July 2016

Characterizing the urban human environment system in Boston, Massachusetts

Rachel S. Danford
University of Massachusetts - Amherst

Characterizing the urban human environment system in Boston, Massachusetts

A Dissertation Presented

by

RACHEL SAMARA DANFORD

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2016

Department of Environmental Conservation

Characterizing the urban human environment system in Boston, Massachusetts

A Dissertation Presented

by

RACHEL SAMARA DANFORD

Approved as to style and content by:

____
Paige Warren, Chair

____
Robert Ryan, Member

____
Craig Nicolson, Member

____
Jennifer Randall, Member

____
Timothy Randhir, Department Head
Department of Environmental Conservation

ACKNOWLEDGMENTS

I would like to thank my advisor, Paige Warren, for all her guidance, support, and patience throughout my graduate career. She has been and will continue to be a role model to me both professionally and personally.

I would also like to thank:

My committee members, Robert Ryan, Craig Nicolson, and Jennifer Randall.

As well as, Michael Strohbach, Chingwen Cheng, Anita Milman, Kate Tooke and all the colleagues and collaborators that I learned from.

The student technicians, volunteers, Citizen Scientists, and participants for their time and expertise.

Finally, I'd like to thank Aunt Kate for babysitting while I worked at True Grounds, Ellie for showing me how much I could get done during nap time, and my husband, Tim, for not letting me give up.

ABSTRACT

Characterizing the urban human environment system in Boston, Massachusetts

MAY 2016

RACHEL DANFORD, B.Sc., BROWN UNIVERSITY

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Ph.D., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Paige Warren

Access to natural resources and restorative green space, especially in urban areas, has become critically important as an increasing number of people throughout the world move into cities (Grimm et al. 2008). Stewardship of natural spaces and a sense of engagement with these environmental benefits are crucial, especially in urban areas where access to nature is more difficult (Kaplan 2000; Ryan 2006) and less equitable (Danford et al. 2014). This research proposes a model where individual and policy level values and decisions shape how urban nature is used, which affects the adoption of environmentally responsible behavior and natural resource conservation and in turn feeds back into environmental values and decisions. The research addresses four gaps in the existing literature; 1) the affect of risk on individual level ERB on private property, 2) how environmental attitudes affect policy level decisions about natural resource conservation, 3) how ecological availability can limit equitable distribution of urban green space, and 4) the ways in which users engage with small, community-driven urban green spaces. Policy implications and suggestions for further research are also discussed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

INTRODUCTION

Access to natural resources and restorative green space, especially in urban areas, has become critically important as an increasing number of people throughout the world move into cities (Grimm et al. 2008). The importance of access to green space and natural resources has been well documented (Ulrich 1984; Ulrich et al. 1991; Herzog et al. 1997; Kuo and Sullivan 2001; de Vries et al. 2003; Sullivan, Kuo, and Depooter 2004). Stewardship and a sense of engagement with these environmental benefits are crucial, especially in urban areas where access to nature is more difficult (Kaplan 2000; Ryan 2006) and less equitable (Danford et al. 2014). Finding ways to encourage stewardship and environmentally responsible behavior, however, is not straightforward. There are a number of competing factors on different scales that affect attitudes and behaviors related to engagement with green space and natural resource conservation.

This research explores these competing factors within one study area, proposing a model where individual and policy level values and decisions shape how urban nature is used, which affects the adoption of environmentally responsible behavior and natural resource conservation and in turn feeds back into environmental values and decisions (Figure 1). Decisions to engage with nature or perform an environmentally responsible behavior are informed by many different factors and on several different scales. Individual attitudes (1) and regional policies (2) both play a role in how people make decisions about engaging with green space and using natural resources (Steg and Vlek 2009). This use and engagement (3 & 4) affects the level of stewardship of green spaces and the conservation of natural resources which can in turn change people's values and attitudes toward the spaces and resources again (Ryan 2006). My work investigates these human-environment interactions across scales and categories, attempting to provide a general picture of our connection to nature in urban areas and how we make environmentally relevant decisions at different scales. The research addresses four gaps in the existing literature, corresponding to the four chapters; 1) the affect of risk on individual level ERB on private property (individual level decision-making), 2) how environmental attitudes affect policy level decisions about natural resource conservation (policy level decision-making), 3) how ecological availability can limit equitable distribution of urban green space (regional access), and 4) the ways in which users engage with small, community-driven urban green spaces (local access). I will then discuss the importance of studying these competing factors, especially with regard to policy applications in urban areas.

Study Area

This work is concentrated in and around Boston, Massachusetts, US. The area is an ideal site for this type of system-wide study of human-environment interaction because it is compactly developed, spatially heterogeneous, and has progressive policies in place to move toward more equitable green space access and encourage natural resource conservation. In each chapter, the specific study area will be described in greater depth.

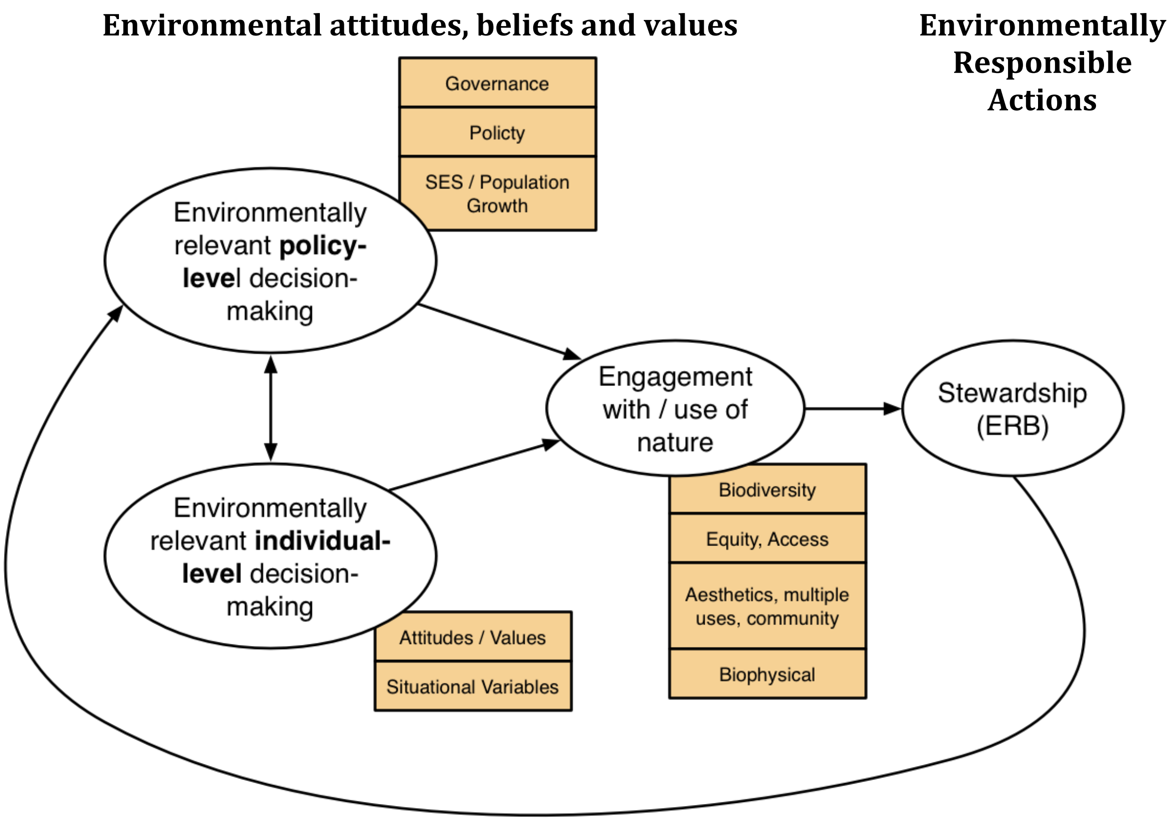

Figure 1: Attitudes, engagement and environmentally responsible actions in a feedback loop.

CHAPTER 1

ENVIRONMENTALLY RELEVANT DECISION-MAKING AT AN INDIVIDUAL SCALE

1.1 Abstract

Although a number of studies have investigated the link between environmental attitudes and environmentally responsible behaviors, few have considered the element of risk to property or person in the decision to act environmentally. As the human population continues to expand and encroach on wildlife habitat, "risky" environmentally relevant decisions become increasingly important. For example, the decision to remove a dead tree standing on one's property reduces possible habitat and food sources for wildlife but also protects against possible risk to home and family. Using the theory of planned behavior, we test how the level of risk (defined by the proximity of a dead tree) affects the decision to remove or maintain a dead tree in one's yard. We find that attitudes towards dead trees and the perceived risk to property are significant predictors of intention to remove a dead tree from one's yard. Furthermore, we find that the level of risk moderates the link between attitudes and intention: the relationship between attitudes and intention is strong in the low-risk group but nonsignificant in the high-risk group. These results agree with existing literature on the moderating effect of effort on environmental behavior. These findings suggest that when the environmental situation is risky, the traditional method of increasing awareness of the environmental benefits to encourage environmentally responsible behavior may be insufficient.

1.2 Introduction

The decisions humans make every day have profound impacts on the environment (Vitousek et al. 1997). Human dominated urban areas are associated with fragmentation and degradation of wildlife habitat, decreased biodiversity, modified ecosystem functioning, and other disturbances and chronic stresses (McDonnell, Pickett, and Groffman 1997; Alberti, Marzluff, and Shulenberger 2003; Alberti 2005). Human decisions that lead to negative impacts are not generally made maliciously, but instead often arise through the interplay of many factors; such as aesthetic and spiritual values, attitudes, beliefs, effort, and the approval of others. Research has shown how these factors are involved in forming environmentally responsible values and attitudes (Oskamp et al. 1991; Vining and Ebreo 1992; Schultz, Oskamp, and Mainieri 1995; Schultz and Oskamp 1996; Zelezny 1999). Decisions to act pro-environmentally, when taken collectively, can have a considerable affect on our environment. Small behaviors, such as recycling or planting native vegetation, can have a profound effect when many people perform these actions in concert (Brower and Leon 1999).

Although the determinants of pro-environmental behaviors are well-studied in the literature, some types of environmental decisions have not been thoroughly investigated. One such type of decision is the decision to act pro-environmentally when the action might incur risk to self or property. "Risky" decisions such as these may involve relatively simple environmentally responsible actions such as maintaining native vegetation or dead trees on private property, but may have great benefit for the environment, especially when many people perform these actions in concert (Brower and Leon 1999). However, the fact that one must assume some amount of risk to produce the environmental benefit complicates these decisions. To investigate this type of environmental action we will use a well-tested behavioral model, the Theory of Planned Behavior (TPB; Ajzen 1991; Ajzen 2003).

1.3 Literature Review

1.3.1 The Theory of Planned Behavior (TPB) and pro-environmental behaviors

The TPB is one of the most widely-used theories describing the relationship between values and beliefs and subsequent behaviors. The theory proposes that reasoned and considered actions can be predicted by three main variables: 1) attitudes toward the behavior, 2) subjective norms about the behavior and 3) perceived behavioral control to perform the action. These three variables predict a fourth, behavioral intention, and the four variables together are predictive of actual behavior. The three main variables are influenced by beliefs related to the ultimate behavior (Figure 1.1). Attitudes are influenced by beliefs about the emotional, physical and social outcomes of the behavior. Subjective norms are a function of the perceived expectations of important others. Perceived behavioral control represents the subject's belief that he or she has the skills, resources and knowledge to perform the action (Ajzen 1991; Ajzen 2003).

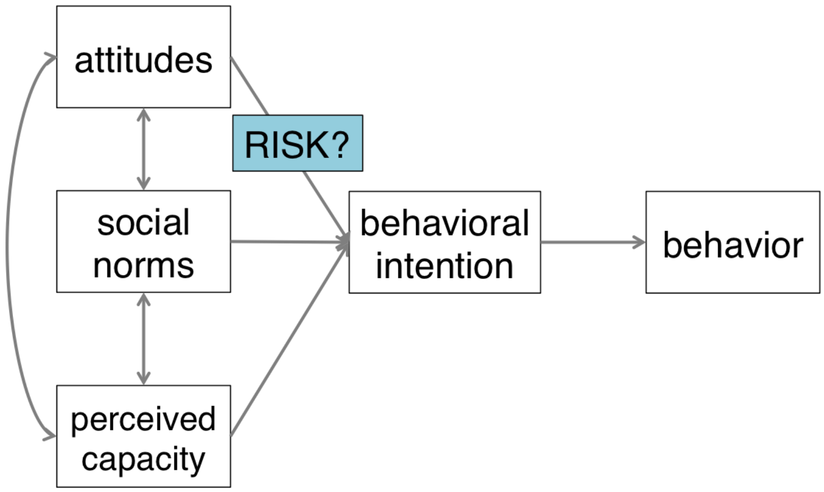

Figure 1.1. Theory of Planned Behavior (modified from Ajzen 2001).
How perceived risk can moderate the attitudinal-behavioral link.

The TPB is a robust model that has often been used to investigate the determinants of environmentally relevant intentions and behavior (*recreational activities*-Ajzen and Driver 1992; *recycling*-Schultz and Oskamp 1996; *hunting behavior*-Hrubes, Ajzen, and Daigle 2001; *public transportation use*-Heath and Gifford 2002; Tonglet, Phillips, and Read 2004.

Although meta-analysis has demonstrated broad support for the TPB (Armitage and Conner 2001), some decisions and behaviors may require additional variables to increase the predictive usefulness of the model (Conner and Armitage 1998; Terry, Hogg, and White 1999). Several researchers have suggested that additional variables should be added to the TPB to better predict environmentally responsible behavior (Heath and Gifford 2002; Kraft et al. 2005; Routhe, Jones, and Feldman 2005). In this study, we test the TPB variables of attitudes, social norms, and perceived behavioral control, along with the additional variables of gender, level of urbanization, and environmental knowledge, with respect to the specific environmentally relevant choice of removing or maintaining a dead tree on private property.

1.3.2 Gender

Gender differences in environmental attitudes and behaviors have been thoroughly studied in the literature. Although there has been some controversy as to whether gender is influential on environmental attitudes and behavior (Hines, Hungerford, and Tomera 1987), recent work has found that gender plays a significant role in pro-environmental attitudes (Zelezny, Chua, and Aldrich 2000). Meta-analyses of research on gender differences in environmental contexts over the last two decades finds that women often report more positive environmental attitudes than men and that, as a single variable, there is a strong effect of gender on environmental behavior (Zelezny, Chua, and Aldrich 2000).

1.3.3 Level of urbanization

Researchers began to look at a person's location on an urban gradient as a predictor of environmental attitudes and behaviors in the last two decades (Mankin, Warner, and Anderson 1999). Manfredo, Teel, and Bright (2003) found that general values toward wildlife were positively correlated with level of urbanization; residents in more urbanized areas held more positive attitudes about wildlife than rural residents. (Mankin, Warner, and Anderson 1999) found that urbanites in Illinois, U.S were more likely to value wildlife in the same way that they valued pets or people than were rural Illinois residents. Urban residents also possessed less overall knowledge about wildlife than their rural counterparts and had less encounters with wildlife species. Generally, researchers find that residents from more urbanized areas have a more positive view of wildlife (Williams, Ericsson, and Heberlein 2002), likely due to increased education levels and fewer unpleasant encounters with wildlife (Mankin, Warner, and Anderson 1999).

1.3.4 Environmental Knowledge

Environmental education research indicates that knowledge about environmental issues does not, in itself, produce pro-environmental behavior (Hungerford and Volk 1990). In truth, knowledge of the issue seems to only be an important variable if the individual was not aware that an environmental issue existed before being educated (Hines, Hungerford, and Tomera 1987). However, environmental education is still touted as a reliable way to encourage pro-environmental attitudes and behaviors (Williams, Ericsson, and Heberlein 2002; Cooper et al. 2007).

The TPB considers knowledge to be an antecedent to attitudes, but other researchers argue that the role of knowledge in the TPB is still unclear (Eagly and Chaiken 1993; McEachern and Warnaby 2008). Environmental knowledge, especially knowledge about the environmental benefits of a specific behavior, may have important utility in modeling environmentally responsible behavior. Therefore, we measured participants' knowledge of the environmental benefit of leaving dead trees on private property to determine if this knowledge affected intention separately from the influence of attitudes.

1.3.5 Past Behavior

Several studies have found that past behavior is the best predictor of future behavior (Conner and Armitage 1998). Some researchers hypothesize that previous behavior may allow subsequent behavior to become habitual and therefore be influenced by different determinants, while others believe that past behavior, conceptualized as habit, has an independent effect on behavior and intention (Mullen, Hersey, and Iverson 1987). In contrast, (Ajzen 1991) argues that past behavior will be mediated by perceived behavioral control. Repeating the behavior will lead to familiarity with the behavior and increased perception of control over the behavior. We add past behavior as a separate variable to test whether past behavior has an independent effect on intention in an environmentally risky decision such as removing a dead tree on private property.

1.3.6 Risk and decision-making in an environmental context

Many fields have integrated risk into the TPB as an additional explanatory variable in order to predict behaviors in contexts ranging from food safety to smoking (Higgins and Conner, M. 2003; Lobb, Mazzocchi, and Traill 2007). Environmental researchers have used the TPB to look at risk associated with global warming (Kahlor 2007) and windfarm installation (Kempton et al. 2005; Firestone, Kempton, and Krueger 2009) in the context of how participants integrate perception of the risk to the environment into their attitudes and intentions. However, little research has investigated how people make environmentally responsible decisions when the decision-maker must assume possible risk to self in order to perform an action that produces environmental benefit (*but see* Gregory 2002 *for a review of value trade-offs, including risk, in environmental contexts*).

We manipulate risk level to experimentally investigate whether risk moderates any of the relationships between traditional predictors and intention when the environmental action is perceived as “risky” to person or property. These types of actions can have important consequences for urban and suburban ecosystems. For example, leaving dead trees standing and maintaining native vegetation can protect native habitat for wildlife (Theobald, Miller, and Hobbs 1997; Blewett and Marzluff 2005) and choosing not to clear land for firebreaks can increase the availability of natural areas in human dominated locations, diminishing the negative impacts of suburban sprawl (Pickett, Cadenasso, and Grove 2001; Bryant 2006; Cooper et al. 2007).

In the present study we use the environmental decision to take on the risk of leaving a dead tree on private property to examine how risk influences environmentally relevant behavioral intentions in a TPB context. We predict that 1) TPB variable plus the additional determinants discussed above will predict a person's intention to assume the risk of a dead tree on private property better than TPB variables alone and 2) the level of perceived risk will influence the relationship between determinants and a person's intention to assume the risk of a dead tree on private property.

1.4 Methods

1.4.1 Participants and Design

Participants were recruited through posters in coffee shops, grocery stores, and libraries as well as postings on community web bulletin boards and community email lists. Participants were directed to a website with a link to the survey and then randomly redirected to one of the two risk conditions. A total of 236 participants responded to the survey, hosted through Survey Monkey (Finley 1999), between March 2009 and December 2009.

Of the surveys submitted, 21 were not used because the participants did not indicate which town they lived in. An additional 11 surveys were not included because the participants did not respond to some or all of the TPB items. Finally, 21 surveys were not included because the participants indicated they did not own a house.

The final sample was 183 participants, 86 participants in the high-risk condition and 97 in the low-risk condition. Participants were 67.8% female (*n* = 124), the majority of participants were between 40 and 64 years of age (75.4%), with a graduate or professional degree (59.6%), and a total household income of over $100,000 per year (50.3%). Ninety-two participants (50.3%) indicated that they had had a tree removed in the past. The participants were distributed relatively evenly throughout the five towns along the urban gradient: Cambridge (*n = 36*), Arlington (*n = 51*), Medford (*n = 41*), Lexington (*n = 29*), Concord (*n = 26*). A nonrespondent analysis was performed on the 53 surveys that were not included in our final sample.

1.4.2 Measures

Table 1.1 shows the measures used in our analysis. Since there has been little research done on the decision to maintain or remove dead trees on private property, we conducted a focus group to collect data on the factors that suburban residents considered when faced with this type of decision (*n* = 23, 16 female participants) (Francis et al. 2004). All participants were asked five open-ended questions about their attitudes and opinions regarding dead or dying trees in their yards. A survey was then prepared using the information collected from the focus group as well as literature regarding attitudes toward city-owned street trees (Sommer, Guenther, and Barker 1990; Dwyer, Schroeder, and Gobster 1991; Gorman 2004). These items were rated by an expert panel on three scales: 1) construct validity, 2) relevancy, 3) conciseness. Items were reworded or dropped based on the panel's feedback (Fowler and Cosenza 2009).

Table 1.1 Study Measures

Theory of Planned Behavior Measures

Indicate how strongly you agree or disagree with each statement on a scale from 1(strongly disagree) to 7(strongly agree).	Mean	SD
Attitudes (alpha = .89)		
Leaving a dead tree standing in my yard…		
… would be risky	4.8	1.5
… would be irresponsible	4.0	1.9
… would be unsafe	3.8	1.7
…cause me to use my yard less	2.9	1.6
…could cause damage to my house	4.6	1.4
…could attract animals that could damage my house	3.5	1.5
…could attract animals that carry disease	2.9	1.4
Dead trees are ugly and should be removed	3.6	1.7
A dead tree in my yard would ruin my view	3.3	1.6
Dead trees are unhealthy and should be removed	3.8	1.7
Subjective Norms (alpha = .79)		
…would make it harder to sell my house	5.0	1.3
People who are important to me would think leaving a dead tree in my yard is irresponsible	3.9	1.4
People who are important to me would think leaving a dead tree in my yard would look ugly	3.8	1.5
Perceived Behavioral Control (alpha = .62)		
A dead tree would be easy to remove	3.6	1.7
Removing a dead tree would be affordable	3.9	1.7
I know who to contact to have a dead tree removed	3.7	1.7
Behavioral Intention (outcome)		
How likely are you to have the arborist (tree professional) remove the dead tree for you?	4.7	2.0
What factors did you consider when making your decision to leave or remove the tree?	(open ended/qualitative)	

Additional Measures

DETERMINANT	*% in sample*
Gender	
Female	67.8
Male	31.1
Prefer not to say	1.1
Level of urbanization	
Cambridge (most urbanized)	19.7
Arlington	27.9
Medford	22.4
Lexington	15.8
Concord (least urbanized)	14.2
Removed a tree in the past	
Yes	50.3
No	26.2
Did not respond	23.5
Environmental Knowledge	
Responded correctly:	
to both statements	25.1
to one statement	74.9
to neither statement	0.0
Risk level (treatment)	
High-risk condition	53
Low-risk condition	47

1.4.2.1 Theory of Planned Behavior measures

Attitudes were measured by averaging and mean-centering responses to 10 items on a scale from 1 (strongly disagree) to 7 (strongly agree). These items involved statements about the riskiness, aesthetics, and economics of leaving a hazard tree standing in one's yard. The scale involved both positive and negative items, positive items were reverse coded for analysis (alpha = .89).

Subjective norms were measured by averaging and mean-centering responses to 3 items on a scale from 1 (strongly disagree) to 7 (strongly agree). These items involved statements about the social acceptability of leaving a hazard tree standing in one's yard (alpha = .79)

Perceived Behavioral Control was measured by averaging and mean-centering responses to 3 items on a scale from 1 (strongly disagree) to 7 (strongly agree). These items involved statements about the ease and affordability of removing a dead tree from one's yard (alpha = .62).

Behavioral Intention was measured by participant responses to 1 item in the context of a short vignette (Table 1.3) about a dead tree in their yard: 'How likely are you to have the arborist (tree professional) remove the dead tree for you?' on a scale from 1 (not at all likely) to 7 (extremely likely).

Table 1.2. Vignettes used in the two risk conditions

Low-Risk	*Imagine that when you look out your window you see a dead or dying tree standing in your yard. It is a large tree with several cavities and dead branches in it. However, this tree is too far away from your house to cause any damage if it fell. You ask an arborist (tree professional) to look at the tree, and she tells you that she cannot predict if or when the tree might fall. She gives you an estimate of how much it will cost to have the tree completely removed, and you think that the price seems reasonable for the amount of work she will do.*
High-Risk	*Imagine that when you look out your window you see a dead or dying tree standing in your yard. It is a large tree with several cavities and dead branches in it. This tree if close to your house and if it fell it would cause damage. You ask an arborist (tree professional) to look at the tree, and she tells you that she cannot predict if or when the tree might fall. She gives you an estimate of how much it will cost to have the tree completely removed, and you think that the price seems reasonable for the amount of work she will do.*

1.4.2.2 Additional measures

Environmental knowledge was measured by summing the correct responses to two items: ‘Many different animals live in dead or dying trees’ and ‘Dead or dying trees are important for the environment’. *Past behavior* was measured by asking participants to respond with ‘yes’ or ‘no’ to the question ‘Have you ever removed a dead or dying tree from your yard’. Participants were also asked to indicate their *gender* and the town they lived in.

