MEET THE STUDENT-AUTHORS, CONTINUED...

**Lorena Moreno**

I am a junior from Santa Cruz, Bolivia. I am majoring in environmental, soil, and water sciences. The Crop, Soil, and Environmental Sciences Club has been a positive experience in my college career. Through the club I have gained experience in team projects, research, and have made good friends.

**Graham Duffy**

I was born and raised in Eureka Springs, Ark. I majored in environmental, soil, and water sciences and graduated in summer 2004. I am also an active member of the Crop, Soil, and Environmental Sciences Club.

**Jonathan Peck**

I was born in Little Rock, Ark. I grew up in Morrilton, Ark., where I graduated from high school in 1998. I am an environmental, soil, and water sciences major and my expected graduation is May 2005. I enjoy outdoor activities such as hunting, fishing, and boating.

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**INTRODUCTION**

In the spring of 2002, the Crop, Soil, and Environmental Sciences (CSES) Club at the University of Arkansas adopted the wetland in Bryce-Davis Park through the Fayetteville Parks and Recreation Department. The wetland is located on the west side of Fayetteville in a public park adjacent to a residential subdivision. The east side of the park contains a playground, a sheltered picnic area with park benches, and a basketball court. The west side of the park contains the wetland, which has been overrun with Japanese honeysuckle (*Lonicera japonica*) and tall fescue (*Festuca arundinacea*). The club is working in conjunction with the city to remove the invasive species and restore the wetland with native vegetation.

Wetlands serve many functions for the environment such as improving water quality, recharging groundwater, cycling nutrients, sequestering carbon, supporting food production, and providing critical habitat for many wildlife species. The four primary objectives of the club in regard to the wetland in Bryce-Davis Park are: 1) remove invasive species from wetland; 2) provide opportunities for experiential learning; 3) facilitate student research; and 4) encourage outreach by linking students with their community. In order to accomplish these objectives the club has been interacting with many organizations to restore the wetland. After two years of hard work, the club has taken many steps toward accomplishing these goals.
MATERIALS AND METHODS

Experiential Learning

Working in the wetland has given students the chance to experience first-hand many of the principles taught within the CSES Department. This type of experiential learning is made possible through “wetland workdays” held several times throughout the university’s fall and spring semesters. During these workdays, various specialists from within and outside the department have volunteered to share their expertise in a variety of subjects such as wetland delineation, soil and water analysis, weed control, bird identification, and habitat assessment.

Initially, to confirm the area as a wetland, plant, soil, and hydrological characteristics were investigated using Army Corp of Engineers and Natural Resources Conservation Service guidelines. Students evaluated the area and searched for wetland boundaries. Plant and soil scientists from within the CSES Department instructed students to research 1) the presence/absence of hydrophytic vegetation; 2) whether or not the soil had gleyed coloring which would indicate anaerobic conditions or water-logging; 3) any redbottomic features in the rhizosphere; and 4) the presence/absence of standing water or hydrologic indicators suggesting previously flooded conditions. Gathering this information allowed students to make reasonable conclusions as to where the transition between the upland and wetland occurred.

Following these initial field sessions, students conducted targeted sampling and lab analysis of soil-quality parameters. Soil samples collected in April 2003 were analyzed for properties including pH (1:10 soil:water ratio), moisture (following oven-drying at 105°C), total carbon and nitrogen (C & N, by combustion), Mehlich III-extractable phosphorus (P, analyzed by inductively coupled plasma spectroscopy), microbial biomass (using the chloroform-fumigation-extraction method), and dissolved organic C (extracted by 0.5 M K2SO4 and analyzed on a total organic C analyzer) and inorganic N (extracted at a 1:10 soil:extract ratio in 2M KCl and analyzed colorimetrically on an auto-nutrient analyzer, Table 1). Samples were collected at two-meter intervals on multiple transects within the wetland. Water-quality studies were conducted in the spring of 2002 to determine the nutrient status (N, P) and the possible presence of hydrocarbon contaminants (data not shown).

In order to assess the wetland’s importance as a natural habitat, a graduate student in ornithology at the university joined the club during one of the wetland workdays in April 2003 to catalog the many species of birds using the wetland as a source of forage and habitat (Table 2). The data collected will assist students in monitoring how restoration efforts affect birds using the wetland in Bryce-Davis Park.

RESULTS AND DISCUSSION

Restoration

Restoration is the main goal for working in the wetland, but it is expected to be a long process since manual removal of invasive plants is time consuming. However, the club is proceeding by clearing away invasive species in “sections”. The Parks and Recreation Department has enhanced visibility of the wetland by removing mounds of soil that had been pushed in front of the wetland during the construction of a drainage ditch around the neighborhood. The club has planted native species in these cleared areas (Table 3).

Additionally, several plots have been set aside with the reintroduction of native grasses for the long-term evaluation of restoration on below-ground ecology and nutrient cycling (see related article in this issue of Discovery). In addition to the club’s work, a class in the Landscape Architecture Department constructed an observation deck, allowing the community to observe and appreciate the wetland ecosystem.

Research opportunities

There are many facets of this wetland that provide opportunities for students to conduct individual and group research projects with the help of advisors. Acquiring field and laboratory experience and establishing relationships with professors outside of class are some of the many benefits students receive by performing research. Along with conducting research come opportunities for undergraduate students to present projects at local and national scientific meetings and to publish their findings in scientific journals. Group research projects involve investigating alternative methods of removal for L. japonica. In the summer and fall of 2003 the club used a tarp to block sunlight and prevent photosynthesis to the plants of L. japonica. Club members have also been interacting with the city to evaluate the benefits and hazards of herbicide use and inquire about the selective use of Rodeo Roundup®. In addition, a controlled burn option was discussed with the Fayetteville Fire Department, the Parks and Recreation Department, Forest Service, and Nature Conservancy. It was concluded that this would not be an economical option. To date, manual removal has been the most extensively used, but this method is very labor and time intensive.

