This thesis introduces concepts of ecological design that guide the process-based framework I have developed to restore and create ecological urban landscapes.
Abstract

Conventional urban growth tends to happen irrespective of environmental context, causing the degradation of ecologically functional and diverse landscapes. This trend separates people from native ecological processes and the inherent benefits they provide (McHarg 1969). Urban systems become unsustainable by failing to incorporate the economic, cultural and ecological values of natural features, relying instead on outsourced energy and high-maintenance infrastructure. In contrast, concepts of ecologically supportive landscapes inspire the design and growth of cities in alignment with natural features. Recognizing the value that increased green space has for the improvement of urban ecologies, this thesis focuses on the restoration of existing natural features to sustain local ecologies and cultural connection to the landscape.

Restoring and enhancing natural features can help society understand that cities are not built upon a blank slate, but are part of a functional ecological landscape (Beatley & Manning 1997). Urban settings that utilize natural processes and express aesthetic qualities of nature demonstrate cultural awareness of environmental context. These visual cues build a sense of place by connecting people to the local ecology, which is the key to sustaining the integrity of local natural landscapes across the globe. With this thesis I introduce an adaptable framework through a case study of Copenhagen, Denmark, that municipalities may use to evaluate and design ecological urban landscapes. This framework defines ‘systems of nature’ based on trends that support landscape identity, providing site-specific interventions that inform local and systemwide restoration efforts.

Keywords | place-based urban landscapes, ecological restoration, contextual systems of nature, ecological matrix, native cities, Copenhagen, Denmark
Preface
With the health of and cultural connection to natural landscapes threatened by environmental degradation, I am motivated as a designer to restore the ecological integrity of urbanized landscapes. I spent my childhood in Missouri’s forested countryside and my last four years studying Environmental Design in the foothills of Boulder. This lifelong exposure to nature gives me personal insight to the role that the landscape plays in our development as individuals and our future built environments. My study abroad experience in Copenhagen further influenced my interest in the ways cities express connections to nature. While studying Urban Design, I learned about the city’s landscape-oriented development plan, walked along the foggy waterfronts, biked and jogged along the green corridors, watched the deer nibble in the fields of Deer Park, and rode the trains out into the vibrantly colored countryside. I am captivated by the innate sense of place these natural features seem to bring to the city, and curious as to how they support local ecologies that characterize the native landscape. The idea of native cities, environments where people recognize a place based on its identity to the natural landscape and feel at home because of it, is what has compelled this thesis and my pursuit as an environmental designer.
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I am grateful to an amazing group of people who have inspired me to pursue a career in restorative ecological design and have made my honors thesis project possible. Thanks to Tori, my honors thesis advisor, for her unwavering confidence and support, and for all of her effort and time spent shaping me over the past four years as a designer and researcher. She is so incredibly compassionate and inspires me to be so. Thanks to my most wonderful sidekicks in Copenhagen, Michalla Friis, Copenhagen native, and Erin Swaney, CU Environmental Design student, for their willingness and enthusiasm to photograph my five study sites. To Ryan Wakat, for his stunning photos and constant encouragement. To my Danish instructors Courtney Coyne Jensen and Bianca Hermansen for educating me with their knowledge of Copenhagen’s urban design strategies. To Georgia Lindsay for her amazing dedication to me and to my fellow ENVD honors students, and for guiding us with her personal research experience. Thanks to Sharon Collinge, my secondary advisor, for her compelling feedback throughout the course of my project. Thanks, most of all, to my family. Grandpa David, for his role in shaping the Environmental Design Program into a perfect fit for me, and for encouraging me to study in Denmark to discover my Danish heritage. Thanks to my incredibly loving parents for their faithful support, and for my childhood of rolling in the grass and jumping on horse backs, completely immersed in nature.
Introduction

Our perception that humans are separate from nature has led to the design and planning of cities irrespective of their environmental context. The resulting urban systems rely on outsourced energy and high-maintenance infrastructure instead of natural processes that support local ecosystems. In contrast, design can preserve and restore natural landscape features and the ecological, functional, and cultural benefits they support (Austin 2014, Beatley 2008, Beatley & Manning 1997, Forman 2014, McHarg 1969). In cities that sustain local ecosystems, people can connect to their native aesthetics and ecological services that improve qualities of urban life (Astbury 2013). This ecological literacy fosters an awareness of the wider landscape and strengthens the city’s sense of place (McHarg 1969), which is necessary to promote the development and growth of cities based on bioregional health (Newman & Jennings 2008). The cultural basis of urban ecological design is discussed in Ecological & Cultural Connection to the Landscape. Designing cities to support local ecosystems means both increasing green space as well as acknowledging and improving natural features that already exist (Beatley & Manning 1997, Forman 2014). Through the Lens of Copenhagen introduces the latter concept in the context of nature in Copenhagen.

In the Framework to Strengthen Urban Ecological Systems I apply the method I have developed of revealing trends to suggest interventions that would improve ecological health. This framework involves GIS mapping and identification to investigate nature based on qualitative information. Images, personal on-site experience, and reports provide this contextualization, which I then represent graphically. My intention is that teams of designers, planners, and ecologists can interpret these graphics for the strengths and weaknesses of each area, and overlay them to reveal trends of ecological and cultural connection across the city. This information can guide the restoration and reintegration of natural features into local communities and regional ecology.
Design with the existing ecology as functional and aesthetic inspiration to create urban landscapes that foster ecological literacy and a sense of place.
Place-Based Urban Landscapes

Landscape architects, designers, and planners within the last 50 years have led initiatives to restore natural landscapes within cities. The work of Richard T.T. Forman and Ian McHarg has defined landscape ecology as a guide to design urban environments based on physiographic features and biological patterns (Forman & Godron 1986, McHarg 1969). The practices of landscape and ecological urbanism, biophilic design, and regional environmental planning incorporate nature into cities to support ecosystem services that create functional and livable landscapes (Beatley 2008, Corner 2006, Forman 2014, McHarg 1969, Newman & Jennings 2008, Waldheim 2006). People can visually connect these benefits with regional ecosystems. This cultural connection develops ecologically-minded communities who take measures to sustain the wider bioregion by restoring nature within the city.

