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Understanding and influencing urban residents' knowledge about wildland management in Austin, Texas

Laura E. Martin · Michael G. Sorice · Urs P. Kreuter

Abstract Due to increasing exurban settlement around Austin, Texas and subsequent land use changes, the City of Austin Wildland Division faces competing pressures from residential communities regarding land and wildlife management actions. Current environmental education and outreach efforts in Austin focus on developing environmental literacy about the city's wildland areas adjacent to exurban settlement as well as their management program. The desired outcome is to promote more positive perceptions and motivate pro-environmental behaviors that are consistent with the city's wildland program. We conducted a mail survey of 1,000 residents living near the urban wildlands to better understand factors that influence residents' proficiency in four knowledge domains: karst aquifers, endangered species, rangeland ecology, and the city's management program. Regression analyses identified positive associations between local newspaper readership and residents' environmental knowledge of karst aquifer geology, rangelands, and city's wildland program. Previous engagement in environmentally oriented education programs or organization was positively associated with all four knowledge domains. Some strategies for information dissemination about the wildlands include the use of local newspapers and homeowners association newsletters. Newer, younger residents are the suggested target audience for initiating a proposed environmental education and outreach program. Such programs should incorporate both local environmental organizations and homeowners associations.

Keywords Environmental outreach · Wildland-urban interface · Urban-rural interface · Demographics · Environmental education · Exurban residents · Wildland management · Information channels

L. E. Martin · M. G. Sorice · U. P. Kreuter (✉)
Department of Ecosystem Science and Management, Texas A&M University, College Station, TX, USA
e-mail: urs@tamu.edu

L. E. Martin
e-mail: lauramartin@tamu.edu

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Introduction

In this manuscript we report the results of a study commissioned by the City of Austin's Wildland Division in Texas to gain clarity about the knowledge and perceptions of wildland-urban[1] interface residents about the biophysical aspects of the Edwards Aquifer and about land management applied to wildlands to protect water quality and endangered species habitat. Land management actions that enhance ground cover are fundamental for maintaining water quality in karst areas, such as the Edwards Aquifer, because limestone is a poor filter for water entering aquifers. Furthermore, protecting endangered species habitat is a legal mandate to which the City of Austin must adhere.

The City of Austin's goal of gaining information about residents' knowledge and perceptions about the wildlands is to develop an effective environmental education and outreach program that enhances literacy about these protected areas. The educational and outreach aspects of environmental programs are interlinked; education programs alone are likely to have limited impact whereas outreach efforts without a clear educational message are inefficient. The specific objectives of this study were to: (1) better understand urban residents' baseline knowledge about natural resource management issues; (2) identify socio-demographic characteristics related to such knowledge; and (3) examine the potential for different education and outreach approaches to increase literacy about the wildlands and about environmental issues related to water and endangered species conservation at the wildland-urban interface.

Rapid development in central Texas is leading to ever-greater impacts on key ecosystem services, including the delivery of clean water and the provision of habitat for federally protected endangered species. One solution to this challenge is for municipal governments to strategically purchase land or obtain conservation easements in areas that are critical for protecting ecosystems that deliver these services. In addition, an informed public that understands and accepts broader land management goals aimed at protecting ecosystems can ameliorate potential conflicts between wildland management goals and urban residents' interest.

Environmental literacy within the wildland-urban interface is, therefore, important to ensure the successful implementation of ecosystem management practices that enhance long-term ecological heath of protected areas. However, as urban development increasingly impinges on protected open spaces, a knowledge gaps about the extent to which residents are affecting or being affected by nearby wildland areas may grow. Many educational/outreach campaigns have been based on incomplete knowledge about target populations and their environmental perceptions. Currently, there is a lack of information about the willingness of urban residents to learn about and support ecosystem management strategies that protect open spaces within urbanizing areas. This is especially true in Austin-Roundrock, Texas, which was the nation's second fastest growing metropolitan area between 2007 and 2008 (Bernstein 2009).

Factors influencing environmental knowledge

Environmental education and outreach help people to develop environmental knowledge and the skills to transform such knowledge into action through individual and group efforts

[1] We use the term wildland-urban interface in this paper in the context of communities that are mixed in with undeveloped wildland areas (USDA and USDI 2001). It was created in conjunction with wildland fire policy (Radeloff et al. 2005). The broader term *urban-rural interface* is more frequently used to imply the co-existence of urban and rural features in the same region (Allen 2003).

for the purpose of achieving a quality life within a quality environment (Marcinkowski 1991). Enhancing environmental literacy can increase people's abilities to understand environmental science and to discern associated policy processes and decision-making (Schneider 1997). Roth's (1992) framework, states that environmental literacy is a way of thinking that draws upon environmental sensitivity, knowledge, skill, attitude, values and behavior.

Factors that influence urban residents' environmental knowledge include social status, information channels and participation in environmental organizations. Past research has indicated that environmental knowledge was positively correlated with youth, male gender, levels of education and income and participation in an environmental organization (Arbuthnot 1974; Van Liere and Dunlap 1981; Arcury and Johnson 1987; Mohai and Twight 1987; Arcury 1990; Schultz and Stone 1994; Theodori and Luloff 2002; Heer et al. 2003; Maloney and Ward 1973 but see Arcury 1987). We expected these same characteristics to hold for Austin residents.