Currently the most extensive individual research project involves evaluation of the soil microbial community and the effects of invasive species on the nutrient availability in soil. Initial results were presented in fall...
2003 by a student member of the club at the American Society of Agronomy’s (ASA) national annual meeting in Denver, Colo. Plans are to continue this project to evaluate long-term effects of revegetation with native grasses on nutrient availability in soil undergoing restoration. Other students who attended the ASA meeting presented a poster entitled “Continued Assessment and Rehabilitation in Neighborhood Wetland” and, for the second consecutive year, received second place in the ASA Student Club Poster Contest. Students were able to attend the meeting thanks to various fundraising events conducted by the club, including the sale of seed kits to local FFA chapters for educational purposes; contributions from the Registered Student Organization for ASA registration fees; and largely thanks to the generosity of the CSES Department.

**Outreach**

A final objective for the wetland is to encourage community involvement in the restoration process and enjoyment of the wetland at Bryce-Davis Park. In this effort, students have conducted neighborhood surveys to determine residents’ responses to restoration efforts. A trail is being constructed that will provide Fayetteville residents a way to more fully experience this valuable ecosystem. Additionally, a local Boy Scout troop assisted with restoration efforts by revegetating an area adjacent to the observation deck with native grasses. These examples of outreach and the continuation of the restoration process promote connections with the citizenry, city officials, and other organizations to accomplish mutual goals and provide unique opportunities to establish relationships within and beyond the university.

**Future Plans**

In order to restore the wetland at Bryce-Davis Park, the club plans to continue investigating various removal techniques and revegetating with native plants. Students in the club will also continue to have opportunities to conduct their own individual research projects. Conducting research is a vital component of the adoption of the wetland. Other long-term goals include conducting annual assessments of wildlife populations as the club attempts to promote native plant and wildlife diversity. Outreach goals will be expanded so that this wetland can serve as an outdoor classroom for people of all ages for education on the importance of wetlands in the environment. This may be accomplished by the establishment of a nature trail, with signs along the trail informing visitors of wetland benefits and aiding them in identifying native plants and wildlife.

**ACKNOWLEDGMENTS**

The CSES club would like to thank:

- The faculty and staff of the Department of Crop, Soil, and Environmental Sciences (CSES Department) for their assistance, especially Dr. Chuck West, Dr. Moye Rutledge, Dr. Kristofoor Brye, Dr. Nathen Slaton, Dr. John Mattice, Dr. James Barrentine, Ms. Gloria Fry, Ms. Carla Coker, and Ms. Susan Fletcher for all their help and guidance throughout this project.
- Dale Bumpers College of Agricultural, Food and Life Sciences for an Undergraduate Research Grant.
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- Rebecca Ohman, Lisa Netherland, and the Fayetteville Parks and Recreation Department for their continued cooperation and assistance.
- Boy Scouts of America and the University of Arkansas Landscape Architecture Department for their contributions to improving the wetland.
- Ms. Nancy Wolf and the University of Arkansas Soil Testing Lab in Fayetteville, Ark., for conducting soil analyses.
- CSES Department for financial support to attend American Society of Agronomy national meetings.
- Karen Sykes, David Burton, Audrey Stuart, and Juan Mayta for initiating the wetland adoption and revegetation efforts, and for past club leadership.
- Rob Doster for bird identification.
Table 1. Soil properties of the wetland in Bryce-Davis Park in Fayetteville, Ark. in April, 2003 (n = 11)

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved organic carbon (C, µg g⁻¹)</td>
<td>35.25</td>
<td>18.78</td>
</tr>
<tr>
<td>Inorganic nitrogen (N, µg g⁻¹)</td>
<td>3.99</td>
<td>2.81</td>
</tr>
<tr>
<td>Mehlich-III extractable phosphorus (µg g⁻¹)</td>
<td>20.48</td>
<td>8.74</td>
</tr>
<tr>
<td>Microbial biomass C (µg g⁻¹)</td>
<td>115.50</td>
<td>50.44</td>
</tr>
<tr>
<td>Microbial biomass N (µg g⁻¹)</td>
<td>12.48</td>
<td>10.00</td>
</tr>
<tr>
<td>Microbial biomass C:N</td>
<td>13.04</td>
<td>14.64</td>
</tr>
<tr>
<td>Moisture (g g⁻¹)</td>
<td>0.44</td>
<td>0.18</td>
</tr>
<tr>
<td>pH</td>
<td>6.10</td>
<td>0.60</td>
</tr>
<tr>
<td>Soil C:N ratio</td>
<td>12.73</td>
<td>0.38</td>
</tr>
<tr>
<td>Total C (%)</td>
<td>2.72</td>
<td>0.75</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.21</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 2. Bird species identified in the Bryce-Davis Park wetland in Fayetteville, Ark., in April 2003

