THE WATER PROJECT

WATER ANALYSIS: TARGETING ENGAGEMENT THROUGH RESEARCH

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OVERVIEW

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The faculty members of the Science and Math Division at Defiance College have developed The WATER Project to guide undergraduate research and to engage undergraduates in environmental issues. Undergraduates now have a tremendous opportunity to (1) learn first-hand how land use and agricultural practices affect water quality in streams, ponds, and wetlands; (2) develop research and problem solving skills that will be essential in their professional careers; and (3) learn the latest environmental monitoring techniques.

The project has both local and international components. The local component focuses on monitoring and restoration efforts in relation to the Maumee River watershed while the international component focuses on monitoring the New River Lagoon watershed in Belize, Central America. Nearly 80% of the 4.2 million acres that the Maumee River watershed drains into Lake Erie is row-crop agricultural land. Runoff from these fields has had detrimental effects on the watershed's biotic (e.g., plant and animal species) and abioitic (e.g., water chemistry) attributes. For example, the Maumee River discharges more suspended sediment into Lake Erie than any other tributary (Moog and Whiting, 2002).

Belize is home to some of the most unspoiled ecosystems in the western hemisphere. Fortunately, the Belize government is aware of the potential

of these wonderful natural resources and is actively taking steps to protect and preserve them. These efforts will benefit the environment and people alike.

Over the past two decades, ecotourists flocking to enjoy Belize's natural treasures have more than tripled. Numbers are still low relative to more popular Central American and Caribbean destinations. Additionally, the infrastructure to support these visitors is lagging. Most Belizeans have yet to experience any substantial economic benefits. Many continue to live in poverty and practice subsistence farming.

Without proper environmental monitoring and regulations, a growing population often has detrimental effects on the environment. For example, an increase in commercial agricultural output, subsistence farming through slash-and-burn deforestation and illegal use of banned pesticides (e.g., DDT) have all contributed to a degradation of the environment in Belize. As a result, proper environmental monitoring has become essential to help the country achieve a better balance between economic prosperity and the natural resources that drive that fortune. Subsequently, one of the main objectives of this project is to aid the current evaluation and begin long-term monitoring of a preserve impacted by diverse and potentially negative influences.

We have begun the first phase of the project, which is to use the Maumee River watershed as the primary study site for determining what variables may have the greatest impact on fragile species. Evaluating the overall environmental conditions involves using indicator species, such as aquatic invertebrates and amphibians, to correlate with environmental variables, such as water quality and bacterial counts.

The next phase of the project consists of two parts: (a) developing a model for monitoring the impact of economic development on the local ecosystem and, (b) adapting this model to the economic and environmental conditions in Belize. If economic use of the natural resources is to be sustainable, it is essential to have the ability to closely monitor the impact such utilization has on the ecosystem. Not only will this provide early warnings of overuse but will also provide guidance for restoration of injured environments.

The final phase of the research will be to use the lessons learned to promote self-supporting and sustainable economic use of the local ecosystems in Belize by the local people. Cottage industries have the potential to bring economic benefits to the local population while at the

same time providing strong economic incentives to protect the local environment. The research will both provide the basis needed to monitor the impact of the land use and provide guidance to targeted restoration efforts.

Students participating in this project undoubtedly will increase their own awareness and appreciation of environmental issues and the complex nature of the solutions. Interested students of any discipline will be allowed to formulate their own projects which may examine any aspect of this multifaceted problem. The collective results and conclusions will be shared with appropriate individuals to assist future efforts and awareness. We believe it's the summation of these smaller contributions that ultimately lead toward the improvement of environmental, social, and economic conditions.

RESEARCH PLAN

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The watershed research plan was specifically designed to guide undergraduate research and to engage undergraduates in environmental issues. This provides students experience not only with the scholarship of designing and conducting research but also engagement with the community. Students are expected to communicate the results of their research with the greater community in an effort to affect meaningful change.

