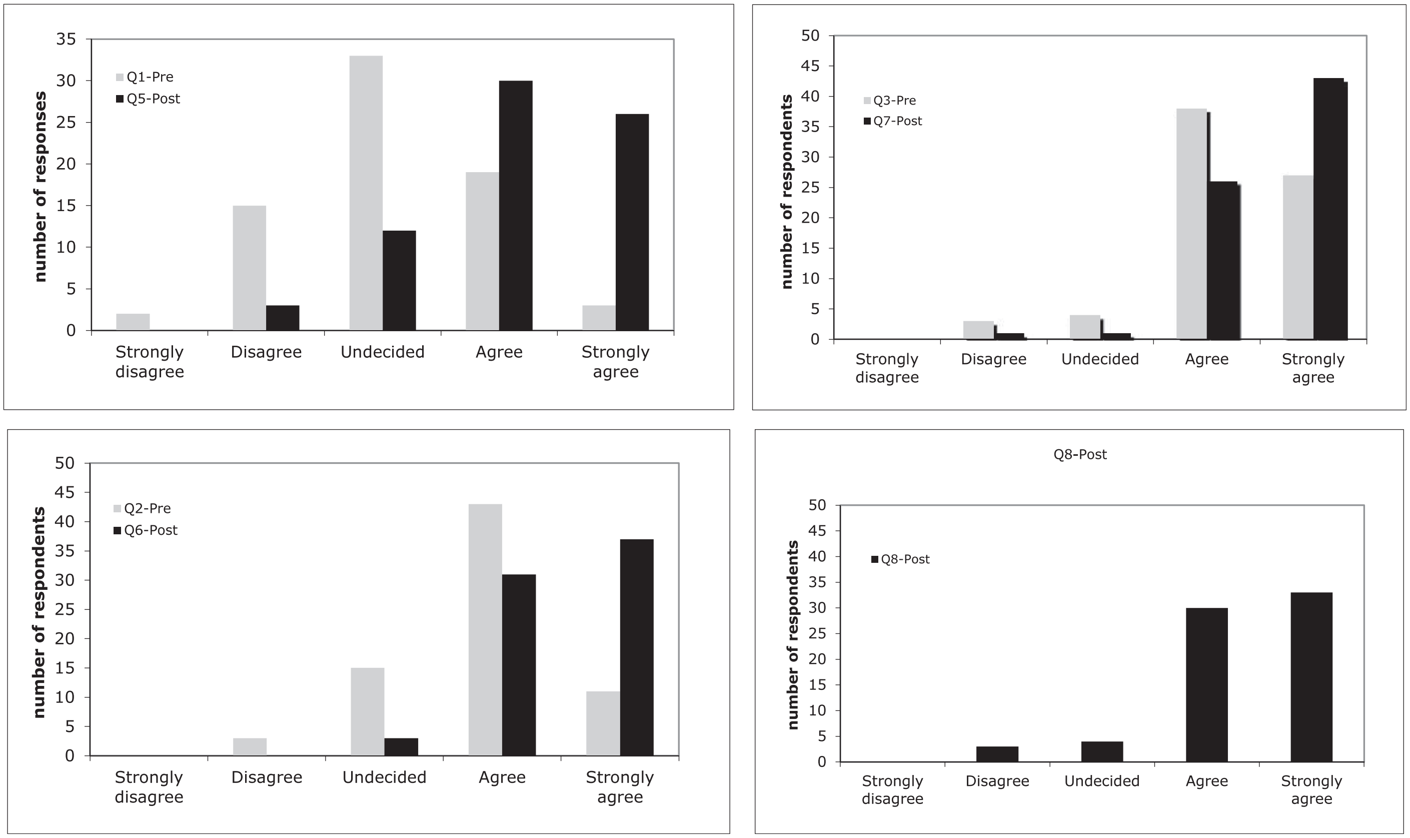

FIGURE 4: Differences in responses to paired questions.

