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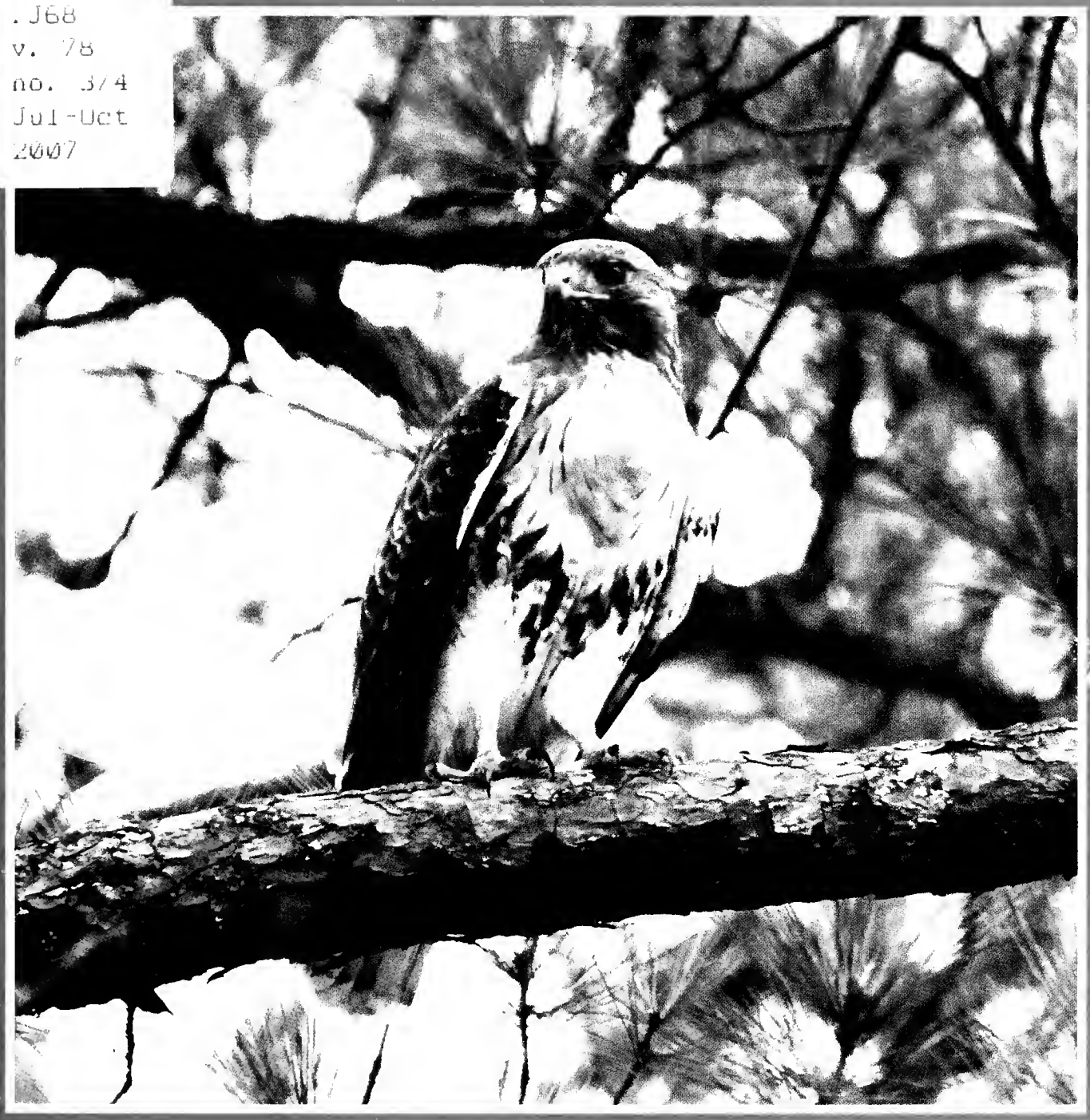

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Photo courtesy of: Bill Garland, U.S. Fish and Wildlife Service, Biologist, Anniston, Alabama. Photo was taken at the Mountain Longleaf National Wildlife Refuge, Anniston, Alabama. The refuge contains scattered large pines needed for nesting and open foraging areas critical to this Bird of Prey.

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ARTICLES:

HYBRID VEHICLES – ARE UNIVERSITY STUDENTS IN NORTH ALABAMA READY TO BUY THEM?

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ABSTRACT

In this case study, the writers researched North Alabama college students' knowledge of and willingness to purchase hybrid vehicles via a survey administered to a convenience sample of 200 North Alabama university students. The results show that the majority of university students have at least heard about hybrid cars and know what they are. They also know the sources of fuels used in these cars. Students who are considering purchasing hybrid cars believe the main benefits of hybrid vehicles are contributing to less dependence on foreign oil and promoting a cleaner environment rather than saving money on gasoline. Upper-level college students are a strong potential market for hybrid vehicles because in a short time, they will be in the auto-buying market. Therefore, a study on college students' attitudes toward hybrid vehicles will generate valuable insights to help automakers develop marketing strategies to attract the future hybrid vehicle owners.

INTRODUCTION

A hybrid vehicle is a vehicle powered by two distinct sources of power, most commonly gasoline and electricity. Hybrid vehicles are far more fuel-efficient than are purely gas-powered vehicles, and far more practical for everyday use than are purely electric-powered vehicles. By synthesizing the two sources of power, a vehicle is created which is relatively nonpolluting and cheap to fuel, possesses sufficient power to keep up with interstate highway speeds, and does not require excessive refueling (Ingalls, 2006).

The added boost of electricity enables hybrid vehicles to navigate tough terrain and steep hills without needing large engines, which are usually oversized to provide sufficient power for the one percent of driving times in which such extra power is needed. By keeping electric power in reserve for these rare occasions, gas engines can be built far smaller, yielding much-enhanced performance. Gasoline-based engines can help compensate for the lack of power of an electric car. They can also serve to recharge electrical batteries. (Ingalls, 2006).

A purely electric vehicle normally cannot run more than 100 miles without the batteries needing to be powered again via a slow and inefficient process. By contrast, a hybrid vehicle's electric batteries never need to be manually recharged because energy

derived from the gas engine is converted into electricity automatically. In addition, most modern hybrid vehicles reclaim energy from the deceleration of gradual stops. The two power sources thus work together symbiotically: the gas engine allows electricity to be used practically, while the electrical components allow the gas engine to run more efficiently. This efficiency in turn saves on fuel and dramatically reduces the emission of pollutants (Ingalls, 2006).

There are several types of hybrids: full hybrids are described above; mild hybrids have all the hybrid features except electric-only drive; muscle hybrids use hybrid technology to increase power rather than to increase fuel economy; hollow hybrids have the most limited hybrid characteristics (Rockhold, 2005).

As Figure 1 shows, gasoline prices almost doubled from December 2001 to September 2005. Since gasoline consumption is inelastic in the U.S., it is the automakers' responsibility to produce models that are more fuel efficient and less dependent on gasoline, such as hybrid vehicles. The market trend has shown an increasing demand for hybrid vehicles. By one projection, J.D. Power – LMC estimates that by 2010, there will be a three percent increase in demand in the U.S. market, predicting that 535,000 units will be sold in 2011 (J.D. Power, 2006).

Given the increased interest among U.S. consumers in hybrid vehicles and in this period of sharply escalating gasoline prices, research on consumer understanding of alternative fuels is necessary. Our study focuses on hybrid vehicles, which use one of the several alternative fuels that have been developed. This research targets four areas: knowledge of hybrid vehicles, understanding of the hybrid car industry, likelihood of purchasing a hybrid vehicle, and sample demographic characteristics.

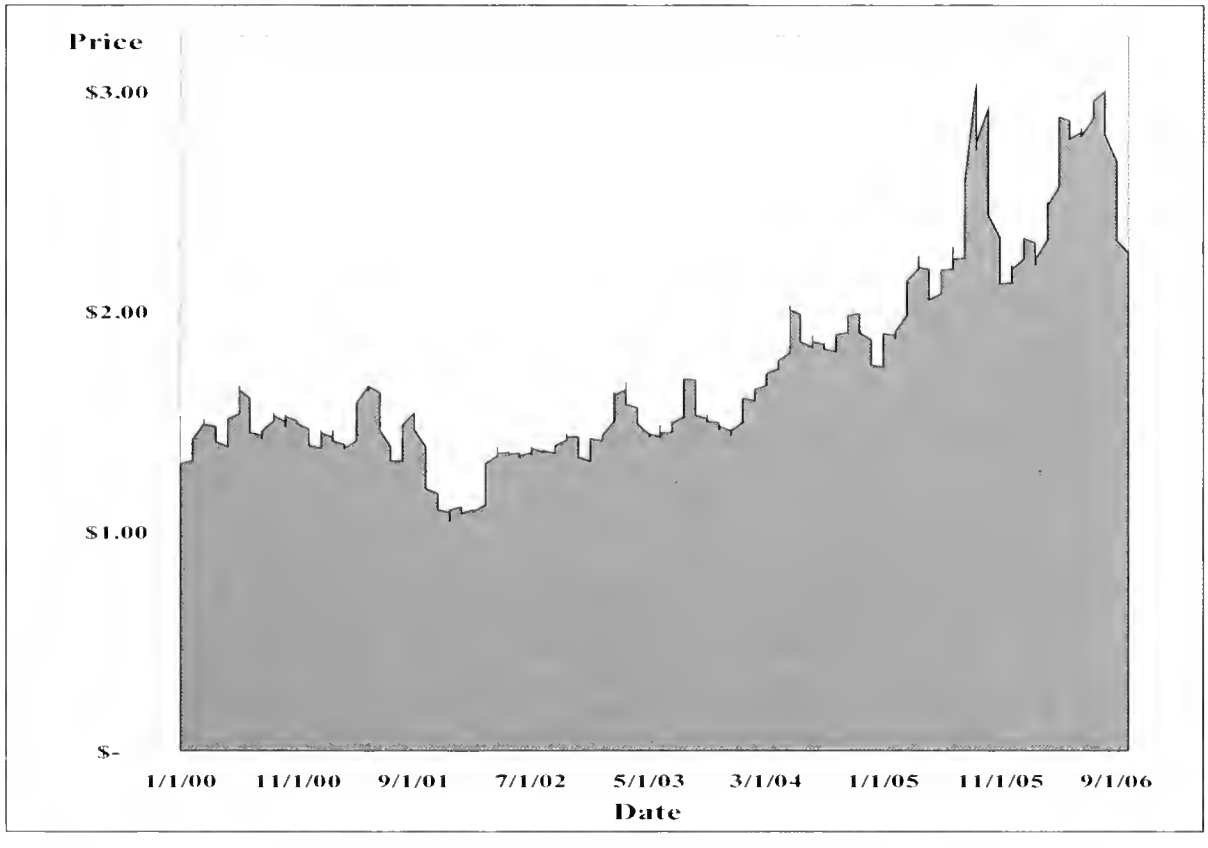

Figure 1. U.S. regular gasoline prices from January 2000 to October 2006

Historical Sketch and Profile of Hybrid Users

The history of hybrid vehicles goes back to 1665. Between that year and 1825, Flemish Jesuit priest and astronomer Ferdinand Verbiest created plans for a steam "car" for Chinese Emperor Khang Hsi, Frenchman Nicholas Cugnot built a steam-powered motor carriage capable of six miles per hour, and British inventor Goldsworthy Gurney built a steam car that successfully completed an 85-mile journey in ten hours. In 1839, Robert Anderson of Aberdeen, Scotland, built the first electric vehicle.

In 1898, Dr. Ferdinand Porsche, at age 23, built the first hybrid, using an internal combustion engine to spin a generator that provided power to electric motors located in the wheel hubs. On battery alone, the car could travel nearly 40 miles.

In 1900, Belgian carmaker Pieper introduced a 3.5 horsepower "voiturette" in which a small gasoline engine was paired with an electric motor under the seat. Two Pieper patents were used by Belgium firm, Auto-Mixte, to build commercial vehicles from 1906 to 1912.

In 1905, H. Piper, an American engineer, filed a patent for a petrol-electric hybrid vehicle. His idea was to use an electric motor to assist an internal-combustion engine, enabling it to achieve 25 mph.

In 1904, The Electric Vehicle Company built 2,000 electric taxicabs, trucks, and buses. However, Henry Ford put the firm out of business when he overcame some of the disadvantages of gasoline-powered vehicles – noise, vibration, and odor – and began assembly-line production of low-priced, lightweight, gasoline-powered vehicles. In 1913, with the advent of the self-starter – making it easy for all drivers to start gasoline engines – steamers and electrics were almost completely wiped out.

Another landmark in hybrid vehicle history was 1910, the year the Commercial hybrid truck was introduced. The truck used a four-cylinder gas engine to power a generator, eliminating the need for both transmission and battery pack. This hybrid was built in Philadelphia, PA, until 1918.

In 1914, the Galt Motor Company introduced the Galt Gas Electric, a pure series hybrid that was said to achieve 70 mpg or do 15 to 20 miles on the battery alone. However buyers were not interested because the car had a top speed of 30 mph.

In 1916, two prominent electric-vehicle makers – Baker of Cleveland, OH, and Woods of Chicago, IL, – offered hybrid cars. Again, consumers were disappointed in the top speeds of the vehicles (around 35 mph).

The 1920 – 1965 time span was an inactive period for electric and hybrid cars. However, in 1966, the U.S. Congress introduced the first bills recommending use of electric vehicles as a means of reducing air pollution. As time went by in the U.S., experimental vehicles were developed, some government agencies began using electric vehicles, and agencies were funded to research hybrid vehicles and to work with industry to improve batteries, motors, controllers, and other hybrid-electric components.

In 1992, the Toyota Prius went on sale in Japan. First-year sales were nearly 18,000. During 1997 – 1999, a few all-electric cars were introduced in California. Although enthusiasm was high at first, the electrics failed to reach beyond a few hundred drivers for

each model, and within a few years, the all-electric programs were dropped. Honda released the first hybrid car – the Insight – to the U.S. mass market in 1999. The vehicle won several awards and achieved an EPA mileage rating of 61 mpg city and 70 mpg highway.

In 2000, Toyota released the Toyota Prius, the first hybrid four-door sedan, in the U.S. Two years later, Honda released its Civic Hybrid. Unlike the Prius, this was quite unusual looking, the hybrid Civic was identical to the conventional Civic in both appearance and drivability. In 2004, the Toyota Prius II won several prestigious awards in North America, demand rose markedly, and Toyota increased its production for the U.S. market from 36,000 to 47,000. Interested buyers had to wait up to six months for the 2004 Prius. That same year, Ford released the Escape Hybrid, the first American hybrid and the first SUV hybrid.

At first, some hybrid producers were estimated to have taken a loss of about $10,000 per car to stimulate demand. Now buyers are often paying more – sometimes several thousand dollars more – than the sticker price for the Prius. In addition, hybrids maintain their resale value, sometimes selling for as much as or more than their original price.

Regular maintenance for hybrids is no different from that of gasoline-only vehicles, and the Honda Civic Hybrid and Toyota Prius have earned the highest ratings for reliability and owner satisfaction from Consumer Reports. Hybrids are also backed by the same warranties as are conventional cars, and additional warranties cover the hybrid systems and typically last for eight years or 100,000 miles.

Hybrids pose no more danger in a collision than do conventional vehicles, and most offer safety technologies such as stability control, anti-lock brakes, and side air bags. Because of these safety features, owners may save money on their insurance, depending on their carriers (Rockhold, 2005).

In an Office for the Study of Automotive Transportation study, director Walter McManus describes hybrid owners as having a higher level of education than does any other group of car drivers. Additionally, they have higher incomes, are more likely to be female, and are a few years older than is the average car buyer. They are likely to be urban dwellers with no children. From a behavior point of view, they drive fewer miles on average, plan to keep their cars longer than does the typical person, are willing to pay more for an environmentally friendly product, want to do something to help reduce pollution, and expect fuel prices to increase a lot faster than other people do (Cited in Who's Driving Hybrids," 2005). Another characteristic common to this market is a desire to reduce U.S. dependence on foreign oil. An opinion poll conducted by Opinion Research Corporation for the Civil Society Institute and 40mpg.org revealed that the view U.S. automakers should follow the same path as Toyota was shared by 80 percent of the independents, 73 percent of the Republicans, and 86 percent of the Democrats (Cited in "Poll Reveals Support for Increased Hybrid Vehicle Development," 2005).

David Welch (2005) attributes the higher sales of the Prius over the Accord to consumers' preference for the conspicuous display of greenness. On the other hand, Joe Mateja (2005) writes, "Consumers don't seem to care."

From another vantage point, Garling and Thogersen (2001) report that the best predictor of buyer behavior in this context is if the consumer believes an innovation has the five characteristics identified by Rogers (originally 1962) as influencing the rate of adoption. The characteristics are relative advantage (advantage relative to its predecessor), compatibility (congruence with society's values, etc.), simplicity, communicability (the degree to which the innovation can be demonstrated, explained and/or the results of its use observed), and trialability (degree to which the innovation can be tried on a limited basis). Their research focused on the marketing of electric vehicles, which – of course – were intended to achieve most of the same results as are hybrid vehicles.

Michael Copeland (2005) reports that these days, "The gas-sipping technology isn't just for tree huggers." Both Toyota and Honda unveiled their first major advertising campaigns aimed at the mainstream in 2005. Another author commenting on the new centrist hybrid buyers is Kerwin (2004), who reported from the results of Ford's focus group studies that the typical buyer of the Ford Escape was "someone supermainstream, not the stereotype of the die-hard environmentalist who was the early hybrid customer."

Given that more and more hybrid vehicle buyers are fitting into the so-called normal category, it is appropriate to study the attitudes of various demographic groups toward the product category. A beginning is this study that focuses on North Alabama university students' knowledge of and interest in hybrids.

Consumer Doubts and Incentives Offered To Encourage Purchase of Hybrids

Several factors have caused some consumers to have mixed feelings about hybrid vehicles. One frequently occurring concern is the belief that gas mileage figures are frequently inflated by both certain automakers and by the Environmental Protection Agency. Second, some unethical dealers are taking advantage of high demand by adding so-called *market adjustments* between $5,000 and $10,000 – price gouging. In addition, some consumers are wary of the vehicles' complex computer system. Ironically, although as stated, some hybrid drivers get an insurance discount, Allstate charges more to hybrid buyers than to those who drive their conventional counterparts because of the higher price of some of the parts and the difficulty encountered in installing them (Benton, 2005).

At this stage in the development of the hybrid market, finding a competent repairperson may be difficult and buyers should probably take their vehicles to a dealer-based mechanic. Of course, dealers' rates are higher than those of independent mechanics (Rockhold, 2005).

A 2005 *Kelly Blue Book* survey found that more than half of the consumers polled cited concerns about service and longevity issues and/or felt they need to know more about the hybrid technology before buying one. In addition, 55 percent were concerned about the hybrid's limited battery pack life. (Cited in "KBB Study Reveals Consumers Concerned About Current Hybrids," 2005.)