Level of urbanization was determined by assigning each participant to an urban rank depending on which town they reported living in. We used three common characteristics to identify locations along an urbanization gradient: 1) population density, 2) housing density, and 3) road density (Hahs and McDonnell 2006). Each town was given a rank (1-urban to 5-suburban) for each characteristic. The ranks were then averaged to give an overall urbanization rank for each town, with Cambridge, MA ranking as the most urban and Concord, MA ranking as the least urban or most suburban area (Table 1.2). The level of urbanization variable was then dummy coded to allow for inclusion in a regression analysis.

Table 1.3
Mean urbanization rankings of five Massachusetts towns comprising the study area.

Densities[a]	**Cambridge**	**Arlington**	**Medford**	**Lexington**	**Concord**
Population	15,768	7,942	6,826	1,849	875
Housing	6,995	3,747	2,787	691	246
Road	22.2	23.4	16.9	9.3	5.1
Mean Rank	**1**	**2**	**3**	**4**	**5**

[a]per square mile

1.4.3 Risk Level

To manipulate risk level, participants were randomly assigned to one of two risk conditions. In the high-risk condition, the participant read a vignette about a dead tree located near their house. In the low-risk condition, the vignette placed the dead tree far from the house (Table 1.3). With exception of this vignette, all participants answered an identical survey.

1.5 Results

1.5.1 Qualitative analysis

Respondents wrote down any factors that they considered when making the decision to keep or remove the tree and then ranked them by importance. The responses were qualitatively analyzed, grouped into # themes, and ranked by number of times they appeared in overall responses (Table 1.4).

Table 1.4 Factors considered in environmentally relevant decision-making: decision to keep or remove a dying tree.

Ranking	*Decision to keep*	*Decision to remove*
1	cost to remove	aesthetics – "dying trees are ugly"/ makes room to plant a new, healthy tree
2	provides wildlife habitat	risk of damage to property/injury
3	effort to safely remove/ not sure exactly how to remove	utility (e.g. firewood)
4	"it's a natural cycle"	danger to other trees/landscaping
5	---	effort to clean up after a dying tree

1.5.2 Non-respondent analysis

The 53 surveys that were not included in the final sample were analyzed to determine if the participants who chose not to answer were significantly different from the final sample. These participants were similar to the final sample on all demographic variables except for income, where the majority of the participants indicated a significantly lower household income than the final sample ($\chi^2 = 9.665$, $df = 1$, $p < 0.01$). However, the number of non-respondents who chose not to answer the income question (52%) was much greater than the number of respondents who chose not to answer (7%), which may have skewed our results.

1.5.3 Hierarchical Linear Regression

To test the influence of traditional predictors, TPB variables, and risk level on intention to remove a dead tree, we include traditional variables and TPB variables within a regression analysis (Model 1), and then extend the model with risk level (Model 2). Finally, we include the interaction between risk level and attitudes (Model 3).

Table 1.5 shows that the model including risk in addition to the traditional and TPB variables has greater predictive power on intention than the model without risk (Model 2, R^2 = .29; Model 1, R^2 = .12). Including the interaction between risk and attitudes significantly increased the predictive power again (Model 3, R^2 = .37).

In the model that included traditional predictors plus TPB variables (Model 1), only attitudes is a significant predictor of intention; subjective norms, perceived behavioral control, gender, level of urbanization, past behavior, and environmental knowledge are non-significant variables. In the extended model where risk level is included (Model 2), risk exerts a strong positive influence on intention. The significant interaction between risk level and attitudes in Model 3 has a negative influence on intention.

Table 1.5
Regression analysis for intention to remove a dead tree on private property

Model		B	SE	β	t	Sig.
1	(Constant)	4.23	1.05		4.04	.00**
	Gender	.15	.38	.03	.40	.69
	Past behavior	-.32	.41	-.07	-.79	.43
	Urban rank 4	-.28	.56	-.05	-.50	.63
	3	.20	.54	.04	.37	.72
	2	.56	.81	.06	.70	.49
	1	.35	.57	.07	.62	.54
	Attitudes	.63	.20	.36	3.13	.00*
	Subjective norms	-.23	.19	-.135	-1.24	.22
	Perceived beh. control	-.05	.13	-.04	-.41	.68
	Environmental knowledge	.27	.41	.06	.66	.51
2	Risk level	1.84	.33	.44	5.57	.00**
3	Attitudes X Risk level	-1.06	.27	-.40	-3.98	.00**

* *p* < .01. ** *p* < .001

1.5.4 Simple slopes analysis

To investigate whether risk level influences the relationship between attitudes and intention we performed a simple slope analysis on the significant interaction between risk and attitudes. Using the simple slope equation,

$$\hat{y} = \hat{b}_0 + \hat{b}_1 x + \hat{b}_2 z + \hat{b}_3 xz$$

we calculated the simple slope at each of four points; low-risk/positive attitudes, low-risk/negative attitudes, high-risk/positive attitudes, and high-risk/negative attitudes (Figure 1.1). In the high-risk condition, attitudes failed to predict intentions, the simple slope was not significantly different from zero (simple slope = -.003, t = -.06, p = .95). In the low-risk condition, attitudes were strongly and positively predictive of the intention to remove a dead tree on private property (simple slope = .22, t = 5.03, p = 0).

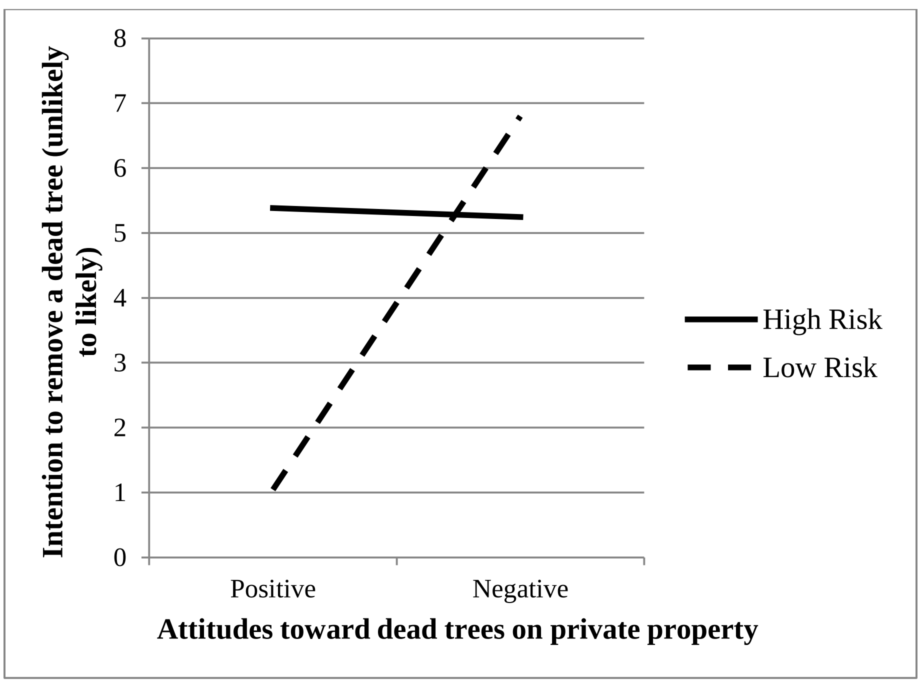

Figure 1.2 Risk moderates the relationship between attitudes and behavioral intention

1.6 Discussion

Humans are more likely to engage in nature when they feel some control over that nature (Kaplan and Kaplan 1978), and that control can be signaled by "cues to care" such as fences, hedges, landscaped plantings, edged paths, etc. (Kaplan, Kaplan, and Ryan 1998). Respondents overwhelmingly listed aesthetics as the reason they would chose to remove a dead or dying tree. Many felt that dead trees were ugly, and wanted to use the space occupied by the dying tree to plant a new, healthy tree. In fact, aesthetics was ranked as even more important than risk of damage to property or injury in the decision to have a dead or dying tree removed. Dead and dying trees visually signaled ugliness, danger and disease to the respondents. In this case, the visual perception of "good" nature as being clean and healthy can lead to selective conservation and ultimately reduce wildlife habitat, deplete soil nutrients, and curtail the food chain. In suburban areas like our study area, where green space is already disturbed and fragmented, protecting the "ugly" parts of nature, along with the aesthetically pleasing elements, is critical for preserving ecological health.

As we predicted, participants in the high-risk condition were much more likely to remove a hazard tree from their yard. Our results also show that including perceived risk in the theory of planned behavior model almost doubled the explained variance in the model. However, further analysis of the interaction between attitudes and risk showed that perceived risk may be the *only* predictor worth considering when one is dealing with a risky environmentally relevant situation. As predicted, our results showed that in low-risk situations attitude was highly correlated with behavioral intention, but in high-risk situations participant's attitudes did not predict behavioral intentions. In fact, even those participants with negative attitudes toward removing hazard trees indicated they would remove the tree in the high-risk condition.

A comparable moderating effect can be seen in several studies, which found that effort moderates the link between attitudes and behavior in the theory of planned behavior model. (Schultz and Oskamp 1996) found that when it was difficult to recycle, only those with strong pro-recycling attitudes recycled, but when it was easy to recycle, even participants with only weakly favorable attitudes toward the environment would recycle. Other research has found a negative relationship between effort and the strength of the attitude-behavior link (Bagozzi, Yi, and Baumgartner 1990) or a curvilinear relationship between the variables (Stern 2000).

A paper by (Kaiser and Schultz 2009) discusses these conflicting findings, citing artifacts created by methodological issues. Specifically, they noted that restriction of range at the high and low extremes of effort may cause ceiling effects and deflate correlations. Their studies found that there is often restricted variability in the low-effort (extremely easy) behaviors but not in the high-effort (extremely difficult) behaviors (e.g. in low effort situations, everyone behaved the same way, creating a floor effect). This restricted variability might deflate correlations in low effort conditions, creating a false interaction. Our data could have an analogous problem in the high-risk condition, i.e. everyone is equally likely to remove the hazard tree, creating a ceiling effect. Based on (Kaiser and Schultz 2009), we looked at the distribution of responses in the high-risk and low-risk conditions using a cutoff standard deviation of 0.50. Item distributions with a standard deviation greater than 0.50 do not suffer from restriction of range.   None of our distributions had a standard deviation less than 0.80 (Table 1.1). This variance indicates that there was no ceiling effect caused by the high-risk condition (e.g. there were participants who did not intend to remove the hazard tree, even in the high-risk condition). This allows us to have more confidence that our results do not arise from an artifact of extremely risky behavior.

Our findings expand understanding of risky contexts and their influence on people's engagement in environmentally relevant decision-making. In a meta-analysis of the determinants of environmental behavior, (Bamberg and Möser 2007) identified knowledge, skills, attitudes, moral norms, and problem awareness as important factors in the prediction of environmentally responsible behavior. This study suggests that risk could be added to that list. Many researchers have called for increased environmental education and awareness to encourage environmentally responsible actions (Hungerford and Volk 1990; Dunlap and Mertig 1995; Pelletier et al. 1999; Nordlund and Garvill 2002) or maintained that understanding a person's degree of *biophilia* (Wilson 1984) or connectedness with nature is important for predicting environmentally responsible behavior (Nisbet, Zelenski, and Murphy 2009). (Pooley and O'Connor 2000) suggested that emotions and beliefs are the most important factors in determining environmental attitude. Our research suggests that situations involving personal risk may require a different approach to promote environmentally responsible behavior.

The results of this study support the call for environmental education and awareness in some situations, specifically when the perceived risk of the behavior is low. When the perceived risk is high, however, policy-makers may be better served by concentrating money and effort on disseminating information that will address the perceived risk of the behavior instead of educating the public about the environmental benefits of the behavior, since our results suggest that risk perception can weaken the relationship between attitudes and behavioral intention (see Figure 1.4). In the situation examined in this study, perceived risk might be reduced by the knowledge that snags (i.e. dead trees) may stand for many years depending on the type of the defect and the tree species (Kane, Ryan, and Bloniarz 2001). Also, educating people about the possibility of removing a problem limb or careful pruning while leaving a good portion of the dead tree standing may reduce the perception of risk. As our results show, when perceived risk is reduced, attitudes and values become more important. Future research might concentrate on the effectiveness of these and other interventions designed to reduce the level of perceived risk.

Understanding and encouraging environmentally responsible behaviors in high-risk contexts, such as minimizing the use of fire breaks and maintaining dead or dying trees, can have wide-ranging affects on wildlife in developed areas. Dead and dying trees can lessen the impacts of habitat fragmentation for some species and shrink the habitat disturbance zone around housing units by including usable wildlife habitat within disturbed areas, such as yards (Theobald, Miller, and Hobbs 1997; Warren, Kane, and Lerman 2007). By identifying the most useful predictors of environmentally responsible behavior in these risky situations, policy makers can channel time and money toward the best interventions and increase the likelihood of environmental protection in urban and suburban areas.

CHAPTER 2

ENVIRONMENTALLY RELEVANT DECISION-MAKING AT A POLICY SCALE

2.1 Abstract

Research on environmentally relevant behaviors (ERB) traditionally focuses on the individual scale, yet interactions between scales also impact ERB. We examine these cross-scalar interactions through the lens of water conservation, where decisions made at the water provider level interact with decision-making at the residential level with implications for water conservation. We draw from environmental behavior theory to develop a conceptual model of conservation choices used to 1) characterize the factors considered by water providers when making conservation decisions, 2) map the relationship between water provider decision-making and residential decision-making and 3) identify areas where the efficiency of conservation programs could be improved. Results suggest that water providers choose conservation programs based primarily on their attitudes toward water conservation and capacity factors without monitoring residents' attitudes, rates of participation, or associated water savings. These findings indicate inefficiencies in the current system that may be improved by tightening connections between residents and providers.

2.2 Introduction

Water availability in urban areas has become a crucial issue that is growing in importance as climate change impacts fresh water resources already affected by land use change and urbanization (Bates et al. 2008). In more than nine percent of U.S. watersheds, demands for freshwater exceed the natural supply (Averyt et al. 2013). Residential water use and unaccounted for water are two areas where major savings can be realized from comparatively small conservation measures (Vickers 2005). Conserving residential water presents a unique challenge, in that it depends upon the attitudes and behaviors of many different individuals with varying degrees of interest in and knowledge of water as a natural resource (Brooks 2006). Residential water conservation is a valuable lens through which to study cross-scalar interactions in environmentally relevant behavior because mobilization of water conservation in the U.S. occurs across multiple interconnected scales (e.g., consumer, provider, watershed, regional) and decisions at one scale can have a direct impact on the attitudes, opinions, and behaviors of actors at other scales.

The choice to engage in environmentally relevant behavior, including water conservation, is influenced by attitudes towards the environment, beliefs about one's ability to act "pro-environmentally" (Russell and Fielding 2010), and the context within which water conservation takes place that either directly influences the set of potential actions or mediates the social norms that influence behavior. Whereas the influence of attitudes and beliefs on environmentally relevant behavior has been addressed in more depth (Ajzen 1991; Stern 2000), there has been little research on the influence of context on environmentally relevant behavior in general (*with the exception of* Guagnano, Stern, and Dietz 1995; Schultz and Oskamp 1996; Hunecke et al. 2001). Furthermore, to our knowledge, there are no studies investigating interactions across actors and scales to understand how decisions made by some entities, e.g., the water provider, are both influenced by and influence the context within which other entities, e.g., residential water users, make decisions to engage in environmentally relevant behavior.

Our research takes a first step towards understanding cross-actor and scalar environmentally relevant behavior through a study of the water conservation tools offered to residents in the Ipswich and Parker watersheds in Massachusetts. We apply knowledge gleaned from environmental behavior change theories to the public policy level to explore the choice of water conservation tools offered by water providers in the region. Analyzing water provider decisions within a behavior change framework allows us to better understand the complex interactions that influence how public water conservation policies are made and how those decisions subsequently influence residential environmentally relevant behavior. We begin by briefly reviewing theories of environmental behavior change and describe a conceptual model of the links between environmentally relevant behavior at the water provider and the residential levels. We then provide background about the water use issues in our study area and present our in-depth analysis of the attitudes, beliefs and perceptions and contextual factors influencing conservation behavior at both the residential and water provider levels, and the interaction between the two. We conclude with a discussion of the implications of these interactions on water conservation.

2.3 Literature Review

2.3.1 Model of Residential Water Conservation

A number of theories seek to explain human actions in response to the environment, including the theory of planned behavior (Ajzen 1991), the value-belief-norm theory of environmentalism (Stern 2000), Protection Motivation Theory (Grothmann and Patt 2005) and others (Dahlstrand and Biel 1997; Gatersleben, Steg, and Vlek 2002; Steg and Vlek 2009). Though these theories have different disciplinary underpinnings and foci, all converge in concluding that actions are influenced by a similar range of factors including: attitudinal factors, contextual factors and personal capacity factors. Evidence suggests that these factors interact to predict intention and behavior, although the influence of each varies by the specific environmentally relevant behavior undertaken (Stern 2000). These three groups of factors form the basis for our conceptual model of residential water conservation (Figure 2.1) and are described in detail below.

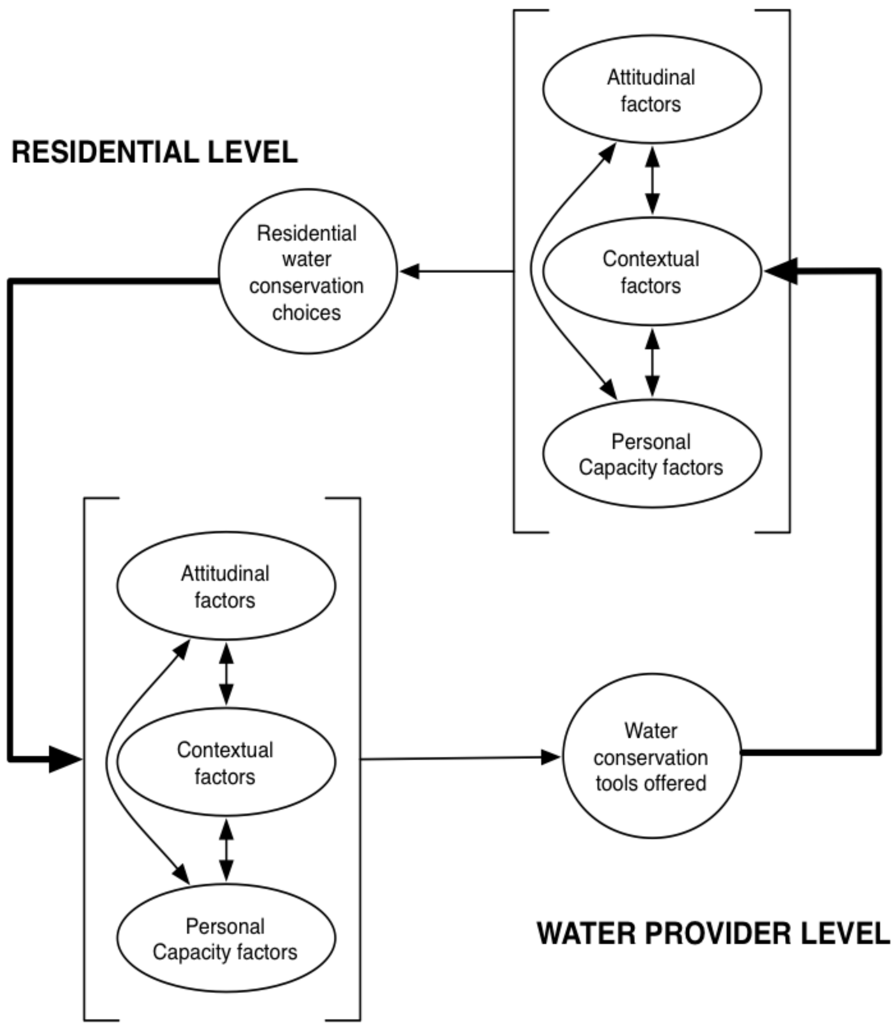

Figure 2.1. A conceptual model of the connections between water provider and residential levels and their influence on water conservation behavior.

Attitudinal factors include beliefs and values about the action to be performed, personal moral norms, beliefs about the consequences of the action for self or others, and beliefs about the difficulty of undertaking the action. In terms of water conservation, attitudes about the positive outcomes of water conservation have been linked to actual reduced water consumption (Kantola, Syme, and Nesdale 1983; Harland, Staats, and Wilke 1999; Lam 2006; Clark and Finley 2008). Awareness of environmental issues (Clark and Finley 2008) and one's personal moral norms (Harland, Staats, and Wilke 1999) have also been linked to water conservation intentions and self reported conservation behavior.

Personal capacity factors include the actor's perceived ability to perform the action, knowledge required to perform the action, time to act, and beliefs about affordability, authority to implement, etc. In some cases, an actor might inaccurately perceive their level of capacity, for example, a water provider may choose not to implement a certain conservation tool because they believe that their constituents will not accept it, when in fact their constituents would easily adopt the measure.

Contextual factors are especially important but sometimes overlooked in environmentally relevant behavior research (Stern 2000). These factors address the *actual* abilities and constraints of the actor, including monetary incentives/taxes, physical difficulties of the action, existing infrastructure or technology, public policies and support, and economic and political context. Contextual factors also include social norms surrounding the action to be performed. For example, the social acceptability of the perceived outcomes of water conservation affect the intention of residents to conserve water (Lam 1999; Trumbo and O'Keefe 2005; Lam 2006; Jones et al. 2010). Whereas the marked effect of contextual factors on environmentally relevant behavior has been documented, including in studies that demonstrated how cost and effort (Jones and Hunt 2010) or incentives and disincentives (Olmstead and Stavins 2009) affect water conservation, little research has investigated interactions across actors and scales that influence the contextual factors experienced by both.

With respect to water conservation, decisions made by water providers influence attitudes of and contextual factors encountered by residents. Outreach and education programs impact social norms (Steg and Vlek 2009) and the tools and programs water providers offer affect the effort or monetary investment necessary for residents to engage in water conservation. This nested relationship, wherein decisions at the water provider level influence environmentally relevant behavior at the residential level, highlights the multiple points of entry for achieving conservation behavior and the need for greater understanding of decision-processes at the water provider level.

Our conceptual model of residential water conservation (Figure 1) addresses the interconnections between the provider and residential level by explaining how attitudinal, contextual, and personal capacity factors interact to influence the choices water providers make regarding which water conservation tools to implement, The water conservation tools offered, in turn, directly affect residential water conservation at the contextual level by influencing a resident's actual capacity to conserve water (i.e. the ease, cost, and social acceptability of conserving water). The attitudes and subsequent water conservation actions of residents then feed back into the water provider's decision-making process, influencing his or her decisions about whether to continue or change particular offerings based on participation and acceptance. Our conceptual model is unique in that it addresses the decision-making processes that lead to public policy, whereas most models of environmentally relevant behavior address the decision-making processes of individuals.

2.4 Methods

2.4.1 Study Area

The Ipswich and Parker watersheds, located in eastern Massachusetts, provide water to over 350,000 people in 26 communities north of Boston (Figure 2.2). The watersheds cover a combined total of 237 square miles and their rivers' base flow is derived mainly from groundwater and wetlands (MA Office of Water Policy 2013). Low-flow events attributed to seasonal evapotranspiration rates and high water withdrawals between 1995 and 2000 (MA Office of Water Policy 2013) prompted watershed stakeholders, including town water providers, government officials from the MA DEP, and environmental advocates from the Ipswich River Watershed Association (IRWA) and other community groups, to meet in November of 2001 to discuss ways to restore healthy streamflow (Ipswich River Watershed Management Council (IRWMC) and Ipswich River Watershed Association (IRWA) 2003). Residential water withdrawals are seen as a key factor influencing flow levels (Zarriello and Ries 2000), thus controlling residential water demand is seen as an important step towards sustaining the watersheds (Zarriello 2002).

Figure 2.2. Twenty-six communities that draw water from the Ipswich River and/or Parker River watersheds (MassGIS (Office of Geographic Information) 2011). *Boxford relies solely on wells, no public water system.