Below are seven specific objectives for The WATER Project and proposed tasks to address each objective. Some of these objectives are being addressed with the current ongoing projects while others have yet to be examined. All students working on the project are expected to: "Develop pertinent skills in field sampling, data collection and analysis" (*specific objective 1*), "Collect baseline data on the biotic and abiotic environment" (*specific objective 2*), and "Raise awareness through outreach education in the community" (*specific objective 6*). In addition, depending on the student's individual research goals, other specific objectives may be addressed.

Specific objective 1

Develop pertinent skills in field sampling, data collection, and analysis: Students are expected to learn specific skills necessary to conduct research associated with The WATER Project. The total skill set will vary depending on a student's particular research goals. However, the following methods and procedures are common to all. These skills include conducting water quality sampling, maintenance of a data base, statistical analysis of data, and interpretation and presentation of results. Others skills common to many but not all of the research projects conducted under The WATER Project include plant and invertebrate sampling, use of GPS (Global Positioning System) and the use of various laboratory equipment.

Specific objective 2

Baseline data collection on the biotic and abiotic environment: Baseline weather and water quality data will be collected at specific sites and on a regular schedule. This data provides the basis for comparisons between sites. The collection consists of weather station monitoring at the Thoreau Wildlife Sanctuary in rural Defiance, frequent surveys of water quality indicators at various sites, and monthly surveys of water quality at three sites on major rivers in Defiance county. Additionally surveys of plant and invertebrate populations will be conducted at the Thoreau Wildlife Sanctuary in the spring and fall.

Specific objective 3

Identify biotic (e.g., plant or invertebrate populations) and abiotic (e.g., water chemistry levels) environmental parameters in the baseline data that lay outside expected norms or transient deviations attributable to natural phenomena: The baseline data collected will be compared to EPA standards and other literature to determine if they fall outside expected norms. Additionally, site-to-site comparisons will be used to help identify parameters outside the expected norms for the local sampling sites. Since the measured environmental parameters are expected to fluctuate following seasonal trends or periodic deviations due to naturally occurring fluctuations, analysis is necessary to determine whether or not the observed variations are attributable to these natural phenomena.

Specific objective 4

Examine the effect of specific human activities or remediation efforts on measured environmental parameters: Once the natural variation in the environmental parameters has been identified, the next step is to examine anthropogenic (human caused) influences. Activities such as construction, residential or

industrial runoff, point source pollution, and agriculture practices can have detrimental impacts on the environment. Comparisons will be made between sites that are seemingly not influenced by human related activities and those that may be. Significant differences between these sites will direct attention to specific casual agents that may be responsible for the observed variations. In addition, comparisons between sites can also be used to evaluate the efficacy of regional restoration efforts by private or public agencies. Lastly, restoration projects, test plots, and laboratory investigations may be used to examine further how specific human activities may impact the environment.

Specific objective 5

Establish a causal link between measured water quality levels and the observed impact on the local environment: In order to facilitate the rapid and cost effective monitoring of sensitive sites in the environment, it is necessary to demonstrate that water quality indicators presage specific changes in the environment. This linkage can be examined through the use of test plots and laboratory research. Test plots consist of small controlled field experiments where restoration or disturbances are implemented. The field experiment can then be closely monitored to measure the resulting effect on water quality levels and plant and invertebrate populations. In the laboratory, the effect of varying water quality levels on plant and animal species can be directly measured. The choice of treatment levels is dictated by water quality values directly observed in the field. Particular attention must be paid to water quality levels that are observed to differ greatly between control and experimental sites.

Specific objective 6

Raising awareness through outreach education in the community: Experimental results will be presented to the Defiance College community through presentations at forums such as the McMaster Symposium, the Carolyn M. Small Honors Symposium, and science seminars. Open campus workshops on The WATER Project will be developed and presented by participating faculty and students. Dissemination of research results to the wider community will be through the visitation of local schools and contact with local community groups, local news outlets, and agencies such as the AWARE program sponsored by the Ohio Farm Bureau Federation. Additionally, efforts will be made to engage the community in cleanup drives, restoration projects and other programs.