Studies of the influences of prior information sources on residents' environmental knowledge can be categorized into formal (e.g., television, newspapers, radio) or informal (e.g., social networks) sources. Newspaper readership has been positively associated with environmental knowledge (Ostman and Parker 1987; Brothers et al. 1991) and may be a more important information source than television or radio (Bailey 1971). More recently, Toman et al. (2006) suggested that local media are more effective at raising awareness of educational programs whereas interpersonal communication of environmental information is more useful for changing residents' behavior. Personal experience also can be a useful predictor in explaining environmental knowledge. For example, residents who had previously requested to receive information about natural resource issues in their local watershed were more knowledgeable about environmental issues (Williams 2001). Heer et al. (2003), however, found that frequency of accessing a local forest recreation area had no significant relationship with forest perception and knowledge. Based on the preceding research results, we expect newspaper readership, receipt of City of Austin mailings, use of the internet and previous participation in an environmental organization to be positively related with local knowledge about the wildland program, karst aquifers, endangered species and rangeland management issues.

Background

Texas leads the nation in conversion of productive farm and ranch land to smaller ranchettes and residential subdivisions. Due to this land use conversion, impervious cover increasingly replaces the wildlands and covers aquifer recharge features. This results in increased storm water runoff, greater potential for erosion and flooding, increased contamination of ground water and diminished surface flow recharge of aquifers (DeFries et al. 2004). These water-related issues are of great concern in Texas where the Edwards Aquifer and Colorado River serve as the primary source of water for San Antonio and Austin. For example, the Barton Springs segment of the aquifer provides at least 35,000 residents in the Austin area with drinking water and all of Austin's residents with recreational amenities (Barrett and Charbeneau 1997). This portion of the Edwards Aquifer consists of karst geological features comprising a network of underground caves and channels that provide sink inlets for ground water, which is then rapidly transported through the permeable bedrock (White 2002). Characteristically, such karst aquifer geology provides very little water filtration. Maintenance of vigorous herbaceous plant cover on

the soil surface is critical for adequate water filtration, and the maintenance of such ground cover in these ecosystems requires the periodic application of fire.

In response to these challenges, the City of Austin has proactively attempted to minimize the negative effects of land fragmentation on water quality as well as endangered species habitat by acquiring over 30,000 acres of wildlands through fee simple acquisition and conservation easements. These lands are managed under two programs. The Balcones Canyonland Preserve (BCP) focuses on endangered species habitat creation and preservation (RECON and USFWS 1996) while the mission of the Water Quality Protected Lands (WQPL) is to improve water quality and increase aquifer discharge rates (WQPL 2001).

Methods

Based on information obtained via a focus-group meeting and electronic communication with City of Austin's Wildland Division staff we identified key areas of concern and issues pertaining to these concerns. In addition, researchers with expertise in karst geology, rangeland management, and endangered species habitat were asked to identify key questions to succinctly evaluate resident's knowledge about these issues. A second focus-group meeting with 10 residents identified by the City of Austin staff enabled us to obtain information regarding baseline knowledge about these issues, which was then used to create a survey questionnaire. We used the combined information to develop pertinent questions for the survey questionnaire.

In June and July of 2009, we conducted a survey of residents living within a half-mile band of the City of Austin's WQPL and BCP areas in Travis and Hays County (Fig. 1). Using GIS and county tax records, we randomly selected 500 residents living near the WQPL and 500 living near the BCP areas. We administered the mail survey using a modification of Dillman's (2000) multiple contact approach, substituting a post card for a third questionnaire as the final reminder. In September 2009, we mailed a one-page survey to 300 randomly selected non-respondents. Of these 54 returned completed questionnaires. Their responses were used to conduct a limited non-response bias assessment by comparing them to those of the initial respondents.

The 12-page questionnaire consisted of four areas of inquiry: (1) survey participants' characteristics; (2) local environmental knowledge; (3) knowledge about the wildlands and level of support for management on them; and, (4) broader environmental awareness and knowledge. Environmental knowledge consisted of four aspects: biophysical characteristics of karst aquifers, rangeland ecology, endangered species, and the City of Austin's wildlands program. For each category respondents answered a series of true-false questions (*Yes*, *No*, or *Don't Know*). To facilitate interpretability, we standardized knowledge scores for each domain for a total score of 100. Data for management knowledge were obtained by providing *Yes*, *No*, or *Don't Know* response options and a seven-point Likert-type scale (1 = Strongly Disapprove and 7 = Strongly Approve) was used to measure respondents' support for land management (e.g., controlled fire, use of herbicides) and public-use activities (e.g., hiking, horse trails). Indicators of broader environmental awareness and education consisted of five behavioral items in which respondents were asked to indicate participation (1 = Yes and 0 = No) in environmental education programs.