2.4.2 Study Participants

Participants were recruited via emails, phone calls, and visits to their office between February and November of 2013. Water suppliers from 11 communities (42% response rate), two officials from the Massachusetts Department of Environmental Protection (MA DEP), and three employees from non-profit groups participated in our research. Monitoring, testing and outreach requirements combined with insufficient funding and staffing and a failing infrastructure place a heavy burden on small municipal water departments (Levin et al. 2002). Thus, the employees of water providers in our study population were under high demand to fill multiple roles. Water providers from 14 communities in our population were unable to participate in our interview due to scheduling conflicts or could not be reached after several recruiting phone calls, emails, and in-person visits. One community, Boxford, relies solely on private wells and does not have a water department, so was not recruited. Though data only cover 11 towns, they cover the diversity across the watersheds in terms of size of population served, type of water supply, density of the town, and per capita income.

For each water provider, we recruited the water superintendent, though in some cases after speaking to the superintendent we were referred to a colleague who the superintendent thought could better answer our questions. In total, we interviewed seven water superintendents, two water managers, one water supervisor, and one environmental compliance coordinator. The length of time water provider interviewees had spent in their current position ranged from two years to 40 years.

2.4.3 Interview Instrument and Coding

During the semi-structured interview we asked water providers to describe their perceptions of the value of water conservation for their community, implementation and enforcement of their current water conservation policies, their perceptions of resident attitudes toward water conservation policies, and their perception of water conservation in the larger watershed. Water providers were also asked to list and describe the water conservation programs that had been implemented in their town in the last decade, including the start and end dates (if applicable), reasons and process for implementing the program, and perceived participation and success rates of the program. Interviews with state officials and nonprofit organization’s staff were slightly modified to learn participants’ views on water conservation in the watershed and their specific connections with water conservation programs and policies. Interviews lasted between 45 and 90 minutes depending on the interviewee. Interview transcriptions were analyzed using QSR International's NVivo 10, a qualitative data management and analysis program.

2.5 Results

Our qualitative analysis addressed three questions, 1) what water conservation tools water providers choose to offer to residents, 2) what attitudinal, contextual and personal capacity factors water providers consider when making these choices and 3) how those relate to the choices water providers make.

2.5.1 Conservation Tools Offered

A total of 42 conservation tools were offered to residents over the 11 communities we interviewed. There was overlap in these tools, for example, each town's increasing block rate was counted as a separate instance. Since each town separately chooses which programs to implement and how to implement them, each conservation program in a town was viewed as unique for our purposes. The programs fell into six broad categories covering outreach (from both internal and external sources), financial policies (disincentives and incentives), leak detection, and internal mandatory irrigation policies (required by the town for conservation that were not an answer to a state requirement) (Table 2.1).

Table 2.1: Types of conservation programs that are currently or have been offered by the 11 providers in our sample over the past ten years.

Categories	**Description**	**Programs described by interviewees**
Internally developed outreach (*7 water providers*)	Outreach that has been conceived of and implemented by the water department or by a consultant hired by the department for that purpose.	school curriculum, voluntary water restrictions/bans, water bill insert/ occasional mailings, workshops, rain barrels, low impact design (LID) demo residential, LID demo municipal/industry, free audits
Externally developed outreach (*8 water providers*)	Outreach materials that have been conceived of and implemented by an external group (usually advocacy or governmental group)	conservation kits (Environmental Protection Agency - EPA), pamphlets in lobby (Greenscapes/Mass. Water Resources Authority - MWRA)
Financial disincentives (*7 water providers*)	Rate structures or other economic policies that "tax" water use in some way	increasing block rate, unsubsidized outdoor meter, increased summer rate for residential water use
Financial incentives (*4 water providers*)	Rebates or discounts for purchasing water efficient appliances, irrigation systems, etc.	appliance rebates
Leak detection (*3 water providers*)	Programs that reduce unaccounted for water by identifying and repairing leaks in the system	meter software, hiring technicians to run lines
Internal mandatory irrigation policies (*4 water providers*)	Restrictions, bans or other policies that the town requires residents to participate in but are not required by the state.	mandatory rain gauges/moisture sensors for outdoor irrigation

Seven water providers used financial disincentives as part of their conservation program, the most popular being the increasing block rate structure. Although none of our interviewees officially monitored participation in or success of specific conservation programs, most interviewees believed that financial disincentives were the most successful at reducing water consumption. One water provider told us that their economic disincentive program has been so successful for the past decade that they have not had to institute any other conservation programs to meet their permit requirements for maximum per capita water use. Several providers also pointed to leak detection as very successful in reducing water demand.

All providers mentioned outreach programs as useful for raising awareness although the general consensus was that they were not very successful in reducing consumption. Many of the outreach and economic incentive programs implemented within the last ten years, such as audits, discounted rain barrels, and appliance rebates, had already been discontinued by the time of our interviews. Reasons for this included lack of funding (i.e. the grant that was funding it ran out), perceived lack of interest/participation from residents, or the belief that saturation was reached in the community. Still, providers did believe that outreach and economic incentives could be useful for increasing awareness for residents.

> *"I'm not sure that you see any dramatic reduction from efforts like [rebates or free audits], but it makes people feel good, so it gets them thinking about it (Interviewee #10, 8/13/13)."*

2.5.2 Factors Affecting Water Provider Actions

Through our descriptive analysis of the interviews we identified factors that water providers considered when choosing which conservation tools to offer to residents (Table 2.2). We categorize these factors into attitudinal, contextual and perceived capacity based on our conceptual model (Figure 2.1). For each group, we describe relevant themes from the interviews, discuss behavioral patterns, and compare public policy choices with regards to attitudinal, contextual, and capacity factors.

Table 2.2: Factors water providers consider in regards to implementing water conservation measures

Attitudinal factors	Contextual factors	Personal (and organizational) capacity factors
Perceived necessity for their community	Existing infrastructure	Necessary knowledge/skills
Beliefs about value in general	Availability of alternate water supply	Required funding/grant writing ability
Awareness of issue/need for conservation	Social and political acceptability/pressure	Necessary time/staffing
Perceived norms		Demographic variables (land use, population served, etc.)

2.5.2.1 Attitudinal Factors

Water providers discussed a range of beliefs about the value of water conservation both for their town and in general. Many cited outdoor water use during the summer months as a major issue in their town and water conservation as necessary to meet either demand or external requirements. Those water providers who had issues with water supply in their town also unanimously maintained that water conservation was valuable in general.

> *" We have a lot of homes that use a lot of water in an attempt to keep their lawns green, so if there's one area that [we] target to conserve water it probably is outdoor water use (Interviewee #7, 3/7/13)."*

> *"Outside water use is…the biggest problem the district has (Interviewee #4, 3/7/13)."*

Other interviewees explained that water supply in their town was not an issue because their water source could withstand increased demand or because water demand in their town had been steadily declining. Water providers who did not have a supply problem in their town fell into two categories. Several believed that although water supply was not an issue for their town, water conservation was still important and people "should be educated" about it.

> *"[Water conservation] is important but…it really hasn't been a pressing need only because our water consumption has been declining over the years (Interviewee #2, 3/14/13)."*

> *"[Water conservation] is just one of the ways that we felt that we needed a road to go down to try to help to do what we could because the Ipswich River faced issues and the cost of water and the whole big picture and it was just another way that we tried to do our part, what we felt was the right thing to do (Interviewee #8, 3/6/13)."*

One interviewee did not have a supply issue in his town and also did not believe water conservation in the Ipswich watershed was as important as advocates and government departments made it out to be. Rather, he believes low flow events in the Ipswich are natural and cyclical.

Interviewee beliefs can be categorized into three groups based on whether the water provider believed it was necessary in their service area and whether the water provider had positive attitudes toward the value of water conservation in general: Group 1) necessary and positive, Group 2) unnecessary and positive and, Group 3) unnecessary and not positive. We used these three groupings to investigate descriptively how attitudinal factors affect the number and type of conservation programs that water providers decide to offer to residents. We compared the total number of conservation tools offered per water provider over the three water supply/conservation value categories. As we would anticipate from our conceptual model, attitudes toward water conservation played a role in subsequent conservation choices. Although no water provider offered zero conservation options to residents, the necessity of conservation and the belief about the value of conservation was related to the number of conservation programs offered in that those providers in group 1 offered a greater number of tools to their residents than those in group 2 or than the provider in group 3.

Disaggregating the conservation programs by types (see Table 2.1) provides a more in-depth look at how attitudinal factors related to conservation decisions at the water provider level (Figure 2.3).

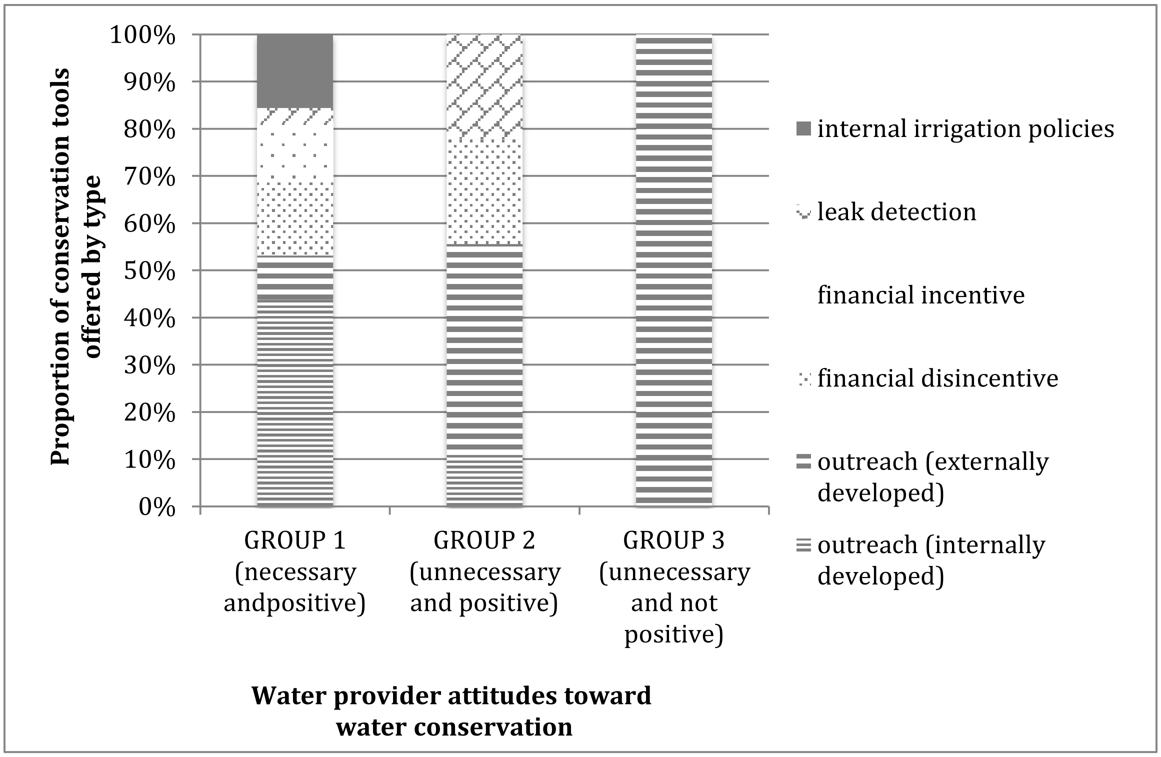

Figure 2.3. Proportion of the total tools offered in each factor category is shown for conservation subtypes.

Water providers in group 1 not only offered the majority of conservation programs overall but also offered the majority of the internally developed outreach programs and were the only group to implement economic incentives or internal mandatory restrictions. In contrast, those water providers in group 2 relied more on externally developed outreach and leak detection. The provider in group 3 offered one conservation tool in the externally developed outreach category.

Though our conceptual model depicts feedback between water providers and residents, water providers in our study area are not required to seek input from residents about their water conservation opinions. Interviewees explained that perceptions of expected norms toward water conservation are instead based upon informal dealings with individual residents, for example when a resident calls to discuss their water bill or visit their information booth at a town fair.

> *"I really don't know. I don't talk to the public a lot myself about it. Little things I've heard, you always hear people talking about their bill…because we have extremely high rates (Interviewee #9, 3/4/13)."*

Based on these limited interactions with residents, water providers believed aesthetics (green lawns) and economics drive residential conservation behavior. Five water providers believed that lawn aesthetics was the most important driver for residents, four water providers believed economics was the most important driver and one said that aesthetics and environmental drivers were important. In wealthier towns, aesthetics was often viewed a priority, perhaps because residents were less likely to be concerned about the water bill.

> *"The town is very rich and they like their pretty lawns…I've been told by residents that 'I have the money to pay for the water, I will use as much as I want (Interviewee #6, 3/13/13)'"*

No interviewee thought residents only consider environmental factors when choosing whether to conserve water, though one said economics and environmental factors were both important.

Our dataset does not demonstrate a clear relationship between perceived drivers of residential water conservation behavior (aesthetics, economics, or environmental) and the number or type of conservation tools the water providers offered. Water providers who believed aesthetics drive the behavior of their residents offered an average of 3 conservation tools, with outreach being most prevalent. Those who believed economics to be most important offered an average of 3.5 conservation tools, again with outreach being the most prevalent type offered. Interestingly, the only two water providers who mentioned environmental considerations as driving their residents' choices are also the providers that offered the most conservation tools (13 combined) and that offered the highest proportion of financial incentive options.

Overall, attitudes about water conservation played a large role in water providers' subsequent choices about which conservation tools to implement (Figure 2.4). Water providers who believed conservation was necessary for their service area as well as valuable in general offered the most conservation tools to their residents and also offered the majority of internally developed outreach programs. They were also the only group to offer economic incentives and the only group to institute internally mandated irrigation policies.

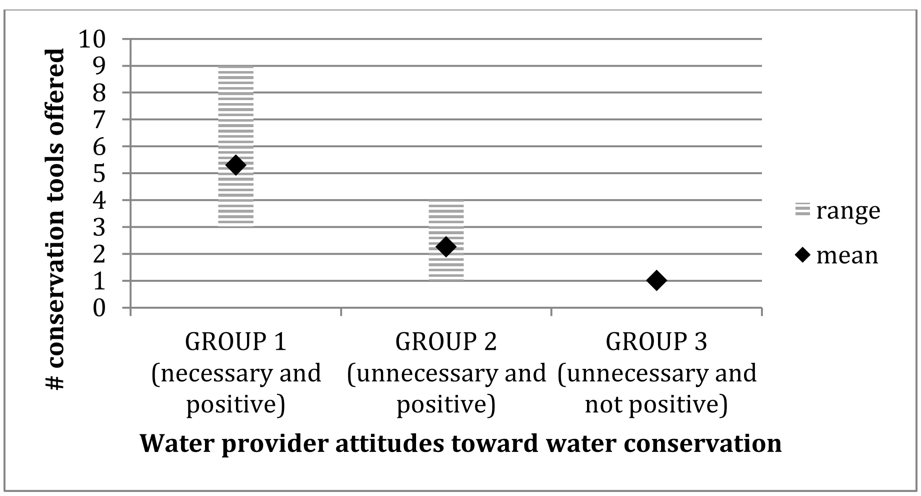

Figure 2.4. Range of the total number of conservation tools offered per provider compared over attitudinal factors.

2.5.2.2 Contextual Factors

As our conceptual model shows, context is important at both the water provider and residential levels, since the conservation choices that water providers make become part of the context within which residents make their conservation choices and therefore affect residents' actual capacity to conserve water. Water provider interviewees cited permit requirements, pressure from environmental groups, and existing infrastructure as important contextual factors that influenced their decisions to provide conservation tools to their residents.

Four of our interviewees cited permit requirements as the reason that they implemented their conservation tools. In Massachusetts, under the Water Management Act (Commonwealth of Massachusetts 1985; MA EEA 2005), water providers must either register or obtain a permit from the MA DEP in order to withdraw water from surface and groundwater sources. Permits require an annual average daily withdrawal rate and may require additional conditions, such as a seasonal peak limit on withdrawals, monitoring requirements, performance standards, and water conservation requirements. Registrations are based on use prior to 1985 and have not historically had conservation requirements attached to them. Although permit requirements vary by water provider, water providers drawing from the Ipswich and/or Parker rivers are required to engage in water conservation, including ensuring full cost pricing, enforcing the plumbing code, and public education. Water providers have flexibility in how they implement water conservation, and conservation requirements can be fulfilled through individual community programs or through membership in Greenscapes, a regional coalition that provides public education and outreach about low impact design and other residential water conservation information (Greenscapes 2012).

Outreach from environmental and community organizations has changed the way residents and politicians view the Ipswich and Parker watersheds by highlighting environmental and recreational issues. In doing so, these organizations have shaped the context in which water providers make decisions about water conservation, both through public opinion and external requirements. Ultimately, political pressure from environmental groups and community organization caused changes to water conservation practices in some of our study towns. For instance, four water providers said advocacy and support from community groups and vocal residents encouraged them to implement certain conservation programs, for example rain barrels, for their community.

Decisions regarding whether and what water conservation tools to offer to residents are influenced not only by permit requirements and external pressure, but also by the infrastructure and supply context within which the water provider operates. Tools to incentivize residents to conserve may not be necessary if the water providers themselves can take direct actions to conserve water or can find other sources of supply. For example, many interviewees explained the greatest potential for conservation lies in improved metering and leak detection. Moreover, grants for those types of conservation measures are more easily obtained than grants to incentivize resident action.

Availability of alternative supply sources is another contextual factor influencing water provider decisions. Four providers said they considered shifting to alternative water supplies either because they wanted to ease the burden on the Ipswich without having to engage their customers in conservation (interviewee #5, 3/7/13), or because conservation alone could not sufficiently reduce consumption (interviewee #8, 3/6/13). Two of those towns did switch to buying some or all of their water from sources outside the Ipswich/Parker watershed, the other two stated that the high cost associated with connecting to alternate sources made it unfeasible (interviewee #4, 3/7/13).

2.5.2.3 Personal and Organizational Capacity Factors

Personal capacity factors encompass perceptions and beliefs about funding availability, feasibility of conservation, and acceptance from residents. Perceptions about the ease of acquiring funding, the effectiveness of the conservation tools being offered and the acceptance by residents influence water providers decisions about which tools to offer to residents and how long to offer these tools.

Though water conservation tools may provide benefits to water providers, there is a cost associated with design and implementation of them. The availability of funding to cover those expenses greatly influenced the choices of water providers. Interviewees cited funding from the Massachusetts DEP Water Conservation Grant Program (*for a summary report see* Harper 2010) and other small grants as influencing their decisions. Seven of the interviewees stated the Massachusetts DEP grant as a reason for providing low or no cost conservation kits (faucet aerators, low flow shower heads, etc.) to their residents. Two rain barrel programs and a number of leak detection and fixture or efficient appliance rebates were funded through external grants. Conservation tools that were not covered by grants were offered less frequently, though one water provider chose to use the water department budget to fund a rain barrel program.

Even education and outreach programs were primarily based on grant funding. Water providers who offered outreach and education tools beyond that of bill stuffers (i.e.

school curriculum, landscaping demos, etc.) did so with funding from a grant, at least initially. Yet interviewees expressed they had had difficulty obtaining funding to conduct educational outreach or to hire a consultant or fund a staff member to coordinate an integrated conservation program and therefore were unable to conduct those activities even though such activities are a priority for them.

Not only is the availability of funding important, interviewees also made choices about which conservation tools to provide based on their beliefs about the likelihood that the tool would succeed in reducing consumption. For instance, one interviewee decided not to institute an ascending block rate or an allotment per person rate because she believed there was no way to make these tools effective.

> *"So…a lot of people will assign ascending block rates, but that penalizes large families that, you know, maybe they are consistent year round, but they have six kids…they're never going to be in that low block no matter what they do. And then they say, you know, we'll assign an allotment per person, but then implementation, like our billing system doesn't know how many people live in the house. And people who come and go, and so, there are lots of ideas out there, but they have to be implemented (interviewee #10, 8/13/13)."*

Providers' beliefs about whether residents would accept and adopt conservation tools also influenced their choices. One provider cited the high proportion of renters in the town as a reason not to provide free audits and machine rebates, since renters would not be able to use these tools. Two interviewees stopped offering certain conservation tools because the demand for them had waned. In their opinion, those residents who were interested in using the conservation tool had already obtained it and there was no reason to continue offering it to the residents that were not interested in it.

2.5.3 Influence of Contextual & Capacity Factors on Conservation Tools Offered

We clustered the respondents into groups based on the contextual and capacity factors they said were most salient in their communities: Group A (funding issues) consisted of two water providers who felt the most difficult part of implementing conservation programs was securing funding. Group B (staffing issues) consisted of four water providers who cited lack of staff or lack of a staff member dedicated to conservation as their main capacity issue with regards to implementing conservation. Group C (infrastructure issues) consisted of one water provider who discussed failing infrastructure as the main obstacle to conservation. Group D (residential make-up) consisted of two water providers who believed that conservation was made difficult by the specific demographics of the town's residential population (i.e. large households/large lawns). Lastly, two water providers did not face capacity issues in regards to conservation because sufficient supply meant they did not plan to institute any conservation tools and were included as Group E in our analysis.

In looking across these groups, water providers who cited funding as the main capacity obstacle to implementing conservation measures offered the greatest number of conservation tools to their residents, while water providers in the other three groups offered about the same number of tools to their residents. Water providers who did not have capacity issues offered the fewest conservation tools. This is not surprising, since their lack of capacity issues stemmed from the fact that they felt there was no need for conservation measures in their towns (Figure 2.5).

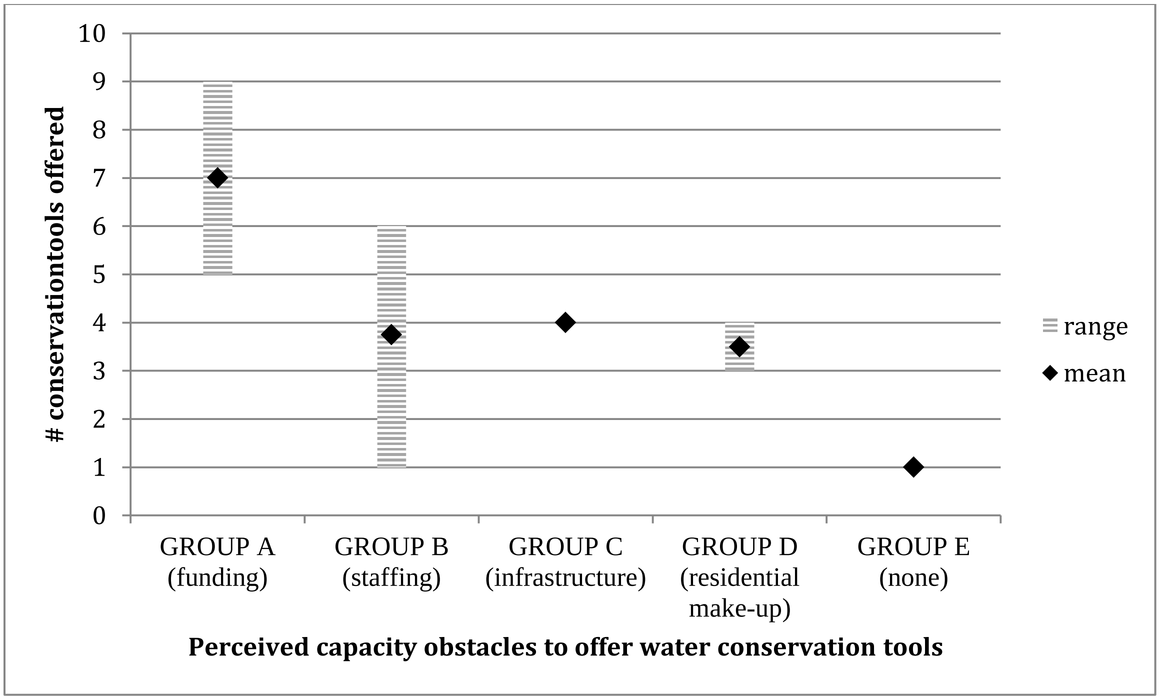

Figure 2.5. Range of the total number of conservation tools offered per provider compared over capacity issues water providers perceived as important to their ability to implement conservation measures.