Specific objective 7

Develop a model for monitoring the environmental impact of economic exploitation of the New River Lagoon watershed in Belize: This phase of the project consists

of two parts: (a) developing a model for monitoring the impact of economic development on the local ecosystem and, (b) adapting this model to the economic and environmental conditions in Belize. If economic use of natural resources is to be sustainable, it is necessary to have the ability to closely monitor the impact such utilization has on the ecosystem. Not only does this provide early warnings of over use, it also provides guidance for restoration of injured environments. Data collected on the Maumee River watershed will be used to develop a monitoring program on the local ecosystem. This monitoring program can then be tested for its effectiveness in predicting the environmental impact of restoration and land use projects. As the model for monitoring and predicting the impact of human activity is refined it will be adapted for export to the New River Lagoon watershed in Belize.

Specific objective 8

Promote self-supporting and sustainable economic use of the New River Lagoon watershed in Belize: The development of a model for monitoring the environmental impact of economic exploitation of the New River Lagoon watershed in Belize will facilitate economic development of natural resources in a sustainable way. Close monitoring of important indicators of environmental health can make it possible to recognize deleterious exploitation of the environment before the effects are irreversible. Further, restoration projects can be initiated and targeted to have the greatest impact. The final phase of the research will be to use the lessons learned from research to promote self-supporting and sustainable economic use of the ecosystems in Belize by the local people. These cottage industries will bring economic benefits to the local population while at the same time providing strong economic incentives to protect the local environment. The scientific research will provide the basis needed to both monitor the impact of the land use and provide guidance to targeted restoration efforts.

BACKGROUND ON BELIZE

Spiro Mavroidis

Demography

Belize was known as British Honduras until its independence in 1981. Its current population size of approximately 275,000 people is as diverse as its environment. The major ethnic group is the Mestizo (48.7%). They are of mixed Mexican and Mayan descent. Other groups include Creole (24.9%),

Maya (10.6%), and Garifuna (6.1%) (Peedle, 2004). Creoles are descendants of European settlers and African slaves. The Garifuna trace their origins to the Caribs who with the Arawak emerged out of South America near 160 AD. Other minority groups include Mennonite, Chinese, East Indian, and Arab (Peedle, 2004). Belize has a parliamentary democracy with the Queen of England as the head of state. English is the official language but most people speak both English and Spanish or Creole.

Agriculture

The Mayan civilization in Central America dates back more than 3,000 years. Belize holds some of the largest Mayan ruins. At its prime, the Mayan population numbered more than a million in Belize alone. A recently discovered city in the Caracol Maya site is one of the largest in the region (Peedle, 2004). After the greater Mayan civilization collapsed, the primary form of agriculture was slash-and-burn (or *milpa*, meaning "corn field" in Aztec). This mode of farming is still practiced by many subsistence farmers. Mayans in the southern part of the country (Toledo District) have been the most impoverished due primarily to the low productivity of *milpa* and their geographical isolation. Although they comprise more than 65% of the southern population, most do not have ownership rights to land. Those that do have only long-term rental agreements (Levasseur and Olivier, 2000). This part of the country is on the southern end of the Mayan mountains connected to the rest of Belize by only a few dirt roads and no paved roads. The newly-built southern highway is the main contributor to the recent rebound of the Toledo District. In addition, the Toledo Small Farmers Development Project was formed for "improving the standard of living of the mostly subsistence farmers and bringing them into modern agriculture" (Ausdal, 2001. p. 582). Some success stories include the productive cacao market of the 1980's, mostly driven by Hershey Foods Corporation, and the more recent rebound of the cacao industry in the late 1990's influenced by a British organic company willing to pay 70 cents per pound above world market price (Emch, 2003). This fortune came to an abrupt halt when Hurricane Iris (October 8, 2001) destroyed as much as 85% of the cacao trees (Emch, 2003).

Currently, citrus and sugar cane farming predominates in the north while citrus and banana growing are common in the central and southern part of the country (Programme for Belize, personal communication). Mennonite communities in northwestern Belize rotate corn and soybean crops throughout the year.