The diagram above moves through the process of creating place-based urban landscapes, beginning with the restoration of natural landscape features. This supports natural ecosystem services and creates visual identity, which both inspire and develop ecologically minded communities. Cultural awareness leads to planning and design decisions that help sustain the bioregion, thus rooting urban landscapes in place.

Ecological Restoration

- supports ecosystem services & visual identity
- develops ecologically minded communities
- & sustains the bioregion

Creating Place-Based Urban Landscapes
Restore natural landscape features

Modern cities are problematic in that they underutilize the landscape’s natural, life-sustaining processes that once defined the form and livelihood of civilization. Forward-thinking urban planners, designers, and ecologists are working to restore this interaction with local ecosystems (Beatley & Manning 1997, Corner 2006, Forman 2014, McHarg 1969, Sanderson 2009, Waldheim 2006). More than simply raw materials to be consumed on a global scale, natural landscapes create diversity with their richness of sustenance and cultural inspiration. They perform organic processes that cleanse the planet and produce habitable, complex environments. By restoring natural features we can sustain these processes and benefit from their life-enhancing qualities. This vernacular approach is a solution to restore our connection with natural processes and improve ecological and societal health (McHarg 1969, Seamon 1993). The study of local landscape ecology is thus a means for sustainable, place-based urbanization (Forman & Godron 1986, McHarg 1969).

Create visual identity

Ecological literacy develops through a presence of distinct forms, flora, and fauna that people can identify to the region’s native ecosystems (Beatley 2008). Preserving these systems as part of the city (e.g., mature forests, wetlands, riparian zones) creates areas for native biodiversity to exist, thus supporting visual identity. A patchwork of waterways and green space nurtures wildlife by enabling navigation throughout the city in connection with the wider bioregion, making the city accessible to beneficial species such as pollinators who improve ecological health (Beatley & Bekoff 2013, Ignatieva et al 2011). Although non-native species exist, the presence of native communities is important for visual consistency and for interspecies interaction across the region. These interrelationships improve the city’s resilience against invasive species that threaten unique native ecologies, displace wildlife, and diminish beneficial natural processes (ASLA 2003).
Support ecosystem services

Urban fabrics shaped in response to landscape features benefit from ecological processes that absorb pollution and provide natural resources, thus reducing strain on the wider bioregion (Austin 2014, Beatley & Manning 1997, McHarg 1969). Connection and diversity across the urban fabric are necessary to sustain these ecological services (McHarg 1969, Sanderson 2009). A multifunctional green infrastructure of open space, parks, greenways, and riparian waterfronts supports connectivity and ecological flow, with traceable economic savings (Austin 2014, Astbury 2013, McHarg 1969, Forman 2014). These natural areas improve urban resilience and livability through temperature regulation, carbon sequestration, stormwater detention and filtration, food production, and mitigation of natural disasters and climate change (Beatley & Manning 1997). They also provide refuge for wildlife and community space for gathering, recreation, and educational programs (Astbury 2013, McHarg 1969).

Develop ecological communities

In natural ecosystems, organisms rely on the physical environment for their survival. This sensitivity towards place defines *oikos*, latin for “eco”, meaning home (McHarg 1969). The basis of urban ecological design is to restore this connection between urban systems and the local ecology. Natural areas in the city make visible the processes upon which communities rely, as well as the impact urban activity has on ecological health (Astbury 2013). Environmentally conscious communities and the larger municipality can lead efforts to protect and restore ecosystems in order to preserve cultural identity and the resources and experiences they provide (Astbury 2013, Beatley & Manning 1997).
Sustain the bioregion

Aligning urban form with natural landscape features helps sustain bioregional health by protecting beneficial ecosystem services (Austin 2014, McHarg 1969, Sanderson 2009, Waldheim 2006). Bioregional planning recognizes the natural ecological capital of a landscape (e.g., abundant forests, healthy riparian areas, thriving shorelines) that provide these services and habitat for native species (Beatley 2012, Beatley & Manning 1997, Newman & Jennings 2008, Vejre 2010). Reversing the trends of globalization, cities are unique to the surrounding bioregion when characterized by the native flora and fauna that define local ecosystems (Beatley & Manning 1997). Urban ecological design can support the presence and performance of a landscape’s ecological capital within the city, helping to 1) reduce outsourced energy (Beatley, 2008, Beatley & Manning 1997) support peoples’ connection to the ecology and a cultural sense of home (Astbury 2013, Beatley & Manning 1997, McHarg 1969), and 3) restore and connect the urban ecology to the wider bioregion (Forman 2014, McHarg 1969).
Ecological & Cultural Connection to the Landscape
Through the Lens of Copenhagen

Nature in the city is a gradient of areas with ecological value commonly measured by spatial factors of size, distribution and connection (Forman 2014, Forman & Godron 1986). This thesis focuses on classifying systems of nature within the city based on qualitative factors that strengthen ecological health and cultural connection to nature. I combine GIS mapping, on-site experience and photos, and reports on ecological context to comprehend levels of diversity, variation, access, and cultural elements of identified areas. I then translate this qualitative information into a matrix that represent values across the urban fabric of Copenhagen. Designers can develop interventions based on this matrix format that will improve ecological health across natural systems, integrating the city as part of the wider natural landscape.