A 2005 Polk Center study found 61 percent of those polled who never owned a hybrid indicated that the cost of a hybrid alone might deter them from purchasing one. Nearly 30 percent said the benefits they could potentially receive from a hybrid vehicle

do not justify the additional costs. (Cited in "Polk Center Study Finds Consumers Hesitant on Hybrids, 2005.) For example, Thane Peterson (2005) reports one would have to own a hybrid for at least eight years and do a lot of in-town driving for the fuel savings to offset the initial price premium.

According to a 2005 TechnoMetrica Market Intelligence survey, American citizens have more confidence in Toyota and Honda than they do in their U.S. counterparts (Ford, General Motors, and Chrysler). In the poll, Nissan and Volkswagen did not fare well either, with only 17 and 16 percent of respondents respectively indicating they thought these companies were committed to hybrids. (Cited in "Survey Reveals U.S. Consumers' Faith in Japanese Hybrid Pursuits," 2005).

In an effort to reassure consumers leery of buying hybrids, several corporations, not-for-profit institutions, and governments have created incentives to promote the use of these products. Examples include cash rebates/subsidies/grants to go toward retrofitting costs, bonuses/supplements to monthly automobile allowances, permission to use High Occupancy Vehicle lanes regardless of the number of riders, exemption from parking fees, state and federal income tax credits, exemptions from sales/excise taxes, and exemptions from motor vehicle emissions testing requirements.

MATERIALS AND METHODS

During the fall of 2005, questionnaires featuring closed-ended questions were administered to 200 college students at Alabama A&M University, The University of North Alabama, The University of West Alabama, and J. C. Calhoun Community College, all of which are in the northern half of the state. The respondents were not evenly distributed among these four colleges. Most of the usable questionnaires were completed by Alabama A&M University students (40%); The University of North Alabama and The University of West Alabama each contributed 25% of the survey subjects; Calhoun Community College provided the last 10% of the subjects. The distribution of the returned questionnaires is the result of natural turnout without any intentional manipulation. A total of 157 usable surveys were tabulated in this study.

The questionnaire featured twenty-six questions in four areas targeting the writers' research interests: students' knowledge of hybrid vehicles, students' understanding of the hybrid car industry, their likelihood of purchasing a hybrid vehicle, and their demographic characteristics.

The researchers then coded answers to each of the questions, input the data values, and analyzed data values using both spreadsheets and the Statistical Package for the Social Sciences.

The objectives of this research have been stated. The study does not propose any theoretical model, and since a convenience sample was taken, the statistical significance of the results was not calculated.

RESULTS

Demographic Profile of the Subjects

As shown in Table 1, of the 157 college students included in the study, for the percentage who answered the question regarding gender, 48 percent are males and 52 percent are females. Among the respondents, the majority (77%) is in the 19-23 year age category. African American students make up 60 percent of the subjects, while Caucasians are about 33 percent; the rest of the subjects are in other ethnicity groups.

In the survey, 32 percent of the subjects are in the senior year of their studies, followed by 28 percent sophomores and 23 percent juniors. As the largest classification in this study, senior students give the writers a better and clearer vision of the subjects' potential impact on the hybrid automobile market.

Among all of the research subjects, 61 percent majored in business and related subjects such as management, marketing, accounting, and finance. Art and Sciences students made up 19 percent of the sample; the rest of the students are evenly distributed among engineering, education, and professional studies.

Table 1. University students' demographic profile*

Gender		Age range		Ethnicity		Classification		Major	
Male	48.30	≤ 18	6.67	Black	60.00	Fresh-man	11.26	Arts	8.67
Female	51.70	19 – 23	76.67	Hispanic	1.33	Sopho-more	27.81	Natural Science	6.67
		> 23	16.67	Asian	0.67	Junior	22.52	Social Science	3.33
				Am. Indian	2.67	Senior	31.79	Engineer-ing	6.00
				Alaskan Native	1.33	Graduate	3.31	Business	60.67
				White	33.33	Other	3.31	Education	8.00
				Other	0.67			Profess-ional	6.67

***All data reported in percentages.**

Knowledge of Hybrid Cars

Most of the subjects do have some knowledge of hybrid cars. Table 2 shows almost half (48%) classified their knowledge level of hybrid cars as *heard of, but that is about it.* Another 30 percent stated they were *familiar with* the product category. Over half knew hybrid vehicles have two energy sources, but 41% did not know. However, 70 percent know hybrid vehicles are more fuel-efficient than are their traditional counterparts.

Table 2. Knowledge of hybrid cars among students

Familiarity with hybrid cars		How many sources of energy does a hybrid car use?		Do hybrid cars get more mpg than nonhybrids?		Hybrid cars % of U.S. car market	
Expert	3.18%	One	1.56%	Yes	69.53%	< 25%	65.60%
Heard of	47.77%	Two	50.78%	No	5.47%	25 – 50%	24.00%
Familiar with	29.94%	More than two	7.03%	Don't know	25.00%	51 – 75%	10.40%
Never heard of	19.11%	Don't know	40.63%				

When the researchers asked students how they felt about the concept of hybrid cars on a scale 1 to 10 (1 being *hate* and 10 being *love*), on average, students' responses are 7 with a standard deviation of 2. This indicates most students do have some interest in hybrid cars, but it is likely the passion for owning a hybrid car is quite uneven among them.

To the extent that the sample is representative of the general population, the majority of students in North Alabama believe that the U.S. market has not stepped into the hybrid car-buying era yet since 66 percent of the students know that the sales revenue from hybrid cars is less than 25 percent of annual auto sales revenue. Because younger people are usually more influenced by their peers than are their older counterparts, this could be another reason why the North Alabama region has not been a popular area for hybrid cars.

In terms of the popular brand name hybrid cars, 11 percent of the students know Toyota's Prius, and 17 percent are familiar with the Honda Civic. Therefore, around 28 percent of the respondents recognize brand names of imported hybrid cars. On the other hand, only 7 percent of the subjects are able to name Ford's Escape as a domestic brand name of hybrid vehicle. From this finding, it is obvious that foreign automakers are doing a far better job in advertising their hybrid cars than what has been done domestically. This, in turn, is evidence of another aspect of U.S. automakers being less competitive than are their foreign competitors.

Perceptions of Hybrid Cars and Readiness for Hybrid Cars

Fifty percent of the student respondents believe the major contribution of hybrid cars is being *less dependent on foreign oil*, followed by 40 percent who believe the number one benefit is *having a cleaner environment*. All these responses appeared in Table 3 are coincident with the purpose of the auto industry's manufacturing hybrid cars. Therefore, effectiveness of the media and commercial advertisements in promoting hybrid cars is evident.

It is the common belief that hybrid cars are sold at a premium compared to their similar size, traditional, gas-fueled vehicle counterparts. When asked if they expected 1) better performance, 2) more features, or 3) both – considering the higher initial cost of hybrids – 52 percent expected better performance, 16 percent anticipated more features, and a third thought hybrid vehicles should have *both* better performance *and* more features.

One of the most interesting findings in this study is the break-even time anticipated for the fuel efficiency of hybrid cars to offset their higher initial costs. Most (59%) of the sample felt it would take between 5 and 10 years to recoup the initial higher cost of the product. Twenty-one percent thought it would take less than five years, and another 17 percent believed it would take 11 to 15 years to see the break-even milestone. Thus, this study indicates that North Alabama college students are not well aware of the period required to recover their premium if they buy a hybrid car only for its fuel efficiency. This finding was expected because news reports vary in their estimates of the break-even time and miles per gallon of various vehicles.

North Alabama university students are similar to U.S. citizens in general when it comes to whether they have more faith in the foreign or domestic automobile industry efforts to bring down the premium for hybrids. Twenty-seven percent feel foreign manufacturers are trying to reduce the initial cost, while only 19 percent believe U.S. automobile manufacturers are making reasonable efforts to reduce the amount of the premium.

Students were questioned on purchase intentions in general and for hybrids in particular. Table 4 shows sixty percent of the samples say it will be more than a year before they consider buying a vehicle, and 51 percent think they will buy a new auto rather than a used one. True to U.S. citizens in general, North Alabama college students are not enthusiastic about compact cars, with 39 percent intending to buy a mid-size car, 21 preferring a full-size car, and 27 percent planning to buy an SUV. Regarding purchase intentions for hybrids, 44 percent of the students are uncertain about the likelihood of their buying a hybrid, and 30 percent indicate they would either definitely buy one within the next three years or probably buy one within the next five years. For the respondents who indicated any interest in buying a hybrid, almost 70 percent are not sure whether they will buy an import or a domestic vehicle. Almost half say they are willing to pay between 11 and 20 percent more for a hybrid, and 24 percent indicate they will consider a smaller car to help offset the hybrid premium. When asked to choose between an upscale imported traditional car and a domestic hybrid SUV, 30 percent preferred the former, while 49 percent preferred the latter, and 22 percent favored another product type altogether.

Table 3. Perceptions of main contribution of hybrids and the hybrid price premium

Main contribution of hybrid cars to our society		With the premium, hybrid cars should have		The premium and savings will break even in	
Cleaner environment	39.68%	Better performance	51.59%	< 5 years	20.63%
Enhancing children's health	7.14%	More features	15.87%	5 – 10 years	58.73%
Less dependent on foreign oil	50.00%	Both	32.54%	11 – 15 years	16.67%
				≥16 years	3.97%

Have US automakers tried to reduce the premium		Have foreign automakers tried to reduce the premium	
Yes	18.25%	Yes	26.83%
No	27.78%	No	16.26%
Don't know	53.97%	Don't know	56.91%

Table 4. North Alabama university students' readiness for hybrid cars

Likelihood of buying a hybrid car		Domestic or foreign hybrid car		How much more are you willing to pay for a hybrid car?		Willingness to buy a smaller hybrid if a large one costs too much		Preference: foreign up-scale gas-powered car/ domestic hybrid SUV	
Definitely	6.30%	Domestic	12.82%	≤ 10%	26.09%	Yes	23.93%	Up-scale	29.57%
Probably	23.62%	Imported	17.95%	11 – 20%	47.83%	No	28.21%	Domestic	48.70%
Don't know	44.09%	Cannot decide	69.23%	21 – 30%	19.13%	Maybe	26.50%	Neither	21.73%
Probably not	18.11%			31- 40%	4.35%	Other	21.36%		
Definitely not	7.88%			≥ 41%	2.60%				

Will buy a car in…		Used or new car		Size of the car	
Now	13.42%	New	51.05%	Compact	10.42%
In 6 months	8.05%	Used	48.95%	Midsize	38.19%
In one year	10.74%			Full size	20.83%
1 – 2 years	27.52%			SUV	27.08%
More than 2 years	38.93%			Other	3.48%
Other	1.34%				

DISCUSSION

In this research study, the purpose was to get a general idea of North Alabama college students' knowledge and understanding of the relatively new fuel-efficient, environmentally friendly hybrid vehicles. The writers believe college students represent the future major consumers in this market and that hybrid vehicles are at the forefront of the future trends of new, energy efficient transportation. Therefore, a better understanding of college students' preferences will help automakers determine what types of vehicles will become big sellers in the near future.

From the demographic characteristics of the respondents, it is noted that young African American students are the majority of the sample. Given the fact that Alabama A&M University (AAMU) is one of the Historically Black Colleges and Universities (HBCUs) and AAMU provided 40 percent of the respondents, this is not a surprise. The results also indicate that more than half of the surveyed students are majors in a business discipline. Therefore, in this survey, the focus is on African American business majors.

The results show that the majority of students at least have heard about hybrid cars and know what they are. They also know the sources of fuels used in these cars. All these results clearly indicate that the hybrid carmakers are doing a very good job of informing future potential consumers about the concept of hybrid cars. The research results also show that foreign carmakers are doing a better marketing job promoting their brands of hybrid cars than any of the domestic carmakers. Therefore, it is recommended that for maximum impact, domestic hybrid carmakers enhance their advertisements, media mix, and other promotional tools.

Most students believe the main reason to buy hybrid cars is to contribute to less dependence on foreign oil and to a cleaner environment rather than to save money on gasoline. In this study, it was found that students have been misinformed about the premium charged on hybrid cars and the actual money they can save by driving hybrid cars. The researchers suggest that the media and government agencies be more honest and ethical and provide accurate mileage information, while continuing to stress environmental benefits to potential hybrid car consumers.

Students in this study are like the typical domestic consumers who want to drive larger cars or SUVs rather than midsize or compact cars. Therefore, there is reason to believe the domestic auto industry will have more success with larger cars than with small hybrids like the most popular make and model, Toyota Prius.

In general, to the writers' knowledge, this is the pioneer study relating this demographic group to the future of hybrid cars. Although a convenience sample was taken, the current statistics presented here may well represent young consumers from the North Alabama region and should well reflect U.S. college students' attitudes towards hybrid cars. A follow up study might be feasible when more information and data on car rental companies' hybrid vehicles demand report becomes available in the North Alabama region and/or for the entire country.

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REVENUE ESTIMATION PRACTICES IN THE U.S. MUNICIPAL GOVERNMENTS: FINDINGS AND IMPLICATIONS

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ABSTRACT

This study uses ICMA's 1999 Revenue Estimation Survey to examine the state of municipal revenue forecasting as well as the influence of the city size and forms of government on the use of forecasting methods in American cites. The study showed that revenue forecasting was mainly the responsibility of finance and budget officers, and that municipalities predominantly used traditional forecasting approaches such as expert and trend methods. Only 22% of the 531 municipalities surveyed used econometric methods to forecast for at least one of their revenue sources, and the method was often used to estimate sales tax. In addition, municipal forecasters perceived sales and income tax revenues as being the most difficult to forecast. It was found that city size (population) was positively associated with the use of econometric models, and reformed government (council-manager form) was not positively associated with the use of econometric models.

INTRODUCTION

The production of revenue forecasting is one of the most critical functions in local government budget. In many cities, revenue forecasting sets the stage for the upcoming year's budget deliberation. Since numerous factors affect local government revenue, accurate revenue estimation is complicated. Yet, poor forecasts may result in either a revenue shortfall or a revenue surplus. When a local government overestimates its revenue, it will be faced with raising additional revenues, cutting expenses or some combination of the two (Rodgers and Joyce, 1996; Voorhees, 2002). On the other hand, underestimation will result in a revenue surplus. Although this condition places less stress on the local government, consistent underestimation and resultant holding of excessive funds by local governments may result in citizen dissatisfaction.

Although some work has examined the practices of state revenue forecasting (Bretschneider et al. 1989; Cassidy et al. 1989; Rodgers and Joyce, 1996; Shkurti and Winefordner, 1989; Voorhees, 2002), few studies have examined the revenue forecasting practices in American cities (Forrester, 1992; McCollough, 1990). Therefore, educational and professional background of municipal forecasters, the use of revenue forecasting methods, and the influence of institutional factors (e.g., government size and forms of municipal government) is not well understood in municipal governments. This paper explores the state of municipal revenue forecasting as well as the influence of government size and municipal forms on the use of forecasting methods based on survey data obtained from the "*1999 Revenue Estimation Survey,*" which was conducted by the International City/County Management Association (ICMA). Since previous surveys on municipal forecasting practices were conducted using data from the late 1980s (Forrester, 1992; McCollough, 1990), this study provides valuable up-to-date information on the state of municipal revenue forecasting practices.

The next section describes the characteristics of sample data, the educational and professional background of municipal revenue forecasters, and the types of revenue used by sample cities. Section three discusses the types of revenue forecasting methods used, the perceived difficulty of forecasting alternative revenue sources, and the influence of population size and government structure on the use of econometric methods in municipalities. Section four concludes the paper with a discussion of avenues for future research.

DATA AND BACKGROUND INFORMATION ON MUNICIPAL REVENUE FORECASTING AND FORECASTERS

A. Characteristics of Sample Data

The ICMA's 1999 Revenue Estimation Survey was sent to chief financial officers of all municipalities with populations exceeding 25,000 as identified by the ICMA municipal government database in the summer of 1999. Of the 1,232 municipalities that received the survey, 531 responded (response rate—43%). Respondents were composed of city managers (0.6%), finance officers (76.2%), budget officers (11%), analysts/planners (1.7%), and others (10.6%). Table 1 shows the response rates by municipal population, Table 2 by geographic region, and Table 3 by metro status. As Table 1 indicates, cities with populations of 250,000 and over are under-represented in the sample. Geographically, Southern and Western cities are somewhat over-represented and Northeast and North-central cities are under-represented in the sample. In terms of metro status, non-metropolitan cities are slightly over-represented in the sample.

Table 1. Survey Response Rate by City Population

Population	# of cities surveyed	# of cities responded	response rate (%)
25,000-49,999	677	285	42.1
50,000-99,999	351	161	45.9
100,000-249,000	139	65	46.8
250,000-499,999	38	14	36.8
500,000-1,000,000	17	4	23.5
Over 1,000,000	10	2	20
Total	1232	531	43

Table 2. Survey Response Rate by Geographic Region

Geographic region	# of cities surveyed	# of cities responded	response rate (%)
Northeast	285	78	27.4
North-central	317	130	41
South	295	149	50.5
West	335	174	51.9

Table 3. Survey Response Rate by Metro Status

Metro status	# of cities surveyed	# of cities responded	response rate (%)
Central city	482	208	43.2
Suburban city	630	265	42.1
Non-metro city	120	58	48.3

B. Who Produces Revenue Estimates?

Respondents were asked "Who produces the technical estimate of revenue for the upcoming year?" and were offered the choices of city manager, finance officer, budget officer, external experts, departments, and other. The survey instrument also allowed respondents to check all of the above. Finance officers were the most cited (76%) individuals who were responsible for producing the revenue estimate, followed by budget officers (26%), city managers (9.1%), and external experts (4.2%). While most cities relied on finance or budget officers, 27.4% responded that they used individual departments (e.g., planning department, public safety, police department), which have responsibilities to provide services as well to produce revenue estimates.[1]

It should be noted that unlike state governments, which rely heavily (43 states) on outside experts (largely state university consulting) for revenue forecasting (Voorhees, 2002), municipalities relied only minimally on outside experts (22 cities or 4.1% of 531 sample cities), which confirmed previous findings by Forrester (1992). One explanation for this might be lack of financial resources for hiring of outside experts. Another reason

could be municipal officials' beliefs that external experts are no better at forecasting than are internal budget and finance personnel (Forrester, 1992). Due to the relatively small size of total revenue collection and easily identifiable revenue sources in many municipalities, experienced internal finance and budget officers may indeed be better estimators than hired outside experts (Schroeder, 1996).

Cities hiring outside experts tended to be predominately small to medium-sized. Of the 22 cities that acknowledged hiring outside experts, 11 had populations of 25,000-49,999, 6 had populations of 50,000-99,999, 3 had populations of 100,000-249,999, and only one had a population of 250,000 and over. This may be due to a lack of experienced in-house revenue forecasters or sophisticated forecasting techniques in small to medium-sized cities. In contrast, large cities can afford experienced in-house forecasters with a more sophisticated knowledge of forecasting techniques, which will lead to less need for outside experts.