Natural Resources and Biodiversity

More than 85% of Belize is covered by forests (Levasseur and Olivier, 2000). Approximately 70% of these are considered pristine and most are protected and designated as natural reserves, sanctuaries, or national parks (Alexander, 2000). Most of these are tropical rainforests located in central and southern Belize. The northern part consists of rainforests, pine savanna, and wetlands. Deforestation rates in Belize are relatively low (0.25% per year; Levasseur and Olivier, 2000). However, because of the high rate of population growth in the Toledo District (2.7% per year), there is growing concern of forest degradation resulting from the increased use of slash-and-burn practices.

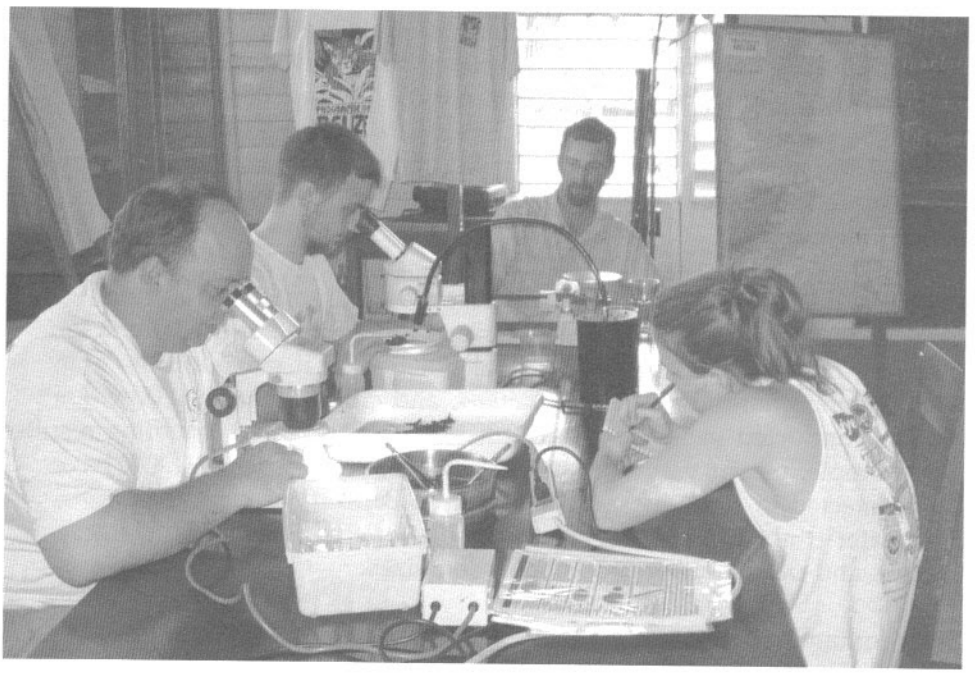
Belize's biodiversity includes 533 species of birds (33 threatened), 155 species of mammals (15 threatened), 107 species of reptiles (7 threatened), approximately 700 species of trees, and more than 240 varieties of orchids (Peedle, 2004; Pither and Kellman, 2002). Belize also hosts one of the largest coral reef systems in the world, second only to the great barrier reef of Australia. These unspoiled natural resources are the driving force for the increased ecotourism that has gone from 60,000 annually in the 1980's to over 325,000 in 2000 (Boxill, 2003). Although lack of a proper infrastructure (e.g., roads, hotels, etc.) has stymied faster growth of the number of stay-over visitors, tourism still is the major contributor to the country's gross domestic product (GDP). Day visitors arrive via cruise ships. In the fall of 2004, the country reached its highest yet arrival rate of three ships per day (Programme for Belize, personal communication). Many of these tourists are ushered to various nature preserves and animal sanctuaries. Some of these areas were created for the protection of specific species. This includes the *Cockscomb Basin Wildlife Preserve* established for the elusive jaguar. In 1985 the *Community Baboon Sanctuary* was established as a private protected area to assure the survival of a population of black howler monkeys (*Alouatta nigra*, or baboon in Creole). The government approved the project with the consent of the local village council, 16 landowners, and funding from World Wildlife Fund (WWF). A 33-km stretch of the Belize River ravine was protected from hunting and farming. Now, more than 100 members of the community farm this area in harmony with the needs of the howler monkeys (Alexander, 2000).