2.5.4 Connections Between the Water Provider and Residential Levels

Our conceptual model shows the influence that water provider choices have on the context within which residents decide to engage in water conservation. Ideally, residents' actions and attitudes feed back into water provider's beliefs about the importance of water conservation and their capacity to offer water conservation tools to their constituents. It is here that we find a disconnect; water providers are making decisions about conservation measures without input from residents about their specific needs and without monitoring residential acceptance or adoption. In fact, out of all our interviewees, only one told us they implemented conservation based on input from an advisory committee that included residents. Not only is there little input from residents on the choice of conservation tools (type & number), there is also little communication regarding uptake of those tools when they are offered. None of the interviewees monitored residential acceptance of conservation tools or rates of participation. Several expressed their desire to conduct such monitoring but cited under-staffing and budgetary constraints as preventing it. Instead, respondents explained their knowledge of residential preferences stemmed from information informally gleaned from residents who called to ask questions about water treatment or about their water bills or from people who visited water booths at town fairs. Water providers then use this informal information combined with their expertise to make the best decisions possible about offering conservation in their towns.

2.6 Discussion

Our research highlights the need to understand cross-scalar interactions that influence water conservation by descriptively analyzing decision-making at the water provider level and its relation to decision-making at the residential level. In particular, we illustrated how attitudinal, contextual and perceived capacity factors influence providers' choices of water conservation tools offered to their service area, and how those choices are related to knowledge of resident's attitudes and water conservation behavior. Most research on water conservation has focused on the expected savings from specific conservation tools at the user level (Inman and Jeffrey 2006; Lee, Tansel, and Balbin 2011) with little consideration of what drives the decision to offer specific water conservation tools at the provider level. Thus, the role of the water provider in selecting which tools and programs to offer, and thereby which tools are available to residents, is underappreciated.

Our findings indicate that water providers in the Ipswich and Parker watersheds offer a wide variety of conservation tools to their constituents and consider several factors when making decisions about which tools to implement. Providers differ in their beliefs about the necessity of water conservation in their community and their attitudes toward water conservation in general. These differences are reflected in the type and number of conservation tools they offer to residents, with water providers with more positive attitudes toward water conservation offering a greater number and variety of conservation tools to their residents. Contextual factors and capacity factors also influence water providers' decisions about water conservation tools, although these factors were more uniform across providers.

In terms of interaction with residents, although water providers held strong ideas about the drivers of residents' behavior, water provider communication with residents was limited due to capacity constraints. Providers in our study area rarely sought input from residents about which conservation tools should be implemented, and lacked information on both rates of residential participation in their conservation programs and on the subsequent water savings achieved. Water providers explained despite efforts, they simply did not have the staff or funding to monitor the residential uptake of conservation tools that were offered. The limited resources of water providers was apparent even during our recruitment of water providers for this study, when six water providers expressed interest in the study but were unable to schedule a time to participate due to understaffing.

As information on residential attitudes and behaviors is lacking, water providers explained that they made decisions about water conservation programs based primarily on funding availability, external requirements, and personal attitudes about the value of water conservation. This finding points both to potential inefficiencies in the system as well as potential points for improving them. Tightening the connections between residents and providers would likely lead to greater savings, as better informed water providers would be able to choose the water conservation tools residents would be most willing to adopt.

We expect our findings about the factors influencing water conservation choices and interactions between water providers and residents are not unique to Massachusetts. Watersheds across the U.S suffer from water supply shortages induced by a combination of high demands and changes in precipitation and land use patterns (U.S. Geological Survey (USGS) 2008). Consequently, small water providers are under increasing pressure to conserve water (Larson et al. 2009). Yet small water providers have limited resources and capacities (Levin et al. 2002) and water providers are understaffed and underfunded. As such, our research suggests there is likely a widespread need for policies or third party interventions that aid in communicating to water providers the attitudes of residents and in monitoring the uptake of water conservation tools in their service areas.

Though our model emphasizes the contextual interactions between the water provider and residential consumer, it is not the only cross-scalar relationship exerting influence on decision-making processes. For example, as described in our findings, decisions made by the MA DEP regarding what grants to offer affect the contextual factors influencing water provider decision-making. In any complex environmental process, we can expect to find multiple such cross-scalar interactions. Specific examples of environmental issues where cross-scalar interactions may be particularly important include; fisheries, climate change mitigation, recycling/waste management, and land use/urban development. In all these examples, individual decisions and actions can have measurable impacts and are also shaped by decisions made at other scales. In highlighting the water provider – residential consumer connection, our research serves to bring the importance of these nested relationships to the fore, and thereby challenges scholars to move beyond single actor models of environmentally relevant behavior.

Such an approach is useful, in that it also helps in identification of points of leverage within the system. For example, in the Ipswich/Parker watersheds, this model helped us identify the disconnect whereby water providers lacked knowledge of residential attitudes and preferences and the ability to monitor how residents respond to the conservation tools the water providers were implementing. Our model is generalizable, and can be applied to any environmental issue that involves interactions across multiple-scales. In this way, our model provides an important contribution to the literature on encouraging environmentally relevant behavior by providing a valuable first step towards understanding these complex cross-scalar relationships.

CHAPTER 3

ACCESS TO URBAN NATURE AT A REGIONAL SCALE/POLICY LEVEL

3.1 Abstract

Considerable attention has been paid to the benefits that urban trees provide and recent research has focused on how the distribution of trees in the urban landscape is affected by socioeconomic processes like social stratification, as indicated by associations with income, race, ethnicity, and education. These studies have found marked disparity in urban canopy cover, with primarily low income and minority neighborhoods commonly being underserved. However, few studies have investigated the potential to overcome urban canopy inequities through urban planning and reforestation. This question becomes even more important as many U.S. cities pledge to increase urban canopy cover as part of larger climate change mitigation strategies. Can today's heavily developed U.S. cities use these tree planting initiatives to increase equity in urban canopy cover while still providing the infrastructure and housing necessary for expected population growth? This case study characterizes the socioeconomic drivers of the current urban canopy cover in Boston, Massachusetts, and further explores the possibility of distributing trees to increase equitable access to environmental justice and ecosystem services, while meeting housing and infrastructure needs. Results suggest that even when tree planting initiatives focus specifically on increasing canopy cover for environmental justice communities, equitable distribution of urban trees is difficult to achieve. Our findings indicate that difficulties arise not only from the expected policy and funding aspects, but also from ecological ones, including the physical availability of tree planting sites in environmental justice communities.

3.2 Introduction

3.2.1 Benefits of Urban Trees

Trees contribute to the quality of urban life in many ways, including improving air quality (Nowak 1994; Nowak and Crane 2002), mitigating urban climate (Souch and Souch 1993; Bolund and Hunhammar 1999; Akbari, Pomerantz, and Taha 2001), contributing to energy and water conservation and carbon sequestration (McPherson 1990; Nowak 1994; Nowak and Crane 2000; Hutrya, Yoon, and Alberti 2010) decreasing stormwater runoff and mitigating flooding risks (Sanders 1986; Bolund and Hunhammar 1999), helping to remediate brownfields (Westphal and Isebrands 2001), and increasing biodiversity and providing habitat for urban wildlife (Johnson 1988; Strohbach, Lerman, and Warren 2013). Trees also provide social and cultural benefits to urban residents, such as reduction of noise levels (Cook 1978; Bolund and Hunhammar 1999), improved urban aesthetics (Schroeder 1989), enhanced sense of community (Brunson, Kuo, and Sullivan 2001), and reduction of stress (Ulrich 1984; Kaplan and Kaplan 1989; Kaplan and Kaplan 2003). However, there are costs associated with urban trees. Inappropriate tree selection or placement can affect water use in arid climates, and can cause human health issues associated with allergies to pollen or potential injuries due to tree failure, urban forests can support insects that are associated with infectious diseases (e.g. insect born diseases), and the monetary cost of planting a tree coupled with the cost of tree maintenance and the fossil fuels burned to power maintenance tools may outweigh the benefits of urban trees in some cases (Nowak and Dwyer 2007; Lyytimäki et al. 2008; Pataki, Carreiro, and Cherrier\ldots 2011). Therefore, careful tree planting and management plans are essential to achieve the maximum community benefits of trees.

3.2.2 Distribution of Urban Trees as an Environmental Justice Issue

Environmental justice research in recent decades has shifted from a focus on avoiding proximity to environmental waste and pollution to gaining access to environmental and community resources as a measure of quality of life (Witten, Exeter, and Field 2003). These community resources include outdoor recreation and parks (Emily Talen 1998; Tarrant and Cordell 1999; Wolch, Wilson, and Fehrenbach 2005), urban greenways (Lindsey, Maraj, and Kuan 2001), public playgrounds (Talen and Anselin 1998), and urban tree cover (Dwyer et al. 2000). Since urban trees provide important social and physical benefits to urban residents, inequitable access to these benefits creates an environmental justice condition (N. C. Heynen 2003; N. Heynen, Perkins, and Roy 2006). This uneven distribution of urban trees is often the result of socioeconomic factors instead of ecological ones (Landry and Chakraborty 2009). It is important to note that the factors affecting distribution of urban trees are often a combination of current drivers (i.e. where new trees can be planted, funding for upkeep) and historical processes (i.e. social stratification, neighborhood succession (Warren et al. 2010). These factors interact to create current inequity in tree canopy cover, and researchers have found that cities differ in which socioeconomic factors are associated with canopy cover (Landry and Chakraborty 2009). Canopy cover has been positively correlated with education level (Heynen and Lindsey 2003; Kendal, Williams, and Williams 2012), homeownership (Heynen and Lindsey 2003; Landry and Chakraborty 2009), employment (Kirkpatrick, Daniels, and Davison 2011), housing age (Heynen and Lindsey 2003; Kendal, Williams, and Williams 2012), and income level (Iverson and Cook 2000; Landry and Chakraborty 2009; Pham et al. 2012). Canopy cover has been negatively correlated with rentership (Heynen and Lindsey 2003; Landry and Chakraborty 2009), household density (Iverson and Cook 2000; Kendal, Williams, and Williams 2012), and minority population (Heynen and Lindsey 2003).

3.2.3 U.S. City Tree Planting Initiatives

Many U.S. cities are implementing tree planting initiatives as part of larger climate change mitigation plans and in order to improve quality of life for urban residents. Notable initiatives include New York City's MillionTreesNYC (www.milliontreesnyc.org), Los Angeles' MillionTreesLA (www.milliontreesla.org), Chicago's Tree Initiative (www.chicagotrees.net/chicago-trees-initiative), and Boston's Grow Boston Greener (www.growbostongreener.org). Policy makers tout the benefits of urban canopy and the importance of increasing the urban forest and claim a focus on redressing inequity in urban canopy cover. However, the success of these programs is seldom measured and the actual potential to remedy inequities is unknown.

Can today's heavily developed U.S. cities use tree planting initiatives to remedy urban canopy cover inequities while still providing the infrastructure and housing necessary for expected population growth? To answer this question we explored the case study of Boston, Massachusetts, to understand the ecological and socioeconomic potential for planting trees to equalize urban canopy cover in an intensely developed city. More specifically, we investigated three questions: (1) What is the current state of urban canopy distribution in the City of Boston, and what neighborhoods are most lacking the benefits provided by urban tree cover? (2) What is the range of possible scenarios for planting trees in Boston while taking into account the real-world availability of planting sites under current land use constraints and future population growth? and (3) How much can each of these future scenarios realistically increase the equity of urban tree cover in Boston?

3.3 Methods

3.3.1 Study Area and Data

The study area is Boston, Massachusetts, located in the Northeastern United States (Figure 3.1). It is home to over 625,000 people across approximately 121 km^2 (population density around 5000 per km^2) and is one of the oldest cities in the U.S. The City of Boston and the surrounding region of Greater Boston is an Urban Long-Term Research Area Exploratory (ULTRA-Ex) site, one of several such research sites across the country, funded jointly by National Science Foundation and USDA Forest Service.

Information regarding socio-economic data was obtained from the Massachusetts Metropolitan Area Planning Council (MAPC) based on 2000 U.S. Census data. As in previous research, we used tree canopy cover as an indicator of the spatial distribution of trees within Boston (Heynen, Perkins, and Roy 2006). Tree canopy cover data was obtained from the Urban Ecology Institute's 2005 urban tree cover survey (Urban Ecology Institute 2008). Baseline data regarding projected population growth is derived from MAPC. GIS data (e.g. land use, impervious area, building footprint, roads) were obtained from the Office of Geographic Information for the Commonwealth of Massachusetts (www.mass.gov/mgis/).

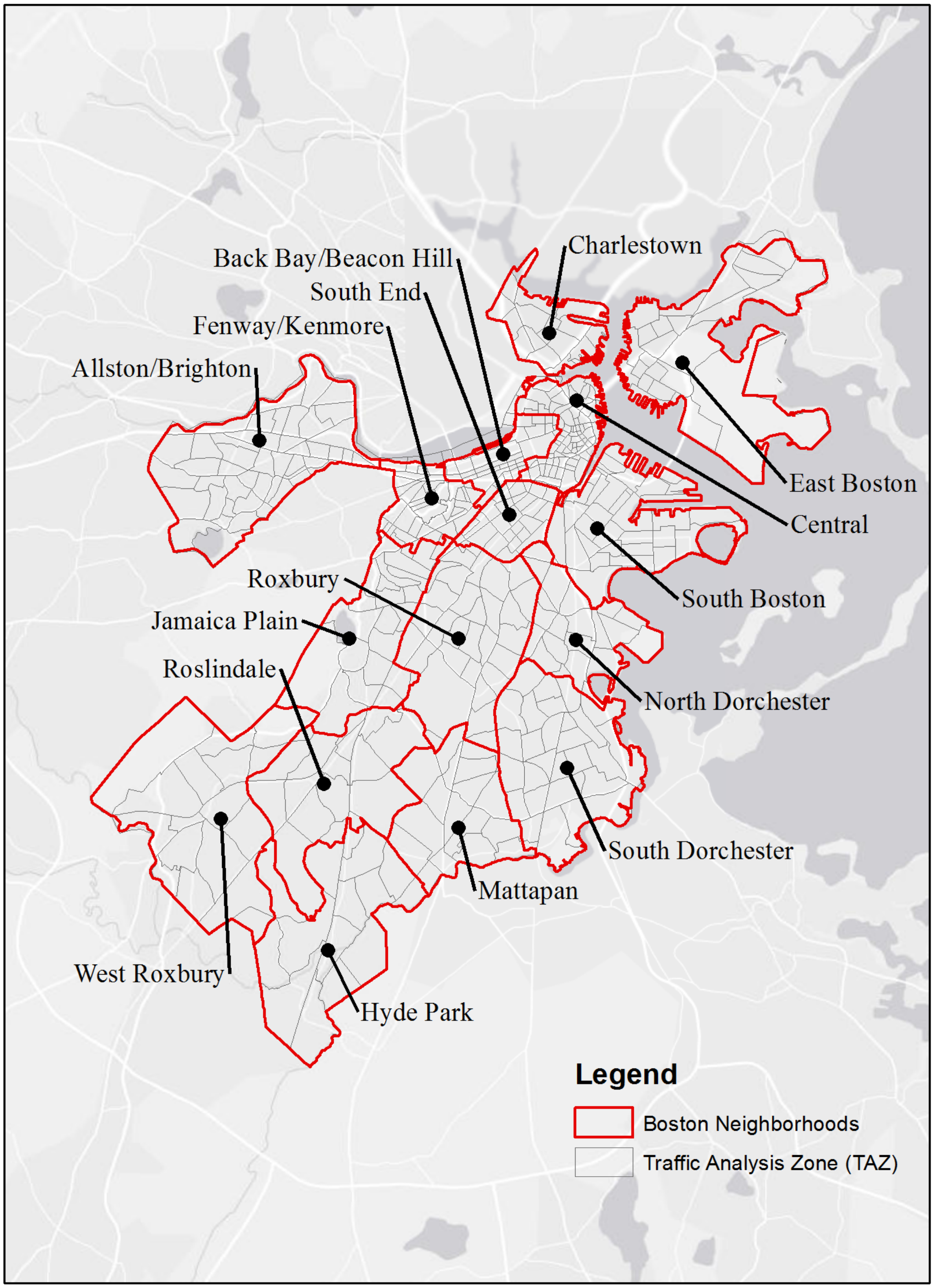

Figure 3.1. Map of Boston, Massachusetts, with neighborhoods and traffic analysis zones outlined. (Basemap: ©2013 Esri, DeLorme, NAVTEQ).

We used the Traffic Analysis Zone (TAZ) as the unit of analysis for our scenarios. This was done to maintain compatibility with MAPC data, which uses the

TAZ for all projections. A TAZ is commonly delineated by state or local transportation officials and usually consists of one or more census blocks, block groups, or census tracts. MAPC used TAZs specifically for tabulating traffic-related data, such as journey-to-work and place-of-work statistics, and as a unit for projecting population and employment growth. Although TAZs can be any size, exurban TAZs are often larger than urban TAZs, which can be as small as a city block or even a single building.

All statistical analyses were performed using the statistical package R (R Development Core Team 2012).

3.3.2 Grow Boston Greener

We used the goals of the Boston tree planting initiative, Grow Boston Greener, to inform our projections of plausible tree planting goals in the city over the next 30 years. Grow Boston Greener (GBG) is a competitive mini-grant program that provides small grants for tree plantings in Boston neighborhoods. Grants are available to non-profit organizations and their partners. The program is a joint effort between the city of Boston and Boston Natural Areas Network (BNAN) to increase and improve the urban forest of Boston (Boston Natural Areas Network 2006; Grow Boston Greener 2012). Through Grow Boston Greener, nonprofit organizations can apply for funds to plant trees in publicly accessible areas, especially those areas that are identified as underserved by tree canopy in the State of the Urban Forest report (Urban Ecology Institute 2008).

The city of Boston endeavors, through Grow Boston Greener, to increase the overall percent canopy of Boston to 35%, a 6% increase from 29% canopy cover estimates in 2005 (Urban Ecology Institute 2008). According to Grow Boston Greener, this increase will require the planting of approximately 100,000 trees by 2020, as well as the upkeep of currently planted trees through community stewardship (Grow Boston Greener 2012).

3.3.3 Scenarios

We used a scenario analysis approach to explore the range of possible arrangements for planting trees in Boston while taking into account the real-world availability of planting sites under current land use constraints. Input variables used for each scenario are explained in section 2.5.3. For this study, we developed five tree distribution scenarios using input from MAPC population projections and Grow Boston Greener targets. Two of the scenarios, *Current Trends* and *MetroFuture*, were based on 30-year population projections (2000 to 2030) provided by MAPC. The *Current Trends* scenario assumed the status quo, with no focus on tree planting or population growth in Boston proper. Population change, economic conditions, and land conversion are projected to continue along their present trajectories. The *MetroFuture* scenario is based on the strategies developed by the MAPC over the past seven years. This scenario emphasizes densification in Boston as well as an increased investment in urban greening.

The third scenario, *Green Equity*, was developed by our Boston Metro Area ULTRA-Ex team to assess the potential for achieving even greater equity in urban canopy cover. This scenario projects a modest population increase in Boston that is greater than *Current Trends* but less than *MetroFuture*. Our greening target for the *Green Equity* scenario was an overall percent canopy cover of 40%, which has been recommended for U.S. cities where the ecological climax community has the potential to be temperate deciduous forest (Heynen and Lindsey 2003).

To assess the policy goals of the Grow Boston Greener initiative, we also calculated the overall canopy cover and equity that would result from a *Grow Boston Greener* scenario using our model and information from the Urban Ecology Institute's 2008 State of the Urban Forest Report (Urban Ecology Institute 2008). Finally, to provide an upper limit for tree distribution we looked at the equity and greening implications of planting every tree that could be potentially planted based on our calculations. In this *All Trees* scenario, we distributed trees solely on the basis of ecological availability (i.e. a tree is planted in every potential tree planting site regardless of socio-economic factors).

3.3.4 Population Projections

Population projections for the year 2030 for both *Current Trends* and *MetroFuture* were provided by MAPC. MAPC used standard methods for projecting population growth based on Massachusetts' birth and death rates, by age-sex-race cohorts for the region, and a community's overall recent growth trends. Projections were presented by MAPC for a public review period where the 101 municipalities, 6 adjoining Regional Planning Agencies (RPAs) and 2 collaborating agencies, Central Transportation Staff (CTPS) and the Executive Office of Transportation (EOT) were invited to comment (Metropolitan Area Planning Council 2006). We projected the *Green Equity* population at 72% of the *MetroFuture* population increase for each TAZ, keeping the distribution of population the same as that for the *MetroFuture* scenario. The *Green Equity* scenario plays out a plan to reduce pressure from urban infill that could interfere with greening efforts relative to that under *MetroFuture.* In contrast with *Current Trends,* however, it still commits to growth focused on the urban core of the metropolitan.

For the *Grow Boston Greener* and *All Trees* scenarios, we used *MetroFuture* population projections, since *MetroFuture* is the agreed upon plan for Boston growth and we were interested in how these two scenarios would affect equity under Boston's current plan.

To ensure the population projections were reasonable, we compared the projected populations for each scenario to the population of Boston from previous decades. Figure 3.2 shows that the projected populations for our scenarios do not exceed the highest historical population in Boston. This provides a real world check to ensure that our projected populations are realistically achievable for the city of Boston (US Census Bureau 2010).

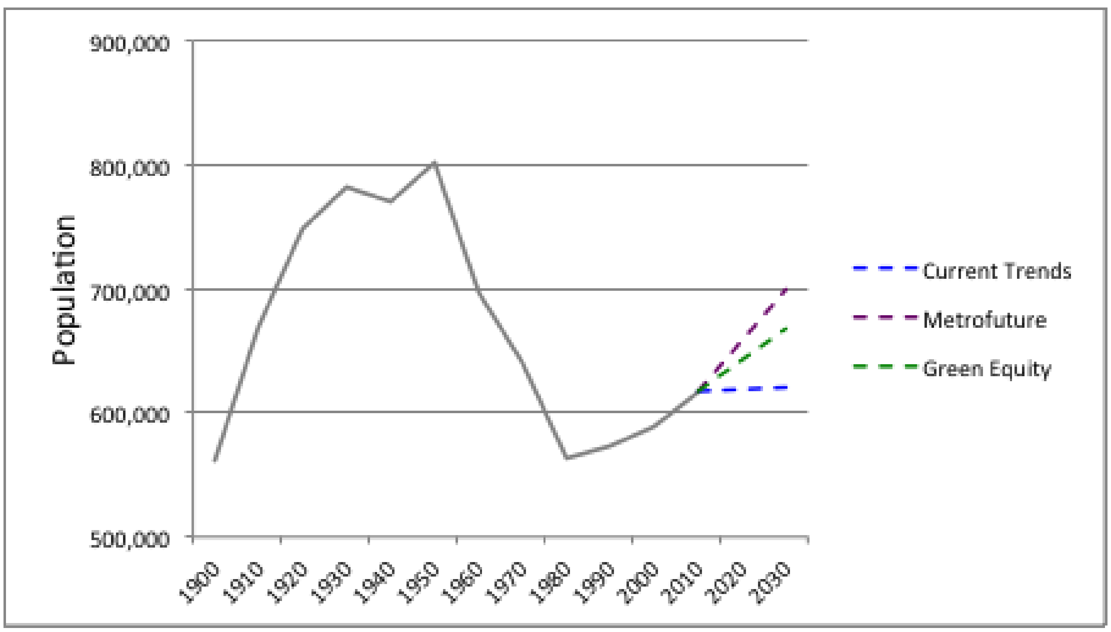

Figure 3.2. Population and Population Estimates (Boston, 1900-2010) and 2030 Scenario Population Projections (MAPC).

3.3.5 Distribution of Trees

3.3.5.1 Tree Planting Potential Analysis

Urban tree planting can be accomplished in two ways in the already built-out Boston: retrofitting existing conditions or redeveloping the site. Each TAZ has tree planting potentials whether or not experiencing population growth. Our estimate of the number of trees that could be allocated to each TAZ in each scenario was based on three conditions: (1) tree planting on impervious areas; (2) tree planting on pervious areas; (3) street trees.

Tree planting on impervious areas excludes building footprints and roads and focuses on retrofitting or redesigning existing large impervious surfaces, such as parking lots, in commercial, industrial, and institutional land uses. In addition, current tree canopy areas overlapping with impervious areas were subtracted under the assumption that new trees will not be planted underneath existing tree canopy. Several case studies for impervious areas reduction in parking lots demonstrate an average of 19% potential through alternative parking design (Table 3.1). We used 20% for the tree planting potential on impervious areas for estimating reasonable number of trees.