A central strategy of the Melbourne Principles for Sustainable Cities is connecting urban form with the wider bioregion to help balance societal demands with ecosystem health (Newman & Jennings 2008). Urban development that allows finger-like patterns of open space to exist within central, more densely populated areas is considered “perhaps the broadest conception of natural process in metropolitan growth and metropolitan open-space distribution” (McHarg 1969: 65). The City of Copenhagen exemplifies this pattern of urban development (Beatley 2012, McHarg 1969, Newman & Jennings 2008). The Urban Planning Act of 1938 strengthened the city’s comprehensive combination of open space preservation and transit-oriented development. The current “Finger Plan” has guided radial lines of development between wedges of preserved forested land that support ecological connectivity within the city (Beatley 2012). Similar to patterns that define natural landscapes, this ecological patchwork facilitates regional flows of nutrients and wildlife, supporting ecological services and cultural connection to the landscape (Beatley 2008, Forman 2014).
Copenhagen’s comprehensive Finger Plan has guided radial lines of development out from the city center. This pattern has allowed open space to exist in more central locations of the city, thus improving overall bioregional health by increasing connectivity and ecological flow across the city (Beatley 2012).

(Danish Ministry of the Environment Geodata Board a & b 2013)
Locations 1 through 36 are identified by Copenhagen’s Technical and Environmental Administration as part of the urban ecology, as well as areas that I have included based on my experience and further research of landscape and urban design in Copenhagen (City of Copenhagen a 2012).

(Danish Ministry of the Environment Geodata Board a & b 2013)
Copenhagen’s Technical and Environmental Administration recognizes the importance of an ecological patchwork for wildlife to navigate the city between large, preserved natural areas, and for ecological benefits at a neighborhood scale. The Administration distinguishes “bynatur,” meaning urban nature, and “bynære natur,” meaning peri-urban nature (City of Copenhagen a 2012). Bynatur functions primarily for recreational use and contrasts with urbanized settings. Often isolated from other patterns of vegetation and water, these areas receive less regional influx and necessitate human intervention. Bynatur creates ephemeral interactions between urban dwellers and the wildlife that find refuge and migrate across the urban fabric. Bynære natur identifies areas that share a closer resemblance and proximity to the surrounding natural landscape. Programmed less for recreational use, these large areas have a higher capacity for biodiversity. These areas support native ecosystems and both permanent and migrating wildlife, thus bringing the natural environment and its colors into increasingly urbanized zones (City of Copenhagen a 2012).
Preserved and restored natural areas support native species habitat and migration and help people associate the city with the local ecological landscape. Wildlife adapted to Copenhagen’s inner city conditions and modified coastal areas include squirrels, bats, and a variety of birds including the swan, common swift, sparrow hawk, kestrel, house sparrow; as well as little, Arctic, common, and Fjord terns. Squirrels are prominent in the city (although not on the eastern island of Amager) and find habitat in parks, gardens, cemeteries, and urban forests with coniferous and deciduous trees (City of Copenhagen a 2012). Wildlife in the outer districts and interstitial open areas of Copenhagen include squirrels, foxes, hedgehogs, and a variety of bats (such as the water, troll, dwarf, brown, and mold-bat) who live in the city during the autumn and winter months and migrate outward for the summer. Several birds are known to breed and migrate across the outer districts, including the cormorant, grey heron, graylag goose, bittern, marsh harrier, black-headed and other gulls, the great spotted woodpecker, and the Eurasian penduline tit (City of Copenhagen a 2012).

Certain species are more sensitive (due to size and habits) and require larger areas of bynære natur. For example, hedgehogs are vulnerable to traffic, and deer live in herds and require more space and resources to survive. Areas of bynære natur are also home to the fox, Denmark’s main predator in place of the nearly-extinct wolf, that helps maintain population balance. A variety of reptiles and amphibians (including the snog snake, the green toad, moor frog, newt, water salamanders) and insects (butterflies in particular) need a range of vegetation and aquatic habitat conditions in order to survive. Priority species of plants that support these and other species of wildlife and are identifiable to the Danish landscape include the riparian saw-wort, willowleaf yellowhead, the widespread marsh orchid, and large broomrape (City of Copenhagen a 2012).
Ecologically indicative colors visually connect nature within the city to the wider landscape, and their appearance in building color palettes expresses a cultural consciousness of the local environment (Lange 1997, Porteous 1996). In addition to color as a visual indicator, texture and form demonstrate ecological diversity and species richness, indicating a navigable urban ecosystem (Forman 2014). Complex plant communities supported by varying surface conditions create habitat for a diversity of aquatic, terrestrial, and aerial wildlife. Greater natural surface area (e.g., vegetation, organic matter) and variation in topography within these habitats provides a platform for rich ecologies and the services they provide, including pollution metabolism and storm mitigation (Beatley 2013, Forman 2014). The transition between areas of nature and the surrounding urban context determines access and visual connection to these processes, either encouraging or limiting cultural associations with nature.
Through this process of conceptualizing nature in Copenhagen, I have developed a method for cities to guide design interventions that improve the quality and function of existing ecologies. Doing so creates visual identity to the wider landscape and connectivity across the bioregion.

Two main perspectives distinguish this work: 1) Whereas increasing green space is a common approach of nature-oriented design (Beatley & Manning 1997), my thesis focuses on the restoration of existing natural features to improve the quality of urban ecologies. 2) In the fields of Landscape and Urban Ecology, the term ‘system’ normally refers to spatial networks (Forman 2014, Forman & Godron 1986, McHarg 1969). My thesis introduces ‘systems of nature’ to be based on shared qualities that support landscape identity.

I apply this adaptable framework to Copenhagen to show how different types of nature in the city currently support connections with the wider bioregion. The first phase produces specific interventions for the different areas I chose to investigate. The second phase produces system-based interventions that are focused on improving multiple areas and are driven by similar restoration goals.
This framework guides ecological design interventions to improve the quality and function of a city’s existing natural landscape. I have provided a case study of Copenhagen that includes both detailed and generalized descriptions of each step to allow for the adaptation of this process to different cities and scales. This study explores how different types of nature in Copenhagen currently support connections with the wider bioregion.

