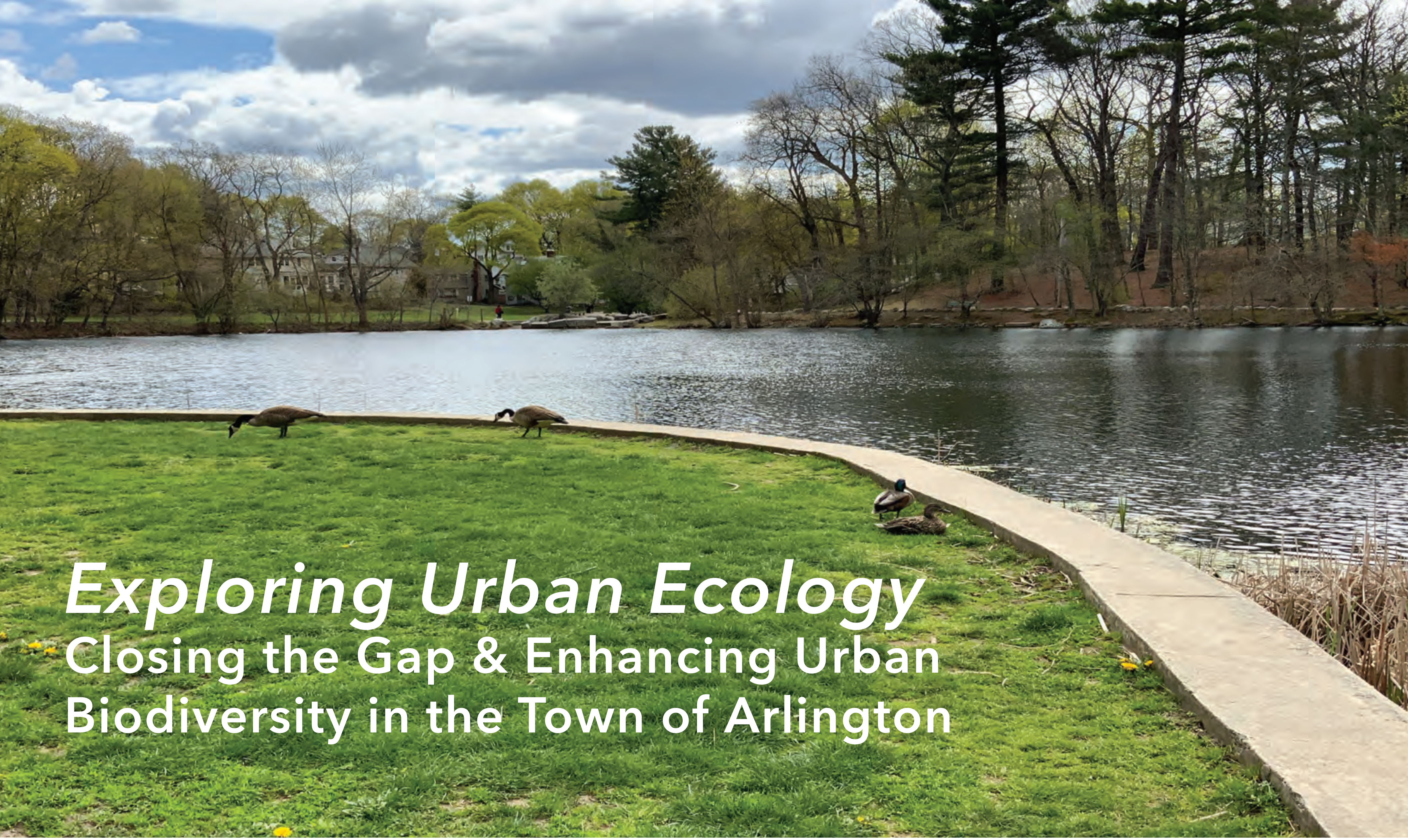

Exploring Urban Ecology

Closing the Gap & Enhancing Urban Biodiversity in the Town of Arlington

Tufts University
Graduate School of Arts and Sciences
Urban and Environmental Policy and Planning

Town of Arlington, Massachusetts

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Cover photo taken by Arlington Tufts UEP Field Project Team

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Land Acknowledgement

Tufts University's Medford/Somerville campus is located on colonized Wôpanâak (Wampanoag) and Massa-adchu-es-et (Massachusett) traditional territory. The Town of Arlington, the study area for this project, is located on the ancestral lands of the Massachusett Tribe. Since the project focuses on how we can repair and enhance the ecology in the Town, we believe it is important to recognize the original stewards of the land of which we are discussing.

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Glossary

Biodiversity: The variety of living species on Earth, including plants, animals, bacteria, and fungi (National Geographic, 2022).

Citizen Scientists: When the public voluntarily helps conduct scientific research. Citizen scientists may design experiments, collect data, analyze results, and solve problems.

Climate Change: The long term, anthropogenic shift in temperatures and weather patterns.

Ecosystem Services: Benefits provided to humans by an ecosystem or environment such as shade, drainage, or erosion control.