The effectiveness of ecotourism is still in question. Although tensions exist and villagers did not benefit as they originally anticipated, a recent survey suggested most villagers do not want the sanctuary to be abolished. Rather, they continue to support the original goals of the sanctuary in hopes of benefiting through tourism to the area (Alexander, 2000).

A 1996 study in Belize examined the three main objectives of ecotourism: generation of financial support to protected areas, local economic benefits, and generation of local support for conservation (Lindberg *et al.*, 1996). The latter two objectives were often met while the first was not. The authors of the 1996 study added that income generation for the protected area could be increased by raising user fees with minimal effect on visitor numbers (Lindberg *et al.*, 1996). Nonetheless, without proper precautions and constant evaluation by the preserve managers, ecotourists may be having a negative impact on the very animals they hope to support (Grossberg *et al.*, 2003).

Study Site

The Rio Bravo Conservation and Management Area (RBCMA) is located in northwest Belize in the Orange Walk district. Its 260,000 acres are composed of tropical rainforest, wetlands, and savanna and are managed by a nonprofit organization, Programme for Belize (PFB). RBCMA was set up by the donation of 90,000 acres by the Coca-Cola Company and was initially funded by the Massachusetts Audubon Society, Coca-Cola, The Nature Conservancy, USAID, The MacArthur Foundation, and Perkin-Elmer (Sutherland, 1998). Later, more land was added as part of a forest carbon management project in an attempt by U.S. utility companies to



offset CO_2 emissions produced in the U.S. which contribute to global greenhouse gases (Kinsman *et al.*, 2000). Presently, Programme for Belize is self-reliant from funds raised through ecotourism, research visitors, and selective mahogany tree harvesting. Economic evaluation and management of renewable resources in RBCMA have been studied to maximize financial gain with minimal environmental impact (Eade and Moran, 1996). In addition Programme for Belize oversees two facilities. One, Hillbank Field Station, provides facilities for tropical ecology courses and research while the other, La Milpa Field Station, is geared for ecotourists.

After a successful fact-finding trip to Belize in the fall of 2004, the Hillbank Station was chosen as our primary study site to base the international component of our WATER Project. This decision was made after evaluating several key project objectives and concerns. These include relative accessibility, safety, resources and accommodations, common interests and goals, and the likelihood of making a significant positive impact on the surrounding communities and the environment.

Environmental Impact

RBCMA is surrounded by Mennonite farms, citrus orchards, villages and a sugar cane processing factory. Tributaries running through these communities drain into the New River Lagoon which ultimately empties into the Caribbean Sea. A sugar cane processing factory is situated along the bank of the lagoon. Unregulated commercial fishing has decimated many of the lagoon's fish populations during the past decade (local residents, personal communication). There is significant poaching of various animals (e.g., deer, howler monkeys, iguanas, etc.) on the preserve even though local park rangers patrol the area (PFB, personal communication).

Poaching and the depletion of fisheries are readily evident negative impacts on the preserve. Less obvious are soil and water contamination resulting from the varying agricultural practices that surround the area (e.g., Mennonite modern farming, *milpa*, and citrus orchards). Previous studies conducted in Belize in the RBCMA have revealed troubling results. For example, mercury and organochloride pesticides such as DDT have been detected in crocodile eggs in northern Belize (Wu *et al.*, 2000; Rainwater *et al.*, 2002). These contaminants may reduce egg hatching success and ultimately reduce population sizes.

Such contaminants not only threaten the immediate ecosystem but also may be deposited further into marine environments. A recent study found an accumulation of DDT in marine polychaetes (Mulsow and Landrum,

2000). Polychaetes are marine annelids that are deposit or filter feeders. Feeding behavior was significantly reduced after a relatively short exposure period to DDT (Mulsow and Landrum, 2000). While most organochlorides such as DDT have been banned from many Central American countries, their use may still continue illegally in agriculture (Alegria *et al.*, 2000). Some of these organochlorides may be spread atmospherically either regionally or globally. Such evidence was found in a study that examined air samples in several Central American countries, including Belize (Alegria *et al.*, 2000).