6. Routine human activities (lawn care, snow removal, etc.) have an impact on the quality of groundwater beneath the South Oval.
7. Students affect the water quality of Mirror Lake during the annual jump.
8. This lab has changed your thoughts on how humans can affect water resources.

Individual student responses were not tracked between pre- and postlab surveys; thus, our results represent a compilation. For the five laboratory sections surveyed, 98 students completed the prelab survey (conducted 1 week before the lab was administered) and 78 students completed the postlab survey. The reduced number of responses to the postlab was due to too few surveys returned in one lab section. That section was eliminated in the analysis of both pre- and postlab survey data. As a result, there were 72 prelab surveys and 71 postlab surveys analyzed.

For the paired questions, the Student's *t*-test, assuming unequal variances, was utilized to determine whether there was a difference in the responses pre- and postlab. The null hypothesis was that there was no difference in attitude. The analysis revealed a significant difference in attitude about whether water quality is a major issue facing the citizens of Ohio, $t(72) = 7.21$, $p < 0.001$, with a higher proportion of student indicating a greater importance; a significant difference as to whether routine human activities can have an impact on the quality of groundwater beneath the South Oval, $t(57) = 5.70$, $p < 0.01$, with a higher proportion of students agreeing about impacts of human activities on groundwater quality; and a significant difference in attitude as to whether students affect the water quality of Mirror Lake during the annual jump, $t(29) = 2.90$, $p < 0.01$, with a higher proportion of students indicating that students can change the quality of Mirror Lake during this event.

Before the lab, nearly half of the students surveyed (46%) were undecided about whether water quality was a major issue facing citizens of Ohio and 31% of the students agreed or strongly agreed with statement 1 (Fig. 4). After the lab, 17% of the students were undecided and 79% of the students agreed or strongly agreed that water quality is a major issue facing the citizens of Ohio.

Before the lab, most students (75%) agreed or strongly agreed that routine human activities had an impact on groundwater quality beneath the South Oval, but after the lab, 96% agreed. Most students (90%) agreed or strongly agreed before the lab that the jump had an effect on water quality in Mirror Lake. However, before lab, 53% agreed and 38% strongly agreed. After the lab, 37% agreed and 61% strongly agreed. For the unpaired question about how the lab had affected students' thoughts on human activities affecting water quality, 90% of the students agreed or strongly agreed with statement 8: "This lab has changed your thoughts on how humans can affect water resources." One student who strongly agreed before the lab that the jump had an effect on water quality commented on the survey, "Friends of mine have gotten sick from jumping into Mirror Lake." The observations are consistent with pre- and postlab survey results from previous environmentally oriented, experience-based laboratory exercises focusing on hands-on aspect of immediate environmental relevance (Ballantyne and Packer, 2009; Hofstein et al., 2011).

The students' presurvey opinions about the jump's effect on Mirror Lake were not surprising. The jump is a well-known campus tradition, and over the 4 years during which we had been studying water quality of Mirror Lake water before and after the jump, there has been campus, local, national, and international press coverage about the water quality study. It would be surprising if the students did not have opinions presurvey. Responses to the statement about the jump's effect on Mirror Lake water quality showed that more students strongly agreed with the statement after (43%) than before (37.5%) the lab.

Student Comments

The prelab survey included one question in which the students could readily expand their answers. When asked what parameters they would test for to prove or disprove whether students affected the water quality of Mirror Lake, the majority of students ($n = 107$) answered that they would sample the water before, during, and after the event. Additional responses in decreasing order consisted of urine/sweat ($n = 90$), pH/acidity ($n = 77$), and fecal matter ($n = 24$). Again, comments regarding the sampling for urine/sweat and fecal matter were not surprising given the previous publicity associated with our sampling efforts. The pH response proved interesting, because it appeared several students may have associated a drop in pH with increasing urine content. Responses such as this offered opportunities for clarification during subsequent classroom and laboratory discussion. A much lower number of responses addressing the sampling for deodorants, perfumes, other personal hygiene products, pharmaceuticals, and birth control ($n = 9$) suggested only a small portion of students were previously aware of additional chemicals. In addition, a low number of responses addressing the sampling of shoes of those entering the lake ($n = 9$) or pre-event sampling of the turf ($n = 5$) may suggest an elementary understanding of runoff as a flow pathway. The general nature of these comments invoke a prelaboratory exercise, elementary-level understanding of water quality issues, and are consistent with what was observed during the administration of the labs.