Invasive Species: A species that is not native to its environment and, upon being introduced to an area, becomes overpopulated and has the potential to harm the overall health of the environment.

Native Species: A species whose presence in that region is the result of only local natural evolution during history, and the species was not the result of human intervention.

Non-native species: Plants and/or animals living in areas where they do not naturally exist.

Orthophotography: A computer-generated image of an aerial photograph in which displacements (distortions) caused by terrain relief and camera tilts have been removed. It combines the image characteristics of a photograph with the geometric qualities of a map.

Pollution: The introduction of harmful materials into the environment.

"Safe to fail" builds: A safe to fail build or project is an (typically small) experimental element in the building and design project designed to test out an idea, but built in such a way that it can fail without major consequence.

Suitability Analysis: A suitability analysis, or suitability study, is a GIS-based process used to determine the appropriateness of an area for a particular use, based on a set criteria.

Urban Ecology: Urban ecology is the interactions amongst the built environment, land management practices, and environmental processes. It is defined as "the study of nature in cities, of humans in cities, and of the coupled relationship between humans and nature" (Atlanta City Design: Nature, 2020).

List of Acronyms

GIS: Geographic Information Systems.

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

TCCM: The Technical Committee on Coastal and Marine Environment.

SLH: A Sustainable Landscape Handbook is a booklet describing how homeowners and property managers can enhance biodiversity on their own land through sustainable gardening, with the added benefits of carbon sequestration and water runoff prevention.

MAPC: Metropolitan Area Planning Council, the regional planning agency serving 101 cities and towns in the Greater Boston area.

MyRWA: Mystic River Watershed Association, the watershed coalition that serves the towns and cities along the Mystic River, including Arlington.

Executive Summary

The world is in the middle of a biodiversity crisis. Climate change and urbanization threatens biodiversity, contributing to the ongoing sixth mass extinction, the first since the age of dinosaurs 65 million years past (IPBES, 2019). The gravity of this situation, and its impact on people, is only beginning to be recognized in policy and planning. Policymakers and city planners are seeking to address the biodiversity decline in their climate change and ecological conservation plans, in order to safeguard our natural and built environment. The Town of Arlington reached out to the Urban and Environmental Policy & Planning Department at Tufts University to conduct a field project on reassessing its ecological land management plans in light of this crisis and conduct research to determine how biodiversity can be enhanced at the municipal scale.

Exploring Urban Ecology: Closing the Gap & Enhancing Urban Biodiversity in the Town of Arlington, MA aims to investigate the gaps within the Town of Arlington's current plans and conditions in order to introduce an urban ecology framework into ecological and environmental planning in Arlington, MA. Urban ecology is defined as "the study of nature, of humans in cities, and of the coupled relationship between humans and nature" (Atlanta City Design: Nature, 2020). In this report, we utilize an urban ecology framework to promote the idea that city landscapes are part of the solution in protecting biodiversity and acknowledge urban ecology as a valuable practice that enhances it. By conducting a literature review of urban ecology, a policy inventory review of the Town of Arlington's plans, and a biodiversity potential study of Arlington using spatial methods, the Team analyzed gaps where the Town of Arlington can improve on its urban ecology planning processes. The findings of this project will be used to help lay the groundwork for the Town of Arlington's planning department to integrate urban ecology into their planning process.

The literature review, focusing on measuring, monitoring, and mapping as well as integration, was an important step to establishing a base of understanding around effective biodiversity management and the interdisciplinary efforts that are required to do so. Case examples highlighted ways municipalities and cities have effectively propagated biodiversity and urban ecology in multiple avenues including connectivity, watershed, and tree cover. Additionally, we were able to examine effective frameworks and plans that have successfully initiated interdisciplinary collaboration in the goal of a unified understanding of what is required to productively manage biodiversity. From examining case examples and Arlington's current ecologies, we outlined five biodiversity-enhancing categories that would be the framework for our recommendations in efforts to create a pathway to holistic, unified biodiversity management.

Secondly, the Team conducted a policy inventory review of the Town's plans in order to assess what has and has not been done relating to ecological land management and urban ecology. The Town has set goals and actions for ecological land management such as using more native vegetation in landscaping, managing invasive species, reducing nutrient inputs to water bodies from fertilizers, and so forth. To address the biodiversity crisis at a higher level, these goals need to be unified and complemented by further strategy. The Team sorted the Town's completed and ongoing actions from Town plans relating to biodiversity and compared them to urban ecology elements identified from the literature review. The result is a policy inventory table which allowed the team to analyze the ecological management actions that have been completed and those that are still ongoing.

Thirdly, the spatial analysis in this project involved conducting a suitability analysis of biodiversity potential in order to provide insights on where the Town can focus its efforts on the protection and enhancement of existing biodiversity. Through this analysis, it was found that biodiversity suitability was highest and generally more consistent near bodies of water, including the Upper & Lower Mystic Lake and the Arlington Reservoir. On the other hand, the regions within the Town that contain the least potential for biodiversity are the areas zoned for housing, particularly single-family housing. These findings influenced the Team's gap analysis and discussion points.