Turning to educational backgrounds of municipal revenue forecasters, 57.7 % of respondents held a master's or other advanced degree, including 1.1% holding doctoral degrees. About 41.4% had completed a bachelor's degree, and only 0.6 % reported holding an associate or two-year degree. Since the survey did not ask about majors, the composition of these degree subjects or majors is unknown. The survey also shows that about 79% of the respondents were trained in forecasting methods, while 14.8% replied they were not. Of those who received training, 64.7% were trained as part of business school coursework, 63.7% had participated in stand-alone workshops or seminars in forecasting, and 40.1% received the training as part of public administration education. Regarding forecasters' professional affiliation, 95.1% of the respondents replied that they were affiliated with the Governmental Financial Officers Association (GFOA), 28.7% with International City/ County Management Association (ICMA), 3.9% with American Institute of Certified Public Accountants (AICPA), and 15.2% with others.[2] The results indicate that over half of the municipal revenue forecasters received professional education (a master's degree or higher) in their respective areas and 8 out of 10 were trained in forecasting methods.[3] It also shows that most of the municipal revenue forecasters are professionally affiliated with GFOA and ICMA.

C. Types of Revenue Used by Cities

This section briefly provides background information on the major types of revenue used by the respondent cities. Detailed analysis on the revenue structure of the sample is beyond the scope of this study. Therefore, analysis will not be addressed in this paper. Table 4 presents major tax revenues and intergovernmental aids used by municipalities in FY 1999. Nationally, 98.3% of sample cities (519) collected property taxes, 77.1% collected sales taxes (387), and 20% collected income taxes (91) in the year.[4] The data confirmed the traditional use of property taxes by almost every city, and it indicated that a growing number of states have permitted local sales tax to be instituted at one or more levels of their local governments, as is evidenced by the high percentage of sales tax collection (77.1%) in the sample cities.[5] Sales taxes were more heavily used in large cities (populations over

250,000). However, local income taxes were not common, being demonstrated by only 20% of sample cities. This is partly because not many states allow their local governments to tax income.[6] Table 4 also shows about 95% of cities received state aid and about 90% of cities received federal aid in FY 1999. Specifically, small cities (population size 25,000-49,999) tended to record a receipt of state and federal aid that was slightly below the national average.

Table 4. Cities Used Alternative Revenue Sources (%)

Population/revenue types	property	sales	income	state aid	federal aid
25,000-49,999 (n= 285)	98.7	72.3	22.9	93.2	86.7
	(278)	(194)	(56)	(260)	(235)
50,000-99,999 (n= 161)	98.8	80.8	17.1	96.1	92.80
	(158)	(122)	(22)	(148)	(141)
100,000-249,999 (n= 65)	100	84.1	15	98.4	95.2
	(64)	(53)	(9)	(62)	(60)
250,000-499,999 (n= 14)	92.9	92.9	14.3	92.9	85.7
	(13)	(13)	(2)	(13)	(12)
500,000 and over (n= 6)	100	83.3	33.3	83.3	100
	(4)	(5)	(2)	(5)	(4)
Total (n= 531)	98.3	77.1	20.0	94.8	89.7

**In calculating the percentage, missing cases are excluded in each population size.

Table 5. Types of Revenues Used by Metro Status (%)

Metro status	Property	Sales	Income	State aid	Federal aid
Central city	98.5	76.6	19.4	95.5	92.6
Suburban city	97.7	76.1	19.7	93.3	86.2
Non-metro city	100	83.3	23.5	98.3	94.7

Table 6. Types of Revenues Used by Region

Region	Property	Sales	Income	State aid	Federal aid
Northeast	98	22.4	11.9	97.4	92.6
North-central	99.2	63.3	53.4	93	88.7
South	96.6	90.3	11.5	94.4	90.8
West	98.8	97.1	4.1	95.2	92.2

Table 5 shows revenue usage patterns grouped by metro status. It is interesting to note that non-metro cities recorded a slightly higher utilization rate of all three major tax revenues (property, sales, income) than the central and suburban cities. This may be attributed to a relatively lower reliance on user charges, fees, and other nontax revenue sources in many non-metro cities compared to central and suburban cities in a metropolitan area. Many of these non-metro cities are small to medium-sized and, unlike the central and suburban cities in metropolitan areas, do not have rich nontax revenue sources (Bland, 1988; Ladd and Yinger, 1989). This size difference and lack of nontax revenue sources may have resulted in a record of relying on taxes by non-metro cities that was above the national average. Table 6 presents revenue sources by region. Since state legislation limits the revenue sources of local governments, generalizations on the use of different revenue sources by different regions can be difficult. However, the results show that sales taxes are used at a higher rate than the national average in Southern and Western cities and below national average in Northeast and North-central cities. Compared to the national average, income taxes are underutilized in Northeast, Southern, and Western cities and over-utilized in the North-central cities. The distribution of state aid is quite even across the regions while relatively few Northeast cities received federal aid in FY 1999.

USE OF REVENUE FORECASTING METHODS AND THE IMPACT OF INSTITUTIONAL FACTORS ON THE USE OF ECONOMETRIC METHODS

A. Types of Revenue Forecasting Methods Used

The survey respondents answered that each respondent used an average of 4.9 years of prior data producing revenue estimates for the upcoming year. About half of cities used less than five years of prior data and 93.4% of cities used ten years or less prior data to produce revenue estimates (Table 7). Only 6.6% of cities used more than 10 years' worth of prior data. Given that longer periods of data are required for more sophisticated forecasting methods such as econometric model (Schroeder, 1996), municipal practices of using prior year data suggest that almost half of sample cities may not be set up to use sophisticated forecasting methods that require longitudinal time series data.

Table 7. Percent of Cities that Used Prior Data in Forecasting Revenue Estimation

Years	<5 years	5-10 years	>10 years	Not specified
Percentage	49.9	43.5	2.6	3.9

The survey listed only four types of forecasting methods (expert forecasting, trend forecasting, deterministic forecasting, and econometric forecasting) and asked respondents to check all applicable forecasting methods for each source of major municipal revenues such as property tax, sales tax, state aid, federal aid, income tax, and other fees. The survey described expert forecasting as the prediction of a revenue source made by a person who is very familiar with the particular source of revenue. Trend forecasting was defined as the prediction of a revenue from a specified source based on prior changes in the revenue from that source. Deterministic forecasting was defined as the prediction of revenue based on a percentage change in social, economic, or other variables that directly affect the revenue from that source, and econometric forecasting was described as the prediction of revenue from a source based upon statistically estimated coefficients of one or more economic predictor variables.

Each forecasting method has its strengths and weaknesses, and has its niches (Schroeder, 1996). Previous research has suggested that due to the complex nature of government revenues, mathematically sophisticated models do not unconditionally outperform simpler models (Downs and Rocke, 1983). In practice, depending on the circumstances (e.g., government size, revenue size, organizational history, available forecasting techniques, staff skills), municipalities tend to pick and choose one method over another for different revenue sources.

Table 8. Forecasting Methods Used by Municipalities

Method/revenue fees	total	property	sales	state aid	federal aid	income	other
Expert	91.3% (481)	77.6%	48.3%	57.3%	46%	13.8%	64.9%
Trend	89.9% (477)	53.8%	66.7%	38.6%	24.4%	16.1%	77.5%
Deterministic	53.5% (284)	50.9%	51.9%	32.2%	17.7%	10.2%	55.5%
Econometric	21.8% (115)	34.2%	62.3%	22.8%	11.4%	10.5%	43%

Value in parenthesis in the total (first) column represent the number of cities that used the method for at least one of their revenue sources.

Table 8 indicates that traditional approaches such as expert forecasting and trend forecasting are still the predominant forecasting methods used by municipalities. It indicates 91.3% (481 out of 531 sample cities) and 89.9% (477 cities out of 531 sample cities) of respondent cities used expert forecasting and trend forecasting respectively to estimate at least one of their revenue sources. In contrast, slightly over half of the cities (53.5%--284

cities) used deterministic forecasting and only 21.8% (115 cities) of the cities employed econometric forecasting to estimate at least one of their revenue sources.

Of 481 cities that used expert forecasting methods for at least one of their revenue sources, 77.6% (373 cities) used the same method to forecast property tax, 48.3% for sales tax, 57.3% for state aid, and 46% for federal aid. Thus, the finding indicates that expert forecasting is the most heavily used method to estimate property tax. Trend forecasting seems to be heavily used to forecast sales tax. Of the 477 cities that employed trend forecasting for at least one of their revenue sources, 53.8% used the method to estimate property tax, 66.7% for sales tax, 38.6% for state aid, and 24.4% for federal aid. Deterministic forecasting was used evenly for both property tax and sales tax estimation. Of the 284 cities that used deterministic forecasting, 50.9% employed the method for property tax forecasting, 51.9% for sales tax, 32.2% for state aid, and 17.7% for federal aid. The econometric model seems to be the most favored method to forecast sales tax, as 62.3% of respondents used the method for sales tax, followed by property tax (34.2%), state aid (22.8%), and federal aid (11.4%). This suggests that forecasting sales tax requires more complex and elaborate techniques, perhaps due to the sensitivity of tax revenue to the changing economic and demographic variables.

Table 9 indicates that many cities used (or considered using) more than one method in forecasting individual revenue sources. It should be noted the percentage of cities that used more than three forecasting methods to produce revenue estimates in the case of sales tax and income tax was higher than that for either property tax or intergovernmental aids. This may suggest the relative difficulty of estimating sales and income taxes.

Table 9. Cities Used Alternative Forecasting Methods

# of methods used	property tax	sales tax	state aid	federal aid	income tax
1	52.6% (278)	39.8% (154)	52.6% (257)	51.9% (236)	58.2% (53)
2	27.9% (145)	37.7% (146)	21.5% (1050	12.1% (55)	40.6% (37)
3	12.3% (64)	19.1% (74)	5-4.5% (22)	1.8% (8)	13.2% (12)
4	2.3% (12)	6.2% (24)	2.0% (10)	1.5% (7)	5.5% (5)

Five hundred nineteen cities utilized property tax, 387 cities sales tax, 488 cities state aid, 454 cities federal aid, and 91 cities income tax. Figures in parentheses represent the number of cities using alternative forecasting methods. It appears that there were discrepancies in reporting of both revenue sources utilized as well as various methods used. Therefore, the sum of each column does not add up to exactly100%.

Table 10. Combination of Forecasting Methods Used (number of cities)

Combination of methods/revenue type	property	sales	income
Expert and trend forecasting	171	173	42
Expert and deterministic forecasting	82	83	15
Expert and econometric forecasting	24	47	9
Trend and deterministic forecasting	85	115	22
Trend and econometric forecasting	22	55	10
Deterministic and econometric	22	39	5

Table 10 shows combinations of forecasting methods used for three major municipal tax revenues (property, sales, income) in detail. It seems that the combination of expert and trend forecasting is the most widely used method for estimating the three major municipal tax revenues. The next most widely used method is a combination of trend and deterministic forecasting, followed by deterministic and econometric forecasting methods. The findings displayed in Table 9 and 10 suggest that most municipal forecasters use more than one method in estimating individual revenue sources. It also shows that disproportionately large numbers of cities still heavily rely on traditional approaches (expert or trend methods) or a combination of traditional methods (e.g., expert and trend methods). Only a few cities use more advanced techniques such as a combination of deterministic and econometric methods

B. Perceived Difficulty of Forecasting Alternative Revenue Sources

Table 11 presents municipal forecasters' perceptions on the degree of difficulty in estimating alternative revenue sources. The survey indicates that about 81% of respondents perceived that forecasting property tax was easy (37% easy and 43.2% somewhat easy), while 19% found it difficult. On the other hand, almost half of respondents (49%) replied they experienced difficulties (6.3% difficult and 42.5% somewhat difficult) in estimating the sales tax revenue. Forecasting income tax was also perceived to be tough as 40% of respondents replied having difficulties. Thus, of three major municipal tax revenues, forecasting sales tax tended to be the most difficult, followed by income and property tax. Since income and sales tax revenue is elastic to the changing income and economy (Bland, 1989; Schroeder, 1996), the tax revenue will be deeply affected by the fluctuation of income and economy in the short-term. This makes the forecasting of sales and income tax difficult. A related question in the survey also supports this perspective.

Table 11. Degree of Perceived Difficulty in Estimating Revenue Sources (%)

Revenue/difficulty	difficult	somewhat difficult	somewhat easy	easy
Property tax	3.3	15.7	43.2	37.7
Sales tax	6.3	42.5	44.8	6.5
Utility tax	5.7	28.3	55.5	10.6
Income tax	9.9	29.7	53.8	6.6
License fees	2	30.7	53.9	13.5
User fees	3.8	34.7	52.8	13.7
Federal aid	14.4	34.5	37.4	13.7
State aid	10.5	35.6	40.9	13

Asked whether the state of the economy affected the accuracy of their forecasting, 86.4% of respondents answered that the economy significantly affected their accuracy while only 14.6% disagreed. However, unlike the sales or income tax, forecasting property tax tends to be relatively less difficult, in part because property tax revenue is less sensitive to the fluctuating economy in the short-term (Schroeder, 1996). It is highly likely that the perceived difficulty in forecasting income and sales taxes may have led municipal forecasters to heavily rely on the econometric method in estimating these taxes as this method tends to generate more accurate estimates when models are well specified (Mocan and Azad, 1995; Schroeder, 1996), compared to other forecasting methods.

Estimating fees and licenses seemed not to be too difficult, as 67.4% answered they did not find it difficult to forecast the revenue. Accurate forecast of federal and state aid was as difficult as sales taxes, as 49% and 46% of respondents answered they had difficulties in forecasting federal and state aid, respectively. The perceived difficulty of forecasting federal and state aid could be attributed to the changing nature of fiscal federalism and the annually fluctuating size of intergovernmental aids to local governments.

C. Influence of Institutional Factors on the Use of Econometric Methods

A body of literature documents that institutional factors such as organizational size and form of government influence the probability and speed of adopting innovation. This includes the adoption of advanced technology in municipal governments (Moon and Bretschneider, 1997; Rogers, 1995; Svara, 1990, 1999; Weare et al. 1999). In the realm of revenue forecasting, the econometric method is often cited as the most sophisticated and innovative technique, and tends to produce a more accurate estimate than any other method if the model is properly specified (Mocan and Azad, 1995; Schroeder, 1996). Thus, this section tests the impact of two primary institutional variables (government size and the form of government) that have strongest effects on the adoption of innovation (the use of econometric method) in cities.

Impact of Government Size on the Adoption of Econometric Methods

Previous literature on technology diffusion and adoption shows that larger organizations tend to adopt new (advanced) technologies and innovations more frequently and speedily than their smaller counterparts, in part because larger cities have the advantage of greater administrative, technical, and financial resources than smaller cities in searching for alternative managerial innovations (Moon, 2002; Musso et al., 2001; Weare et al., 1999). Also, larger municipal governments with more stakeholders tend to be pressured to find ways to provide service more efficiently and effectively, which lead them to be more receptive to innovations (Moon, 2002). Although the econometric method maybe the most sophisticated and innovative forecasting technique, the employment of the method requires extensive use of economic and demographic variables such as personal income, wages, employment, retail sales, housing values, population growth, and other data for longer periods of time. Few municipal governments produce and store detailed longitudinal data, in part because they lack the administrative, technical, and financial resources to maintain and use such data for their revenue forecasting (McCollough, 1990; Schroeder, 1996). Specifically, as small cities have difficulties in providing such resources, it is hypothesized that city size will be positively associated with the use of econometric methods.

Table 12. Municipal Size and the Use of Econometric Methods

Population size	# of cities used econometric	percentage
25,000-49,999 (n= 285)	52	18.2
50,000-99,999 (n= 161)	35	21.7
100,000-249,999 (n= 65)	18	27.7
250,000-499,999 (n= 14)	7	50
500,000-over (n= 6)	3	50
Total (n= 531)	115	21.7

Table 12 shows that 50% of cities with populations over 250,000 (large cities)[7] adopted an econometric method to forecast their revenue sources. However, the average percentage of the adoption rate decreases with the decrease in city sizes. For example, 27.7% of cities with population of 100,000-24,999, 21.7% of cities with population of 50,000-99,999, and only 18.2% of cities with population of 25,000-49,999 adopted econometric methods. Overall, Table 12 suggests a casual observation that a positive association exists between the city size and the level of econometric methods adoption, which indicates larger municipal governments are more likely to be an econometric adopter. This may be because large cities which have greater administrative, technical, and financial resources can afford the use of more advanced technology than smaller cities in producing their revenue estimate. The finding in the study confirms the previous finding (McCollough, 1990) that the city size is positively related to the use of econometric methods.

Impact of Government Types on the Use of Econometric Methods

Previous research documents the influence of the type of government and its policy attitude (Moon, 2002; Svara, 1990, 1999). Professional city managers under reformed governments (e.g., council-manager type) may be more proactive in introducing technological innovations to the public sector than either the elected city mayor under the mayor-council form or council members under the commission form of city government. This is in part due to the cooperative nature of the internal process in the council-manager form of city government and the background of professional city managers (Moon, 2002). These managers tend to value administrative effectiveness, making the reformed city more receptive to managerial reforms and innovations (Moon, 2002; Svara, 1990). Given that the use of econometric models is more complex, sophisticated, innovative, and effective in producing revenue forecasts, it is hypothesized that there will be a positive association between the degree of reformedness of government and the use of econometric methods.

Table 13 indicates that 27.2% of mayor-council forms of government used econometric methods while only 19.7% (80 cities) of the council-manager form of government used econometric methods for at least one of their revenue sources. T-tests were conducted to see whether the mean differences between mayor-council government and (less reformed government form) council-manager government (reformed government form) are statistically significant.[8] The statistical results indicate that mean differences in adoption of econometric models are weakly significant ($p < 0.10$). The results seem to suggest that reformed forms of government are negatively associated with the use of econometric methods, which is against the hypothesized relationship. A further analysis is needed in order to explore why reformed government is negatively associated with the use of econometric methods.

Table 13. Forms of Government and the Use of Econometric Methods

Government structure	# of cities adopted econometrics	percentage
Mayor-council form (n= 114)	31	27.2
Council-manager (n= 407)	80	19.7
Commission (n= 7)	3	42.9
Representative town meeting (n= 3)	1	33.3

Table 14. City Size, Forms of Government, and Use of Econometric Techniques

Size/form	mayor-council	council-manager	commission	town*	total
250,000-49,999	63 (17)	215 (33)	5 (2)	2	285
50,000-99,999	32 (6)	129 (29)	0	0	161
100,000-249,999	10 (3)	53 (14)	1	1 (1)	65
250,000-499,999	5 (3)	78(3)	1 (1)	0	14
500,000-999,999	3 (1)	1 (1)	0	0	4
1.000,000 over	1 (1)	1 (0)	0	0	2
Total	114 (31)	407 (80)	7 (3)	3 (1)	531 (115)

Figures in parentheses represent the number of cities used an econometric method. Town* represent town representative form government.

