EXPLORING THE RELATIONSHIP BETWEEN TREES AND STRESS IN THE URBAN ENVIRONMENT

by

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A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Plant and Soil Sciences

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ABSTRACT

The research literature describes a positive relationship between seeing plants and human well-being. More rapid recovery from surgery, reduced incidence of neighborhood crime, increased baby birth weight and increased trust of neighborhood merchants are among the benefits attributed to exposure to trees and shrubs. This thesis attempts to find a common explanation for these outcomes. It examines the connection between urban trees and community stress. Each of the above outcomes can be attributed, in part, to stress reduction. The literature indicates that stress reduction is one of the consequences of exposure to plants. Stress levels were measured at the block level in Wilmington Delaware by means of a survey mailed to 1982 residents. Physical conditions were catalogued using an on-site inventory. The survey and inventory demonstrate that the total number of trees on a block has a strong negative relationship with community stress and a positive relationship with self-reported health. The results suggest that moderation of stress is one of the factors that underlies the beneficial consequences of exposure to green vegetation on inner city blocks. This research should prove useful to city planners and urban residents alike.

Chapter 1

INTRODUCTION

Exploring the Relationship Between Trees and Stress in the Urban Environment seeks to understand the apparent relationship between the natural environment and community stress.[1] It is hypothesized that the number of trees at the block level, will have a negative correlation with the level of community stress and that lower community stress will be confirmed by better self-reported health and sense of safety.

Previous studies have elucidated the contribution of urban trees to the physical environment. Beneficial impacts include pollen reduction (Nowak and McPherson 1993), carbon sequestration (Cairns and Meganck 1994, 14; Nowak and McPherson 1993), reduction of rainwater run-off (Tyrväinen et al. 2005, 97), sound reduction (Pathak, Tripathi, and Mishra 2007, 67) and ambient temperature moderation (Bolund and Hunhammar 1999, 296).

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[1] The terms strain, stress and stressors are often confused. They have a long entangled history in sociology and psychology. Stressor is traditionally an engineering term. It is similar to the weight of a heavy truck on a bridge. Strain refers to the passive response of the bridge, in this case sagging. In contemporary research papers stress is used in place of strain. A second illustration of this relationship would be the sound of jackhammers outside a city dwelling in the street. This would be considered a stressor for the residents. Stress (strain) would be the psychological response to that stressor.

The behavioral impact of tree cover is more difficult to quantify than the physical impact. Nevertheless, data exist that show that views of greenery improve health outcomes (Ulrich 1984, 421), street trees improve the shopping experience (Wolf 2004, 45), landscaping around public housing projects reduces negative social behavior (Kuo and Sullivan 2001a, 359) and the presence of trees on residential streets has a negative correlation with crime rate (Donovan and Prestemon 2010, 210).

Each of these behavioral studies measures the consequence of exposure to landscaping in the urban environment. Stress reduction through exposure to landscaping is one of the psychological phenomena that tie these outcomes together. Reduced stress improves focus (Linden et al. 2005, 23–36), hastens healing (Parsons 1991, 17), increases trust (Wolf 2009, 37), and tempers anger (Kuo and Sullivan 2001, 558). The medical and criminological literature demonstrate that high stress increases criminal behavior (Eitle and Turner 2003, 254) and leads to poor health (Shonkoff 2008; Sapolsky 2005). The goal is to discover if urban trees, as a specific form of urban landscaping, have the ability to reduce stress.

There is a very practical purpose for this research. The field of urban forestry seeks to improve city life by planting trees and increasing urban green spaces (Elevitch 2004, 396). To garner public support for this goal, empirical studies have been published describing the environmental benefits of tree cover in the city (McPherson 2003, 5; Nowak and McPherson 1993). The behavioral benefits of tree cover in the city are much more difficult to quantify and have not been adequately described. At this point it is unrealistic to seek a causal relationship between the number of trees on a block and stress reduction, but short of making such a claim, this research seeks to build a theoretical

basis for the relationship and to validate that relationship by comparing self-reported safety and health data on treed and un-treed streets.

There are two potential audiences for this research, the health care community and residents and administrators of the urban community. In many ways the health care community has already adopted this message.[2] Horticultural therapy is an advanced and well-respected science for improving the human condition. A simple Google Scholar search for horticultural therapy turns up 9,690 sources. At the epidemiological level, the study of the health benefits of urban greenery is well advanced in Scandinavia (Grahn and Stigsdotter 2003, 2), Australia (Maller et al. 2006) and the United States (Branas et al. 2011).

Since health and safety are the primary concerns for city residents, a second audience for this project is residents and local government. Stress is a major component of city life (Milgram 1970). By 2025, 60% of the world's population is expected to live in urban areas (Bhatta 2010, 17–36). To ensure the prosperity of future generations, it incumbent on us to understand what makes safe and nurturing urban environments for humans.

This research examines the impact of urban trees at the block level to measure the effect of nature on stress, which is new to existing literature methodologies. Other studies have measured the impact of nature on behavior by using building landscaping as

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[2] Nemours Children's Hospital is completing a new major facility where every patient room has a view of natural green surroundings ("Hospital Expansion | Nemours" 2014)

a cue (Kuo and Sullivan 2001a, 352), films of country roads (Parsons et al. 1998, 122) and strolls through woodland landscapes (Van Den Berg, Hartig, and Staats 2007, 85).

A second unique aspect of this research is that it focuses on the relationship between trees and stress. Other studies (Donovan and Prestemon 2010, 22), have used broken windows theory,[3] routine activity theory[4] and eyes on the street[5] to explain changes in social behavior attributable to tree canopy. Kuo and Sullivan refer to the mitigation of "some of the psychological precursors to violence" (2001, p.360). Without denying the relevance of previous explanations, the expectation here is to understand how stress fits into the tree/social behavior paradigm

Finally, this study uniquely collected empirical data on the physical environment at the block level and relates that data to social outcomes. In sociological research, the usual model, except for broken windows theory, is to seek explanations for behavior in society itself, not the physical environment.

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[3] Broken windows theory (J. Q. Wilson and Kelling 1982) postulates that: "at the community level, disorder and crime are usually inextricably linked, in a kind of developmental sequence. Social psychologists and police officers tend to agree that if a window in a building is broken and is left unrepaired, all the rest of the windows will soon be broken."

[4] Routine activity theory suggests that "the dispersion of activities away from households and families increases the opportunity for crime and thus generates higher crime rates"(L. E. Cohen and Felson 1979, 558).

[5] Jean Jacobs argued in her book, *The Death and Life of Great American Cities* (Jacobs 1961), that mixed-use neighborhoods have people watching the streets throughout the day, both from the ground-floor shops and the mid-rise apartment buildings above those shops. These 'eyes on the street,' she argued, reduced crime.

This thesis works from an integrated behavioral model. It crosses the line between evolutionary biology and social theory. Intrinsic to this approach is the understanding that our behavior has roots in both our evolutionary past and in the relationships we have within society (E. O. Wilson 1998, 8).

Urbanization continues to encroach on rural areas at an unabated rate in the United States, Europe and parts of Asia. In 2007 the world urban population exceeded the world rural population for the first time in history (United Nations 2011). Natural parkland, even agricultural fields, within reasonable distances of urban dwellers provide an escape hatch – the great outdoors (Stigsdotter and Grahn 2011, 2). But as urban and suburban communities push into natural areas, that escape hatch becomes more difficult to utilize. The foundational thought of this thesis is that a lack of exposure to natural elements in the landscape, especially trees, is deleterious for humans. The objective is to provide an empirically derived explanation for why a dearth of trees in the urban landscape has this effect.

Chapter 2

LITERATURE REVIEW

The literature review is divided into three sections. The first, Natural and Built Environments, cites researchers and natural philosophers who have considered the relationship between natural environments and human behavior. The second section cites authors who have contributed to the stress literature, particularly, those who have studied the relationship between the physical environment and stress. The last section cites authors who have studied the effects of stress on well-being.

Natural and Built Environments

Certain themes are revisited over and over again: what is beauty in the landscape; is beauty the same as preference; is our preference for natural landscapes related to the need for suitable habitat; what configuration of tree canopy and understory is most attractive; is initial environmental judgment subconscious or conscious; is it exceedingly rapid or is it a drawn out process; is attentional restoration related to habitat selection; if our evaluation of environmental surroundings is initially subconscious, how is it transformed to action; are emotions related to environmental evaluation; are emotions related to stress?

Before the 18th century, thoughts regarding our relationship to nature belonged in the realm of aesthetics. The study of aesthetics dates back to Classical times (Lothian 1999, 7). Aesthetics is the study of the guiding principles that describe relative beauty – how things in the physical world impact the visual senses. Most Classical and Medieval writers considered beauty to be objective. Beauty was a component of the item being viewed. Such qualities as proportion, texture and symmetry were aspects of this objective notion of beauty.

The 18th century British philosophers David Hume (1711-1776) and Edmund Burke (1729-1797) considered beauty to be subjective. Beauty was, for them, in the eye of the beholder. They reasoned that such characteristics as proportion, texture or symmetry were found to inhabit both objects of beauty and objects lacking beauty. The specific characteristics did not seem to control the overall evaluation. It was clear that it would be impossible to catalogue qualities of beauty because beauty had a strong subjective quality (1999, 30).

The German philosopher Immanuel Kant (1724-1804) moved the discussion one step closer to our modern notion of beauty. In the third of his great treatises, *Critique of Judgment* (1790), Kant describes the nature of the aesthetic experience. For Kant, the perception that something is beautiful is an immediate non-cognitive response. We determine beauty without thinking. It is a non-conceptual judgment without limits or desire. This response is public and universal (1999, 32). Most important is the idea that a judgment of beauty is immediate and

universal. We shall see that Kant's idea that humans make instantaneous non-cognitive aesthetic judgments is echoed by subsequent writers describing habitat preferences.

In Art as Experience, the American philosopher John Dewey (1859-1952) picked up on the discussion of aesthetics (2005). He theorized that human intuitional development is firmly rooted in the natural world:

> To grasp the sources of the aesthetic experience it is, therefore, necessary to have recourse to animal life below the human scale. The activities of the fox, the dog and the thrush may at least stand as reminders and symbols of that unity of experience which we so fractionize when work is labor and thought withdraws us from the world. (2005, 18)

The English geographer, Jay Appleton, in *The Experience of Nature* (1975) was the first to face the issue of whether specific landscapes, apart from aesthetics, have an impact on human behavior. He starts out by covering the issue of aesthetics in much the same way it is explored above. But he takes the next logical step and examines what components of the life of the fox, the dog, and the thrush relate to our experiences as humans (1975, 68). Our most basic drive, according to Appleton, even before procreation, is habitat selection:

> All this leads to the proposition that aesthetic satisfaction, experienced in the contemplation of landscape, stems from the spontaneous perception of landscape features which, in their shapes, colours, spatial arrangements and other visible attributes, act as sign-stimuli indicative of environmental conditions favourable to survival, whether they really are favourable or not. This proposition we call habitat theory. (1975, 69)

Appleton goes on to write that all animals, including humans, experience pleasure, or aesthetic satisfaction, when visually confronted with a landscape that has the potential to satisfy biological needs. Biological needs should be thought of, not only as food sources, but also as prospect and refuge. Appleton spends the subsequent sections of his book exploring how implementation of prospect and refuge designs in landscapes contribute to their positive aesthetic experience (1975, 70).

R. Zajonc, in an address to the American Psychological Association titled, "Feeling and thinking: Preferences need no inferences" (1980), continued the discussion of beauty, aesthetics and rapid processing. Recalling Kant and Appleton, Zajonc describes a certain set of affective responses that occur rapidly, without effort (1980, 156)[6]. They are primarily related to approach and avoidance and can be found in all animal species. Zajonc uses such words to describe these responses as: effortless; unavoidable; irrevocable; difficult to verbalize; but easy to communicate (1980, 69). While the prevailing notion among psychologists of his day was that affective responses followed cognition, Zajonc maintained that the first reactions of any organism to new stimuli are affective. "It is further possible that we can like something or be afraid of it before we know precisely what it is …" (1980, 154). He calls this class of emotional responses preferenda, and speculates that their rapid stimulus-response pathway may be separate or at least

[6] In the following discussion, the word "affect" is used as a synonym for emotion, the only difference being that in psychology "affect" is seen as influencing behavior or action.

partly independent of cognitive pathway. Due to the primitive evolutionary nature of preferenda, they seem to have a deep biological component (1980, 169).

In a paper titled "Habitat Selection: General Theory and Applications to Human Behavior", Gordan Orians describes the need for all organisms to seek their niche in nature – the spot where their traits most efficiently match the surroundings (1980). Organisms are genetically inclined to find the right spot and this urge is at work among all life from bacteria to humans. It is possible to examine human behavior in the light of this inclination. Emotions are the mediators between environment and action. Orians calls the study of this pursuit "habitat selection theory" (1980, 49) and goes on to explain why the east African savanna would be the most suitable site for early hominids to evolve.

To summarize, writers and researchers through the ages have described a certain type of emotional response of which we are generally unaware. It occurs rapidly and colors our later more reasoned responses. These early feelings converge around such emotions as attention, fear, curiosity, and survival and guide our subsequent behavior. They are the source for aesthetic judgments. Of all landscapes, the savanna produces the most positive response in humans because it is best suited for human habitability.

E. O. Wilson coined the term *biophilia* to describe the concept that humans have an innate relationship with nature that exists as a holdover from the millions of years spent in evolution (1984, 10). Wilson's extensive and popular writings

expand on this topic but mainly follow the lines of reasoning first described by Appleton, Zajonc and Orians. While his use of the term biophilia is unique among modern scientists, he was by no means the earliest scientist to recognize this association.

Another geographer, Roger Ulrich, conducted his research into environmental aesthetics while at the University of Delaware and Texas A&M University. His well-reasoned conclusions drawn from meticulously designed experimentation put solid data behind years of speculation about the impact of natural surroundings on human behavior. The following are salient conclusions from Ulrich's extensive research.

- Emotional responses are primary in environmental assessment, they come first. Cognitive responses follow later and are modified by the primary response (1983).
- The human response to nature has evolutionary roots. It is related to habitat selection and survival. It is emotional at its core. By rapidly signaling the emotions, "like or dislike" the brain modifies our behavior (1983, 94).
- Empirical studies demonstrate that humans prefer or like natural environments. Natural environments reduce stress (Roger S. Ulrich et al. 1991, 222).
- Restoration comes from stress reduction (Roger S. Ulrich 1979, 20).
- Urban environments increase stress, sadness, arousal factor and decrease attentiveness (1979, 21).
- The stress level is related to the endocrine system: high stress leads to increase in stress hormones, cortisol, epinephrine and norepinephrine (1993, 120).

- In addition to an almost instantaneous emotional response to natural scenery, our systolic blood pressure decreases within 3-6 minutes after exposure (1993, 104).
- The use of photographic slides as a visual cue, as opposed to being on site, is a research-tested technique. Slides are legitimate surrogates for the real environment (1979, 17).

In two studies, John H. Falk and John D. Balling provide support for the notion that humans have an innate evolutionary preference for savanna-like landscapes: "Development of Visual Preference for Natural Environments" (John H. Falk and J. D. Balling 1982), "Evolutionary Influence on Human Landscape Preference" (2009). In the first they queried American children. In later work they queried children from Nigeria's rainforest. They found that children from both countries under twelve years of age had strong preference for the savanna landscape. Older children and adults continued to prefer savanna-like landscapes, but this preference was mediated by their experience of local landscapes.

In two works of research history and modern neuroscience, "The Potential Influences of Environmental Perception on Human Health" (Parsons 1991) and "The View from the Road: Implications for Stress Recovery and Immunization" (Parsons et al. 1998), psychologist Russ Parsons supports Ulrich's theories of stress reduction and restoration from exposure to natural scenes. Some of his findings include:

- Stress reduction can be measured using blood pressure, electrodermal activity, and facial EMG activity (1998, 120).

- Urban environments were shown to produce stress because they provide no evolutionary cues of protection or support (Parsons 1991, 16).
- The ability to recognize the lack of cues of habitability is probably hard wired (1991, 6).
- Fast environmental processing provides a selective advantage (fight or flight). Note here that Parsons suggests hard wiring only for negative cues (1991, 6).
- These findings are consistent with contemporary neural research into the role of the limbic system (1991, 9).
- The limbic system, part of the primitive brain, is responsible for rapid pre-cognitive responses to the environment, emotional reactions, and neuro-hormonal modulation (1991, 9).
- If urban environments without greenery activate the limbic system, then we should expect to witness negative affect and the increase of stress hormones. Research indicates this is in fact the case (1991, 4).
- Natural scenes not only provide stress reduction but also provide an element of inoculation to deal with future stressors (Parsons et al. 1998, 133).
- An increase in stress hormones has both behavioral and long term health effects (Parsons 1991, 16).

Ulrich's theory that rapid pre-cognitive processing occurs at the onset of new environmental stimuli and mediates behavior through emotion is not the only empirically tested model.

Steven and Rachael Kaplan authored an influential collection of books and papers over the past 40 years exploring the relationship between natural landscapes and human behavior. In contrast to Ulrich's work on the natural environment and

stress, the Kaplans describe a more generalized evolutionary model based on preference (R. Kaplan 2004). Through evolution humans have come to intuitively know which environments make them comfortable and which environments put them ill-at-ease. Environments that provide our needs (shelter, look-out and provisions) and that we understand are the ones we prefer, they provide restoration (2004). We run into difficulty in environments, like city-scapes, that are too complex. In the following citations the concept of restoration is often mentioned. It is the hallmark of the Kaplan's work and comes from the lessening of the burden to focus which is necessary in urbanized settings. In natural environments focus is not necessary. It is replaced by fascination (R. Kaplan 2004).