To begin the process, mapping provides a base analysis of nature in the city. Areas for investigation are then defined and contextualized through visual analysis and documentation. These layers of qualitative information are combined into a matrix that can be overlaid to reveal trends across the system. This information enables designers to develop a system-based approach guided by site-specific suggestions.
Steps Applied to Copenhagen

1 Map | A system-based investigation of nature in an urban context is necessary for municipalities to improve the overall ecological health of these areas. Mapping produces a base analysis of water and vegetation features that can provide habitat and cultural connection, especially where they overlap (Forman 2013). I developed the map ‘Natur i København’ (pages 11 and 12) using nature analysis datasets that include water bodies, rivers and canals as well as forests, nature reservations, parks, and open space (Ministry of the Environment Geodata Board a & b 2013). Framework users can work with similar municipal datasets to begin contextualizing the health of natural features. I considered the Ministry’s designation of overall ecological status for water systems as ‘high’, ‘moderate’, and ‘low’, and interpreted the ecological status for vegetation based on each layer’s potential for ecological diversity, as ‘high’ for forests, nature reserves, and open space, ‘moderate’ for parks, and ‘low’ for farmland (McHarg 1969).

2 Identify | This base analysis enables the identification of natural areas with certain spatial and ecological qualities. I cross-referenced the map ‘Natur i København’ with my own photos and individual site reports to select five areas that represent a range of ecological conditions. The map on page 19 shows how Deer Park, Vestvolden, the Inner Lakes, Amager Beach Park, and Charlotte Garden vary in terms of scale, form, location, and ecology. Whereas I selected a range of conditions, many different definitions of nature can be used to apply this framework. Examples include particular form or scale; type of ecology (e.g., forest, plains, marshland); habitat that supports a particular species; distribution throughout the city or along a transect for a comparative study; bynatur or bynære natur; proximity to the city center (e.g., inner city parks); by district (e.g., urban center and surrounding neighborhoods), which can be combined for a citywide analysis. The Site-Specific Profiles depict the ecological conditions at each place in order to inform systemwide interventions.
I selected Deer Park for its large size and variety of ecosystems that it holds, Vestvolden to represent Copenhagen’s fortifications that now support artificial ecologies, The Inner Lakes for their central location and role to support urban wildlife, Amager Beach Park for a look at a coastal ecology with recreational activities that happen on the shore, and Charlotte Garden because it is a relatively new courtyard design that celebrates the coastal ecology.

(Danish Ministry of the Environment Geodata Board a & b 2013)
A combination of qualitative sources can be used to develop realistic ecological profiles of identified sites. To contextualize areas for this study, I have used images\(^1\), reports from the city’s several environmental departments\(^2\), and both my own experience and class lectures while in Copenhagen. I chose to look at six specific indicators because they represent ecological function and are what people see and connect with the natural landscape. They can also be captured through images that have made my off-site analysis possible. These indicators include access for both people and wildlife; surface variation that supports ecological diversity; qualities of water and vegetation; color for species richness and cultural expression; and native biodiversity. Conditions that demonstrate health sustain functioning ecological services and visual identification of these areas to native ecologies. The next step involves measuring and translating this qualitative information into a visual format to evaluate overall site health and determine necessary intervention.

\(^{1}\)Site images were captured personally and through collaboration with colleagues within the last two years.

\(^{2}\)Resources include a study of ecological areas in the city prepared by Copenhagen’s Technical and Environmental Administration (City of Copenhagen a 2012), the Danish Ministry of the Environment’s Nature Guide (Danish Ministry 2014), and specific descriptions of Charlotte Garden (SLA 2004, Särnsjö 2009).
Designers commonly use the method of overlaying geospatial information in order to analyze physical attributes and make decisions (McHarg 1969). I have adapted this idea to create ecological matrices that represent layers of contextual information to provide an evaluation and communication tool for designers. These matrices show overall ecological health and can be used to compare different areas of nature and define systems based on qualities that they share. I have developed one for each of my five study areas to represent the information that is elaborated in each site profile. Each point along a matrix line reflects a stand-alone degree of this particular quality. This enables comparison of each quality across the sites. This method is represented by the five matrices above. For instance, Deer Park, Vestvolden, and the Inner Lakes are highly accessible, more so than Amager Beach Park and Charlotte Garden. The latter two and Deer Park are richer in terms of color palette and cultural expression. The filled area of a matrix represents the combined contribution of these qualities to the site’s ecological and cultural value; thus, the broader the fill the better. The red zone indicates a degree of necessary ecological intervention and prioritizes areas to focus on improving.
Step 5 develops a composite of site-specific analyses in order to apply the framework at a city-wide scale. This step of overlaying matrices can guide intervention and help prioritize ecological restoration goals. The matrix above is a composite of the matrices for each of my study areas in Copenhagen, revealing similarities across sites in terms of ecological health, as well as common areas in need of improvement that are represented by the red zone. The strategy used to carry out these improvements within each site will vary depending on context (e.g., water quality improvement for the more naturalized setting of Amager Beach Park versus the engineered Inner Lakes). These specific interventions are guided by the suggestions listed within each site profile. The next section of Site-Specific Profiles precedes this type of Composite Matrix (above) and Profile which I have developed to represent nature in Copenhagen (pages 49 - 53).
Site-Specific Profiles

Deer Park                Vestvolden                  The Inner Lakes          Amager Beach Park       Charlotte Garden