Table 14 presents the distribution of sample cities that used econometric methods along with city size and forms of government. It indicates that 407 cities (76.6%) of 531 samples were comprised of the council-manager form of government, 114 cities (21.5%) mayor-council form, 7 cities commission form (1.3%), and 3 cities (0.5%) the representative town meeting form. Further analysis shows that 344 cities (77.1%) of 446 small to medium-sized cities (population under 100,000) were operating under the council-manager form of government. Thus, the finding indicates that the bulk of small-to-medium sized cities are operated under the council-manager form of government. It seems that one of the reasons why council-manager forms of government underutilized the econometric methods is their lack of proper administrative, technical, and financial resources necessary to use the econometric method as the bulk of small to medium-sized cities were largely operated under council-manager form of government. This conclusion is in part supported by the positive relations between the city size and the use of econometric methods presented in Table 12. Thus, the findings seem to suggest that city size, not the forms of government, may be the influential factor that affects the use of econometric techniques by municipalities. Previous research (McCollough, 1990) has indicated that many small to medium-sized governments tend to have small staff and are plagued by missing data. Regardless of reformedness of cities, this deficiency may have made the application of statistical methods such as econometric models beyond their capability. Although they may have kept relevant data, the lack of experience, skill, and time required to run a complex forecasting method also may have led to less utilization of econometric models in these cities.

Another possible explanation of why the council-manager form of government tended to rely less on the use of econometric methods can be found by looking at city officials' past forecasting experiences. Due to the relatively small and stable sizes of revenues in small to medium-sized council-manager cities, the use of expert forecasting

or trend forecasting methods based on experts' experience who are familiar with socio-economic and demographic situations in their cities may have produced a more accurate, efficient, and effective estimation than employing econometric methods. As a result, they may not feel the need to invest their scarce resources to employ relatively costly econometric methods to forecast their revenue estimate.

CONCLUSION

This study primarily examined the background of municipal revenue forecasters, the use of municipal revenue forecasting methods, and the influence of city size and government forms on the use of econometric methods by analyzing ICMA's 1999 Revenue Estimation Survey. The study has provided up-to-date knowledge on the state of municipal revenue forecasting practices and the influence of the size and forms of municipal government on the adoption of econometric methods.

The survey showed that revenue forecasting was mainly the responsibility of finance and budget officers rather than the realm of individual departments (e.g., planning departments), and about 58% of forecasters held a master's degree or higher and 80% received training in forecasting methods.

Traditional approaches such as expert and trend methods were the dominant forecasting techniques used in municipalities. Cities tend to use (or consider) more than one method in forecasting their revenue sources, and an expert forecasting method was the most widely utilized technique overall, followed by trend forecasting, deterministic forecasting, and econometric forecasting. Only 22% of cities used econometric models for any one of their revenue sources, and the utilization of an econometric method is quite low compared to the practices in state governments (Voorhees, 2002). For cities using econometric methods, the technique was most widely used to forecast sales tax, followed by income and property tax. The survey also indicated that sales tax is perceived as being the most difficult to forecast, and income tax is the second most difficult. Forecasting property tax was considered the easiest among the three major municipal tax revenues. The analysis also indicated forecasting federal and state aid was as difficult as sales and income tax. This suggests that revenue sources that are sensitive to a fluctuating economy (e.g., sales and income) in the short-term are difficult to estimate. Similarly, fluctuating intergovernmental aid also placed a big burden on municipal forecasters in producing accurate estimations for federal and state aids.

The study showed that city size was positively associated with the use of econometric methods, as larger cities tended to use econometric methods more heavily than the small and medium-sized cities. However, the degree of reformedness of municipal government was not positively associated with the use of econometric methods. Actually, the council-manager form of municipal government was negatively associated with the use of econometric methods, which contradicted the hypothesized relation. This relation may be due in part to the relative lack of administrative, technical, and financial resources

needed to employ econometric methods in small to medium-sized cities that are largely managed by the council-manager form of government. It may also be based on the municipal forecasters' experience that a sophisticated method does not necessarily outperform simpler models due to the complex nature of revenue generation.

To have a better understanding on the influence of the size and forms of municipal governments on the use of different forecasting methods, interviews with finance directors would be desirable. Also, as municipalities continue to improve the accuracy of their revenue forecasting, future studies need to empirically examine the forecasting accuracy of alternative methods and factors affecting accuracy. It should be noted that few studies have investigated this area at the municipal level (Bahl and Schroeder, 1984; Downs and Rocke, 1983; Khan, 1989; MacManus, 1992; Rubin, 1987).

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ENDNOTES

[1] Since the questionnaire allowed respondents to check 'all applicable', the sum of reliance on city manager (9.1%), finance officer (75.8%), budget officer (26%), external experts (4.2%), and departments (27.4%) exceeds 100%.

[2] For both the training and professional affiliation, the survey instrument allowed respondents to mark 'all applicable.'

[3] Since previous municipal surveys did not address educational background and professional affiliation of the municipal forecasters, it was hard to tell whether there was progress in the professionalization of the municipal forecasters in the past.

[4] Since several cities did not answer whether they collected the specific revenue sources, percentages appearing here excluded missing data. Three cities were missing for property tax, 29 for sales tax, and 77 for income tax.

[5] In 1999, local governments in 36 states reported they collected general sales taxes at least at one level of their local government. On the contrary, only 29 states reported they collected the general sales tax in 1989. Source: Bureau of Census, State and Local Finances: 1998-1999. Accessed from www.census.gov in October 2002.

[6] Local governments in 17 states reported they collected local income taxes in 1999. Source: Bureau of Census, State and Local Finances: 1998-1999. Accessed from www.census.gov in October 2002.

[7] Classification of city size varies among studies for different purposes. A recent study defines small cities as cities with populations less than 50,000, medium-sized cities between 50,000 and 100,000, and larger cities between 100,000 and 299,999, and largest cities with populations greater than 300,000. See Edward Glaeser and Jesse Shapiro, "City Growth and the 2000 Census: Which Places Grew and Why," Survey Series, Brookings Institution (May 2001). This study defines small cities as those cities with populations less than 50,000, medium-sized cities between 50,000 and 100,000, and large cities with populations greater than 250,000.

[8] Commission and representative town meeting forms of government are excluded from the analysis (t-test). This is because the sample size of these forms of government is too small to derive a meaningful statistical significance.

THE SYSTEMATIC POSITION OF THE MONOCOTYLEDONS INFERRED FROM 26S RNA GENE DNA SEQUENCES

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ABSTRACT

Although there is no consensus concerning the precise phylogenetic position of the monocotyledons within the angiosperms, most studies suggest that the monocotyledons are diverged from a common ancestor with a basally diverged dicotyledon group. In the present study, a high-level angiosperm phylogeny consisting of 92 terminal taxa was inferred from a data set from the first kb segment of the large ribosomal subunit (26S) rRNA gene DNA sequences. Using maximum likelihood methods this analysis recovered a best tree that suggests that the monocots are sister to a clade consisting of the eudicots and the eumagnollids. Sister to this clade is *Ceratophyllum* L. (Ceratophyllaceae).

INTRODUCTION

Current evidence suggests that the monocotyledons (monocots) are a monophyletic group (Dahlgren, 1980; Duvall et al., 1993; Chase et al., 1993; Parkinson et al., 1999). Although there is no consensus concerning the precise phylogenetic position of the monocots within the angiosperms (Angiosperm Phylogeny Group (APG), 2003), most studies suggest that the monocots are diverged from a common ancestor with a basal dicotyledon (dicot) group. For example, non-molecular-based studies have suggested that the monocots are most closely related to the Ranales (Ranunculales, Nymphaeales, Magnoliales, *Ceratophyllum* et al.) (Hutchinson, 1959), the Nymphaeales (Cronquist, 1981; Takhtajan, 1969, 1980), the Ariflorae (Thorne, 1976), the Dioscoreales (Huber, 1969), early shrubby dicotyledons (Stebbins, 1974), the Dioscoreales and the Magnoliifloreae (Dahlgren and Clifford, 1982), the Melanthiales (Thorne, 1992) and the paleoherbs (Aristolochiales, Nymphaeales, Piperales) (Behnke, 1969, 1971; Loconte and Stevenson, 1991).

DNA-based studies likewise have failed to reach a consensus as to the phylogenetic position of the monocots. For example, studies have suggested that the monocots are positioned in a clade with *Nelumbo* and *Ceratophyllum* (Hamby and Zimmer, 1992), sister to the paleoherbs (Chase et al., 1993), positioned with the Magnoliales, Laurales, Aristolochiales, Piperales, Nymphaeales in an unresolved clade (Qiu et al., 1993), sister

to either the Gunneraceae and the Dilleniaceae, the ranunculids or *Ceratophyllum* (Soltis et al., 1997), positioned with the eudicots Ceratophyllaceae, Laurales, Magnoliales and Piperales in an unresolved polytomy (APG, 1998), basal within the angiosperms (Donoghue and Mathews, 1998), sister to *Chloranthus* (Mathews and Donoghue, 1999), sister to the Laurales (Parkinson et al., 1999), positioned with the Eumagnoliids (Winterales, Laurales, Magnoliales, Chloranthales, Piperales) in an unresolved polytomy (Soltis et al., 2000), sister to *Ceratophyllum* (Zanis et al., 2003) and sister to four magnoliid groups (Canellales, Piperales, Magnoliales, Laurales) (Davis et al., 2004).

To date, the primary DNA sequences that have been used to infer higher order angiosperm phylogenies include the mitochondrial genes *atp*A, *cox*1, *SSU*, the chloroplast genes *rbc*L *psa*A, *psb*B and *atp*B, and the nuclear small ribosomal subunit (18S). Although these gene sequences have been analyzed separately and in various combinations and suggest that the monocots appear to have evolved from a common ancestor with a basally diverged dicot group, there is no consensus concerning the exact phylogenetic position of the monocots within the angiosperms.

The purpose of this study is to construct a high-level phylogeny of the major angiosperm groups with the aim to infer the phyletic position of the monocots. Large ribosomal subunit (26S) DNA gene sequences were used exclusively in a maximum likelihood analysis.

MATERIALS AND METHODS

Scientific name, voucher information, and GenBank accession numbers for the taxa analyzed in this study are listed in Table 1. Following (Chase et al., 1993; Doyle et al., 1994; Soltis et al., 1997; Soltis et al., 2000; Zanis et al., 2003) a set of gymnosperms (specifically *Gnetum* and *Ephedra* (Gnetales)) was designated as outgroup. An approximate 1 kb DNA segment of the 26S gene was sequenced for the taxa included in this analysis. This segment, which spans base positions 4-969 in *Oryza sativa* (Sugiura et al., 1985) is characterized by conserved segments and more variable expansion segments (Kuzoff et al., 1998). Sequences of the 26S gene have been shown to be informative in higher-level plant systematic studies (Kuzoff et al., 1998).

Total DNA was extracted from tissue using the CTAB method of Doyle and Doyle (1987). DNA sequences were amplified via polymerase chain reaction (PCR) (Mullis and Faloona, 1987, Saiki et al.,1988) from DNA extracted for the species listed in Table 1 with combinations of forward and reverse primers referenced in Neyland (2002). Amplification was achieved with Tfl enzyme (Epicentre Technologies, Madison, WI), using the following thermocycling protocol: a hot start at 94° C for 3 minutes; 30 amplification cycles of 94° C for 1 minute, 55° C for 1 minute; 72° C for 3.5 minutes, a terminal extension phase at 72° C and an indefinite terminal hold at 4° C. The double-stranded PCR product was purified with QIAquick (Qiagen, Hilden, Germany) using the manufacturer's protocol. Two µl of each sample was electrophoresed in a 1.0% agarose mini-gel for quantification against a known standard. Automated sequencing was conducted on an ABI Prism 377 Sequencer with XL

Upgrade (housed at Louisiana State University, Baton Rouge, LA, USA) using ABI Prism, Big Dye Terminator cycle sequencing protocol (P.E. Applied Biosystems, Foster City, CA, USA). Sequences have been deposited in the GenBank database (Table 1).

A maximum likelihood search of 1000 replicates was performed using the Phylogenetic Analysis Using Parsimony (PAUP) version 4.0b10 software (Swofford, 2002). Maximum likelihood analysis is the most computationally intensive approach to phylogenetic inference and is also one of the most valuable and robust (Stewart et al., 2001). Starting trees were obtained through step-wise addition. In this search, the transition/transversion ratio was estimated at 1.5 based on the value obtained in a preliminary parsimony-based analysis of the same data. Empirical nucleotide frequencies were used and branches less than or equal to one were collapsed.

As a measure of clade stability or robustness, bootstrap support (Felsenstein, 1985; Sanderson, 1989) was calculated. One thousand full heuristic bootstrap replications were employed in this analysis. Transition/transversion rates were calculated using MacClade software (Maddison and Maddison, 2003).

RESULTS

Alignment of sequences required the introduction of gaps that overwhelmingly occurred in the first three 26S expansion segments as defined by Kuzoff et al. (1998). After the introduction of gaps, the total length of the sequenced data set was 1029 bases. Figure 1 illustrates a gap imbedded in a variable region for a subset of sequences for a subset of taxa. Situated between nucleotide positions 125 and 143, this variable region is flanked by conserved sequences. Copies of aligned sequences are available from the author.

Table 1. Sequenced taxa used in this analysis. All specimens with indicated voucher/accession numbers were sequenced by the author and are housed at the McNeese State University (MCN) herbarium. DNA sequences from other sources are indicated in the footnotes below.

Taxon	Voucher/ accession number	GenBank accession number
Monocots		
Basal		
Acoraceae		
Acorus calamus L.	EEB 19970056	AF203679
Alismataceae		
Sagittaria graminea Michx.	R. Neyland 345	AF203680
Araceae		
Arisaema triphyllum (L.) Schott	R. Neyland 500	AF203678
Hydrochartaceae		
Limnobium spongia (Bosc) Steud.	R. Neyland 1025	AF203681
Lilioids		
Alstroemeriaceae		
Alstroemeria pulchra Sims	R. Neyland 1852	AF290586
Amaryllidaceae		
Crinum americanum L.	R. Neyland 785	AF293854
Asparagaceae		
Asparagus officinalis L.	R. Neyland 1853	AF203683
Asphodelaceae		

Asphodeline lutea (L.) Reichenb.	R. Neyland 1895	AF290584
Campynemataceae		
Campynema lineare Labill.	R. Neyland 1926	AF364029
Corsiaceae		
Corsia sp.	R. Neyland 1834	AF205514
Colchiaceae		
Colchicum autumnale L.	R. Neyland 1921	AF331971
Cyclanthaceae		
Carludovica palmata Ruiz. & Pav.	R. Neyland 1839	AF205127
Dioscoreaceae		
Dioscorea macrostachya Benth	R. Neyland 1887	AF205123
Iridaceae		
Alophia drummondii (Graham) R. C. Foster	R. Neyland 1851	AF203685
Liliaceae		
Lilium michauxii Poir.	R. Neyland 1822	AF205126
Orchidaceae		
Listera australis Lindl.	R. Neyland 1689	AF203686
Cypripedium kentuckiensis C. F .Reed	R. Neyland 1821	AF205119
Smilacaceae		
Smilax bona-nox L.	R. Neyland 486	AF293852
Taccaceae		
Tacca chantrieri André	R. Neyland 1842	AF205124
Commelinoids		
Anarthriaceae		
Anarthria humilis R. Br.	B. G. Briggs 9476	AF466389
Arecaceae		
Trachycarpus fortunei (Hook.) H. Wendl.	R. Neyland 1885	AF290588
Wodyetia bifurcata A. K. Irvine	R. Neyland 1885	AF290588
Cannaceae		
Canna flaccida Salisb.	R. Neyland 363	AF205521
Centrolepidaceae		
Centrolepis strigosa Roem. & Schult.	B. G. Briggs 9132	AF466388
Commelinaceae		
Commelina virginica L.	R. Neyland 901	AF205516
Cyperaceae		
Rhynchospora latifolia (Baldwin) Thomas	R. Neyland 301	AF205518
Ecdiocoleaceae		
Ecdeicolea monostachya F. Muell	K. A. Meany T20	AF466387
Eriocaulaceae		
Eriocaulon decangulare L.	R. Neyland 796	AY079519
Haemodoraceae		
Anigozanthus flavidus DC.	R. Neyland 1884	AF290587
Juncaceae		
Juncus effusus L.	R. Neyland 453	AF205520
Musaceae		
Musa paradisica L.	R. Neyland 1916	AF331972
Philydraceae		

Philydrum lanuginosum Gaertn.	Graham & Barrett 1	AF205519
Poaceae		
Oryza sativa L.	e	M11585
Pontederiaceae		
Pontederia cordata L.	R. Neyland 266	AF205517
Restionaceae		
Restio tetraphyllus Labill.	M. Chase 560	AF486829
Velloziaceae		
Xerophyta retinervis Bak.	EEB 19970041	AF205878
Xyridaceae		
Xyris laxifolia var. iridifolia (Chapm.) Kral	R. Neyland 325	AF66386
Zingiberaceae		
Zingiber officinalis Roscoe	R. Neyland 1840	AF205522
Dicots		
Basal		
Amborellaceae		
Amborella trichopoda Baill.	a	AF479238
Austrobaileyaceae		
Austrobaileya scandens C. T. White	f	AY095452
Canellales		
Winteraceae		
Drimys winteri J. R. Forst. & G. Forst.	d	AF036491
Tasmannia insipida R. Br. ex DC.	f	AY095469
Ceratophyllaceae		
Ceratophyllum demersum L.	f	AY095456
Chloranthales		
Chloranthaceae		
Chloranthus multistachys S. J. Pei	f	AY095457
Hedyosmum bonplandianum H. B. K.	f	AY095461
Laurales		
Lauraceae		
Sassafras albidum (Nutt.) Nees	e	AF264140
Monimaceae		
Hortonia floribunda Wight ex Arn.	f	AF264143
Magnoliales		
Annonaceae	f	AF264140
Asimina triloba (L.) Dunal	f	AY095451
Magnoliaceae		
Magnolia denudata Desr.	b	AF389256
Nymphaeales		
Nymphaeaceae		
Nuphar sp.	g	AY292901
Nymphaea sp.	f	AY095465
Piperales		
Aristolochiaceae		
Aristolochia macrophylla Lam.	f	AY095450
Piperaceae		

Piper betle L.	f	AY095467
Saururaceae		
Saururus cernuus L.	f	AY095468
Eudicots		
Asclepiadaceae		
Asclepias viridis Walt.	R. Neyland 1759	AF148280
Asteraceae		
Tragopogon dubius Scop.	d	AF036493
Boraginaceae		
Heliotropium curvassicum L.	R. Neyland 1309	AF148274
Buxaceae		
Buxus sp.	f	AY292911
Pachysandra procumbens Michx.	b	AF389244
Cactaceae		
Pereskia aculeata P. Mill.	a	AF479092
Campanulaceae		
Lobelia puberula Michx.	R. Neyland 1122	AF148276
Caricaceae		
Carica papaya L.	a	AF479145
Caryophyllaceae		
Stellaria media (L.) Cirillo.	a	AF479084
Convolvulaceae		
Evolvulus sericeous Sw.	R. Neyland 1761	AF148270
Ipomoea lacunosa L.	R. Neyland 1492	AF146016
Cucurbitaceae		
Cucurbita pepo L.	a	AF479108
Cyrillaceae		
Cyrilla racemiflora L.	R. Neyland 856	AY561838
Ericaceae		
Arctostaphylos uva-ursi (L.) Spreng.	R. Neyland 2094	AY596455
Euphorbiaceae		
Euphorbia polychroma A. Kerner	a	AF479125
Hydrophyllaceae		
Phacelia hirsuta Nutt.	R. Neyland 480	AF146533
Iteaceae		
Itea virginica L.	a	AF479216
Lythraceae		
Lythrum salicaria L.	a	AF479240
Malvaceae		
Sterculia apetala (Jacq.) H. Karst	a	AF479137
Menispermaceae		
Menispermum canadense L.	b	AF389257
Menyanthaceae		
Nymphoides aquatica (J. F. Gmel.) Kuntze	R. Neyland 1813	AF148283
Nelumbonaceae		
Nelumbo lutea (Willd.) Pers.	b	AF389259
Oxalidaceae		

Oxalis dillenii Jacq.	a	AF479230
Plantaginaceae		
Plantago virginica L.	R. Neyland 444	AF148277
Platanaceae		
Platanus occidentalis L.	c	AF274662
Poleminiaceae		
Phlox divaricata L.	R. Neyland 1812	AF148281
Ranunculaceae		
Ranunculus recurvatus Poir.	h	U52631
Rubiaceae		
Mitchella repens L.	R. Neyland 276	AF148279
Rutaceae		
Citrus aurantium L.	a	AY177420
Saxifragaceae		
Saxifraga mertensiana Bong.	a	AF479224
Scrophulariaceae		
Mazus pumilus (Burm. f.) Steenis	R. Neyland 368	AF148278
Solanaceae		
Physalis angulata L.	R. Neyland 355	AF148271
Outgroup		
Ephedraceae		
Ephedra distachya L.	d	AF036489
Gnetaceae		
Gnetum gnemon L.	d	AF036488

Soltis et. al. (2003) = a; Kim et al. (2004) = b; Fishbein et al. (2001) = c; Kuzoff et al. (1998) = d, Sugiura et al. (1985) = e; Zanis et al. (2003) = f; Qiu et al. (1993) = g; Ro et al. (1997) = h.