The findings from the policy inventory review and spatial analysis, with support from the literature review, informs our gap analysis and discussion. These findings, with brief explanations in the following paragraphs, help address our research questions, while also expanding the conversation around the application of urban ecology within the Town of Arlington.

Opportunities to Incorporate Urban Ecology Elements in Town Plans and the Decision-Making Process: The Town of Arlington must consider how urban ecology elements can be implemented deeply into the planning and decision-making processes.

Private Property Considerations in Urban Ecology: The lack of private property considerations in sustainable landscape management can act as a restriction to effectively incorporate urban ecology and protect urban biodiversity.

Supporting High-Biodiversity Areas: The Town of Arlington should also ensure that high-biodiversity potential areas are still being supported and that local wildlife can still thrive and not be disrupted.

Utilizing Biodiversity Metrics: The Town should aim to measure a greater range of urban ecology metrics and utilize those metrics to implement successful biodiversity enhancement actions.

Collaborative Fronts: Successful urban ecology frameworks include joint efforts between cities and municipalities, which the Town of Arlington should ensure to foster relationships with their shared borders.

From our gap analysis findings and discussion, we came up with five groups of recommendations that the Town of Arlington Planning & Community Department can take into account to further urban ecology in their planning process. Our recommendations are covered in the following paragraphs, with brief point of actions that can be taken.

Learning and Community

1. Enhance learning and accessibility through means such as community gardens and wildlife habitat areas, educational events and workshops and by partnering with local Schools and universities. Materials should also be created in other languages to foster inclusion.
2. Engage the community in the creation and maintenance of habitats through volunteer programs and educational initiatives.

Private Property

1. Incentivize private property owners to incorporate urban ecology by implementing incentives and rewards for private property owners to incorporate urban ecology practices, and provide materials for their residents.

Planning and Policy

1. Create plans that incorporate data metrics to inform decision making by using the completed actions table categories as a checklist when creating or discussing new plans.

Data and Mapping

1. Create a connectivity map with other areas.
2. Develop a system for ongoing monitoring and evaluation of the Town's ecological health, including regular assessments of water quality, soil health, and air quality.
3. Utilize technology such as GIS mapping and remote sensing to track changes in the Town's ecological landscape over time.
4. Develop an urban fabric map of Arlington using satellite imagery.

Supporting and Creating High-Biodiversity Areas

1. Implement measures such as creating pollinator gardens, bird-friendly habitats, or butterfly corridors
2. Promote the use of native plant species to provide food and shelter for local wildlife.
3. Consider creating a constructed wetland and maintaining bees on public property.

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Introduction

The world is rapidly urbanizing in the midst of a sixth mass extinction event, creating a multi-faceted biodiversity crisis (Pievani, 2014). In the last fifty years, wildlife populations have plunged by almost 70% (WWF, 2022). North America has experienced a precipitous decline in the last half century, 20% of biodiversity, defined as the variety of living species on Earth, including plants, animals, bacteria, and fungi (National Geographic, 2022) has been lost on the continent. Global biodiversity loss is widely attributed to human activities, with agriculture, pollution, logging, hunting, invasive species, and the changing climate being considered the six most key threats (UN Environmental Program, 2022). Some of these key drivers interact with one another in complex ways, making it difficult to distinguish between issues. To address the six significant threats to biodiversity, consideration of all landscapes is needed.

There may be a societal tendency to believe in the biological deserts fallacy the concept that cities and nature are separate entities and that the former are meant to be devoid of biodiversity and important flora and fauna (Spotswood et al., 2021). But while urbanization does generally contribute to the loss of biodiversity, new research shows that it can also maintain it and act as a refuge for certain species (Spotswood et al., 2021). In this report, we promote the idea that city landscapes are part of the solution in protecting biodiversity and believe in acknowledging urban ecology as a valuable practice that enhances it. **Defined as the study of nature in cities, of humans in cities, and of the coupled relationship between humans and nature (Atlanta City Design: Nature, 2020), urban ecology is crucial to protecting biodiversity in densely settled areas.**

Not only does supporting urban ecology aid in the global fight against biodiversity loss, it also provides many other benefits. Although often overlooked in urban environments, biodiversity plays a significant role in supporting human health and well-being (Hubbart, 2022). For example, urban biodiversity in the form of tree cover, green spaces, and green infrastructure can reduce air pollution and mitigate noise pollution (Aerts et al., 2018). It also enhances cooling and combats the urban heat island effect (Bowler et al., 2010). The presence of green spaces and trees is positively associated with air pollution reduction, which greatly affects the inhabitants of urban regions (Kruize, et al., 2019). Restored and well-maintained urban ecosystems can also mitigate flooding by absorbing runoff and providing shade.

