Balancing Perceived Sensory Dimensions and Biotopes in Urban Green Space Design

by

Amanda Lockwood

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ABSTRACT

BALANCING PERCEIVED SENSORY DIMENSIONS AND BIOTOPES IN URBAN GREEN SPACE DESIGN

Amanda Lockwood Advisor: Robert Corry
University of Guelph, 2017

Eight Perceived Sensory Dimensions (PSDs) were identified from previous studies to describe user preferences of park qualities and characteristics: nature, culture, prospect, social, space, rich-in-species, refuge, and serene. Recently, PSDs and biotopes have been integrated to enhance park users’ preferences and vegetation structure. Usable green space needs to balance social aspects (PSDs) and environmental aspects (biotopes) at the design stage. This study assesses urban green spaces through experimental design based on the inclusion of the biotope ‘green space’ and PSDs. Designs were created based on market squares in Guelph and London, Ontario, by including biotope characteristics for plazas and PSDs. Designs were critically analyzed to determine that PSDs and the biotope category ‘plaza’ had a positive relationship aside from the PSD ‘nature’. This research contributes to the understanding of socially and environmentally cohesive urban green spaces, providing landscape architects with tools for creating usable green spaces in Southern Ontario cities.

Key words: Plaza, Preferences, Landscape, Design Exploration, Virtual Model, Design Principles
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BALANCING PERCEIVED SENSORY DIMENSIONS AND BIOTOPES IN URBAN GREEN SPACE DESIGN

CHAPTER 1: INTRODUCTION

With populations increasing and cities expanding, the demand for green space in urban environments is evident. Densification causes greater demand in infrastructure for uses such as residential, commercial, and industrial, which can reduce the demand and likelihood for urban green spaces to be included in urban design. Close proximity to green spaces have many beneficial impacts on users, such as improved mental and physical health. Green spaces also create enjoyable sites with restorative qualities and social spaces for human interaction. It is important for green spaces to be considered at the design stage to improve the quality of cities not only for the user but for increased ecological functions. Local habitats found in urban green spaces provide direct ecosystem services to cities and greatly impact the quality of life for park users.

Previous studies have developed perceived sensory dimensions (PSDs) as a means of analyzing how landscapes are perceived and experienced. PSDs were used in more recent studies to estimate preference of qualities and characteristics in parks and as a means to analyse park success. Landscape perception through PSDs can be applied in urban green space assessment and design for highly functional and enjoyable sites. To avoid the occurrence of single-source bias that can be created through individual perceptions, and to include an element of ecology, there is a need for landscape perception to be analysed alongside other characteristics.

Biotopes are particular habitats found in green spaces and are an important aspect for enhancing and preserving urban biodiversity. Biotopes have different levels of vegetation structures that play an important role in species richness. There is currently a gap in knowledge on how social and ecological factors interact in urban green spaces to create successful urban parks. Integrated design through the perceptible aspects of green spaces (PSDs) and ecological aspects (biotopes) may create more sustainable green spaces and lead to a more sustainable city.

It is not only the integration of ecology and landscape perception that creates an ideal green space in cities, but the appropriate combination that allows for a usable and...
enjoyable site. The relationship between biotopes in urban green spaces and PSDs might help to determine the optimal combination. Previous studies have developed a description and characteristics of PSDs that have primarily been used in urban park analysis. Similarly, biotopes have been developed in previous studies to create a classification system based on land use and habitat type. These sets of characteristics can be further developed and analyzed to create a set of principles for landscape design of urban green spaces.

Urban green spaces have variable sizes, shapes, contexts, and characteristics. What might be a workable combination of perception and ecology in one green space type might differ from other types. In some southern Ontario cities - because of increasing densities that result from provincial planning policies - urban cores are becoming more intensively developed. As city densities increase the perception and ecological function of green spaces deserve additional scrutiny.

There is a gap in research on how PSDs and biotopes interact in urban green spaces. Using southern Ontario cities with specific attributes can be a method to describe the application of PSDs and biotopes to urban green space design. Designs could be critically evaluated to learn which PSDs are present and how they are compatible with the highest level of biotope characteristics. Analysing the relationship of PSDs and biotopes in designs could help identify synergies and conflicts between the two variables, and help determine a functional combination to create a socially usable and ecological urban green space.

The following chapters will critically review the literature on landscape perceptions through the established approach of PSDs, and on the application of biotope principles for ecological objectives. Applying principles in combination for urban green spaces - particularly those in the urban core - provides examples of challenges and synergies among principles. Critical review of the approach could yield insights for the practice of landscape architecture in urban green spaces. Findings can be instructive for enhancing the cultural and ecological function of cities.

Using a landscape architectural design process for urban green spaces and digital visualization technologies provides an application of landscape perception and ecological principles. The visual depictions can form a basis for critique of the principles and approach. The discussion will elaborate on the relationship between PSDs and biotopes in urban green spaces. How biotopes and PSDs merge within an urban space will be
determined based on the designs to show their synergies and conflicts. This new approach will be analysed to determine whether it is successful and whether the two variables are a compatible approach in research. Biotopes and PSDs will also be analysed separately to determine their independent success in a landscape design application. They will be analysed to determine whether designing with principles is an appropriate method for biotopes and PSDs and what the strengths or constraints are to applying specific characteristics. This research will contribute to the understanding of socially and environmentally cohesive urban green spaces, providing planners and landscape architects with tools and principles for creating usable green spaces in Southern Ontario cities.
CHAPTER 2: LITERATURE REVIEW

With the increase of densification in large cities the need and demand for green spaces is evident. Green spaces need to be considered at the design stage with attention to both the user and the environment. This literature review will discuss the importance of green spaces in cities while outlining the ideals of designing green spaces for the user and maintaining and highlighting the need for biodiversity.

2.1. THE NEED FOR GREEN SPACES IN CITIES

Green spaces have become an important amenity with the increase of densification in cities. Where populations are increasing and cities are expanding spatially there is a decrease in per capita space resulting in a loss of green space. As of 2008, fifty percent of the global population was living in cities and this number will continue to rise in the next fifty years (Grimm et al., 2008). While the definition of cities varies, Wu (20014) summarized that all cities have several common characteristics that help define them: high population density, abundant built structures, extensive imperious surfaces, altered climatic and hydrological conditions, air pollution, and modified ecosystem functions and services. However, Wu (2014) goes on to say that human population density and extensive impervious surfaces areas are two of the more important factors that define a city, and are what are most related to ecological and environmental characteristics of a city.

The urban population resides on less than three percent of the earth’s surface resulting in great densification of cities (Grimm et al. 2014). Densification causes greater demand for space in cities for residential, commercial, and industrial use, reducing the likelihood for urban parks through development pressure, while the users demand for green space increases. Cities share several common characteristics, such as high population density, abundant built structures, extensive impervious surfaces, altered climatic and hydrological conditions, air pollution, and modified ecosystem functions and services (Grimm at al., 2008; Wu, 2014). It is at the design stage that green spaces need to be considered and integrate into cities. Steiner (2016) investigated the need for ecological processes to be considered at the design phase through projects such as the High Line in New York City, New York and the Toronto waterfront in Toronto, Ontario. He determined that urban landscape projects illustrate how designing with nature in mind can improve the
quality of cities for plants, animals, and the user through improved ecosystem services (Steiner, 2016).

Societal awareness and scientific documentation have recognised the multiple benefits that ecosystems and green environments have for the city and its occupants. Proximity to a green space, along with its properties, have been proven to have multiple benefits on the user's mental and physical health. Pearson and Craig (2014) outline the importance of proximity to green space and its association with lower levels of stress, reduced symptoms of depression and anxiety, and improved attention deficit disorder in children. Similarly, Kaplan (2001) notes green spaces promote health and restoration due to mental fatigue by serving as a resource for physical activities. The qualities found within a landscape instill a pleasurable feeling and provide restorative qualities for the user. Grahn and Stigsdotter (2010) outlined this through an ecological approach to perception. They suggest that fundamentally, and through conditioning, the user looks for characteristics in their environment that provide them utilities, in this case pleasure and beauty, which in turn provides them happiness. De Jong et al. (2011) concluded that perceived qualities in the urban green environment are likely to be relevant for health and well-being in association with perceived availability of the green space itself.

Ecologists largely ignored cities for most of the 20th century, while focusing on surrounding natural ecosystems (Grimm et al., 2008). It was thought that there was little connection between cities and the idea of ecology, and it was not until the 1980s and 1990s when urban ecology became mainstream. Scientists determined that the environmental impacts of urbanization, the importance of patch dynamics and biodiversity, and the sustainability movement of this time period was responsible for this surge of interest (Wu, 2014). The definition of urban ecology is ever evolving and described by urban geographers, planners, and social scientists in varying ways. Luck and Wu (2002) define urban ecology as the study of understanding “the relationship between the special pattern of urbanization and ecological processes”. Alberti (2008) defined urban ecology as the study of the ways that human and ecological systems evolve together in urbanizing regions. Wu (2014) defines urban ecology as the study of the relationship between people and their urban environment. However, this definition is more related to the human aspect of urban ecology, with little focus on the environmental side. For the purpose of this study, I define urban ecology by using Wu (2014)’s bio-ecology approach which defines urban ecologyas
the study of the relationship between people and their urban environments with focus on the
distribution and abundance of plants and animals in and around the city. Sustainability is
defined as an adaptive process of facilitating and maintaining a virtuous cycle between
ecosystem services and human well-being through concerted ecological, economic, and
social actions in response to changes within and beyond the urban landscape (Wu, 2014).

Cities are often full of underutilized areas and leftover spaces with potential
opportunities for access and connection to nature. Swanwick et al. (2003) suggests that
cities are comprised of the built environment and the external area between buildings.
Green and grey space are considered to be the external area between the built environment
and are potential areas for landscape development. Grey space consists of impermeable
hard surface such as concrete or asphalt, while green space consists of land that has
permeable soft surfaces such as soil, grass, shrubs, trees and water (James et al., 2009).
Landscape architects can focus on potential areas in the urban setting that can be
developed into usable green space by either improving the existing design of green space
or repurposing potential grey space. The integration of green space into the urban setting is
not a new concept, it is regarded as an important quality of urban life but it is variable in
terms of the opportunities it presents and its physical characteristics. In cities green spaces
range from small plazas to large conservation areas and can be connected by corridors to
make up a city’s green network (Jankevica, 2013). As Bolund and Hunhammer (1999)
outlined in their study, green spaces can also be developed as, or take on the form of street
trees, lawns and parks, urban forests, cultivated land, wetlands, lakes and seas, and
streams. Bolund and Hunhammer (1999) identified the seven types of local ecosystems
listed above as areas that provide local and direct ecosystem services to cities and
substantially impact the quality of life of urban dwellers.

2.2. DESIGNING FOR THE USER (PERCEIVED SENSORY DIMENSIONS)

Most often, park designers have used well-defined and quantifiable attributes, such
as size, distance, diversity of flora and fauna, habitat types, and units (Qui and Nielson,
2015). While this has proven to be a valuable way of monitoring the ecological success of a
park, it does not take into account the social aspect and how the park is actually used. With
densification in urban environments, it is important to develop restorative city parks. Small
urban parks can be created to act as stepping stones between larger green spaces and directly connect people and nature on a daily level. Kaplan, Kaplan, and Ryan (1998) outlined the importance of everyday nature for the well-being of everyday people by fostering physical and mental health.