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actitis macularia</td>
<td>Spotted sandpiper</td>
</tr>
<tr>
<td>Agelaius phoeniceus</td>
<td>Red-winged blackbird</td>
</tr>
<tr>
<td>Butorides virescens</td>
<td>Green heron</td>
</tr>
<tr>
<td>Cardinalis cardinalis</td>
<td>Northern cardinal</td>
</tr>
<tr>
<td>Carduelis tristis</td>
<td>American goldfinch</td>
</tr>
<tr>
<td>Carpodacus mexicanus</td>
<td>House finch</td>
</tr>
<tr>
<td>Cyanocitta cristata</td>
<td>Blue jay</td>
</tr>
<tr>
<td>Erithacus rubecula</td>
<td>Robin</td>
</tr>
<tr>
<td>Gallinago delicata</td>
<td>Wilson’s snipe</td>
</tr>
<tr>
<td>Geothlypis trichas</td>
<td>Common yellowthroat</td>
</tr>
<tr>
<td>Hirundo rustica</td>
<td>Barn swallow</td>
</tr>
<tr>
<td>Poecile carolinensis</td>
<td>Carolina chickadee</td>
</tr>
<tr>
<td>Quiscalus quiscula</td>
<td>Common grackle</td>
</tr>
<tr>
<td>Seiurus noveboracensis</td>
<td>Northern waterthrush</td>
</tr>
<tr>
<td>Thryothorus ludovicianus</td>
<td>Carolina wren</td>
</tr>
</tbody>
</table>

Table 3. Native plant species reintroduced into the wetland at Bryce-Davis Park in Fayetteville, Ark., by the Crop, Soil, and Environmental Sciences Club in 2003

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Plant type</th>
<th>Wetland indicator status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campsis radicans</td>
<td>Trumpet creeper</td>
<td>Vine</td>
<td>Facultative</td>
</tr>
<tr>
<td>Amorpha canescens</td>
<td>Lead plant</td>
<td>Shrub</td>
<td>ND¹</td>
</tr>
<tr>
<td>Callicarpa sp.</td>
<td>Beauty berry</td>
<td>Shrub</td>
<td>ND</td>
</tr>
<tr>
<td>Cephalanthus occidentalis</td>
<td>Buttonbush</td>
<td>Shrub</td>
<td>Obligate wetland</td>
</tr>
<tr>
<td>Lindera</td>
<td>Spicebush</td>
<td>Shrub</td>
<td>ND</td>
</tr>
<tr>
<td>Ilex deciduas.</td>
<td>Possum haw</td>
<td>Shrub</td>
<td>Facultative wetland</td>
</tr>
<tr>
<td>Carpinus caroliniana</td>
<td>Blue beech</td>
<td>Tree</td>
<td>ND</td>
</tr>
<tr>
<td>Panicum virgatum</td>
<td>Switchgrass</td>
<td>Grass</td>
<td>Facultative</td>
</tr>
<tr>
<td>Sorghastrum</td>
<td>Indian grass</td>
<td>Grass</td>
<td>ND</td>
</tr>
<tr>
<td>Andropogon gerardii</td>
<td>Big bluestem</td>
<td>Grass</td>
<td>Facultative</td>
</tr>
<tr>
<td>Schizachyrium scoparium</td>
<td>Little bluestem</td>
<td>Grass</td>
<td>Facultative upland</td>
</tr>
</tbody>
</table>

¹ ND=wetland indicator status not determined
Effects of thinking-aloud pair problem solving on the troubleshooting performance of undergraduate students in a power technology course

Michael L. Pate*, George W. Wardlow†, and Donald M. Johnson§

ABSTRACT

A randomized post-test-only experimental design with a counter-balanced internal replication was used to determine the effects of thinking-aloud pair problem solving (TAPPS) on the troubleshooting performance of college students in a power technology course. The experimental results were stable across two troubleshooting tasks. Students who participated in the pair problem solving groups were significantly more successful ($p \leq 0.05$) at troubleshooting engine faults than were students in the control groups. Among students who successfully completed the troubleshooting tasks across both groups, there were no significant differences in time required for completion. These findings indicate that the use of pair problem solving may be an important step in the development of metacognitive skills among students in technological troubleshooting.

* Michael L. Pate graduated in December 2003 with a B.S. in agricultural education, communications and technology.
† George W. Wardlow is a professor in the Department of Agricultural and Extension Education.
§ Donald M. Johnson is a professor in the Department of Agricultural and Extension Education.
INTRODUCTION

All students, including those enrolled in colleges of agriculture, will encounter problems of increasing technological complexity over the course of their lives. The ability to effectively and efficiently solve these problems will become increasingly important. How efficient are undergraduate agriculture students in solving technological problems? Are problem-solving strategies overtly used by students in courses? Are there teaching and learning practices that enable students to more effectively solve technical problems?

The theoretical framework for this study was built around metacognition, technical troubleshooting as a specialized problem-solving process, and the thinking-aloud pair problem-solving approach as a mechanism to promote cognitive self-awareness and monitoring. Relevant literature from each of these areas was reviewed to inform this study.

Metacognition

According to Sternberg (1983), metacognitive skills are the executive thinking skills used by individuals to develop strategies for problem resolution. Flavell (1976) described metacognition as “the active monitoring and consequent regulation and orchestration of these [cognitive] processes in relation to... some concrete goal or objective” (p. 232). Berardi-Coletta, et al. (1995) stated that metacognition is “an active reflective process that is explicitly and exclusively directed at one’s own cognitive activity. It involves the self-monitoring, self-evaluating, and self-regulation of ongoing tasks” (p.206).

Technical Troubleshooting

According to Holyoak (1995), “A problem arises when we have a goal—a state of affairs we want to achieve—and it is not immediately apparent how the goal can be achieved” (p. 118). Given this definition of a problem, problem solving is simply the process of finding the best solution that allows movement from the present state to the goal state (Gobert and Simon, 1996).
Halpern (1984) further described the dimensions of problem solving by stating that problems have an anatomy consisting of (a) the initial state; (b) the goal state; and (c) the problem space, which contains all of the possible paths whereby one can move from the initial state to the goal state. According to Halpern (1984), the key to effective problem solving is the ability to recognize and select the most efficient solution path from the myriad of potential solution paths present in the solution space.