From the maximum likelihood analysis, the score of the best tree found had a log likelihood value of -24735.98808. This maximum likelihood tree suggests that the monocots are monophyletic and are sister to a clade composed of the eudicots, and the eumagnoliids Fig. 2). The eumagnoliids are an informal group composed of the Canellales,

	119	125/----------Variable Region with Gap---------/ 143	149
Restio	A A T C G G G T G G G T T G C G C C - C T G T C C G A A T T G		
Gnetum	A A T C T G G C G G C G G T C G - - - C G G C C C G A A T T G		
Ephedra	A A T C G G G C G G T C C T T G C G G C C G T T C G A A T T G		
Ceratophyllum	A A T C G G A T G G T C C T G - - - - C C A T C C G A A T T G		

Figure 1. Illustrates a gap imbedded in a variable region for a subset of sequences for a subset of taxa. Situated between nucleotide positions 125 and 143, this variable region is flanked by conserved sequences.

Laurales, Magnoliales, Piperales and Chloranthales (sensu Soltis et al., 2000). Sister to this clade is *Ceratophyllum* L. (Ceratophyllaceae). The branch leading to the monocot split received less than 50% bootstrap support and is, therefore, not strongly supported (Fig. 2).

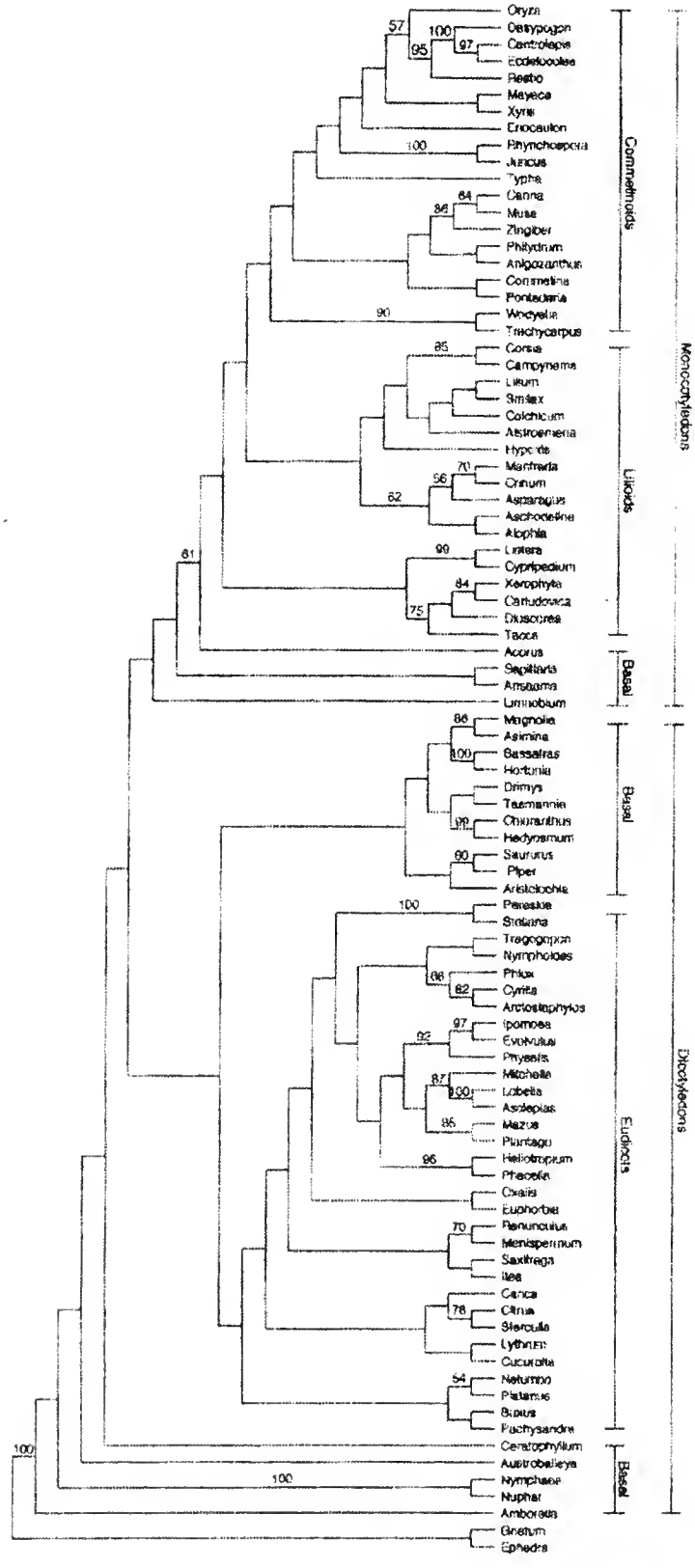

Figure 2. The best tree (log likelihood value of -24735.98808) from a maximum likelihood search. Bootstrap values greater than 50% are indicated above each branch.

DISCUSSION

The best maximum likelihood tree recovered in this study generally agrees with other molecular-based studies that place the monocots within or near the basal dicots. However, as is evident from the above referenced previous molecular-based studies and the present study, there remains no consensus on the exact phylogenetic position of the monocots within the angiosperms. This disparity likely is due to several factors. For example, because the monocots represent an ancient group, there is certainly homoplastic noise in the sequence data due to nucleotide base reversals. Additionally, the use of different genes and genomes and the employment of disparate sequence analysis methods in these studies may have contributed to the variation in the recovered phylogenetic relationships. Inferring phylogenetic relationships from molecular data requires the selection of an appropriate method from an array of techniques (Swofford and Olsen, 1990). Of the existing approaches to inferring phylogenies directly from character data, that of maximum parsimony has been the most widely used. However, parsimony methods may yield inconsistent estimates of the evolutionary tree when amounts of evolutionary change in different lineages are sufficiently unequal (Felsenstein, 1978; Hasegawa and Fujiwara, 1993). When data sets involve moderate to large amounts of change, parsimony methods can fail (Felsenstein, 1985). For example, in their phylogenetic study of seed plants using sequences from all three plant genomes, Soltis et al. (2002) found that maximum likelihood analyses of chloroplast sequences produced topologies highly similar to those produced from mitochondrial sequences. However, parsimony analyses using chloroplast DNA produced similar results only when the more degenerate third codon position was eliminated from the data set. Soltis et al., (2002) concluded that third codon positions in chloroplast DNA genes may be misleading in phylogenetic analyses of seed plants. Because ribosome genes (as used in the present study) are not framed into codons, the elimination of third codon positions to reduce homoplastic noise is not applicable in 26S-based phylogenetic analyses.

Although fossil pollen suggests that a monocot-dicot dichotomy may have occurred as late as 90-112 MYA in the Cretaceous (Cronquist, 1981; Gandolfo et al., 1998). molecular analyses often suggest an older date. An analysis of chloroplast sequences by Wolfe et al. (1989) suggests that the split may have occurred about 190 MYA in the Jurassic. An analysis of GADPH sequences by Martin et al. (1989) suggests that the dichotomy occurred about 300 MYA in the Carboniferous. The oldest date for the monocot-dicot divergence has been estimated at 360 MYA near the Devonian-Carboniferous boundary from an analysis of rRNA gene sequences (Troitsky et al., 1991). Regardless of this disparity, the monocots are an ancient group and a substantial number of homoplastic reversals undoubtedly have occurred in their DNA sequences. Therefore, the use of the maximum likelihood method may recover more reliable phylogenies than that of the parsimony method at this particular level of investigation.

An additional problem in determining the phylogenetic position of the monocots within the angiosperms is designating an appropriate outgroup. Several previously

mentioned studies have used various gymnosperm groups (particularly the Gnetales) as outgroup. However, no gymnosperm group has been identified as sister to angiosperms (Stuessy, 2004). Indeed, several recent studies suggest that the Gnetales are sister to other conifers and not the angiosperms (Goremykin et al., 1996; Hansen et al., 1999; Samigullin et al., 1999; Winter at al., 1999; Bowe et al., 2000; Schmidt and Schneider-Poetsch, 2002; Soltis et al., 2002). Therefore, studies that position the Gnetales as sister to the angiosperms may recover misleading phylogenies (including the position of the monocotyledons).

Mathews and Donoghue (1999) noted that the great differences between angiosperms and all other seed plants render homology assessments exceptionally difficult in morphological analyses and may lead to long-branch attraction (sensu Felsenstein, 1978) in molecular analyses. This may result in the spurious attraction among highly diverged sequences. More specifically, distant conifer outgroups might cluster erroneously with the most diverged angiosperms. However, in an attempt to overcome this problem, Mathews and Donoghue (1999) presented an analysis of duplicated phytochrome PHYA and PHYC gene sequences to root the angiosperms. Their results suggested that *Amborella* is the most basally diverged angiosperm. Furthermore, other molecular-based studies that used conifers to outgroup the angiosperms have also recovered trees that show *Amborella* as the most basally diverged angiosperm (Parkinson, 1999; Soltis et al., 2000; Zanis et al., 2003 and the present study). If angiosperm trees are to be rooted in molecular-based phylogenetic analyses, then there appear to be few alternatives to using extant conifer sequences as outgroup.

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THE EFFECT OF FOREST MID-STORY REDUCTION ON BREEDING BIRD POPULATIONS IN MONTANE LONGLEAF PINE STANDS OF THE TALLADEGA NATIONAL FOREST, ALABAMA

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ABSTRACT

The effect of mid-story reduction in a montane longleaf pine forest on bird species richness and habitat characteristics was examined on the Shoal Creek Ranger District, Talladega National Forest. Sites in which the mid-story had been removed mechanically or by fire (treated) and sites with a dense mid-story remaining (untreated) were compared. Bird species such as the American robin (*Turdus migratorius*), Bachman's sparrow (*Aimophila aestivalis*), common yellowthroat (*Geothlypis trichas*), Eastern bluebird (*Sialia sialis*), and Northern bobwhite (*Colinus virginianus*) were detected only in treated stands, while Acadian flycatcher (*Empidonax virescens*), wood thrush (*Hylocichla mustelina*), yellow-billed cuckoo (*Coccyzus americanus*), and yellow-throated vireo (*Vireo flavifrons*) were detected only in untreated stands. The remaining species were found in both management types. The habitat characteristics most strongly related to the management regimes and thus to the breeding bird assemblages were hardwood basal area and the midstory density at 7.5 m above the ground. Changes in vertical structure did influence the assemblages of breeding birds. The influence of mid-story removal should be considered when making management decisions

INTRODUCTION

Longleaf pine (*Pinus palustris*) forest communities are one of the most diverse ecotypes in temperate North America, providing critical habitat for many threatened and endemic species (Peet and Allard 1993, Noss 1988). It has been estimated that longleaf forest systems occupied as much as 90 million acres before European settlement (Frost 1993). Logging, agricultural clearing, turpentining, and grazing by feral swine have reduced the longleaf ecosystem to approximately 3.2 million acres (Outcalt and Outcalt 1994). Much of the remaining acreage has been altered from its original condition by forest fragmentation and fire suppression.

Longleaf pine forests historically ranged from Virginia southward to Florida, and westward into Texas, and occupied most of the Coastal Plain (Frost 1993). Longleaf forest also occupied mountainous topography in parts of Alabama and Georgia (Shankman and Wills 1995, Frost 1993). In the mountains, longleaf occurred along ridge-tops and dry slopes with relatively poor, shallow soils and low water-holding capacities (Shankman and Wills 1995). These drier sites were more prone to periodic lightning fires than were the deeper, moister soils of the bottoms and valleys that supported hardwood forests. Native Americans also initiated burns in these areas in order to improve game habitat and reduce undergrowth (Harper 1958, Cowdrey 1983). It was these fires (natural and human-initiated) that maintained the integrity of the longleaf stands, as they eventually were replaced by other forest types in the absence of fire (Christensen 1981). Historically, montane longleaf forests are thought to have resembled the open, park-like longleaf forests of the Coastal Plain (Shankman and Wills 1995).

To increase and restore the habitat of the red-cockaded woodpecker (*Picoides borealis*), the US Forest Service is conducting hardwood mid-story reductions and rotational burning in upland pine-dominated habitats. Typically, these hardwood midstory reductions are achieved by felling of hardwoods (<22-cm diameter at breast height [dbh]). Prescribed burning is then used to maintain the open understory. These practices increase the amount of sunlight reaching the forest floor and generally promote the growth of herbaceous plant species (Engstrom et al. 1984). Such management practices should affect breeding bird communities. Cover and food resources should change through the reduction of the midstory layer and the release of the herbaceous and low-shrub layers. The effects of hardwood midstory management on breeding birds have been studied to some extent in Coastal Plain longleaf communities (Hill 1998a, Dunning and Watts 1990, Engstrom et al. 1984). However, the effects of forest management on birds that breed in montane longleaf stands are still virtually unknown. Hill (1998) observed higher bird species richness in mature and recently established longleaf pine stands than in hardwood stands in the Talladega Mountains. However, no previous study has examined the effects of hardwood mid-story removal in fire-suppressed, longleaf pine stands on overall breeding bird communities in the Talladega Mountains. This study examines avian presence, species richness, and woody plant community structure in two montane longleaf pine management regimes: open-canopy stands with little or no hardwood mid-story (treated) and stands with a dense, mixed hardwood mid-story (untreated).

METHODS AND MATERIALS

Study Area

The study was conducted within the Shoal Creek Ranger District of the Talladega National Forest in Calhoun and Cleburne Counties, Alabama. This area is composed of mixed-hardwood and pine forests with elevations ranging from about 200 m to 560 m. Fifty-seven 100m X100m plots were established within montane longleaf stands, 29 of which were located in unmanaged longleaf stands with at least moderate hardwood mid-story densities

(untreated sites). The remaining 28 points were located in treated longleaf stands that had been regularly burned or had received mechanical mid-story reduction. Only upland, montane longleaf stands occupying upper slopes, ridges, or bluffs were considered for the study. Stand area ranged from approximately 2.4 to 32 hectares. Due to the dendritic arrangement and clinal variation of most of the longleaf stands across the landscape, this study did not attempt to correlate stand size and avian community characteristics.

Bird Surveys

Breeding bird surveys were conducted for two years (2002 and 2003) during a period (beginning 10 May and ending 12 June) when all birds in the area were assumed to be potential breeding individuals. Each of the 57 plots was sampled once per season by the same observer. A point count was conducted from the center of each plot following the technique described by Ralph (1993) and Hamel et al. (1996) in which the observer records all birds detected within a ten-minute period. Next, a 50-minute walking inventory of the entire 100m x 100m plot was performed. Flyovers and transients were not included. All point counts and plot inventories were conducted in the morning from twenty minutes before sunrise until 1030 CST. Birds were detected by sight and sound. Plots were surveyed in a mixed alternating sequence between treated and untreated stands to minimize photoperiod and weather biases. Survey points were spaced at least 300 m away from each other and at least 60 m away from frequently-used Forest Service roads to minimize disturbance from traffic.

Habitat Assessment

Habitat variables were measured for each of the plots on the same date of the respective census. Measurements were taken from the plot center. Hardwood and pine basal area, mid-story density, and canopy cover were measured following a modified version of that described by Hamel et al. (1996). Mid-story density (vegetation profile) was estimated using a version of the "checkerboard" method (Hamel et al. 1996). With this technique, a 0.5-m by 0.5-m board is gridded with 25 equal squares against which foliage coverage is read at three heights (0, 2.5, and 5 m) from the center of the plot at a distance of 10 m in each of the cardinal directions. Due to the open nature of the longleaf stands, this technique was expanded in the second study season to include one 7.5-meter reading in each of the cardinal directions at 10 m and a repeat of the four elevations (0, 2.5, 5, 7.5m) at 20m from point center. Basal areas of pines and hardwoods were measured with a 10 basal area prism to determine square feet per acre and then converted to metric units (10 ft^2 English = 2.296 m^2). Percent cover of overstory, midstory, shrub, and herbaceous layers was placed into categories (0 = 0%; 1 = 1 to 25%; 2 = 26 to 50%; 3 = 51 to 75%; 4 = 76 to 100%) based on ocular estimation (Hamel et al. 1996). In addition, the presence or absence of dominant plant species was recorded for each plot.

Data Analysis

Bird communities in the treated and untreated sites were compared using Sorensen

and Jaccard indices to estimate similarity between the two community types (Brower et al. 1997). Total species richness (S) was defined as the total number of species recorded within treatment types over both years.

A t-test (p=0.05) was used to compare mean basal areas and midstory densities of vegetation in plots between the two treatment types. The Mann-Whitney test statistic was used to compare the strata cover values between the two treatment types.