In their contribution to *Children and Nature, Psychological, Sociocultural, and Evolutionary Investigations* (Kahn 2002, 227), the Kaplans explore an age disparity in appreciation for natural surroundings first described in "Evolutionary Influence on Human Landscape Preference" (J. H. Falk and J. D. Balling 2009). Empirical data demonstrates that pre-adolescents and post-adolescents from both North America and African rain forests have similar preferences for savanna landscapes, while adolescents, not necessarily rejecting the former, preferred scenes denoting urban mobility, action and excitement (R. Kaplan and S. Kaplan 2002, 232). After adolescence the data demonstrated a return to pre-adolescent preference for savanna and the addition of a second preference, the home landscape. The conclusion of these studies is that while initial preferences seem to have an evolutionary basis, they can be modified through experience (J. H. Falk and J. D. Balling 2009, 483).

Exploring another direction, the Kaplans found that reading an environment involves understanding, meaningful action and restoration. Overly complex landscapes are difficult to read and therefore not preferred (R. Kaplan and S. Kaplan 2003, 1484).

> Natural areas have the potential to be both attractive and restorative. They encourage outdoor activities and have the potential for making one's neighbors more reasonable and one's community safer. They can thus enhance exploration and understanding as well as facilitating meaningful action in the form of community participation.(2003, 1487)

The most useful contribution of the Kaplans' work is Attention Restoration Theory (ART) (R. Kaplan 1989, 177). ART describes a process whereby the mental fatigue of living in an urban environment is reduced by time spent in a natural setting. This reasoning closely approximates Ulrich's conclusions regarding stress reduction and inoculation (Roger S. Ulrich et al. 1991). Urban life requires directed attention and focus (S. Kaplan 1995, 172). Directed attention consumes energy and is ultimately exhausting. When our resources for focusing are depleted we become stressed and irritable. A natural environment does not require the same level of attention. Instead, our response to natural scenes is fascination. Fascination is restorative. Since natural environments remove the need for directed attention we experience restoration (S. Kaplan and R. Kaplan 2003, 1487).

Figure 1 A woodland path. Recalling Kaplan's model, notice how the curving path is intriguing and pulls in the attention of the viewer to the focal point at the center of the picture. The canopy signals protection, the path provides direction and evokes curiosity. Walking on this path would be restorative.

Figure 2 A tree-lined Wilmington street. Observe how similar this urban street is to the woodland scene above. Here too, the trees signal protection as they define the path. The attention of the viewer is drawn to the focal point. The street appears to be one we would like to stroll down.

In a throwback to the 19th Century, Steven Kaplan (1995) traces the concept of directed attention, fatigue and restoration first to William James (1842-1910) and then to Frederick Law Olmsted (1822-1903). James wrote about voluntary attention that went against the grain; it is a difficult mental activity pursued in the face of mental distraction. Olmstead described the need for respite from directed attention, especially in urban settings where attention was on high alert. He used the ability of natural settings to provide sources of restoration in his designs (1995, 169–182).

Frances E. Kuo and William Sullivan in "Environment and Crime in the Inner City: Does Vegetation Reduce Crime?" (2001a) use empirical data collected at Chicago's public housing projects to show that the rate of reported negative social behavior was less around buildings with landscaping than buildings with no landscaping. This was the first work to relate landscaping to the crime rate. Public housing buildings were rated by an independent jury for their intensity of landscaping. Crime data was provided by the Chicago Police Department. The crime figures included total crime, property crime and violent crime (2001a, 356). In the tradition of the Kaplans, Kuo and Sullivan attribute the effect of landscaping on the crime rate to the greater use of landscaped outdoor space. Landscaping makes the space attractive and encourages fascination. Greater use means better surveillance and more familiarity with neighbors.

Two contemporary criminology theories fit nicely with Kuo and Sullivan's work: "Crime Prevention through Environmental Design" (CPTED) (Jeffery 1977)

and “Eyes on the Street” (Jacobs 1961). CPTED postulates that it is possible to influence a perpetrator’s decision on whether to commit a crime or not by designing landscapes that look cared for and delimit boundary lines. “Eyes on the Street” involves incorporating the street-scape into the home space. Comfortable out door space becomes an extra room, an added social space. Residents look out onto the street when it is a social place. They turn their backs on the street when it is an unwelcoming, unsocial place.

Bruce Hull and Antony Harvey in “Explaining the Emotion People Experience in Suburban Parks” (1989) record the different feelings individuals have when viewing (1) large trees in parks with no understory, (2) trees with impassable understory and (3) understory with no trees but with paths. Using photographs of uniquely composed landscapes they interviewed 60 individuals in Melbourne, Australia. They found that large trees with no understory elicited the most pleasurable responses. This landscape was associated with beauty. Impassable understory with trees elicited more arousal and less sense of beauty. Scenes with dense understory and paths that permitted way-finding were mid way between the previous two.

“In Affect, Cognition, and Urban Vegetation”, Vergil Sheets and Chris Manzer (1991) perform two controlled experiments using drawings and slides of city streets to demonstrate a causal relationship between the presence of urban greenery and positive affect. The first experiment used line drawings. Participants viewed a street scene without trees and shrubbery. Later they viewed the same

street with trees and shrubbery. In the slide experiment subjects observed the same alteration to the scene, except this time the slides were of actual landscapes. The responses were the same. The addition of greenery caused a positive emotional response and the presence of greenery caused the subjects to draw favorable cognitive conclusions about the living conditions on the street.

In an volume edited by Stephen R. Kellert and Edward O. Wilson, *The Biophilia Hypothesis* (1993), Judith Heerwagen and Gordon Orians wrote a chapter titled, "Humans, Habitats, and Aesthetics" (1993, 143). Humans respond through affect to landscapes in a problem solving way. Our brains have evolved to help us solve problems. The primary problem for any organism is habitat selection. There is a process for selecting habitat that according to Heerwagen and Orians involves the models of both Roger Ulrich and the Kaplans. This is the grand synthesis:

> We divided the process of exploration into three stages. Stage one, accompanying an initial encounter with a landscape, is the decision to explore the landscape further or to ignore it and move on. Responses at this stage are known to be highly effective and almost instantaneous (Ulrich, 1983; Zajonc, 1980) if the response to the first stage is positive, then stage 2, information gathering, follows. During this stage, cognition figures prominently and the process of exploration may last many days. Stage 3 concerns the decision to remain in the environment to carry out a certain set of activities. Depending on the relevant activities, the length of stay may be brief or last a lifetime. *(1993, 143)*

A chapter by Gordon Orians and Judith Heerwagen, "Evolved Responses to Landscapes" in *The Adapted Mind* (Barkow, Cosmides, and Tooby 1992, 555), provides an encyclopedic history of information on savanna theory. They impose a certain order on the various types and approaches to the research. They start of with

the comparison of our emotional responses (affect) to such basic things as sweets and sexual activity. These items elicit desire and pleasure but they are also critical to our survival. The need for the attainment of these items has evolved in such a way as to effect our emotions. Habitat selection works on a similar level. It has its own genetically based emotional values that guided early hominids and guide us even today.

Thomas Nelson, Thomas Johnson, Michael Strong, and Gail Rudakewich studied the effect of tree canopy in "Perception of Tree Canopy" (2001). Tree attractiveness is related to the completeness of the canopy. Diseased or damaged canopy does not provide the same positive affect. Trees in full leaf are perceived as more attractive than bare leaf trees. These are the conclusions of a survey of 239 individuals who were asked to rate computer generated images of bare leaf to fully leafed trees for attractiveness and fecundity. This conclusion suggests that the subconscious evaluation of our surroundings is more complex than whether or not trees and landscaping exist. We also intuitively assess the quality of the tree cover as an indicator of the appropriateness of the habitat.

Terry Hartig, Gary Evans, Larry Jamner, Deborah Davis, and Tommy Gärling report on the restoration provided by views of nature in "Tracking Restoration in Natural and Urban Field Settings" (2003). They found that both Ulrich's model of stress reduction and Kaplan's model of restoration have merit. Research shows them to have discrete brain circuitry. In this study 112 randomly selected adults were compared in their stress recovery and directed attention

restoration after a series of activities in the field. Two groups were subjected to an activity that required high concentration. Then one group was placed in a room with tree views. A second group was placed in a viewless room. Sitting in a room with natural views provided a greater decline in measures of physical stress than sitting in a viewless room. In another experiment, the researchers compared the effect of walking on a path in the woods to walking down the sidewalk in an urban setting. The same result was observed. Performance on attentional tests and self-rating of mood were positively affected by natural settings.

"Environmental preference and restoration: (How) are they related?" is a research paper by Agnes E. van den Berg, Sander L. Koole, and Nickie Y. van der Wulp (2003, 135). The authors examine restoration and beauty by exposing study participants to a frightening movie. This was intended to induce stress. The subjects were then divided into two groups. One viewed a movie of natural environments, the other viewed a movie of urban environments. Participants' moods were evaluated at each stage of the experiment. In addition they performed concentration tests. Natural scenes were reported as more beautiful than urban scenes. Natural scenes improved mood and focus. The researchers concluded that the potential for restoration is one of the qualities that determines preference or beauty.

Landscape evaluation can be unconscious and almost instantaneous, as short as 200 milliseconds, according to Jari Heitanen and Kalevi Korpela in "Do Both Negative and Positive Environmental Scenes Elicit Rapid Affective

Processing?" (2004). Affective processing, or priming, is the notion that previous conscious or unconscious experience can modify present activity. Environmental surroundings may set a mood in our minds that continues after the initial scene is gone. Even the shortest glimpse of one scene alerts our neural networks to respond quickly to similar viewings of other scenes. Scenes that are incongruent with the first scene take longer to process. Affective priming is measured by the time it takes for subjects to respond to the second scene. Our initial affective response modifies our later cognitive response. In this research subjects were shown natural scenes on a computer with three levels of attractiveness, low, medium and high. These were the prime stimuli. In short order the subjects were shown pictures of human facial expressions, stretching from angry to happy. These were the target stimuli. Subjects were asked to evaluate the faces they were shown after seeing the environmental scenes. The time was measured between seeing the faces, the target stimuli, and their evaluation of the facial mood. Negative prime stimuli were the most powerful. They had the shortest response time to evaluating negative faces. Attractive environmental scenes, though not as powerful, also reduced elapsed time in recognizing happy faces and took longer in recognizing angry faces. The conclusion can be drawn that environmental scenes affect mood with negative scenes having the greatest power.

Kathleen Wolf studied the attitudes of shoppers and store owners to street and landscape trees in inner-city shopping districts. In "Nature in the Retail Environment: Comparing Consumer and Business Response to Urban Forest Conditions" (2004), she used a mail survey sent out to 2,500 residents and 1,000

business owners. The surveys contained black and white images of different levels of treed landscaping in Pacific Northwest cities. The respondents were asked to rate the benefits and annoyances they experienced due to urban tree cover. Shoppers and business owners provided more positive ratings for districts with trees than without. Shoppers were more enthusiastic about trees, owners less so. Roots, broken side walks and "bird feathers and feces" were noted but only considered minor irritations. The overall picture was that tree covered streets contribute to a positive shopping experience in spite of minor annoyances. In commercial districts anything that attracts and holds consumers is be a benefit to the community.

In a second study, "Strip Malls, City Trees, and Community Values" (2009), Kathleen Wolf sent a mail survey to 1,200 households spread over Seattle, Washington; Tacoma, Washington; and Portland, Oregon. Subjects were asked to report on: how vegetation influenced the quality of the strip malls represented by color photographs in the survey; whether the landscape appearance of the mall made any difference in their usage of the commercial establishments; and whether there was any correlation between the landscape character of the site and what the shoppers would be willing to spend. "Judgments of products and merchants were more positive in heavily landscaped places as were inferences about product value, product quality, and merchant responsiveness" (2009, 37). On the subject of spending habits, "respondents consistently reported greater willingness-to-pay values for goods and services in the landscaped mall at an overall rate of 8.8%" (2009, 38).

While Dr. Wolf's two studies cited above are narrowly focused on commercial districts and the shopper experience they point to the common phenomenon of unconscious processing of the landscape making a tangible differences in shopper behavior. The sight of urban greenery sets up a mood in the shoppers mind to linger longer, trust more and possibly spend more at the site. Is it possible that street trees in residential neighborhoods elicit some of the same effects?

Another explanation for our perceptual connection to natural settings originates in Holland. Jannick Joye in "Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture" (2007), writes from an architectural point of view, pursuing the idea that landscape satisfaction depends on readability. He uses the Kaplan's notion of complexity (S. Kaplan 1987, 10) to relate nature to fractals (Joye 2007, 150). Fractals are repeating visual shapes that seem to speed cognition. Nature is full of these shapes. As the Kaplans point out, humans prefer low to moderately complex landscapes. Fractals allow rapid processing of the complexity of a scene.

A study by Ke-Tsung Han: "An Exploration of Relationships Among the Responses to Natural Scenes: Scenic Beauty, Preference, and Restoration" (2009) examines three interrelated systems described in the literature involving human perception of the landscape: stress reduction, focus restoration and preference . Explaining the differences between Ulrich's theories of stress reduction and the Kaplan's theory of restoration, Han points out that Ulrich's model is based on an

affective response. We judge the surrounding environment rapidly. That unconscious judgment results in varying levels of stress or calm. The Kaplan's model envisions a cognitive process starting with attentional fatigue. Restoration takes place in natural environments resulting in improved focus. This process is stretched out over time. The final model, preference, is related to beauty. The question for the Han was whether the idea of landscape beauty is something different from the Ulrich and Kaplan models or whether the idea of beauty is actually part of their constructs. He concluded that beauty is a process in its own right.[7]

In conclusion, many empirical studies over the past fifty years make a firm case for biophilia. Even as modern man objectively ponders philosophy, religion, aesthetics, science and mathematics, our primitive neural network subtly informs these esoteric thoughts with its own subjective concerns of shelter, lookout, and survival. These subconscious thoughts are expressed in attitudes as simple as "like and dislike." Such affective responses are at first almost instantaneous. Later they inform more deliberate evaluation. For most of our evolutionary development the site of broad spreading trees has elicited positive effect since it signaled sites for lookout, sites of protection and sources of food. It is not farfetched to say that the emotions which enabled us to select appropriate habitat in those distant ages are still at work in us today.

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[7] The history of the study of beauty is thoroughly covered in *Aesthetics and Psychobiology* by D. E. Berlyne, 1971.

The Stress Paradigm

For the purposes of this research, there are two fundamental questions about stress: (1) does stress only come from social input or is it also the product of physical conditions on the block such as lack of habitability; and (2) are the lessons learned from sociological research on the effectiveness of stress buffers and modifiers applicable to the physical environment of the street?

At the start, it is helpful to have a grasp on what stress is, how it differs from strain, and the nature of stress in a modern twenty first century city. Many of the research papers cited in the subsequent sections of this project pick up on concepts commonly used in the stress literature, but disciplinary issues often cloud the meaning. For example, the environmental tradition concentrates on how the autonomic nervous system assesses an objectively threatening situation that requires adaptation at an unconscious level. The psychological tradition focuses on cognitive appraisal of the situation, can I cope with the specific demands being placed on me (S. Kaplan 1995, 178)? The biological tradition concentrates on physiological responses to psychological and physical threats (S. Cohen, Kessler, and Gordon 1995, 4). Each one of these viewpoints has validity in its own right since they are each interrelated and none of them occurs independently of the others. The following selections focus on the question of how stress relates to our social and environmental surroundings.

In the psychological tradition, Stanley Milgram included a quote about stress in the city in a paper titled, *The Experience of Living in Cities*:

> When I first came to New York it seemed like a nightmare. As soon as I got off the train at Grand Central I was caught up in pushing, shoving crowds on 42nd Street. Sometimes people bumped into me without apology; what really frightened me was to see two people literally engaged in combat for possession of a cab. Why were they so rushed? Even drunks on the street were bypassed without a glance. People didn't seem to care about each other at all. (1970, 1461)

Milgram went on to suggest that stress described here is a symptom of sensory overload. There is more input to the cognitive system in a large city than any human can handle. This overload alters mental functioning, the use of social norms and how we carry out our daily lives (1970, 1462).

Subsequent research on stress is less picturesque and more analytic. Helen Berry in "Crowded suburbs and killer cities: a brief review of the relationship between urban environments and mental health" (2007), examines what it is about urban environments that makes them stressful. Three explanations have been put forward to explain the stressful nature of city life: psychosocial stressors, concentrated disadvantage, and social drift. Psychosocial stressors include exposure to the incivilities Milgrim described above, the feeling of lack of safety on the street and in the home. Concentrated disadvantage suggests that the density of the population increases physical and social incivilities, and thereby stress. Social drift originally suggested that mentally and socially handicapped individuals concentrated into ever more impoverished neighborhoods as their condition worsened. It appeared that cities attracted individuals with social problems. More recent analysis has shown that while cities may attract such populations, they also contribute to the depression cycle in individuals (2007, 223).

The long career of R. S. Lazarus stands as the scientific foundation of stress research. In an attempt to sort out the confusion between stress and strain, Lazarus points out that the term stress should be used to indicate external pressure on a system, the weight of numerous cement trucks on a suspension bridge. The term strain should be reserved for the response of the bridge to the load (R. S. Lazarus 1993, 2). Contemporary usage, this paper included, employs stressor to indicate the outside condition or inner perception that produces a negative response. Stress is used in place of strain to indicate the physiologic response to stressors.

In *From Psychological Stress to the Emotions: A History of Changing Outlooks* (1993), Lazarus describes a model for the stress/stressor process: 1) the individual is first presented with a causal agent of change, this is the stressor; 2) the mind and body respond with an immediate evaluation or appraisal of whether the agent is noxious or benign; 3) if the agent is noxious, the mind initiates a coping response; 4) the coping response, which may be conscious or unconscious, is a highly intertwined web of action, emotion and physiological symptoms. In some cases these systems feed back on themselves (1993, 4). Lazarus goes on to explore the involvement of emotions. The language of the primary evaluation phase (#2) is emotion:

> We sense things about our relationship to the environment without being able to verbalize them. Our emotions often reflect this ephemeral kind of knowing and evaluating as well as the more deliberate and analytic processes studied in modern cognitive psychology. (1993, 15)

"The Sociological Study of Stress" (Pearlin 1989, 241) is a highly competent and detailed paper touching on some of the differences between the sociological and epidemiological research of stress. Pearlin follows the progression from causal agent to coping response described above. The author points out that stressors often come from the social domain (personal or institutional roles), but others may arise in the environment. The latter might include living near an area of poverty or crime. Some stressors are sudden, known as life events (car crash, divorce), and others are chronic, such as low self-esteem. Stressors may cluster. A child born with an irritable nature eventually wears down the parents. Discouraged parents may become poor parents. Poor parenting adds to the difficulties of the child at school. Difficulties at school encourage delinquent associations. Stressors reinforce each other. The coping response (#3) uses mediators to modify the challenge of the stressor. If stressors increase stress, mediators reduce stress. At the social level, self-esteem, mastery and social support are mediators. At the environmental level, natural scenery may act as a mediator by reducing stress levels.