We conducted ordinary least squares regression analyses to explore how socio-demographic and behavioral variables related to knowledge. First, four models examined the relationship between respondent characteristics and each of the four knowledge categories (karst aquifer geology, endangered species, rangeland ecology, and the wildland

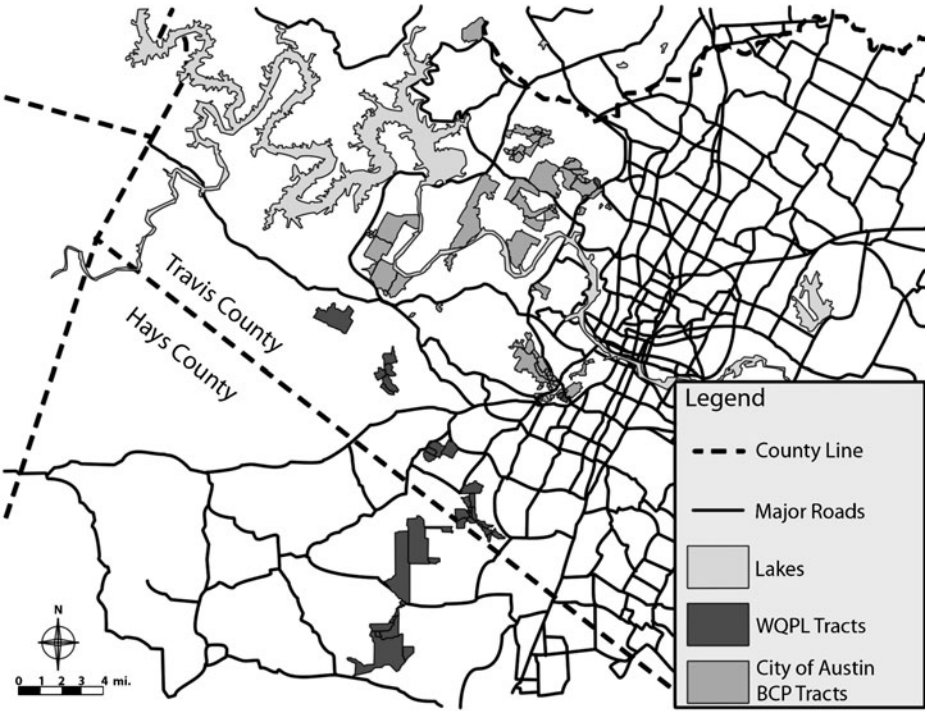

Fig. 1 Location of City of Austin's Water Quality Protection Land (*WQPL*) and Balcones Canyonland Preserve (*BCP*) around which residents were selected

program). The next set of models examined the relationships between information channels, behavioral indicators, and knowledge categories while controlling for socio-demographic characteristics.[2] Both socio-demographic and behavioral variables were entered into the model simultaneously. Again, four models were estimated, one for each knowledge category (karst aquifer geology, endangered species, rangeland ecology, and the wildland program). All analyses were done in SPSS version 17.0. We used α=0.10 to indicate statistical significance because this study was exploratory and we did not want to eliminate any possibly significant variables that could aid further research efforts. For regression models, we assessed regression assumptions and multicollinearity. Diagnostics indicated that assumptions were reasonably met. Furthermore, variance inflation factor scores were less than 2.0 in all models indicating no issues with multicollinearity.

Results

Of the 1,000 questionnaires, 36 were undeliverable. Of those eligible to respond, 450 participants returned questionnaires (47% response rate), of which 337 respondents were completed and useable. The limited non-response analysis found that the initial respondents were more likely to have been notified about prescribed burns (X^2=5.74, p=0.057), more

[2] The socio-demographic factors used as controls in this model are not reported in Table 6 having previously been discussed in the context of Table 5.

likely to have observed city personnel patrolling the wildlands (X^2=5.74, p=0.013), and more likely to perceive that the wildlands increased their property value (X^2=7.73, p=0.021). These differences suggest that respondents may be more aware of the actions on the wildlands and perceive their property to be more valuable due to its proximity to the wildlands. Thus, the results of our study should be interpreted with this in mind.

Descriptive statistics

The average age of the respondents was 52 years, 57% were male and 83% had at least a bachelor's degree. On average, respondents had lived in or near Austin for 20 years and resided at their current address for 10 years (Table 1). Close to half (46%) had an annual income greater than $125,000 and 43% owned a home valued greater than $350,000. Additionally, 73% of respondents were members of homeowners associations. Around 35% of respondents had accessed the Wildlands at least one time within the last year.

Information sources were a key factor influencing the assimilation of new information (Table 2). When survey participants were asked to indicate the information channels from which they had previously heard about the wildlands: 38% selected local newspapers, followed by local television (27%), city mailings (23%), and the Internet (18%). The results showed that 27% of respondents, who indicated that they were homeowner association members, had previously received mailings from the City of Austin Wildlands Division. Additionally one quarter (25%) of all respondents reported that they had not previously heard of the wildlands.

We were also interested in residents' past environmental interest and behavior (Table 2). Only 5% of respondents had previously participated in an environmental program administered by the city's wildlands division. Those who had previously participated in an environmental organization (27%) were more willing to participate in a city-based environmental education and outreach program. Not surprisingly, there were more respondents that thought environmental education programs were important (71%) than those willing to participate in an environmental education class (47%). Only 14% of respondents were willing to host an environmental education class in their neighborhood. Finally, just over one third (37%) of respondents were undecided about whether or not they would become a member of an environmental education program. Membership involves a willingness to join an environmental education program for a longer period of time than attending a single informational class or seminar.