The word “nature” is used broadly and there are many conflicting perspectives on what characteristics ‘nature’ contains, leading to differing views of the relationship between people and nature. The world nature can include a wide variety of outdoor settings, as outlined by Kaplan, Kaplan, and Ryan (1998), including parks and open spaces, street trees, vacant lots, backyard gardens, fields and forests. Furthermore, these natural spaces can range from tiny to large, from visible through the window to more distant, and from carefully managed to neglected. The natural spaces that are beneficial to human well-being are greatly diverse.

With the diversity of nature and natural spaces outlined, it is important to consider social design, and the need for users to be considered at the design stage. PSDs were created in previous studies in psychology on how landscapes are perceived and experienced (Kaplan, 1995). Kaplan developed the dimensions as a means for determining what users liked about a green space when dealing with mental health restoration. They have been developed further and used in several studies ranging from six to nine dimensions. Van Herzele (2005) found five dimensions in her study to introduce socially inclusive design to woodlots in Antwerp, Belgium: nature, culture, social, space, and serene. Grahn and Sorte (1985) identified six PSDs including nature, culture, prospect, social, refuge and serene. Berggren-Bärring and Grahn (1995), Grahn et al. (2005), and Maikov et al. (2008), Grahn and Stigsdotter (2010), de Jong et al. (2011), and Pershardt et al. (2013) have identified eight dimensions: nature, culture, prospect, social, space, rich in species, refuge and serene. The users experience in a green space can be characterised by several of the sensory dimensions which can each range from high to low, often with one or two dimensions dominating (Qui and Nielsen, 2015). Qui and Nielsen 2015 also used the eight PSDs listed above in their study to determine whether PSDs are a reliable tool for urban green space assessment and planning. The PSDs commonly used in recent studies are shown in Table 2.1.
Table 2.1: Perceived Sensory Dimensions in Previous Studies

<table>
<thead>
<tr>
<th>Studies</th>
<th>Nature</th>
<th>Culture</th>
<th>Prospect</th>
<th>Social</th>
<th>Space</th>
<th>Rich in Species</th>
<th>Refuge</th>
<th>Serene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grahn and Sorte (1985)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Berggren-Barring and Grahn (1995)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Van Herzele (2005)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grahn et al. (2005)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Maikov et al. (2008)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Grahn and Stigsdotter (2010)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>De Jong et al. (2011)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pershardt et al. (2013)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Qiu and Nielsen (2015)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Nature, culture, social and serene were used in every study outlined in the literature review. These are all well-defined dimensions that can be found in green spaces in urban, peri-urban, and suburban landscape as demonstrated in the previous studies. Grahn and Sorte (1985) did not use space, or rich in species in their analysis on how urban parks are used by different groups. Van Herzele (2005) did not use prospect, rich in species, and refuge in their study on socially inclusive design. Grahn and Sorte (1985) and Van Herzele (2005) focused their studies on social issues and social design for green spaces. Less importance was placed on the need for ecological factors such as rich in species. Studies involving PSDs have often focused on issues of mental restoration with little attention given to the vegetative structure or ecological conditions of the site (Grahn and Sorte, 1985, Van Herzele, 2005, de Jong et al., 2011, Pershardt et al., 2013).

The eight PSDs have been used in these recent studies to estimate preferences of qualities and characteristics in parks and as a means of analysing urban park success. De Jong et al. (2011) used PSDs to qualitatively analyse the characteristics of small parks in Helsingborg, Sweden. Their study concluded that the PSD method is a successful tool for assessment and mapping of experiences in an urban park. They have increasingly been applied to studies that examine the relationship between landscape characteristics and the user’s health and well-being (Grahn and Stigsdotter, 2003). They have also been used as
indicators in the design and planning process (Skarback, 2007) and to better understand the relationship between green space and stress restoration (Grahn and Stigsdotter, 2011; Peschardt and Stigsdotter, 2013).

Peschardt and Stigsdotter (2013) characterised PSDs in a study generated to determine the perceived restorative qualities of small urban parks in Copenhagen, as shown in Table 2.2, which elaborates on the eight PSDs by creating a description and determining characteristics that would be present for each dimension.
Table 2.2: Perceived Sensory Dimension (Peschardt and Stigsdotter, 2013)

<table>
<thead>
<tr>
<th>PSD</th>
<th>Description:</th>
<th>Characteristics:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>An environment with a natural quality in the form of green surroundings.</td>
<td>• Natural quality</td>
</tr>
<tr>
<td></td>
<td>Vegetation is not too structured, with free flowing lines. The environment</td>
<td>• Less structured</td>
</tr>
<tr>
<td></td>
<td>should not be crowded.</td>
<td>• Free flowing lawns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not crowded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Variation in topography</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Variety of vegetation</td>
</tr>
<tr>
<td>Culture</td>
<td>An environment with cultural features such as fountains, statues, or ornamental</td>
<td>• Fountains</td>
</tr>
<tr>
<td></td>
<td>plantings. There is an element of human culture at the core of the environment.</td>
<td>• Statues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ornamental plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Structured</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Showy vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pastoral quality</td>
</tr>
<tr>
<td>Prospect</td>
<td>An environment with open grass lawns or small recreation areas where vistas</td>
<td>• Well-manicured lawn</td>
</tr>
<tr>
<td></td>
<td>are present.</td>
<td>• Football fields on grass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ball diamonds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sports facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elevation change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Views/vistas</td>
</tr>
<tr>
<td>Social</td>
<td>An environment with seating and opportunities for entertainment. There are</td>
<td>• Entertainment areas</td>
</tr>
<tr>
<td></td>
<td>both sunny and shaded areas and good lighting to ensure a safe environment for</td>
<td>• Restaurant/café</td>
</tr>
<tr>
<td></td>
<td>social gatherings at all times.</td>
<td>• Market stalls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shelter from wind</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sun and shade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Seating and benches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Paths with hard surfaces</td>
</tr>
<tr>
<td>Space</td>
<td>An environment that has a strong sense of connection. The area should have a</td>
<td>• Open area not broken up by paths</td>
</tr>
<tr>
<td></td>
<td>strong central area not divided by paths or sections.</td>
<td>• Shelter from wind</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sun and shade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gathering places</td>
</tr>
<tr>
<td>Rich in</td>
<td>An environment that supports a diversity of plant and animal species.</td>
<td>• Natural and native plantings</td>
</tr>
<tr>
<td>Species</td>
<td></td>
<td>• Diversity of plants</td>
</tr>
<tr>
<td>Refuge</td>
<td>An environment where play and recreation equipment, tables, and benches are</td>
<td>• Tables and benches</td>
</tr>
<tr>
<td></td>
<td>present. Vegetation is present and there is a sense of safety.</td>
<td>• Play equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Area for active play and seating to watch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
</tr>
<tr>
<td>Serene</td>
<td>An environment is silent and calm. It is not crowded and bikes are not</td>
<td>• Calm feeling</td>
</tr>
<tr>
<td></td>
<td>abundant. The area is clean with no litter or noise pollution. This is a safe</td>
<td>• Not crowded</td>
</tr>
<tr>
<td></td>
<td>environment.</td>
<td>• Does not support bikes or electric vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clean and well maintained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Buffer from traffic noise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
</tr>
</tbody>
</table>
Previous studies have focused on the perception of the user, as indicated by the general idea of the PSDs themselves. De Jong et al. (2011) suggest that perceptions are subject to single-source bias, and other studies have shown that they must be used together with an objective assessment to provide legitimacy (de Jong et al., 2011). Single source bias occurs in research when overlapping variables come from data collected from a single source. This type of data collection could lead researchers to think a relationship exists, or does not exist, between two variables when this is not necessarily the case. Collecting data from multiple sources will strengthen the relationships and produce more accurate results (de Jong et al. 2011).

Grahn et al. (2010) and Pershardt and Stigsdotter (2013) used questionnaires to gather information on use and users of urban green spaces. Both studies focused on the relationship with park users and stress and the restorative properties of the parks in Scania, Sweden, and Copenhagen, Denmark, respectively, with little emphasis placed on environmental or secondary factors. De Jong et al. (2011) used cross-sectional data from a public health survey conducted in Scania, and compared these data to landscape data obtained from GIS to assess perceived green environmental attributes for urban parks. It was not until Qiu and Nielsen’s (2015) study that another factor was introduced as secondary data for PSDs. In this study, Qiu and Nielson (2015) look at biotopes and PSDs in urban parks by looking at landscape attributes, character, size, and shape as well as users’ recreational experience of PSDs through onsite questionnaires.

There is a gap in knowledge on how social and ecological factors interact in small parks, and how they can be used to create successful urban parks (Forsyth and Musacchio, 2005). While PSDs can be used to determine effective parks based on users’ perception, this alone is not enough to determine a successful park. Often green spaces with less vegetation or canopy cover can be used more frequently for recreation and social activities. Qui and Nielson (2015) found that green spaces with more biodiversity, such as woodlots, are not used as frequently for social or recreational activities as green spaces such as ornamental park and residential green space. While the presence of PSDs is evident, ecological benefits also need to be present to ensure that the park is beneficial to the user, as well as the environment.
Cheshmehzangi (2016) outlines the need for integrated urban design. He states the need for multi-layer and multi-dimensional design for the built environment, including environmental, social, economic, and cultural. Incorporating all of these elements into design will achieve a more sustainable design for the city. Wu (2014) also outlines that it is necessary to integrate research methods from several fields, including geography, environmental psychology, sociology, landscape ecology, urban planning and design. Without adequate consideration for multiple services, research could lead to partial conclusions, which would be a disservice to our work towards a more sustainable city (Wu, 2014).

2.3. ECOLOGICAL DESIGN THROUGH BIOTOPES

With increasing urbanisation it is necessary for social and environmental scientists to develop a new concept and understanding that will help landscape architects make better decisions about green spaces in cities. With the increase of densification in cities, urban green spaces are not often considered at the design phase. This causes the ecological functions of the green spaces, and the city as a whole, to falter. When introduced to cities, urbanization leads to increased patch fragmentation and diversity often expressed as more edges or smaller patch sizes (Grimm et al., 2008). According to Grimm et al. (2008) urbanization also alters the biogeochemical cycles in cities, which leads to urban heat islands, modified hydrological systems, and changes to biodiversity and species richness.

According to Gao et al. (2011) and Qui and Nielsen (2015) existing and potential biotope qualities in an urban green space are essential in order to preserve and enhance urban biodiversity and to provide various opportunities for how people use the space. A biotope is defined as a region of “a habitat associated with a particular ecological community” (Qui and Nielsen, 2015). The vegetation structure of each biotope plays a significant role in the perspective of urban biodiversity. Gao et al. (2011) state that fragmentation could cause the changes in distribution and abundance of organisms in a landscape, regardless if it is a positive or negative effect on biodiversity. This is directly related to the vegetation structure of existing habitats. Gao et al. (2011) further explain that biotopes with old and well-stratified vegetation will generally support more species richness than biotopes with vegetation concentrated to single layer.
Vegetation structures can be used as a tool for maintaining cities and enhancing urban biodiversity as well as promoting an enjoyable space for the user. Gao et al. (2011) conducted a study in Helsingborg, Sweden to determine the importance of vegetation structure in biotope mapping. Gao et al. (2011) used five biotopes found in cities: open green area, partly open green area, partly closed green area, forest, and grove, clump of trees, thickets, tree belts or avenue. The biotopes were created by using urban land use types according to a series of factors, such as size of land, duration of land use, location within the city, maintenance intensity, and neighbouring uses. They also took into account other parameters such as vegetation type, succession, the gradient of humidity and land management (Gao et al., 2011).