The global biodiversity crisis may seem far removed, but pollution, invasive species, and the changing climate affect the Town of Arlington as well. For example:

- Climate Change: The Town of Arlington is at risk of flooding due to its proximity to the Mystic River watershed (Town of Arlington, Zoning Working Group 2022), which could displace wildlife and damage biodiversity, including soil microbes that support a large web of ecosystems.
- Invasive Species: Lawns and other cultivated areas are leading to invasive species in Arlington. Just recently narrowleaf bittercress was spotted near the Arlington reservoir (iNaturalist, 2023).
- Pollution: Fertilizer and pesticide runoff from yards is getting into watersheds such as the Mystic river, and has already been known to cause issues such as algae bloom (River, 2019).

> ***"Urban Ecology is the study of nature in cities, of humans in cities, and of the coupled relationship between humans and nature."***
>
> *(Atlanta City Design: Nature, 2020)*

1.1 Overview of Arlington

Arlington is bordered by Medford, Somerville, Cambridge, Winchester, Lexington, and Belmont the close proximity to Boston and major suburbs makes Arlington a popular place to live today, and there are approximately 43,000 residents despite the Town's relatively small footprint. Due to extensive development, mostly for single-family homes, the Town has limited opportunities for managing habitats, which are mostly confined to a small number of open space parcels that are often designated for recreational activities (Morgan, 2022).

In 2023, the Town was awarded an Accelerating Climate Resiliency grant from the Metropolitan Area Planning Council in partnership with the Towns of Winchester and Stoneham. This grant promotes urban ecology and goes towards the creation of a sustainable landscaping handbook (MAPC, 2022). The handbook is an important first step towards enhancing biodiversity through habitat corridors and increased landscape connectivity. These goals are achievable but require identification of best management practices through qualitative and quantitative analysis.

Like the rest of Massachusetts and New England, Arlington is already experiencing the impacts of climate change (Town of Arlington, Department of Planning, 2019). By focusing on climate adaptation and mitigation, the Town will be able to bolster its defenses against the effects of a warming planet, such as inland flooding, heavy winds, and drought. Currently, the Town of Arlington faces two primary threats from climate change related impacts the risk of flooding along Mill Brook and a risk of urban heat islands (UHI) (Town of Arlington, 2020). As these climatic factors can also have negative impacts on local wildlife and native flora, the Tufts Field Project team will include these climate risks in their final report and recommendations.

1.2 Project Goals

Urban ecology is the study of the interrelationship between nature and humans together in cities. To demonstrate this correlation, it is necessary for the Town to recognize the existing waterways, flora, fauna, and soil as the integral components of the entire community. The Town of Arlington has already realized this importance, and taken steps in the process. For instance, the Town has implemented hazard mitigation and stormwater planning, and crafted an ambitious scope of ecological land management efforts – this includes protecting green spaces, incorporating native vegetation, handling invasive species, and addressing nonpoint source pollution from fertilizers. To address the biodiversity crisis at a higher level, these goals need to be unified and complemented by further strategic prioritization and actions.

1.3 Key Research Questions

How can the Town of Arlington enhance and protect biodiversity given concerns about climate change?

1. What could an urban ecology framework look like for Arlington?

2. How can the Town of Arlington apply conservation techniques to increase biodiversity along habitat corridors and strengthen existing land management practices?

3. Which sites of concern or interest within the Town would benefit the most from an urban ecology framework?

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Methods

This project adopts a mixed-method research approach that involves both qualitative and quantitative research methods to respond to the Team's research questions. The qualitative analysis, including the literature review, action implementation table, and gap analysis, provides an in-depth understanding of the existing urban ecology plans, policies, and practices in the Town of Arlington. The GIS analysis employs quantitative methods to conduct a suitability analysis. By combining both approaches, the project Team can provide more robust recommendations that consider both the strengths and weaknesses of the Town's urban ecology plans and provide targeted interventions to improve the urban ecology planning process in the Town of Arlington (see Figure 2.1).