Stepwise discriminant analysis (p=0.05) was used to determine which habitat variables were most strongly related to the two management regimes. Stepwise discriminant analysis initially selects the variable that produces the greatest discrimination between bird communities (treated vs. untreated). The first variable is then paired with each of the remaining variables to locate the combination that produces the greatest discrimination. This procedure continues until all possible variables have been selected or the remaining variables do not contribute to discrimination (Klecka 1980). Those variables significant at the 0.05 level were considered to be diagnostic for the group (treated vs. untreated).

RESULTS

Bird Populations and Abundance

A total of 48 bird species were recorded over the two study seasons. Total breeding bird species richness was similar (treated; S=44, untreated; S=41) for both treatment types. Communities expressed some similarity between species assemblages (Sorensen coefficient; CC_s=0.831, Jaccard coefficient; CC_j=0.712) as reflected in the species found in both treatment types (Table 1). Overall, 7 species were found exclusively in treated stands, and 4 species were found only in untreated sites (Tables 2 and 3).

Habitat Characteristics

Mean hardwood basal area of the treated and untreated stands was significantly different at 0.52 and 5.71 m^2/ha, respectively. Mean conifer basal area was similar between the two management types (Table 4). Hardwood mid-story densities differed significantly among treatments at the 0, 5.0, and 7.5 m levels at both the 10m and 20m reference distances (Table 4). Neither canopy height nor overstory dbh differed significantly between treatment types. Through stepwise discriminant analysis, it was determined that the vegetation variables most strongly related to the treatment types and thus the bird assemblages were hardwood basal area and midstory density at 7.5 m.

The plant species composition was different in the treated and untreated sites. Treated sites had a relatively open overstory of predominantly longleaf pine. Blackgum (*Nyssa sylvatica*; occurrence rate, OR=92.9%), sourwood (*Oxydendrum arboretum*; OR=92.9%), and blackjack oak (*Quercus marilandica*; OR=89.3) were the most frequently recorded hardwood species in treated stands. Lowbush blueberry (*Vaccinium pallidum*; OR=100%) was the most common shrub, and bracken fern (*Pteridium aquilinum*; OR=100%) and bluestems (*Andropogon* spp., *Schizachirum* spp.; OR=92.9%) were the most common ground covers. Untreated sites were generally occupied by predominantly

longleaf pine overstory with a dense midstory (Table 1). The most common trees in untreated sites were red maple (*Acer rubrum*; OR=96.6%), blackgum (OR=89.7%), blackjack oak (OR=89.7%) and sourwood (OR=89.7%). Lowbush blueberry (OR=100%) was the most common shrub, and bracken fern (OR=100%) and catbrier (*Smilax* spp.; OR=79.3%) were the most commonly detected ground covers.

Table 1. Breeding bird species present in treated and untreated montane longleaf pine stands on the Talladega National Forest, AL in 2002 and 2003 and their nesting and feeding guilds*.

Common Name	Scientific Name	Nesting Guild	Foraging Guild
American crow	*Corvus brachyrhynchos*	T	GO
American goldfinch	*Carduelis tristis*	S	I/Gr
Black-throated green warbler	*Dendroica virens*	T	AI
Black-and-white warbler	*Mniotilta varia*	G	BI
Blue jay	*Cyanocitta cristata*	T	AO
Blue-gray gnatcatcher	*Polioptila caerulea*	T	AI
Blue-headed Vireo	*Vireo solitarius*	T/S	AI
Brown thrasher	*Toxostoma rufum*	S	GO/SO
Brown-headed cowbird	*Molothrus ater*	T/S	GO
Brown-headed nuthatch	*Sitta pusilla*	C	AI/BI
Carolina chickadee	*Poecile carolinensis*	C	AI
Carolina wren	*Thryothurus ludovicianus*	C	GI/SI
Chipping sparrow	*Spizella passerina*	S/G	GI/Gr
Downy woodpecker	*Picoides pubescens*	C	BI
Eastern towhee	*Piplio erythrophthalmus*	S/G	GO/SO
Eastern wood-peewee	*Contopus sordidulus*		T AI
Great-crested flycatcher	*Myiarchus crinitus*	C	AI
Hairy woodpecker	*Picoides villosus*	C	BI
Hooded warbler	*Wilsonia citrina*	S	AI/SI
Indigo bunting	*Passerina cyanea*	S	SO/Gr
Mourning dove	*Zenaida macroura*	S	GGr
Northern cardinal	*Cardinalis cardinalis* GO/SO/Gr		S
Northern flicker	*Colaptes auratus*	C	BI/GI
Ovenbird	*Seiurus aurocapillus*		G GI
Pine warbler	*Dendroica pinus*	T	AO
Prairie warbler	*Dendroica discolor*	S	SI
Red-bellied woodpecker	*Melanerpes carolinus*	C	BI
Red-headed woodpecker	*Melanerpes erythrocephalus*	C	BI
Red-eyed vireo	*Vireo olivaceus*	T	AI
Ruby-throated hummingbird	*Archilochus colubris*	T/S	N
Scarlet tanager	*Piranga olivacea*	T	AI
Summer tanager	*Piranga rubra*	T	AI
Tufted titmouse	*Baeolophus bicolor*	S	AI/AO
White-breasted nuthatch	*Sitta carolinensis*	C	BI
White-eyed vireo	*Vireo griseus*	S	SI
Yellow-breasted chat	*Icteria virens*	S	SI/SO
Yellow-throated warbler	*Dendroica dominica*		T AI/BI

*T=tree, S=shrub, G=ground, C=cavity, A=arboreal, B=bark, Gr=granivore, I=insectivore, N=nectivore, O=omnivore

Table 2. Breeding bird species present in treated montane longleaf pine stands on the Talladega National Forest, AL in 2002 and 2003 and their nesting and feeding guilds*.

Common Name	Scientific Name	Nesting Guild	Foraging Guild
American robin	*Turdus migratorius*	S	GI/AO
Bachman's sparrow	*Aimophila aestivalis*	G	GI/Gr
Common yellowthroat	*Geothlypis trichas*	S/G	SI
Eastern bluebird	*Sialia sialis*	C	GI
Northern bobwhite	*Colinus virginianus*	G	GO
Red-cockaded woodpecker	*Picoides borealis*	C	BI
Worm-eating warbler	*Helmitheros vermivorus*	G	GI/SI

*S=shrub, G=ground, C=cavity, B=bark, Gr=granivore, I=insectivore, O=omnivore

Table 3. Breeding bird species present in untreated montane longleaf pine stands on the Talladega National Forest, AL in 2002 and 2003 and their nesting and feeding guilds*.

Common Name	Scientific Name	Nesting Guild	Foraging Guild
Acadian flycatcher	*Empidonax virescens*	T	AI
Wood thrush	*Hylocichla mustelina*	S	GI
Yellow-billed cuckoo	*Coccyzus americanus*	T	AI
Yellow-throated vireo	*Vireo flavifrons*	T	AI

*T=tree, S=shrub, G=ground, A=arboreal, I=insectivore

Species and Guilds Among Treatments

Bird species detected only in untreated sites (Table 3) preferred to nest in trees and shrubs (Hamel 1992). Likewise, they were primarily arboreal insectivores with the exception of the wood thrush, a ground feeding insectivore (Table 3). The wood thrush typically feeds on the ground beneath a dense tree and shrub layer (Hamel 1992). The untreated sites typically had a mid-story that was significantly denser than treated sites (Table 4). Bird species detected exclusively in treated sites (Table 2) were shrub, ground, or canopy nesters (Hamel 1992). While there was no statistical difference between shrub cover values or densities at 0 and 2.5 m for the management regimes (Table 4), the reduced density and cover values of overstory and midstory favored those species nesting on the ground or in shrubs. Also, all species detected only in treated sites, except the red-cockaded woodpecker, are ground or shrub foragers (Table 2).

Table 4. Habitat variable means (± SD) of hardwood-thinned montane longleaf pine stands (Treated) versus unthinned longleaf stands (Untreated) on the Talladega National Forest, AL in 2002 and 2003 and t-test results*.

Habitat Variable	Mean ± SD		*P* value
	Treated	*Untreated*	
Overstory DBH (cm)	30.20 ± 4.11	29.36 ± 3.12	0.296
Overstory height (m)	16.80 ± 1.55	16.96 ± 1.35	0.507
Basal area (m^2/ha)			
Hardwood	0.52 ± 0.90	5.71 ± 4.11	<0.001
Conifer	12.49 ± 4.75	13.38 ± 5.29	0.342
Canopy cover value*			
Overstory (>8.8m)	2.76 ± 0.62	3.65 ± 0.67	<0.001
Midstory (2.4-8.8m)	2.21 ± 0.46	3.38 ± 0.77	<0.001
Shrub (0.4-2.4m)	2.89 ± 0.97	2.79 ± 0.88	0.787
Herb (>.4m)	4.5 ± 0.74	3.33 ± 0.93	<0.001
Midstory density (% at 10m reference)			
0m	69.11 ± 18.17	60.77 ± 24.89	0.046
2.5m	22.41 ± 25.45	35.42 ± 27.17	0.007
5m	9.57 ± 16.42	29.77 ± 20.99	<0.001
7m	8.18 ± 12.58	35.52 ± 24.16	<0.001
Midstory density (% at 20m reference)			
0m	82.53 ± 19.11	68.45 ± 22.88	0.006
2.5m	36.25 ± 32.81	39.86 ± 31.41	0.678
5m	15.14 ± 20.45	35.76 ± 21.53	0.0006
7m	14.36 ± 13.44	52.93 ± 23.30	<0.001

* Cover Values were tested with Mann-Whitney statistic. All other values were tested with a t-test.

DISCUSSION

In a study in south Mississippi (Wood et al. 2004) found greater abundances of Bachman's sparrow and common yellowthroat in sites with mid-story removal. Species such as the Acadian flycatcher was more common in pine stands with dense mid-stories. White et al. (1999) compared burned and unburned stands in the Georgia Piedmont. As in this study, certain species showed preference for burned sites. Bachman's sparrow was strongly associated with burned sites, while yellow-billed cuckoo was strongly associated with unburned sites.

It appears that open montane longleaf stands maintained by fire or mechanical midstory removal produce a predictable assemblage by providing a dense herbaceous ground cover. However, a large percentage of the species found in mature, open, longleaf communities do not directly utilize its dense herbaceous and shrub layers. Although a large

proportion of the macroarthropod prey that is located on or within the arboreal longleaf substrate migrates there from the herbaceous and shrub layers (Hanula and Franzreb, 1998). Species such as pine warbler, yellow-throated warbler, brown-headed nuthatch, summer tanager, and Northern flicker utilize the longleaf trunks, limbs, and foliage for foraging and nesting. These birds contributed to the high species richness of open montane longleaf stands and would probably be rare or absent in treeless systems. This study suggests that avian richness is also high in hardwood-encroached longleaf stands. The loss of a dense herbaceous layer in these communities is compensated by the increase in vertical structure and leaf area throughout the understory as predicted by MacArthur and MacArthur (1961). The yellow-billed cuckoo and yellow-throated vireo are deciduous leaf gleaners, and the reduction of vertical structure and leaf area is likely a cause of their decreased abundances in the treated stands. Treated stands provided little vertical structure but maintained dense herbaceous and low-shrub layers (Table 4) which yielded high arthropod biomass, seeds, and nesting cover (Yarrow and Yarrow, 1999).

CONCLUSIONS

Management strategies to reduce mid-story density and provide habitat for the red-cockaded woodpeckers creates an open longleaf canopy and a dense herbaceous ground cover. Bird species such as American robin, Bachman's sparrow, common yellowthroat, Eastern bluebird, and Northern bobwhite are favored by this strategy (Table 2). Other species such as the Acadian flycatcher, wood thrush, yellow-billed cuckoo, and yellow-throated vireo were never detected in the stands with lower density midstory (Table 3). This indicates that the vertical structure of both management regimes (treated and untreated) is likely required to maintain bird species richness in the study area.

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FIVE MILE CREEK BIOASSESSMENT STUDY: BASELINE EVALUATION OF STREAM HEALTH USING FISH COMMUNITIES

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ABSTRACT

During fall 2005 and spring 2006, habitat assessments and fish bioassessments were conducted at six sites on Five Mile Creek in Jefferson County, Alabama and two sites on nearby rural streams. Habitat scores and index of biotic integrity (IBI) scores for the fish communities were calculated for all sites. The Five Mile Creek sites all had IBI scores lower than those of the rural streams, suggestive of impairment. Impairment did not appear to result primarily from habitat degradation as the habitat scores for the Five Mile Creek sites were similar to those of the reference streams. The IBI and habitat scores for each of the Five Mile Creek sites were not correlated, further supporting the idea that the impairment of the fish populations was primarily due to poor water quality. Five Mile Creek IBI scores were highest at the three downstream sites. Land use analysis indicated that most of the land in the upper portion of the watershed was residential and industrial as compared to more rural in the downstream portions of the watershed. We conclude that urban nonpoint source and industrial point source pollutants have been the main sources of water quality impairment on Five Mile Creek.

INTRODUCTION

Five Mile Creek lies in the Warrior River basin and drains 20,202 hectares of Jefferson County, Alabama. The creek originates at the eastern base of Red Mountain, and there is considerable urban and industrial development in the upper part of the watershed. Historically, industrial discharges, improperly treated sewage, runoff from coal mines and urban development have all contributed to impairment of both the water and aquatic habitat quality of Five Mile Creek.

Sloss Industries (a coke producing facility in Tarrant) has been identified as a major contributor to the degradation of the stream. During an assessment of the creek in September 2001, Alabama Department of Environmental Management (ADEM) employees documented significant deterioration of the creek resulting from the Sloss discharge (Alabama Rivers Alliance, 2002). Five Mile creek has been dubbed "Creosote Creek," due

to the chemical odor and appearance of its water (Freshwater Land Trust, 2006). Coal tar creosote is a by-product of the high temperature treatment of coal to make coke, and it is toxic to plants, animals, and humans (Agency for Toxic Substances and Disease Registry, 2002).

Five Mile Creek has been one of the most polluted waterways in Alabama as reflected in its ADEM usage designation of "Agricultural and Industrial" (the lowest level of protection). In 1997, a small downstream section of the creek was upgraded to "Fish and Wildlife" (F&W) usage, and finally, in 2003, ADEM upgraded the entire length of Five Mile Creek to F&W. The F&W designation establishes minimum water quality standards that are believed to protect existing species and their uses within the designated area (Alabama Department of Environmental Management, 2006). The higher classification greatly reduces the amount of toxic substances that can legally be discharged into the waterway.

Despite the fact that Five Mile Creek has a history of suffering from human impact, it has not been without its defenders. In recent years, a number of organizations have formed with the intention of restoring and protecting Five Mile Creek and its watershed. These organizations include the Black Warrior Riverkeeper, the Black Warrior River Clean Water Partnership and the Five Mile Creek Greenway Partnership. The Greenway Partnership was created after an intergovernmental agreement was signed by the cities of Birmingham, Center Point, Tarrant, Fultondale, Brookside and Graysville that pledged cooperation to develop a series of parks and greenways along the entire 45.1 km length of Five Mile Creek (Freshwater Land Trust, 2006). The Cawaco (Cahaba, Warrior, and Coosa) Resource Conservation and Development Council, the Jefferson County Commission, the Freshwater Land Trust, and the Regional Planning Commission of Greater Birmingham also signed the agreement. The greenway is intended to provide a riparian buffer zone to help improve habitat and water quality of the creek, while at the same time stimulating economic revitalization and growth for the communities along the Creek (Freshwater Land Trust, 2006).

As part of the greenway development project, habitat restoration projects will be implemented along Five Mile Creek. In order to determine whether such projects have been successful in improving the biological condition of the river, it is critical to have data on the pre-project status of biological communities in the creek. U.S. EPA Rapid Bioassessment Protocols (RBPs) provide a means of obtaining quantitative data on the biological status of a river. If the same protocols are used in subsequent years, it is possible to determine whether the biological communities in the creek have improved subsequent to restoration efforts. RBPs are an assemblage of well-documented methods that can be used to assess habitat quality, water quality, and biological integrity of a stream ecosystem. RBPs work best when a reference site is included in the study. A reference site is a pristine or minimally disturbed site that represents the natural range of variation in water chemistry, habitat and biological conditions for the region where the study is being conducted (Barbour et al., 1999). Reference sites provide an example of a waterway's biological potential if it were not impacted by harmful outside influences. The ideal reference site is a pristine site on the stream being assessed. However, in many parts of the country (especially urban areas) such

sites no longer exist. In these situations, a relatively undisturbed (usually rural) stream in the same watershed typically serves as the reference. If sufficient biological, geological and land use data are available for a watershed, mathematical models may be used to estimate the expected biological status of a stream in the absence of human disturbance (e.g. Baker et al., 2005). These techniques create a "virtual" reference site.

The United States Environmental Protection Agency (EPA) originally formulated RBPs as cost effective methods for analyzing the physical and biological status of a stream. In addition, RBPs have been scientifically validated, are environmentally benign, and produce information that is easily interpretable to the public. The EPA has found that the use of biological monitoring has also helped in identifying the causes of impairment to aquatic ecosystems, evaluating the effectiveness of control and mitigation programs, and documenting the success of watershed management plans (Barbour et al. 1999).

The objectives of the current study were to perform habitat assessments and fish assessments of fish populations at six sites spanning the length of Five Mile Creek and two other sites on nearby streams. All sites are in the Locust Fork watershed of the Black Warrior River basin. These assessments will provide data that can serve as a baseline for future studies documenting what is hoped will be the improving health of Five Mile Creek.

MATERIALS AND METHODS

Study Sites

Six of the study sites are on Five Mile Creek and two are on nearby creeks, all in the Locust Fork watershed (Table 1, Fig. 1). The Blackburn Fork and Gurley Creek sites were selected as potential reference sites because they are rural and were expected to be less impaired compared to Five Mile Creek. At each site a sampling reach of ~ 100 m in length was selected for study. Sampling reaches were selected that were representative of the stream and which contained examples of all habitat types (e.g. riffles, runs, pools, root wads, undercut banks, etc.).

Habitat Assessment Protocol

A habitat assessment and physical/chemical characterization of water quality were performed within each sampling reach using protocols from Barbour et al. (1999). The habitat assessment was performed after the fish were collected. Ten habitat variables were scored:

Table 1. The study sites.