In his recent book, *Why Do Criminals Offend*? *A General Theory of Crime and Delinquency (2004),* criminologist Robert Agnew updates and streamlines his earlier work, *Foundation For a General Strain Theory of Crime and Delinquency*(1992). He draws on a variety of well-tested criminological hypotheses and clusters them into domains. He explains that there are five life domains in which individuals have different social pressures and are likely to have different responses. These life domains include the self (comprised of the

personality traits of irritability and low self-control), the family (poor parenting practices, no or bad marriages), the school (negative school experiences, limited education), peers (peer delinquency), and work (unemployment or bad jobs) (Agnew 2004, 11). Writing from a psychological point of view Agnew downplays the possibility that stress might originate from other sources than social structure but he does reaffirm that a major source of criminal behavior is stress, "irritability dramatically increases one's level of strain and the likelihood of responding to strain with crime (2004, 44)".

The issue of whether environmental stressors can cause stress was discussed publicly in the press in 1986 between psychologists Sheldon Cohen (Sheldon Cohen 1986, 716) and Richard Lazarus (Richard S. Lazarus and Folkman 1986, 718). The Cohen/Lazarus debate has special significance for this project because it relates to how stressors and mediators are best measured. Richard Lazarus initiated the Stress and Coping Project at U.C. Berkeley (Hyman 2002). The goal of this group was to explore the issues surrounding appraisal and cognition in the stress paradigm. The Stress and Coping Project produced the Hassles Scale in 1977 (Richard S. Lazarus 1997). In contrast to the commonly accepted notion that life stressors lead to negative social and physical states, Lazarus maintained that accumulated stress from small affronts and incivilities was a more powerful model. The group listed a series of micro-stressors such as loneliness, getting stuck in a traffic jam, losing your wallet or arguing with your employer. In conjunction with the hassles scale, the group provided a list mediators called uplifts. These, they reasoned, provided inoculation or buffering from hassles.

Uplifts might include completing a task, giving a present, good music, and getting or giving love. Lazarus used these combined scales to predict stress for 75 married couples. He found there was a stronger correlation between the total hassles score and psychological and physical health than between the more commonly used life stressor scores and the same dependent variables (Bradley 2014). He also found that the uplifts scale without the hassles scale was not a particularly good predictor of psychological or physical health.

Following the publication of the Hassles Scale a heated discussion ensued in the journal, American Psychologist (Sheldon Cohen 1986, 717; Richard S. Lazarus and Folkman 1986, 718). Sheldon Cohen had produced his Perceived Stress Scale (PSS) in 1983 (1983). Like the Hassles Scale, the PSS predicts "psychologic symptoms, physical symptoms, and health behaviors" based on a multi item scale.[8]

[8] Abbreviated versions of the PSS have been created and verified by Dr. Cohen.

Some of the fourteen questions asked on the PSS include (1983):

	Never	Almost Never	Sometimes	Often	Fairly Often
In the last month, how often have you felt that you were unable to control the important things in your life?	x	x	x	x	x
In the last month how often have you felt nervous and "stressed"?	x	x	x	x	x
In the last month how often have you felt confident about your ability to handle your personal problems?	x	x	x	x	x
In the last month, how often have you been able to control irritations in your life?	x	x	x	x	x

A careful reading of Cohen's questions indicates that he has separated the stress paradigm from the environment. Unlike Lazarus who uses environmental cues to elicit a response, Cohen keeps the questioning on the theoretical level. He notes, in "A Global Measure of Perceived Stress", that measuring specific stressors may be productive but that it is an impractical approach to use every time a new stressor comes along (1983, 387). How much better it would be to have a global measure that requires no mention of specific stressors? Cohen goes on to criticize Lazarus on his methodology, "because the Hassles Scale is composed of a list of events, it is inherently inappropriate for assessing appraised stress because it directly ties the appraised stress level to the number of occurring events" (Sheldon Cohen 1986, 717) . Lazarus replied that the PSS arises from a misunderstanding of stress paradigm. The Hassles Scale uses a systems view of stress that involves multiple dimensions including, "the environmental context of demands, constraints,

and resources; personal agendas of individuals such as goal hierarchies and beliefs about themselves and the world; and appraisal and coping process" (Richard S. Lazarus and Folkman 1986, 718) . Finally, Dr. Lazarus wraps up his argument by writing:

> Those who press demand for purely objective measures of stress present those of us who accept the premise of the individual's vulnerability with a classic catch– 22. No environmental event can be identified as a stressor independent of its appraisal by the person. (Richard S. Lazarus et al. 1985, 776)

When Agnew, Lazarus and Cohen refer to environmental stress they do not necessarily mean the sky, rocks and trees environment. They mean the social environment. It is tempting to interpret these writers as open to the idea that the physical environment can be a stressor or buffer. In fact, Lazarus includes the physical environment as a small part of his list of possible hassles (1985, 774), but it is not until more recent times that the spotlight has focused on how the physical environment relates to stress. Even today, some writers still exclude the physical environment as a source of stress.

In the spirit of Richard Lazarus, Andrew Steptoe and Pamela Feldman took a serious look at whether neighborhood characteristics had an impact on self-reported health (2001, 177). They observed that mortality and health can be predicted for different age groups in the United States and in the United Kingdom by place of residence. They set out to make a list of neighborhood features that might cause chronic stress. They mailed out a survey to 2,788 London residents which included, among other things, ten questions regarding problems that might

arise in any neighborhood. Residents were asked to report whether the particular feature was not a problem, some problem or serious problem. The questions included the following topics (2001, 181):

Litter in the streets
Smells and fumes
Walking around after dark
Problems with dogs
Noise from traffic or other homes
Lack of entertainment (cafes,cinemas, pubs, etc.)
Traffic and road safety
Places to shop
Vandalism
Disturbance by neighbors or youngsters

A neighborhood problems score was calculated from the 658 (24%) returned surveys by totaling up the responses by individuals and averaging the individual responses to the neighborhood level. The authors found that after controlling for age, sex and socioeconomic status, "high levels of neighborhood problems were associated with poorer self-rated health, psychological distress, and reduced ability to carry out activities of daily life (2001, 183)."

A 2007 a study from the Netherlands evaluated data from 2914 residents living in 75 Amsterdam neighborhoods. In "The Association of Neighbourhood Psychosocial Stressors and Self-rated Health in Amsterdam, The Netherlands", Charles Agyemang and associates basically replicated Steptoe and Feldman's work (Agyemang et al. 2007). They created a list of environmental stressors, aggregated individual and neighborhood stress scores from the responses to their survey and

then compared those scores to self-reported health outcomes. Their list of stressors included the following items (2007):

Local crime
Nuisance from drug misuse nearby
Nuisance from youngsters hanging around
Rubbish on the street
Graffiti
Feeling unsafe
Nuisance from noise
Nuisance from neighbors
Dissatisfaction with green space
Unemployment

Dr. Agyemang found significant association between self-reported poor health and nuisance from neighbors, drug misuse, youngsters frequently hanging around, rubbish on the streets, feeling unsafe and dissatisfaction with green space. The association between dissatisfaction with green space and poor self-reported health was more significant for low income residents than middle income. Among the same group, there were no significant associations between self-reported health and neighborhood crime, graffiti or noise. The authors speculate that there may be a connection between poor neighborhood environments and activation of the neuroendocrine system based on chronic stress.

Ralph Taylor directly addressed the issue of whether negative environments at the neighborhood level could cause stress in a book edited by Gary W. Evans, *Environmental Stress* (1982, 286). He acknowledged that interest in whether the physical environment influences stress was low until recently. Much more popular was research into social environments, groups and individual differences. Taylor

refers back to work by Popenoe (Popenoe 1973) that enumerates aspects of a neighborhood approach. These include social integration, social control, a sense of security and ease, organizational ties, collective identity or sense of place and socialization. Residents value neighborhoods that have these qualities; they are dissatisfied with neighborhoods that lack them. Neighborhoods where the physical environment blocks these qualities are stressful. Neighborhoods that contribute to these qualities reduce stress.

In a project designed to test the validity of Robert Agnew's General Strain Theory, David Eitle and R. J. Turner administered questionnaires to 956 black teen males in Dade County Florida (2003). Their goal was to understand how race, life events and chronic stressors relate to criminal behavior among minority teenagers. They found that race was not a significant factor. Instead, the most significant contribution to negative behavior was chronic stress. Chronic stress may not begin with an identifiable event, rather it is a low level open-ended condition without a discernable endpoint. Chronic stress includes such domains as neighborhood, employment, partner relationships, parental relationships, and schooling-based sources. Note the inclusion of neighborhood as a physical stressor in this model. Etile and Turner found strong support for Agnew's General Strain Theory. Both life events and chronic stress are associated with criminal involvement, independent of social control and differential association. The reality is that young black men are exposed to more negative life events and stressors than other groups. This accounts for the statistical observation that they are involved in more criminal activity than other racial groups.

In his book, *Transient criminality: a model of stress-induced crime*, Anthony Mawson proposes that "transient criminality" results from acute environmental stress and/or physiological disturbances in a context of diminished social supports (1987). He posits a synthesis of situational factors and biological science concepts to explain stress-induced crime, and illustrates how the resulting model can explain theft, burglary, vandalism, homicide, assault, and rape. This is useful research for understanding single or spasmodic violent criminal acts. Mawson integrates the environment, the self and social support into a unified theory.

To summarize the stress arguments, urban stressors have an effect on city residents. City life is by definition stressful. Large dense population induces a sort of sensory overload. In addition, city life attracts individuals with social problems and contributes to a depressive cycle. Stress comes from both social interaction and the physical environment. Stressors can be categorized into domains or groups that negatively affect both social behavior and health. The stress response in humans has a recognizable pattern: the subconscious recognition of a threat; an emotional evaluation; later in time, a cognitive evaluation; and last, a coping response. This is not a clean pathway. It is possible for each of these steps to feed back on the previous ones and reinforce them. Since stress in humans relies on the individual's appraisal, it is difficult to isolate as an objective measure. Neighborhood physical features have been shown to modify stress levels and self-reported health. Stress in the neighborhood may originate in the lack of habitable qualities. Not only is self-

reported health affected by the poor environmental quality, but social behavior is also affected.

Exposure to green provides relief, restoration and reduction of the physiological symptoms of stress as outlined in the Natural and Built Environments section of this literature review. This is an important concept because it is hypothesized that trees on the block provide relief from environmental stress. In contrast, studies in the stress literature make clear that negative environments, whether social or physical increase stress levels. Few authors in the social sciences make the claim that some factors actually mediate stress but the following two research papers are an exception. Both deal with social situations, not physical stressors, but they make a strong case for the idea that positive factors have the ability to mediate the effect of negative factors.

In 1988 Anita DeLongis, Susan Folkman and Richard Lazarus (1988) examined the correlation between the Hassles and Uplifts Scale and health and mood among 75 married couples. They found that when daily hassles increase, self-reported health and mood tend to decline. Within the group they were observing, there was a thirty percent variation in these results. An increase in hassles did not translate uniformly into a decrease in positive mood or reports of poorer health. On closer observation they found that this variation could be attributed to different levels of social support and self-esteem among the couples. The negative effect of hassles was moderated by self-esteem and social support.

> One of the ways that social support may protect people from the potentially damaging effects of exposure to stress is through its

> effects on mediating the appraisal and coping processes. For people with support, fewer situations should tax or exceed their resources and, consequently, less stress should be experienced. (1988, 487).

In a paper titled, "The Life Stress Paradigm and Psychological Distress", Walter Ensel and Nan Lin confirm the phenomenon that DeLongis et al described (1991, 321–341). In a three wave longitudinal study of 1,091 adults between 18 and 70 years of age in upstate New York the authors utilized two types of stressors -- social and psychological. Two types of resources were specified, social support and self-esteem. They theorized "that the presence of certain psychosocial resources reinforces and strengthens a person psychological equilibrium and emotional stability, plus reducing the likely onset of distress" (1991, 323). While they found support for the power of social resources to directly reduce distress, they found no support for the buffering or stress suppressing models. Applying this lesson from sociology to biophilia as described by Ulrich and Kaplan, positive natural scenery might have the ability to reduce urban stress but does not appear to have the power of inoculation against future exposure.

Relating Stress to Health

The previous section noted that both Richard Lazarus and Sheldon Cohen attempted to create scores for neighborhood stress. Cohen's was an objective measure that plumbed the psychosocial attitudes of individual residents. The Lazarus measure was a subjective evaluation of social conditions. How did they know that their composite figures represented stress? Lazarus wrote, "Overall, there was a significant relationship between daily stress and the occurrence of both concurrent and subsequent health problems such as flu, sore throat, headaches, and

backaches (DeLongis, Folkman, and Lazarus 1988, 486).” Cohen wrote: “In sum, the PSS provided significant prediction of a variety of health-related outcomes independent of psychologic (and physical) symptomatology (1986, 717).” Both researchers used the hypothesis that chronic stress has a negative impact on health as validation for their respective scores.

More recently, the connection between stress and health has become accepted wisdom. Consider the recommendations of Delaware’s Department of Health and Social Services. Using local epidemiological data (Center for Disease Control and Prevention 2014) the State advises :

> If you feel threatened all the time, and you haven't learned how to cope, you may have chronic stress. Chronic (or constant) stress can weaken your body's immune system, leading to frequent illness. Chemical changes in your body caused by the stress response can contribute to ulcers or colitis. Chronic stress may lead to chronically high blood pressure, called "hypertension"—a leading cause of heart disease. (“DPH Healthy Living Information: Stress” 2014)

The relationship between stress and health is described in a podcast by David Shonkoff titled *Cumulative Risk Burden* (2008). He explains how brain circuits build from birth, one upon another like the skin of an onion. Stressors can have negative effects on these layered circuits. Each layer is permanently laid down. Stress-caused damage is permanent and accumulates, leading to negative health, negative behavior and perceptual distortions in later life. The child raised in a stressful environment is likely to show these symptoms as an adult.

Robert Sapolsky focuses on the connection between stressors and health (2004) at the individual level. Based on his work with baboons in the wild, we have learned much about stress in primates. In early evolutionary times stress was a life-saving response. The response to outside threat was fight or flight, a term coined by Walter Cannon in 1932 (1963). The body responded to threat by making more blood available to leg muscles, reducing blood flow to digestion and increasing mental focus, all in an effort to flee the encroaching predator. The primates who avoided capture were the ones to pass on their genes.

In today's urban environment, stress has serious health implications. In a National Geographic video recording, *Stress - Portrait of a Killer*, John Bredar explains that we no longer need to fight or flee but our bodies still respond in the same way (2008). In evolutionary times, once the threat was over we could relax. In modern times threats are chronic, though at low levels. We have difficulty turning off the response.

Sapolsky focused on social rank and its negative correlation with stress levels (2005). A huge component of stress is lack of control and lack of predictability. This relates to social rank. Low rank is characterized by higher levels of stress hormones, higher blood pressure, higher heart rates and deteriorating health. High rank is characterized by lower rates of stress hormones, lower blood pressure, lower heart rate and longer life. Stress hormones over time kill brain cells particularly in the hippocampus, responsible for learning and memory. Stress feels bad. Dominant baboons have more numerous dopamine

receptors. Low rank baboons have fewer receptors due to the shrinking of the hippocampus. They lose some of the ability to feel good. Weak baboon communities require high vigilance due to the threat of more powerful neighbors. This increases stress.

Sir Michael Marmot's report to England's Secretary of State for Health follows directly from research like Robert Sapolsky's (Marmot 2010). The sub-text of the Marmot report is that "health inequalities that could be avoided by reasonable measures are unfair. Putting them right is a matter of social justice" (2010, 3). The emerging understanding of stress is the basis for Marmot's report. Improvement of education opportunities for English society is the recommended solution to empower individuals of low social rank and little social control.

Sapolsky, Brader and Marmot attribute stress to social conditions, they use a structural approach. Individuals lacking social rank, education, and opportunity may suffer stress and consequently poor health. The Annals of the New York Academy of Sciences published a volume in 2010 titled, *The Biology of Disadvantage* (Adler and Stewart 2010). This is a series of articles by various authors that explores the connection between low economic status and health. This collection of papers is also based on the stress paradigm described above. The authors write from an epidemiological point of view. They do not refer to hierarchy or rank but economic status. In a sense, economic status has become a substitute for hierarchy and rank used in earlier studies. It substantiates the connection between stress and health.

There is a giant leap, easily missed, between the work of Shonkoff, Sapolsky and Brader and Marmot, Adler and Stewart, all cited above. The first three examine the stress/health paradigm on the individual level. The second three examine it at the epidemiological level. The understanding is that it is valid to aggregate results from the individual to the neighborhood level in the health field. This is, in fact, the basis of epidemiology. There are certainly differences between individual health characteristics and community health characteristics but much good has come from the technique of aggregation. The individual pathway from stress to poor health, multiplied many times over by members of a community becomes a useful statistical outcome used for this research ("What Is Epidemiology" 2014). Not all the factors that lead an individual to high stress apply at the community level, but many do. Approaching it from the other direction, researchers must be careful not to apply results from aggregated studies to individuals.