Table 3.1. Case studies for impervious reduction in parking lots

Case Studies	Impervious Reduction	References
Sacramento Home Depot Parking Lot	18%	(McPherson 2001)
Green Parking Lot Case Study: Heifer International Inc.	27%	(Industrial Economics, Inc. 2007)
Fitzgerald Marine Reserve Parking Lot	18%	(San Mateo County 2009)
Commercial/Industrial Template for Conservation vs. Conventional Site Planning and Stormwater Design	14%	(Conservation Design Forum Inc. 2003)
Average	**19%**	

For tree planting on pervious areas, we estimated the number of additional trees that could be planted on current planting beds or lawn areas in residential, commercial, industrial, and institutional lands. All current forest, wetlands, water, agriculture, recreational, utilities, and transportation lands were excluded from our calculations. In addition, current tree canopy areas overlapping with pervious area (derived from an inverse of GIS impervious area data) were also subtracted. The maximum potential for tree planting on pervious areas (tree canopy covers entire planting beds and lawn areas) would leave no open lawn areas in private yards. Considering the culture in the Northeast where direct sun is appreciated year round, we conservatively used 50% of potential pervious areas for additional tree planting estimation.

We derived the number of trees that can be planted on impervious and pervious areas with greening potential from dividing the total tree planting area by the proposed tree crown area. Based on an inventory for Boston, the average canopy of a tree in the city is 27 m^2 (Nowak and Crane 2002). Assuming a circular crown shape, this translates to roughly 6 m crown diameter. Therefore, we used a circular area with 6 m in diameter for estimating the number of trees.

The potential for additional street trees was estimated based on characteristics derived from the street tree inventory of Boston (Urban Ecology Institute 2008) and the Massachusetts Department of Transportation road data set (MassDOT; www.mass.gov/mgis/). First, we extracted the current number of trees per street segment and normalized it to 100 m. Then, we analyzed the existing street tree densities for each of MassDOT's road types (six classes from limited access highways to minor street or road with no street name) in order to get an estimate of the kind of densities that are realistic for Boston. We used the 95th percentile (95% of the streets in Boston have fewer trees per 100 m) for each road, multiplied it by the respective length of the street type in each TAZ and subtracted the number of existing trees to get an estimate of the maximum potential street trees that could be allocated into each TAZ. We used a 4 m crown diameter for estimating the canopy added by street trees, because 4 m is the average crown diameter of a street tree in Boston (Urban Ecology Institute 2008).

Table 3.2 Potential greening area and number of trees for the city of Boston

Tree Planting Potential Areas	# of Trees	Estimated Crown Diameter
Tree planting on impervious surface	212,967	6m
Tree planting on pervious surface	207,987	6m
Street Trees	123,956	4m

3.3.5.2 Canopy Loss due to Population Growth

Population growth in Boston will likely have an impact on tree canopy, but the magnitude of this impact depends on development patterns and best management practices. To estimate loss of tree cover due to population growth, we used data from (Nowak and Greenfield 2012). Nowak and Greenfield (2012) used paired aerial photographs to assess tree cover changes and population changes over time in 20 major U.S cities, including Boston. Our analysis used data from 18 of these cities. We excluded two cities, New Orleans and Detroit, because of their expected extreme tree cover losses due to hurricane Katrina and the emerald ash borer, respectively. According to Nowak and Greenfield (2012) data, the remaining 18 cities lost an average of 1.9 m^2 of tree cover per person per year. Assuming linear population growth from 2000 to 2030, we integrated this number over the change in population for each TAZ in each scenario (Table 3.3). We used *MetroFuture* population projections (and therefore canopy loss projections) for both our *All Trees* and *Grow Boston Greener* scenarios.

Table 3.3: Percent canopy loss at rate of 1.9 m^2 per person per year for each scenario

	Population Increase	Canopy Loss
Current Trends	7%	-1.00%
MetroFuture, All Trees, Grow Boston Greener	18%	-2.58%
Green Equity	13%	-1.58%

3.3.6 Scenario Inputs

After integrating canopy loss for each scenario, we distributed canopy cover based on our tree planting potential analysis coupled with social criteria (see below) for adding new canopy in each TAZ for each scenario. In the *Current Trends* scenario, we targeted an overall canopy cover of 29% with no net change under the assumption that no new trees will be planted, there would be some canopy loss due to population growth, and existing trees that were not lost to population growth would be replaced if they died or failed.

The *MetroFuture* scenario targeted an increase in overall urban canopy cover to 35% (Grow Boston Greener 2012). Tree planting efforts are focused on compact growth areas. In our model, compact growth areas were represented by areas with high population density. As a rule, we used population density greater than 75% of existing TAZs (13,000 persons per square m) to represent high population density. For each TAZ with 'high' population density, we added the maximum potential of canopy cover. Since it would be unlikely for officials to completely ignore residents who did not fit this threshold of high population density, we distributed a fraction of potential trees in TAZs below the 75% population density threshold. These TAZs received 33% of the total potential canopy cover.

For the *Green Equity* scenario, we targeted an increase in overall urban canopy cover to 40%. Tree planting efforts would be focused on Environmental Justice areas of Boston. Environmental Justice areas are typically associated with areas of low-income or ethnic minority residents who have disproportionately low access to green space or ecosystem services (US EPA 1994). However, our analyses found that TAZs with a large minority population (defined as African American and Latino by MAPC) were not associated with low canopy cover. Increased minority population was weakly but positively correlated with increased canopy cover in Boston (see section 3.1). For this reason, we did not include percent minority population in our model criteria. We modeled Environmental Justice areas in the *Green Equity* scenario by TAZs with a median household income less than $44,600 per year. For each TAZ that met these conditions, we added the maximum potential canopy cover. As in the *MetroFuture* scenario, we deemed it unlikely for residents above the median household income to be ignored completely by officials. Therefore, we added 33% of the potential canopy cover to those TAZs that were above the income threshold (Figure 3.3).

The Grow Boston Greener initiative sets a goal of increasing canopy cover by 6% in the city of Boston through the planting and maturation of 100,000 trees by 2030, with tree planting concentrated on areas identified as "underserved" by the State of the Urban Forest Report (Urban Ecology Institute 2008; Grow Boston Greener 2012). We considered Boston neighborhoods that Urban Ecology Institute identified as having overall canopy cover less than 29% (ranging from 6% to 24%) as "underserved". Based on our calculated tree planting potentials for TAZs within each of these neighborhoods, we determined that the total number of trees we could add to "underserved" neighborhoods was 268,636. However, the Grow Boston Greener initiative provides for 100,000 trees to be planted. To meet their tree planting target we planted 50% of the potential in each "underserved" neighborhood and 8% potential in neighborhoods that were not considered "underserved", for a total of 102,285 trees. *MetroFuture* scenario population and canopy loss projections were used for this scenario.

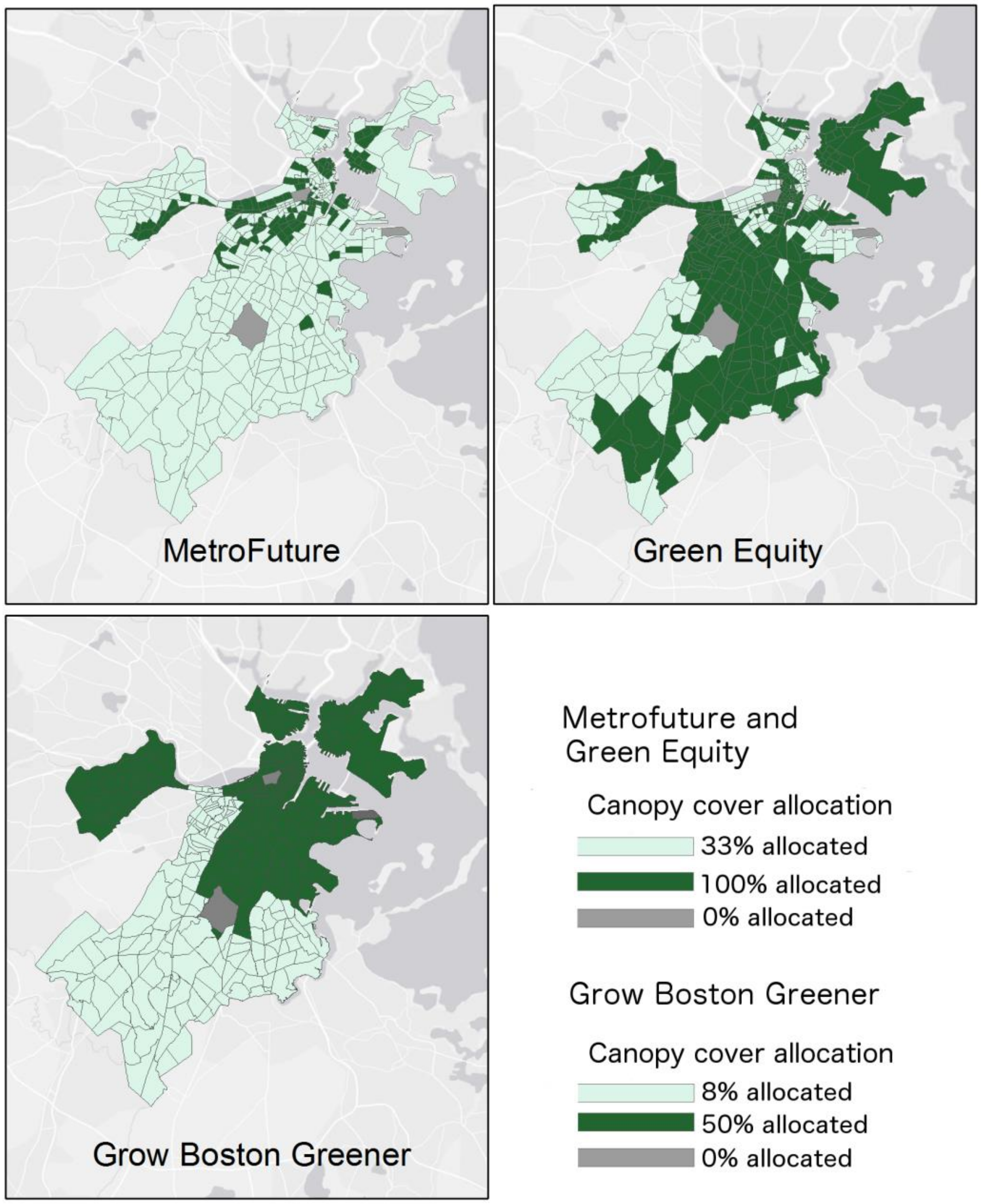

Figure 3.3. Canopy cover allocation for MetroFuture, Green Equity and Grow Boston Greener scenarios. (Basemap: ©2013 Esri, DeLorme, NAVTEQ).

To explore a Boston in which trees are distributed purely on ecological availability and funding for tree planting is not an issue, we created an *All Trees* scenario, in which we added the entire calculated tree planting potential for each TAZ. *MetroFuture* scenario population and canopy loss projections were used for this scenario.

3.3.7 Scenario Outcomes

3.3.7.1 Canopy Cover (Greening)

After using our scenarios to distribute potential trees, we assessed changes in overall canopy cover for each of the scenarios by converting the number of trees to percent canopy cover. We multiplied the potential number of trees by the average crown area (12.56 m^2 for street trees and 28.26 m^2 for non-street trees) to obtain the tree canopy area in m^2 in each TAZ. To obtain overall proportion of canopy cover for Boston for each scenario, we divided the sum of the canopy area by the sum of the land area in each TAZ

3.3.7.2 Equity Measures

We used the Gini Index as a measure of canopy cover equity. The Gini Index is commonly used in economic studies and has been successfully used in canopy cover equality studies (Jenerette et al. 2011). The index identifies the degree of inequality in the distribution of a variable, a value of 0 indicates perfect equality and a value of 1 indicates complete inequality. Gini coefficients were calculated using the statistical program R (R Development Core Team 2012), and the ineq R package (Zeileis 2012).

3.4 Results

3.4.1 Current distribution of tree canopy

We used socio-economic attributes—median household income, population density, and percent minority population—to explore correlation with tree canopy distribution. Pearson's correlations indicated that urban canopy cover was positively correlated with median household income (r = .31) and percent minority population (r =.25) (Table 3.4).

Table 3.4: Correlations, percent urban canopy cover and socio-economic variables for TAZs with population > 10 in 2000.

	median household income	population density	% minority population
% canopy cover	0.31*	-0.04	0.25*

* indicates significance at $p < 0.05$

3.4.2 Model Results

3.4.2.1 Canopy Cover

The results indicate that our targets for tree canopy cover were not met in any scenario in which potential trees were added except for the *All Trees* scenario. The *MetroFuture* scenario reached 33% (target of 35%), the *Grow Boston Greener* scenario reached 32% (target of 35%) and the *Green Equity* scenario reached 39% canopy cover (target of 40%) (Figure 3.4).

Adding 100,000 new trees to TAZs in "underserved" neighborhoods in the *Grow Boston Greener* scenario resulted in a 3% increase in canopy to 32%, in contrast to the 6% increase to 35% aimed for in the Grow Boston Greener initiative. One major factor affecting the calculation of tree canopy is the size of tree crown diameter. In our model, in order to meet the target of 6% increase, an average tree diameter of 70 m^2 would be required for 100,000 trees proposed by the Grow Boston Greener initiative. In contrast, planting all available potential trees (375,930) in the *All Trees* scenario increased the overall percent canopy cover to 40%, which is above the City's target of 35% and equal to our *Green Equity* scenario target.

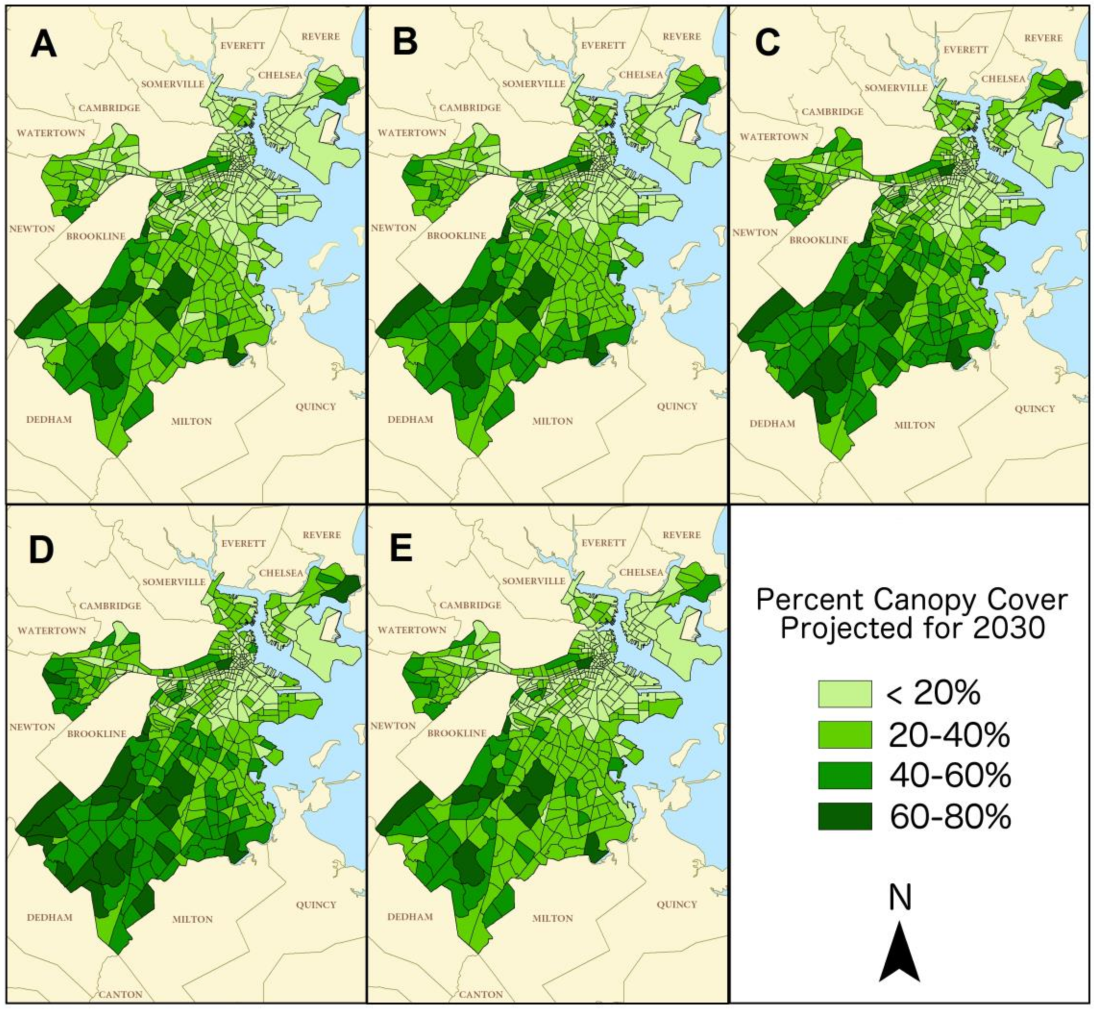

Figure 3.4. Resulting percent canopy cover by TAZ in each of the five scenarios. A) Current Trends, B) MetroFuture, C) Green Equity, D) All Trees and E) Grow Boston Greener. (Basemap: ©2013 Esri, DeLorme, NAVTEQ).

3.4.2.2 Equity

We calculated the Gini Coefficient for current tree distribution from UEI (2005) canopy cover data and current median household income data from MAPC (Gini Coefficient = 0.201). This level appears to be similar to levels of vegetation variability for Phoenix in 2000 according to (Jenerette et al. 2011). Table 3.5 shows the greening and equity outcomes for each of our scenarios. As expected, canopy cover distribution was least equitable (Gini coefficient closest to 1) in the *Current Trends* scenario because we did not add trees in this scenario and 20,361 trees were lost due to projected population growth (Gini Coefficient = 0.212). Canopy cover was most equitable in the *Green* Equity scenario, since our distribution was focused on addressing equity issues in this scenario (Gini Coefficient = 0.157). The *MetroFuture* scenario was more equitable than *Current Trends* and less equitable than *Green Equity* with a Gini Coefficient of 0.180. Adding all potential trees (*All Trees* scenario) resulted in a Gini coefficient more equitable than *MetroFuture* but still less equitable than *Green Equity* (Gini coefficient = 0.162). The *Grow Boston Greener* scenario was as equitable as the *MetroFuture* scenario, but required adding about 20,000 fewer trees (Gini coefficient = 0.180). It is worth noting that, even though the *Green Equity* scenario is the "most" equitable of the scenarios we looked at, none of our scenarios approach a *truly* equitable distribution of canopy cover, i.e. a Gini coefficient of 0.

Table 3.5: Inputs and outcome of the five tree planting scenarios.

INPUTS	Current Trends	Metro-future	All Trees	Grow Boston Greener	Green Equity
Pop. Increase (2000-2030)	31,449	109,389	109,389	109,389	79,479
Canopy loss due to pop. Increase	7%	18%	18%	18%	13%
(Tree Distribution) Potential tree planting focused in:	No additional trees	High pop density TAZs	All TAZs	TAZs in neighborhoods with overall canopy cover < 29%	TAZs with low median household income
Overall % canopy cover	29%	33%	40%	32%	39%
Trees added in scenario	None	121,751	420,392	102,285	365,076
OUTCOME					
Equity (0 = perfect equity)	0.212	0.180	0.162	0.180	0.157

3.5 Discussion

3.5.1 Socio-economic factors and canopy distribution

Our results indicate that low income neighborhoods are associated with disproportionately low levels of urban canopy in the city of Boston. Our finding that minority neighborhoods are weakly correlated with increased canopy cover may seem surprising. However, predictors of canopy distribution vary from city to city depending on historical and cultural context. Age, geographical characteristics, and political and cultural backgrounds all affect how current socioeconomic drivers are associated with canopy cover in U.S. cities and socioeconomic drivers of canopy cover differ from city to city. (Heynen and Lindsey 2003) investigated the correlation of canopy cover in urban areas in Central Indiana and found education level and housing age, but *not* population density or median household income were associated with urban canopy cover. In contrast, (Iverson and Cook 2000) did find housing density and median household income to be associated with canopy cover in Chicago, Illinois. (Pham et al. 2012) found that both income and minority status were associated with canopy cover in Montreal, Canada, but that income was more negatively associated with vegetation than minority status was in all their models. Our finding that higher percentages of minority residents had moderately more canopy cover may relate to the fact that in Boston some of the higher percentage minority neighborhoods are more distant from the high-density downtown which has fewer trees; and/or the resultant tree canopy could be the result of abandonment of property, which results in urban forests "regenerating" on vacant lots. As a result, in the city of Boston low income seems to be a more significant Environmental Justice indicator than minority status.

3.5.2 Tree Canopy Cover and Equity

To ensure that our study was real-world applicable and useful for policy makers we chose to constrain our scenarios by actual socioeconomic and land use variables. This led to an inability to reach our target goals for canopy cover and equity, even in the *Green Equity* scenario where we focused potential tree planting in Environmental Justice communities. Interestingly, utilizing the entire calculated potential for tree planting resulted in lower equity than using most of the calculated potential and distributing based on income (as we did in the *Green Equity* scenario). This may be due to site constraints. For instance, communities most in need of trees may not have the pervious surface necessary to plant the trees, while areas that already have high canopy cover may have more land available for more trees. Site constraints can decrease equity even more as the number of total trees planted increases without focusing on the neighborhoods that need trees most.

The Grow Boston Greener initiative's goal of a 6% increase in overall canopy cover is not met in our *Grow Boston Greener* scenario. To achieve this goal, the 100,000 trees planted by 2020 would have to reach a crown area of approximately 70 m^2 by 2030, which is roughly a crown diameter of 9.44 m. This is unlikely in such a short timeframe. We used a target crown size of 28.62 m^2, which is realistic for trees growing in densely populated urban areas, where trees may have slower growth rates and increased mortality due to urban stressors (Nowak, Kuroda, and Crane 2004). Still it is important to note that given enough time the 100,000 additional trees may reach a 6% canopy cover increase. (Peper, McPherson, and Mori 2001) found that most tree species would not reach a 9 m crown diameter by 15 years, but that 30 years was sufficient for several species to reach or exceed that diameter. Therefore, Grow Boston Greener's goal may be achievable by 2050 assuming a low mortality rate and funding for upkeep.

Green Equity was the most equitable of our scenarios, but required adding 3 times the number of trees than were added to *MetroFuture* or *Grow Boston Greener* (365,076 trees). However, our model shows that this number of trees is at least ecologically plausible, and may be necessary to approach an optimal level of canopy cover that could provide the greatest benefit for the city (Heynen and Lindsey 2003).

3.5.3 Tree Planting Implementation and Equity

Although few studies have explored whether tree planting initiatives are actually successful in equalizing urban canopy cover, several studies focused on the MillionTreesLA (MTLA) initiative in Los Angeles appear to support our findings. Researchers studying the initiative found that practical issues such as funding, stakeholder disagreement, and lack of oversight greatly affected the actual rate of tree planting in MTLA. Most notably for our study, although one goal of MTLA was to redress the issue of poorer neighborhoods of color having fewer trees, in reality trees were "planted opportunistically where partnerships can be forged" (Pincetl et al. 2012). Furthermore, researchers found that poorer neighborhoods were underserved by the planting initiative since residents and community groups were responsible for requesting plantings and many immigrants residing in the poorer neighborhoods did not request trees because participation required a signature (Pincetl 2010). This model of tree planting is very similar to the one used in Grow Boston Greener. A recent newspaper article reported that issues of funding, maintenance, and canopy loss due to storms and disease have slowed Grow Boston Greener's progress towards its goal of 100,000 trees planted by 2020, but that the economic upturn gives policy makers hope that the initiative will pick up in future years (Abel 2012).

The MTLA studies did not specifically investigate whether the availability of tree planting sites might also affect efforts to increase tree cover in environmental justice communities. Our *Green Equity* scenario assumed a focused effort to increase tree cover in these communities and found that, even if obstacles such as funding and stakeholder disagreement can be overcome, equalizing canopy cover distribution will still be difficult in Boston's Environmental Justice communities because public tree planting sites are often not available in those communities as they are often located near areas prone to higher air and water pollutants and less open space such as intensely built-out industrial, transportation or utilities land uses.