(Google Earth 2013)  a  b  c  d  e

The following profiles demonstrate the contextualization process for these five areas of urban nature. Each profile describes ecological services and cultural connections that are supported by qualities of access, surface variation, water, vegetation, color, and biodiversity. These ecological indicators are detailed and illustrated by corresponding images on each page. For each site-specific matrix I have taken into account this qualitative information and the designations prescribed by the GIS data on the site identification map (page 19). I have derived my suggestions for intervention based on the red zone within each matrix.
Ecological Services & Cultural Connection

Deer Park is a 1.5 square kilometer historical relic of Copenhagen’s once abundant natural landscape with a variety of habitat conditions that support both prevalent and sensitive wildlife. A large deer population still remains after King Christian VI preserved this area in 1617 as hunting ground. Deer Park has a long cultural history and is a popular attraction for its various monuments, including the ancient Viking burial mounds that are scattered throughout the landscape and Eremitageslottet (Hermitage Palace), a small castle regularly frequented by Denmark's Queen (Danish Ministry 2014).
ACCESS
Gravel pathways and roads accommodate cultural activities and leave large portions of mature forest, open plains, and marshland largely untraversed by people. These sections of habitat make Deer Park livable for larger species that need wide areas with abundant resources of food and shelter. Species that are sensitive to human interaction can find refuge in more secluded areas. A patchwork of green space increases connectivity between Deer Park the large Furesø Lake and stretch of forested area called Nørreskov to the west. These three areas contribute to the fingers of nature that increase ecological connectivity across the interlacing fingers of urban development (Danish Ministry 2014).

SURFACE VARIATION
Historic glacial movement created the undulations in this landscape that make Deer Park ecologically diverse. Small valleys support marshland habitat that are surrounded by hilly, forested terrain and open plains that are dotted with patches of moor grass. The pathways and roads are semi-permeable gravel, reducing impacts of runoff (Danish Ministry 2014).
WATER

Low areas carved out by glaciers have filled in as lakes and marshland with gradually sloping edges. These conditions support transition zones of vegetation that provide habitat for a variety of riparian species and insects. Increased ecological diversity attracts greater numbers of migrating species who are attracted to these areas. Mølleåen (Mill River) runs from the northwestern corner through the park and empties into Strandmøllen Sound. Its ‘moderate’ ecological designation is most predictably a result of Rådvad Dam, which reduces nutrient and biological flow along the river (Danish Ministry 2014).

VEGETATION

The dense oak and beech forests of Deer Park are dotted with conifers and hollow, old growth trees that provide breeding areas for bats and resting spots for migrating birds. The forest, plains, and marshland ecosystems provide an abundance of resources that support biodiversity. The deer feeding on leaves, small plants, and young trees continually alters growth patterns in the park. In the springtime people anticipate blankets of the small white anemone flower to cover the forest floor, and over 300 different species of mushrooms throughout the year (Danish Ministry 2014).
COLOR

Richness in color across Deer Park demonstrates high levels of ecological diversity. A spectrum of greens and reds color the leaves and bark of the birch and oak stands. The variety of structural forms indicates species diversity, providing several different habitat types. Tufts of golden moor grass spot the plains, resembling the natural danish plains landscape.

BIODIVERSITY

Deer Park is a major contribution to the ecological integrity of Copenhagen for its great size and ecological diversity. As its name suggests, Deer Park supports a significantly large population of approximately 1600 fallow deer, 300 red deer, and 100 sika deer (native to Asia). A lack of predator species has allowed the otherwise outbred gene of albinism to characterize the herd. With room for large, quiet areas, priority species such as hedgehogs and the fox potentially find habitat here. Woodpeckers and bats can be spotted in the forests, and aquatic species such as frogs, great crested newt, and the rare fairy shrimp live in the shallow waters (Deer Park 2014).
Potential Intervention

Improving fluvial flows throughout Deer Park would support a regional influx of riparian nutrients and migrating species. Restoration and encouragement of waterways in less densely wooded areas would create tall grass and shrub land habitat, thus increasing biodiversity within Deer Park. Sections of the forest that are harvested for wood should be carefully monitored as to not degrade these intermingled riparian habitats.
Ecological Services & Cultural Connection

Vestvolden is one of several examples from Copenhagen of a civil defense feature that has transformed into natural habitat. This historic fortification protected the western edge of the city throughout the late 19th and 20th centuries. The channel of water and its vegetated banks are lined by a paved pathway, making Vestvolden both an ecological and transportation corridor.

The filled area represents the contribution of each of these contextualized components to the site’s overall value. The broader the fill, the better. Red zones indicate a degree to which improvements are needed to build ecological and cultural connection.
ACCESS

Vestvolden is a rare case of ecological connectivity in the western portion of Copenhagen. Beginning at Utterselv Bog, which is a significant breeding area for birds, this 15 kilometer waterway improves wildlife navigation between nearby parks and water features and the Øresund coast. A pathway follows the course of Vestvolden and provides pedestrian access to this natural area. Part of a wider bicycle highway system, Vestvolden encourages navigation of the outer city using sustainable modes of transit, improving urban livability (City of Copenhagen a 2012).

SURFACE VARIATION

Vestvolden’s channel of water is flanked by heavily forested, variously sloping hillsides. The banks are structured by old military bunkers that begin right at the water’s edge in some areas and further back in others. This variation creates areas of riparian habitat lower in the channel that transition to the adjacent forest, scrub, and grassland habitat (City of Copenhagen a 2012).
WATER
Utterselv Bog to the north supplements the water that flows down Vestvolden. Overlapping roads and weirs interrupt surface water flow in multiple areas. These stagnant areas with low oxygen levels are inadequate to support healthy aquatic and riparian habitats, thus reducing overall water quality. Runoff, noise, and light pollution along overlapping roads also discourages aquatic life and migration along the lakes (City of Copenhagen a 2012).