MacPherson (1998), indicated that technical troubleshooting is a special category of problem solving. Morris and Rouse (1985) posited that three skill sets are essential in technical troubleshooting: (a) the ability to make tests, (b) the ability to replace or repair faulty components, and (c) the “ability to employ some kind of strategy [italics in original] in searching for the source” of the fault (p. 504). Jereb (1996) emphasized the importance of strategy in troubleshooting, when he stated that, “The question of how to come from a given starting situation to a desired end situation is usually the essence of each technical problem” (p. 2). This is congruent with the work of Halpern (1984) who indicated that the key component of the problem-solving process was the ability to recognize and select the most efficient solution path from among all possible paths. Morris and Rouse (1985) concluded that identifying and employing an effective strategy was the most difficult skill set for troubleshooters to develop.

Thinking-Aloud Pair Problem Solving

One strategy of interest to educators who seek to improve the acquisition of problem solving strategies is the “thinking aloud” technique. Lochhead and Whimbey (1999) discussed this technique and Narode, et al. (1987), labeled it “pair problem solving” and described the process. The technique focuses on having students express their thoughts aloud while engaging in problem-solving activities in order to externalize the thinking process. This “thinking aloud” gives the speaker, and a student partner as a “listener,” oral feedback on what is understood and what is only vaguely processed. These authors claim that thinking aloud in pairs allows for the creation of new ideas by allowing the speaker to listen to what is said in a way that cannot occur when s/he is working quietly and alone.

Some researchers have found the thinking-aloud pair problem solving (TAPPS) process to be an effective strategy in teaching students to think, while others have found different results. Johnson and Chung (1999) conducted a study on the abilities of college students to troubleshoot electronics problems in an aviation technologies program. These authors noted that troubleshooting is a series of cognitive processes that requires combining or managing acquired information with existing knowledge. In this quasi-experimental study, they found that thinking aloud significantly improved troubleshooting abilities. Thinking-aloud pair problem-solving subjects performed at significantly higher levels than a comparison group in their ability to recognize faults and to locate specific faults, and in their ability to correctly evaluate faulty hypotheses they generated.

Hogan (1999) conducted a study on the thinking-aloud technique and its impact on collaborative scientific reasoning among eighth-grade science students.

Thinking-aloud subjects gained in metacognitive knowledge about collaborative scientific reasoning but their performance on problem solving was not significantly different than those who didn’t verbalize their thoughts. An earlier study by Flaherty (1975) on overt verbalization and practice in problem solving among high school students found results similar to those of Hogan. This begs the question, “Does thinking-aloud pair problem solving (TAPPS) improve the troubleshooting abilities of students?”

The purpose of this study was to determine if the TAPPS technique improved student success at troubleshooting common problems in small spark-ignition engines, compared with the traditional work-alone technique. The hypotheses tested were as follows:

$H_{01}$: In an engine electrical system troubleshooting task, there will be no differences in success rate or completion time between the experimental and control groups.

$H_{02}$: In an engine air/fuel delivery system troubleshooting task, there will be no differences in success rate or completion time between the experimental and control groups.

MATERIALS AND METHODS

This study utilized a post-test only control group design (Campbell & Stanley, 1966) with counterbalanced internal replication. Thirty students in a college course on small power technology during the spring 2003 semester comprised the subjects in the study. Students were randomly assigned to two groups: experimental or control.

Identical small spark-ignition engines were prepared, each with the identical fault to their primary electrical system, for each subject in the study. No clues were given, even about the general engine system in which the fault existed, only that the fault was not an internal component fault. Subjects in the control group were asked to work alone to troubleshoot their respective engines, identify the fault, repair the fault, and test run the engine.

The experimental group participated in the TAPPS treatment. Subjects in the experimental group were pre-
presented with an engine and asked to complete the same task. They were assigned a thinking-aloud partner who encouraged them to verbalize their thought processes as they completed the troubleshooting task using such statements and questions as, “What are you doing now?” and “Tell me what you are thinking.” Subjects in both groups were audio recorded to insure reliability of the data. Whether or not they were successful at troubleshooting the problem and the time to completion were recorded on a written instrument as measures of the major dependent variables.

While the TAPPS students did have a fellow student to prompt them to talk aloud during the problem solving process, the thinking aloud partner was specifically instructed to only prompt the student to verbalize their thought processes as they attempted to solve the problem. The partner could not assist the problem solver in any other way such as by offering clues or asking leading questions about the specific problem.

For the second round of the study, the groups were reversed. The subjects in the control group became the experimental group, and the experimental group became the control group. The engines were returned to working order and a new fault in the air/fuel delivery system was created in each engine. The subjects in the experimental group completed the troubleshooting activity with a thinking-aloud partner, and the control group completed the task without the aid of a thinking partner. Again, each subject was audio recorded and their success and completion times were recorded.

The test for differences between groups on the nominal dependent variable, task completion (successful or unsuccessful), was the Chi-square test of association. Independent t-tests were used to determine if there were significant differences in completion times between successful students in the experimental and control groups.

**RESULTS AND DISCUSSION**

Prior to testing the null hypotheses, student pre-test scores were analyzed to determine if differences existed between the two student groups on their knowledge of basic engine principles and operating theory. No significant differences were found, $t(28) = 1.35, p = .19$. Thus, pre-existing differences between groups on level of subject matter knowledge were not assumed to be a confounding factor in this counter-balanced design.