This finding implies policy goals of increasing urban tree cover equity in Boston need to be in tandem with associated land use policies and landscape ordinances. For example, development codes can require new (re)developments to reach a certain percentage of canopy on sites as well as on the streets and provide incentives for building parking garages and shared parking spaces to free up more surface area for tree plantings. In addition, more aggressive and innovative urban planning and design strategies will be critical to allow even more trees to be planted on impervious parking surfaces and in unconventional places such as green roofs.

The city of Boston has embarked on an ambitious plan to create an even more "livable" city for its residents, while maintaining and enhancing infrastructure, economy and housing. There are many obstacles to this goal, not least of which we have found is the physical availability of potential planting sites for proposed increases in tree canopy cover. Taken together, our findings have important implications for policy makers, managers and community organizers. First, they illustrate the ecological problems with using tree planting initiatives to increase environmental equity in urban areas. For example, our scenarios show that even with a strong focus on planting in underserved areas, canopy cover equity in some neighborhoods will be nearly impossible to attain, due to a lack of physical space to plant trees. Second, our results reinforce findings from other studies that outline the policy and funding difficulties that tree planting initiatives face. It is important to note, however, that even very small clusters of urban trees can provide important ecosystem services for neighborhoods (Streiling and Matzarakis 2003; Strohbach, Lerman, and Warren 2013), therefore, tree planting initiatives are still very important, even if optimal equity is never obtained.

The most important and potentially useful implication of our study is that tree planting initiatives alone cannot provide the environmental equity that is required for a more "livable" city. We suggest that policy makers create more comprehensive "green initiatives", using the techniques from this study to take into account a neighborhood's current development and infrastructure. In neighborhoods where planting sites are available, funding could be used to plant trees, increasing both the local "urban nature" benefits to neighborhood residents as well as providing city-wide ecosystem services from overall canopy cover. In neighborhoods where planting trees is ecologically difficult – due to lack of planting sites – funds could be allocated to greening alternatives. Greening alternatives, such as green roofs or walls, rain gardens, and bioswales, are pockets of nature in the city that can have similar local social and psychological benefits as trees in neighborhoods where tree planting is impossible. By broadening tree planting initiatives to include other types of urban nature, policy makers and managers may improve their chances of creating environmental equity in densely developed cities.

CHAPTER 4

ACCESS TO URBAN NATURE ON A LOCAL LEVEL AND INDIVIDUAL SCALE

4.1 Abstract

Living in a city offers many benefits and conveniences, but urbanites also contend with social, cultural, psychological and physical stressors associated with city life. The Reasonable Person model suggests meeting people's informational needs can ameliorate these stresses. Meeting these informational needs is not only important for well-being, but has been shown to reduce crime and improve public health outcomes in urban areas. Urban nature and green space is uniquely suited to meet these informational needs, but the distribution of green space in densely developed cities is notoriously inequitable and large public parks are often not accessible to minority and low income user groups. This study examines small pocket parks and street side landscaping to determine whether these types of green spaces might be valuable to city residents. Using systematic behavioral observation, we investigate visitation of and engagement with these small green spaces in Boston, MA and compare spaces that were designed through community initiatives with urban nature sites that were left dormant or "wild". We find that minority user groups visit both types of sites more than would be expected from a population service area analysis. Our engagement findings show that visitors are using community-designed sites to meet informational needs more than wild sites. Finally, our results echo previous findings that visitation is correlated with vegetation abundance, regardless of site type. Our findings show that these community-designed and managed urban green spaces can meet the informational needs necessary to ameliorate city stressors, and are also more

accessible to minority user groups which may not be using the larger, city-designed parks. Since this and other work suggests that with sufficient vegetation cover, community-designed spaces may provide similar wildlife viewing opportunities to small urban wilds, community-designed green spaces should be considered as part of any effort to enhance access to nature in the city.

4.2 Introduction

Cities offer economic, transportation, social and cultural benefits, but urbanites face social, cultural, psychological and physical stressors due to over stimulation, lack of access to restorative spaces, and crowding (Kaplan and Kaplan 1989; Hartig, Mang, and Evans 1991; Stephen Kaplan and Kaplan 2003). Decades of research by Kaplan and Kaplan (1989; 2003; 2009) among others (Jackson 2003; Ryan 2006; Joassart-Marcelli 2010) has shown clear psychological, physical and public health benefits of access to green space in urban areas. However, true access requires more than just the existence of green space. As the Kaplan's research shows, not all green spaces are created equal and people's preferences determine how they engage with urban green spaces.

In the last twenty years, research has given us invaluable insight into people's preferences for different characteristics of urban green space and into how people's engagement with green space is affected by different cultural and ecological characteristics of that green space (Kaplan, Kaplan, and Ryan 1998; Kaplan 2004; Fuller et al. 2007; Dallimer et al. 2012). Kaplan and Kaplan's work, among others, has shaped how green space is designed and implemented in many U.S. cities. However, not all urban green space benefits from a careful planning and design phase, some of the most important green spaces, in terms of access, are community green spaces, arising sometimes spontaneously, sometimes with mini-grants or through community funding. From the standpoint of both effective policy and expanding existing theory, then, it is important to characterize a city's unofficial green spaces, to understand how city residents are engaging with these spaces, and to start to uncover what characteristics, including ecological characteristics, prompt the most meaningful residential engagement, which we describe in more detail below.

In this paper we use behavioral and ecological measures to characterize different types of unofficial urban green spaces in Boston, MA, but common in many cities throughout the U.S. We explore which user groups prefer which type of green space, how different types of green space prompt different types of engagement, relationships between ecological value and visitation, and which user groups have access to neighborhood green space.

4.3 Literature Review

4.3.1 Community-driven green spaces: pocket parks and street side landscaping.

Cities buzz with information, and humans are programmed to need, want and use this information (Kaplan 1995; Kaplan and Kaplan 2005; Kaplan and Kaplan 2009). The Reasonable Person Model (RPM) focuses on the interrelationships between three domains of human informational needs, 1) exploration and comprehension, 2) opportunity for meaningful action, and 3) mental restoration. When these needs are met, people function well in a community (Kaplan 2000). When these needs are unmet, urban residents face social ills, such as crime and lack of community (Kaplan and Kaplan 2003).

Access to green space in cities is often unbalanced, with low income populations (Danford et al. 2014), minority populations (Heynen and Lindsey 2003), and young people (Ryan & Buxton 2015) at a disadvantage. Pocket parks, street side landscaping, and community gardens may be a valuable resource to increase access to nature experiences for these user groups. Designing small, restorative green spaces within cities can be an effective way to promote exploration and comprehension (Kaplan, Kaplan, and Ryan 1998). Although many types of environments can technically elicit fascination and be restorative, natural spaces seem to be particularly useful for this purpose (Herzog et al. 1997; Frumkin 2001; Berman, Jonides, and Kaplan 2008).

There has been a great deal of research on the beneficial effects of nature on our physical, psychological and social lives, therefore we will not provide an in-depth review of the literature here. Suffice to say that viewing natural scenes and/or being in natural environments has been shown to promote healing (Ulrich 1984; Lewis 1996); lower stress and provide mental restoration (Hartig, Mang, and Evans 1991); and increase community cohesion (Lewis 1992; Lewis 1996).

4.3.2 The value of ecologically rich urban green spaces

Urban green spaces offer important opportunities for physical and psychological health where access is otherwise limited in compact developed areas. The amenities of urban green spaces, such as aesthetically pleasing landscaping, park benches and tables to gather and socialize, equipment to play and recreate with, and quiet places to reflect and mentally restore have all been shown to impact urban residents' physical and psychological well-being. However, the investigation into how the ecological value of an urban green space might affect human well-being is just beginning. There is some information that ecological richness, or at least the perception of ecological richness, does play a role in human preference for and behavior in urban green space. For instance, (Taylor et al. 1998) found that children in a public housing development in Chicago, IL were about twice as likely to be observed playing in “high vegetation” urban green spaces than in “low vegetation” ones, and the quality of play was also different in “high vegetation” spaces, where the incidence of creative play was significantly more. (Fuller et al. 2007) found a positive association between perceived and actual species richness (birds, butterflies and vegetation) and self-reported well-being. Residents’ aesthetic appreciation of green space has also been shown to increase with perceived and actual plant diversity (Lindemann-Matthies, Junge, and Matthies 2010). Dallimer et al. (2012) found no association between actual species richness (birds, butterflies and vegetation) and psychological well-being, but did find an association between *perceived* species richness and well-being.

The psychological, physical, social, and ecological benefits of access to green space in urban areas is well understood, but the problem of providing equal access to green spaces for all user groups remains. Small, community-driven pocket parks and street side landscaping are possible solutions to increase environmental equity in cities. This study characterizes these types of green spaces in a typical U.S. city to explore how they are being used and whether they are providing increased access for minority user groups.

4.4 Methods

This study focuses on two main types of small urban green spaces in the inner city neighborhoods of Boston, MA and examines how type of green space affects people's engagement. The study contributes to our understanding of the determinants of how people engage in green space in their neighborhoods by identifying how people use "improved" versus "dormant" urban green spaces. In both cases, the space can be defined as an "urban green space", but the intent behind the green space differs and, subsequently, physical characteristics of the green space also differ.

4.4.1 Systematic Behavioral Observation

4.4.1.1 Study Sites

We selected pairs of "improved" and "dormant" green spaces in Boston. Improved sites were publicly or quasi-publicly accessible green spaces that were developed for the community through the efforts of a local neighborhood organization with support from the CityRoots program. CityRoots was a community-driven program run by the Urban Ecology Institute that supported community planting projects in Boston inner-city neighborhoods. The full list of CityRoots sites in Boston can be found at http://goo.gl/Tqdgtx as of April 4, 2016. An array of suitable spaces were identified from the CityRoots sites, including parks, schoolyards, street side improvements and community gardens. Improved sites were chosen based on 1) accessibility to public, 2) ability to track improvement history to specific community sources, and 3) availability of a comparable "dormant" site for pairing. Improved sites were of two categories. Street side sites were plantings such as trees, shrubs, or flower boxes along a street or along the edge of a public facing building. Lot transformation sites were plantings and improvements to a once vacant or underutilized parcel. Unlike street side sites, lot transformation sites could be entered by a user and often, but not always, included recreation areas such as a bench, shade tree, etc. “Dormant” green spaces were paired with a street side or lot transformation site, chosen within a 250 meter radius of the improved space and chosen based on 1) accessibility to public and 2) similarity to the improved site in shape, size and location context (i.e. near a busy street). “Dormant” spaces were defined as parcels of land without improvements or intervention (with the exception of city mowing several times per season). See Figure 4.1 for site status and type examples. Site pairs used in this study were part of a larger urban ecology dataset which included a total of 66 sites. The overall dataset includes behavioral observations as well as ecological inventories of birds, insects, and vegetation, although not all types of data were collected in all sites. Behavioral observation data was collected in a total of 10 site pairs (20 sites), 7 site pairs were observed over two field seasons (summer 2010 and 2011) at 7 distinct times of day (weekday: early and late morning, noon, early and late afternoon, and weekend: morning and afternoon). An additional 3 site pairs were added in the second field season using the same methodology.

Figure 4.1: Examples of each site type and status. a) Lot Transformation – Improved, b) Lot Transformation – Dormant, c) Street Side – Improved, d) Street Side – Dormant.

4.4.1.2 Observational Data Collection

Observations were collected for 15 minutes from a car parked on the street or an inconspicuous location adjoining the space. Two observers coded impressions of site users' demographics (e.g. minority status, age) and marked if people performed any of 21 distinct behaviors (Table 4.1). Behaviors occurring beside the site (in the case of street side sites) or beside or inside the site (in the case of lot transformation sites) were coded for each visitor within the observation time frame. Visitors that were already in the site when the observation began were included in the coding. Visitors that switched behaviors mid-observation were coded for both behaviors. Weather, temperature, time of day, and any pertinent details were also marked on the data sheet. If there was a disagreement between the two observers for a particular observation, an average was taken. Coder reliability was at 96%.

Table 4.1. Behaviors coded during observation, grouped into five types.

Category Name	**Description**	**Type**
Talking to others	# visitors talking to others	Communication
Talking on phone	# visitors talking on their cell phone	Communication
Dog Walking	# visitors walking their dog	Exercise
Exercise	# of visitors exercising in site	Exercise
Playing games	# of visitors playing a physical game in site	Exercise
On foot	# visitors on foot	Passage
Biking	# visitors biking	Passage
Skateboarding	# visitors skateboarding	Passage
Rollerblading	# visitors rollerblading	Passage
In car	# visitors in car parked nearby	Passage
Pass by	#f visitors that passed by site	Passage
Pass Through	# visitors that went through site	Passage
Listen to Music	# visitors listening to music	Relaxing
Gardening	# visitors gardening/doing maintenance	Relaxing
Eating	# visitors eating/drinking	Relaxing
Smoking	# visitors smoking	Relaxing
Read/Write	# visitors reading/writing	Relaxing
Sleeping	# visitors sleeping in site	Relaxing
Stop	# visitors that slowed down/stopped	Viewing (Stop.Point.Look)
Point	# visitors that turned head/pointed	Viewing (Stop.Point.Look)
Sit and Look	# visitors sitting nearby/looking	Viewing (Stop.Point.Look)

4.4.2 Ecological Data Collection

To explore how biodiversity might impact resident engagement with urban green space in Boston, MA, we used bird and vegetation data from the larger dataset of the Boston Metro Area ULTRA-EX (www.umass.edu/urbaneco/). Eleven of our behavioral observation sites overlapped with bird observation sites within the larger dataset. Bird sampling was conducted by skilled volunteer birders from the Boston area as part of a Citizen Science project. The volunteers were provided with maps, detailed instructions, coding sheets, and general times of day and month in which to conduct their counts. For a full, detailed account of the methods employed see Strobach (2013).

Four of our behavioral observation sites overlapped with vegetation inventory sites from the larger dataset. Vegetation surveys were conducted by two trained student field technicians. The technicians were provided with training, detailed instructions, coding sheets and a camera to take photographs at the North, South, East and West corners of the site. Data from this study is still being analyzed.

4.4.3 Service area analysis

Using QGIS, we conducted a modified service area analysis to estimate the population with potential access to our sites (Wright Wendel, Zarger, and Mihelcic 2012). We placed a 400m buffer around each of our sites based on the buffer used for "small" green spaces in (Wright Wendel, Zarger, and Mihelcic 2012) and determined population centroids using 2010 Census data at the Block Group level. Populations located within a site service area (based on centroid) were assumed to have access to that site.

4.4.4 Statistical Analysis

To investigate whether user group was related to type of site visited, as well as type of activity engaged in, Wilcoxon rank sums tests were performed. In addition, a non-parametric Spearman test was performed to identify potential correlations between variables studied: site type, number of visitors, visitor activities, bird species richness, and vegetation species richness. The JMP 11 software package was used for all statistical analysis.

4.5 Results

4.5.1 Service Area Analysis

A service area analysis showed that the white population was much lower than the minority population within the service areas of the green spaces we studied. Furthermore, white user groups used all green space sites at a lower proportion than what would be expected based upon the white population served by the sites, while minority user groups used all green space sites at a higher proportion than what would be expected based upon minority population served (Figure 4.2).

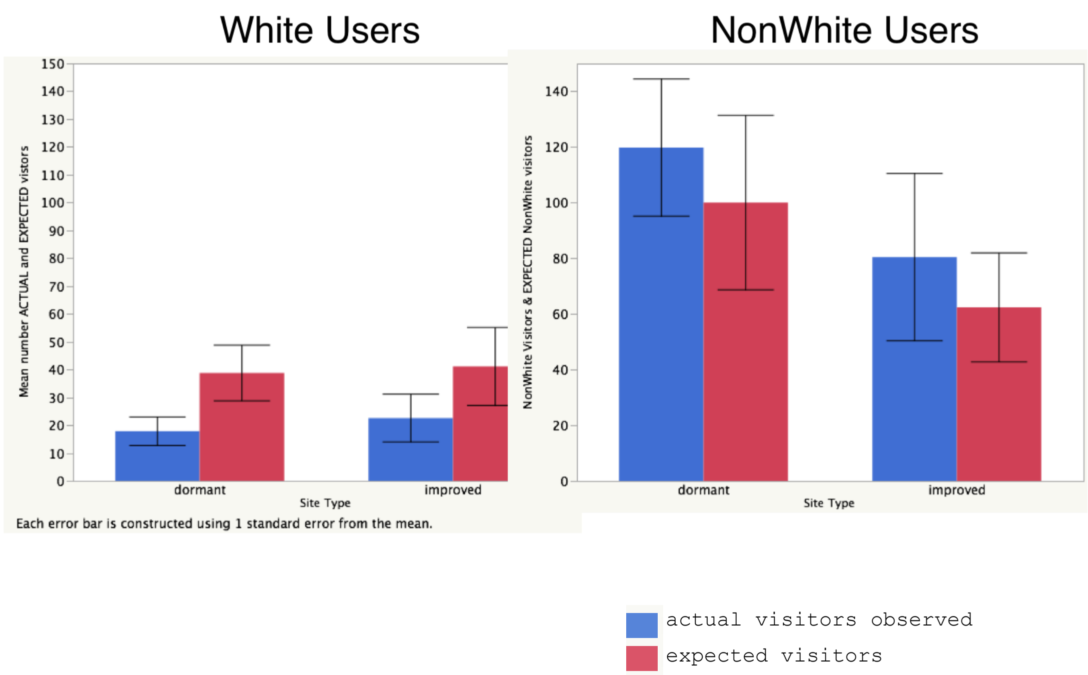

Figure 4.2. The proportion of white and minority users observed visiting improved and dormant sites compared with the number of white and minority users expected to visit each site based on population served by the sites.

4.5.2 Behavioral

Data on the average number of visitors for each site, user groups, and site type are presented in Table 4.2. For all user groups, Improved sites received more visitors than

Dormant sites and Street Side sites received more visitors than Lot Transformation sites. All green space sites had more minority visitors than white visitors, and more adult visitors than children or elderly visitors.

Table 4.2. Average number of green space users by category and site type obtained from 210 systematic green space observation of 20 sites in Boston, MA

Mean # users (rounded)	All Sites	"Improved" sites	"Dormant" Sites	Street side sites	Lot Transformation sites
All Users	100	106	94	126	89
Male	55	57	52	64	51
Female	46	49	43	62	38
White	13	17	9	25	8
Minority	86	88	84	100	80
Children	30	31	28	34	28
Adult	66	71	61	90	56
Elderly	3	3	3	2	4

The results of Wilcoxon rank sums tests comparing number of visitors from each user group across site status (improved versus dormant) and site type (street side versus lot transformation) is presented in Table 4.3. Overall, we observed significantly more visitors in street side sites than in lot transformation sites ($Z = 5$, $p < .0001$) for all user groups except elderly. We also observed significantly more "White" visitors in the Improved sites than in the dormant sites ($Z = -2.13$, $p = 0.03$). Site status had no effect on visitation from any of the other user groups.

Table 4.3 Results of Wilcoxon rank sums tests for each user group compared over site status (improved versus dormant) and site type (street side versus lot transformation)

	by site status		by site type	
User group	*Z*	*p*	*Z*	*p*
All Users	-1.5	0.13	5	<.0001*
Male	-1.28	0.2	4.2	<.0001*
Female	-0.91	0.36	5	<.0001*
White	-2.13	0.03*	6.5	<.0001*
Of Color	-0.78	0.43	2.7	0.01*
Children	-0.85	0.39	2.3	0.02*
Adults	-1.57	0.12	6	<.0001*
Elderly	-0.15	0.88	-0.88	0.38

The prevalence of activities engaged in by visitors over the different user groups are shown in Table 4.4. Activities were grouped into five main categories: passage, viewing, communication, restoration, and exercise.

Table 4.4 Percentage of activities in each of five activity categories over all user groups

	all sites	improved	dormant	street side	lot trans
passage	75%	68%	82%	76%	74%
viewing	16%	20%	11%	17%	15%
communication	2%	2%	1%	1%	3%
restoration	2%	2%	1%	1%	2%
exercise	3%	3%	3%	2%	3%

Visitors were significantly more likely to engage in viewing (Z = -4.72, p < .0001), communication (Z = -2.38, p = 0.02), and restoration (Z = -3.04, p = 0.002) activities in the "improved" sites than the "dormant" sites. Visitors were also significantly more likely to engage in communication (Z = 2.78, p = 0.006), and restoration (Z = 2.84, p = 0.005) activities in the lot transformation sites than in the street side sites. Finally, visitors were significantly more likely to engage in passage activities in the street side sites than the lot transformation sites (Z = 4.53, p < .0001)

4.5.3 Ecological

Data on bird species richness and abundance in our sites is provided in Table 4.5. Number of bird species observed ranged from 14 in the highest diversity site to three in the lowest diversity site. Most common species observed were House Sparrow, European Starling, Blue Jay, Northern Mockingbird, and Rock Pigeon. The abundance of birds counted in each site ranged from a minimum of 16 to a maximum of 107.

Table 4.5. Ecological measures in green space sites (-- indicates data for this measure not collected in this site).

Site.ID	Site.Status	Site.Type	Bird Diversity	Bird Abundance	Tree Diversity	Tree Abundance
10a	improved	lot trans	14	80	--	--
12a	improved	lot trans	7	84	5	18
1a	improved	lot trans	11	61	4	24
2a	improved	street side	7	74	--	--
4a	improved	street side	6	31	--	--
4b	dormant	street side	6	16	--	--
5a	improved	street side	9	42	2	38
6a	improved	lot trans	11	45	--	--
BT-a	Improved	lot trans	--	--	3	18
B4b	dormant	street side	3	25	--	--
C3b	dormant	lot trans	9	51	--	--
A3b	dormant	street side	10	107	--	--

There was no relationship between site type and any ecological measure (Wilcoxon rank sums, all p-values > 0.05). Correlations between number of visitors and bird diversity and number of visitors and bird abundance were generally weak but positive over every user group except the White user group, in which visitation was weakly negatively correlated with diversity (r = -.3159) and not correlated with abundance (r = -.0589). All activity types were positively correlated with both diversity and abundance.

Data on tree cover in our sites is provided in Table 4.5. Number of tree species observed ranged from five in the highest diversity site to two in the lowest diversity site. Species observed included Maple, Birch, Oak, Cherry, Apple, and Crab Apple. The abundance of trees counted in each site ranged from a minimum of 18 to a maximum of 38 and tree dbh ranged from 20cm to 300cm. Mean number of visitors was strongly positively correlated with tree abundance across all user groups (r = .9667) and weakly to moderately negatively correlated with tree diversity across all user groups (r = -.5468). Tree abundance and tree diversity were moderately negatively correlated (r = -.7400).

4.6 Discussion

This study used systematic behavioral observation of 20 green space sites over two years to characterize how different user groups engage with different types of small, community-driven, urban green spaces in the city of Boston. To further explore how green space characteristics affect visitation and engagement we compared these measures to ecological measures derived from other ongoing research. Our study provides valuable information about a little studied cross-section of urban green space, namely small, community-driven areas, that can be an important and practical way of increasing access to nature for underserved user groups in U.S. cities.

4.6.1 Service Area Analysis

Our service area analysis revealed that White user groups used all green space sites at a lower proportion than what would be expected based upon the white population served by the sites. We also found that minority user groups used all green space sites at a higher proportion that what would be expected based upon minority population served. Previous research in a large, city-designed, urban park found that white, affluent users are more likely to visit public park space than minority user groups (Byrne, Wolch, and Zhang 2009). We found the opposite for the small, community-driven green spaces in our study. This type of pocket green space is much more flexible than a large urban park, suggesting that this type of green space may be valuable in addressing environmental inequity in urban areas. There is better potential for equitable distribution of this type of green space, since even densely developed neighborhoods without large swaths of green space may be able to improve a vacant lot or street side patch. There is also potential for greater quantity of this type of green space, since funding can be achieved through mini-grants or corporate partners. Increasing access to green space of any kind has important implications for improving community cohesion and reducing crime (Maller et al. 2006; Berney 2010). The use of sites in our study implies that community-driven green spaces can serve as a valuable part of a larger effort to improve equitable access to desirable green spaces.