ENGAGING THE GREATER COMMUNITY

This study has provided a significant opportunity to engage the campus community (and even the greater collegiate football community, because the event was aired during the game) about an environmental concern—water quality.

Scientific Community

Further student involvement allowed initial results of the study to be presented for feedback to members of the university and greater scientific community. Students first presented the scientific results at the Ohio State University-wide Denman Undergraduate Research Forum in 2010, where results were well received and facilitated initial collaboration with the Department of Chemistry. This exposure also resulted in the study's inclusion in a university-produced YouTube-based public service announcement encouraging students to get involved in research at the university (http://www.youtube.com/watch?v=XkxYMm1v7F4). Furthermore, a student presentation at the 2010 Goldschmidt Conference allowed undergraduate exposure to the greater scientific community (Von Bargen et al., 2010). These conversations proved constructive in both modification of the sampling design for future events and construction of the laboratory exercise.

Outside Community

The project presented a learning opportunity to educate the greater university community. Many residents in the surrounding Columbus area are graduates of Ohio State and either have participated or know of someone who has participated in the Mirror Lake jump. Prior to the 2009 event, the local newspaper (*The Columbus Dispatch*) was informed of the initial 2008 results in an effort to publicize the upcoming sampling campaign. This led to an article, printed on the day of the event, highlighting the student sampling campaign (Caruso, 2009) that was picked up by the Associated Press and published in dozens of newspapers nationwide. The article was also mentioned during ABC's national telecast of the Ohio State versus Michigan game later that week.

Media exposure had two unforeseen benefits. First, the publicity sparked the interest of students who were not in previous contact with the School of Earth Sciences. This led to additional student volunteers during subsequent years during the night of the sampling and helped generate a list of others who were interested in taking part in future sampling campaigns. Second, the results allowed us to engage the community in a basic water quality issue where both the proposed research question and the outcome should be readily understandable. Both faculty and students mentioned that their neighbors and fellow students were inquiring about the study and the initial results. Conversations were also initiated via e-mail inquiries from both the public and members of the media who were interested in the results from the 2009 sampling campaign, along with potential follow-up studies.

As part of our continuing effort to engage the community, we are working to make the Mirror Lake dataset publically available online. The initial link for the dataset will appear on a Web page hosting information on other water quality initiatives undertaken by the School of Earth Sciences. It is our hope that this study of interest will help bridge the gap of public awareness on water quality efforts beyond their immediate surrounding environment.

Project Tailoring

We readily acknowledge that not every university has such a tradition as the jump event chronicled here. In that spirit, we have included a data table from the 2-year experiment (Table I) so that the proposed calculations, as well as those thought up by others, can be carried out. Furthermore, one proposed method for testing whether the Mirror Lake jump triggers an anoxia event is to organize a student "jump in" during the summer to document the effect of seasonality on the results. If this is to be done, we find no reason this experiment cannot be carried out at additional sites.

CONCLUSIONS

Student-initiated sampling of Mirror Lake during the annual jump-in event at Ohio State has resulted in a sustained undergraduate research initiative. The experience has enabled students' to become involved in a hands-on experience in all facets of research, including experimental design, water sampling, analytical techniques, data management and interpretation, and research presentation. Classroom use of the resulting dataset has captured student interest in water quality issues and provided a link to understanding issues of a larger scale. This discussion has led to additional areas of inquiry that have already fostered interdepartmental collaborations. Public availability of the dataset is intended to lead to future research questions and promote independent research initiatives.

Acknowledgments

We thank the following Ohio State students for their assistance with sample collection: Kelly Deuerling, Rachael Gray, Catherine Maxwell, Jeffrey Pigott, Daniel Reaman, Jameson Scott, and Jamey Stutz. We are also grateful to the Ohio State University Facilities Operations and Development and the City of Columbus Police Department for providing access to Mirror Lake before, during, and after the event.