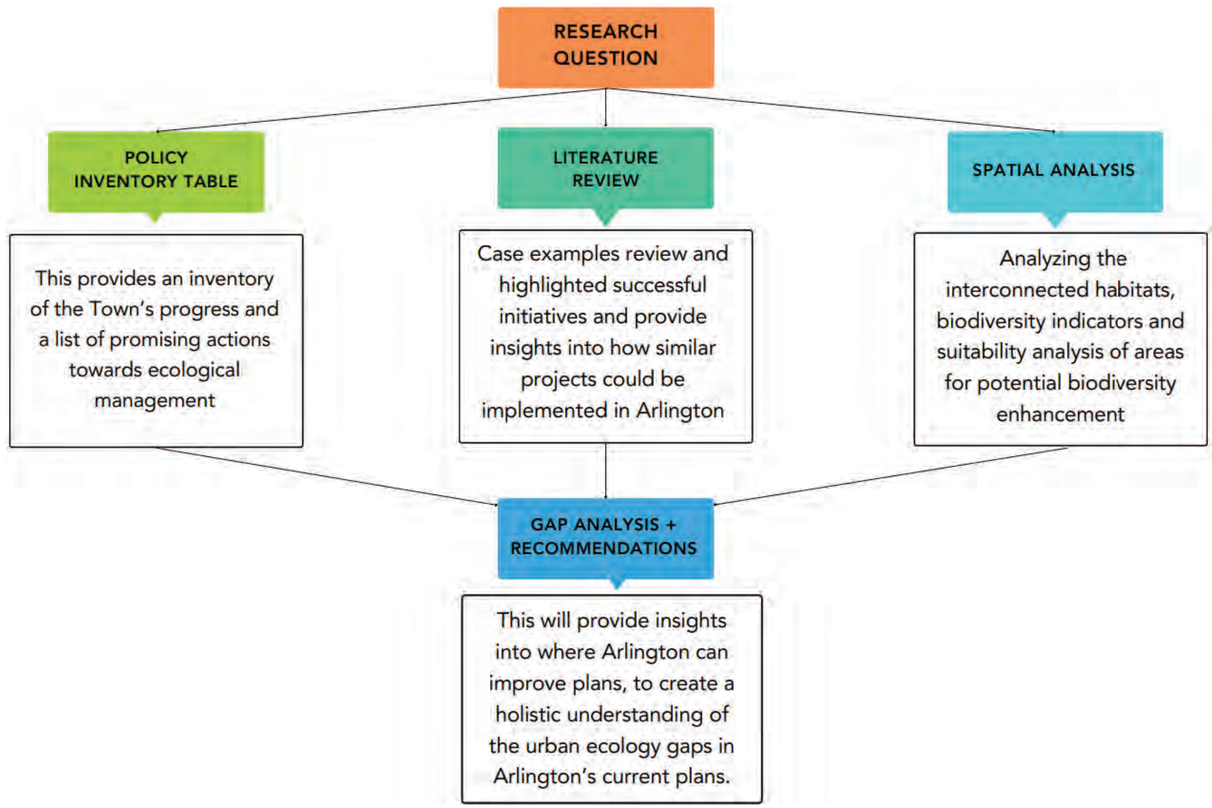

Figure 2.1: Flow chart summarizing the Team's methods.

2.1 Literature Review

The literature review investigates a range of approaches, frameworks, indicators, and methods that could be employed to assess and enhance urban ecology in Arlington. Search terms such as "urban ecology case studies", "urban ecology in cities examples", and "biodiversity enhancement in cities examples", were used to find scholarly articles. This review primarily examines case studies and examples of what other municipalities and cities are doing to improve their urban ecology and habitat connectivity. Cases were selected based on the innovativeness of their approach, and their resemblance to Arlington in terms of size, population or landscape. While cases from a variety of global landscapes are included, all cases are reviewed with an eye as to how they can be applied to Arlington. Sustainable landscaping initiatives and climate risk management plans were also explored. As literature was reviewed, major categories, such as connectivity and tree cover were formed. These categories are the basis for analyzing the Policy Inventory Table, to identify gaps in Arlingtons progress towards bettering urban ecology. This review guides the policy invetory review, the spatial analysis and the gap analysis that are described in more detail below.

2.2. Policy Inventory Review

For the policy inventory review, we conducted a comprehensive review of all the existing town plans and created an inventory of the ecological land management actions in Arlington, MA. As part of this process, the Team reviewed all adopted and drafted town plans that contained information relevant to biodiversity. The review process enabled the Team to identify and create an inventory of the current, ongoing, and inactive ecological land management actions in Arlington.

The following plans were assessed as part of this process:

- Tree Management Plan (Tree Management Plan, 2018)
- Public Land Management Plan (Public Land Management Plan, 2022)
- Municipal Vulnerability Preparedness Plan (Municipal Vulnerability Preparedness Plan, 2018)
- Open Space and Recreation Plan Hazard Mitigation Plan (Open Space and Recreation Plan Hazard Mitigation Plan, 2022)

The Team developed an action implementation table to guide the understanding of the current and anticipated ecological management actions undertaken by the Town. Based on this table, the Team sorted the completed and ongoing actions with the methods for enhancing biodiversity and urban ecology that is identified in the literature review. The result of this is a policy inventory table (see Figure 4.1). The plans were color-coded to indicate whether they had already addressed each element or not. This process provided a clear overview of the ecological management actions that have been completed and those that are still ongoing, enabling the Team to identify areas that require further attention.

2.3 Spatial Analysis

The geospatial analysis in this project provides a baseline understanding of the existing conditions in Arlington and explores ways to improve habitat suitability and enhance biodiversity potential. The Team chose to conduct a suitability analysis of potential biodiversity to identify prioritization areas within the Town of Arlington that may benefit the most from an urban ecology framework. Additionally, geospatial analysis is used to explore areas within the Town that are most suitable for biodiversity; this information could be used to better understand which municipal open spaces to prioritize in environmental management.

We chose to use four input layers based on our literature review (Atlanta City Design: Nature, 2020). We include slope because of its impact on vegetation patterns, and species density because it helped us see where the most biodiversity occurred. We also include proximity to water as an input layer because of its importance to sustaining life, and proximity to roads because of the landscape fragmentation it presents for wildlife.