Multiple biotopes can be found in one type of green space, which will further increase the biodiversity. For example, an ornamental park located in a city could contain both a partly open green area biotope, as well as a grove biotope. Furthermore, mixed habitats such as open grasslands, partly-open grounds, woodlands wetlands, and arable fields create a richness of flora and fauna and create more than one kind of habitat for species (Gao et al., 2011).

Qui and Neilson (2015) looked at the relationship of the eight PSDs and urban green space attributes (biotopes). They concluded that the diversity of PSDs in an urban green space is influenced by the number of biotopes. Specifically, Qui and Nielson (2015) found that the more diverse biotopes an urban green space encompasses, the greater the number of sensory dimensions that were highly experienced. However, aside from the number of biotopes found within the study area, the size of the space also has an effect on the number of PSDs experienced. Qui and Nielson (2015) found that, often, green spaces with fewer biotopes were used for recreation and mental activities more often than green spaces with more biotopes such as urban forests.

Overall, their results suggest that the diversity of PSDs of an urban green space is influenced by the number of biotopes and/or the urban green space size, and not definitively the biotopes themselves. It is not only the presence of biotopes and PSDs that create an ideal green space, but the proper combination that allows for optimal use. Gao et al. (2012) conclude that vegetation in urban parks needs to be enhanced through design and management to meet the requirements of both biodiversity and recreational purposes.
Qui and Nielsen (2015) characterized the ‘Green Space’ biotope (Table 3: Biotope Characteristics). They defined the biotope ‘Green Space’ into four categories based on the amount of canopy cover found on site. The green spaces were further defined by their temporal aspects (level and age of vegetation) and spatial aspects (vegetation layers). Qui and Nielsen (2015) suggested that by including the characteristics outlined in Table 2.3 in a site design will ensure an increased level of biodiversity.

*Table 2.3: Biotope Characteristics (Qui and Nielsen, 2015)*

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open green area</strong></td>
<td>&lt;10% canopy cover of trees/shrubs</td>
<td>Can include: Lawn, grazed land, meadow, and/or succession area</td>
<td>Dry/fresh/wet</td>
<td>Can include: One-layered Two-layered Multi-layered</td>
</tr>
<tr>
<td><strong>Partly open green area</strong></td>
<td>10-50% canopy cover of trees/shrubs</td>
<td>Can include: Lawn, grazed land, meadow and/or succession area</td>
<td>Dry/fresh/wet</td>
<td>Can include: One-layered Two-layered Multi-layered</td>
</tr>
<tr>
<td><strong>Partly closed green area</strong></td>
<td>50-90% canopy cover of trees/shrubs</td>
<td>Can include: Species less than 30 years, 30-80 years, and/or 80+ years</td>
<td>Deciduous and/or conifer and/or swamp</td>
<td>Can include: One-layered Two-layered Multi-layered</td>
</tr>
<tr>
<td><strong>Forest</strong></td>
<td>&gt;80% canopy cover of trees/shrubs</td>
<td>Can include: Species less than 30 years, and/or 80+ years, and/or clear cut</td>
<td>Deciduous and/or conifer and/or swamp</td>
<td>Can include: One-layered Two-layered Multi-layered</td>
</tr>
<tr>
<td><strong>Grove/clump of trees/thicket/tree belt or avenue</strong></td>
<td>1-10% canopy cover Less than 50m across</td>
<td>Can include: Species less than 30 years, 30-80 years, and/or 80+ years</td>
<td>Deciduous and/or conifer and/or swamp</td>
<td>Can include: One-layered Two-layered Multi-layered</td>
</tr>
</tbody>
</table>

When introducing the urban aspect into ecosystems, other factors need to be considered to properly analyze their ecological function. Alberti and Marzluff (2004, pg. 16) consider urban ecosystems as “complex coupled human-natural systems where people are the dominant modifiers of ecosystems, thus producing hybrid social-ecological landscape patterns and processes”. The research produced on urban ecologies is vast and studies
have shown that analysing such spaces needs to be done within an interdisciplinary approach as traditional ecological design has fallen short in creating an alternative aesthetic to urbanism (Steiner, 2014).

Studies on urban ecology have shown that higher levels of natural features such as vegetation and water are more pleasurable to users. Gyllin and Grahn (2005) conducted a study on biodiversity based on participants, perceptions of words/expressions associated with biodiversity. They concluded that areas containing spontaneous vegetation and water scored higher on a measure of biodiversity than did areas characterised by a low cut lawn and more uniform vegetation.

However, biotopes and PSDs cannot simply be increased without limit or consequence. Nassauer (1995) outlines that the common green space user associates nature with pastoral conventions of picturesque, a cultural not ecological concept. She demonstrates that applied landscape ecology is a design problem that requires placing undesirable forms (the scientific concept of ecology) inside a familiar attractive package (the cultural concept of nature). Within cities, people tend to perceive landscapes that exhibit biodiversity as messy, weedy, and unkempt and tend to be mistaken for a lack of care. Trees, shrubs, flowers, and grasses look attractive to the user unless there is “too much” (Nassauer, 1995). The preferred combination of scientific and cultural concepts of ecology must be synthesized to ensure an enjoyable green space for the everyday user.

2.4. SUMMARY

In dense urban cities the need for green space is increasingly evident. Growing populations and constant expansion have caused a greater demand for available green spaces with close proximity to the user. Green spaces can take on the form of street trees, lawns and parks, urban forests, cultivated land, wetlands, lakes, seas and streams. Attributes such as size, distance, diversity of flora and fauna, habitat types and units are the attributes most commonly used to define and design green spaces. While these attributes can create a functioning green space in theory, social aspects of green spaces in the form of PSDs and environmental aspects in the form of biotopes should be considered to create a truly usable space.
PSDs have been developed in previous studies to analyze the restorative qualities of green spaces for the user. They can be used further to analyze the preferences and qualities and characteristics of an urban park as a means for analyzing success. However, ecological aspects also need to be considered in order to preserve and enhance biodiversity within cities. Biotopes are determined by the vegetation structure of the green space and can help determine the biodiversity existing on site. The social characteristics of landscape design through PSDs, combined with the ecological characteristics of biotopes, can be used to create an integrated and highly functioning green space. Explorations into how PSDs and biotopes can guide urban design might demonstrate the practicality of the synthetic approach to integrate ecological concepts into cities.
CHAPTER 3: METHODS

The aim of this study is to analyze the relationship between the diversity and type of biotopes in urban green space and users’ perceptions of eight sensory dimensions. The research purpose intends to learn if and how PSDs and biotope richness can be optimized for urban green spaces through design. The hypothesis is: 1) the richness of characteristics biotopes present and the PSDs in an urban green space will show a positive relationship and 2) PSDs and biotope richness will be variably compatible.

3.1. IDENTIFICATION OF PERCEIVED SENSORY DIMENSIONS

The eight PSDs used in this study were drawn from the studies conducted by Grahn et al. (2005), Maikov et al. (2008), Grahn and Stigsdotter (2010), De Jong et al. (2011), Pershardt and Stigsdotter (2013), and Qiu and Nielson (2015). Pershardt and Stigsdotter (2013) developed the guidelines for determining eight PSDs as outlined in Table 2.2. These eight PSDs are commonly used and understood through their previous studies. The eight PSDs used in this study are: nature, culture, prospect, social, space, rich in species, refuge, and serene. The PSDs cover all social and ecological aspects of urban parks and provide a thorough image of their characteristics. Below, the PSDs are listed based on Pershardt and Stigsdotter (2013) and operationalised for use during this study.

3.1.1. Nature

A characterisation of nature consists of a sensation of a wild and untouched atmosphere. Wild or untouched refers to vegetation that appears to be untouched by having a natural form unaltered by human intervention. It has an environment with a natural quality in the form of green surroundings. Vegetation is not too structured with free flowing lines that are a continuous unbroken line not structured by a geometric pattern. If gardens and walkways are defined by straight or diagonal lines this would not be considered free-flowing. Aspects of the park would be designed but established on nature’s terms and not need to be constantly maintained to be aesthetically pleasing. The environment should not be crowded by objects, or have the ability to be crowded by users. Pathways should be at least three metres wide to provide adequate room for walking in both directions and an open gathering space to account for overflow. The presence of nature can be determined by the existence of more than 50% vegetation.
with the following three characteristics: wild or untouched, free flowing lines, and/or not crowded.

3.1.2. Culture

A park with a characterization of culture creates a sensation of cultivated, man-made surroundings that are shaped by history or culture. There is an element of human culture at the core of the environment. The space could be decorated with fountains, statues, or ornamental plants to create this environment. Ornamental plants are defined as any plants that are not native to the area and are arranged in a showy/colourful manner. Alternatively, vegetation can be arranged in a structured manner, whether it is native to the area or not. A structured feeling can also be achieved by an overall geometric layout of the site and unobstructed pathways. Cultural parks can also have a pastoral quality, which is shown by an idealized version of country life. This could be achieved by an open and relatively flat or rolling section of lawn or framed by large trees and water. The presence of culture should include three of the following characteristics: fountains, statues, ornamental/showy vegetation, structured, or pastoral quality.

3.1.3. Prospect

The characterization of prospect is to have an open planar view. The space will have flat and well-cut lawns and scattered trees to ensure the space is not overly crowded or disturbed by objects. The open grass lawns create areas for light recreation and vistas are present. Sport facilities such as football or soccer fields or baseball diamonds can also contribute to the feeling of prospect. Baseball diamonds must not be enclosed by fences or structures in the outfield to ensure the view is not disturbed. An elevation change can also give a sense of prospect as it allows for an outlook over the space. The elevation change should be at least one metre to contribute to the feeling of prospect. This may allow for views or vistas, but views and vistas can also be achieved through a pleasing view down a long narrow opening. This can be achieved by creating unobstructed pathways with an attractive view at the end. The presence of prospect should include at least one of the following characteristics: well-manicured lawn, football or soccer field (sports field), baseball diamond, elevation change, and/or views/vistas.
3.1.4. Social

A social urban green space will create a sensation of an environment that allows area for socializing, such as entertainment or exhibition space. These spaces could include a raised or flat area for theatre or musical performances or a large flat screen to be used during events. Market stalls should either be present or a flat open space should be available for a seasonal market space. Facilities such as washrooms, change rooms, water fountains, and garbage/recycling receptacles should be present to ensure users do not need to leave the space. They should also be located in a clean and convenient location near recreation or entertainment areas. Seating should be provided in both sunny and shaded areas and shelter from wind, providing comfortable seating at all times. Seating should be located adjacent to or within recreation or entertainment areas. Good lighting ensures a safe environment for social gatherings both day and night. The presence of social should include at least three of the following characteristics: entertainment area, restaurant or café, market stalls, facilities, shelter from wind/sun/shade and/or seating.

3.1.5. Space

For an urban green space to have a sense of space, it must be spacious and free, without too many paths or roads dividing the space. Shelter from wind and both sun and shade should be present in gathering areas. Space creates an environment that has a strong sense of connection by having a strong central area that isn’t divided. The presence of space should have a general gathering area that is not broken up by paths or roads and that is not specifically designated for a recreational activity.

3.1.6. Rich in Species

Rich in species refers to the sensation of seeing a wide range of species both flora and fauna. The presence of rich in species should contain both natural and native plantings with a diversity of plants (more than three different species).