VEGETATION
The northern portion of Vestvolden supports a high diversity of grassland species, including sections with the great broomrape. A buffer of vegetation runs the length of Vestvolden, ranging from 50 to 150 meters wide. Low growing ground cover and leaf litter carpets the entire area. Much of the shrub vegetation along the canal is thickly overgrown, indicating nutrient availability but also the presence of invasive species including Canadian goldenrod, Japanese convolvulus, giant hogweed, as well as stray garden plants (City of Copenhagen a 2012).
COLOR
The ground cover, shrub, tree bark, and foliage is relatively monotone along the entire course (City of Copenhagen a 2012). This suggests low species diversity, which can be attributed partly to the dense canopy of the trees and shrub overgrowth that blocks light and reduces understory growth.

BIODIVERSITY
Vestvolden is considered to be a “biological dispersal corridor” for its elongated pattern that supports connectivity (City of Copenhagen a 2012). Whereas barriers degrade ecological health by hindering movement along the channel, Vestvolden serves as a flyway for birds like the bittern, marsh harrier, black-headed gull, and the greylag goose, particularly to and from Utterselv Bog. Invasive species have spread along Vestvolden and threaten native morels and rare mushrooms that this area is known for, such as the stinkende fladhat in the image above (City of Copenhagen a” 2012).
Potential Intervention

Clearance and replacement of invasive and overgrown scrub with native plants like broomrape would help sustain a healthy ecology by attracting native, more specialized wildlife such as butterflies. Clearance around the bunkers would improve the accessibility of these cave-like features for bats, also making them a more prominent cultural reminder of the role the landscape has played in Copenhagen’s civil defense history (City of Copenhagen a 2012).
Ecological Services & Cultural Connection

The Inner Lakes contribute to Copenhagen’s central urban ecology as a 0.64 square kilometer stepping stone between the coast and areas of bynære natur to the west. Their central location allows urban dwellers to identify with and benefit from nature. Pathways and docks along the lakes provide spaces for gathering and recreation where people can feel the lakes’ urban cooling effects and observe behavioral and seasonal patterns of native species (City of Copenhagen a 2012).
ACCESS
Similar to Vestvolden’s elongated pattern, Sortedams Sø (Black Pond Lake), Peblinge Sø (Student Lake), and Sankt Jørgens Sø (Saint George’s Lake) form an arc of water along the western edge of Copenhagen’s city center. The lakes are entirely surrounded by urban fabric and are therefore accessible by people. A pedestrian path runs their perimeter, allowing close access to the waterfront. In terms of wildlife, the surrounding patchwork of city parks improves connectivity between the lakes and larger natural areas such as Fælledparken and the Citadel (City of Copenhagen a 2012).

SURFACE VARIATION
Heavily trafficked bridges bisect the lakes to connect the center of Copenhagen with western districts of Nørrebro, Osterbro, and Fredriksberg. The area around the lakes is relatively uniform, characterized by a tightly packed, gravel pedestrian path that eliminates the potential for this transition zone to support ecological diversity.
WATER
The Inner Lakes receive water from Damhussøen, Utterselv Bog and Emdrup Lake to the west. Water is retained for approximately one year before it is released to other urban lakes through underground pipes. This eliminates the potential for surface flows to serve as a biological corridor and as a visual connection to the wider fluvial network. Problems with water quality include nutrient imbalance and algal blooms, caused by a lack of natural cleansing processes of riparian and aquatic ecologies (City of Copenhagen a 2012). Contamination from stormwater runoff is also a contributor to poor water quality.

VEGETATION
Young and mature trees create a buffer between the water and surrounding streets and buildings. These trees as well as those on the two islands in Sortedams Sø provide refuge for birds and bats navigating the inner city. An overall lack of plant communities along the water’s edge reduces natural cleansing processes. Restoration projects financed by Copenhagen's Center for Parks and Nature have increased some areas of vegetation to improve water quality and increase species diversity (City of Copenhagen a 2012).
COLOR
A muted color palette characterizes the surrounding buildings, suggesting a cultural response to the foggy atmosphere that the lakes create. Barren biological color around the waterfront is due to a lack of vegetation cover and diversity.

BIODIVERSITY
Fugleøen (Bird Island) and Fiskeøen (Fish Island) improve the habitat conditions of Sortedams Sø. These islands provide secluded nesting and breeding areas for city dwelling and migrating birds, including the great cormorant, gulls, the tufted and mute swan, greylag geese, the great crested grebe, coots, heron, goosander and mallard ducks. Artificial nesting platforms supplement bird habitat as well. These bird populations feed on aquatic life, which is relatively imbalanced itself due to disproportionate numbers of predatory species (City of Copenhagen a 2012).
Potential Intervention

Vegetation conditions and water quality can be improved by diversifying the perimeter of the lakes. Certain areas could be reserved as habitat and redefined with a gradual slope. This zone could support riparian habitat, providing feeding and breeding zones for fish, birds, and insects. Broadening the slopes and shallow waters around Fugleøen and Fiskeøen would also increase riparian habitat and levels of biodiversity (City of Copenhagen a 2012).
Ecological Services & Cultural Connection

Since the 1930s, Amager Beach Park has served as a recreational amenity and is a popular destination for visitors. The dune island and lagoon were designed in 2005 to protect the developed coastal area against erosion and flooding caused by intensifying weather patterns. The island is 2 kilometers long and has increased the recreational area and wildlife habitat along the beach. It also supports native coastal ecologies that are threatened by rising sea levels (City of Copenhagen 2012).
ACCESS
Amager Beach Park is located on the eastern coast of Amager Island, approximately 4 kilometers away from the center of Copenhagen. Amager Beach Park is served by several metro stations and is easily accessed by neighboring communities. Relatively large inland developments disconnect the beach from other western areas of bynære natur. Bridges crossing over the lagoon connect with pathways that lead to designated recreational areas on the southern portion of the island, leaving areas reserved as habitat to the north.