Relating Stress to Safety/Danger

The relationship between stress and safety/danger is not causal in the same way as the health relationship. Instead, stress is associated with safety/danger through the perception of crime. Local crime is a frequently used outcome variable in studies on the effects of nearby vegetation. Kuo and Sullivan reported that the mean number of crimes per building in their study of the Ida B. Wells housing project in Chicago (2001a) varied with the amount of outdoor landscaping. Geoffrey Donovan and Jeffrey Prestemon showed that in Portland, Oregon, "trees

in the public right of way are associated with lower crime rates" (2010). In a Baltimore study, Austin Troy, J. Morgan Grove and Jarlath O'Neil Dunne found "that a 10% increase in tree canopy was associated with a roughly 12% decrease in crime" (2012, 262).

The relationship between crime and stress is described in "Landscapes of Fear and Stress" by Jack Nasar and Kym Jones. The authors write, "Fear of crime is a major urban background stressor (1997, 291)." As a stressor, fear may produce negative physical symptoms. In urban environments humans are adept at recognizing hot spots, potential crime areas, where victimization might occur. Referring back to Appleton (Appleton 1975), Nasar and Jones write that hot spots could be parks at night, dark allies, college campuses, places where incivilities are more likely, where entrapment is a possibility and concealment available. By recalling Appleton, Nasar and Jones suggest a negative version of prospect refuge theory. That is, if refuge is attractive and stress reducing, inhospitable environments are associated with stress. This is the underpinning of Crime Prevention Through Environmental Design (CPTED). It is stressful to live in a fearful environment.

"The influence of crime prevention through environmental design on victimization and fear of crime" (Hedayati Marzbali et al. 2012) also comes from CPTED research. In this study 300 households in Panang, Malaysia, were selected. From these 164 residents were randomly chosen. The respondents filled out surveys designed to reveal their expressed fear of crime and victimization. In

addition, onsight observations were made. Relevant to this study is the following statement:

> A common measure of perceived risk refers to a cognitive dimension of fear (Franklin and Franklin 2009). It is derived from the Natural Crime Victimization Survey (NCVS) and is based on a single item: (1) How safe do you feel walking alone at night in the area where you live? It asks respondents to judge perceived risk in their local area (Rountree and Land 1996).

In the search for a utilitarian measure of community stress, self-reported health and sense of safety play a big part. Health is causally related to chronic stress. Safety is associated with stress through perceived crime and incivilities. These well-documented associations will be used to validate measures of stress.

Summary

Biophelia, our relationship with nature, lingers in our neural networks from earliest evolutionary times. Its focus is individual well-being. It guides our selection of habitable surroundings to increase chances of survival. We unconsciously recognize habitat qualities and act on these evaluations through the emotions, like or dislike. These emotions are communicated instantaneously and modify our later responses. Broad spreading trees have signaled good habitat from our earliest days. Using this model, published research confirms that trees elicit positive emotions. In modern times most humans do not inhabit the African savanna. We are, for the most part, no longer hunter-gatherers, but we still have the neural makeup of our ancestors. We are still in search of good habitat. When we don't find it, we are stressed.

The built environment of modern cities holds few cues for habitability. This induces stress. Stress is most often thought of as a social phenomenon but the physical environment also plays a role. Since chronic stress in modern society is related to poor health, various techniques have been developed to measure it. These take into account both positive and negative inputs. In the environmental realm, the good feelings we experience among trees may mitigate some of the stress we feel in urban centers. In the literature, stress measurement is validated through health outcomes and sense of safety. Poor health is causally related to stress. Issues of safety and danger are also closely tied to stress because danger causes stress, such as the fear of walking outside at night, and in other cases, danger is the result of neighborhood stress, such increased rates of criminal activity.

The hypothesis for this research is that in urban situations, the number of trees at the block level has an inverse relationship with the level of stress when controlling for other predictors. This relationship will be explained by means of a physical inventory of residential blocks and a survey of block residents. Two measures of stress measurement will be employed in the survey. Self reported health and sense of safety will be used as validation for the two stress measurements.

Figure 3 A Wilmington street without trees. Even though the homes have front porches, the glare of the sun makes them unwelcoming. All the surfaces are hard.

Figure 4 A Wilmington street shaded by trees. These homes lack front porches but the consecutive trunks and dappled canopy provide a sense of calm and welcome.

Chapter 3

MATERIALS AND METHODS

Introduction

To operationalize measurement of the three variables used in the hypothesis, tree cover, community stress and self-reported health and safety, it was necessary to select an urban center with private and public trees, select a geographic unit of measurement within that urban center, inventory the physical attributes of the geographic units including tree cover, determine the median income of the geographic units, and survey the units for the level of community stress. In addition, it was necessary to collect information on health and safety outcomes to ensure that the measures of stress employed were valid.

Research Location

The urban site selected for this research was Wilmington, DE. Wilmington is the largest city in the State of Delaware with a population just over 71, 525 (Bureau 2014a). It is not the capital of the state. That distinction goes to Dover. Wilmington lies within 20 miles of the University of Delaware and therefore provided easy access for data collection. On the surface Wilmington appears to be a typical eastern seaboard midsize city. It has Delaware River port facilities. It has access to rail transportation on the main Amtrak line between Washington and New York. It has convenient access to both I-95 and I-495. The residents of Wilmington

prospered between the Civil War and the Second World War forging steel, building ships and synthesizing chemical compounds. For years Wilmington was the manufacturing home for major chemical companies including DuPont de Nemours and Hercules. More recently, like other rust belt cities, manufacturing has declined. Today banking and credit card operations are Wilmington's most prosperous occupational sectors.

Wilmington has a troubled racial history. The city was occupied by the Delaware National Guard for twenty months after the assassination of the Dr. Martin Luther King Jr. in 1968. Today the population is 58% African American, 32% White and 10% other minorities. It has an unemployment rate of 6.5%. In comparison to other mid-size cities, "It topped the list in terms of violent crime, outranking 233 other cities for this dubious honor, with 1,703 violent crimes per 100,000 residents" (R. Nelson 2014). With its polarized racial mix and high crime rate, Wilmington was an ideal location to research the effect of trees and stress.

Individuals, Blocks and Census Tracts

Early work on biophilia concentrated on the individual as the unit of measurement. In 1974, Roger Ulrich used the individual in his exploration of why people choose certain ways to commute home from work and not others (1974). Later, Dr. Ulrich examined the effect of natural scenery on the stress response of individuals in "Visual landscape's and psychological well-being" (1979).

Rachael Kaplan changed the scope of research in a paper published in 1993, "The role of nature in the context of the work place" (1993, 197). Part of her report was based on studies by Stephen Kaplan in (1988). She compared job satisfaction for employees. Some were exposed to natural scenes where they worked and others were exposed to built scenes. She found that exposure to natural scenes significantly improved job satisfaction. But the unique aspect of the research was that Kaplan had aggregated the workers into two social groups. She compared the mean response between those who had natural views and those who did not. By examining group responses to the environment she had changed the unit of measurement and opened the door to the possibility that the effect of green might have a social component to it.

In 1998, a study was carried out in Chicago's Robert Taylor Homes by Frances Kuo, Magdalena Bacaicoa and William Sullivan (1998, 42). This was one of the first projects that used the residential environment to study the effect of green in urban environments. Preference and sense of safety were compared between residents of landscaped buildings and residents of un-landscaped buildings. This comparison was not among individuals but it was among the groups of individuals who lived in different building environments. The Kuo, Bacaicoa and Sullivan research focused on the group level.

There is a strong case to be made for using an aggregated unit of measurement.

> The interest in neighborhoods and health has been driven by several interrelated trends within public health and epidemiology. The first

> trend is a growing sense that purely individual-based explanations of the causes of ill-health are insufficient and fail to capture important disease determinants. This has been reflected in discussions of the need to consider not only individual characteristics but also characteristics of the groups or contexts to which individuals belong in understanding the distribution of health and disease.(Diez Roux and Mair 2010, 125)

An unpublished paper by Taylor, Gottfredson and Bower from 1981(Evans 1982, 296) hypothesized that defensible space[9] and neighborhood social ties at the block level would strengthen territorial attitudes and reduce crime rates and sense of fear. Using a sampling of 63 blocks in Baltimore their hypothesis was well supported. In the same paper they reported that at the individual level defensible space and social ties had no effect on fear and crime:

> ...at the individual level, physical features were completely unrelated to outcomes such as fear and perception of problems. This suggests that the role played by design is much more salient, or relevant, for impacts at particular levels of aggregation. (1982, 297)

Why is it that stress-related responses such as sense of safety and health are more sensitive to measurement at the block level than at the individual level? According to Taylor it is essentially the concept of neighborhood (1982, 288) . The neighborhood is home, it provides social interaction, social control, sense of

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[9] "Defensible space" is a term coined by city planner Oscar Newman. It refers to the physical environment in urban locations and whether is instills the sense of safety, ownership and responsibility.

security, organizational ties and sense of place. These values are lost at the individual level. It appears we have gone full circle back to Appleton's theory of prospect and refuge (Appleton 1975, 73) where it is the characteristics of habitat that our minds have evolved to recognize.

If the block captures the essence of home turf, how does the census tract fare in a discussion of stress related responses? Census tracts have higher populations than blocks. Census tract boundaries are drawn to encompass neighborhoods, taking into account physical boundaries, ethnicity and socioeconomic status. The average population of a census tract is 4,000. Census tracts are commonly used as a proxy for the neighborhood (Evans, Gary, Kantrowitz, Elyse, and Schamberg, Michelle 2014, 2). The census tract is the smallest unit on which population characteristics are published and therefore the most convenient to use. Census tracts may well meet Taylor's description of neighborhood better than blocks but trees are not usually planted by census tract, they are planted by block. The census tract is too large an area to respond productively to the nature of locally planted trees.

For this study, 310 out of an approximate total of 1,600 blocks in Wilmington, Delaware, were selected for their uniform size and their visually observed residential nature using Google Earth (*Google Earth* (version 7.1.2.2041) 2013) and Microsoft Bing (Bing Maps - Driving Directions, Traffic and Road Conditions 2014). Tree canopy coverage ranged from 0% to 100%. Commercial districts, irregular shaped blocks, riverbanks and freeway entrances were avoided.

The residential nature of the block was fine-tuned by consulting a Wilmington cross-reference directory (Consumer and Business Guide for Wilmington, Delaware and Vicinity 2012-2013 Edition 2012). Cross-reference directories compile information on the residents and businesses of major American cities by tracking census data, telephone directories and other public records. These directories are used by businesses to locate customers and create customized mailing lists. Bound versions are available by the year. Online versions are available, updated monthly ("Targeted Sales Leads | Consumer & Business Sales Leads | Salesgenie" 2014). A typical directory will list city streets in alpha-numeric order followed by residential names and addresses. Businesses on the street are included. Beside each address will be the names of residents over eighteen years of age and any available telephone numbers. The listing for each street also includes the number of residents, the census tract and the median income. At the back of the book all telephone numbers for that particular urban center are listed in numeric order followed by name and street addresses.

Using a cross-reference directory it was possible to determine the number of inhabited dwellings on each of the 310 blocks. From this selection, 150 were chosen that had an adult population of at least 20 residents and no major commercial properties. The selection of 150 blocks was then plotted on a large Wilmington City map to ensure that all city neighborhoods were represented. From this sampling frame eighty blocks were randomly identified.

Before the mailing, parameters were set for qualifying blocks and block responses. In order to be included in statistical analysis a block had to have a minimum of 5 returned surveys that included responses on both stress measures and responses on the health and safety.

Physical Inventory

The City of Wilmington has a street tree population of 136,000 trees. The city urban forest administrator, Amanda Tolino, in conjunction with the city Tree Commission, has created an action plan for administering and upgrading the urban forest (Tolino 2014). The city's management plan includes an up-to-date street tree inventory developed in a partnership between the Delaware Center for Horticulture and the Davey Resource Group, part of the Davey Tree Expert Company ("City of Wilmington Street Tree Inventory" 2014). Called Tree Keeper, the inventory software is used by many municipalities across the United States ("Urban Forestry Management Software : Tree Keeper" 2014). The Wilmington street tree inventory was examined as part of the collection process for the physical inventory. Since the city inventory only included trees in the city right-of-way it was not suitable as the sole source for tree frequency at the block level. For the specific count of block trees it was in general agreement with the on-site street tree count carried out for this research. Any difference is attributable to different reporting dates. The city inventory is updated monthly while the on-site tree count was carried out only once in November 2013.

To augment the city inventory, a physical inventory card was used to collect onsite data at the block level (Appendix A). In this study, the block is defined as the area between the faces of the buildings on each side of the street extending laterally to the middle of the crossing street. Three measures of tree cover were gathered. The first measure was the count of street trees. The second measure was a count of all trees with canopy extending into the facing block area, including street trees. The third measure was the percent canopy cover calculated from aerial photographs of each block taken from Google Earth (*Google Earth* (version 7.1.2.2041) 2013) and Microsoft Bing (Bing Maps - Driving Directions, Traffic and Road Conditions 2014).

The street tree count was made by physically visiting the block and counting the trees. According to the City of Wilmington:

> Street trees are trees that fall within the public right-of-way (R-O-W). Usually these trees are between the sidewalk and curb in tree pits. However, sometimes the trees are still considered street trees when they are on the other side of the sidewalk, depending on the width of the particular street's R-O-W. ("Frequently Asked Questions About City Trees:: Government:: City of Wilmington, Delaware" 2014)

Trees in front yards or growing from alleyways are not considered street trees. Street trees are usually planted by the municipality or the resident in the sidewalk in spaces cut from the concrete or in strips along the curb prepared when the sidewalk was installed. Planting basins are most often the size of a single sidewalk block, 3'x4' or 4'x4'. In the street tree guidelines of one major city it is stipulated that no tree may be planted on a sidewalk less than 6'6" in width and that

any planting must leave an unobstructed sidewalk width of four feet (Reiskin 2010). Street trees are planted in many varieties and sizes based on the preferences of the resident, preference of the local street tree organization, community landscape design guidelines and municipal code. Small trees such as Prunus serrulata 'Kwanzan' grow to approximately 25 ft. and develop a broad canopy. Tall trees such as Platanus × acerifolia grow 60'-90'. The effect created by a block of small flowering street trees planted in consecutive spaces is very different from the effect created by a block of mature London Plane trees arching high over the street. Both situations occur on the streets of Wilmington, Delaware.

The second measure of tree frequency was also calculated by physically visiting the block. This is the total of all trees. This number includes street trees and the adjacent trees not growing in sidewalk planting basins. Some Wilmington blocks have small front yards. Trees growing from these private spaces were included. In some cases trees growing on the cross streets were so large that part of their canopy extended into the facing block area, these were included under the total tree category. Neglected alleys make ideal sites for weed trees such as Ailanthus altissima to take hold. These were counted. Essentially, any plant with a canopy and an upright trunk of more that 5' in height was included in the total tree count. By subtracting the street tree count from the total of all trees, a subset measure of Other Trees was created.

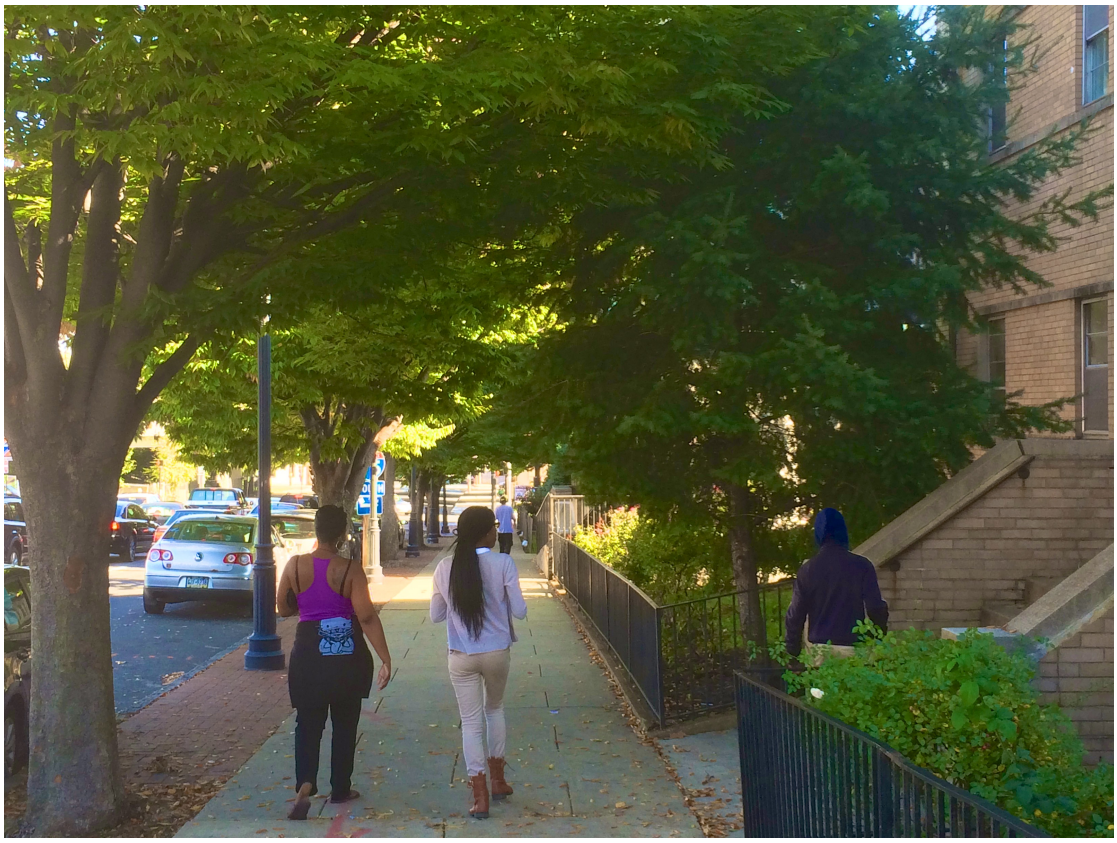

Figure 5 The Zelkova trees (Zelkova serrata) on the left are in the Wilmington city right-of-way; they are therefore street trees. The Norway Spruce (Picea abies) on the right side of the sidewalk is not in the right-of-way and therefore is classified in this research as Other Trees.