4.6.2 Visitation across site type

Looking at how visitation differed over site type, it was our prediction that visitors would use improved sites more than dormant sites. The differences between improved and dormant sites are stark, with improved sites offering amenities like gardens, benches, etc. and dormant sites offering none of these features. White users did visit sites selectively by type, using improved sites significantly more than they used dormant sites. Interestingly, visitors from minority user groups used both site types equally. This is an important finding as it implies that something about the improved sites (or surrounding context) is not allowing minority groups to get the full benefit from them. Either the characteristics of the improved sites that we deem as restorative or meaningful are not accessible to minority user groups, or minority user groups are getting something out of the dormant sites that we are not recognizing. It is outside the scope of this paper to determine what might be affecting visitation in this way, suffice to say that both internal characteristics (amenities, language of signage, other visitors present, etc.) and external characteristics (codified racism, transport access, etc.) may be factors in visitation (Byrne and Wolch 2009). Still, the fact that minority user groups are using these small, community green spaces at such a high rate is an important finding.

Previous research has found that large urban parks are visited by white users at a much higher rate than minority user groups, with one of the likely factors being that large urban parks are often located in affluent suburban neighborhoods and are not easily accessible to all users (Byrne and Wolch 2009; Byrne 2012; Weber and Sultana 2013). Park visitation is closely related to the pool of potential users (Byrne, Wolch, and Zhang 2009) and urban cores often do not have the available pervious surface to provide large urban parks like those that can be found at the city's periphery (Danford et al. 2014). Our findings show that these smaller, community-driven sites are able to reach a different pool of users than the large city-sponsored parks, often largely minority and low income. However, it is important to also explore whether these small community-driven sites provide opportunities for quality engagement with green space.

4.6.3 Engagement

This study sought to characterize engagement with urban green spaces across two dimensions. First, comparing unimproved or "dormant" green spaces with green spaces that, through community intervention, had been improved with the sole purpose of serving residents. Second, comparing the improved sites by their accessibility, i.e. could people enter the site, or could they just view the site, and did that matter? Overall, people engaged with improved sites more than dormant sites, whether they could enter the site or just view it from the street. This accords with robust findings about the psychological and physical benefits of green space discussed earlier in this paper. This is not to say that the opportunities to enter and manipulate lot transformation sites will not be more useful for community building than the opportunities provided by street side sites. Research has shown that being involved with the creation and stewardship of a community site is an important factor of attitudes toward the green space itself, and sometimes the environment in general (Ryan 2006). Although we found that street side sites can provide opportunities for engagement with nature, they may not provide opportunities for ongoing meaningful action. Lot transformation sites can provide opportunities for meaningful action long-term to visitors who can use the space for community gardening, exercising or meeting with neighbors. Researchers maintain that large urban parks and those in the US national park system are designed based upon white, middle-class ideals about Nature and stewardship (Spence 1999), one probable factor in the low visitation rates of minority users. The types of community green spaces in this study may have the added benefit of being more malleable and open to the changing needs of the specific community they service.

4.6.4 Ecological

Our ecological sample was small, 11 sites for birds and four sites for vegetation. However, our results do agree with previous findings that salient vegetation features (e.g.

trees) attract people to parks and provide opportunities for engagement (Taylor et al. 1998; Lindemann-Matthies, Junge, and Matthies 2010). Community green space, like those we studied, can provide important places for wildlife habitat and biodiversity beyond city-designed conservation space. For example, community green space covers 18% of Stockholm, which is more than twice the land area specifically set aside for conservation landuse in that city (Colding, Lundberg, and Folke 2006).

In summary, our findings suggest that small, community-driven green spaces can play an important role in equitable access to green space in urban areas. We found that pocket parks and street side landscaping are being used for many types of leisure and restorative activities by user groups that, to a large extent, are not engaging with the outdoors at public urban parks. Some of these green spaces provide opportunities for meaningful action, stewardship, and community engagement, while others provide opportunities for restoration and fascination. The reality of funding and resources means these green spaces may be created quickly, distributed more equitably, and be more flexible to a community's needs than a large public park. Our limited data on the ecological characteristics of these green spaces is consistent with previous findings that higher visitation rates are associated with abundance of salient ecological features (e.g. trees). Our data does not address how these types of green spaces may provide ecological value to cities through ecosystem services such as flood mitigation and air quality improvement. However, it is clear that small urban green space can be a valuable habitat for wildlife, particularly if the spaces connect to other existing green space (Strohbach, Lerman, and Warren 2013) and may provide ecosystem services when taken as a whole across a city (Colding, Lundberg, and Folke 2006; Danford et al. 2014).

Many studies addressing access to urban green space recommend careful policy, planning, and governance to increase equitable distribution. This study finds that community-driven green space, funded through mini-grants and planned by community leaders using non-profit resources, can also be valuable in the effort to increase equitable access to urban green space. City greening initiatives wishing to increase equitable access to the outdoors should consider incorporating funding for groups that focus on providing resources to communities to design and implement small green space in their neighborhoods.

GENERAL DISCUSSION

Natural spaces are crucial for providing opportunities for urban residents to rejuvenate, recreate, and form social bonds (Herzog et al. 1997; Frumkin 2001; Berman, Jonides, and Kaplan 2008). Engagement with nature can provide well-being, healing, and public health benefits (Hartig, Mang, and Evans 1991; Lewis 1992; Lewis 1996; Ulrich 1984). Beyond that, there is something almost spiritual about being in nature, something that we are losing as more people move into cities and more meadows are paved and forests are turned into farming monocultures.

In this dissertation, I have provided four related but unique examinations of the human-environment system in a compactly developed greater metropolitan area, focusing on access to nature and environmentally-oriented behaviors that support natural features in cities. The first two chapters investigated environmentally relevant decision-making on an individual and policy-level scale. In the first chapter, I considered individual level environmentally relevant decision-making. This chapter demonstrates the many competing factors that individuals consider when making a decision to act in an environmentally responsible way. Chapter 1 also provided insight into a disconnect between environmentally relevant attitudes and environmentally responsible behavior. My results echoed similar findings in the literature, but with risk to person or property, a variable that has not been widely studied in regards to environmentally relevant behavior.

In the second chapter, I explored environmentally relevant decision-making at the policy scale by describing how water suppliers make decisions about residential water conservation efforts in their towns and communities. As expected, the system that municipal water suppliers work within is a complex one. State mandates require thresholds to be met but leave the decision-making to the individual town supplier. In theory, this is preferable, as it allows suppliers to be flexible and meet the conservation needs of their specific community. Our study finds that in practice, water suppliers face staff and funding shortages and are not able to adequately include residents in the decision-making process, affecting the ability of the towns and state to meet water conservation goals.

In the third and fourth chapters, I switched focus to explore access and engagement with urban nature. The third chapter investigated the difficulties in providing equitable access to urban nature through policy. Here, I examined several different models that attempted to distribute trees equitably throughout metropolitan Boston, factoring in the current status of trees and development and projecting several different futures with different levels and locations of development. Although each model had its advantages and disadvantages, the ultimate finding from this study was the limiting effect of ecological availability on environmental justice and equity. Without space for planting, and funds and people to provide stewardship, even the most progressive and heavily funded tree planting policies will likely not succeed in providing equitable access to urban nature for residents.

The fourth chapter explored access and engagement with green space on a local, community-driven level. In this chapter, I observed small, community-improved, urban green spaces and small, unimproved, urban green spaces and compared visitation to and engagement with these sites. This study found that minority status of the users played a role in visitation, with minority users visiting these sites at a much higher rate than white users did. Although, overall, community-improved sites were visited more than unimproved sites, minority groups visited both site types at an equal rate. The study's findings suggest that small, community-driven green spaces can provide urban nature to groups that lack access to larger, city and state-created green space, which may be geographically or culturally inaccessible to some minority users. In this way, these local, community-driven sites can play an important role in equitable access to green space in urban areas.

Taken separately, the four studies in this dissertation fit neatly within the first section of our conceptual model (Figure 1, reprinted below). Although this dissertation did not specifically investigate stewardship in the second section of the model, my findings do suggest some insights into how the two sections of the model may fit together. Perhaps the clearest example is seen in the second chapter, where water suppliers base residential water conservation decisions on their perception of residents' attitudes toward water conservation. Findings suggest that perceptions of individual attitudes can inform environmentally relevant decision-making at the policy level. Water supplier respondents cited residents' disinterest in water conservation, unawareness of water sources and shortages, and desire to use water for uses other than health and safety (e.g. landscaping, pools). These beliefs about residents' values shaped which conservation tools suppliers offered and advertised. Suppliers were less likely to offer tools that depended on individual conservation effort, and more likely to use tools like taxes and restrictions. In this case, a negative feedback loop could be occurring, where residents at the individual level are not acting as water stewards, at least not in a way that is recognized at a policy level. This informs policy decisions about what conservation tools and options are offered, which in turn affects how residents use water and engage with water conservation tools in their town. The type of use and engagement further affects the likelihood that residents will act as water stewards, and stewardship, or lack thereof, shapes individual attitudes about the value of water, beginning the feedback loop again.

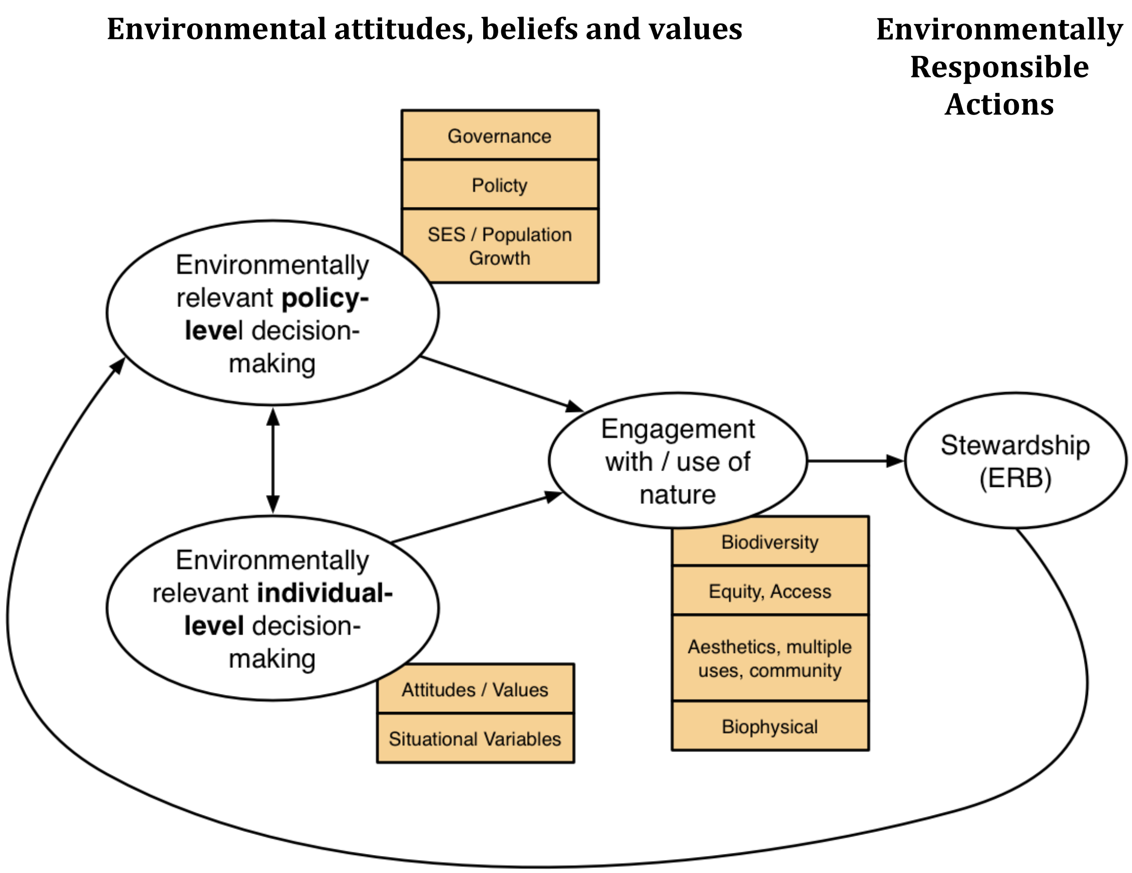

Figure 1: Attitudes, engagement and environmentally responsible actions in a feedback loop.

This work begins to describe the complex and varied system-wide human-environment interaction in an urban setting as part of a larger effort by the Boston Metro Ecological Research project. It is clear that social, economic, historical, and ecological drivers all play a part in how we perceive and influence urban nature, a system as complex as any ecosystem on earth. Understanding how nature influences human beliefs, values, perceptions and misconceptions, and how that in turn influences environmental policy, stewardship, and the ecological quality of urban nature, will only become more critical as cities face intensified environmental stressors due to climate change and increasing population. The first step in this effort is characterizing urban nature in cities, how it is used, who is and isn't able to access it, and how it is being cared for. This work provides this valuable information for one city, as well as a conceptual model that can be used to characterize the human-environment system in other cities in the same way.

BIBLIOGRAPHY

Abel, D. 2012. “Boston Struggles with Goal to Plant 100,000 Trees.” *The Boston Globe*, July 8, sec. Metro.

Ajzen, I. 1991. “The Theory of Planned Behavior.” *Organizational Behavior and Human Decision Processes* 50 (2): 179–211. doi:10.1016/0749-5978(91)90020-T.

Ajzen. 2003. “Constructing a TpB Questionnaire: Conceptual and Methodological Considerations.” *Retrieved April*, 2015. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=736395518517858810related:-lFyj9IzOAoJ.

Ajzen, I., and B.L. Driver. 1992. “Application of the Theory of Planned Behavior to Leisure Choice.” *Journal of Leisure Research* 24 (3): 207–24.

Akbari, H., M. Pomerantz, and H. Taha. 2001. “Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas.” *Solar Energy* 70 (3): 295–310.

Alberti, M. 2005. “The Effects of Urban Patterns on Ecosystem Function.” *International Regional Science Review*, 28 (2), 168-192.

Alberti, M., J.M. Marzluff, E. Shulenberger. G. Bradley, C. Ryan and C. Zumbrunnen 2003. “Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban ecosystems.” *BioScience*, 53 (12), 1169-1179.

Armitage, C.J., and M. Conner. 2001. “Efficacy of the Theory of Planned Behaviour: A Meta-Analytic Review.” *British Journal of Social Psychology* 40 (4): 471–99.

Averyt, K., J. Meldrum, P. Caldwell, G. Sun, S. McNulty, A. Huber-Lee, and N. Madden. 2013. “Sectoral Contributions to Surface Water Stress in the Coterminous United States.” *Environmental Research Letters* 8 (3): 035046.

Bagozzi, R. P., Y. Yi, and J. Baumgartner. 1990. “The Level of Effort Required for Behaviour as a Moderator of the Attitude-Behaviour Relation.” *European Journal of Social Psychology*. 20(1), 45-59.

Bamberg, S., and G. Möser. 2007. “Twenty Years after Hines, Hungerford, and Tomera: A New Meta-Analysis of Psycho-Social Determinants of pro-Environmental Behaviour.” *Journal of Environmental Psychology* 27 (1): 14–25.

Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof, eds. 2008. *Climate Change and Water: technical Paper vi."* Intergovernmental Panel on Climate Change (IPCC). https://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.shtml.

Berman, Marc G., John Jonides, and Stephen Kaplan. 2008. "The Cognitive Benefits of Interacting With Nature." *Psychological Science* 19 (12): 1207–12.

Berney, Rachel. 2010. "Learning from Bogotá: How Municipal Experts Transformed Public Space." *Journal of Urban Design* 15 (4): 539–58. doi:10.1080/13574809.2010.502344.

Blewett, C. M., and J. M. Marzluff. 2005. "Effects of Urban Sprawl on Snags and the Abundance and Productivity of Cavity-Nesting Birds." *The Condor* 107 (3): 678–93.

Bolund, P., and S. Hunhammar. 1999. "Ecosystem Services in Urban Areas." *Ecological Economics* 29 (2): 293–301.

Boston Natural Areas Network. 2006. "Trees and Orchards." *Retrieved April 2014*. http://www.bostonnatural.org/trees_and_orchards.htm.

Brooks, D.B. 2006. "An Operational Definition of Water Demand Management." *Water Resources Development* 22 (4): 521–28.

Brower, M., and W. Leon. 1999. *The Consumer's Guide to Effective Environmental Choices: Practical Advice from the Union of Concerned Scientists.* Harmony Books.

Brunson, L., F.E. Kuo, and W.C. Sullivan. 2001. "Resident Appropriation of Defensible Space in Urban Public Housing: Implication for Safety and Community." *Environment and Behavior* 33: 626–52.

Bryant, M. M. 2006. "Urban Landscape Conservation and the Role of Ecological Greenways at Local and Metropolitan Scales." *Landscape and Urban Planning* 76 (1-4): 23–44.

Byrne, J. 2012. "When Green Is White: The Cultural Politics of Race, Nature and Social Exclusion in a Los Angeles Urban National Park." *Geoforum*, The Global Rise and Local Implications of Market-Oriented Conservation Governance, 43 (3): 595–611.

Byrne, J., and J. Wolch. 2009. "Nature, Race, and Parks: Past Research and Future Directions for Geographic Research." *Progress in Human Geography* 33 (6): 743–65.

Byrne, J., J. Wolch, and J. Zhang. 2009. “Planning for Environmental Justice in an Urban National Park.” *Journal of Environmental Planning and Management* 52 (3): 365–92.

Clark, W.A., and J.C. Finley. 2008. “Household Water Conservation Challenges in Blagoevgrad, Bulgaria: A Descriptive Study.” *Water International* 33: 175–88.

Colding, J., J. Lundberg, and C. Folke. 2006. “Incorporating Green-Area User Groups in Urban Ecosystem Management.” *AMBIO: A Journal of the Human Environment* 35 (5): 237–44.

Commonwealth of Massachusetts. 1985. “General Laws Chapter 21G Massachusetts Water Management Act.” Retrieved January, 2015 https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter21G.

Conner, M., and C.J. Armitage. 1998. “Extending the Theory of Planned Behavior: A Review and Avenues for Further Research.” *Journal of Applied Social Psychology* 28: 1429–64.

Cook, D.I. 1978. “Trees, Solid Barriers, and Combinations: Alternatives for Noise Control.” *Information Systems Divisions, National Agricutural Librar*y.

Cooper, C.B., J. Dickinson, T. Phillips, and R. Bonney. 2007. “Citizen Science as a Tool for Conservation in Residential Ecosystems.” *Ecology and Society* 12 (2): 11.

Dahlstrand, U., and A. Biel. 1997. “Pro-Environmental Habits: Propensity Levels in Behavioral Change.” *Journal of Applied Social Psychology* 27 (7): 588–601.

Dallimer, M., K.N. Irvine, A.M.J. Skinner, Z.G. Davies, J.R. Rouquette, L.L. Maltby, P.H. Warren, P.R. Armsworth, and K.J. Gaston. 2012. “Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-Being and Species Richness.” *BioScience* 62 (1): 47–55.

Danford, R.S., C. Cheng, M. Strohbach, R. Ryan, C. Nicolson, and P. Warren. 2014. “What Does It Take to Achieve Equitable Urban Tree Canopy Distribution? A Boston Case Study.” *Cities and the Environment (CATE)* 7 (1).

De Vries, S., R.A. Verheij, P.P. Groenewegen, and P. Spreeuwenberg. 2003. “Natural Environments-Healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health.” *Environment and Planning A* 35 (10): 1717–32.

Dunlap, R.E. and A. Mertig. 1995. “Global Concern for the Environment: Is Affluence a Prerequisite?” *Journal of Social Issues* 51: 121–38.

Dwyer, J.F., D.J. Nowak, M.H. Noble, and S.M. Sisinni. 2000. "Connecting People with Ecosystems in the 21st Century: An Assessment of Our Nation's Urban Forests." *General Technical Report-Pacific Northwest Research Station, USDA Forest Service*.

Dwyer, J. F., H. W. Schroeder, and P. H. Gobster. 1991. "The Significance of Urban Trees and Forests: Toward a Deeper Understanding of Values." *Journal of Arboriculture* 17 (10): 276–84.

Eagly, A.H., and S. Chaiken. 1993. *The Psychology of Attitudes*. Fort Worth: Harcourt Brace Javanovich College Publishers.

Finley, R. 1999. *Survey Monkey Online Software Application*. Portand, OR.

Firestone, J., W. Kempton, and A. Krueger. 2009. "Public Acceptance of Offshore Wind Power Projects in the USA." *Wind Energ.* 12 (2): 183–202.

Fowler, F. and C. Cosenza. 2009. "Design and Evaluation of Survey Questions." In *The SAGE Handbook of Applied Social Research Methods*, 375–412. Sage Publications

Francis, J.J., M.P. Eccles, M. Johnston, A. Walker, J. Grimshaw, R. Foy, E.F.S. Kaner, L. Smith, and D. Bonetti. 2004. "Constructing Questionnaires Based on the Theory of Planned Behaviour: A Manual for Health Services Researchers." *Centre for Health Services Research*, May, 1–42.

Frumkin, H. 2001. "Beyond Toxicity Human Health and the Natural Environment." *American Journal of Preventive Medicine* 20 (3): 234–40.

Fuller, R.A., K.N. Irvine, P. Devine-Wright, P.H. Warren, and K.J. Gaston. 2007. "Psychological Benefits of Greenspace Increase with Biodiversity." *Biology Letters* 3 (4): 390–94.

Gatersleben, B., L. Steg, and C. Vlek. 2002. "Measurement and Determinants of Environmentally Significant Consumer Behavior." *Environment and Behavior* 34 (3): 335–62.

Gorman, J. 2004. "Residents' opinions on the Value of Street Trees Depending on Tree Location." *Journal of Arboriculture* 30 (1): 36–44.

Greenscapes. 2012. "Partner Communities." *Greenscapes.org*. *Retrieved April 2013*. http://greenscapes.org/?page_id=70.

Gregory, R.S. 2002. "Incorporating Value Trade-Offs into Community-Based Environmental Risk Decisions." *Environmental Values*, 461–88.

Grimm, N.B, D. Foster, P. Groffman, J.M. Grove, C.S Hopkinson, K.J. Nadelhoffer, D.E. Pataki, and D.P.C Peters. 2008. "The Changing Landscape: Ecosystem Responses to Urbanization and Pollution across Climatic and Societal Gradients." *Frontiers in Ecology and the Environment* 6 (5): 264–72.

Grothmann, T. and A. Patt. 2005. "Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change." *Global Environmental Change* 15 (3): 199–213.

Grow Boston Greener. 2012. "Welcome." *Retrieved April 2013.* http://www.growbostongreener.org/gbg/index.html.

Guagnano, G.A., P.C. Stern, and T. Dietz. 1995. "Influences on Attitude-Behavior Relationships A Natural Experiment with Curbside Recycling." *Environment and Behavior* 27 (5): 699–718.

Hahs, A.K. and M.J. McDonnell. 2006. "Selecting Independent Measures to Quantify Melbourne's Urban–rural Gradient." *Landscape and Urban Planning*, 78(4), 435-448.

Harland, P., H. Staats, and H. A. M. Wilke. 1999. "Explaining Proenvironmental Intention and Behavior by Personal Norms and the Theory of Planned Behavior 1." *Journal of Applied Social Psychology* 29 (12): 2505–28.

Harper, M.M. 2010. "Summary Report for the Water Conservation Grant Program: January 2005 - April 2010." Massachusetts Department of Environmental Protection. http://www.mass.gov/eea/docs/dep/water/wcgsumm.pdf.

Hartig, T., M. Mang, and G.W. Evans. 1991. "Restorative Effects of Natural Environment Experiences." *Environment and Behavior* 23 (1): 3–26.

Heath, Y., and R. Gifford. 2002. "Extending the Theory of Planned Behavior: Predicting the Use of Public Transportation 1." *Journal of Applied Social Psychology* 32 (10): 2154–89.

Herzog, Thomas R., Andrea M. Black, Kimberlee A. Fountaine, and Deborah J. Knotts. 1997. "Reflection and Attentional Recovery as Distinctive Benefits of Restorative Environments." *Journal of Environmental Psychology* 17 (2): 165–70.

Heynen, N.C. 2003. "The Scalar Production of Injustice within the Urban Forest." *Antipode* 35: 980–98.

Heynen, N.C., and G. Lindsey. 2003. "Correlates of Urban Forest Canopy Cover Implications for Local Public Works." *Public Works Management & Policy* 8: 33–47.

Heynen, N., H.A. Perkins, and P. Roy. 2006. “The Political Ecology of Uneven Urban Green Space the Impact of Political Economy on Race and Ethnicity in Producing Environmental Inequality in Milwaukee.” *Urban Affairs Review* 42: 3–25.

Higgins, A. and M. Conner. 2003. “Understanding Adolescent Smoking: The Role of the Theory of Planned Behaviour and Implementation Intentions.” *Psychology, Health and Medicine* 8 (2): 173–86.