Table 1 presents descriptive statistics on student performance in the electrical troubleshooting task, by group. Students using the TAPPS technique (experimental group) had a significantly higher success rate than did those students who did not use the TAPPS technique (control group), $\chi^2 (1) = 5.56, p \leq .02$. Therefore, the first part of Ho, positing no relationship between group and task outcome, was rejected. Using the effect size descriptors proposed by Rea and Parker (1992), the magnitude of the phi coefficient ($\phi = .39$) indicated that there was a moderate association between group and task outcome.

For those students successfully completing the electrical troubleshooting task, there was no significant difference between groups in the mean time (minutes) required, $t (19) = -.34, p \leq .74$. Therefore, the second part of Ho, positing no relationship between group and completion time, was not rejected.

Table 2 presents descriptive statistics on student performance on the fuel/intake task by group. Students using the TAPPS technique had a significantly higher success rate than did those students who did not use the TAPPS technique, $\chi^2 (1) = 4.54, p \leq .03$. Therefore, Ho, positing no relationship between group and task outcome, was rejected. Using the effect size descriptors proposed by Rea and Parker (1992), the magnitude of the phi coefficient ($\phi = .39$) indicated that there was a moderate association between group and task outcome.

For those students successfully completing the electrical troubleshooting task, there was no significant difference between groups in the mean time (minutes) required, $t (16) = -.45, p \leq .66$. The second part of Ho, positing no relationship between group and completion time, was not rejected.

For both iterations of the study, significantly higher proportions of the subjects in the experimental treatment groups (thinking-aloud pair problem solving) successfully completed the troubleshooting tasks. Effect sizes ranged from moderate to relatively strong. This finding indicates that students engaged in troubleshooting small spark-ignition engine faults are more likely to be successful if they overtly verbalize their cognitive problem-solving processes. This supports assertions by researchers who indicate that the thinking-aloud process assists the problem solver in avoiding skipping steps in reasoning, skipping over important information, or being unaware of getting bogged down in a component of the problem (Heiman & Slomianko, 1987).

However, successful small-gasoline-engine troubleshooters who participated in the thinking-aloud pair problem solving (TAPPS) group were not significantly different in the time it took to complete the tasks compared to successful troubleshooters in the control group. Thus, it can be concluded that the time required to elicit metacognitive skills through verbalization does not adversely affect time for completion. No differences in time required for task completion, coupled with higher success rates for the TAPPS group, indicate that the TAPPS process yields a higher efficiency rate at technical troubleshooting.
Since the control-group subjects in the replication were thinking-aloud participants (experimental group) in the first round of the study and were largely successful in task completion by using overt verbalization, one might assume that the subjects would transfer these skills to their second-round troubleshooting task. This does not appear to be the case. It seems that while students can successfully use problem solving skills when externally prompted, they do not appear to do so when the external prompt is removed.

Further research should be conducted to validate these results. Additionally, if thinking-aloud pair problem solving results in more efficient troubleshooting through the elaboration of thought processes, research is needed to determine strategies to invoke these processes when the external prompt is removed. This would allow students to exhibit true metacognitive skills and to become successful, independent problem solvers. More specifically, educators may be able to overtly teach these skills to students.

**ACKNOWLEDGMENTS**

This project was supported by an undergraduate research grant from the Dale Bumpers College of Agricultural, Food and Life Sciences.

**LITERATURE CITED**


**Table 1. Student performance on the electrical troubleshooting task by group.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Minutes to completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Control (n = 12)</td>
<td>5</td>
<td>41.7</td>
<td>7</td>
</tr>
<tr>
<td>Experimental (n = 18)</td>
<td>16</td>
<td>88.9</td>
<td>2</td>
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</table>

*Based only on students with a successful task outcome

Note: χ² (1)= 5.56, p ≤ .02
Table 2. Student performance on the fuel/intake troubleshooting task by group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Successful</th>
<th>%</th>
<th>Unsuccessful</th>
<th>%</th>
<th>Minutes to completionz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (n = 18)</td>
<td>8</td>
<td>44.4</td>
<td>10</td>
<td>55.6</td>
<td>33.0</td>
</tr>
<tr>
<td>Experimental (n = 12)</td>
<td>10</td>
<td>83.3</td>
<td>2</td>
<td>16.7</td>
<td>29.1</td>
</tr>
</tbody>
</table>

z based only on students with a successful task outcome

Note: $\chi^2 (1) = 4.54, p \leq .03$
Microbial biomass and nitrogen availability under the invasive plant species *Lonicera japonica* and native grasses in wetland soil

*Kimberly R. Payne*, Mary C. Savin†, and Peter J. Tomlinson§

**ABSTRACT**

Invasive plants decrease aboveground biodiversity and suitable wildlife habitat. Wetlands are especially valuable ecosystems because they provide habitat, floodwater control, and function as filters for urban runoff. Wetland soils also act as sinks for nutrients. This characteristic reduces levels of excess nutrients often found in adjacent aquatic systems. The importance of soil functions in wetlands necessitates further investigation of the effects of invasive species on belowground nutrient pools. Approximately 75% of a small neighborhood wetland located in Fayetteville, Ark., has been invaded by *Lonicera japonica*. The effects of *L. japonica* and its replacement with native grasses on soil microbial biomass and nutrient pools were evaluated. Eight plots were established in April 2003. Four were left vegetated with the invasive species *L. japonica* while the other four were revegetated with transplants of five native grass species: *Andropogon gerardii*, *Schizachyrium* spp., *Sorghastrum nutans*, *Panicum virgatum*, and *Tripsacum dactyloides*. Soil samples were taken three times over the growing season, once prior to the removal of *L. japonica* and twice after transplanting occurred. Microbial biomass, soil carbon and nitrogen, Mehlich III- extractable phosphorus, pH, moisture content, and inorganic nitrogen were analyzed and significance was tested using a one-way ANOVA test (P < 0.05). Temporal changes in the inorganic N pool and pH were significant. However, data showed no significant differences between treatments for any of the properties tested, suggesting that data need to be collected for more than one growing season before significant changes may be observed following revegetation.