Knowledge items

Of the four knowledge domains, respondents were most knowledgeable about rangeland issues (*Median knowledge score*=70%, *Mean*=60%, *SD*=30%) followed by endangered species (*Median knowledge score*=57% *Mean*=51%, *SD*=26%,), karst geology (*Median knowledge score*=50%, *M*=44%, *SD*=31%), and the city's wildland management program (*Median knowledge score*=40%, *Mean*=37%, *SD*=24%). See Tables 3 and 4 for response choice distributions for individual questions. Most respondents correctly identified the definition of a rangeland (72%) and the associated ecosystem services such as carbon sequestration and water filtration (69%) that rangelands provide (Table 4). The majority (78%) knew that a decrease in perennial grasses tends to result in increased soil erosion and 71% also knew that an increase in ground cover by grasses improves water infiltration.

At least half of the respondents knew the habitat characteristics of the target endangered species, the Golden-cheeked warbler (*Dendroica chrysoparia*) (58%) and Barton Spring's

Table 1 Descriptive statistics for socio-demographic items used in regression analyses

Socio-demographic variables	Median	Mean	SD
Age	52.0	52.5	12.4
Years of residence in or near Austin, Texas	17.0	20.3	13.9
Years of residence at your current address	7.0	10.0	8.4
Gender		Frequency	%
Male		195	59.1
Female		135	40.9
Highest level of education:		Frequency	%
Less than High school		3	0.9
High School diploma		28	8.5
Vocational diploma		7	2.1
Associate's degree		11	3.3
Bachelor's degree		135	41
Post graduate degree		145	44.1
Less than a Bachelors degree		49	14.9
Obtained at least a Bachelors degree[a]		280	85.1
Total household income in 2008.		Frequency	%
Less than $50,000		22	7.4
$50,001–$75,000		30	10
$75,001–$100,000		39	13
$100,001–$125,000		47	15.7
$125,001–$150,000		41	13.7
Greater than $150,001		120	40.1
Annual income <$125,000		138	46.2
Annual income >$125,000[a]		161	53.8
Approximate property value		Frequency	%
Less than $150,000		2	0.6
$150,001–$200,000		13	4.1
$200,001–$250,000		22	6.9
$250,001–$300,000		53	6.9
$300,001–$350,000		46	14.5
$350,001–$400,000		47	14.8
$400,001–$450,000		24	7.5
$450,001–$500,000		35	11
Greater than $500,000		76	23.9
Property value <$350,000		136	42.8
Property value >$350,001[a]		182	57.2
Member of a homeowner association?		Frequency	%
Yes[a]		242	73.1
No		89	26.9
Proximity of property to City of Austin wildland		Frequency	%
Across the fence		61	18.3
Within one block		54	16.2
More than a block[a]		161	48.2
Don't know		58	17.4

Table 2 Descriptive statistics for knowledge/information source and behavioral variables used in regression analyses

Knowledge and information source variables		
Knowledge of public access points to wildlands	Frequency	%
Yes[a]	170	51.1
No	163	48.9
Sources used for information about the wildlands	Frequency	%
Local Newspaper	128	38
Local TV channel	92	27.3
Internet	61	18.1
Not previously heard of BCP or WQPL	85	25.2
Previous receipt of City of Austin mailings about wildlands		
Yes[a]	77	23.2
No	192	81.0
Behavioral variables		
Access to BCP and/or WQPL during previous 12 months[b]	Mean	SD
BCP	2.8	21.9
WQPL	4.9	30.7
	Frequency	%
Never accessed the BCP and/or WQPL	219	65.2
Accessed BCP and/or WQPL at least once[a]	117	34.8
Previous or current participation in environmental organization	Frequency	%
Yes[a]	90	27.4
No	239	72.6
Participation in last 12 months, in environmental education opportunities regarding the City of Austin wildlands?	Frequency	%
Yes[a]	17	5.2
No	312	94.8
Willingness to participate in environmental education class	Frequency	%
Yes[a]	160	48.6
No	82	24.9
Don't know	87	26.4
Willingness to host environmental education class in neighborhood	Frequency	%
Yes[a]	46	13.9
No	176	53.3
Don't know	108	32.7
Willingness to become a member of environmental education program	Frequency	%
Yes[a]	93	28.4
No	115	35.1
Don't know	120	36.6

[a] Item calculated and used in multiple regression analyses

[b] Dummy variable created for respondents who accessed either BCP or WQPL at least one time

Table 3 Percent distribution of response choices by survey participants' to questions about karst aquifers and endangered species, rangeland management, and the City of Austin's wildlands