Site	Sample Date	County	Lat-Long
Five Mile Creek at Huffman High School	6/14/2006	Jefferson	N33° 36.812' W86° 41.108'
Five Mile Creek at Hewitt Park in Tarrant	11/09/2005	Jefferson	N33° 36.354' W86° 44.762'
Five Mile Creek at Hwy 31 in Fultondale	10/19/2005	Jefferson	N33° 35.448' W86° 48.221'
Five Mile Creek at Brackett Loop Road	10/26/2005	Jefferson	N33° 36.315' W86° 53.139'
Five Mile Creek at Cardiff St. in Brookside	11/02/2005	Jefferson	N33° 38.217' W86° 55.313'
Five Mile Creek immediately upstream of the Prudes Creek WWTP	6/21/2006	Jefferson	N33° 38.300' W86° 56.848'
Gurley Creek at Bone Dry Road	7/19/2006	Jefferson	N33° 48.136' W86° 45.179'
Blackburn Fork of the Little Warrior River at House Road	6/07/2006	Blount	N33° 52.794' W86° 34.832'

The Five Mile Creek sites are listed from upstream to downstream.

epifaunal substrate/available cover, riffle quality, embeddedness, channel alteration, sediment deposition, frequency of riffles, channel flow status, bank vegetative protection, bank stability, and riparian vegetative zone width. Each variable was given a score ranging from 0-20, with twenty signifying the most optimal conditions. The ten habitat variable scores were summed to obtain a composite habitat score. Angus and Marion completed all sections of the field data sheets and habitat assessment forms in consensus. The habitat scores from the six Five Mile Creek sites were evaluated by comparing them with that of the Gurley Creek reference site. The Blackburn Fork reference was not used in the comparisons because its habitat score was lower than anticipated and not indicative of an undisturbed site. The habitat score for each Five Mile Creek site was enumerated as a percent of the score attained by the reference site, and the overall habitat quality was evaluated according to the criteria in Table 2 (United States Environmental Protection Agency Office of Water, 1997).

Fish Sampling Protocol

All sites were sampled upstream from major tributaries and bridge/road crossings. Sampling was done only when the stream level was low to moderate and never immediately after a heavy rainfall. Two different methods of fish collecting were used: backpack electrofishing and seining. These are the most commonly used fish collection methods in fresh water habitats. Both methods are environmentally benign and cause very little mortality (Barbour et al., 1999).

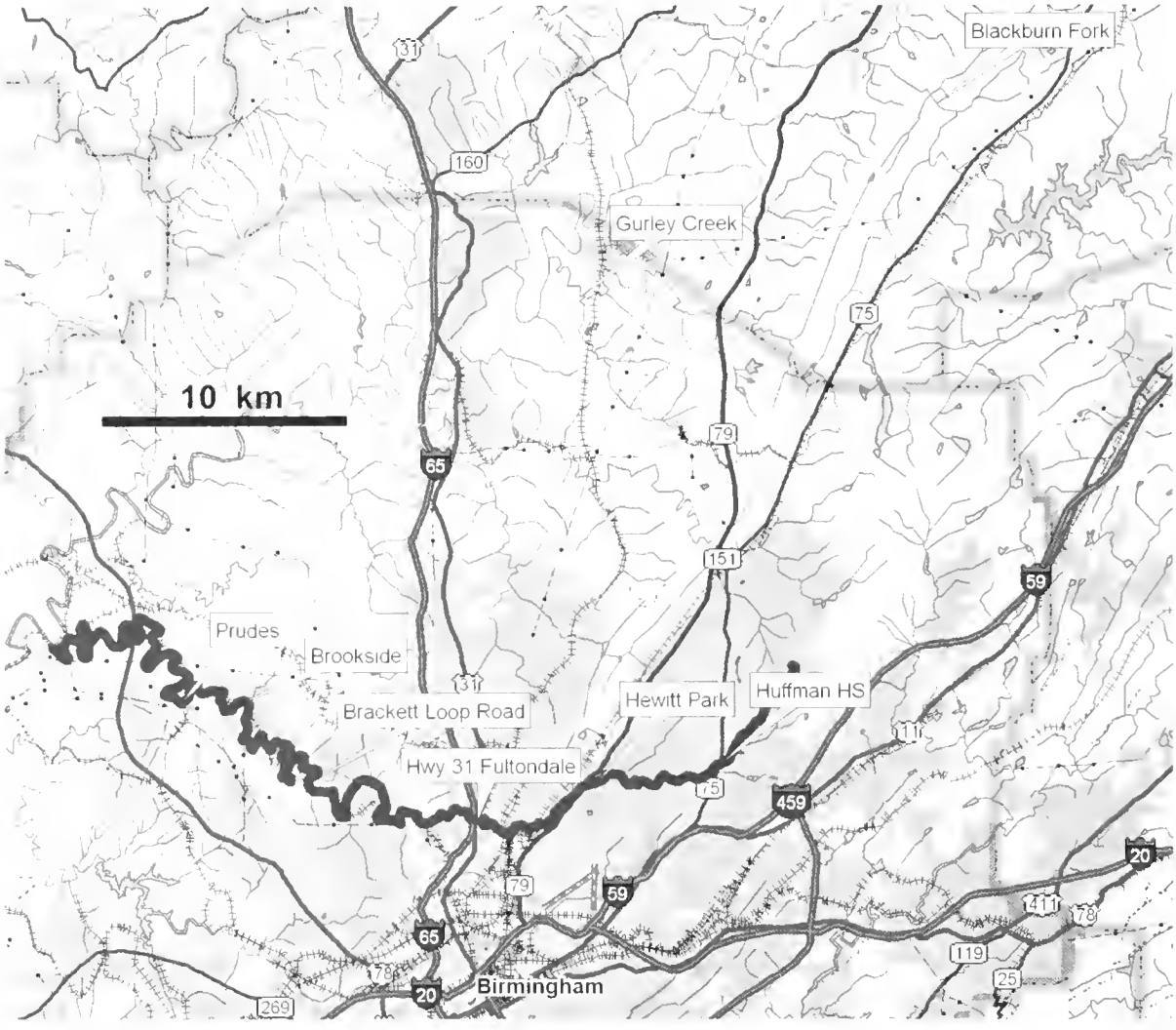

Figure 1. The study sites.

The two methods each have distinct sampling biases, and it has been shown that the use of both methods provides a more complete assessment of the species present at a site than either method alone (Onorato et al., 1998). Electrofishing was done with a Smith-Root backpack unit with a 300W generator; seining was done with a 1.8 × 4.6 m, 0.3 cm mesh seine. The stream reach was first sampled by electrofishing, working upstream, for 30 min. All habitats were sampled in proportion to their abundance in the reach. Fish were placed into 19 L buckets as they were collected. After completion of the electrofishing sample, all fish >20 mm total length were identified to species, enumerated, and weighed by taxonomic group (e.g. by family except the bass, which were weighed separately from other Centrarchidae). Any fish that could not be identified with certainty on site were anesthetized with MS-222 (tricaine methanesulfonate, 300 mg/L), preserved in 10% formalin and brought back to the laboratory for identification. After processing, all of the fish captured by electrofishing were released back into the stream (i.e., sampling with replacement). The same reach was then re-sampled, again working upstream, for 30 min using a seine. The fish captured by seining were identified, enumerated, and weighed in the same way as the fish captured by electrofishing.

Table 2. Habitat and IBI Quality Criteria.

Quality Designation	Habitat Score required*	IBI Score required
Excellent	>90%	>55
Good	>75 - 90%	47 – 55
Fair	>60 - 75%	38 – 46
Poor	≤60%	26 – 37
Very Poor		<26

*** as a percent of the score attained by the reference site**

Index Of Biotic Integrity Calculation

The data obtained from the rapid bioassessment of all eight sites were used in a multimetric analysis called the Index of Biological Integrity (IBI). Karr (1981) created the IBI as a bioassessment tool that is now considered a standard analysis technique for the quantification of stream biological integrity. A modified IBI, developed specifically for the Black Warrior River basin (O'Neil and Shepard, 2000), was used in this study. The multimetric approach utilized in the IBI method is helpful for making objective evaluations of complex ecological systems (O'Neil, 2002). Twelve biological metrics are used in the IBI. They are based on the taxonomic and trophic composition of the fish assemblage and the abundance and health of fish (O'Neil and Shepard 2000). The metrics included in the IBI are shown in Table 3. They have been used in previous bioassessment studies in the Black Warrior watershed (O'Neil and Shepard, 2000, O'Neil, 2002).

Each metric is scored against an expected value from a reference site and given a score of 1, 3, or 5, with 5 being the highest attainable score. O'Neil and Shepard (2000) adjusted some of the IBI metrics to better reflect the characteristics of fish populations in southeastern streams. Metric scoring protocols were also modified to accommodate streams of different sizes. Since larger streams tend to support more species than small headwater streams, any IBI metric that measures species richness must be adjusted for stream size (O'Neil and Shepard, 2000). This has been done by basing scoring criteria on observed metric value vs. drainage area regressions for unimpaired streams in the southeastern U.S. The scores of all metrics are summed to produce the IBI score which can range from 12 to 60 with scores in the range of 56-60 being deemed "excellent," followed by "good" (47-55), "fair" (38-46), "poor" (26-37), and "very poor" (<26). If repeated sampling fails to produce any fish, a "no fish" designation is given (O'Neil and Shepard, 2000).

Table 3. Metrics used in IBI Calculations.

Metric	Trend Seen With Human Impairment
Number of native species	Declines as sensitive species become rare or extirpated
Number of darter species	Declines as sensitive species become rare or extirpated
Number of minnow species	Declines as sensitive species become rare or extirpated
Number of sunfish species	Declines as sensitive species become rare or extirpated
Number of sucker species	Declines as sensitive species become rare or extirpated
Number of intolerant species	Declines
Proportion as sunfishes	Increases as tolerant species thrive in nutrient rich and severely disturbed streams
Proportion as omnivores and herbivores	Increase in nutrient rich streams
Proportion as insectivorous cyprinids	Declines due to reduced abundance of insect prey
Proportion of top carnivores	Declines in impaired streams
Number collected per hour	Declines if toxicity is a factor Increases in enriched streams
Proportion of individuals with anomalies	Increases due to poor health caused by stress

Geographical Information

The sampling sites (represented as points) were initially described in rough latitude-longitude coordinates from TerraServer.com. The points were then more accurately located using Environmental Systems Research Institute, Inc. (ESRI) ArcMap software and Globexplorer, LLC's 6-inch imagery. The watersheds for the individual sites on Five Mile Creek were then delineated in ArcMap using the ArcHydro extension developed by The Center for Research in Water Resources of the University of Texas at Austin, and ESRI. Stormwater Management Authority's (SWMA's) 1998 10-meter posting Digital Elevation Model (DEM) was used in ArcHydro's delineation of the watersheds for the areas in Jefferson County and U.S. Geological Survey's 30-meter posting National Elevation Dataset (NED) for the areas outside of Jefferson County. These watersheds were then clipped overall to the boundaries of the HUC12 for Five Mile Creek developed by the Advisory Committee on Water Information. The final areas were then calculated by ArcMap.

The land use data (year 2000 data displaying Anderson level 2 land use codes) were derived by SWMA. The data were clipped to the appropriate watershed produced by the above procedure. Since all of the Five Mile Creek sites are in the same watershed, land use proportions at sites progressively further downstream are cumulative and include land use areas at all upstream sites.

RESULTS

Five Mile Creek originates in urban Huffman. Land use proportions gradually change heading downstream as the percent of the watershed used for residential, commercial and industrial purposes decreases and more land consists of mixed hardwood/evergreen forest. In the uppermost site (Huffman High School), 60.5% of the land was residential, while only 19.2% was forest. Conversely, at the most downstream site, Prudes Creek, 28.4% of the watershed was residential, and 50.4% was forest (Fig. 2).

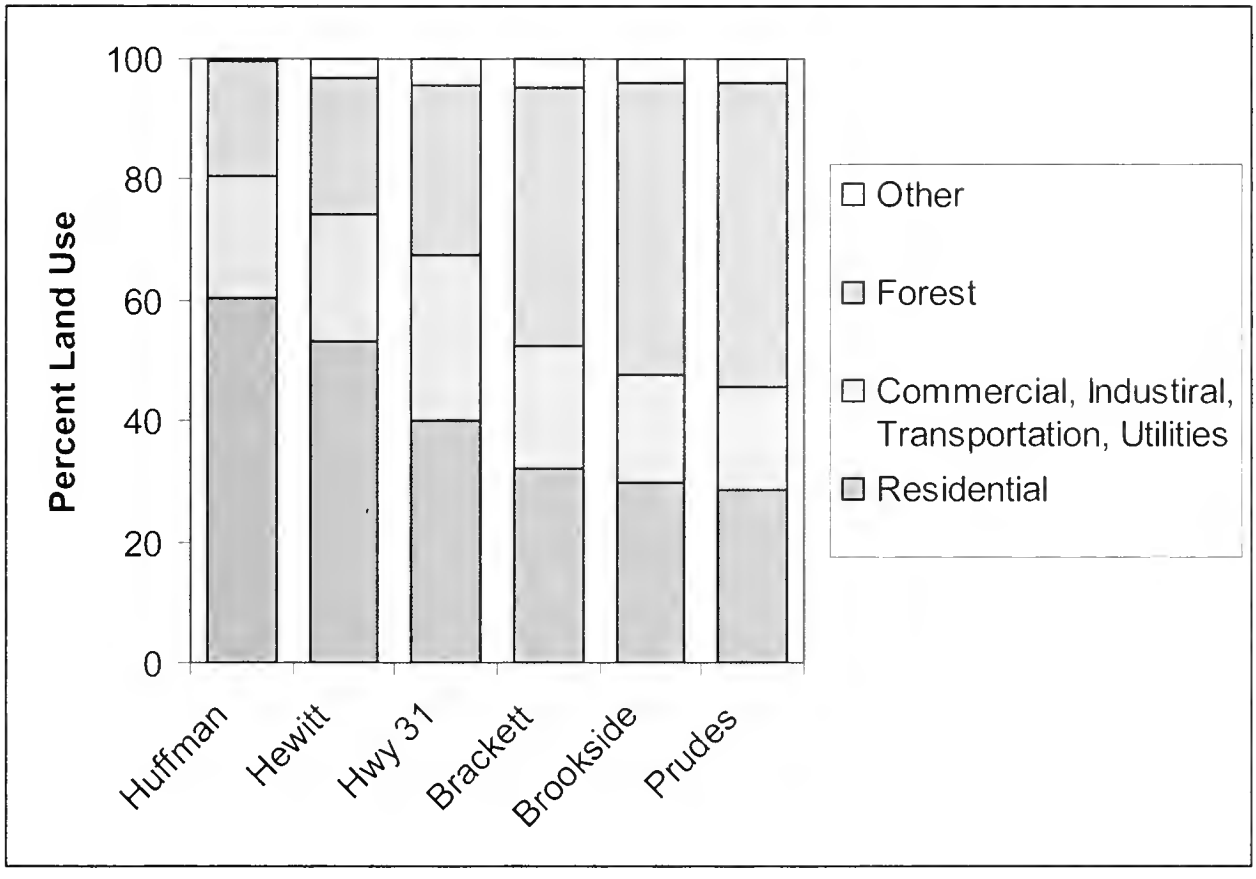

Figure 2. Percent land use in the surrounding watershed for the six Five Mile Creek sites (listed upstream to downstream).

Table 4. Habitat and IBI scores and grades for the study sites.

Site	Habitat Score	Habitat Grade	IBI Score	IBI Grade
Huffman	101	Fair	32	Poor
Hewitt	141	Good	30	Poor
Hwy 31	137	Good	32	Poor
Brackett	134	Good	36	Poor
Brookside	117	Fair	42	Fair
Prudes	122	Fair	38	Fair
Gurley	167	Reference	46	Fair
Blackburn	143	Good	38	Fair

The Five Mile Creek sites are listed from upstream to downstream.

Composite habitat scores for the six sites on Five Mile Creek ranged from 101 to 141. The reference site, Gurley Creek, received a score of 167. When compared with Gurley Creek, habitat scores for three of the Five Mile Creek sites were graded "good" and the other three were graded "fair" (Table 4). There was no upstream-downstream trend in habitat scores.

Thirty-one different species of fish were collected (Table 5). Three species were especially common. *Campostoma oligolepis* (largescale stoneroller) was the most abundant fish species (948 individuals), followed by *Cyprinella venusta* (blacktail shiner, 578 individuals) and *Notropis stilbius* (silverstripe shiner, 523 individuals). Only one site (Blackburn) had a fish population that was not dominated by one or more of these three species (Fig. 3).

Also of note was the lack of darter (family Percidae) species diversity in the Five Mile Creek sites (Table 5). Five darter species were collected at the Gurley Creek reference site. One Five Mile Creek site (Hwy 31) had two darter species. At all other sites, only a single darter species was collected. Most darter species are sensitive to disturbance so they tend to be rare or absent at impaired sites. Monitoring darters can help in detecting changes in environmental quality (Mettee et al., 1996).

Geographical trends were observed in the percent omnivores/herbivores and percent insectivores metrics. The three most common fishes caught (*Campostoma oligolepis, Cyprinella venusta, and Notropis stilbius*) are all omnivores (Mettee et al., 1996). In the sites progressively more downstream, the percent omnivores/herbivores decreased from 89.3 percent to 3.3 percent (Fig. 4) and the percent insectivores increased from 7.9 percent to 79.9 percent (Fig. 5). Both trends are indicative of improving water and/or habitat quality.

Table 5. Species and numbers of all fish collected.

	Huffman	Hewitt	Hwy31	Brackett	Brookside	Prudes	Blackburn	Gurley	Total
Campostoma oligolepis	446	131	109	85	5	12	7	153	948
Cyprinella callistia	0	0	0	0	0	0	3	36	39
Cyprinella venusta	0	0	115	212	197	43	0	11	578
Luxilus chrysocephalus	1	2	1	0	1	0	0	0	5
Notropis asperifrons	0	0	0	0	0	0	0	1	1
Notropis chrosomus	0	0	0	0	0	0	25	0	25
Notropis stilbius	0	0	6	14	153	248	40	62	523
Pimephales vigilax	0	0	0	1	2	0	0	0	3
Semotilus atromaculatus	42	0	3	3	0	0	0	0	48
Hyptentelium etowanum	19	9	2	4	5	4	1	4	48
Moxostoma erythrum	0	0	0	0	0	10	0	6	16
Ameiurus natalis	0	1	0	0	3	0	0	0	4
Ictalurus punctatus	0	0	0	0	1	0	0	0	1
Fundulus olivaceus	0	0	0	0	0	0	4	0	4
Gambusia affinis	1	1	24	0	14	0	2	0	42
Chaenobryttus gulosus	0	0	0	0	0	0	1	0	1
Lepomis cyanellus	20	5	7	3	1	0	0	1	37
Lepomis macrochirus	6	6	1	0	1	0	20	1	35
Lepomis megalotis	0	4	8	4	35	19	26	12	108
Micropterus coosae	0	1	0	0	0	0	2	0	3

Table 5. Species and numbers of all fish collected (continue)

Micropterus punctulatus	0	0	0	0	3	14	0	8	25
Micropterus salmoides	1	0	1	0	1	0	1	0	4
Pomoxis nigromaculatus	0	0	0	0	0	0	0	1	1
Etheostoma artesiae	9	0	1	0	0	0	0	0	10
Etheostoma douglasi	0	0	0	0	0	0	14	7	21
Etheostoma stigmaeum	0	0	0	0	0	0	0	8	8
Percina brevicauda	0	0	0	0	0	0	0	1	1
Percina caprodes	0	0	0	0	0	0	0	2	2
Percina nigrofasciata	0	2	6	1	12	13	5	1	40
Cottus carolinae	1	18	0	0	0	0	39	0	58
TOTAL	546	180	284	327	434	363	190	316	2640

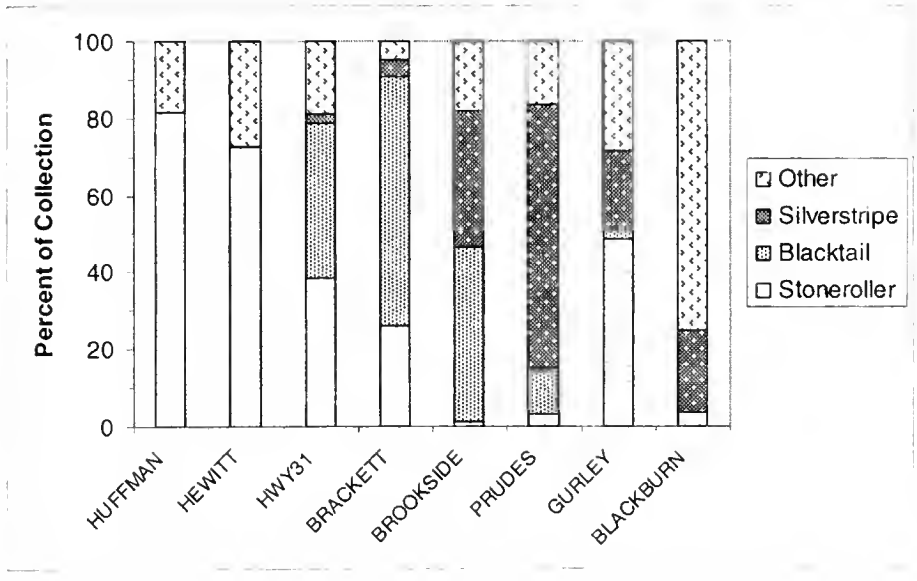

Figure 3. Percent of collection made up of stonerollers, blacktail shiners and silverstripe shiners at each of the sites. The Five Mile Creek sites are listed from upstream to downstream.