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INTRODUCTION

Invasive plant species are considered to be a problem because they out-compete native vegetation, effectively reducing plant diversity. This reduction in diversity leads to a reduction in wildlife habitat and forage. Native plant species are beneficial to native wildlife because these two groups have co-evolved. Thus, native plant species most likely provide associated wildlife with the best resources. While biodiversity is not ranked as high as resilience and adaptability when determining ecosystem health, it is still used as a major indicator of ecosystem health (Schläpfer et al., 1999). The underlying assumption is that the greater the number of species that live in an area, the more productive and efficient the ecosystem. Studies monitoring the effect of plant diversity on nutrient retention have resulted in positive correlations (Schläpfer and Schmid, 1999). Schwartz et al. (2000) found that higher levels of diversity led to more durable and sustainable ecosystems. Stable, diverse ecosystems were resilient and able to “spring back” from changes within the environment more readily than ecosystems with low diversity of species. Thus, an understanding of how invasive plant species change an environment could enhance understanding of why diversity is better for stability.

Damage to ecosystems by invasive plant species can sometimes be measured economically; for instance, the annual cost in the United States associated with the losses due to invasive plant species and measures implemented to control these invasive plants is approximately $25,000,000 (Pimentel et al., 1999). While pasture and food crop producers absorb the majority of this cost, the Bureau of Land Management also spends millions of dollars trying to control invasive species (Bureau of Land Management, 2004). Although much is known about the interactions among plants, crops, and wildlife, and although progress is being made, an effective pro-
gram for preventing the spread of invasive plants appears to be far from reach. In 1999, President Bill Clinton created the Invasive Species Council, whose duties include preventing the spread of invasive species and restoring areas disturbed by invasive plants (“Invasive Species,” 1999).

One example of an invasive species is *Lonicera japonica*. *Lonicera japonica* is an invasive plant vine found throughout eastern North America, including Arkansas, that out-competes native vegetation by producing expansive root systems and dense aboveground stands, with which native plants may be unable to compete for sunlight (Nuzzo, 1997). *Lonicera japonica* is able to out-compete other plants above- and belowground by producing rhizomes that allow for very rapid growth (Nuzzo, 1997). *Lonicera japonica* has invaded a small neighborhood wetland in Fayetteville, Ark. This wetland clearly shows the above ground adverse effects associated with *L. japonica*. Approximately 75% of the vegetation is *L. japonica*, and removal of the *L. japonica* from trees at the wetland reveals deep scars on the cambium. Dense mats of growth prevent sunlight from reaching the ground. This wetland is currently undergoing restoration by the University of Arkansas undergraduate Crop, Soil, and Environmental Sciences Club in conjunction with the Fayetteville Parks and Recreation Department and other local organizations. Restoration efforts aim to remove *L. japonica* and restore native vegetation that will provide habitat and forage for wildlife.

The ultimate goal of this restoration effort is to utilize the wetland as a recreational area and an outdoor classroom. In this study, the objectives were to determine the effects *L. japonica* has on nutrient levels, soil pH, and microbial biomass, and how these properties change following revegetation with native grasses.

Little is known about the response of soil microbial communities to the displacement of native plants due to invasive species (Kourtev et al., 2002). The removal of invasive species in order to promote the growth of native species and restore plant biodiversity is often a challenging task. Since plant and soil microbial communities are so interwoven, it seems insight into interactions between invasive species and soil microbes, and the resultant soil changes, could provide a better understanding of that which is required to promote biodiversity and prevent infestations by invasive species.

**MATERIALS AND METHODS**

**Site Description**

The 0.2-hectare wetland being investigated is located in a neighborhood park in Fayetteville, Ark. Eight plots (2 m x 2 m) were established in April 2003. In May 2003, the aboveground portion of *L. japonica* was removed manually from four of the plots, which were then revegetated a week later with transplants of five native grass species: *Andropogon gerardii*, *Schizachyrium* spp., *Sorghastrum nutans*, *Panicum virgatum*, and *Tripsacum dactyloides*. Plots received no irrigation water or fertilizer.

**Soil Samples**

Eight random surface soil samples (10-cm depth) were collected and combined within each plot. Initial soil samples were collected in April 2003, while the dominant vegetation on all plots was *L. japonica*. Soil samples were again collected in June and October 2003. Sterile soil cores with a diameter of 1 cm were used to collect the samples for April and October. Sterile soil cores with a diameter of 5 cm were used to collect samples in June. All samples were stored on ice for transport to the laboratory. The samples were sieved through stacked 4-mm and 2-mm mesh sieves and stored at 4°C. All extractions were conducted within 4 d of collection. In April soil samples were analyzed for total carbon and nitrogen and Mehlich III-extractable phosphorus. Additionally, soil samples were analyzed for moisture, microbial biomass carbon and nitrogen, pH, and inorganic nitrogen on all sampling dates.

**Gravimetric Water Content**

Gravimetric water content was calculated after oven drying moist soil (5 g) for 24 h at 105°C. Results for all nutrient analyses are reported on per gram of dry soil basis.