	True	False	Don't know
Karst aquifers			
Karst geology refers to a network of chambers and channels in limestone that are created over time by water dissolving the underground limestone	54.4[a]	0.3	45.3
Limestone karst acts as a very good filter for impurities in surface water flowing down through it.	54.1	12.5[a]	33.3
Karst aquifers recharge rapidly after a heavy rainfall as surface runoff penetrates through features such as caves and cracks.	44.3[a]	12.2	43.4
Recharge features in karst aquifers are generally evenly distributed throughout the zone that catches rainfall entering the aquifer.	7.1	36.5[a]	56.4
It is very important to maintain good grass cover in the contributing zone to ensure that higher quality water is available to recharge karst aquifers.	42.2[a]	8.9	48.9
The application of nitrogen fertilizers to lawns in the contributing and recharge zones of karst aquifers can directly affect water quality.	75.8[a]	1.2	23.0
The direction of flow of underground water travelling through a karst aquifer is always the same as the direction of the surface water flow.	1.2	37.4[a]	61.3
The Edwards Aquifer is a karst type aquifer and Barton Springs is a typical karst aquifer discharge feature.	47.7[a]	0.3	52
Endangered species			
The Golden-cheeked warbler is an endangered migratory songbird that nests exclusively in the Texas Hill Country.	63.4[a]	3.0	33.5
Nesting habitat for Golden-cheeked warbler consists of areas with mature juniper/cedar trees mixed with oaks and other hardwood trees.	57.9[a]	0.3	41.8
Black-capped vireos are less affected than Golden-cheeked warblers by the brown-headed cow birds that lay their eggs in the nests of other birds.	4.9	6.7[a]	88.4
Ideal Black-capped vireo nesting habitat is often synonymous with good habitat for white tailed deer.	17.2[a]	1.2	81.5
Springs of the Edwards Aquifer, including Barton Springs, provide habitat for several endangered salamander species.	84.4[a]	0.0	15.6
The application of fertilizers, herbicides and pesticides in residential areas in the contributing zone can directly impair the health of salamanders.	81.8[a]	0.6	17.6
Endangered invertebrates living in karst caves depend on nutrients that are transferred from surrounding areas by water and animals into the caves.	47.0[a]	2.4	50.6

[a] Correct response

salamander (*Eurycea sosorum*) (84%) (Table 3). However, a large majority (88%) were uncertain about the negative impacts of the brown-headed cowbird (*Molothrus ater*) on the Golden-cheeked warbler.

The average percent correct for the karst aquifer geology knowledge domain was slightly lower compared to the knowledge level score for the endangered species domain (Table 3). The primary misconception about karst aquifer geology was that karst limestone acts as a good filter for impurities in surface water percolating through it despite the fact that karst geomorphology and the associated thin soils are a poor filtering agent (Mahler et al. 1999). Over half (54%) believed this to be true; however, the majority (76%) of respondents knew that fertilizers used within the recharge and contributing zone could negatively affect the water quality.

Questions about the history of the City of Austin's wildlands program resulted in the lowest scores (Table 4). The majority of respondents selected *Don't Know* (59%) when

Table 4 Percent distribution of response choices to questions about rangelands and the City of Austin's wildlands program

	True	False	Don't know
Rangeland ecology			
Rangelands are grasslands and savannas that consist mainly of native grasses and forbs with some disbursed trees across the landscape.	72.1[a]	0.3	27.6
Rangelands provide important ecosystem services, such as carbon sequestration and water filtration.	69.1[a]	0.3	30.6
Grasslands and open savannas in Texas are the result of long-term exclusion of fire.	7.6	42.2[a]	50.2
Decrease in the abundance of perennial grasses (grasses with multi-year life cycles) tends to result in increased soil erosion.	77.7[a]	1.8	20.4
Increase in the density of woody plants, especially juniper/cedar trees, tends to lead to an increase in ground cover by grasses and forbs.	12.9	53.1[a]	34.0
Increase in ground cover by grasses and forbs tend to improve surface water infiltration into the soil.	71[a]	1.5	27.4
To ensure the delivery of high quality water, it is more important to prevent soil erosion in the lower part of a drainage basin than in its upper reaches.	17.8	18.7[a]	63.5
Long-term suppression of natural fires increases the probability of uncontrollable wild fires occurring.	67.5[a]	5.2	27.4
Because white-tailed deer are native to Texas, high populations do not negatively affect other rangeland species.	3.3	68.4[a]	28.3
Wild hogs are native to Texas and have little impact on other wildlife.	3.4	66.8[a]	29.9
City of Austin wildlands program			
Water Quality Protection Lands were purchased mainly through voter approved Municipal bonds.	31.7[a]	3.7	64.6
Water Quality Protection Lands include land owned by the City of Austin as well as private land on which the City owns a conservation easement.	57.1[a]	0.6	42.3
Water Quality Protection Lands are restricted exclusively to the Edwards Aquifer recharge zone.	6.2	38.6[a]	55.2
The amount of land included in the Balcones Canyonlands Preserve meets the obligations imposed by Federal permit that led to its creation.	12.2	3.4[a]	84.4
The Balcones Canyonlands Preserve is a regional preserve system set aside for endangered species in Travis, Hays, and Williamson Counties.	37.9	3.4[a]	58.7
City of Austin, Travis County, Lower Colorado River Authority, and The Nature Conservancy own land in the Balcones Canyonlands Preserve.	37.6[a]	1.5	60.9
Conservation easements always restrict traditional forms of land use such as cattle grazing.	11.5	32.0[a]	56.5
Water quality and endangered species habitat in Austin can be affected by the type of rangeland management practices applied on wildlands.	77.1[a]	0.6	22.3
Leaving the land untouched and unmanaged is one of the best treatments for wildland areas to protect the ecosystems they represent.	24.2	41.6[a]	34.3
The Austin area has just about the right number of white-tailed deer per acre to represent a healthy population and sustainable population.	4.3	46.8[a]	48.9

[a] Correct response

asked to indicate if the BCP was a regional preserve established for endangered species. Only just over one third (38%) knew that lands in the BCP are managed and owned by the City of Austin, Travis County, Lower Colorado River Authority, and The Nature Conservancy. Even less (32%) respondents knew that the Water Quality Protected Lands were purchased mainly through voter approved municipal bonds, but over half (57%) knew that the Water Quality Protected Lands included private land and land on which the city owns a conservation easement.