The Town of Arlington boundaries on ArcGIS are clipped with these four layers in mind, before a reclassification function is run on a scale of 1 to 5, with 5 being the best (see Figure 2.2). The layers with water and road proximity will be calculated via Euclidean distance before reclassifying. Once these steps are completed, the following task would be to use the raster calculator function to add up the "scores" from each pixel. Whichever add up to 17 or higher could be considered what the Team has termed "biodiversity prioritization areas" due to their high suitability scores – areas that have the largest interconnected zones of these high scores may be pointed out as places for the Town to focus conservation efforts on if they aren't private property. If they are privately owned, they may represent a future initiative to encourage homeowners or property managers to create pollinator habitats.

Slope

We utilized Digitized Elevation Model (DEM) data from MassGIS for elevation data, which we then converted to slope using the calculated percent rise feature. We then reclassified this raster layer on a scale of 1 to 5 in four degree increments, with 0 to 4 degrees being the best for biodiversity, 4 to 8 degrees being very good, 8 to 12 degrees being acceptable, and so forth based on our literature review. The layer was clipped to the Town's boundaries.

Proximity to Water Bodies

We used data about bodies of water from the Town of Arlington GIS page. Using the Euclidean Distance tool, an output raster layer was created that calculated the distance from each pixel to the nearest body of water. This layer was reclassified on a scale of 1 to 5, with a distance of 0 to 800 meters from water being the best for biodiversity, 800 to 1600 meters from water being very good, 1600 to 2400 meters being acceptable, 2400 to 3200 meters being suboptimal, and 3200 to 4500 meters being rather poor for biodiversity. The layer was then clipped to the Town's boundaries.

Proximity to Roads

We used data about roads from the Town of Arlington GIS page as well. Similarly to the water analysis, the Euclidean Distance tool was used to create an output layer. However, the resulting layer was reclassified in the opposite manner on the 1 to 5 scale, with distance from roads being better. This layer was then also clipped to the Town's boundaries.

Species Density

Species data for the Town of Arlington was downloaded from the iNaturalist website in the mammals, birds, insects, and plant categories. This data was provided in a comma-separated value (CSV) file that was uploaded to the ArcGIS platform and read in using the Calculate XY feature. Each point that appeared on the map thus represented a single sighting of plants or wildlife. From here, the Kernel Density function was utilized to calculate the density of biodiversity in Arlington, resulting in a new raster layer. This layer was then reclassified on the same 1 to 5 scale and clipped to the Town's boundaries.

Because of the nature of iNaturalist and citizen science, we would like to briefly acknowledge that this data may be skewed towards areas where people are more likely to be looking for biodiversity, but it was by far the best source for highly localized species data.

Unweighted and Weighted Suitability Maps

In order to compare our results, we chose to include a weighted suitability analysis that factored in species richness more heavily than the rest of the input layers. This layer accounted for 40% of our analysis and was followed by distance from roads at 30% weight because the presence of pavement and vehicle traffic were likely to be less accommodating for flora and fauna. The final two layers, proximity to water and slope were then weighted at 15% each before being added together. Weighting was done in the Raster Calculator function by multiplying species richness by 0.4, road proximity by 0.3, and water proximity and slope by 0.15. A more comprehensive overview of our spatial analysis using GIS can be seen on Figure 2.2 and Appendix B.

2.4 Gap Analysis

The gap analysis ties all aspects of the project together, providing a comprehensive look at Arlington's future: where the Town should be going and how to get there. In the context of enhancing urban biodiversity for the Town, a gap analysis provides a comprehensive overview of where the Town stands in terms of its ecological efforts, where it needs to be, and how it can get there. By using the prepared implementation table, literature review and GIS analysis we diagnosed the areas Arlington is missing in its current urban ecology work and developed a path to fixing them.

Here are the step-by-step methods for conducting a gap analysis to enhance the urban biodiversity for the Town of Arlington:

1. Assess the current state of urban biodiversity in the Town of Arlington. This includes a review of the action implementation table containing the existing data and action status on different management initiatives in the Town's plans. This provides a baseline understanding of the current state of biodiversity and helps identify the gaps to be addressed
2. Examine existing policies, plans, and goals, related to biodiversity conservation and compare them to the previously identified biodiversity baseline. This comparison is used to form Arlington's biodiversity target goals.
3. Once the baseline policies and target goals are determined, a comparison is done to identify the gaps in urban biodiversity for the Town. This involves analyzing the strengths and weaknesses of the existing policy and planning frameworks and identifying the areas where improvements are needed.
4. The literature, and case studies are reviewed in order to determine if there are any important aspects missing from Arlington's urban ecology plan.
5. Developed strategies to bridge the gap between the existing state and the target state of urban biodiversity in Arlington.