REFERENCES

Apedoe, X.S., Walker, S.E., and Reeves, T.C. 2006. Integrating inquiry-based learning into undergraduate geology. *Journal of Geoscience Education,* 54(3):414–421.

Ballantyne, R., and Packer, J. 2009. Introducing a fifth pedagogy: experience-based strategies for facilitating learning in natural environments. *Environmental Education Research,* 15(2):243–262.

Caruso, D. 2009 (November 18). Wee bit of pee in Mirror Lake after OSU jumps. *The Columbus Dispatch,* p. A1.

Fryar, A.E., Thompson, K.E., Hendricks, S.P., and White, D.S. 2010. Incorporating a watershed-based summary field exercise into an introductory hydrogeology course. *Journal of Geoscience Education,* 58(4):214–220.

Graney, J., Salvage, K., and Zhu, W. 2008. A watershed-based approach to environmental education integrating ecology, hydrology, and geochemistry. *Journal of Contemporary Water Research & Education,* 138(1):22–28.

Herrick, J.H. 1984. The OSU Mirror Lake hollow. Columbus, OH: Office of Campus Planning and Space Utilization, Ohio State University, 82p.

Hofstein, A., Eilks, I., and Bybee, R. 2011. Societal issues and their importance for contemporary science education: A pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education,* 9:1459–1483.

Hunt, S. 2010 (July 19). St. Marys' algae hits worst point of the summer. *The Columbus Dispatch*.

Kirk, K.B., Halstead, J.A., and Thomas, J.J. 1997. Field studies in environmental science: An interdisciplinary college course on a local watershed. *In* Warwick, J.J., ed., Proceedings of the AWRA Annual Symposium, Water Resources Education, Training, and Practice: Opportunities for the Next Century. Herndon, VA: American Water Resources Association, TPS-97-1, p. 501–508.

McConnell, D.A., Steer, D.N., and Owens, K.D. 2003. Assessment and active learning strategies for introductory geology courses. *Journal of Geoscience Education,* 51(2):205–216.

McConnell, D.A., Steer, D.N., Owens, K.D., Knott, J.R., VanHorn, S., Dick, J., Foos, A., Malone, M., McGrew, H., Greer, L., and Heaney, P.J. 2006. Using conceptests to assess and improve student conceptual understanding in introductory geoscience courses. *Journal of Geoscience Education,* 54(1):61–68.

McDonald, R.H., Srogi, L., and Stracher, G.B. 2000. Building the quantitative skills of students in geoscience courses. *Journal of Geoscience Courses,* 28:409–412.

Saad, L. 2011. Water issues worry Americans most, global warming least. Available at http://www.gallup.com/poll/116590 (accessed 30 August 2010).

Semken, S., and Freeman, C.B. 2008. Sense of place in the practice and assessment of place-based science teaching. *Science Education,* 92(6):1042–1057.

Udert, K.M., Larsen, T.A., and Gujer, W. 2006. Fate of major compounds in source-separated urine. *Water Science and Technology,* 54:413–420.

Von Bargen, J.M., Trierweiler, A.M., Goldsmith, S.T., Deuerling, K.M., Mondro, C.A., Stutz, J.E., Welch, S.A., and Carey, A.E. 2010. Impact of anthropogenic bioturbation on nutrient chemistry of a small urban pond. *Geochimica et Cosmochimicat Acta,* 74(12, Suppl.):A1086.

Welch, K.A., Lyons, W.B., Graham, E., Neumann, J., Thomas, J.M., and Mikesell, D. 1996. Determination of major element chemistry in terrestrial waters from Antarctica by ion chromatography. *Journal of Chromatography A,* 739:256–263.

Woltemade, C.J., and Blewett, W.L. 2002. Design, implementation, and assessment of an undergraduate interdisciplinary watershed research laboratory. *Journal of Geoscience Education,* 50:372–379.