Explaining knowledge levels

Model fit (the R^2) was low for the socio-demographic regression model (Table 5). This is likely due to the indirect relationship between respondent characteristics and knowledge. However our interest here was exploratory—to identify potential associations between knowledge and characteristics that may help the City of Austin better target educational/outreach programs. We were interested in identifying potential relationships between socio-demographic variables for future elaboration; thus, we focus on statistically significant relationships rather than model fit.

The regression of each knowledge category on socio-demographic variables indicates a number of characteristics that may be related to environmental literacy (Table 5). Age was significant for three of the four knowledge models. As age increased, knowledge about endangered species, rangelands, and the city's wildlands program increased. Gender was also significant for three of the models. Male respondents were more knowledgeable than female respondents regarding karst geology, rangeland ecology, and the city's wildland program. Income was associated with increased knowledge for endangered species and the city's wildland program. Further, landowners who had property values greater than $350,000 were less knowledgeable about karst geology and city's wildland program. City residence length was a better indicator of knowledge than residence length at a particular address. It was associated with higher levels of knowledge for karst geology, endangered species, and the city's wildland program. Finally, membership in a homeowner association was surprisingly correlated with lower knowledge levels about endangered species and rangeland ecology.

When information sources and behavioral items were added the fit of the models increased (ΔR^2 ranged from +0.09 to +0.16 for each model) (Table 6). Compared to other information channels, respondents who used local newspapers as one of their information sources were more knowledgeable about karst geology, rangeland ecology and the city's wildland programs. Receipt of notices from the City of Austin, by contrast, was negatively associated with rangeland ecology knowledge. Knowledge of the access points to wildland areas was positively associated only with rangeland knowledge but accessing a wildland in the past year was not related to knowledge level in any model.

Behavioral items were related to knowledge levels in some cases. A respondent's intention to participate in an environmental education class was positively associated with endangered species knowledge but willingness to host such a class was negatively associated with knowledge about the city's wildland program. Joining an environmental education program was not associated with knowledge level for any model. Finally, past participation in a city-based environmental education program was not related to knowledge level; however, membership in an environmental organization was associated with increased knowledge for all models.

Overall, these results indicate that, in most cases, older male respondents that had lived in the City of Austin for a longer period of time were more knowledgeable about local

Table 5 Regression analyses showing the extent to which socio-demographic variables can explain the variation in knowledge scores

Variable	Karst aquifers			Endangered species			Rangelands			City of Austin wildlands		
	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value
(Constant)	18.87	1.66	0.10	43.05	4.60	<0.01	35.13	3.35	<0.01	9.62	1.10	0.28
Age	0.40	0.90	0.37	0.41	3.27	<0.01	0.48	2.71	0.01	0.30	2.06	0.04
Male	8.62	2.09	0.04	1.56	0.45	0.65	8.96	2.32	0.02	10.28	3.21	<0.01
Education[a]	0.77	0.14	0.89	−7.37	−1.58	0.12	1.16	0.22	0.83	1.40	0.31	0.76
Annual income[b]	3.14	0.70	0.49	7.19	1.90	0.06	2.13	0.50	0.62	6.84	1.94	0.05
Property value[c]	−7.58	−1.71	0.09	−0.47	−0.13	0.90	−3.16	−0.75	0.46	−9.22	−2.67	0.01
Years residence in City	0.34	2.02	0.05	0.37	2.58	0.01	0.15	0.90	0.37	0.36	2.76	0.01
Years residence at address	−0.38	−1.24	0.22	−0.02	−0.10	0.92	0.02	0.08	0.94	−0.10	−0.42	0.68
Homeowner assoc member	−4.39	−0.94	0.35	−6.75	−1.75	0.08	−8.86	−2.06	0.04	−1.45	−0.40	0.69
House >1 block from wildland	3.16	0.79	0.43	3.36	1.01	0.31	0.91	0.25	0.81	4.68	1.52	0.13
Sample size		231			234			233			229	
Adjusted R^2		0.06			0.05			0.08			0.12	
$F_{(df)}$, *p*-value		$2.48_{(9)}$, $p<0.01$			$2.48_{(9)}$, $p=0.01$			$3.35_{(9)}$, $p<0.001$			$4.50_{(9)}$, $p<0.001$	

ß-coeff = Beta coefficient; *t-stat* = Student t statistic; *p-value* = probability

[a] Bachelor's degree or higher

[b] Income >$125,000

[c] Property value >$350,001

Table 6 Regression analyses showing extent to which information sources, past participation in an environmental organization, and behavioral intention explains knowledge scores