2.5 Recommendations

This report provides recommendations for enhancing biodiversity by utilizing a combination of methods, including literature review, spatial analysis, and gap analysis. These recommendations include policy recommendations as well as other suggestions related to monitoring, improving accessibility, or outlining specific actions that can be taken by the Town to support better decision-making. By utilizing GIS analysis and identifying potential locations, natural ecosystems, and species proximity, these recommendations can be tailored to various areas throughout Arlington.

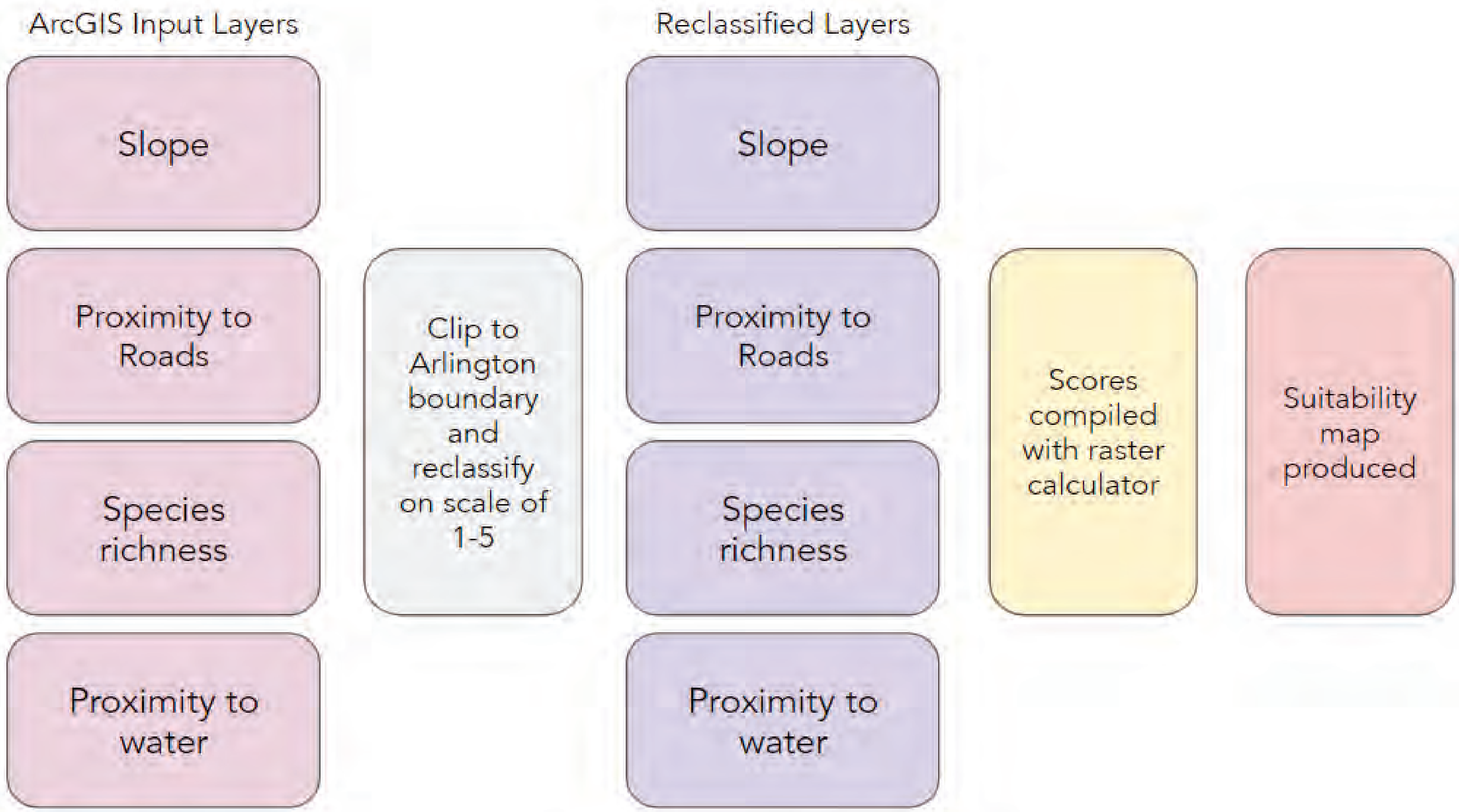

Figure 2.2: Flow chart of the Team's spatial analysis (Created by Tiffany Wu)

Literature Review

3.1 Introduction

This literature review explores case examples dealing with innovative techniques that integrate urban ecology and enhance biodiversity in cities. The review is organized into major categories that emerged from the literature.

The first category of literature reviewed focuses on measuring, monitoring and mapping urban ecology. This category outlines techniques for developing an understanding of a community's current urban ecology and city landscape. This is particularly important as it creates the foundation for planning to enhance urban ecology (Atlanta City Design: Nature, 2020). Urban ecology very much requires enhancing biodiversity as one of its main goals (Hubbart, 2022). However, the two require different methods and data to develop an understanding of a given area's current 'state'. While there is significant overlap, biodiversity metrics typically focus on measuring flora and fauna diversity and health in a given area. Urban ecology metrics take this a step further by also considering the built environment and human concerns, such as heat islands (Honnay et al., 2000; Atlanta City Design: Nature, 2020). Because of how integrated urban ecology is to the rest of city planning, it was found that successful urban ecology requires integration into the planning process (Aminzadeh 2014, pg. 3,).