Hines, J.M., H. R. Hungerford, and A.N. Tomera. 1987. “Analysis and Synthesis of Research on Responsible Environmental Behavior: A Meta-Analysis.” *The Journal of Environmental Education* 18 (2): 1–8.

Hrubes, D., I. Ajzen, and J. Daigle. 2001. “Predicting Hunting Intentions and Behavior: An Application of the Theory of Planned Behavior.” *Leisure Sciences* 23 (February): 165–78.

Hunecke, M., A. Blöbaum, E. Matthies, and R. Höger. 2001. “Responsibility and Environment Ecological Norm Orientation and External Factors in the Domain of Travel Mode Choice Behavior.” *Environment and Behavior* 33 (6): 830–852.

Hungerford, H. R., and T. L. Volk. 1990. “Changing Learner Behavior through Environmental Education.” *Journal of Environmental Education* 21 (3): 8–21.

Hutrya, L., B. Yoon, and M. Alberti. 2010. “Terrestrial Carbon Stocks across a Gradient of Urbanization: A Study of the Seattle, WA Region.” *Global Change Biology* 17 (2): 783–97.

Inman, D., and P. Jeffrey. 2006. “A Review of Residential Water Conservation Tool Performance and Influences on Implementation Effectiveness.” *Urban Water Journal* 3: 127–43.

Ipswich River Watershed Management Council (IRWMC), and Ipswich River Watershed Association (IRWA). 2003. “Regional Water Conservation Plan for the Ipswich River Watershed.” http://ipswich-river.org/wp-content/uploads/2010/03/finalconservplan04.pdf.

Iverson, L.R., and E.A. Cook. 2000. “Urban Forest Cover of the Chicago Region and Its Relation to Household Density and Income.” *Urban Ecosystems* 4: 105–24.

Jackson, Richard J. 2003. “The Impact of the Built Environment on Health: An Emerging Field.” *American Journal of Public Health* 93 (9): 1382–84.

Jenerette, G.D., S.L. Harlan, W.L. Stefanov, and C.A. Martin. 2011. “Ecosystem Services and Urban Heat Riskscape Moderation: Water, Green Spaces, and Social Inequality in Phoenix, USA.” *Ecological Applications* 21: 2637–51.

Joassart-Marcelli, P. 2010. “Leveling the Playing Field? Urban Disparities in Funding for Local Parks and Recreation in the Los Angeles Region.” *Environment and Planning* 42 (5): 1174.

Johnson, T.H. 1988. *Biodiversity and Conservation in the Caribbean: Profiles of Selected Islands*. International Council for Bird Preservation.

Jones, M., K. Evangelinos, P. Gaganis, and E. Polyzou. 2010. “Citizens’ Perceptions on Water Conservation Policies and the Role of Social Capital.” *Water Resources Management* 25 (2): 509–22.

Jones, M., and W. Hunt. 2010. “Performance of Rainwater Harvesting Systems in the Southeastern United States.” *Resources Conservation and Recycling* 54: 623–29.

Kahlor, L.A. 2007. “An Augmented Risk Information Seeking Model: The Case of Global Warming.” *Media Psychology* 10 (3): 414–35.

Kaiser, F. G., and P. W. Schultz. 2009. “The Attitude-Behavior Relationship: A Test of Three Models of the Moderating Role of Behavioral Difficulty 1.” *Journal of Applied Social Psychology* 39 (1): 186–207.

Kane, B., D. Ryan, and D.V. Bloniarz. 2001. “Comparing Formulae That Assess Strength Loss due to Decay in Trees.” *Journal of Arboriculture* 27 (2): 78–87.

Kantola, S.J., G.J. Syme, and A.R. Nesdale. 1983. “The Effects of Appraised Severity and Efficacy in Promoting Water Conservation: An Informational Analysis.” *Journal of Applied Social Psychology* 13 (2): 164–82.

Kaplan, S. and R. Kaplan. 2009. “Creating a Larger Role for Environmental Psychology: The Reasonable Person Model as an Integrative Framework.” *Journal of Environmental Psychology* 29 (3): 329–39.

Kaplan R. 2004. "The social values of forests and trees in urbanised societies." *In Forestry Serving Urbanised Societies*. Vol 14. C. Konijnendijk, J. Schipperijn and K. Hoyer (eds). IUFRO World Series, Vienna.

Kaplan, R., S. Kaplan, and R. Ryan. 1998. *With People in Mind: Design And Management Of Everyday Nature*. Island Press.

Kaplan, R., and S. Kaplan. 1989. *The Experience of Nature: A Psychological Perspective*. Cambridge University Press.

Kaplan, S. 1995. “The Restorative Benefits of Nature: Toward an Integrative Framework.” *Journal of Environmental Psychology* 15 (3): 169–82.

Kaplan, S. 2000. “Human Nature and Environmentally Responsible Behavior.” *Journal of Social Issues* 56 (3): 491–508.

Kaplan, S, and R. Kaplan. 1978. *Humanscape*. North Scitiate, MA: Duxberry Press.

Kaplan, S, and R. Kaplan. 2005. “Preference, Restoration, and Meaningful Action in the Context of Nearby Nature.” *Urban Place: Reconnecting with the Natural World,* 271–98.

Kaplan, S, and R. Kaplan. 2003. “Health, Supportive Environments, and the Reasonable Person Model.” *American Journal of Public Health* 93 (9): 1484–89.

Kempton, W, J Firestone, J Lilley, T Rouleau, and P Whitaker. 2005. “The Offshore Wind Power Debate: Views from Cape Cod.” *Coastal Management* 33 (2): 119–49.

Kendal, D., N.S.G. Williams, and K.J.H. Williams. 2012. “Drivers of Diversity and Tree Cover in Gardens, Parks and Streetscapes in an Australian City.” *Urban Forestry & Urban Greening*. 11 (3): 257-265.

Kirkpatrick, JB, GD Daniels, and A. Davison. 2011. “Temporal and Spatial Variation in Garden and Street Trees in Six Eastern Australian Cities.” *Landscape and Urban Planning* 101: 244–52.

Kraft, P., J. Rise, S. Sutton, and E. Røysamb. 2005. “Perceived Difficulty in the Theory of Planned Behaviour: Perceived Behavioural Control or Affective Attitude?” *British Journal of Social Psychology* 44 (3): 479–96.

Kuo, F.E., and W.C. Sullivan. 2001. “Environment and Crime in the Inner City: Does Vegetation Reduce Crime?” *Environment and Behavior* 33 (3): 343–67.

Lam, S.P. 1999. “Predicting Intentions to Conserve Water From the Theory of Planned Behavior, Perceived Moral Obligation, and Perceived Water Right.” *Journal of Applied Social Psychology* 29 (5): 1058–71.

Lam, S.P. 2006. “Predicting Intention to Save Water: Theory of Planned Behavior, Response Efficacy, Vulnerability, and Perceived Efficiency of Alternative Solutions.” *Journal of Applied Social Psychology* 36 (11): 2803–24.

Landry, S.M., and J. Chakraborty. 2009. “Street Trees and Equity: Evaluating the Spatial Distribution of an Urban Amenity.” *Environment and Planning A* 41: 2651.

Larson, K. L., D. D. White, P. Gober, S. Harlan, and A. Wutich. 2009. “Divergent Perspectives on Water Resource Sustainability in a Public–policy–science Context.” *Environmental Science & Policy* 12 (7): 1012–23.

Lee, M., B. Tansel, and M.l. Balbin. 2011. “Influence of Residential Water Use Efficiency Measures on Household Water Demand: A Four Year Longitudinal Study.” *Resources Conservation and Recycling* 56: 1–6.

Levin, R.B., P.R. Epstein, T.E. Ford, W. Harrington, E. Olson, and E.G. Reichard. 2002. "US Drinking Water Challenges in the Twenty-First Century." *Environmental Health Perspectives* 110 (Suppl 1): 43.

Lewis, C. 1992. "Effects of Plants and Gardening in Creating Interpersonal and Community Well-Being." *The Role of Horticulture in Human Well-Being and Social Development,* 55–65.

Lewis, C. 1996. *Green Nature/human Nature: the meaning of plants in our lives.* University of Illinois Press.

Lindemann-Matthies, P., X. Junge, and D. Matthies. 2010. "The Influence of Plant Diversity on People's Perception and Aesthetic Appreciation of Grassland Vegetation." *Biological Conservation* 143 (1): 195–202..

Lindsey, G., M. Maraj, and S. Kuan. 2001. "Access, Equity, and Urban Greenways: An Exploratory Investigation." *The Professional Geographer* 53: 332–46.

Lobb, A.E., M. Mazzocchi, and W.B. Traill. 2007. "Modelling Risk Perception and Trust in Food Safety Information with the Theory of Planned Behaviour." *Food Quality and Preference* 18 (2): 384–95.

Lyytimäki, J., L.K. Petersen, B. Normander, and P. Bezák. 2008. "Nature as a Nuisance? Ecosystem Services and Disservices to Urban Lifestyle." *Environmental Sciences* 5: 161–72.

MA EEA. 2005. "310 CMR 36.00: The Water Management Act Regulations." *Retrieved January 2014*. http://www.mass.gov/eea/agencies/massdep/water/regulations/310-cmr-36-00-the-water-management-act-regulations.html.

Maller, C., M. Townsend, A. Pryor, P. Brown, and L. St Leger. 2006. "Healthy Nature Healthy People: 'contact with Nature' as an Upstream Health Promotion Intervention for Populations." *Health Promotion International* 21 (1): 45–54.

Manfredo, M., T. Teel, and A. Bright. 2003. "Why Are Public Values toward Wildlife Changing?" *Human Dimensions of Wildlife* 8 (4): 287–306.

Mankin, P. C., R. E. Warner, and W. L. Anderson. 1999. "Wildlife and the Illinois Public: A Benchmark Study of Attitudes and Perceptions." *Wildlife Society Bulletin*, 465–72.

MA Office of Water Policy. 2013. "Ipswich River Watershed." *Retrieved April 2014.* http://www.mass.gov/eea/air-water-climate-change/preserving-water-resources/mass-watersheds/ipswich-river-watershed.html.

MassGIS (Office of Geographic Information). 2011. "Major Watersheds Layer." *Retrieved April 2013.* Commonwealth of Massachusetts, Information Technology Division. http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/watrshds.html.

McDonnell, M., S. Pickett, P. Groffman, P. Bohlen, R.V. Pouyat, W.C. Zipperer, R.W. Parmelee, M. M. Carreiro, and K. Medley. 1997. "Ecosystem Processes along an Urban-to-Rural Gradient." *Urban Ecosyst*ems 1(1): 21-36.

McEachern, M.G., and G. Warnaby. 2008. "Exploring the Relationship between Consumer Knowledge and Purchase Behaviour of Value-Based Labels." *International Journal of Consumer Studies* 32 (5): 414–26.

McPherson, E.G. 1990. "Modeling Residential Landscape Water and Energy Use to Evaluate Water Conservation Policies." *Landscape Journal* 9: 122–34.

Metropolitan Area Planning Council. 2006. "Baseline: Population and Employment Projections 2010-2030." *Retrieved April 2013*. http://www.mapc.org/data_gis/data_center/2006_Projections/2006ProjectionMethodologyFinal.doc.

Strobach, M., S.B. Lerman, and P.S. Warren 2013. "Are Small Urban Greening Areas Enhancing Bird Diversity? Insights from Community-Driven Greening Projects from Boston." *Landscape and Urban Planning* 114: 69–79.

Mullen, P.D., J.C. Hersey, and D.C. Iverson. 1987. "Health Behavior Models Compared." *Social Science and Medicine* 24 (11): 973–81.

Nisbet, E. K., J.M. Zelenski, and S.A. Murphy. 2009. "The Nature Relatedness Scale: Linking Individuals' Connection With Nature to Environmental Concern and Behavior." *Environment and Behavior* 41 (5): 715.

Nordlund, A.M., and J. Garvill. 2002. "Value Structures behind Proenvironmental Behavior." *Environment and Behavior* 34 (6): 740–56.

Nowak, D.J. 1994. "Air Pollution Removal by Chicago's Urban Forest." *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*, 63–81.

Nowak, D.J. and D.E. Crane. 2000. "The Urban Forest Effects (UFORE) Model: Quantifying Urban Forest Structure and Functions." In .

Nowak, D.J. 2002. "Carbon Storage and Sequestration by Urban Trees in the USA." *Environmental Pollution* 116: 381–89.

Nowak, D.J., and J.F. Dwyer. 2007. "Understanding the Benefits and Costs of Urban Forest Ecosystems." *Urban and Community Forestry in the Northeast*, 25–46.

Nowak, D.J., and E.J. Greenfield. 2012. "Tree and Impervious Cover Change in US Cities." *Urban Forestry & Urban Greening*.

Nowak, D.J., M. Kuroda, and D.E. Crane. 2004. "Tree Mortality Rates and Tree Population Projections in Baltimore, Maryland, USA." *Urban Forestry & Urban Greening* 2: 139–47.

Olmstead, S.M., and R.N. Stavins. 2009. "Comparing Price and Nonprice Approaches to Urban Water Conservation." *Water Resources Research* 45.

Oskamp, S., M. J. Harrington, T. C. Edwards, D. L. Sherwood, S. M. Okuda, and D. C. Swanson. 1991. "Factors Influencing Household Recycling Behavior." *Environment and Behavior* 23 (4): 494.

Pataki, D., M. Carreiro, J. Cherrier, N.E. Grulke, V. Jennings, S. Pincetl, R.V. Pouyat, T.H. Whitlow, and W.C. Zipperer. 2011. "Coupling Biogeochemical Cycles in Urban Environments: Ecosystem Services, Green Solutions, and Misconceptions." *Frontiers in Ecology and the Environment* 9 (1): 27-36.

Pelletier, L. G., S. Dion, K. Tuson, and I. Green-Demers. 1999. "Why Do People Fail to Adopt Environmental Protective Behaviors? Toward a Taxonomy of Environmental Amotivation." *Journal of Applied Social Psychology* 29 (12): 2481–2504.

Peper, P.J., E.G. McPherson, and S.M. Mori. 2001. "Equations for Predicting Diameter, Height, Crown Width, and Leaf Area of San Joaquin Valley Street Trees." *Journal of Arboriculture* 27: 306–17.

Pham, T., P. Apparicio, A-M. ASeguin, S.M. Landry, and M. Gagnon. 2012. "Spatial Distribution of Vegetation in Montreal: An Uneven Distribution or Environmental Inequity?" *Landscape and Urban Planning* 107: 214–24.

Pickett, S. T. A., M.L Cadenasso, and J.M. Grove. 2001. "Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas." *Annual Review of Ecology and Systematics* 32: 127–57.

Pincetl, S. 2010. "Implementing Municipal Tree Planting: Los Angeles Million-Tree Initiative." *Environmental Management* 45: 227–38.

Pincetl, S., T. Gillespie, D.E. Pataki, S. Saatchi, and J.D. Saphores. 2012. "Urban Tree Planting Programs, Function or Fashion? Los Angeles and Urban Tree Planting Campaigns." *GeoJournal*, 1–19.

Pooley, J. A., and M. O'Connor. 2000. "Environmental Education and Attitudes: Emotions and Beliefs Are What Is Needed." *Environment and Behavior* 32 (5): 711.

R Development Core Team. 2012. “R: A Language and Environment for Statistical Computing.” http://www.R-project.org/.

Routhe, A.S., R.E. Jones, and D.L. Feldman. 2005. “Using Theory to Understand Public Support for Collective Actions That Impact the Environment: Alleviating Water Supply Problems in a Nonarid Biome*.” *Social Science Quarterly* 86 (4): 874–97.

Russell, S., and K. Fielding. 2010. “Water Demand Management Research: A Psychological Perspective.” *Water Resources Research* 46 (5).

Ryan, R.L. 2006. “The Role of Place Attachment in Sustaining Urban Parks.” *The Human Metropolis: People and Nature in the 21st-Century City*, pps 61.

Ryan, R.L. and J. Buxton 2015. Applying RPM to urban greening projects: Insights from the inner city. In Kaplan, R. and Basu, A. (Eds.), Fostering reasonableness: Supportive environments for bringing out our best. Ann Arbor: Michigan Publishing (Maize Books). pp. 176-193.

Sanders, R.A. 1986. “Urban Vegetation Impacts on the Hydrology of Dayton, Ohio.” *Urban Ecology* 9: 361–76.

Schroeder, H.W. 1989. “Environment, Behavior, and Design Research on Urban Forests.” *Advances in Environment, Behavior, and Design* 2: 87–117.

Schultz, P.W., S. Oskamp, and T. Mainieri. 1995. “Who Recycles and When? A Review of Personal and Situational Factors.” *Journal of Environmental Psychology* 15 (2): 105–21.

Schultz, P. W., and S. Oskamp. 1996. “Effort as a Moderator of the Attitude-Behavior Relationship: General Environmental Concern and Recycling.” *Social Psychology Quarterly* 59 (4): 375.

Sommer, R., H. Guenther, and P. A. Barker. 1990. “Surveying Householder Response to Street Trees.” *Landscape Journal (USA)* 9 (2): 79–85.

Souch, C.A, and C. Souch. 1993. “The Effect of Trees on Summertime below Canopy Urban Climates.” *Journal of Arboriculture* 19: 303–303.

Spence, M. 1999. "Dispossessing the Wilderness: Indian Removal and the Making of the National Parks" Oxford University Press, New York .

Steg, L., and C. Vlek. 2009. “Encouraging pro-Environmental Behaviour: An Integrative Review and Research Agenda.” *Journal of Environmental Psychology* 29 (3): 309–17.

Stern, P.C. 2000. “New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior.” *Journal of Social Issues* 56 (3): 407–24.

Streiling, S., and A. Matzarakis. 2003. "Influence of Single and Small Clusters of Trees on the Bioclimate of a City: A Case Study." *Journal of Arboriculture* 29: 309–16.

Strohbach, M.W., S.B. Lerman, and P.S. Warren. 2013. "Are Small Greening Areas Enhancing Bird Diversity? Insights from Community-Driven Greening Projects in Boston." *Landscape and Urban Planning* 114 (June): 69–79.

Sullivan, W.C., F.E. Kuo, and S.F. Depooter. 2004. "The Fruit of Urban Nature Vital Neighborhood Spaces." *Environment and Behavior* 36 (5): 678–700.

Talen, E., and L. Anselin. 1998. "Assessing Spatial Equity: An Evaluation of Measures of Accessibility to Public Playgrounds." *Environment & Planning A* 30 (4): 595-613.

Talen, E. 1998. "Visualizing Fairness: Equity Maps for Planners." *Journal of the American Planning Association.* 64 (1): 22-38.

Tarrant, M.A., and H.K. Cordell. 1999. "Environmental Justice and the Spatial Distribution of Outdoor Recreation Sites: An Application of Geographic Information Systems." *Journal of Leisure Research* 31 (1): 18.

Taylor, A.F., A. Wiley, F.E. Kuo, and W.C. Sullivan. 1998. "Growing Up in the Inner City Green Spaces as Places to Grow." *Environment and Behavior* 30 (1): 3–27.

Terry, D.J., M.A. Hogg, and K.M. White. 1999. "The Theory of Planned Behaviour: Self-Identity, Social Identity and Group Norms." *The British Journal of Social Psychology* 38: 225.

Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. "Estimating the Cumulative Effects of Development on Wildlife Habitat." *Landscape and Urban Planning* 39 (1): 25–36.

Tonglet, M., P. S. Phillips, and A. D. Read. 2004. "Using the Theory of Planned Behaviour to Investigate the Determinants of Recycling Behaviour: A Case Study from Brixworth, UK." *Resources, Conservation & Recycling* 41 (3): 191–214.

Trumbo, C.W., and G.J. O'Keefe. 2005. "Intention to Conserve Water: Environmental Values, Reasoned Action, and Information Effects Across Time." *Society & Natural Resources* 18 (6): 573–85.

Ulrich, R. 1984. "View through a Window May Influence Recovery from Surgery." *Science*, 224–25.

Ulrich, R. S., R. F. Simons, B. D. Losito, E. Fiorito, M. A. Miles, and M. Zelson. 1991. "Stress Recovery during Exposure to Natural and Urban environments1." *Journal of Environmental Psychology* 11 (3): 201–30.

Urban Ecology Institute. 2008. "State of the Urban Forest: A Summary of the Extent and Condition of Boston's Urban Forest." Boston, Massachusetts: *Retrieved April 2013.* http://www.growbostongreener.org/gbg/pdfs/State of the Urban Forest Report.pdf.

US Census Bureau. 2010. http://www.census.gov/.

US EPA. 1994. "Executive Order 12898." *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* 11.

U.S. Geological Survey (USGS). 2008. "Water Availability: A Matter of Quantity, Quality and Use." Media Advisory, U.S. Geological Survey, Dept of the Interior, March 20.

Vickers, A. 2005. "Managing Demand: Water Conservation as a Drought Mitigation Tool." In *Drought and Water Crises*, 173. Boca Raton, FL: Taylor & Francis Group.

Vining, Joanne, and Angela Ebreo. 1992. "Predicting Recycling Behavior from Global and Specific Environmental Attitudes and Changes in Recycling Opportunities1." *Journal of Applied Social Psychology* 22 (20): 1580–1607.

Vitousek, P. M., H.A. Mooney, J. Lubchenco, and J.M. Melillo. 1997. "Human Domination of Earth's Ecosystems (vol 277, Pg 494, 1997)." *Science* 278 (5335): 21.

Warren, P.S., S.L. Harlan, C. Boone, S. Lerman, E. Shochat, and AP Kinzig. 2010. "Urban Ecology and Human Social Organization." *Urban Ecology. Cambridge University Press, Cambridge, UK*, 172–201.

Warren, P.S., B. Kane, and S. Lerman. 2007. "Contribution of Urban-Suburban Tree Care Practices to Reduced Habitat for Cavity Nesting Birds." presented at the ESA/SER Joint Meeting, San Jose, CA.

Weber, J., and S. Sultana. 2013. "Why Do So Few Minority People Visit National Parks? Visitation and the Accessibility of 'America's Best Idea.'" *Annals of the Association of American Geographers* 103 (3): 437–64.

Westphal, L.M., and JG Isebrands. 2001. "Phytoremediation of Chicago's Brownfields–consideration of Ecological Approaches and Social Issues." *Brownfields 2001 Proceedings, Chicago IL. Retrieved April 2013. Http://nrs. Fs. Fed. us/pubs/jrnl/2001/nc_2001_ Westphal_001. pdf.)*.

Williams, C.K., G. Ericsson, and T. Heberlein. 2002. "A Quantitative Summary of Attitudes toward Wolves and Their Reintroduction (1972-2000)." *Wildlife Society Bulletin*, 575–84.

Wilson, E.O. 1984. *Biophilia*. Harvard University Press.

Witten, K., D. Exeter, and A. Field. 2003. "The Quality of Urban Environments: Mapping Variation in Access to Community Resources." *Urban Studies* 40: 161–77.

Wolch, J., J.P. Wilson, and J. Fehrenbach. 2005. "Parks and Park Funding in Los Angeles: An Equity-Mapping Analysis." *Urban Geography* 26: 4–35.

Wright Wendel, H.E., R.K. Zarger, and J.R. Mihelcic. 2012. "Accessibility and Usability: Green Space Preferences, Perceptions, and Barriers in a Rapidly Urbanizing City in Latin America." *Landscape and Urban Planning* 107 (3): 272–82.

Zarriello, P.J. 2002. *Effects of Water-Management Alternatives on Streamflow in the Ipswich River Basin, Massachusetts*. US Department of the Interior, US Geological Survey.

Zarriello, P.J., and K.G. Ries. 2000. *A Precipitation-Runoff Model for Analysis of the Effects of Water Withdrawals on Streamflow, Ipswich River Basin, Massachusetts*. US Department of the Interior, US Geological Survey. http://pubs.usgs.gov/wri/wri004029/.

Zeileis, A. 2012. "Ineq: Measuring Inequality, Concentration, and Poverty. R Package Version 0.2-10." http://CRAN.R-project.org/package=ineq.

Zelezny, L. C. 1999. "Educational Interventions That Improve Environmental Behaviors: A Meta-Analysis." *The Journal of Environmental Education* 31 (1): 5–14.

Zelezny, L. C., P. P. Chua, and C. Aldrich. 2000. "Elaborating on Gender Differences in Environmentalism." *Journal of Social Issues* 56 (3): 443–58.