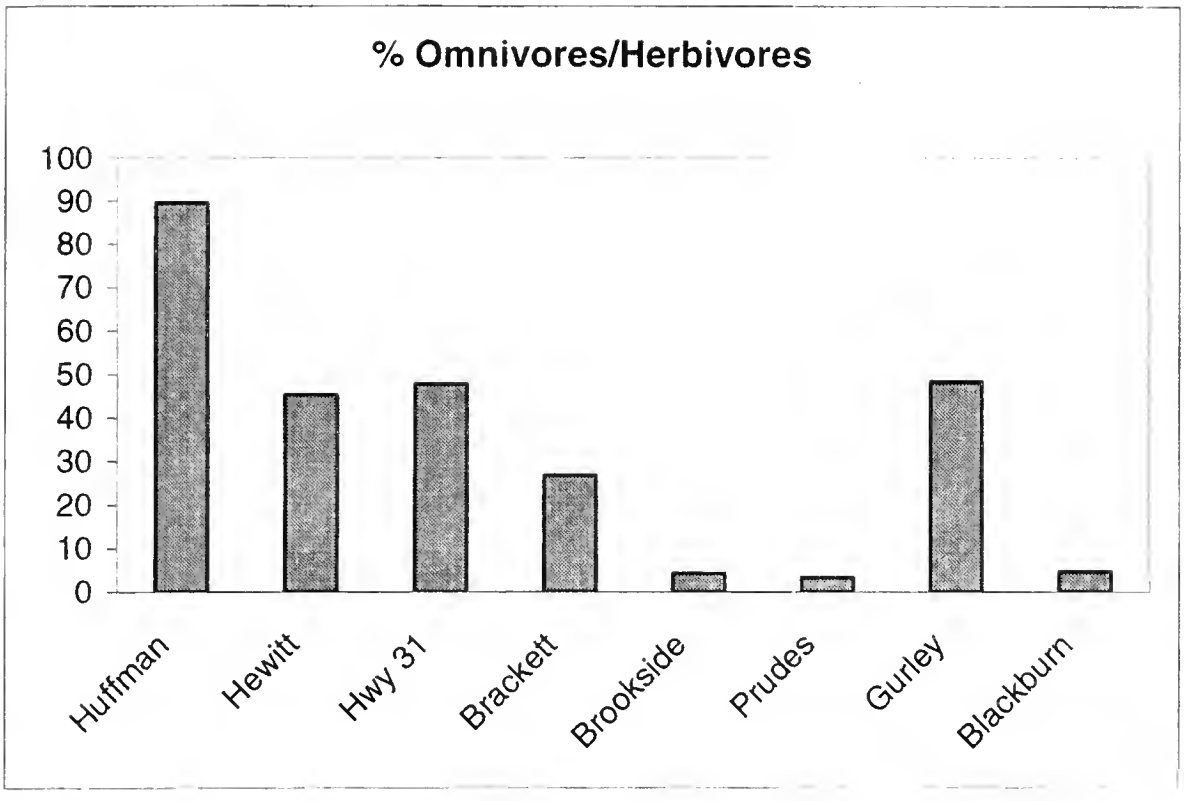

Figure 4. Percent of collection made up of omnivores/herbivores. The Five Mile Creek sites are listed from upstream to downstream.

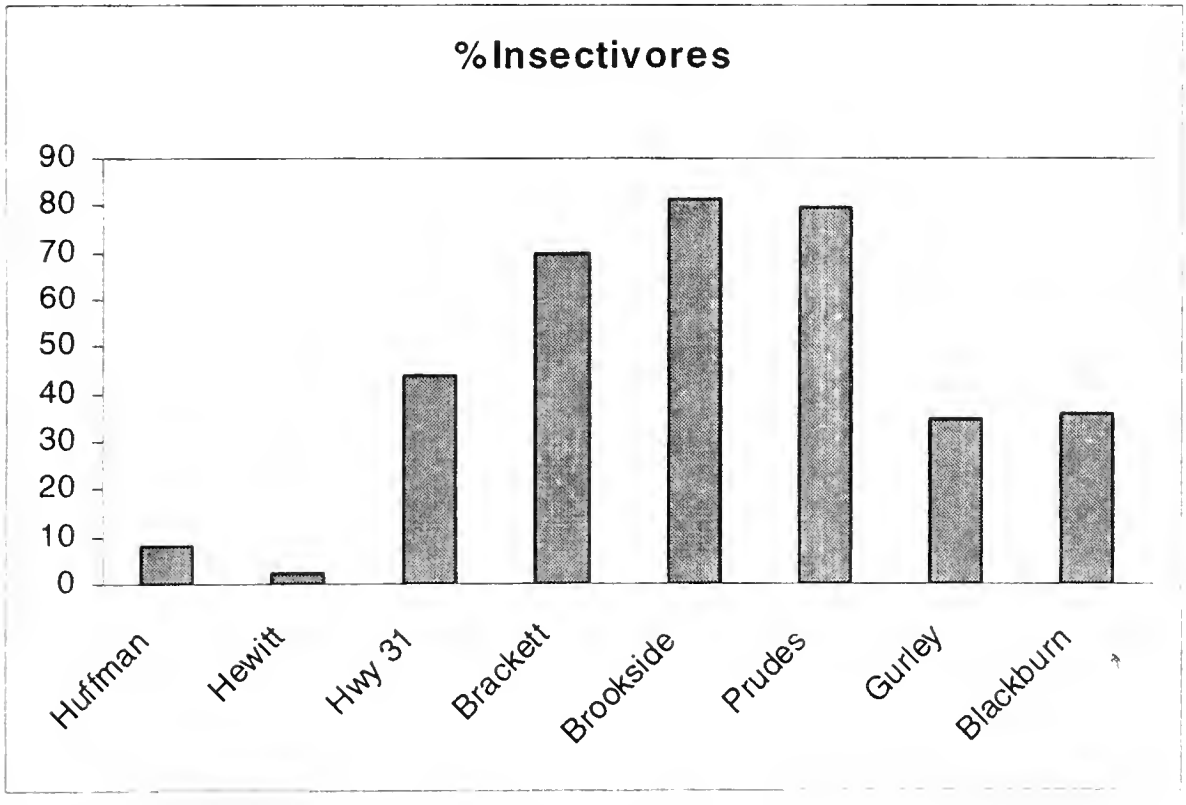

Figure 5. Percent of collection made up of insectivores. The Five Mile Creek sites are listed from upstream to downstream.

Fish IBI scores and grades for the study sites are also shown in Table 4. None of the sites included in this study can be considered to be in a "pristine" condition. Gurley Creek, the reference site, had the highest IBI score (46), which is "fair," but only one point below the score necessary to obtain a grade of "good." IBI scores for the six Five Mile Creek sites, not surprisingly given the history of the stream, were rather low, ranging from 30 to 42. Four of the sites were graded "poor," and two were graded "fair."

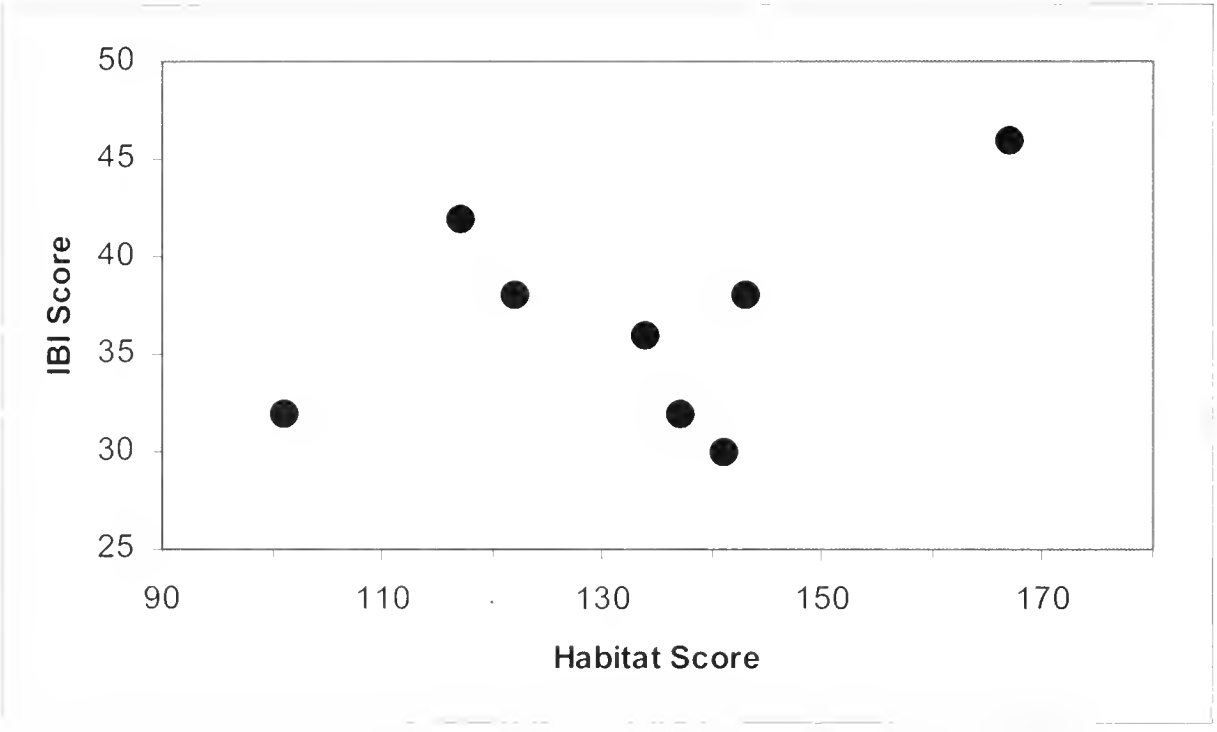

Figure 6. Index of Biotic Integrity (IBI) and habitat scores at each of the collection sites.

The three headwater sites, with the highest proportion of urban development in the watershed, had the lowest IBI values. The more downstream (and more rural) sites had the three highest IBI scores (Fig. 7).

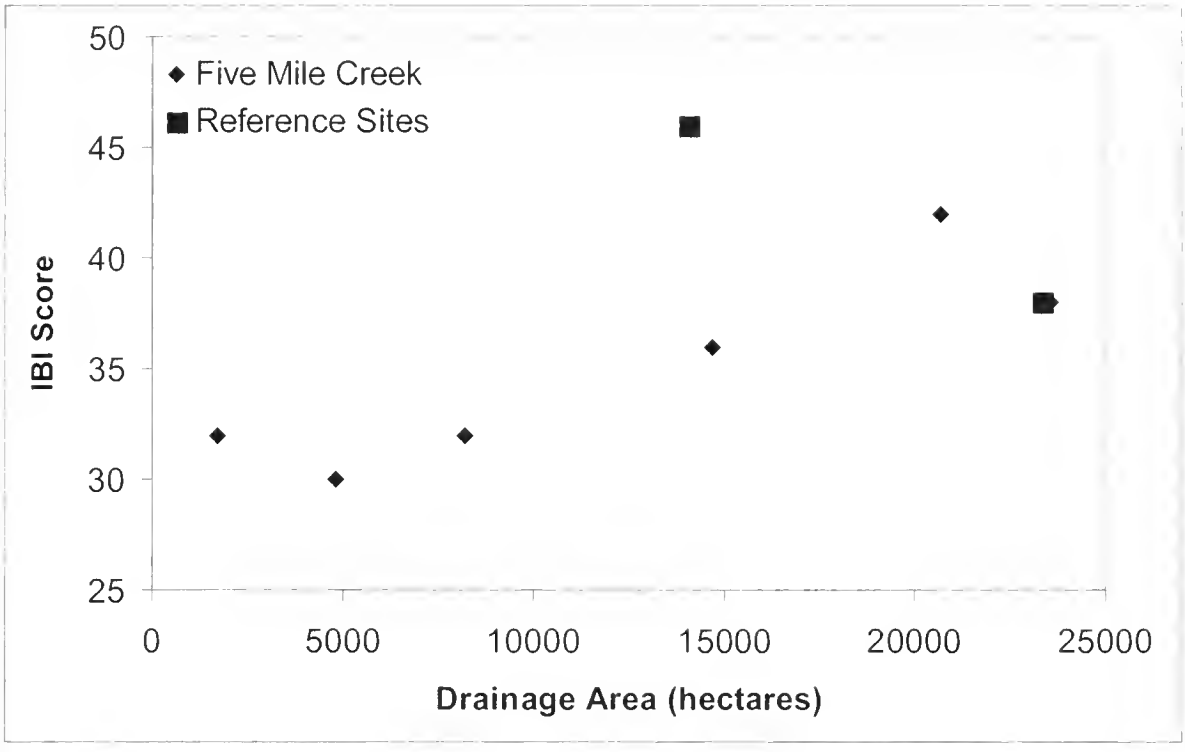

Figure 7. Index of Biotic Integrigy (IBI) scores and drainage areas for each of the collection sites.

The habitat scores of the six Five Mile Creek sites were not significantly correlated with their IBI scores (r = -0.295, p = 0.57, Fig. 6). When the reference sites were included in the analysis, the correlation between habitat and IBI scores increased but remained nonsignificant (r = 0.408, p = 0.32).

DISCUSSION

Undeveloped watersheds typically have few impermeable surfaces, and much of the rainfall percolates through the soil into the ground water. Conversely, as watersheds become developed, impermeable surfaces increase, a larger proportion of the rainfall runs off rapidly, and streams become more prone to flash flooding. The runoff carries pollutants that accumulate on surfaces such as rooftops and parking lots between rain events (NSW Environmental Protection Authority, 1997). Urban streams are exposed to many pollutants, including sediment, heavy metals, and organic chemicals (Field and Pitt, 1989). Five Mile Creek has been especially susceptible to the effects of runoff since its headwaters are in an area that has been developed for many years. As a result, the stream has suffered from both urban and industrial impacts.

Evidence of impairment is evident in the results of the comparisons between the Five Mile Creek sites and the Gurley Creek reference site. Fish populations at all of the Five Mile Creek sites had lower IBI scores than Gurley Creek. The fact that the IBI and habitat

scores at the Five Mile Creek sites were uncorrelated implies that the impaired fish faunas primarily result from poor water quality. The poor water quality was most likely due to the combined effects of the documented industrial pollution from the coal and coke industries in Tarrant and from urban runoff in the headwater regions of the creek. The highest IBI scores were observed in the three downstream sites. There may be a number of reasons for this improvement in the "health" of the fish communities further downstream: reduced proportion of urban land use in the watershed, increased distance from sources of industrial pollution and closer proximity to the Locust Fork, a possible source of recolonization after periodic fish kills. The Locust Fork, which is a tributary to the Black Warrior River, as well as tributary streams to Five Mile Creek, may serve as reservoirs of species diversity that can supply colonists to Five Mile Creek after discrete pollution events have ended and the water quality again becomes tolerable.

We observed a dramatic shift from populations dominated by omnivores/herbivores to populations dominated by insectivores in sites progressively more downstream. This shift is also evidence that Five Mile Creek is more severely impacted in the upstream reaches. As the invertebrate food source decreases in abundance and diversity in response to anthropogenic stressors, the abundance of insectivorous fishes decreases and omnivores tend to predominate (Barbour et al., 1999).

Although the fish populations in Five Mile Creek are somewhat less impacted downstream than in the headwaters, the downstream populations are not in good condition. Evidence of impairment includes IBI scores that rate no better than "fair" at the downstream sites. In fact, the fish populations at all six Five Mile Creek sites were dominated by only three species (Table 5, Fig. 5). Dominance by a few (usually highly tolerant) species is indicative of an impaired fish population (Barbour et al., 1999). In addition to increased abundance of a few dominant species, species diversity in general tends to decrease in streams impacted by human disturbance as the more sensitive species become rare or extirpated (Barbour et al., 1999).

The IBI scores for Blackburn Fork were not as high as expected. It is clear that this site is not suitable for use as a reference. Possible reasons for the "fair" (barely above "poor") status of the fish population in this stream include agricultural runoff, recent development (housing and golf course) in the immediate vicinity, and the fact that it is a tailwater of Inland Lake (a public water supply reservoir).

The Five Mile Creek fish bioassessments provide baseline data on the current biological status of the stream and will be useful information for groups involved in river restoration efforts. If bioassessments are repeated at the same sites in future years and equivalent sampling methods are used, the data provided by this study can be used as a point of comparison, making it possible to determine the extent to which the restoration efforts have been effective in improving the habitat quality and biological diversity of Five Mile Creek. The development of a greenway along the entire length of the stream will improve stream habitat characteristics and streambank stabilization, which, along with cessation of industrial point source pollution, should permit the biota of the stream to continue on their path toward ecological recovery. Vegetated land also helps cities meet

their ozone requirements, can boost the socioeconomic situations in the surrounding areas, and can attract people to the area for recreational activities. Although currently suboptimal, the habitat quality of the stream is still in relatively good condition, and with improvements provided by the Five Mile Creek Greenway Partnership restoration efforts, the biological health of Five Mile Creek should continue to improve.

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