The third measure of trees was the percent canopy cover. On a tree growing in the open, the canopy cover is the area of the circular shadow at mid-day made by the branches extending from the trunk. The radius of the circle is the length of the longest horizontal branch. Clustered trees on a block may contribute to a continuous shadow or canopy. For this research percent canopy cover was calculated by superimposing aerial photographs downloaded from Google Earth (Google Earth (version 7.1.2.2041) 2013) and Microsoft Bing (Bing Maps -

Driving Directions, Traffic and Road Conditions 2014) on a grid. Once the total number of grid squares that comprise the facing block was calculated it was possible to count just the squares that were over the tree canopy. The percent canopy cover is the number of squares over the trees divided by the total squares on the facing block.

Percent canopy cover is a frequently used measure in urban forestry research (Troy, Morgan Grove, and O'Neil-Dunne 2012, 264; Donovan et al. 2011, 391; Holtan, Dieterlen, and Sullivan 2014, 8). An article by Maco and McPherson in the *Journal of Arboriculture* starts out with the paragraph:

> Tree canopy cover, or more precisely, the amount and distribution of leaf area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so do the benefits afforded by leaf area: climate control and energy savings; improvement of air, soil; and water quality; mitigation of storm water runoff, reduction of the greenhouse gas car-bon dioxide; provision of wildlife habitat; and increased real estate value and community vitality. (2002, 270)

The three tree measures, street tree count, total tree count and percent canopy cover were calculated because each measure captures something a little different from the other. To understand the impact of trees on stress it is important to have the most accurate measure possible. To refine the measures on step farther, Street Trees were subtracted from Total Trees to produce the Other Tree measure. This is the count of trees growing in the alleys, on the front lawns and extending into the facing block from adjacent streets. Table 1 shows how these four measures are related.

Table 1 Correlation between tree cover measures.

	Total Trees	**Street Trees**	**Other Trees**	**Canopy**
Total Trees	1.0000	0.8014	0.6051	0.7738
Street Trees	0.8014	1.0000	0.0091	0.6653
Other Trees	0.6051	0.0091	1.0000	0.4077
Canopy	0.7738	0.6653	0.4077	1.0000

Since there is strong positive correlation between Total Trees and Canopy (.77), further analysis was limited to Total Trees, separated out as Street Trees and Other Trees. By separating the two components of Total Trees was possible to achieve more precise analysis.

Other block features captured include the condition of the sidewalk, estimated height of the tallest building and the presence or lack of front porches. Note was made of geographical features such as hot spots (bars, convenience stores and check cashing establishments), adjacent treed streets, nearby shopping districts, nearby parks and security cameras. The neighborhood was rated for upkeep (a rating with the subcategories of gentrified, tidy, litter and graffiti), social order (presence of loitering, drinking, drug sales, prostitution) and the presence of abandoned cars, boarded windows or property damage. This list was narrowed down to eight block characteristics including: poor sidewalk condition, lack of front porches, nearby hotspots, location on a major thoroughfare, adjacent to a shopping district, poor block upkeep, lack of social order and physical signs of decline. These were summated into a score titled Block Features

Cronbach's *a* for Block Features was .5. Since this is a weak rating for the internal consistency, principle component analysis was employed to pare the list down from eight to five features, including: poor sidewalk condition, lack of front porches, poor block upkeep, lack of social order, and physical signs of decline. The new Cronbach's *a* was .6. This is still a weak rating for internal consistency but the face value of the list's components suggests they belong together. All physical data was collected and recorded on the inventory card in March and April of 2014 by the principle researcher.

Median Income

The determination of an appropriate measure of median income was also impacted by the individual, block and census tract issue. Individual median income is not publically available. A question could have been included on the survey that asked the respondent for his/her income but according to the survey literature, income questions are sensitive to respondents and discourage successful survey completion. ("Possible Errors Made When Asking Survey Questions – Survio Blog" 2014; Yan, Curtin, and Jans 2010, 145).

Sociological research often uses socioeconomic status or median income drawn from US Government Census data. *American Fact Finder* is the portal for obtaining this information (Bureau 2014b). Like other domestic compilations of census data, the smallest geographic unit available on *American Fact Finder* is the census tract. The census tract is too large a unit of measure for evaluating the impact of tree cover on neighborhood residents.

The cross-reference directory (Consumer and Business Guide for Wilmington, Delaware and Vicinity 2012-2013 Edition 2012) provide median income data at the street level. A representative from one of the directory companies explained that income numbers were modeled by street. Such factors as the census statistics, real-estate value, warranty response lists, billing statements from bank cards, magazine subscriptions and mortgage information were among the more than 75 sources used by the directory companies. The accuracy of the model is essential to the usefulness of the list as a marketing tool. This explanation was sufficient to proceed with median income data at the street level provided by a commercial enterprise.

Survey Mailing List

Using the "tailored design method" of implementing surveys (Dillman 2009), a mailing list of 2704 names and addresses was generated to send direct mail questionnaires to block residents. The list of resident names and addresses came from two different cross-reference directories ("Targeted Sales Leads | Consumer & Business Sales Leads | Salesgenie" 2014; "Consumer and Business Guide for Wilmungton, Delaware and Vicinity 2012-2013 Edition" 2012). The listings from each directory of names and addresses in the 80 selected blocks were combined. Duplicate names were removed. On blocks where inhabitants rapidly relocate, it is difficult to capture an accurate list of who lives on the block at any one time. One list might be as much as 20% different from the other. It was unclear which was more accurate. The combination of the two directories produced a bulky list but one more likely to catch all of the residents.

Mailing lists may also be inaccurate due to name changes. For example, the hypothetical resident, Bonnie Smith, found her first job at eighteen years of age. In the application for employment she used her maiden name, Bonnie Smith. A couple of years later Ms. Smith married Trent Jones. Her new name became Bonnie Jones. Bonnie and Trent applied for a mortgage to buy a small house but before long their marriage broke up. A couple of years later Bonnie remarried and found a better job. Her new husband was Sam Snyder. Then her name became Bonnie Snyder. Each of the significant occurrences in her life, first job, marriage, first mortgage, second marriage and new job created a paper trail. Each of her 3 names remains in the public domain as if they were different people. In the actual implementation of the survey this name proliferation for one person played out as two or three surveys mailed to the same address with different names but intended for the same person. Respondents typically threw out duplicate surveys and noted the error on their returned version.

Even though there were discrepancies in the names listed, the two cross reference directories generally agreed on the total number of residents in each block. Excluding the duplicates, the total sample was 1988 residents from 80 blocks. This is the number used to generate the 41% survey response.

Questionnaire

The questionnaire begins with three questions designed to put the respondent at ease (Dillman 2009, 158) (Appendix C). The first asks whether the

respondent socializes with his/her neighbor. The second asks about the respondents opinion of street trees and the third asks if the resident would like to see more trees on the block.

The fourth question is a 14 item matrix employing one of two stress instruments included on the questionnaire. The two stress instruments are the Hassles and Uplifts Scale (HAUS) (Agyemang et al. 2007; DeLongis, Folkman, and Lazarus 1988; Steptoe and Feldman 2001)and the Perceived Stress Scale (PSS) (Sheldon Cohen, Kamarck, and Mermelstein 1983). Opinion differs among researchers regarding how community stress should be measured. The PSS is an objective measure that asks individuals about their internal sense of control, accomplishment and social efficacy. The HAUS evaluates community stress using questions that are subjective. It is based on the theory that stress always involves a subjective evaluation. These questions refer to particular neighborhood conditions, social or physical, and inquire about the respondent's opinions regarding them. Both scales are intended for community use, not individual diagnosis. Two instruments were used in the questionnaire to determine which one would respond most vigorously to block physical features such as trees.

The PSS, written in 1983, is highly regarded; it has been used in psychosomatic medicine research (Phillips and Burns 3/08, 202), neuropsychopharmacology (Carpenter et al. 2004), social psychology (S. Cohen, Tyrell, and Smith 1993, 131–140), dermatology (Garg et al. 2001), behavioral medicine (Kramer et al. 2000), neuropsychobiology (Maes et al. 1999), nursing

(Ruiz et al. 2001), and health psychology (Stone et al. 1999). As an objective measure it does not use any questions related to the physical environment.

The HAUS was assembled for use in this project. It employs an approach initiated by Lazarus (DeLongis et al. 1982), running through Steptoe (Steptoe and Feldman 2001) and Agyemang (Agyemang et al. 2007) up to and including contemporary risk assessment. Cumulative risk assessment is a concept that originated in the 1986 Environmental Protection Agency guidelines for determining health effects of exposure to chemical mixtures (Sexton and Linder 2011, S81). After a series of steps to determine exposure toxicity, the EPA suggested that the default option is to assume that constituent actions are additive (US Environmental Protection Agency 1986, 26). This approach has been borrowed by sociologists and used in the modeling of the causes of the health gradients in urban neighborhoods (Evans and Kim 2010). The basic idea is that individuals may be exposed to more than one risk at a time. Some risks are chemical, some are social and some could be the physical environment. Multiple exposures may have a synergistic effect on the individual or they may cause less harm than expected (Sexton and Linder 2011).

Of the 14 questions in the HAUS five had been used by Steptoe. These covered issues with neighbors, loitering, rubbish, noise and traffic. Eight of the questions had been used by Agyemang. These covered issues with drug sales, neighbors, loitering, rubbish, noise, quality of parks nearby, graffiti and unemployment. For this project the six additional questions, unused by previous

researchers, focused on sense of community, police patrol, street lighting, absentee ownership and hotspots (bars, nightclubs and convenience stores). Based on Dillman's design recommendations regarding order effects (Dillman 2009), some of the questions in the Quality of Life Survey were worded to elicit positive effect: parks, sense of community, friendly neighbors, etc. Interspersed among these were questions worded to elicit negative effect: drug sales, loitering, rubbish, etc. In calculating the stress total for each resident, the positive effect question scores were inverted and added to the negative effect question scores. The concept behind this maneuver is based on the Lazarus theory (Richard S. Lazarus and Folkman 1986) that positive items, or uplifts, have the ability to modulate negative hassles.

The HAUS is the summation of survey responses from fourteen questions covering the following topics:

Sense of community	Traffic
Street drug sales	Graffiti
Friendly neighbors	Police patrol
Young people loitering	Unemployment
Street rubbish	Street lighting
Street noise	Absentee property ownership
Good park sites nearby	Bars, night clubs, convenience stores

Respondents were not asked to report the occurrence of these factors, but instead, were asked to reflect on the impact each category had on the quality of life on their block (see Appendix C). Three possible responses were provided, no impact, slight impact and large impact. The internal consistency (Cronbach's alpha) for the scale was .79.

Survey questions 5-9 cover safety on the block. According to the literature there is a correlation between stress and safety, and stress and health (Nasar and Jones 1997, 291; Sapolsky 2004, 3; McEwen and Gianaros 2010, 193). Based on this association, stress and safety measures were included because they validate the HAUS and PSS. There are two approaches to measuring the variables safety and health, the objective and the subjective.

Focusing on safety/danger, *The Uniform Crime Report* (UCR) (Federal Bureau of Investigation 2014a) is an objective measure. *The National Crime Victimization Survey* (NCVS) (Federal Bureau of Investigation 2014b) is a subjective measure. One might ask why a subjective measure of safety, such as the NCVS, would be any more valuable than the actual crime rate to describe neighborhood conditions.

Crime rates are published regularly and are convenient to use, but actual crime rates and the sense of crime or sense of safety/danger are two very different things. The actual crime rates for metropolitan areas are available from the Federal Bureau of Investigation. The UCR is collected voluntarily from states and local law enforcement agencies on an annual basis. The NCVS, is a survey of self-reported victimization carried out by the Bureau of Justice Statistics, also part of the federal government. The NCVS is not a report using data supplied to the police like the UCR, but a survey using accepted survey techniques applied to a stratified sample of approximately 38,600 households throughout the United States (2005). Congress has authorized both collection methods in an effort to obtain an accurate picture of criminal activity in the United States. While the UCR figures were available for this research it was difficult

to narrow them down to the block level. The NCVS numbers were unacceptable since they came from a sample population not keyed to neighborhoods.

In a journal article, "Making Sense of Safety" (Nilsen et al. 2004), the authors elaborate on the two dimensions of measuring safety/danger, the objective and the subjective. Their conceptualization is drawn directly from a 1998 World Health Organization report (Centre collaborateur OMS du Québec pour la promotion de la sécurité et la prévention des traumatismes, Régie régionale de la santé et des services sociaux de Québec (Québec), and Direction de la santé publique 2000, 7). Objective safety/danger corresponds to the UCR, the listing of actual crime reports geographically coded. In contrast a subjective measure captures the "individual's internal feelings or perceptions of being safe (Nilsen et al. 2004, 71)", like the NCVS. A measure of subjective safety/danger keys into multiple neighborhood factors that can together be considered community stress. These include, actual crimes, personal victimization, observed suspicious behavior, incivilities and neighbor-reported criminal activity. Subjective safety is the internalization of all of these factors. As such, it is a useful proxy for stress. Question 5 captures the subjective by asking, "How safe do you feel walking alone at night on the block where you live?" Questions 6-8 inquire about individual experiences of criminal behavior and police responses on the block.

Cohen's PSS makes up questions 10-19 (Sheldon Cohen, Kamarck, and Mermelstein 1983). Six of the questions are negatively worded, for example, "In the last month, how often have you found that you could not cope with all the things that

you had to do?" The remaining four have a positive tone, "In the last month, how often have you felt that you were on top of things?" Five possible responses are listed: never; almost never; sometimes; fairly often; very often. The negative questions were scored from 0-4 going left to right ("Scales" 2013) . The positive questions were scored right to left, 0-4. The total of all ten questions produced a stress score.

Questions 20-22 focus on health. Objective health data was unavailable for this project. Current HIPAA regulations limit the disclosure and dissemination of personal health data by government agencies and healthcare facilities (U.S. Department of Health and Human Services 2014). Community health data is available but not at the block level. In parallel with the safety/danger question, the questions on health are subjective in nature. Question 21 asks, "How is your health in general?" Question 22 is a matrix listing six medical conditions suggested by the literature as stress related (Ensel and Lin 1991, 328).

An editorial by Amelie Quesnel-Vallee, "Self-rated health: caught in the crossfire of the quest for 'true' health?" (Quesnel Vallee 2007, 1161) addresses the issue of whether self-reports of health are reliable. For health, it has been a twenty five year quest to determine the value of self-reported health. On one side is the assumption that true health is an objective measure of the absence of disease, particularly those related to mortality. In contrast, the constitution of the World Health Organization employs a holistic definition of true health. It is: "A state of complete physical, mental and social well-being and not merely the absence of disease and infirmity" (World Health Organization 2007).

Both sense of safety and self-reported health have more valuable information behind them than actual health statistics and crime rates. Both measures include a subjective component. The idea of illness has been internalized. The idea of local danger has been internalized. The individual has made both an effective and cognitive evaluation of known facts. The resultant coping response involves a certain level of stress. In the same fashion as Lazarus and Cohen, this research employs the residents' responses on health and safety as indicators of the validity of the stress measures (Sheldon Cohen, Kamarck, and Mermelstein 1983, 391; Richard S. Lazarus 1997, 275).

Questions 23-30 requested biographical information from respondents. These covered such topics as date of birth, years of residency, baby birth weights, education level, employment, housing ownership, gender and racial background.

The final question, 31, asked whether any other adults in the home had received the questionnaire and planned on returning it. This question was asked to encourage participation among residents of the same house.

Time Line

Following IRB approval on 10/22/13, a pre-survey announcement was mailed under University letterhead to the residents of the 80 Wilmington blocks. It was personally addressed and had a first name salutation on the letter (Appendix B).

A week after the pre-survey letter was mailed, the actual survey went out (Appendix C). It too was personally addressed on the envelope but no specific name was printed on the survey. Instead, a survey number was printed on the lower front corner of the front page. This number was keyed to the individuals on the mailing list. Included with the survey was a hand stamped return envelope and a two dollar bill.

A week after the survey mailing was sent, a thank you/reminder note was mailed (Appendix D). It was a thank you for those who had returned the survey and a subtle reminder to those who had not returned it.

Three weeks after the survey was mailed two IRB certified research assistants visited each block. Survey returns had tapered off and it was possible to pinpoint who had responded to the survey and who had not. Bright colored card stock was used to print a "Please Help" card (Appendix E). The card was enclosed in a clear door hanger bag with a duplicate numbered survey and a pre-addressed stamped envelope. The two field assistants were instructed to knock on the door of the designated address. If the resident answered, a prepared script was used as introduction and explanation (Appendix F). If no one answered the door, the survey, envelope and card were left hanging on the doorknob. Even though no two dollar bills were distributed on the personal block visits, returns improved.

The mailing list and survey responses were recorded in Microsoft Excel. When the data gathering was complete, totals were exported to JMP 11, a statistical software package from SAS.

Chapter 4

RESULTS AND DISCUSSION

Results

From 1988 eligible residents on 80 blocks, 810 usable surveys were returned. Block completion rates varied from 19% - 87%. The overall return rate was 41%. Since the ecological features of the residential neighborhoods were collected at the block level, it was necessary to aggregate individual survey data to the block level. Table 2 shows some of the characteristics of the study population recorded from the survey before aggregation.

Table 2 Characteristics of the study population.

Number of participants	810
Number of blocks	80
Respondents per block (min-max)	5-27
Gender	
Male	38%
Female	62%
Ethnicity	
Black	48%
White	44%
Asian	0.5%
Other	0.6%
Declined to Answer	6%
Highest Education Level Completed	
Primary School	0.6%

	Secondary School	2%
	High School	46%
	University	51%
Age		
	Mean Women	49
	Mean Men	50

The study population had a higher percentage of female respondents than male (62%-38%). Reported racial background showed that almost half the survey participants were Afro-American (48%). Six percent of the respondents declined to designate their ethnicity. About half the respondents were college or university educated (51%), followed by a large percentage that were high school educated (46%). The mean ages of women and men were very similar ((49 & 50). None of the figures describing the study population were out of the ordinary.