3.1.7. Refuge

An urban green space with refuge provides a sensation of an enclosed and safe environment, allowing places for people to be active or sit and watch other people be
active. The area will allow for an overall sense of safety with benches and play equipment. Seating should be located against buildings or beside secure structures to ensure a safe feeling. The presence of refuge in an urban park should contain at least two of the following characteristics: tables and benches located against a secure structure, play equipment, area for active play and seating to watch. A feeling of safety is the most important aspect of the dimension ‘refuge’ and should be included for ‘refuge’ to be present.

3.1.8. Serene

For an urban park to be characterised as serene, it must have a sensation of being undisturbed, calm and have an overall safe feeling. This can be achieved by ensuring the site is not located on a busy street with high traffic. There should not be any loud noise sources such as speakers. The overall feeling would be peaceful by not being crowded, having no loud noises within the park or nearby, and no litter. The paths do not support bikes or vehicles and there is a buffer from traffic noise. Bicycles can be discouraged with signs posted at all entrances and bike parking that is located offsite. The urban green space should not have a crowded feeling which can be achieved by ensuring paths are at least three metres wide and an open gathering place is present. The presence of serene should include at least three of the following characteristics: calm feeling, not crowded, does not support bikes or vehicles, and/or a buffer from traffic noise.

The eight PSDs, their description, and characteristics were created by Peschardt and Stigsdotter (2013) as identified in Table 3.1. The description and characteristics can be used in determining the design outline for green spaces in the urban environment. The shaded area in Table 3.1 highlights the aspect of the table that was amended. The table was revised based on literature to include characteristics that might logically be included in the design of the urban green space to ensure the PSD is present. This is shown in the last column labeled ‘Should contain’ and describes real attributes that can be used and replicated in applied projects. The PSD ‘refuge’ was also amended to better describe the dimension. Previously ‘refuge’ was described by Peschardt and Stigsdotter (2013) as an environment where play and recreation equipment, tables, and benches are present. They
also state that vegetation must be present and there will be a sense of safety. Through literature review this did not fully describe ‘refuge’ and the description was amended to: A safe environment where shelter is provided through vegetation or built structures. Play and recreation equipment may be present with tables and benches with visible sightlines, based on Appleton (1975). As a result the characteristics and what the site ‘should include’ were amended to better represent the updated description of ‘refuge’ as outlined in Table 3.1. The most essential aspect of the PSD ‘refuge’ is a safe feeling.
Table 3.1: Perceived Sensory Dimensions

<table>
<thead>
<tr>
<th>PSD</th>
<th>Description:</th>
<th>Characteristics:</th>
<th>Should contain:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>An environment with a natural quality in the form of green surroundings.</td>
<td>• Natural quality</td>
<td>50% vegetation with at least two of the following characteristics: wild, untouched, free flowing</td>
</tr>
<tr>
<td></td>
<td>Vegetation is not too structured with free flowing lines. The environment</td>
<td>• Less structured</td>
<td>lines, not maintained, not crowded</td>
</tr>
<tr>
<td></td>
<td>should not be crowded.</td>
<td>• Free flowing lawns</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not crowded</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Variation in topography</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Variety of vegetation</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Culture</td>
<td>An environment with cultural features such as fountains, statues, or ornamental</td>
<td>• Fountains</td>
<td>At least three of the following characteristics: fountains, statues, ornamental plants, structured,</td>
</tr>
<tr>
<td></td>
<td>plantings. There is an element of human culture at the core of the environment.</td>
<td>• Statues</td>
<td>showy vegetation, pastoral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ornamental plants</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Structured</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Showy vegetation</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pastoral quality</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Prospect</td>
<td>An environment with open grass lawns or small recreation areas where vistas</td>
<td>• Well-manicured lawn</td>
<td>At least one of the following characteristics: well-manicured lawn, football fields, ball diamonds,</td>
</tr>
<tr>
<td></td>
<td>are present.</td>
<td>• Football fields on grass</td>
<td>elevation change and/or views/vistas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ball diamonds</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sports facilities</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lighting</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elevation change</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Views/vistas</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Social</td>
<td>An environment with seating and opportunities for entertainment. There are</td>
<td>• Entertainment areas</td>
<td>At least three of the following characteristics: entertainment area, restaurant/café, market stalls,</td>
</tr>
<tr>
<td></td>
<td>both sunny and shaded areas and good lighting to ensure a safe environment</td>
<td>• Restaurant/café</td>
<td>facilities, shelter from wind/sun/shade and/or seating.</td>
</tr>
<tr>
<td></td>
<td>for social gatherings at all times.</td>
<td>• Market stalls</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good lighting</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Facilities</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shelter from wind</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sun and shade</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Seating and benches</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Paths with hard surfaces</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Space</td>
<td>An environment that has a strong sense of connection. The area should have a</td>
<td>• Open area not broken up by paths</td>
<td>A central gathering area that is not broken up by paths or roads and that is not specifically</td>
</tr>
<tr>
<td></td>
<td>strong central area not divided by paths or sections.</td>
<td>• Shelter from wind</td>
<td>designated for a recreational activity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sun and shade</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gathering places</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rich in Species</td>
<td>An environment that supports a diversity of plant and animal species.</td>
<td>• Natural and native plantings</td>
<td>Both natural and native plantings with a diversity of plants (at least three different species).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diversity of plants</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Refuge</td>
<td>A safe environment where shelter is provided through vegetation or built</td>
<td>• Tables and benches</td>
<td>At least two of the following characteristics: tables and benches located beside a secure structure,</td>
</tr>
<tr>
<td></td>
<td>structures. Play and recreation equipment may be present with tables and</td>
<td>• Play equipment</td>
<td>play equipment, area for active play and seating to watch, open sightlines and a safe feeling.</td>
</tr>
<tr>
<td></td>
<td>benches with</td>
<td>• Area for active play and seating to watch</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Serene</td>
<td>An environment is silent and calm. It is not crowded and bikes are not</td>
<td>• Calm feeling</td>
<td>At least three of the following characteristics: calm feeling, not crowded, clean and well maintained,</td>
</tr>
<tr>
<td></td>
<td>abundant. The area is clean with no litter or noise pollution. This is a safe</td>
<td>• Not crowded</td>
<td>does not support bikes or electric vehicles, clean/well maintained, does not support bikes or</td>
</tr>
<tr>
<td></td>
<td>environment.</td>
<td>• Does not support bikes or electric vehicles</td>
<td>vehicles, and/or a buffer from traffic noise.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clean/well maintained</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Buffer from traffic noise</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe feeling</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

22
3.2. IDENTIFICATION OF URBAN BIOTOPES

Urban biotopes were determined based on the biotope classification system design by Gao et al. (2011). They created a classification to determine urban biotopes in Helsingborg, Sweden based on land use and vegetation habitats using temporal and spatial aspects. Gao et al. (2011) outlined that in previous studies on biotope mapping schemes, classification was based on land use type and habitat type. They determined through their research that habitat structure through temporal and spatial aspects needs to be analysed. Green spaces with long continuity (temporal aspect) positively influence species diversity, facilitate dispersal of birds and other organisms, and allow gene flow between populations (Gao et al. 2011). Similarly, they determined a positive relationship between species vegetation structure and biodiversity of an urban green space. The classification was modified from Gao et al. (2011) and developed to reflect biotopes in cities. Table 3.2: Biotope Characteristics shows the different biotopes found in the urban environment that are relevant to this study. The shaded area identifies adaptations based on research to include biotope characteristics that best represent urban green spaces. The original table was shown earlier in Table 3: Biotope Characteristics (Qui and Nielsen, 2015).

3.2.1. Green Space

The first level was established as a broad category based on the land use type. Urban land use types are classified according to a series of factors, such as size of land use patch, duration of land use, location within the city, maintenance intensity, and neighbouring uses (Sukopp and Weiler, 1988). Most urban biotope mapping schemes classify biotopes based on land use and habitat types, such as parks, school grounds, etc. (Gao et al. 2011). For the purpose of this study the land use has been limited to ‘green space’ for Level 1.
<table>
<thead>
<tr>
<th>Categories of Green Space (Level 1)</th>
<th>Temporal aspects (Level 3)</th>
<th>Spatial aspects (Level 4)</th>
<th>Vegetation quality (Level 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaza area</td>
<td>Can include:</td>
<td>Can include:</td>
<td>Low: 1-30% native</td>
</tr>
<tr>
<td>Built area &gt; green space</td>
<td>Plants in built area,</td>
<td>One-layered</td>
<td>Medium: 40-60% native</td>
</tr>
<tr>
<td>1-10% canopy cover</td>
<td>raised gardens, and/or</td>
<td>Two-layered</td>
<td>High: 70-100% native</td>
</tr>
<tr>
<td></td>
<td>lawn area</td>
<td>Multi-layered</td>
<td></td>
</tr>
<tr>
<td>Open green area</td>
<td>Can include:</td>
<td>Can include:</td>
<td></td>
</tr>
<tr>
<td>&lt;10% canopy cover of trees/shrubs</td>
<td>Lawn, grazed land,</td>
<td>One-layered</td>
<td>Low: 1-30% native</td>
</tr>
<tr>
<td></td>
<td>meadow, and/or</td>
<td>Two-layered</td>
<td>Medium: 40-60% native</td>
</tr>
<tr>
<td></td>
<td>succession area</td>
<td>Multi-layered</td>
<td>High: 70-100% native</td>
</tr>
<tr>
<td>Partly open green area</td>
<td>Can include:</td>
<td>Can include:</td>
<td>Low: 1-30% native</td>
</tr>
<tr>
<td>10-50% canopy cover of trees/shrubs</td>
<td>Lawn, grazed land,</td>
<td>One-layered</td>
<td>Medium: 40-60% native</td>
</tr>
<tr>
<td></td>
<td>meadow and/or</td>
<td>Two-layered</td>
<td>High: 70-100% native</td>
</tr>
<tr>
<td></td>
<td>succession area</td>
<td>Multi-layered</td>
<td></td>
</tr>
<tr>
<td>Partly closed green area</td>
<td>Can include:</td>
<td>Can include:</td>
<td>Low: 1-30% native</td>
</tr>
<tr>
<td>50-90% canopy cover of trees/shrubs</td>
<td>Species less than 30</td>
<td>One-layered</td>
<td>Medium: 40-60% native</td>
</tr>
<tr>
<td></td>
<td>years, 30-80 years, and/or</td>
<td>Two-layered</td>
<td>High: 70-100% native</td>
</tr>
<tr>
<td></td>
<td>80+ years</td>
<td>Multi-layered</td>
<td></td>
</tr>
<tr>
<td>Grove/clump of trees/thicket/tree belt or avenue</td>
<td>Can include:</td>
<td>Can include:</td>
<td>Low: 1-30% native</td>
</tr>
<tr>
<td>1-10% canopy cover</td>
<td>Species less than 30</td>
<td>One-layered</td>
<td>Medium: 40-60% native</td>
</tr>
<tr>
<td>Less than 50m across</td>
<td>years, 30-80 years, and/or</td>
<td>Two-layered</td>
<td>High: 70-100% native</td>
</tr>
<tr>
<td></td>
<td>80+ years</td>
<td>Multi-layered</td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.2. Categories of Green Space

The second level was established by the vegetation structure of the site including the canopy cover ratio of trees and shrubs. Gao et al. (2011) used the vegetation cover for their study based on a four-grade scale (1-10%, 10-50%, 50-90%, and 90-100%). For the purpose of this study, the scale was modified to include an urban plaza and grove, clump of trees, thicket, tree belt or avenue, which are included as urban green spaces. The characteristic ‘Plaza Area’ was added to Table 3.2 to account for the plaza areas present in cities.