**Total Carbon (C) and Nitrogen (N) and Mehlich III-Extractable Phosphorus (P)**

The Soil Testing Lab at the University of Arkansas-Fayetteville conducted total C and N, and Mehlich III-extractable P analyses. Total C and N were measured on oven-dried, ground soil combusted at 1100°C (LECO CN2000, Joseph, Mich.). Oven-dried, ground soil was extracted with Mehlich III solution at a 1:10 (wt:vol) ratio and analyzed by inductively coupled plasma spectroscopy (SPECTRO CIROS ICP, Fitchburg, Mass.).

**Microbial Biomass C and N**

Microbial biomass C and N were determined using a chloroform-fumigation-extraction method as described by Vance et al. (1987). Moist soil (10 g each) was obtained for fumigated and unfumigated analysis. The unfumigated soil samples were extracted immediately with 0.5 M K2SO4 (20 ml). Samples were shaken on a reciprocating shaker (30 min) and filtered through Whatman #42 filter paper. The fumigated soil samples were placed in a desiccator that had been lined with moist paper towels and contained ~25 ml of chloroform. A vacuum was then used to seal the desiccator and boil...
the chloroform. After a fumigation period (24 h), chloroform was removed by evacuating the air within the desiccator six times for 3 min each. Fumigated soils were then extracted as described for unfumigated samples. Total organic carbon (TOC) was measured using a Rosemount Analytical Inc. DC-190 High Temperature TOC Analyzer (Tekmar-Dohrmann, Cincinnati, Ohio). Microbial biomass N was determined using persulfate oxidation as described by Cabrera and Beare (1993). Biomass C and N were each calculated as the difference between fumigated and unfumigated values.

**Inorganic N**

Moist soil (1g) was extracted at 1:10 (wt:vol) ratio with 2M KCl. Extracts were shaken (1 h) and solutions were filtered through Whatman #40 filter paper and stored at 4°C until further analysis. Colorimetric analysis of ammonium concentrations (NH$_4^+$, modified Berthelot reaction) and nitrate concentrations (NO$_3^-$, cadmium reduction) were conducted on a Skalar auto-nutrient analyzer (Norcross, Ga).

**Soil pH**

Moist soil (1 g) was mixed with double deionized water (10 ml) and allowed to sit (1 h). The pH was then recorded using a calibrated, combination pH electrode (VWR Scientific Products, Westchester, Penn).

**Statistical Analysis**

A one-way analysis of variance test (P<0.05) was conducted on both treatments for all sampling times for each of the properties evaluated.

**RESULTS AND DISCUSSION**

**Gravimetric Water Content**

There were no significant differences in gravimetric water content between treatments or sampling times. Mean values for gravimetric water content ranged from 0.27 to 0.36 g water g$^{-1}$ soil for all sampling dates.

**Total C and N and Mehlich III-Extractable P**

Initial levels of total soil C and N and Mehlich III-extractable P did not show significant differences between treatments. Soil C levels ranged between 2.30 and 2.56%. Assuming soil organic matter is twice the amount of soil carbon (Brady and Weil, 2002), the soils were approximately 5% organic matter. While this might be considered high in surface agricultural soils, it is not a high amount for wetland soils. Histosols can have organic matter contents greater than 20% (Brady and Weil, 2002). Saturated soils tend to have greater accumulation of organic matter than upland soils. *Lonicera japonica* prefers soil that is not completely inundated by water for extended periods of time (Nuzzo, 1997). Thus, *L. japonica* surrounds the wetland but has not penetrated the wettest areas. Background soil N levels were not significantly different between treatments and were in the range of 0.16 to 0.20 percent. Soil C:N ratios typically fall between 8:1 to 15:1 for surface soils (Brady and Weil, 2002). The soil C:N ratios of the two treatments were not significantly different and ranged between 13:1 and 15:1. Mehlich III-extractable P levels were not significantly different between treatments and ranged from 12.04 to 16.99 $\mu$g P g$^{-1}$.

**Microbial Biomass C and N**

Microbial biomass C ranged from 124 to 199 $\mu$g C g$^{-1}$ soil, and microbial biomass N values were between 11 and 31 $\mu$g N g$^{-1}$ soil for all sampling dates and treatments (Table 1). Microbial biomass C:N ratios were calculated to be in the range of 7:1 - 14:1 (Fig. 1). Assuming that C:N ratios for bacteria are 3:1 - 5:1 and C:N ratios for fungi are 5:1 - 15:1, these ratios indicate that fungi were the dominant biomass (Sylvia et al., 1998). There were no significant differences between treatments or among sampling dates for microbial biomass C, N, or C:N ratios.

**Inorganic Nitrogen**

No significant difference in the inorganic N pool (Fig. 2) was found between April and October. However, inorganic N levels increased between April and June and decreased between June and October. Most of the inorganic N pool was attributed to NH$_4^+$, which ranged from 1 - 12 $\mu$g N g$^{-1}$ soil. Nitrate was low throughout the growing season and no significant changes were measured among sampling dates. The NO$_3^-$ pools ranged from 0.5 - 1.5 $\mu$g N g$^{-1}$ soil.

**Soil pH**

As with inorganic N, pH increased between April and June and decreased between June and October (Fig. 3). No significant differences between treatments were observed for any sampling date.

It is necessary to study soil microbial interactions with higher plants in order to understand ecosystem processes on a functional level (Wardle, 2002). For example, many papers have been published in soil science that report different nitrogen mineralization under different vegetation regimes (as cited in Wardle, 2002). Scientists have been evaluating plant-soil-microbe interactions in order to determine if there is a link between microbial communities and invasive plant species. Plant species’ effects on microorganisms are thought to be caused by differences in the organic compounds that are excreted by plant roots (Marschner et al., 2001). Plants influence soil microbial communities by either increasing activity by carbon substrate addition (root exudates) or decreasing activity by depleting nutrients and resources from the soil (Wardle, 2002).
Kourtev et al. (2002) analyzed the soil microbial communities under three species of plants: two invasive and one native species. Microbial communities were found to be different under native and invasive species, and the greatest differences in community structure and function were found in the rhizosphere soil (i.e., the soil located in close proximity to the root zone) suggesting that plants have a direct effect on soil microbial communities (Kourtev et al., 2002). Erhenfeld et al. (2001) suggested that the establishment of invasive species causes changes in the structure and function of the soil biota. They proposed that understanding the changes that occur within the soil microbial communities could explain how invasive plants change their surroundings and grow at such alarming rates.