SURFACE VARIATION
The sand dunes and lagoon create a variety of landform conditions that contribute to the ecological health of the coastline. On the other hand, areas on the southern portion of the island and along the original beach are frequently maintained, resulting in uniform conditions that inhibit ecological diversity (City of Copenhagen a 2012). These areas and certain constructed edges around the lagoon have prevented the establishment of plant communities that could enrich habitat conditions for wildlife.
WATER
Slow water movement in the lagoon allows nutrients to build up along the edge, enriching aquatic life and vegetative growth. These conditions provide a source of food and habitat for bird life. Exposed to the waves of the Baltic Sea, the eastern edge of the island is shaped by the water and is littered with seaweed that washes in from the ocean.

VEGETATION
The sand dunes support native grasses that are hardy to coastal weather conditions and ocean spray, including strawberry clover, beach puccinellia, asters, and wormwood, harril, and marram grass. This ecology absorbs the destructive impacts of storm events and provides habitat for wildlife. Areas along the shoreline are frequently visited by people; this foot traffic most likely alters vegetation growth (City of Copenhagen a 2012).
COLOR

Richly colored skies above the Baltic Sea are produced by the air’s high moisture content. Buildings on and along the beach are painted shades of blue or grey as to not distract from the natural beauty that this atmospheric phenomenon creates (Lange 1997, Hermansen 2014).

BIODIVERSITY

Amager Beach Park provides habitat for several species listed on the Danish Nature Agency’s priority protection list, including the bittern, gulls, terns, the greylag goose, and the Eurasian penduline tit, as well as the nogen snake, small water salamander, green toad, and a variety of butterflies. The sand dunes and lagoon provide breeding habitat for these species that prefer the sandy, rocky habitat characteristic of Amager Beach Park (City of Copenhagen a 2012).
Potential Intervention

In consideration of ecological connectivity, Greisvej is a low-traffic path leading inland from Amager Beach Park. A 10-meter buffer of uniform, highly maintained grass runs along its northern edge. This stretch has the potential to become a greenway if planted with native vegetation (City of Copenhagen a 2012). This would increase connectivity and ecological flow between the eastern coast and western areas of bynære natur, such as Amagerfælled and Kalvebod Fælled.
The filled area represents the contribution of each of these contextualized components to the site’s overall value. The broader the fill, the better. Red zones indicate a degree to which improvements are needed to build ecological and cultural connection.

Ecological Services & Cultural Connection

Designed to bring nature into the city, Charlotte Garden was installed in 2004 by Copenhagen-based SLA Landscape Architects (SLA 2004, Särnsjö 2009). This residential courtyard space benefits from the aesthetic and cooling effects of the garden, as well as onsite rainwater absorption. The plant palette celebrates the native coastal ecology, thus creating a sense of place within the city (SLA 2004, Särnsjö 2009).
ACCESS
Charlotte Garden is enclosed by tall residential buildings that protect it from the surrounding urban environment. Two exterior entrances along the eastern wall allow pedestrian access while keeping disturbances such as sound and pollution at a minimum. Paths weave across each end of the garden, keeping the middle portion mostly untraversed and habitable for wildlife that find refuge in the garden. This secluded courtyard is relatively inaccessible to wildlife besides birds and small mammals that can navigate the dense urban fabric.

SURFACE VARIATION
The garden consists of both short and tall grasses as well as several types of trees (SLA 2004). The paths at each end of the garden are paved and delineated by raised metal edges. Curvilinear edges along the paths and grasses create visual movement in this otherwise flat garden.
WATER
The sections of native grass require low maintenance and increase onsite rainfall absorption. This reduces runoff into the sewer system, contributing to Copenhagen’s “cloudburst” initiative to improve local stormwater management across the city (City of Copenhagen b 2012).

VEGETATION
Deriving aesthetic qualities from the local landscape, SLA selected native moor-grass, reed grasses, fescue, and a variety of trees to fill the garden (SLA 2004). The composition of vegetation frames gathering areas, providing shade as well as resting and nesting habitat for wildlife such as squirrels, bats, and birds.
COLOR
Charlotte Garden brings the soft tones of Denmark’s coastal landscape into the city. Resembling the ecology of Amager Beach Park, the native grasses texturize the space with seasonal tones of green and gold (SLA 2004).

BIODIVERSITY
Charlotte Garden’s native grasses are an important, if small, contributor to biodiversity on this site. They provide refuge from the intense urban surroundings that otherwise inhibit access by wildlife to the garden. Small birds, bats, squirrels, and less sensitive species of insects would be the most predictable types of wildlife to occupy Charlotte Garden.
Potential Intervention

Due to its central location and small size, Charlotte Garden has a low wildlife presence. Replacing sections of short cut grass with flowering ground cover and installing vertical gardens with nectar, pollen, and fruit-producing varieties would attract pollinators and provide nesting habitat for birds. Signage could educate residents and visitors of the ecological significance the plant palette has in respect to the native coastal ecology and urban wildlife habitat.
This composite matrix is a combination of the five site-specific matrices, revealing that different types and areas of nature in Copenhagen are highly accessible by people and generally navigable by wildlife. Accessibility contributes to greater levels of biodiversity and the appearance of natural colors in both ecological and built settings. Areas for overall improvement include water quality and vegetation diversity, resulting from areas with uniform surfaces and barriers that inhibit water flow and block species migration.
Combined Ecological Services & Cultural Connection

Protection is a common function for natural areas that harbor ecological processes in Copenhagen. Natural and engineered ecologies absorb the impacts of storm events and rising sea levels that threaten the coastline and central port area. The dunes ecosystem at Amager Beach Park was designed to protect Amager Island’s eastern coast against rising waters, and the natural landscape at Deer Park provides a protective edge along the northern coast of the main island. Inland areas of Vestvolden, the Inner Lakes, and Charlotte Garden represent both large and small scales of stormwater absorption and retention. The vegetation and waterbodies in these areas and Deer Park sequester carbon and have cooling effects on the immediate urban environment (City of Copenhagen a 2012).