### 3.2.3. Temporal Aspects

The third level was established by the type of vegetation and the temporal aspects of the site. The temporal characteristics include aspects of disturbance such as mowing or
grazing, but do not include long term successional processes. Gao et al. (2011) describe a temporal concept in two parts: 1) the continuity of vegetation cover, which is the presence of vegetation over long periods with or without disturbance. The vegetation cover such as shrub, understory, and tree cover is described as woodland continuity, and the grass cover is described as grassland continuity. 2) The approximate mean age of the dominant tree-layer. This is determined on a three-grade scale (0-30 years, 30-80 years, and 80+ years).

3.2.4. Spatial Aspects

The fourth level focused on spatial aspects of the vegetation structure on both the horizontal and vertical dimensions. Gao et al. (2011) described the spatial concept in two parts: 1) Horizontal structure and 2) Vertical structure. Horizontal structure refers to the distribution of vegetation in a plan view and the types of vegetation pattern determined by canopy cover of trees and shrubs. The vertical structure refers to the vegetation elements in a elevation which includes canopy cover (>10m), understory (4-10m), shrub layer (1-4m) and field (grass) layer (<1m).

Level 4 is determined by the vertical structure of the vegetation found on site: one-layered, two-layered, and multi-layered. One-layered represents tree canopy layer or understory, two-layered is a combination of shrub layer, understory or tree canopy layer. Multi-layered is any combination of two or more layers. Gao et al. (2011) determined that these vertical structures represented by layers emphasize the cover conditions of the sites.

3.2.5. Vegetation quality

The fifth level was established by the type of vegetation found on site, specifically whether is it native or not native to the area. For the purpose of this study Level 5 follows a low, medium and high scale concerning the amount of native species (Low: 1-30%, 30-60% and 60-100%). The amount of native species will directly reflect the amount of vegetation located on site, as determined in Level 2. For example, if a plaza area has 1-10% vegetation, of that vegetation 60-100% would need to be native species to be considered a high vegetation quality. Level 5 was amended in Table 3.2 to account for a stronger level of environmental consideration when choosing vegetation for a site.
While different levels (canopy, shrub level, and ground cover) is an ideal way to include biodiversity on the site, native vegetation needs to be considered to truly create a high level of vegetation quality.

3.3. INTRODUCTION TO STUDY AREA

The first biotope characteristic (plaza) from Table 3: Biotope Characteristics, Level 2, was chosen as a representation of the current urban climate, as outlined in the literature review. Densification in cities is resulting in a loss of green space or the design of smaller green spaces. Plazas are generally small in area and consist of a large portion of built area and greatly epitomise the makeup of cities. The sites chosen for design were based on green spaces existing in Southern Ontario cities so that they had consistent and similar characteristics and could be easily replicated.

Two plaza areas were chosen for this study as a representation of the biotope ‘green space’ in cities. Two plazas were chosen as a way to replicate similar characteristics and allow for the sites to be compared and contrasted during analysis. Two sites will also allow for less single-sourced bias to occur.

3.3.1. Plaza Area: Definition and Rational

By definition, a plaza is very basic and variable: a public square or an open space in a city or town. The physical characteristics of a plaza can vary enormously through their space and size, location, and uses. Marcus and Francis (1998) define a plaza as a designed urban open space with the exclusion of cars made ideal for a range of activities such as strolling, relaxing, sitting and socializing. Often, plazas have been identified as under-used spaces that tend to be large, ceremonial and monumental (Carr et al., 1992). Regularly they are attached to a highly used building, and often located in a prominent or central location within the city. Due to their frequently large size and general vastness, plazas are a key way to introduce vegetation into the core of cities. Similarly, because of their variable and large nature, the design of plazas can be overlooked as a social device and are often more of an architecture scheme. Woolley (2003) notes that plazas are regularly seen as large “high-speed” footpaths with few places or reason for social contact. To create a useable and enjoyable space, the social environment needs to be considered at the design stage. Woolley (2003) concluded in a
cross examination of urban plazas that it is the most used plazas that have multiple opportunities for social activity.

For the purpose of this study, the plazas used will be 3000 square metres or less. This size will allow for a replicate to be completed during this study to ensure that plazas can be compared and contrasted. The plazas chosen will also be bounded on at least three sides with a building directly connected to one of those sides side. This is a common arrangement for plazas and again will lead to a common characteristic that can be replicable in further studies. Lastly, the plazas chosen for this study will contain 10% or less of canopy cover. This is the number outlined in Table 3: Biotope Characteristics, which defines a plaza area as have 1-10% canopy cover.

3.3.1.1. Market Square, Guelph

The first site is based on the Market Square Plaza located in Guelph, Ontario. The Market Square is located at 1 Carden Street on the south-east corner of Carden Street and Wilson Street in downtown Guelph, as seen in Figure 3.1. It is attached to Guelph

![Figure 3.1: Market Square, Guelph](image)
City Hall, and next door to the Ontario Court of Justice – Provincial Offences. It is bounded on the remaining three sides by buildings. Directly across from the plaza on both Carden Street and Wilson Street are retail stores and restaurants. Street parking is available on both of these streets.

The approximate size of the Market Square Plaza is 2,790 square metres. Currently there are 260 square metres of canopy cover located in seven small raised gardens located throughout the site and street trees along Carden Street. This results in a total 9.3% canopy cover on site. The main feature of the Market Square Plaza is a large fountain and water element at the center that acts as a wading pool in the summer and a skating rink in the winter.

3.3.1.2. Covent Garden Market Square, London

The second site is Covent Garden Market Square in London, Ontario. The plaza is
located at 130 King Street at the corners of King Street and Talbot Street, and Talbot Street and Covent Market Place in downtown London as seen in Figure 3.2. It is attached to the Covent Garden Market building, which is a daily marketplace for local businesses. It is bounded on the remaining three sides by buildings. Directly across the street to the West is Budweiser Gardens, which hosts Ontario Hockey League games, National Basketball League of Canada games, and various concerts and events. Across the street from the plaza to the north and south are retail stores and restaurants. Street parking is available on all surrounding streets.

The approximate size of Covent Garden Market Plaza is 2,180 square metres. Currently there is 170 square metres of vegetation cover located in raised planters and street trees along King Street. This results in a total of 7.8% canopy cover on site. The main feature of the Covent Garden Market Plaza is the central open space that is used as a local farmers’ market in the summer and a skating rink in the winter.

3.4. DATA COLLECTION AND ANALYSIS

Biotopes and PSDs should both be present in green spaces in optimized proportions to create a truly usable and optimal space. The two sites listed above were chosen as a base to virtually change through design to enhance PSD and biotope characteristics simultaneously. A SketchUp model was completed for each site and conceptual designs were generated. An animated walk-through allows for the site to be experienced at eye level to show how the site will feel for the user. The models show how biotope characteristics and PSDs can be accomplished through design and consequently how the site would be used.

The models were then analyzed to determine the optimal combination of biotope characteristics and PSD characteristics for an urban green space. Different combinations were tried and tested using sketches to determine a green space with the most amount of biotope characteristics and PSDs without compromising the usability of the space. The site sketches began with the data from Table 3: Biotope Characteristics for each model. The characteristics from Levels 2, 3, 4 and 5 were introduced to the sites through design. The models were then analyzed to determine how many PSDs were present, as based on the characteristics from Table 2.2: Perceived Sensory Dimensions.

The sketches were critically reviewed to determine conflicts and synergies between the PSDs and biotope characteristics to determine the optimal combinations. Alterations to the
models was made if it were possible to include more PSDs to the site without compromising the usability. Once a preliminary design was completed for each site, it was analysed to determine the presence of biotope characteristics and number of PSDs. If the site could be altered to include more PSDs or ensure the biotope characteristics were complete, they were made at this time. These alterations continued until all the biotope characteristics were included and as many PSDs were present without compromising the usability of the site.

Final analysis included critical reflection on the PSD and biotope richness, and the common or unique challenges of fit among these attributes. The models and results are described and discussed in the following chapter to inform plaza landscape architecture. Figure 3.3 summarizes the flow of research used in this study.
A biotope characteristics table was created based on Qui and Nielsen (2015) to act as principles for using biotopes in the design of urban plazas.

A PSD characteristics table was created based on Peschardt and Stigsdotter (2013) to act as principles for using PSDs in the design of urban plazas.

A Sketch-up design for Covent Garden Market began by adding the highest level of biotope characteristics to the site.

The Covent Garden Market design was augmented by adding characteristics from the PSD table.

A Sketch-up design for Market Square began by adding the highest level of biotope characteristics to the site.

The Market Square design was augmented by adding characteristics from the PSD table.

The two designs were analyzed to determine whether the highest level of biotope characteristics were achieved and whether all 8 of the PSDs were present.

The analysis results were further analyzed to determine the synergies and conflicts between biotopes and PSDs in urban green space plazas.

*Figure 3.3: Research Flow*
CHAPTER 4: RESULTS AND OUTCOMES

4.1. Covent Garden Market Design

The Covent Garden Market was designed to feature a central lawn gathering area lined with large native trees, as seen in Figure 4.1 and the Video: Covent Garden Market Design. Wide pathways lead to the front of the building from the north, south and west. Three steps lead to a raised walkway surrounding the entrance to the building. The symmetric design has two large flat areas in the North and South sections of the plaza, shown as filled with market stalls and picnic tables. A fountain is located on the west side of the plaza and can be seen from both inside the site and from the sidewalk. Raised gardens surround the site planted with native shrubs and trees and large planters are located against the building.

4.1.1. Plaza area (Biotope)

The design for Covent Garden Market began by looking at the green space biotope. At the second level on the biotope characteristics table, as outlined in Table 3.2, the plaza area was chosen as the base of the design. Therefore, this determines that the built area should be greater than green space (vegetation), and there should be from 1-10% canopy cover on site. The impervious hard surface for the Covent Garden Market
is 75%, while vegetated area is 25%. Of that vegetated area, canopy cover is 10% in the newly designed site.

The temporal aspects in the biotope characteristic table (Table 3.2) outlines that a plaza site should include characteristics in the form of plantings in built area, raised gardens, and/or lawn areas. The Covent Garden Market contains raised gardens that surround the site planted with native shrubs and trees and free standing planters located against the building planted with shrubs and annuals. A large central turf area is also located on site with large native trees.

The spatial aspects of the biotope characteristic table (Table 3.2) outlines that a plaza should contain one-, two-, and multi-layered vegetation. As defined in the methods, multi-layer vegetation includes canopy cover (>10m), understory (4-10m), shrub layer (1-4m) and field (grass) layer (<1m). The Covent Garden Market includes large shade trees in the central lawn area (30 m average), understory trees in the raised garden that surround the site (9 m average), and a shrub layer in the raised gardens (1-2 m average) and planters (3-4m), and a central turf layer (<1m).