Variable	Karst aquifers			Endangered species			Rangelands			City of Austin wildlands		
	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value	ß-coeff	t-stat	*p*-value
(Constant)	10.54	0.91	0.37	31.81	3.46	<0.01	28.00	2.66	0.01	3.68	0.41	0.68
Information sources												
Local newspapers	10.30	2.15	0.03	5.44	1.43	0.16	10.98	2.51	0.01	9.08	2.44	0.02
Notices from city	−5.07	−1.09	0.28	0.84	0.23	0.82	−11.02	−2.58	0.01	−3.45	−0.97	0.33
Internet	2.56	0.50	0.62	−1.85	−0.45	0.65	2.20	0.47	0.64	3.58	0.89	0.37
Local TV	1.98	0.40	0.70	3.49	0.86	0.39	6.37	1.36	0.18	−1.42	−0.356	0.72
Not heard of wildlands	−6.18	−1.27	0.21	−4.60	−1.17	0.24	−3.96	−0.89	0.38	−5.66	−1.50	0.14
Behavior												
Knows access points	3.52	0.76	0.45	5.42	1.47	0.14	7.25	1.71	0.09	4.15	1.15	0.25
Accessed wildlands at least once	−1.09	−0.23	0.82	1.43	0.38	0.71	−2.35	−0.54	0.59	−0.30	−0.08	0.94
Environmental organization	16.03	3.57	<0.01	10.87	3.05	<0.01	12.02	2.94	<0.01	9.35	2.69	0.01
Participated in EE[a] program	3.73	0.452	0.65	0.75	0.12	0.91	8.05	1.11	0.27	5.68	0.93	0.35
Would participate in EE[a] class	4.73	1.07	0.29	10.67	3.04	<0.01	−0.48	−0.12	0.91	3.08	0.89	0.38
Would host EE[a] class	−10.22	−1.53	0.13	−0.61	−0.12	0.91	−6.84	−1.11	0.27	−9.21	−1.77	0.08
Would join EE[a] program	3.04	0.56	0.58	3.79	0.79	0.43	8.16	1.63	0.11	4.58	1.06	0.29
Sample size		225			228			227			223	
Adjusted R^2		0.15			0.21			0.22			0.21	
$F_{(df)}$, *p*-value		$2.92_{(21)}$, $p<0.001$			$3.89_{(21)}$, $p<0.001$			$4.02_{(21)}$, $p<0.001$			$3.829_{(21)}$, $p<0.001$	

ß-coeff = Beta coefficient; *t-stat* = Student t statistic; *p-value* = probability

[a] Environmental Education

environmental issues pertaining to the wildland management program. Additionally, local newspapers as a source of information influence knowledge levels more than local television, Internet, or mailings from the City of Austin. Past environmental behavior and environmental interest such as participation in an environmental organization was positively and strongly related to knowledge.

Discussion

The City of Austin's growth together with resident's desire to live near open space leads to an increase in human-wildland interactions and the possibility for residents to be both positively and negatively affected by adjacent wildland areas. Based on a moderate rate of growth, Austin's population is projected to increase 18% in the next 5 years (TSDC 2000). Therefore, it is imperative to enhance environmental literacy amongst residents regarding the benefits, risks, and expectations associated with living at the wildland-urban interface. Environmental education/outreach programs are the city's preferred method to increase communication between residents and city land managers. Our baseline results indicate substantial knowledge deficits amongst residents living near protected wildland areas. Knowledge was not uniform across the four domains and neither were the indicators of knowledge. From this information residents can be segmented and customized messages can be targeted towards various categories of residents. Such targeted messages can be more effective for enhancing environmental literacy and constituent support for the city's wildland management mission.

Socio-demographic variables and knowledge

The relationship between some socio-demographic variables and environmental knowledge was statistically significant in our study. Our results support some previous studies; however, the literature is not necessarily consistent. For example, gender has been related to greater knowledge and awareness for both males (Holbert et al. 2003) and females (Reading et al. 1994). Although education is often positively related to environmental interest and knowledge (Arcury 1990; Schultz and Stone 1994; Theodori and Luloff 2002), it was not significant in our study. In some cases, neither age, gender, or education are related to environmental awareness (e.g., Laurian 2003). Therefore, although we found some demographic factors to be significant explanatory variables in some knowledge domains, they varied in their explanatory power across the four domains. Furthermore, it might be difficult to systematically use socio-demographic characteristics to stratify residents to develop customized education and outreach programs.

Two exceptions are age and duration of residence in the Austin area, which, aside from gender, were the only demographic variables that were statistically significant in three of the four knowledge domain regression analyses. Age was a statistically significant predictor of knowledge of endangered species, rangeland ecology and the City of Austin's Wildlands, but not karst geology, possibly because landowners neighboring wildlands are, to some extent, aware of these issues.

Period of residence was statistically significant in the knowledge models for karst geology, endangered species and the City of Austin's wildland program, but not rangeland ecology. For the latter, we asked survey participants to address issues that apply beyond central Texas; therefore period of residence in Austin is not likely to affect such knowledge. By contrast, endangered species and karst geology are issues specific to central Texas (i.e.,

place-based) and knowledge about them may be affected by the periodic media coverage of these issues. There is evidence that residence length is associated with community attachment (Brehm et al. 2004) and knowledge of local environmental issues (Williams 2001; Laurian 2003; Shindler and Mallon 2006) but other research results did not support such relationships (McCool and Martin 1994; Stedman 2002). The significance of length of residency can be explained by the idea that it enhances community involvement, and social and emotional ties to the community (Kasarda and Janowitz 1974). Further, place attachment to recreational areas can develop through increased frequency of use during which individuals form emotional attachments to attributes of the local environmental setting (Williams et al. 1992).

Membership in a homeowner association was statistically significant in explaining differences in two knowledge domains (endangered species and rangeland ecology). Interestingly, members were less knowledgeable about these issues than non-members. This might be explained by the idea that members feel more secluded and less affected by external rangeland and endangered species issues, but we have no evidence for this suggestion.