Table 3 shows the correlations of all usable variables gathered from the survey and physical inventory plus median income which was drawn from the cross reference directories (see explanation p.53). HAUS represents the hassles and uplifts scale (p.64). St.Trees is the count of trees in the city right-of-way (p.56). OtherTrees is the count of all trees not in the city right-of-way (p.56). MedInc is the average median income for the block (p.60). Block F. stands for block features and represents the total score of physical observations on the block (p.59). Age is the average age reported by block (p.69). Univ. is the percent of respondents that reported having received a college or university education (p.69). Socialize is the percentage of residents on the block that reported they had socialized with their neighbors in the past year (p.63). Employed is the percentage of respondents that reported part or full-time employment (p.69). OwnHome is the percentage of respondents that reported owning the home

they lived in (p.69). Exp.Crime is the percentage of residents that reported that they had experienced crime personally or knew someone on their block who had experienced crime (p.67). Plc.Visits is the percentage of respondents who reported that police had visited their block in the past month (p.67). Safety is the average score for the block to the question, "How safe do you feel walking alone at night on the block where you live?" (p.67). Health is the average score for the block to the question "How is your health in general?" (p.68). PSS is the average score for the block on the Perceived Stress Scale written by Sheldon Cohen and associates (p.67).

Not all of the data gathered by the inventory and survey is used in the analysis because, in some cases, the responses were so irregular as to make comparison with other terms meaningless. One such variable is baby birth weights. For this variable the block population was far too small to generate useful data. Birth weight comparisons with treed streets work at the epidemiological level (Donovan et al. 2011) but not at the block level. Another unused variable is race. Nine respondents declined to state their racial background. Factoring race into any models would reduce the sample size by an unacceptable 11% due to zero responses. In addition, Eitle and Turner (2003, 255) demonstrate convincingly that it is not race but exposure to environmental factors that is significant in predicting behavior in the neighborhood.

Table 3 Correlations of Variables

	HAUS	St. Trees	Oth.Trees	MedInc	Block F.	Age	Univ.	Socialize	Employed	On.Home	Exp. Crime	Plc.Visits	Safety	Health	PSS
HAUS	1.000	-0.29	-0.57	-0.62	0.569	0.131	-0.55	-0.25	-0.38	-0.24	0.115	0.275	-0.71	-0.55	0.358
St. Trees	-0.29	1.000	0.009	0.028	-0.18	-0.23	0.194	0.184	0.185	0.042	0.081	0.090	0.294	0.259	0.107
Oth.Trees	-0.57	0.009	1.000	0.457	-0.47	0.089	0.558	0.164	0.304	0.351	-0.09	-0.19	0.405	0.420	-0.23
MedInc	-0.62	0.028	0.457	1.000	-0.38	0.142	0.375	0.069	0.196	0.300	0.029	-0.08	0.451	0.339	-0.34
Block F.	0.569	-0.18	-0.47	-0.38	1.000	-0.06	-0.59	-0.12	-0.32	-0.44	0.018	0.210	-0.45	-0.44	0.203
Age	0.131	-0.23	0.089	0.142	-0.06	1.000	-0.08	-0.23	-0.40	0.304	-0.02	0.103	-0.09	-0.43	-0.18
Univ.	-0.55	0.194	0.558	0.375	-0.59	-0.08	1.000	0.175	0.571	0.416	0.085	-0.21	0.566	0.608	-0.25
Socialize	-0.25	0.184	0.164	0.069	-0.12	-0.23	0.175	1.000	0.205	0.214	-0.14	0.029	0.275	0.313	0.071
Employed	-0.38	0.185	0.304	0.196	-0.32	-0.40	0.571	0.205	1.000	0.070	0.136	-0.14	0.388	0.496	-0.09
On.Home	-0.24	0.042	0.351	0.300	-0.44	0.304	0.416	0.214	0.070	1.000	0.001	-0.12	0.260	0.253	-0.23
Exp. Crime	0.115	0.081	-0.09	0.029	0.018	-0.02	0.085	-0.14	0.136	0.001	1.000	0.186	-0.21	-0.02	-0.02
Plc.Visits	0.275	0.090	-0.19	-0.08	0.210	0.103	-0.21	0.029	-0.14	-0.12	0.186	1.000	-0.28	-0.09	0.075
Safety	-0.71	0.294	0.405	0.451	-0.45	-0.09	0.566	0.275	0.388	0.260	-0.21	-0.28	1.000	0.495	-0.32
Health	-0.55	0.259	0.420	0.339	-0.44	-0.43	0.608	0.313	0.496	0.253	-0.02	-0.09	0.495	1.000	-0.38
PSS	0.358	0.107	-0.23	-0.34	0.203	-0.18	-0.25	0.071	-0.09	-0.23	-0.02	0.075	-0.32	-0.38	1.000

Table 4 provides descriptive statistics for the variables shown in the table of correlations above. All variables are based on a sample size of 80 blocks. PSS, HAUS, Street Trees, Other Trees, Median Income, Block Features and Average Age show considerably more variation than the remaining variables.

Table 4 Descriptive statistics of independent variables.

	N	**Max**	**Min**	**Mean**	**Std Dev**
PSS	80	20.6	7.7	13.98	2.95
HAUS	80	31.88	20.17	26.6	2.78
Street Trees	80	25	0	6.6	6.09
Other Trees	80	23	0	3.75	4.56
Median Income x 1000	80	58,000	15,000	34,850	8.74
Block Features	80	7	0	2.41	1.8
Average Age	80	65	27	50.41	7.1
% University	80	100%	0%	44%	0.28
% Who Socialize	80	100%	50%	86%	0.13
% Employed	80	100%	0%	61%	0.21
% Who Own	80	100%	0%	58%	0.29
% Experienced Crime	80	83%	0%	42%	0.18
% Police Visits	80	100%	0%	65%	0.23
Sense of Safety	80	3.5	1.4	2.37	0.46
Sense of Health	80	4.5	2.5	3.47	0.49

Before analyzing the impact of tree cover on stress it is necessary to qualify the measures of stress we are using. Previous researchers used health outcomes to validate their stress measures (Sheldon Cohen, Kamarck, and Mermelstein 1983, 391; Richard S. Lazarus 1997, 275). This study uses self reported health and sense of safety for validation purposes. Table 5 compares the relationship between Sense of Health, the PSS and HAUS. With RSquare Adj =.29 for the HAUS compared to RSquare Adj =.13 for the

PSS, the former provides a better fit for the data. Both stress measures have highly significant relationships with Sense of Health.

Table 5 Comparative health statistics validating PSS and HAUS.

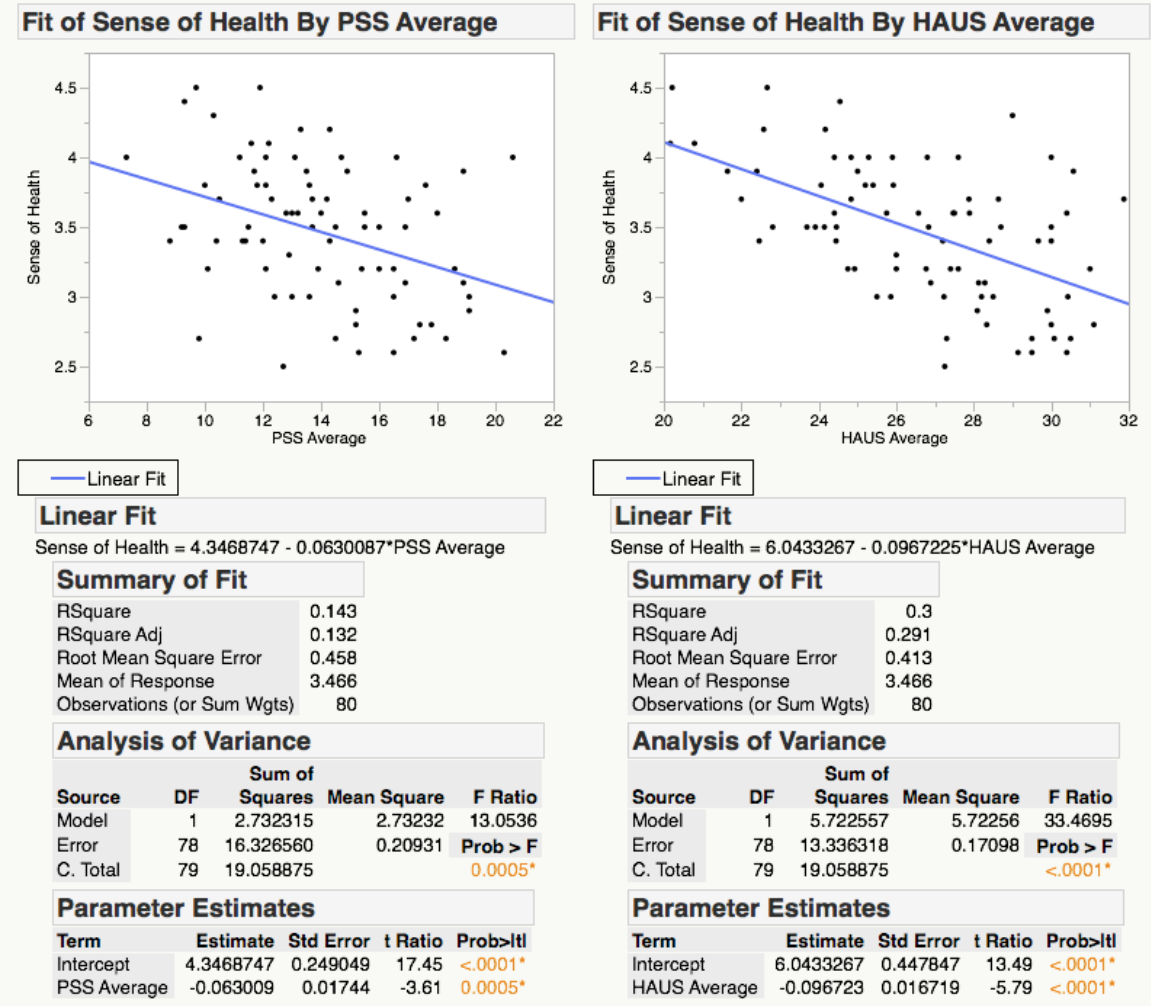

Table 6 compares the relationship between Sense of Safety, the PSS and HAUS. With RSquare Adj =.50 for the HAUS compared to RSquare Adj =.09 for the

PSS, the former provides a better fit for the data. The HAUS' relationship with Sense of Safety is highly significant while the PSS relationship is moderately significant.

Table 6 Comparative safety statistics validating PSS and HAUS.

Tables 7 & 8 model the PSS and HAUS on eleven independent variables. The strategy for these analyses is to sequentially add new variables to the model to allow for change in the fit (RSquare Adj). At the same time, it is possible to examine changes in

the coefficients and test of significance when new variables are added. For each table, Model 1 includes the two measures of tree cover (Street Trees and Other Trees*)*. Model 2 includes the tree cover measures plus Median Income and Block Features in an attempt to account for the relationship with trees. These two variables are the main rival hypotheses and provide a better test of whether trees influence the PSS or HAUS. Issues of collinearity will be checked for each model using VIF (Variance Inflation Factor). Model 3 adds an additional set of covariates to test the essential relationship of the PSS and HAUS to tree cover. Model 4 is a reduced model that includes only the significant variables from Models 1-3. The standardized coefficients are included with Model 4 to compare the relative effects of each variable.

Table 7 shows the results of four models regressing the PSS on ten variables. Model 1 regresses the PSS on Street Trees and Other Trees (these two measures combined equal the total of all trees on the block). In this model Street Trees are not significant (p=.33). Other Trees are significant (p=.04). For the whole model p = .08. There is almost no relationship between tree cover and the PSS. The RSquare Adj for the model is .04 meaning the two tree variables account for as little as 4% of the variance in the PSS.

Model 2 adds the variables Median Income and Block Features. Median Income is negatively related and is significant. However, while the coefficient for Block Features is positive, it is not statistically significant. The RSquare Adj = .10.

Model 3 adds seven more variables to the analysis. Median Income remains negatively significant but none of the additional variables are significant. The explanatory

value of the model drops to RSquare Adj = .05. Removing Median Income from the model does not change the significance of any of the other variables.

Model 4 only includes the one factor that remained significant through the previous models, Median Income. With only Median Income as a variable, the p value increases to moderately significant (p=.002) and the RSquare Adj jumps to .11. There is no evidence that trees have an impact on bock level stress that is measured by the PSS.

Table 7 Model of PSS by Street Trees and other independent variables.

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	
					Std B
Intercept	14.18***	16.73***	17.92**	18.04***	0
Street Trees	.05	.06	.05		
Other Trees	-.15	-.03	.00		
Median Income		-.10*	-.09*	-.12**	-.34
Block Features		.15	-5e-3		
Age			-.04		
Education			-1.53		
Employment			-.42		
Ownership			-.96		
Socialize			2.26		
Experienced Crime			.12		
Report Police Visits			.08		
RSquare Adj	.04	.10	.05	.11	

*p<.05, **p<.01, ***p<.001 (2 tail)

Table 8 matches the HAUS score with Street Trees, and eleven other variables in four linear regression models. Model 1 regresses the HAUS by Street Trees and Other Trees. Together these two measures comprise all the trees on the block. In contrast to the PSS model, trees do have a moderate impact on block stress as measured by the HAUS. In this model Street Trees show moderate negative significance and Other Trees shows high negative significance. The RSquare Adj for the model is .39.

Model 2 adds two variables to the mix, Median Income and Block Features. Street Trees and Other Trees are negatively significant. Median Income is also negatively related and is significant. The coefficient for Block Features is positive and significant. The RSquare Adj for the model improves to .58.

Model 3 adds seven more variables to the analysis. Street Trees, Other Trees and Median Income remain negatively significant. Block Features remains positively significant. None of the additional variables are significant. The explanatory value of the model is RSquare Adj = .63. Removing Median Income from the model does not change the significance of any of the other variables.

Model 4 utilizes only the variables that maintained significance in the previous three models. HAUS is regressed by Street Trees, Other Trees, Median Income and Block Features. Like Model 2, Street Trees (p=.002) and Other Trees (p=.003) have moderately negative significance. Block Features is positively significant (p=.004) while Median Income, still negative, is highly significant (p=.00). The model explains 58% of the variance in the HAUS score. Based on the VIF (variance inflation factor), none of the final variables has issues of collinearity.

Table 8 Models of HAUS by Street Trees and other independent variables.

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	
					Std B
Intercept	28.80***	31.38***	29.54***	31.38***	0
Street Trees	-0.13**	-.11**	-.09**	-.11**	-.23
Other Trees	-.34***	-.16**	-.12*	-.16**	-.27
Median Income		-.13***	-.14***	-.13***	-.39
Block Features		.39**	.35*	.39**	.25
Age			.04		
Education			-1.15		
Employment			-.06		
Ownership			1.19		
Socialize			-1.97		
Experienced Crime			1.48		
Report Police Visits			1.67		
RSquare Adj	.39	.58	.63	.58	

*p<.05, **p<.01, ***p<.001 (2 tail)

Discussion

Tables 5-8 utilize two different measures of stress, the Perceived Stress Scale (PSS) and the Hassles and Uplifts Scale (HAUS) in multiple regression models. Multiple regression is a technique for determining the relationship between a dependent variable and an independent variable or set of variables. Independent variables are thought to influence the dependent variable and are used primarily in one of two roles. The first role is as a specific research variable that we want to test in a model. The second role is as a control or alternative hypothesis in the model. We want to test the primary independent variables while controlling for alternative hypotheses. Regression analysis allows the researcher to determine the direction, strength, and statistical significance of the relationship between the dependent variable and an independent variable, while taking into account the other independent variables in the model. Direction deals with whether

the relationship is positive or negative; strength deals with how much influence a variable has on the dependent variable; and statistical significance deals with the degree of confidence we have that the relationship is real rather than an artifact of a sample. The basic assumptions of regression are that the relationships are linear, the independent variables are not highly correlated with each other, and that the error terms are independent and normally distributed. Each of these assumptions was examined for each of the models.

In this analysis, the PSS and the HAUS scales are dependent variables, and Street Trees, Other Trees, Median Income, and Block Features are independent variables. The primary interest is in the Street and Other Trees variables, but these are tested while controlling for the other independent variables in the model. Regression provides an estimate of the coefficient for each independent variable in the model that reflects the strength and direction of the relationship. These can be thought of as slope coefficients in the equation of a line, and we interpret them as the change in the dependent variable for a unit change in the independent variable. These estimates can be tested using a t-test that determines if the relationship is present or not. The Null Hypothesis for this test is whether the coefficient is different from zero, since a slope of zero implies there is no linear relationship between the independent and dependent variables. A p-value is typically used to determine the statistical significance of the relationship. For this research, a p-value less than .05 provides sufficient evidence that the coefficient is different from zero and therefore reflects a relationship.

The main measure of the overall fit of the model is Adjusted Rsquare (designated as RSquare Adj). RSquare is a measure of the overall fit of the model. It ranges from

zero to 1.0 and reflects the proportion of variability in the dependent variable that is "explained" by the independent variables. It actually shows how much better we understand change in the dependent variable when independent variables are included in the model in contrast to a much simpler comparison based solely on the mean of Y. The Adjusted RSquare is a modification of RSquare that takes into account the number of independent variables in the model. Adjusted RSquare is always smaller than Rsquare, and can be considerably smaller if many of the independent variables in the model do not add explanatory power in the analysis. For example, a regression of HAUS by Street Trees and Other Trees has an RSquare of .40. The RSquare Adj shown in Table 8, Model 1 is .39. This means that Street Trees and Other Trees account for 39% (RSquare Adj =.39) of the change in the HAUS measure of stress. We think of adjusted Rsquare as a more conservative measure of the overall fit of the model.

Table 7 shows that the PSS is not responsive to either the count of Street Trees or the count of Other Trees on the block. The p-values for these variables are higher than .05. The basic reasoning behind the PSS is that lack of social efficacy produces stress (S. Cohen, Kessler, and Gordon 1995, 6). Since this an internal psychological construct, it does not vary with the amount of tree cover on the block. The PSS did vary with one factor, median income ($p<.01$). Median income is related to social efficacy (Adler and Stewart 2004). Those with greater means are able to do more. They can buy bigger cars, have nicer houses and afford better educations. Higher median income provides social status and feels good (Sapolsky 2005). The conclusion is that the PSS is reasonably good at what it was designed to do, predict a level of psychological stress that has an impact on health outcomes. It is not useful in measuring the contributions trees make to community life.