The vegetation quality of a plaza area is determined at level five on the biotope characteristic table as shown in Table 3.2. To achieve a high level of vegetation quality the vegetation on site must contain 70-100% native plantings. The Covent Garden Market contains 30% vegetation, and of that vegetation 74% is native. This was determined by the area of native vegetation within the overall vegetation area. The native plantings are: redbud (Cercis canadensis), the understory trees located in the raised gardens surrounding the site, and the shrubby cinquefoil (Dasiphora fruticosa var. floribunda), located in the raised garden underneath the redbud trees. The larger shrub layer located in the raised planters is native, Amalanchier laevis (smooth serviceberry). Paper birch (Betula papyrifera var. papyrifera) trees located in the lawn area are also native and are considered the large shade trees (canopy cover) of the site. The non-native vegetation located on site is the turf grass located in the lawn area and annuals located in the planters ('Easy Wave Berry Velour' wave petunias).
4.1.2. Nature (PSD)

As outlined in Table 3.1, the PSD ‘nature’ should contain 50% vegetation with at least two of the following characteristics: wild, untouched, free flowing lines, not maintained, and not crowded. The PSD ‘nature’ was not achieved in the Covent Garden Market. While the characteristics (wild, untouched, free flowing lines, not maintained, and not crowded) could have been achieved, the characteristic of 50% vegetation could not without compromising multiple PSDs. This could be achieved by having pathways or gardens that are not geometric or straight lines, by having vegetation that is native and not designed in a structured manner, or having vegetated areas that are not conventionally or visibly maintained such as meadows or forested areas. These aspects would allow for some characteristics of nature to be present while still maintaining the plaza biotope characteristics. However, as outlined in Table 3.2, the biotope subgroup ‘plaza’ should contain built area that is greater than vegetated area. If the site contained 50% vegetation it would not meet the criteria of a ‘plaza’.

4.1.3. Space (PSD)

The PSD ‘space’ is achieved by having a central gathering area that is not broken up by paths or roads and that is not specifically designated for an active recreation activity, as outlined in Table 3.1. The Covent Garden Market has a central lawn area that does not have a recreational designation, as seen in Figure 4.2. The lawn area is large enough to be used for light recreational activities, or could also be used for more passive activities. It is not broken up by paths and is intended for light foot traffic. The large shade trees that line the central lawn area provide shelter from wind and sun to those using the space, while allowing it to remain well connected to the surrounding pathways. The central lawn area is open to a raised walkway to the east, and fountains to the west. All of these aspects ensure that the lawn area is not closed by large or obtrusive structures at its perimeter and adds to the overall spatial feeling.
4.1.4. Prospect (PSD)

The PSD ‘prospect’ can be achieved by having at least one of the following characteristics, as outlined in Table 3.1: well-manicured lawn, football field, ball diamond, elevation change, and/or views and vistas. As shown in Figure 4.2, Covent Garden Market contains the PSD ‘prospect’ by containing three of the above characteristics: a well-manicured lawn, elevation change, and views and vistas. A well-manicured lawn is located in the center of the site and can be well seen from all aspects of the site as well as the street. An elevation change occurs at the eastern extent of the lawn area, at the south and west entrances to the site and at the raised walkway that surrounds the entrance to the building. As stated in the methods, there should be an elevation change of at least one metre. Covent Garden Market has an overall elevation change of one metre from the southern street level to the building entrance. The site is sloped from north to south and therefore the elevation change is not consistent throughout. The two paths that line the lawn create vistas that are bordered by trees on the lawn side and seating with umbrellas on the opposite side (beside the market stalls). The vistas lead to the front of the building and attractive planters with native vegetation along with showy annuals.

Figure 4.2: Central gathering area of Covent Garden Market, looking west, including mown turf and surrounding paper birch trees. The PSDS ‘Space’ and ‘Prospect’ are illustrated here.
4.1.5. Social (PSD)

The PSD ‘social’ can be achieved by including at least three of the following characteristics in a plaza area: an entertainment area, a restaurant or café, market stalls, facilities, shelter from wind and sun, or adequate seating (Table 3.1). The Covent Garden Market design includes three of these characteristics: market stalls, shelter from wind and sun, and adequate seating, as shown in Figure 4.3. Market stalls are present on both sides of the central lawn area allowing for easy access from all entrances to the site. Picnic benches are located beside both sections of market stalls with umbrellas to provide shade. The picnic benches provide seating for plaza users, as do the seat walls of the raised gardens that surround the site. These areas are all located close together to provide adequate space for social interactions. The trees planted in the raised gardens also provide shelter from wind and additional shade for the pathways, as do the large shade trees in the lawn area. This provides for a pleasant space during overly sunny or windy days to ensure optimal use for social activities.

Figure 4.3: Market stalls and picnic benches looking north east in Covent Garden Market. The PSD social is illustrated here
4.1.6. Culture (PSD)

The PSD ‘culture’ can be realised in a plaza area by having at least three of the following characteristics: fountains, statues, ornamental plants, structured, showy vegetation or pastoral, as outlined in Table 3.1. The Covent Garden Market site contains the PSD ‘culture’ by containing five of the above characteristics: fountains, showy vegetation ornamental plants, a structured layout, and a pastoral central lawn area. A large fountain is located at the west end of the central lawn area, as shown in Figure 4.4. The fountain can be seen from inside the site, the adjacent sidewalk, and surrounding areas. It can especially be viewed and enjoyed from the central lawn area. Ornamental trees line the lawn area, contributing to the pastoral qualities of the site. As outlined in methods, water and large shade trees along with flat or rolling grass areas can create a pastoral feeling within a site. Structured native shrubs and trees are located in the raised gardens surrounding the site and showy annual vegetation is present in the large planters located alongside the building. A structured geometric layout with clean, straight lines can be seen in the bird’s eye view of Figure 4.1.

![Figure 4.4](image)

**Figure 4.4:** The central lawn area of Covent Garden Market, looking east, with seating shown on the north side of the lawn. Large walkways show open sightlines and a structured layout with views of the ornamental plants and pastoral qualities. The PSDs ‘Culture’ and ‘Refuge’ are shown here.
4.1.7. Refuge (PSD)

The PSD ‘refuge’ can be achieved in a plaza area by containing at least two of the following characteristics: tables and benches located beside a secure structure, play equipment, area for active play and seating to watch, open sightlines and a safe feeling. The Covent Garden Market provides ‘refuge’ by featuring three of the above characteristics: tables and benches located beside a secure structure, an area for active play and seating to watch and open sightlines as shown in Figure 4.4. Together, these characteristics allow for an overall safe feeling on the site. Tables are located beside the market stalls, which are a secure structure on site. Seat walls also double as benches, and are relatively secure structures on their own, and are also located beside the market stalls. The area for active play is achieved through the central lawn area. Users can participate in active play on the lawn and the nearby tables can be used to sit and watch. Open sightlines are achieved through straight pathways not broken up by obstacles. Market stalls and picnic tables are placed in straight lines to ensure open sightlines are maintained.

4.1.8. Rich in Species (PSD)

The PSD ‘Rich in Species’ is present in a plaza if it contains both natural and native plants as well as a diversity of plants (at least three species), as outlined in Table 3.1. The Covent Garden Market design contains the PSD ‘rich in species’ by encompassing four native species. The design also contains two non-native species. The native species, as shown in Figure 4.5, are the paper birch trees (Betula papyrifera var. papyrifera) located in the lawn area, the redbud trees (Cercis canadensis) and shrubby cinquefoil (Dasiphora fruticosa var. floribunda) in the raised gardens surrounding the site, and the smooth serviceberry (Amalanchier laevis) shrubs located in the planters alongside the building. The non-native species are ‘Easy Wave Berry Velour wave petunias (annuals) located in the planters alongside the building and the turf located in the central lawn area.

4.1.9. Serene (PSD)

The PSD ‘Serene’ is present in a plaza area when it contains at least three of the following characteristics: a calm feeling, not crowded, clean and well maintained, does
not support bikes or vehicles, or a buffer from traffic noise, as outlined in Table 3.1. The Covent Garden Market achieves 'serene' by having providing a site that is not crowded, does not support bikes or vehicles, and has a buffer from traffic, as shown in Figure 4.5. The site is not crowded by designing central pathways that are at least three metres wide and a central gathering area for overflow. The pathways are not obstructed by permanent objects or obstacles. Bikes and vehicles are not supported in the plaza by ensuring bike parking is located just offsite and not within the site boundaries and having signage at each accessible entrance. The raised gardens planted with native shrubs and trees provide a buffer from surrounding traffic noise.

![Figure 4.5: Looking east at the raised gardens surrounding Covent Garden Market and steps leading to the central lawn area. The PSDs 'Rich in Species' and 'Serene' are shown here.](image)

### 4.2. Market Square Design

The Market Square in Guelph is designed with a central lawn area beside a large interactive fountain as seen in Figure 4.6 and the Video: Market Square Design. The fountains are level with the surrounding terrain to allow for users to sit and watch or alternatively use for active play. The central lawn area contains large shade trees at the north/east end and is directly connected to seating and the fountains. The site is lined by street trees to the north, east, and west. A large central walkway leads to the main
entrance from the north side of the site, with vegetation on both sides. Secondary
diagonal walkways lead to the front of the building from east and west sides of the site.
Raised gardens surround the central area with native plantings with edges that double
as a seat wall. The raised gardens separate the site from the surrounding sidewalks
and roadways. A raised seating area with benches overlooks the lawn and fountain to
the west, while benches and native planters line the building. On the east side of the
site is small building with facilities including bathrooms, water fountains, and garbage
and recycling receptacles. On top of the structure is seating with umbrellas with a glass
railing allowing for views over the site.

Figure 4.6: Plan view of the Market Square design, Guelph

4.2.1. Plaza Area (Biotope)

The design for Market Square began by looking at the biotope ‘Green Space’. At the
second level of the biotope characteristics table (Table 3.2) plaza area (Market Square)
was chosen as the base of the design. Under the plaza area characteristics, the plaza
area should have a built area that is greater than vegetated area, and 1-10% canopy
cover. In the newly designed Market Square, the site has 70% built area (30%
vegetation) and, of that vegetation, 10% is canopy cover.
Temporal aspects are outlined in Level three (Table 3.2). The Table outlines that a plaza should include aspects such as plantings in a built area, raised gardens, and/or lawn area. Market square achieves this level by including street trees in a built area (walkway) and grasses and shrubs integrated in pathways, grasses, shrubs, and trees in raised gardens, and a central lawn area with large shade trees.

Spatial aspects are outlined in Level four of the biotope characteristics table (Table 3.2). Spatial aspects of a plaza site should contain multi-layered vegetation, which includes canopy cover (>10m), understory (4-10m), shrub layer (1-4m) and field (grass) layer (<1m). The newly designed Market Square contains large shade trees in the lawn area (18m average) and street trees that run along Carden Street (20m average). Understory trees are included in the raised gardens (8m average). Taller shrubs (3-4m) and shorter shrubs (1-3 m) are located in the raised gardens and planters situated alongside the building and a central grass area covers the field (grass) layer (<1m).

The level of vegetation quality in a plaza is outlined in Level five of the biotope characteristics table (Table 3.2). To achieve a high level of vegetation quality, the vegetation on site should contain 70-100% native plantings. Of the 30% vegetation located on site, the Market Square design contains 70% native vegetation. This is calculated by the area of native vegetation within the total area of vegetation on site. Since the turf grass is the only non-native vegetation on site, the total grass area was removed from the total vegetated area to determine the area of native vegetation on site. The native plantings are: Red maple (Acer rubrum), the shade trees (canopy cover) located in the lawn area; Hackberry (Celtis occidentalis), the street trees (canopy cover) located along Carden Street; Paper birch (Betula papyrifera), and Chokecherry (Prunus virginiana) understory trees located in the raised gardens; red osier dogwood (Cornus stolonifera), Yew (Taxus canadensis), shrubs located in the raised gardens and planters; sedge (Carex spp.) also located in the raised gardens. The only non-native vegetation located on site is the turf grass located in the central lawn area.