Based on the literature and our research results, we draw three conclusions about the use of demographic factors in targeting education/outreach programs for the City of Austin's wildlands. First, age should be taken into consideration. While our survey respondents were adults, it makes sense to develop different programs for school age children and adults. Second, programs aimed at adult education may be more effective in creating wildlands literacy if different programs are developed for younger more recent residents and older longer-standing residents. An alternative strategy might be to enlist longer-standing residents to assist with the development and presentation of programs for more recent residents; this would have the added advantage of enhancing community networks. Third, to efficiently disseminate information about the wildlands to less knowledgeable residents, homeowner association members could be targeted.

Personal experience and knowledge

Personal experience gained by accessing the wildlands for recreation was not a significant predictor of knowledge in our study. The literature contains mixed results about the relationship between personal experiences and environmental knowledge. One study reported a positive relationship between accessing natural resource areas and environmental knowledge (Jacobson and Marynowski 1997) but another found no such relationship (Heer et al. 2003). Consistent with previous research (Maloney and Ward 1973; Heer et al. 2003), we found that previous participation in an environmental organization was positively related with environmental knowledge; this was a statically significant predictor in all four domains of knowledge. This suggests that environmental organization members are more environmentally literate than people who merely access the lands for recreation purposes. Targeting information to residents who are not members of an environmental organization could be useful to enhance literacy about the wildlands. Alternatively engaging members of such organizations to assist in the development and presentation of such programs could be a way of using a more knowledgeable residents to help educate less informed neighbors.

Information channels and knowledge

In our study, the relationship between local newspaper readership and environmental knowledge was statistically significant for all knowledge domains, except endangered species. While newspapers were historically more important source of information than television or

radio (Bailey 1971), more recent studies found that interpersonal communication and personal experiences are more effective (Wright 2000; Williams 2001).

Television and Internet as a source of information were not significant predictors of knowledge in our study. This is consistent with one study in which newspapers readership and television viewing were not found to be positively related with environmental knowledge (Steger et al. 1988), but in another study these variables were significant (Brothers et al. 1991). A recent study also found that Internet did not differ significantly from print media in terms of information framing (Gerhards and Schafer 2010).

Information received in the mail was surprisingly not a significant predictor of knowledge in our study. A previous study found newsletters and brochures to be significant predictors (Williams 2001) but another study did not find such a relationship (George and Crooks 2006). This suggests that newsletters can be an effective medium for information dissemination, but their effectiveness depends on their context, content and format. For example, Armstrong et al. (1999) found that detailed educational brochures influenced recipients' behavior more than a simple reminder card. An earlier study similarly found that information messages could influence acceptance of certain land management activities but the authors stressed the importance of carefully wording messages because poorly targeted messages can lead to unintended outcomes (Brunson and Reiter 1996).

Even more surprisingly in our study, receipt of notices from the City of Austin to neighboring residents was negatively related to rangeland knowledge. To mitigate this deficiency in broader environmental literacy, mailings should incorporate information about the ecosystem benefits of ecologically sound rangeland management. As previously indicated, the content and wording of messages in such notices is important if they are to be an effective outreach tool for creating positive attitudes about land management actions (Brunson and Reiter 1996; Armstrong et al. 1999; Jacobson et al. 2001), such as the periodic application of prescribed fires on the wildlands. For example, a content analysis of newspaper articles pertaining to wildfires and mail survey results showed strong similarities between the public perceived benefits of prescribed fire and those identified by the media (Jacobson et al. 2001).

Conclusion

In our study we identified factors related to four domains of environmental knowledge to explore the potential efficacy of alternative information dissemination strategies for increasing urban residents' literacy with respect to protected wildlands owned by the City of Austin. In this article we presented relationships between various socio-demographic and behavioral factors and survey respondents' knowledge about karst geology, endangered species, rangelands, and the City of Austin's wildlands program. Some results confirm our expectations: residence length, previous participation in an environmental organization and local newspaper readership were positively associated with level of environmental knowledge. By contrast, our study did not identify statistically significant relationships between environmental knowledge and education level, accessing the wildlands, and use of the Internet or television as information sources.

Our results suggest that educational and outreach efforts by the City of Austin to enhance literacy about the wildlands should be customized for various target groups. The most effective initial approach might be to target younger more recent residents of Austin who have not previously participated in an environmental organization. This group was on average least knowledgeable about issues pertaining to the wildlands.

Our results also indicated that developing and presenting environmental education classes might be most effective in reaching a broad range of residents (almost half indicated they would participate in such a class). This could be accomplished in collaboration with homeowner associations and perhaps local environmental organizations. In addition, respondents indicated that their preferred sources of environmental information were newspapers, newsletters, and the Internet and the results of the regression analyses support the notion that local newspaper readership is positively associated with environmental knowledge pertaining to the wildlands and the City of Austin's wildland program. Regular informative articles in local newspapers about the four areas of knowledge (karst geology, endangered species habitat, rangeland ecology and the City of Austin's wildland program) could, therefore, also enhance literacy. Such educational and outreach initiatives would likely also increase support from neighboring residents for the management practices applied to wildlands to achieve the stated water quality and endangered species protection goals.

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