Table 8 analyses variables captured in the HAUS that contribute to life on the block. The reasoning behind the HAUS is that environmental factors both psychological and physical may contribute to stress when they are seen as challenging. Stress comes first from a subconscious appraisal and then from a conscious appraisal that some things or events may tax us beyond our abilities. In contrast to the PSS, the HAUS is very responsive to both Street Trees ($p<.01$). and the Other Trees ($p<.01$) on the block. The RSquare Adj shown in table 8, Model 1 is .39. This means that Street Trees and Other Trees account for 39% of the change in the HAUS measure of stress. Like the PSS, the HAUS also shows a strong connection to Median Income ($p<.001$). Unlike the PSS, the HAUS is moderately impacted by Block Features in addition to trees ($p<.01$). While five of the seven other independent variables show significant impact on the HAUS when fitted individually (Education, Socialize, Employed, Home Ownership and Reporting Police Visits) none of them have significance in the full model.

CONCLUSION, LIMITATIONS AND FURTHER RESEARCH

Conclusion

By means of a physical inventory and a survey of 80 randomly selected blocks in Wilmington DE, it was possible to examine the relationship between the amount of tree cover on a block and the level of community stress. Both the inventory and the survey incorporated redundant instruments for measuring variables. There were three different measures of tree cover, two different measures of stress and two measures to validate the stress score. Not every measure performed as intended but the conclusion is undeniable that tree cover does have a significant impact on community stress.

Regarding the best method for measuring urban tree cover, the physical inventory of eighty blocks in Wilmington, DE, produced three tree cover measures: total trees, street trees and percent canopy cover. Due to the fact that the total tree count and percent canopy cover were highly correlated (.77), the percent canopy cover was eliminated from further analysis. The total tree count was subdivided into the count of street trees and the count of all other trees. Analysis of the data showed that Street Trees and Other Trees were moderately significant in their impact on neighborhood stress (HAUS) in a negative direction. According to Table 3, Street Trees and Other Trees have very little correlation (.009). They explain different things about the tree cover on the block. In future research to determine the measure of tree cover on a block, the dual count of street trees and other

trees is a robust measure to use. Together they capture the large picture and separately they provide detailed information.

The distinction between Street Trees and Other Trees in calculating stress-reduction is an important contribution of this research. In Model 8, Street Trees and Other Trees account for as much as 39% of the variance in the reported level of block stress. Regressed individually on the HAUS, Street Trees has an RSquare Adj of .07** and Other Trees has an RSquare Adj of .31***. For city administrators and urban planners the recognition that both types of tree cover contribute to the overall positive effect of tree canopy in a neighborhood has practical application. Street trees provide a significant contribution but private trees (Other Trees) substantially augment that relationship. Where planting street trees is not a viable option, encouraging private tree planting and tree maintenance is an alternative solution. In a 2005 study on enhancing Wilmington's Brandywine Valley Scenic Byway, three examples of borrowed trees are mentioned. Wilmington and Brandywine Cemetery, Trinity Church and the Delaware Children's Theatre, all on Delaware Avenue, provide:

> existing open space housing trees that are critical to the tree canopy of Delaware....Even though these trees are growing on private land, the city should regard them as valuable resources and should play an active role in their stewardship. This may mean providing assistance for their maintenance and replacement. (Barton, Darke, and Schwetz 2005)

Measuring trees by physical inventory is a time-tested method for gathering data about a city's tree population. More recent developments in satellite photography have taken the penache out of actually walking the streets and recording tree data. Unfortunately, when using satellite photography, it is often difficult to distinguish

between municipal trees and private trees. This project demonstrates that actual neighborhood footwork provides insight to the tree canopy that aerial photography can not provide. It also shows that the tree count and the percent tree cover are highly correlated (.77). Where aerial photography is prohibitively expensive, the tried and true physical inventory is a viable substitute.

A second major contribution of this research is the contrasted applicability of the PSS and HAUS in environmental stress evaluation. The HAUS was highly responsive to the physical environment such as tree cover and block conditions. The PSS was not responsive to these variables. The only variable that impacted the PSS was median income. It also impacted the HAUS. The PSS and HAUS seem to represent two different aspects of stress. The PSS is an internal psychological measure while the HAUS is an environmental measure. Since both have a strong relationship with sense of safety and health, the conclusion must be drawn that stress is not a singular phenomenon but a complex of perceptions and emotions that contribute together to the stress response.

Sheldon Cohen built his perceived stress scale as a streamlined survey instrument to establish an objective level of community stress. At the same time other sociologists were focusing on life events as the source of stress (S. Cohen, Tyrell, and Smith 1993). Richard Lazarus and his associates were focusing on personal hassles (DeLongis, Folkman, and Lazarus 1988). The difference in correlations between health outcomes and the PSS (-.38) and health outcomes and the HAUS (-.55) is substantial. If health outcomes are the measure of how relevant a stress measure is, then a scale like the HAUS, which calls to mind specific irritants rather than general malaise, comes out a

strong winner. It may be a little more cumbersome to use, but the results are much stronger.

The one emotion that both stress models have in common is the sense of challenge to individual wellbeing. The PSS records these challenges based on the interior psychological landscape. The HAUS records these challenges based on the surrounding physical landscape. What can possibly be challenging about the physical landscape of a city block? Consider a block without trees, strewn with litter and marred by graffiti? Does such a block convey a sense of habitability? We are challenged when we are in uncomfortable environments. Through evolution we have learned to recognize the qualities of habitable spaces. Tree canopy is a significant signal of habitability. Upkeep and social order are also important signals. Neither the PSS nor the HAUS is more valid than the other, they just measure different things.

The third major contribution of this research is the confirmation that tree cover has an impact on stress at the block level. The total count of trees on a block can explain as much as 39% of the neighborhood stress variance. This relationship remains moderately significant even when median income and other block features are factored in. These results are based on the number of trees not the canopy cover. The data suggests this benefit comes from small and big trees alike. There is no need to wait decades for trees to grow large before they contribute to stress reduction in the neighborhood. These results build a strong case for investing in urban tree programs. Trees on both private and public space make a moderately significant positive difference in the quality of urban life.

As a modern democratic society we have limited means for directing urban growth. Until recently it was the American dream to own a plot of land in the suburbs. This meant the destruction of vast areas of natural fields and woodland. These areas of wilderness fed the citizens' need for exposure to natural environments. Natural areas were a source of fascination, relief from urban stress and imagination. Today, for most of us, state and federal parks must suffice for our exposure to nature. Interestingly, contemporary journalists have drawn attention to a new trend. Many young adults in the early Twenty-first Century no longer feel the urge to move to the suburbs (Foderaro 1987). They want to live in urban areas where amenities are plentiful and maintenance obligations are few. Does this mean that all association with outdoor nature will be lost when no one has to live outside the city but the farmer? This research points to a way that planners can incorporate some of the benefits of natural areas into modern city-scapes. Urban trees are a slim substitute for natural forests, but this research shows that they provide some of the same benefits by their very presence in the city. If Stanley Milgram was right that living in a city is stressful, then planting trees in the city has the potential to make the urban environment a little calmer.

Limitations

In spite of the high correlation between block canopy cover and total tree count (p.59), the method employed for determining the percent canopy cover for this project was problematic. Canopy cover was observed by means of overhead satellite photography (p.57). Not all the imaging was carried out at the same time of day or from a 90 degree overhead angle. It is difficult to distinguish canopy shadows from true canopy in an aerial photograph. LIDAR imaging would be helpful in future research. Using laser technology, LIDAR can distinguish between shadows and physical features (US

Department of Commerce 2014). Where available, LIDAR imaging would an efficient means for calculating an accurate canopy cover measure on the block.

A second difficulty with this study was the inability to gather either block-centered criminal or health data. Because the unit of measurement is the block, no easily accessible data exists. Access to health data is out of reach due to HIPAA. In some municipalities crime data is available by location (Donovan and Prestemon 2010). A work around is needed in others. Researchers have used geocoding to localize data to the block level (Donovan et al. 2011) but more work needs to be done in this area.

A third difficulty with this study is theoretical. Throughout this paper the term coined by E.O.Wilson, biophillia, is employed (E. O. Wilson 1984). Over time biophilia has taken on many different definitions. The debate continues whether biophilia is a fundamental hard-wired urge to associate with nature, a source of morality, a learning environment that puts humans at their best, or just another category of interest like our fascination with technology. This project did not set out to provide a definitive answer this question. What it did do was to gather data to show that we as humans are more comfortable, less stressed, in the presence of trees. The biophilia argument starts with Appleton (1975). There seems to be little debate that living creatures choose the environments that best suits their physical abilities. At its simplest level biophilia is related to habitat selection. The environment for this study was a specific habitat, residential streets in an urban center. At the basic level this research provides strong support for the idea that we do answer to the call of biophilia to associate with natural environments.

Further Research

The ultimate goal for urban tree/stress studies is to monetize the relationship. If research could show that a certain percentage of tree cover on a block resulted in a specific decrease in medical and policing costs, it would put stress reduction on a par with already established tree benefits such as reduction of rain water runoff costs and reduction of cooling costs. The positive relationship between tree cover and stress reduction is an important concept to establish but it is only half the equation. The second half would be objective measurement of exactly how much stress reduction reduced health and criminal behavior outcomes. These outcomes could be shown to have specific monetary values. The endpoint would be that a municipality could weigh the cost of establishment of tree canopy against the cost of neighborhood policing and emergency medical services.

Holding back this goal is the fact that collecting criminal and medical data at a relevant unit for comparison with block tree cover is a difficult undertaking. Fortunately, not all municipalities have the same traditions governing citizen access to statistics on criminal and medical data. The next iteration of this project should be carried out in a data friendly location. If the Wilmington project is considered a case study, then using a similar method for data collection in other locations might be appropriate. Some of the recommendations for a second case study include:

- Establish a teamwork approach with local authorities before considering a site.

- Determine team-oriented methods for collecting health and crime data from local government. The survey responses used in this research are useful but they are all self reported. Objective confirmation would go along way toward establishing a basis for claiming stress reduction has monetary benefits to local government. Objective data will not be forthcoming with out local partnerships.
- Site the project in the inner city. A common finding in similar research is that low income neighborhoods are more responsive to the benefits of green infrastructure than wealthy neighborhoods (Agyemang et al. 2007, 1044).
- Refine the mailing list for distribution of the survey questions to avoid duplicate requests for information. Keep the contact list and communication with respondents as personal as possible. In person data gathering is expensive and time consuming but in this case it generated the most goodwill and highest success rate.
- Provide a monetary payment for successful completion of surveys. This is an effective incentive for respondents and a useful icebreaker for field researchers encountering suspicious residents.
- Use the HAUS stress measure in the survey questionnaire. Based on this research the HAUS had a better fit with both the physical features of the block and the health and safety concerns of the residents than the PSS.

- Reword some of the biographical questions to make them more understandable for the respondent and more useful for later analysis.
- Include a limited number of psychosocial questions in addition to the ecological questions of the HAUS. The ten question PSS attempts to do this but it is cumbersome. The shortened 4 question version could be included in the same matrix as the ecological questions.
- Standardize the categories in the physical inventory of block features. Try to remove all subjective evaluation. Possibly include a night time observation of sidewalk and street activity (Furr-Holden et al. 2008).

By using the research method employed in this thesis, municipalities will gain further insight into what makes some neighborhoods safe and prosperous and others dangerous and unproductive. The confirmed inverse relationship between tree cover and community stress at the block level is but one of the areas to consider in the quest for neighborhood improvement. Taking into account the whole range of benefits tree canopy provides, sidewalk temperature reduction, pollution reduction, C02 sequestration, rain water run off abatement and now stress reduction, few other local improvements are as uncontroversial as tree planting and as supportive of a quality urban environment.

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Appendix A

PHYSICAL INVENTORY CARD

Block No._____ Date_____ Time of Day_____
Address_____
Houses on both sides Y N No. of street trees___
What is on side of street with no houses?_____
Lawn trees present Y N Cdtn. of st. trees G F P
_____Trees 1-4" _____Trees 4-6"
_____Trees 6-12" _____Trees 12-24"
_____Trees 24-36" _____Trees >36"
_____Total of all trees Street Lights Y N
Predominant tree species_____ (>50%)
Tallest tree ht.____ft. Tallest bldg ht._____ft.
Sidewalk both sides Y N Condition: G F P
Front porches Y N Security Cam. Y N
Describe near by hotspots_____
Adjcnt. treed sts. Y N Intersected block Y N
Major thoroughfare within one block: Y N
Major shop. dist. within one block: Y N
Proximity to local park _____(blocks)

Physical Condition
GENTRIFIED
TIDY
LITTER
GRAFFITI
ABANDONED CARS
VACANT LOT PRESENT
BOARDED WINDOWS
PROPERTY DAMAGE

Social Order
LOITERING
DRINKING
DRUG SALES
PROSTITUTION

Other Vegetation Types
BUSHES
TALL GRASSES
ABANDONED

PHOTO TAKEN?_____ % Block Canopy Cover_____
NOTES_____
_____

Appendix B:

PRE-SURVEY LETTER

DEPARTMENT OF PLANT AND SOIL SCIENCES
University of Delaware
Newark, DE 19716-2170
Ph: 302/831-2531
Fax: 302/831-0605
Email: jtwnsd@udel.edu

Robin Smith
234 W Gilpin St.
Wilmington, DE
19802

Dear Robin,

I need your help. I am a graduate student at the University of Delaware studying for my doctorate. My area of research has to do with the effect of city landscaping on community stress. Would you fill out my Community Life Survey to help shed light on this relationship?

Your involvement in this study is voluntary and your identity will be protected. Your answers will be combined with your neighbors to create a block measure of stress. We will only use your block if more than half of the residents respond. Once we have calculated a block measure, all references to your name will be deleted.

I will be mailing you a copy of the survey next week. Please look out for it. The survey will be numbered so I can keep track of who responds and who needs to be approached in a different manner.

I realize your time is precious and filling out surveys is not high on your list of priorities. On the other hand, research like this is intended to improve our communities. As Wilmington's population expands, access to nature will become harder and harder to achieve. Your input for this study will help send the message that we want safe and attractive neighborhoods for ourselves and for generations to come.

Thank you for your help,

Jay Townsend
Ph.D. Candidate

Appendix C:

QUALITY OF LIFE SURVEY

Community Life Survey

November 2013

Exploring how our physical surroundings impact community life.

University of Delaware Dept. of Plant and Soil Sciences

Survey #_____

DEPARTMENT OF PLANT AND SOIL SCIENCES

University of Delaware
Newark, DE 19716-2170
Ph: 302/831-2531
Fax: 302/831-0605
Email: jtwnsd@udel.edu

Dear Wilmington Resident,

At the Department of Plant and Soil Sciences we are exploring how urban trees and plants effect human emotions. The following survey asks a series of questions to help us understand this relationship. The information you provide coupled with our on-site inventory of the landscaping on your block should provide some answers.

This is a **short survey and will take less than ten minutes to complete**. You are one of 2,700 Wilmington residents randomly selected to receive this survey. The data you provide will be **strictly confidential**. A temporary survey number appears on the envelope and cover of each survey. The purpose of this number is to help us keep track of who has filled out the survey and who needs to be contacted in a different manner. Your responses will not be linked to your name, only to this number. **Please do not remove the number from the survey**. Surveys without a number can not be keyed to your block and will be of no use. The mailing list of **individual names will be deleted** once the questionnaires are returned. Your responses will be kept securely at the University for one year and then **shredded**. Your data will be combined with your neighbors and reported as block totals. Blocks will not be listed by address.

You are not obligated to fill out the survey nor is there any physical risk. If you choose not to be involved, please strike a line across the front page and send it back in the enclosed envelope. We will take you off the mailing list. Keep in mind, however, that there are benefits to your participation. A strong response from Wilmington residents will send a message to city administrators: "we care about our communities and want them to be clean, safe and attractive".

When you have completed the survey please fold it and return it in the attached stamped envelope. If you prefer to take the survey on line, follow this link: http://bit.ly/1gVFsDC. If you would like to receive a Spanish version, call me at 302-831-2531.

Please accept the enclosed $2 bill as a "thank you" for your cooperation,

Jay Townsend
Ph.D. Candidate

Community Life Survey

Questions about the quality of life on your block

1. In the past year did you socialize on the street with your neighbors? Circle one.

Regularly Once in a while Never

2. If there are street trees on your block, what is your opinion of them? Circle one?

Very Positive Positive No Opinion Negative Very Negative

3. If there are no street trees on your block, would you like to see some planted? Circle one.

Yes No

4. Please indicate the impact of the following characteristics on the quality of life on your block. Please rate every item.

		No Impact	Slight Impact	Large Impact
a	Sense of community	○	○	○
b	Street drug sales	○	○	○
c	Friendly neighbors	○	○	○
d	Young people loitering	○	○	○
e	Street rubbish	○	○	○
f	Street noise	○	○	○
g	Good park sites nearby	○	○	○
h	Traffic	○	○	○
i	Graffiti	○	○	○
j	Police patrol	○	○	○
k	Unemployment	○	○	○
l	Street lighting	○	○	○
m	Absentee property ownership	○	○	○
n	Commercial establishments such as bars, night clubs or convenience stores	○	○	○

Questions regarding safety on your block

5. How safe do you feel walking alone at night on the block where you live? Circle one.

Very safe Reasonably Safe Somewhat Safe Very Unsafe

6. Have you or anyone else in your household been a victim of a property crime on your block (including burglary, larceny, theft, motor vehicle theft, arson, shoplifting, and vandalism) in the last twelve months? Circle one.

Yes No

7. Have you or anyone else in your household been the victim of a violent crime on your block (involves the use of a weapon or physical force) in the last twelve months? Circle one.

Yes No

8. Have you or anyone else in your household been subject to sexual intimidation or assault on your block in the last twelve months? Circle one.