4.2.2. Nature (PSD)

The PSD ‘nature’ must contain 50% vegetation with at least two of the following characteristics: wild, untouched, free flowing lines, not maintained, and not crowded as
outlined in Table 3.1. Due to the characteristic that nature must contain 50% vegetation, it was not achieved in Market Square. As outlined in Table 3.2, 'plaza' should contain built area that is greater than vegetated area, therefore causing a conflict between the PSD ‘nature’ and the biotope characteristic ‘plaza’.

4.2.3. Prospect (PSD)

As outlined in Table 3.1, the PSD ‘prospect’ can be achieved by having at least one of the following characteristics: well-manicured lawn, football field, ball diamond, elevation change, and/or views and vistas. Market Square achieved prospect by containing a well-manicured central lawn area and having an elevation change to the upper seating area as shown in Figure 4.7. As stated in the methods, there should be an elevation change of at least one metre for elevation change to be considered a characteristic.

Stairs run along the back of the structure that houses facilities, leading to a large open seating area. The upper seating area also allows for views over the site and surrounding commercial area. Vegetation-lined paths also create vistas, especially the main pathway leading to the entrance to the building.

**Prospect** – well manicured central lawn, elevation change to upper seating area, and views and vistas.

*Figure 4.7: Looking west from the raised platform overlooking the central lawn area, fountains, and raised gardens in Market Square. The PSD ‘Prospect’ is illustrated here.*
4.2.4. Social (PSD)

The PSD ‘social’ can be achieved in a plaza by including at least three of the following characteristics: an entertainment area, a restaurant or café, market stalls, facilities, shelter from wind and sun, or adequate seating, as outlined in Table 3.1. Market Square includes three of these ‘social’ characteristics: facilities, seating, and shelter from wind and sun. The facilities are located under the raised sitting area, as shown in Figure 4.8. The facilities include washrooms/change rooms, water fountains, and waste and recycle receptacles. Seating is located under the raised platform overlooking the central grass and fountain area. Raised planters also provide extra seating in the form of seat walls. The raised structure provides an area sheltered from the sun and wind. These conditions are also minimized by the shade and street trees located on site, and by providing seating alongside the building.

Figure 4.8: The raised platform, looking south in Market Square, including seating above and below the structure, one of the raised gardens, and benches against the building. The PSD ‘Social’ is illustrated here.
4.2.5. Culture (PSD)

The PSD ‘culture’ can be achieved in a plaza area by having at least three of the following characteristics: fountains, statues, ornamental plants, structured layout, showy vegetation, or pastoral qualities, as outlined in Table 3.1. The Market Square design contains three of the above characteristics: fountains, structured layout, and a pastoral central lawn area. The fountains are located between the central lawn area and the building as shown in Figure 4.9. They are level with the ground and can be enjoyed passively from the nearby benches, or actively by running or walking through them. The site has a structured layout through pathways and elements that parallel perpendicular, or diagonal from the building. All of the spaces on site are designed in a geometric pattern, featuring triangle raised gardens and raised seating area, and rectangular walkways and central gathering areas. The central lawn has a pastoral feel by being large and expansive framed by shade trees and the fountains.

**Culture** – fountains, structured layout, and pastoral central lawn area

**Space** – A central lawn gathering area not broken up by pathways or designated recreation

**Refuge** – benches located along the building, area for active play and seating to watch in the central lawn area, open sightlines

*Figure 4.9: Looking south through the street trees at the central lawn area in Market Square including a raised seating area and fountains. The PSD ‘Culture’, ‘Space’, and ‘Refuge’ are illustrated here.*
4.2.6. Space (PSD)

The PSD ‘space’ is achieved in a plaza by having the following quality: a central gathering area that is not broken up by paths or roads and that is not specifically designated for a recreational activity, as outlined in Table 3.1. The central gathering area should also have elements that help to block sun and wind, and be well connected to the rest of the site, but is not critical to achieving the PSD ‘space’. The Market Square has a central lawn that is considered a gathering area. It does not specify any recreational activity, but could be used for light foot-traffic. It is not broken up by paths or roads but is well connected to the surrounding pathways. The building provides shelter from wind and sun, as do the large shade trees located at the end, as shown in Figure 4.9. Adjacent shade is also available beneath the raised platform.

4.2.7. Refuge (PSD)

The PSD ‘refuge’ can be realised in a plaza by containing at least two of the following characteristics: tables and benches located beside a secure structure, play equipment, area for active play an seating to watch, open sightlines and an overall safe feeling. The Market Square achieves ‘refuge’ by providing three of the above characteristics: benches located alongside the building, area for active play and seating to watch, and open sightlines, as shown in Figure 4.9. The area for active play is the central lawn area and adjacent fountains. Seating is located beside these features on a raised platform for users to sit and watch. Pathways are open and not obstructed by objects, and are at least three metres in width. Together, these characteristics create a site that has an overall safe feeling.

4.2.8. Rich in Species

The PSD ‘Rich in Species’ is achieved in a plaza if it contains both native and introduced plants with a diversity of species (at least three different species), as outlined in Table 3.1. The design for Market Square has six native species and one non-native species, as highlighted in Figure 4.10. The native species are the Red maple (Acer rubrum) located in the lawn area: the hackberry (Celtis occidentalis) as street trees: the paper birch (Betula papyrifera), and Chokecherry (Prunus virginiana)
understory trees located in the raised gardens: the red osier dogwood (Cornus stolonifera), and Yew (Taxus canadensis), shrubs located in the raised gardens and planters and the sedge (Carex spp.) located in the raised gardens and planters. The only non-native species located in the Market Square is the grass located in the central lawn area.

Figure 4.10: An entrance into Market Square, looking east, including raised gardens with a variety of vegetation. The PSD 'Rich in Species' is shown here.

4.2.9. Serene

The PSD ‘Serene’ is achieved in a plaza when it contains three of the following characteristics: a calm feeling, not crowded, clean and well maintained, does not support bikes or vehicles, or a buffer from traffic noise (Table 3.1). The Market Square contains ‘serene’ through the following characteristics: not crowded, does not support bikes or vehicles, and a buffer from traffic noise. As outlined in Figure 4.11, the pathways are at least three metres wide, ensuring that they are not crowded. Bikes and vehicles are not supported in Market Square by providing bike parking off site, and signage at all entrances. A buffer from traffic noise is provided by the raised gardens and vegetation and street trees.
Figure 4.11: The 12m wide central walkway in Market Square leading to the main entrance to the building, lined by vegetation both in raised gardens and level with the walkway. The PSD ‘Serene’ is illustrated here.

4.3. Results Summary

Covent Garden Market Square in London and Market Square in Guelph share many similarities in their design features. Both sites are focused on a central lawn area with geometric pathways leading to a main entrance area. They both contain raised gardens with a variety of vegetation. Seating through benches and tables appear in both of the sites and there is additional seating through seat walls. Both sites contain a fountain area, while the fountain in Market Square is much larger and more interactive. The main difference between the sites is in the social aspects: Market Square has a raised platform with facilities and additional seating, while Covent Garden Market feature two large areas for market stalls.

Market Square and Covent Garden Market were both able to achieve the highest level of biotopes for a plaza area. The built area in both sites is greater than the green space and they both reached 10% canopy cover. The vegetation for both sites consists of plantings in built area, raised gardens and a central lawn area. Multi-layered vegetation was achieved through a canopy cover, understory trees, a shrub layer and a field layer. Both sites have a **Serene** – not crowded (at least 3m wide central pathways), does not support bikes or vehicles, buffer from traffic noise with raised gardens and street trees.
high vegetation quality: Covent Garden Market with 74% and Market Square with 70%. After applying PSDs to the sites, it was determined that both sites were not able to achieve nature, and were able to achieve culture, prospect, social, space, rich in species, refuge and serene. The following chapter will interpret the meaning of the results and elaborate on the relationship between PSDs and biotopes in plaza areas.
CHAPTER 5: DISCUSSION

The aim of this study was to analyze the relationship between the diversity and type of biotopes in urban green space and users’ perceptions of eight sensory dimensions. The research study intended to learn if and how PSDs and biotope richness can be optimized for urban green spaces through design. The hypothesis was: 1) the richness of biotope characteristics present and the PSDs in an urban green space will show a positive relationship, and 2) PSDs and biotope richness will be variably compatible. The study did show that the richness of biotope characteristics present and the PSDs in urban green space have a positive relationship and that the two aspects are variably compatible. The discussion below will further outline the relationship between biotopes and PSDs and determine how they are variably compatible.

5.4. Merging Biotopes and PSDs

In this study, plaza areas were analyzed through experimental design by applying biotope characteristics and PSDs. The biotope ‘green space’ was used as the base for determining the sites and was further analyzed using the ‘plaza’ category of green spaces. The characteristics outlined in Table 3.2 were applied to Covent Garden Market in London and Market Square in Guelph. Once the biotope characteristics for ‘plaza’ were added to the sites, they were analyzed to determine which PSDs were present and how the design could be altered to include as many PSDs as possible. The PSDs were applied iteratively and without rank so as not to create a hierarchy between biotopes and PSD or place importance on one PSD over another. They were all considered equally at the design stage and applied to the design at the same level. This approach was considered successful as it was able to include all characteristics for the biotope category ‘plaza’ and seven of the eight PSDs. As mentioned in results, it was fundamentally incompatible to include the PSD ‘nature’ into the two plaza areas since it is not possible to include 50% vegetation into the sites under the biotope characteristics. The two plaza designs created spaces that were usable and functional while creating a biodiverse space through biotope characteristics, and a highly usable space through the seven PSDs.

The addition of biotopes to the PSD method is a fairly new approach. Many PSDs have environmental aspects that include the notion of biodiversity and nature into their success. For example, the PSD ‘nature’ requires that a site has 50% vegetation. ‘Culture’ has
ornamental plants and showy vegetation as two of the characteristics that a site should contain to achieve the PSD. ‘Prospect’ outlines that a well-manicured lawn should be included in a site, and ‘rich in species’ requires that natural and native plantings with a diversity of at least three species should be present. These are all characteristics that are directly related to vegetation and biodiversity and are supported and improved by including biotope characteristics to a site. PSDs ‘serene’, ‘refuge’, ‘space’ and ‘social’ do not have characteristics that are specifically linked to biotopes, but still contain characteristics that could be achieved and/or improved through vegetation. For ‘serene’, using street trees or dense vegetation at the edge of a site can create a buffer from traffic noise, as shown in both of the designs. For ‘refuge’, the central lawn area in both sites acts as an area for active play and also adds to the level of vegetation on site. Similarly, for ‘space’ the central lawn area acts as a central gathering area that is not broken up by paths or roads while adding to the level of vegetation. Lastly, for the PSD ‘social’, large shade trees in the central lawn area in both of the designs, and the street trees in the Market Square design, create shelter from wind and sun while adding to the level of biotope characteristics on site. While these PSDs do not necessarily require vegetation to be achieved, including vegetation in the design strengthens and accomplishes some of their characteristics, which in turn reinforces the PSD and biotope characteristics simultaneously and strengthens the research through providing two sets of data.

When research comes from a single set of data, results are subject to single source bias. This is especially prevalent with perceptions, as they are from subjective and from a single user. By introducing two sets of data collected with multiple sources (biotopes and PSDs), it strengthens the relationship and produces more accurate results. This is further outlined by De Jong et al. (2011), who stated that perceptions, used together with an objective assessment, can enhance validity in a study. Using PSDs and biotopes simultaneously creates a site with two variables and produces a successful tool for designing and assessing both vegetation and experiences in urban parks.