Recently in a 10-week study, the growth rate of Centaurea maculosa, an invasive plant species in North America, was compared in four soils from its native region and six from North America, before and after soil sterilization (Callaway et al., 2004). The results showed sterilization of the native soils caused an average increase of 166% in total plant biomass, whereas sterilization of the foreign North American soils caused only a 24% increase in total plant biomass (Callaway et al., 2004). These results indicate soil microorganisms play a role in controlling the growth rate of higher plants. Callaway et al. (2004) state that once a plant invades an area, it often experiences positive relationships with soil biota due to a lack of effective soil pathogens, whereas in its native habitat negative relationships with soil biota occur. Callaway et al. (2004) suggested that this might be the reason invasive plants are so successful.

In contrast to the immediate effects on plant growth in the study by Callaway et al. (2004), differences between treatments were not observed in this study during the first growing season. Labile nutrient pools—microbial biomass C and N and inorganic N—were chosen for evaluation because they are dynamic pools that respond in the short-term to changes in the environment. Microbial biomass can serve as an indicator of soil health, which is essential for a productive ecosystem. However, the results of this study may not be surprising. The sampling times may have been too soon after transplanting for changes within the soil to be apparent. The native grasses had been planted for less than a month at the June sampling time and less than 4 months at the October sampling. The roots of the L. japonica were not removed from the soil and may need to be degraded before changes are observed. The Kourtev et al. (2001) experiment was carried out on plots where native plants stands were already well established.

The results from the current study indicate that changes caused by the native grasses during the first year of stand development may not have been significant enough to indicate modifications within the bulk soil nutrient pools. Thus, soil sampling and analysis for the aforementioned parameters will continue in 2004, having allowed time for some root degradation and establishment of the native plant community. In addition to monitoring microbial biomass and nutrient cycling, soil-microbial community composition will be examined using polymerase chain-reaction amplification and denaturing gradient gel electrophoresis techniques. These techniques will allow us to examine the changes within soil communities at a greater level of resolution to determine if diversity within targeted soil communities changes with respect to vegetation cover even if the total microbial biomass does not change. This study found that significantly measurable changes due to revegetation might not occur within a single growing season. We suggest that data need to be collected for at least another year before differences among treatments may be observed.

ACKNOWLEDGMENTS

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LITERATURE CITED


Table 1. Mean values (standard deviation) of soil microbial biomass carbon (C) and nitrogen (N) in wetland soil growing Lonicera japonica and soil plots revegetated with five native grass species in the combined months of April, June, and October, 2003 (n = 4)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Microbial biomass C (µg g⁻¹)</th>
<th>Microbial biomass N (µg g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lonicera japonica</td>
<td>152.09 (10.51)a¹</td>
<td>18.56 (2.96)a</td>
</tr>
<tr>
<td>Native grasses</td>
<td>171.82 (40.96)a</td>
<td>19.89 (10.26)a</td>
</tr>
</tbody>
</table>

¹Different letters within column indicate significant differences between treatments and among sampling dates (P < 0.05)

**Fig. 1.** Mean values of microbial biomass carbon-to-nitrogen (C:N) ratios for wetland soils growing Lonicera japonica and five native grass species in April, June, and October, 2003 (n = 4); error bars represent one standard deviation.
Fig. 2. Mean concentrations of inorganic nitrogen (N), ammonium (NH4+), and nitrate (NO3-) in wetland soil growing *Lonicera japonica* and native grass species in April, June, and October, 2003 (n = 4). Error bars represent one standard deviation.

Fig. 3. Mean values (standard deviation) of soil pH in wetland soil plots growing *Lonicera japonica* and five native grass species in April, June, and October, 2003 (n = 4). Error bars represent one standard deviation.
Acaricidal efficacy of various agents in the treatment of naturally occurring *Ornithonyssus sylviarum* (Acari: Macronyssidae) infestations of chickens

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**ABSTRACT**

The northern fowl mite (NFM), *Ornithonyssus sylviarum*, is a commonly occurring external parasite of chickens. Primarily, caged layers have the greatest incidence of this mite, with bird unrest, unthriftiness and lowered production as some of the adverse effects of the infestation. In the current study, birds with natural NFM infestations were randomized into five treatment groups, placed in individual cages in treatment-specific batteries (all in one room), and evaluated for 28 d for infestation quantification by way of index scoring and feather digest. No treatments were 100% effective in eliminating all life stages of the mite. Tetrachlorvinphos in combination with dichlorvos (RAVAP E.C.® Boehringer Ingelheim) was the most effective with consistently negative post-treatment index scores and the greatest decrease in mite life stages (eggs, larvae, and nymphs/adults). Malathion dust (Hi-Yield® Voluntary Purchasing Groups, Inc.) and 10% garlic oil were next in level of effectiveness, with significant (P < 0.05) post-treatment reductions in both index scores and mite life-stage populations. Permethrin (Permectrin II® Boehringer Ingelheim) provided the least control of the infestations, with no significant reductions in index scores and only slight reduction in the abundance of life stages after treatment.

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