Visual cues of native biodiversity in these examples of bynære natur and bynatur strengthen people’s connection to the natural landscape that they see on the coast and by train across the countryside. Charlotte Garden is an example of urban design that uses native plant species as artistic media to celebrate the local landscape (Charlotte Garden 2004). The grasses in Charlotte Garden identify with the dunes of Amager Beach Park and along the main island’s natural coastline, just as the species and landforms of Deer Park characterize the island’s wider bioregion. Climate is also reflected as part of Danish culture through the cool colors of the moist atmosphere and the warm hues of the sunset that appear on the buildings at Amager Beach Park, the Inner Lakes, and surrounding Charlotte Garden.
ACCESS
The elongated patterns of the Inner Lakes, Vestvolden, and Amager Beach Park increase the interface between their edges and the surrounding areas. Several points of entry provide public access, and proximity to other natural features make these areas navigable for wildlife. All five locations are cultural and recreational attractions and are accessible by different modes of transportation.

SURFACE VARIATION
Considering Denmark’s relatively flat landscape, each site has different degrees of topographical change that support various habitats and compatible ecologies. Deer Park, Vestvolden, and Amager Beach Park show good levels of surface variation and ecological diversity (e.g., aquatic, riparian, plains, forest, fresh and salt marsh) whereas the Inner Lakes and Charlotte Garden are limited by hard boundaries of the surrounding urban context. Semi-permeable surface treatments in all five areas slow stormwater runoff and allow for onsite percolation more so than hardscape treatments would.

WATER
All the sites perform a degree of stormwater retention, detention and absorption. The vegetated, undulating grounds of Deer Park improve water quality, whereas contrasting conditions exist at the Inner Lakes. Poor water quality at the Inner Lakes and Vestvolden is a result of stagnant water conditions, which reduces aquatic habitat and the recreational value of these areas.
**VEGETATION**

*Primarily native plant* communities characterize these five areas and provide both wildlife habitat and cleansing processes. Healthy areas include the dune grasses at Amager Beach Park, and the mature oak and beech forests and riparian areas of Deer Park. Overgrown thickets along Vestvolden and narrow riparian zone along the Inner Lakes inhibit plant diversity and ecological health. The grasses at Charlotte Garden function as visual identity, as well as for stormwater management and create a cooling microclimate within the city center.

**COLOR**

Landscape indicative and diverse colors at Deer Park, Amager Beach Park, and Charlotte Garden represent both native ecologies and species richness. The muted architectural color tones around the Inner Lakes and Amager Beach Park suggest that these water features heighten a cultural sensitivity towards the climate’s aesthetic qualities.

**BIODIVERSITY**

These areas are capable of supporting different degrees of native species habitat. With this in mind, conditions along Vestvolden demonstrate that some areas of nature in Copenhagen lack native species diversity due to areas of invasive growth. Large areas and elongated forms support greater biodiversity, although infrastructural barriers that bisect and block these patterns inhibit migration to and from natural features nearby.
System-Based Interventions

The composite matrix and profile for these five sites communicate trends and general improvements for nature across the City of Copenhagen. Prime areas for intervention include vegetation diversity and water quality. Both issues can be addressed by enhancing the transitional zone along water features and by zoning protected areas to receive minimal degrees of maintenance. These strategies can increase the establishment of native plant communities that function as wildlife habitat and filter pollution and runoff from the surrounding urban environment. The creation of fauna passages across infrastructural barriers would also improve water and vegetation conditions. Passages would increase wildlife migration and stimulate interspecies interaction such as pollination and seed dispersal throughout the city. Both human cultivation and biological transportation of native plant species would enrich biological processes along riparian areas, improving water quality through microbial water filtration that plants and wildlife adapted to these zones naturally perform.
Conclusion: The Design of Places Based on Existing Ecologies

Utilizing the place-based method of restoration I have presented as a Framework to Strengthen Urban Ecological Systems, municipalities can improve sustainability and enhance cultural identity. This process of restoring natural features is intended to strengthen an urbanized landscape’s resemblance to and function as a part of the wider bioregion. Ecological matrices help facilitate a more effective dialogue between designers and ecologists. This tool guides the development of both systemwide and site-specific strategies to enrich ecological health and cultural connection to local landscape. Developing restoration goals that address multiple areas of concern can improve the effectiveness of systemwide efforts. This comprehensive yet localized approach encourages collaboration across scales of jurisdiction, working to improve the overall urban ecology.

My next step in developing this framework will be to further contextualize and test ways to strengthen the data used in creating the framework so that it can be applied in other contexts with greater rigor and in cities with other types of data. This will help form a series of guidelines that can be adapted by a range of scaled initiatives including community-led grassroots efforts. The involvement of local communities is important for sociocultural enrichment and to establish responsible interactions between people and their natural environment. By encouraging an awareness of beneficial ecological processes that improve urban livability, urban dwellers can become “stewards of ecosystem services” (Astbury 2013: 72). Creating places that reconnect people with the local ecology in this way helps to restore and protect natural landscapes that are currently threatened by sprawling development and environmental degradation.
Literature Cited


  a. 55°47’34.40” N 12°33’51.75” E.
  b. 55°40’22.91” N 12°25’37.74” E.
  c. 55°41’03.24” N 12°34’23.37” E.
  d. 55°39’20.88” N 12°38’35.86” E.
  e. 55°42’17.23” N 12°33’16.85” E.