Yes No

9. How many times in the past month have the police responded to problems on your block that you know of?

_____ (number of visits to your block in the past month)

Questions regarding individual stress

In the following questions you will be asked about your feelings and thoughts during the last month. In each case please indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but instead, indicate by your choice what seems like a reasonable estimate. For each question fill in the circle below one of the following alternatives:

Never Almost Never Sometimes Fairly Often Very Often

	Never	Almost Never	Sometimes	Fairly Often	Very Often
10. In the last month, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
11. In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
12. In the last month, how often have you felt nervous and "stressed"?	○	○	○	○	○
13. In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
14. In the last month, how often have you felt that things were going your way?	○	○	○	○	○
15. In the last month, how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
16. In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
17. In the last month, how often have you felt that you were on top of things?	○	○	○	○	○
18. In the last month, how often have you been angered because of things that were outside your control?	○	○	○	○	○
19. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

Questions regarding your health

20. Have you or anyone in your household used emergency medical services in the last twelve months? Circle Yes or No on question "a" and fill in the number on question "b".

a. Yes No

b. If yes, how many times _____

21. How is your health in general? Circle one.

Excellent Very good Good Fair Poor

22. Do you or anyone in your household suffer from (circle as many as apply)?

Diabetes	Yes	No
Asthma	Yes	No
High blood pressure	Yes	No
Cardiovascular disease	Yes	No
Stroke	Yes	No
Rheumatic disease	Yes	No

Biographical questions

Your answers will be kept in the strictest confidence and the data will not be shared. Once the report for your block is complete, the list of names will be deleted. Your answers below will help put your previous responses in perspective.

23. What year were you born? 19___

24. How long have you lived at this address? _____ years

25. If you can recall the birth weight of children born into your family while living at this address in the past five years, please record their weights here (lbs. only). If no children were born into your family over the past five years or you do not know, please fill in the appropriate circle.

a. _____lbs child one _____lbs child two _____lbs child three _____lbs child four _____lbs child five _____lbs child six

b. No children were born into my family over the past five years. ◯

c. I do not know. ◯

26. What is the highest educational level you have completed? Circle one.

Primary School Secondary School High School University

27. What is your employment status? Circle as many as apply.

Full time Part time Unemployed Retired

28. Do you own, rent or lease the site where you live? Circle one.

Own Rent Lease

29. What is your gender? Circle one. Male Female

30. What is your racial background? Please fill in the appropriate circle. You may choose more than one response.

American Indian or Alaska native ◯

Native Hawaiian or Pacific Islander ◯

Asian ◯

Black or African American ◯

White ◯

Decline to Answer ◯

31. How many <u>other</u> adults in your home have received this questionnaire in the mail and plan on returning it?

_____ (number of other adults)

Please call 302-654-5151 if you would like someone from Wilmington city government to call you regarding street safety.

Please call Gary Schwetz at 302-658-6262 x111 if you would like someone from the Delaware Center for Horticulture to call you regarding street tree plantings.

Appendix D:

THANK YOU/REMINDER CARD

Dear Wilmington Resident, November 22, 1

Last week we mailed you a "Quality of Life" questionnaire because your bl was randomly selected to help in a study about the physical conditions on Wilming City blocks. If you have already completed and returned the questionnaire, please e our sincere thanks.

If you received this questionnaire and have not returned it, please take the t fill it out and put it in the mail. Your responses are necessary in creating block ave Since many Wilmington blocks are small, it is important to have as many response possible. We are especially grateful for your help with this important study.

If you did not receive a questionnaire, or if it was misplaced, please call us 831-2531 and we will mail another one out for you today.

Sincerely,

Jay Townsend, PhD candidate

Appendix E:

DOOR HANGER CARD

PLEASE HELP!

WE DID NOT RECEIVE YOUR SURVEY BACK.

In this bag you will find a new survey and a stamped reply envelope. Please take a moment to fill it out and return it.

An alternative online English/Spanish version is available at
http://bit.ly/1gVFsDC
You will need the survey number on this bag to complete the online survey.

Thanks in advance for participating with your neighbors in this important project.

Appendix F

SCRIPT FOR FIELD ASSISTANTS ON FOLLOW-UP VISIT

Dear *Mr. Jones*, We are University of Delaware undergraduate students working as field assistants on a graduate research project. My name is _____, and this is_____. We are gathering information to help understand how the physical characteristics of your block, particularly the trees, impact the quality of life. Since the number of residents on each block is relatively small, it is important that the majority of residents fill out our short survey. We have not received your response to the survey mailed last week. Was there some problem with it?

(*wait for resident to answer*)

I have brought an extra one in case you mislaid the last copy. While participation is voluntary, I would appreciate it if you would fill it out and mail it in. A self addressed stamped envelope is included. I will be calling you next week to remind you how important your participation is.

Appendix G

SURVEY COMMENTS

Survey Number	Comments
1010:	I would appreciate a conversation with the person(s) responsible for this questionnaire and the results of the survey as well as the benefits.
1091:	All for section H house address 218. Original lease pasted earlier this year, children, cousins, etc living in house unknown to WHA. Family still receiving deceased persons check. Shooting earlier this year. Whereas man was shot in head + colapsed on west street, began @ this same residence. I wish to remain anonymous.
1125:	The city does not well maintained the nearby park trees, and I don't want any more damn leaves to rake up.
1273:	We done have trees on our block. How can you plant the street to narrow.
1288:	Street cleaning is only 1 x per week + I don't like to rake.
1316:	What about cutting down the tree in the 200 block W. 35th st. Leaves are affer.
1409:	Son – someone took a bike from him at knife point
1561:	Dear Mr. Townsend, Im writing this letter in regauds About the dog feces on our sidewalks and in and around my streets. People just don't care about others. In stead of pickup after there dogs after they have crap on the streets or sidewalks

and even our parks where our childrens play. If you can help us in any kind of way would be so grateful and god bless you.

1582: I don't want a visitor… Thank You! Sam.

1593: Thank you for the $2 bill & phone numbers for the city. Good luck with your Ph.D.! You can do it! ☺

1601: But my husband was held up at gunpoint over 12 months ago on our front porch, and a woman was held up at gunpoint this week 2 blocks away.

1639: I am not against trees, but we have had large Sequoia (only joking) large trees in front of many of the properties, and they roots grew and broke up a lot of the sidewalks, and were growing towards our sewers. City planted wrong trees, and homeowners were responsible for having them removed.

1837: Thank You

1841: Hispanic or don't we count

1860: Greetings, Thank you for sending me this survey. Please let me know if there is anything I can do to help with the success of UD project for Eastside area. There is definitely need to change. My home got broken into the first six month of buying the home. 2nd time was two years ago, during day light, when I was at work. Please contact me if you need any type of support Thank you all you do. Good Luck,

1900: The city don't maintain the ones they've got now.

The park by the liquor store is where the rubbish gather to drink and very likely share dope.

1934: OUTSTANDING MARKETING!!

2028: Would like side walk fix in front f my home.

2040: Potted Plants front only. One block party!City! Cleaning leaves. Garages door. Mail slots. Good improved transit. 3 whites males 1 – over 50. Age? 2 Spanish women, 3 gays males, 5-10 white homeless. Trash can! Needed. Liquor Cobra cans drugs heroin needles ciee bottle. Exercise / health decline. Constant F of 3-5-10 June to dec 2013

2099: We need police annexes a/o beat cops… late spring, summer, and early fall!

2189: Jay, West side of S Harrison St from 50 to 600 only 2 trees. North side Maple + Harrison St. 6 trees to S. Van Burton St. South side of maple st. to S Van Burton st. only 1 tree. Call any time. Thank you for the two bucks. A few weeks ago on a Sunday nite my house away was (unsure of the accuracy of the remainder ->) s hat a drain pipe. Im 82 years old + never leave the house at nite.

2261: *Parking is bad enough on my street, trees on the street would make it worse.

*Parks with basketball courts would attract more drug dealers, which the park on top of the hill already does.

*The "dollar tree" is ruining my street, the most traffic, trash, + crime on this bock since ever. Thank you.

2265: Thank you for this survey!! Wilmington needs this support!

They don't patrol!

2370: We like trees in the community. However, we often run across the damage and hazards their roots cause – sidewalk and patio upheaval and clogged sewer lines.

When it comes to trees in the community the rule must be the right tree in the right location. Otherwise the damage caused may supercede their beauty and benefits.

2439: Sorry – confused about impact. Would these things impact my happiness? That's how im answering now, hence cross-outs.

2440: Yellow card addempanying survey stated this was "new survey" did not receive an "old" one???

2470: Some of the questions were poorly written. Thanks for the 2 bucks!!

2547: Thanks for the cash ☺

2869: Only because I noticed people sneezing when they pass one tree in particular. Nearby park across from block.

2886: But trash is left around them. Not trimmed. Steal newspapers, flowers, + hanging plants, Lawnmower. Polish American citizen.

2942: They need cameras so the police can see. Our corner store need to be closed 27th Tatnall. Theres been murder, drugs and they come from the store & next to the store. This block see alot of police but it does nothing.

3010: I no longer live in the city of Wilmington. I lived in Wilmington from 11/15/2011 to 9/27/13. I have lived in Newark from 9/27/13 to present.

3096: We have some vacant spots.

3110: Karen Jessee (Theresa Jessee died). Those yahoos know what Wilmington is like.

3160: Green spaces for our children, "If not us then who"

3275: Keep the $2. I was happy to help.

3277: Note: You sent another survey to this address to a former resident who is now out of state. We discarded that survey #3278

3293: Jay, I hope this is not too late. Best wishes on your PhD. Thanks for the $2 – I gave it to charity. Happy Holiday.

3398: Hi not really able to answer question just moved in 9/13. Thank you, Patricia Penerva.

3402: Chat on the sidewalk. In home coffee and entertainment. Jay, Thanks for the $2. Good luck with your survey!

3449: Some of the trees here are (I believe) Chinese fruit trees + they fall on the ground + stink + are very dirty lying on the sidewalks. A different tree would be better.

3507: I am not sure I am reading this question correctly.

3519: Property owned by "honk" & no maintenance! Other household on block.

3558: Thunderstorm struck the tree fell on my new car, severe damage incurred. City woodlawn took responsibility for damage to it.

3697: Because I know they destroy concrete, but we need the oxygen they give off.

Appendix H

PERMISSIONS

Hello Jay,

I apologize for my delay in replying (I thought I had, but going through old email, realized I hadn't). Thank you for your interest in Dr. Cohen's work. Dr. Cohen is glad to grant you permission at no cost to use the PSS in your study; permission is always granted at no cost by him for nonprofit educational purposes like yours.

The appropriate reference for the 10-item scale is:

Cohen, S., & Williamson, G. (1988). Perceived stress in a probability sample of the United States. In S. Spacapan & S. Oskamp (Eds.), The social psychology of health: Claremont Symposium on applied social psychology. Newbury Park, CA: Sage.

The appropriate reference for both the 4- and 14-item scales is:

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. Journal of Health and Social Behavior, 24, 385-396.

Scoring information is available at our website, http://www.psy.cmu.edu/~scohen/ Once there, click on 'Scales'.

I wish you success with your project. Thank you for your interest in the Perceived Stress Scale and Dr. Cohen's work.

Sincerely, Ellen Conser

Assistant to Dr. Sheldon Cohen, Robert E. Doherty Professor of Psychology

Appendix I

OBSERVATIONS ON TREE COVER AND MEDIAN INCOME

As part of the onsite inventory, three measures of tree cover were taken for each block: Total Trees; Street Trees and percent Canopy cover. By subtracting Street Trees from Total Trees a fourth measure was created, Other Trees. These are trees not on public property but in private lawns, cracks in the wall and deserted lots. In the Results and Discussion section, Street Trees, Other Trees and Median Income were run in a multiple regression on the HAUS. Controlling for income both tree measures were moderately significant. When correlations are calculated with Median Income it turns out that each measure is quite different.

Table 9 Correlations between median income and four measures of tree cover.

	Median Income	**Total Trees**	**Street Trees**	**Other Trees**	**Canopy**
Median Income	1.0000	0.2936	0.0284	0.4569	0.1895
Total Trees	0.2936	1.0000	0.8014	0.6051	0.7738
Street Trees	0.0284	0.8014	1.0000	0.0091	0.6653
Other Trees	0.4569	0.6051	0.0091	1.0000	0.4077
Canopy	0.1895	0.7738	0.6653	0.4077	1.0000

Table 9 shows that there is only a 3% correlation between Street Trees and Median Income while there is a 46% correlation between Other Trees and Median Income. The explanation for this large difference is that most Other Trees are located in gardens and small front lawns. These amenities are concentrated in wealthy neighborhoods. Poor neighborhoods lack front yards. This tilt toward wealthy neighborhoods gives credence to the perception that trees are mostly found in wealthy neighborhoods and any impact the trees might have on community life is mediated by socio-economic status. Certainly the case for this viewpoint is strong but it also gives us an opportunity to observe the effect of trees on stress totally devoid of income considerations.

Table 9 shows that there is little relationship between Median Income and Street Trees. The question is whether Street Trees have impact on block stress on their own or whether all the credit goes to Other Trees. A linear regression of the block stress measure (HAUS) by Street Trees shows RSquare Adj=.07**. Street Trees by themselves modify block stress by as much as 7%.

This relationship is not as remarkable as the RSquare Adj =.31 value recorded by the HAUS on Other Trees but there can be no quibbling with the fact that Median Income has almost nothing to do with Street Trees and Street Trees do have a considerable impact all on their own.

The correlations between Total Trees and Median Income and Canopy cover and Median Income only vary by 10 percentage points. Both have highly significant explanatory power over the HAUS (RSquare Adj =.31*** for Total Trees and RSquare Adj =.14*** for Canopy). When run in a multiple regression model controlling for Median Income, Total Trees remains highly significant and Canopy comes in at moderately significant.

The bottom line is that Median Income is strongly related to tree cover and community stress. It is possible to separate income from the tree measures by considering only Street Trees or by controlling for income in a regression model. The reasonable conclusion from both approaches is that tree cover on the block modifies stress from 7% (Street Trees alone) to 39% (Street Trees and Other Trees controlling for income).

Appendix J

OBSERVATIONS ON THE RELATIONSHIP BETWEEN THE PSS AND THE HAUS

In 1988, two years after the public discussion between Richard Lazarus and Sheldon Cohen over the virtues of the PSS and the Hassles and Uplifts Scale (HAUS) (Richard S. Lazarus and Folkman 1986; Sheldon Cohen 1986), DeLongis, Folkman and Lazarus published a paper titled "The Impact of Daily Stress on Health and Mood: Psychological and Social Resources as Mediators" (1988). Through empirical testing of the Hassles and Uplifts Scale it became clear that the proposed relationship between the scale and health outcomes could be strengthened if variables were included to account for self-esteem and emotional support:

> Finally, as anticipated, persons with low self-esteem and low emotional support had a higher probability of a positive association between stress and both physical symptoms and poor mood then did those who were high in these psychosocial assets. (1988, 492)

Self-esteem, according to the authors, is an internal resource that protects individuals from being overwhelmed by stressful demands. Such individuals see themselves as being able to better cope with challenges. Emotional support involves social networks. Individuals with emotional support count on family and friends to

help them get through tough situations. Emotional support alters one's sense of isolation and makes it more likely that a challenge will not be appraised negatively.

The authors found that a variable measuring these psychological features impacted the subject's perception of the seriousness of daily hassles.

> High levels of self-esteem and emotional support moderated the relationship between hassles and physical symptoms both on the day hassles increased and on the day following the increase. (1988, 493)

This description of psychological variables sounds very similar to Sheldon Cohen's Perceived Stress Scale. In *American Psychologist*, Dr. Cohen wrote:

> PSS items were designed to tap the degree to which respondents find their lives unpredictable, uncontrollable, and overloading: three issues central to the appraisal of stress. *(1986, 717)*

In the first scenario, DeLongis, Folkman and Lazarus are writing about a "can do" attitude that diminishes the effect of daily hassles on subject's lives. In the second scenario, Sheldon Cohen is writing about a "can't do" attitude, one where the subject's life is unpredictable and uncontrollable. This appears to be the same psychological factor described in opposite terms. Is it possible that the PSS could be the psychological input called for by DeLongis, Folkman and Lazarus? Would it provide a significant contribution to HAUS along with the already verified variables Street Trees, Other Trees, Median Income and Block Factors?

Figure 10 below examines this theory by testing whether the PSS adds to the explanatory power of a regression model of HAUS on Street Trees, Other Trees,

Median Income and Block Features. Model 1 below is the last model shown in the Results and Discussion section (p.82). In Model 2 the PSS was added as an independent variable.

Table 10 Models of HAUS by Street Trees and PSS.

Variables	**Model 1**	**Model 2**	**Std B**	**VIF**
Intercept	31.38***	28.89***	0	
Street Trees	-.11**	-.12***	-.25	1.06
Other Trees	-.16**	-.16**	-.26	1.46
Median Income	-.13***	-.11***	-.35	1.42
Block Features	.39**	.37**	.24	1.40
PSS		.15*	.16	1.17
RSquare Adj	.58	.60		

*p<.05, **p<.01, ***p<.001 (2 tail)

In a one-on-one regression of HAUS by PSS the RSquare Adj=.13**. In the multiple regression model above the PSS makes a significant contribution and adds 2% to the explanatory value of the variables on HAUS. The PSS was certainly not designed to be used in this fashion but it is interesting to see how it contributes to the significance of the data collected in Wilmington in the same way DeLongis, Folkman and Lazarus had predicted.

Appendix K

IRB APPROVAL LETTER

UNIVERSITY OF DELAWARE
RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE: October 22, 2013

TO: Joseph Townsend, MS
FROM: University of Delaware IRB

STUDY TITLE: [452015-1] The Strange Relationship between Street Trees, Crime and Stress

SUBMISSION TYPE: New Project

ACTION: APPROVED
APPROVAL DATE: October 22, 2013
EXPIRATION DATE: October 21, 2014
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 7

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

Appendix K (cont.)

If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.