BELIZE TRIPS

Fall 2004

During the fall of 2004, two McMaster Fellows, Professor Spiro Mavroidis and Dr. Eric Schurter traveled to Belize with a main goal of establishing contacts for future collaborations. More specific goals were to visit potential study sites and to learn to travel within Belize. During the seven-day trip, they visited two organizations that are heavily involved in environmental education and research. The first location was Hillbank Station which is managed by Programme for Belize (see above). The second location was Monkey Bay Wildlife Sanctuary. Monkey Bay Wildlife Sanctuary is located between Belize City and Belmopan, capital of Belize. The sanctuary is a 1,070 acre private preserve located along the Sibun River. It consists of tropical forest, riverine and savannah habitats. The Sibun River runs from the Mayan Mountains (in the Pine Ridge area) through the pine savannah and empties into the Caribbean sea near Belize City. Monkey Bay Wildlife Sanctuary is a *for profit* organization that specializes in hosting ecotourists and providing experiential learning programs to a variety of groups.

Spring 2005

Following the fall trip, the decision was made to form a long-term collaboration with Programme for Belize. Professors Mavroidis and Schurter were joined by newly named McMaster Scholars Sarah Johnson, Brian Putman, and Stacy Sattler (see below). Together they conducted monitoring research on tributaries that emptied into the New River Lagoon. Water samples were taken from five locations. All samples were returned to the college for future analysis of heavy metal and pesticide content. Two locations (Irish Creek and Ramgoat Creek) were surveyed more thoroughly. At each site water chemical analysis was conducted at four different locations over a one kilometer stretch. Aquatic

macroinvertebrates were surveyed as an additional tool for evaluating water quality. Irish Creek, which drains some of the Mennonite agricultural land, was found to have "fair" water quality. Ramgoat Creek which drains some of the citrus orchards but has a large buffer zone had a water quality index value of "very good." Interestingly, the banks of Ramgoat Creek are lined with freshwater mangroves for the first few kilometers.

During the second part of the trip we met with Dr. Edward Boles from the University of Belize. Sarah Johnson arranged the meeting both to discuss his involvement in managing the monitoring efforts of the Sibun River Watershed and to solidify future collaborations on amphibian population monitoring. Dr. Boles oversees numerous student projects that involve environmental research and conservation. The McMaster School for Advancing Humanity financed the purchase of a recording device specifically designed for surveying breeding anurans (frogs and toads). This device was delivered to Dr. Boles and he will supervise amphibian surveys conducted by undergraduates from the University of Belize.

PROJECT ABSTRACTS FROM STUDENT SCHOLARS

Three students (Sarah Johnson, Brian Putman, and Stacy Sattler) were awarded funding from the McMaster School for Advancing Humanity to conduct research on the local Maumee River watershed and help with the initial monitoring phase of the New River Lagoon watershed in Belize. In addition to conducting their own research, these McMaster Scholars helped with the weekly water quality data collection from various sites on the Maumee River watershed during the summer and fall of 2004. Below are the abstracts from each student's research paper as presented in his or her Senior Capstone.

Sarah Johnson

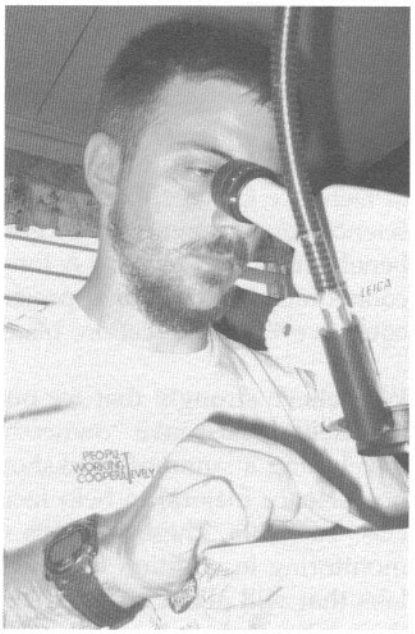
In recent years, amphibian population declines have become very prevalent in many areas of the world. This study attempted to determine some factors that would influence amphibian populations in different habitat areas. Five wetland/pond areas in Northwest Ohio were chosen. Water quality parameters of temperature, pH, conductivity, and dissolved oxygen were tested at each site over a two-month period. During this time, an amphibian call survey was conducted at each site to determine the different species present. A mark-recapture study was used to determine total population numbers. Other surveys, including tree frog call surveys