5.5. Applying Biotopes to Landscape Design

Biotopes were used in this study as a means for preserving and enhancing urban biodiversity while providing opportunities for how the space is used socially. The highest level of biotope characteristics were successfully applied to both Covent Garden Market and
Market Square achieving a high percentage of and multi-level vegetation and a high percentage of native species. The characteristics outlined in Table 3.1 were a successful tool for applying this vegetation to a plaza area while still maintaining a functional space. The results outline that with the highest level of biotope characteristics for a plaza area, seven of the eight PSDs existed. This is in line with Qui and Nielson (2015), who concluded that the more diverse biotopes an urban green space encompasses, the greater the number of sensory dimensions that were highly experienced. They also suggested that the diversity of PSDs of an urban green space is influenced by the number of biotope characteristics. The research conducted by Qui and Nielson (2015) adds validity to this study, which concluded that the richness of biotope characteristics present and the PSDs in an urban green space have a positive relationship and the two components are variably compatible.

After the biotope characteristics were applied to the site designs, PSDs were analysed to determine which were present and how the site could be altered to ensure as many PSDs were present as possible. While looking at the PSD ‘nature’, it was determined that fundamentally, it could not work with the biotope characteristics for plaza. However, as Qui and Nielsen (2015) outlined, biotope characteristics are a tool for enhancing urban biodiversity. With this in mind, the PSD biodiversity could be further increased and ‘nature’ should be able to exist within a plaza area by having 50% vegetation. After designing vegetation in the sites for Covent Garden Market and Market Square, it was determined that Covent Garden Market had 24% vegetation and Market Square had 30% vegetation. Both of these results are far from the level of vegetation that nature requires, but show that it is possible to have relatively high levels of vegetation in an urban plaza, and are much greater than the existing vegetation levels found on site today. Further studies should be done to determine whether 50% vegetation can be present in a plaza area while still maintaining a highly functioning and enjoyable site, and whether the biotope characteristics should be altered to include vegetation cover instead of solely focusing on canopy cover.

5.6. Applying PSDs to Landscape Design

PSDs were used in this study as a means to value the social aspects of plaza success and monitor how a site will be used. They cover all social aspects of urban parks and their characteristics provide a thorough image of how the PSDs can be applied. Of the PSDs, nature, culture, prospect, social, space, rich in species, refuge and serene, nature was the
only PSD not achieved. Of the PSDs achieved, each had different characteristics, and number of characteristics, that it should contain to be achieved in a site. Looking at how many of the characteristics for each PSD were present will show the strength of each PSD in both Covent Garden Market and Market Square and help to determine whether the PSD approach is a fitting in determining whether PSDs are a reliable tool for urban green space assessment and planning.

- Nature was not achieved in both of the sites as it requires 50% vegetation on site, which does not fit with the biotope characteristics for ‘plaza’.
- Culture was achieved in both of the sites: it had five of the six characteristics for Covent Garden Market Square and three of the six characteristics for Market Square.
- Prospect was achieved in both of the sites: it had three of the five characteristics for Covent Garden Market and two of the five characteristics for Market Square.
- Social was achieved in both of the sites: it had three of the six characteristics for both Covent Garden Market and Market Square.
- Space was achieved in both of the sites as they both contained the only characteristic necessary for this PSD.
- Rich in species was achieved in both of the sites by ensuring that both sites have at least three different vegetation species: Covent Garden Market had four and Market Square had six.
- Refuge was achieved for both sites: it had three of the five characteristics for both Covent Garden Market and Market Square.
- Serene was achieved for both of the sites by having three of the five characteristics.

The seven of the eight PSDs that are present in both of the sites successfully achieve an adequate amount of characteristics present as outlined in Table 3.1. However, some of the PSDs have achieved more characteristics than necessary, which could imply that that PSD is stronger than others on site. Similarly, some PSDs might be present, but offer a weak connection. In Covent Garden Market the site achieves the PSD ‘social’ by having an area for market stalls. However, due to the climate in London, Ontario, outdoor markets are seasonal and will not necessarily be on site year-round. Without market stalls, the Covent
Garden Market design does not achieve ‘social’. Also, when looking at the PSD ‘rich in species’, it requires that three species be present on site. This is a relatively small number, which could result in a comparatively weak presence of ‘rich in species’. This is in line with previous research that concluded that previous studies focus on social issues in design with little attention given to the vegetation structure or ecological conditions of the site (Grahn and Sorte, 1985 and Van Herzele, 2005, de Jong et al., 2011, Pershardt et al., 2013). While using PSDs is a successful tool to measure social aspects of an urban plaza, more research needs to be done to elaborate on the characteristics for each PSDs and determine an operationalized system for determining the strength of each PSD in a site.

5.7. Designing via Principles

To create the designs in Covent Garden Market and Market Square a set of design principles was generated as a guide for design. The principles were based on the biotope table created by Qui and Nielsen, (2015) and a PSD table created by Perschardt and Stigsdotter (2013). The tables were used as firm design principles to ensure the sites would have equal guiding values and could be easily replicated in future research. Without these tables, it is possible that the designs would have had features that favoured one PSD over another. It also would have been hard to analyse the designs to determine which PSDs and levels of biotopes were achieved and whether the sites were successful in designing for biodiversity and usability. They encouraged better designs by allowing the sites to have achievable goals with definitive outcomes.

While the principles were critical in creating the designs in Covent Garden Market and Market Square, it can be argued that they hindered the creativity of the designer. With set principles in place, there was not much room to stray from the outlined characteristics to ensure that the highest level of biotope characteristics and the most PSDs possible were achieved. However, the PSD principles did provide for some flexibility, as not every characteristic had to be achieved for the PSD to be present. The two designs were not created completely equal and used different characteristics to achieve PSDs. For example, Covent Garden Market had tables, shelter from sun and shade, and market stalls to achieve social. Market Square also had tables and shelter from sun and shade for social, but it contained facilities instead of market stalls to achieve the PSD. While the principles created some restriction for creativity, they allowed for enough flexibility to create spaces that were
unique while maintaining high levels of biotopes and PSDs.

5.8. Limitations

Both PSDs and biotopes are a relatively new idea in application to urban green spaces and using them as a design tool to analyse success. There is limited research on both topics, and especially on the two topics together. Qui and Nielson (2015) were the first to apply PSDs and biotopes in urban green space and use them as a tool to determine the structure of green spaces and how they are used. Additional research will aid in further developing the characteristics for biotopes and PSDs and allow them to be a valuable tool to enhance urban biodiversity while creating enjoyable and functional spaces for the user.

Due to time restraints, the only biotope examined was ‘green space’ and the only green space category examined was ‘plaza’. Ideally, more green space categories would have been designed and developed to analyze how biotopes and PSDs interact in different green spaces. The biotope category ‘plaza’ is the smallest in size of the green space categories. Looking at an open green area, a partly open green area, and a partly closed area, would have allowed PSDs and biotopes to be analyzed on a larger scale and determine how they relate to sites that do not consist of largely built area (hardscapes), as is the case with the category ‘plaza’. Future research should look at biotopes and PSDs and how they interact in other green space categories to affirm that there is a positive relationship between PSDs and biotopes in urban green spaces.
6. CHAPTER 6: CONCLUSIONS

This study has examined if the diversity and type of biotopes in an urban green space and users perceptions of eight sensory dimensions have a positive relationship. PSDs and biotope richness were optimized for urban green spaces through design by simultaneously introducing the two attributes to plazas in Southern Ontario. The richness in characteristics of biotopes and PSDs present in an urban green space are variably compatible, as demonstrated through experimental design. The sites were chosen based on a set of criteria created through literature review to ensure the sites could be easily replicated in other Southern Ontario cities.

Designs were created for Covent Garden Market in London and Market Square in Guelph by introducing the highest level of biotopes possible for the biotope category ‘plaza’. The highest level of biotope characteristics was successfully achieved to create a site that features different levels of vegetation and a high level of biodiversity. The designs were analysed to determine the PSDs already present in the sites and how they could be altered to create a space with the most PSDs possible.

Aside from nature, seven of the eight remaining PSDs (culture, prospect, social, space, rich in species, refuge and serene) were achieved in both of the sites. The designs were critically reviewed to determine conflicts and synergies between PSDs and biotope characteristics within the sites. It was determined that within these sites, all PSDs except for nature had a positive relationship with the highest level of biotope characteristics for the category ‘plaza’. This study has been successful in determining how biotopes and PSDs can be used together to design a highly functioning space. The two designs showcase urban plazas in Southern Ontario with high levels of biodiversity as determined through biotope characteristics, and highly usable, as determined by the PSDs.

With the increase of densification in cities the need for improved biodiversity is important. Human populations are ever increasing and cities are expanding causing a decrease in per capita space, resulting in a loss of green space. Human population density and extensive impervious surfaces are two important factors that define a city and are directly related to ecological and environmental characteristics of a city. With this increase in densification, urban green spaces are not always considered at the design phase, causing ecological functions to falter. Green spaces not only create spaces for biodiversity
in cities, but also create restorative spaces for human interaction. They connect everyday users to restorative and social spaces to interact with nature. However, there was a gap in knowledge on how social and ecological factors interact in urban green spaces and how they can be used to create successful urban parks.

This study showed how PSDs and biotopes can be present at the design phase to ensure green spaces are beneficial to the user as well as the environment. Integrated design through using multiple layers creates a built space that is environmental, social, economic, and cultural. Incorporating PSDs and biotopes achieves a more sustainable design for green spaces and cities as a whole. Integrating research methods from different fields such as geography, environmental psychology, sociology, landscape ecology, and urban planning and design creates a study with strong and clear research results leading to a healthier and usable urban space. The concept of incorporating PSDs and biotopes creates a foundation for social and environmental scientists to develop a new concept and creates an understanding that will lead landscape architects to make stronger decisions about green spaces in cities.

The use of PSDs and biotopes is a relatively new concept when using them as a tool for landscape design. Further research should be conducted to develop the characteristics of PSDs and biotopes and create a more functional operational system. The characteristics table created for PSDs, first created by Perschardt and Stigsdotter (2013) and applied through this study should be even further expanded to create a more operationalized system. The characteristics and definitions are well outlined but further research will create PSDs that are more definitive and create stronger dimensions in urban green spaces.

The biotope ‘green space’ should also be explored additionally in further research to analyze areas outside of the category ‘plaza’. Due to time restraints, ‘plaza’ was the only biotopes category that was explored in this study. There are five different categories under the ‘green space’ biotope that represent different areas found in the cities. ‘Plaza’ is a unique category as it is the only one that requires that the site has more built area than vegetated area. The other categories (open green area, partly open green area, partly closed green area, and grove/clump of trees/thicket/tree belt or avenue) all contain equal or higher requirements for canopy cover, and fewer stipulations on vegetation cover. These categories should be further explored to determine how PSDs and biotopes interact in the
sites and confirm whether they are in fact an appropriate tool in green space design. This would allow for the PSD and biotope relationship to be analyzed on different scales and in different scenarios and add validation to the hypothesis presented in this study.

Landscape architects and urban designers can use PSDs and biotope levels to design more effective urban green space plazas. While this approach found some limitations, they were only limited challenges and more synergies between PSDs and biotopes were found. This concludes that these principles are principles and appropriate and successful tool as landscape design guides. This demonstrates that landscape architecture can achieve more-sustainable urban plaza designs when building from evidence from within and beyond the landscape architecture professional and disciplinary base.
CHAPTER 7: REFERENCES


Van Herzele, A., 2005. A tree on your doorstep, a forest in your mind. Greenspace planning at the interplay between discourse, physical conditions, and practice. Published Dissertation. Wageningen University, Wageningen.