and "head counts" of green frogs and bullfrogs, were also employed to determine each site's attractiveness to amphibians.

The results showed that the water quality did not differ significantly among the five sites. Each site contained the same basic species, with a few exceptions. However, the small difference in species present between sites and differences in population sizes yielded by the mark-recapture study indicated that some of the sites were more suitable for amphibians than others. Which factors may contribute to these differences are not certain. However speculation regarding depth, human activity, fish and wildlife populations, cover along the shoreline, surrounding landscape and other physical characteristics can be made.

Brian Putman

Aquatic macroinvertebrates are an essential part of the food web in freshwater ecosystems. They are commonly found in leaf packs within a stream and have been known to show leaf type preferences. This research was intended to uncover macroinvertebrate preferences, if any, of three leaf types: eastern red oak, *Quercus rubra*; eastern cottonwood, *Populus deltoides*; and black willow, *Salix nigra*. The overall scope of the project is intended for restoration purposes, where preferred tree species could be replanted on riparian strips. Supplying macroinvertebrates with preferred food types may increase their populations within a stream and thus add to the overall food source for large aquatic predators such as fish and amphibians.



While some leaf type preferences were observed in this research, the majority of the findings were statistically insignificant. However, the results give some insight into seasonal aquatic macroinvertebrate population changes, where macroinvertebrate populations are four to five times higher in the fall season than spring and summer. Another trend that was uncovered is that leaf pack weight loss differs greatly by tree species. (Black willow and cottonwood leaf packs lost more than twice as much mass as red oak leaf packs.)

Stacy Sattler
When phosphorus is introduced into an aquatic system many natural processes are disrupted. In this study the effectiveness of vegetative filter strips in removing phosphorous from agricultural runoff water was researched. Water samples were tested on a weekly basis and soil samples were tested from the filter strips and fields. The results from the water samples showed that the phosphorous levels in the streams were within the "good" quality standard. The data was consistent for the 17-week sampling period. The results from the soil tests indicated that the amount of phosphorous removed from the runoff increased in direct proportion with the width of the filter strip. Overall, the data from this study suggest that vegetative filter strips are one effective way of removing phosphorous from agricultural runoff.

CONCLUSIONS AND FUTURE DIRECTIONS

The WATER Project is entering its third year. During this time, it has evolved from an idea to aid science students in conducting research under a project umbrella with common goals to an interdisciplinary initiative that will examine multiple aspects of environmental issues. Although the project is still relatively young, we have gathered data locally and internationally. Most important, students have had the opportunity to experience and contribute to environmental monitoring.

One of our immediate goals is to have components of The WATER Project incorporated into most science courses (both major and non-major) offered at Defiance College. Because all college students are required to take two science courses, every undergraduate will eventually participate and thus benefit from this project. A long-term goal involving interdisciplinary collaboration is to embed project components into other non-science courses such as education, history, and business.

We believe strongly that for our objectives to be realized, students themselves must take "ownership" of the project. To that end, we are developing a summer workshop/orientation to train students (science and non science majors) to help faculty incorporate the watershed project into class curricula. These students will be responsible for continuous field monitoring in addition to working with faculty and staff to set up lessons/labs that will allow broader student involvement. In addition, because of their intimate involvement and understanding of the project, these individuals also will be the spokespersons for the project and engage in

outreach events through the local schools and organizations. The 2005-2006 McMaster Fellows and Scholars will conduct research in Belize that will analyze soil nutrient levels in fields used for milpa farming, survey for human parasites in rural areas, examine heavy metal and pesticide levels in soil and water, and conduct an opinion survey to assess the attitudes of residents located on the periphery of the Rio Bravo Conservation and Management Area.

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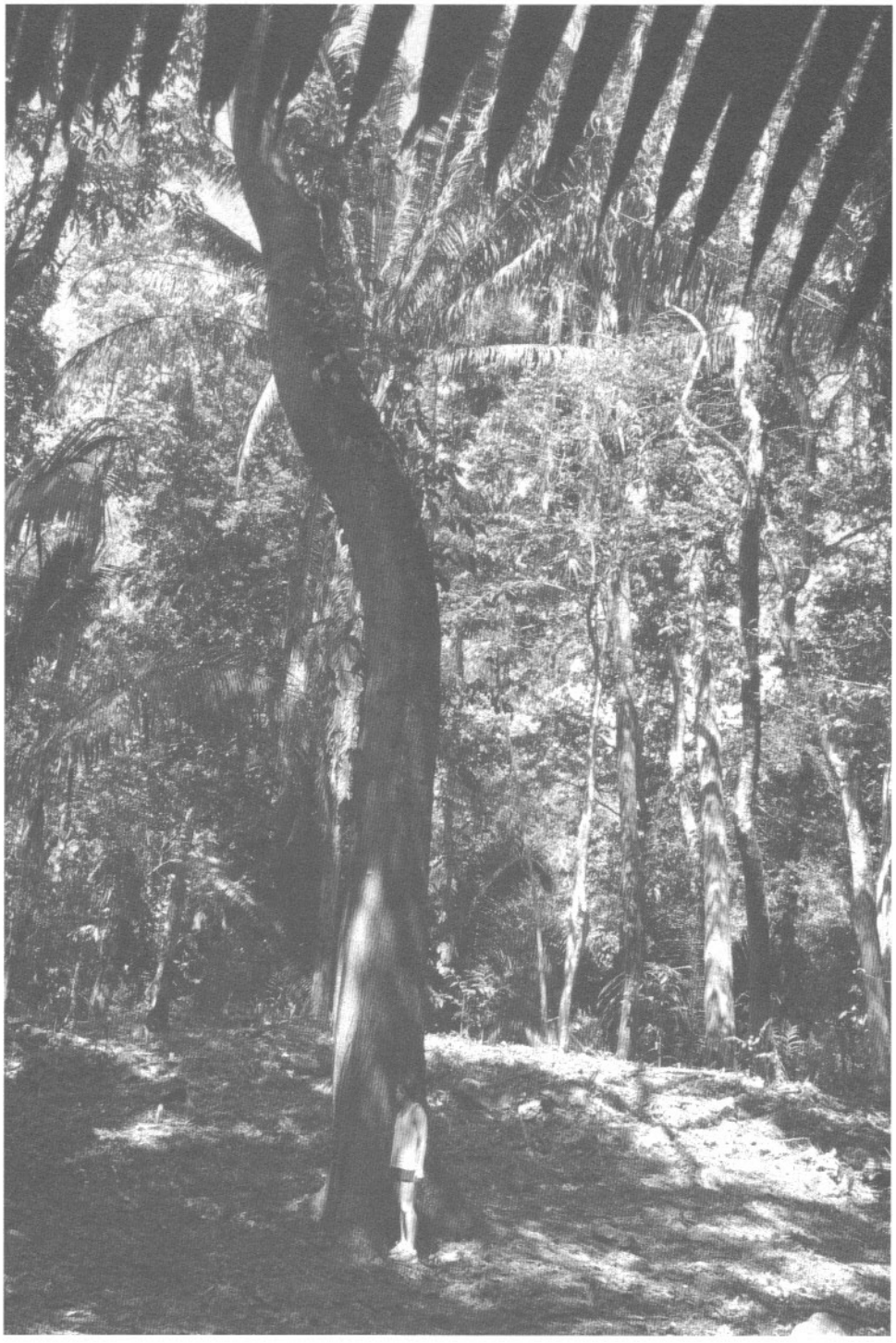

McMaster School For Advancing Humanity

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