Integration has been given its own section, as it is a crucial component in the process of measuring, monitoring, and mapping to effectively enhance urban ecology. Without integration, the data collected through these processes could not be utilized effectively. Following the integration section, the next sections of the literature review discuss major categories that emerged from case examples of enhancing urban ecology. These categories include connectivity, tree cover, water, and private gardens. These categories were identified multiple times in the research and were found to have potential applications for Arlington. By reviewing case examples of these categories, we can gain a better understanding of the approaches used to enhance biodiversity in urban environments and apply this knowledge to the specific context of Arlington.

3.1.1 Case Examples

Examining case examples will provide valuable insight into how communities from around the world are managing, mapping, and improving their urban ecology. Each case is analyzed through the lenses of its potential application to Arlington, MA. Cities presented in case examples differ from Arlington in landscape, size, and budget, but offer transferable study methods and urban ecology solutions.

Our project partner provided us with two examples that we repeatedly referenced throughout the project to guide our priority areas and recommendations:

1. Concord Sustainable Landscaping Handbook: This handbook was constructed by the Town of Concord, Massachusetts, and provides a three-phased, detailed guide on how local residents can design, build, and maintain their private landscapes in a way that conserves water, promotes native species health, and contributes to combating climate change. As stated previously, the Town has received a grant to build its own SLH and is using Concord's as a close reference.

2. Atlanta City Design: Nature: Constructed by the Department of City Planning in Atlanta, Georgia, this report aims to provide an in-depth understanding of ecology's value and position in the City as well as the challenges they face in broadening the value of their forests, watersheds, and native systems. The Team both prioritized this document because of its definition of urban ecology, its connectivity methods, and how it embraces ecological principles

in the context of city growth and development.

3.1.2 Additional Background on Arlington Urban Ecology and Landscapes

Arlington covers around 5.5 square miles and ranges from 4 feet to 377 feet in elevation. It is a part of the Mystic River watershed, and the river runs along the northeastern edge. Other major water bodies in or around the Town of Arlington include Spy Pond, Arlington Reservoir, Upper Mystic Lake bordering Arlington and Medford, and Mill Brook intersecting the Town (See Figure 1.1). Mill Brook is partially covered and does not run open through Arlington. The Town is on a slope from west to east ranging from 115-4 meters above sea level (Topographic maps, n.d.), with Arlington Heights at the highest point and East Arlington at the lowest (Morgan, 2022). Due to this slope, water moves downhill from rocky, less permeable land in the Heights to infiltrate in the sandy soils or reach the water bodies in East Arlington (Morgan, 2022).

Although most private single-family homes have yards (See Figure 1.2), Arlington has a limited amount of public green space. This makes cohesive management of parcels across the entire Town a challenge, and these private parcels can not necessarily be counted on as an established habitat for flora and fauna. The sites the Town does manage are scattered, and are mostly woodlands, with some wetlands near water bodies (See Figure 1.1).

Presently, Arlington has approximately 54 acres protected as conservation land, which represents 1.5% of the total land area, and 8,734 public street trees (Town of Arlington, 2015). These areas serve as the hotspots for Arlington's existing range of flora and fauna as well as buffers for environmental stressors like neighborhood flooding.

The rich agricultural legacy of Arlington persists in its biodiversity. Arlington was known for its celery, beets, squash, lettuce, and cabbages. The strong farming heritage of the Town continued through the 20th century and excellent soil quality, particularly in East Arlington, allowed for the propagation of novel vegetable strains (Robbins Farm Garden, 2010). The Town was also known for its thriving ice industry due to the convenient location of Spy Pond.

3.2 Measuring, Monitoring, and Mapping

The city of Atlanta, Georgia provides an excellent case for demonstrating how to effectively map and measure urban ecology. By utilizing the landscape and city fabric data, Atlanta was able to identify and create habitat corridors and choose restoration areas. Through a combination of mapping techniques and community and expert input, they developed an urban ecology plan that focused on creating equitable access to green space while also prioritizing the protection of high biodiversity areas, riparian habitats, and the restoration of wetlands. The success of Atlanta's approach highlights the importance of engaging with the community and utilizing a multi-disciplinary approach when developing urban ecology plans. The following series of maps provided the basis for ecological protection decisions (Atlanta City Design: Nature, 2020 and see Figure 3.1):

- Habitat Connectivity
- Regional Watersheds
- Local Watersheds and Hydrology
- Topography
- Plant Communities
- Ecosystem Services
- Carbon storage
- Flood Mitigation Potential
- Parks and Open Space Access

These mapping techniques, as well as the methods for creating strategically placed ecological corridors, and protecting important biodiversity hubs, could

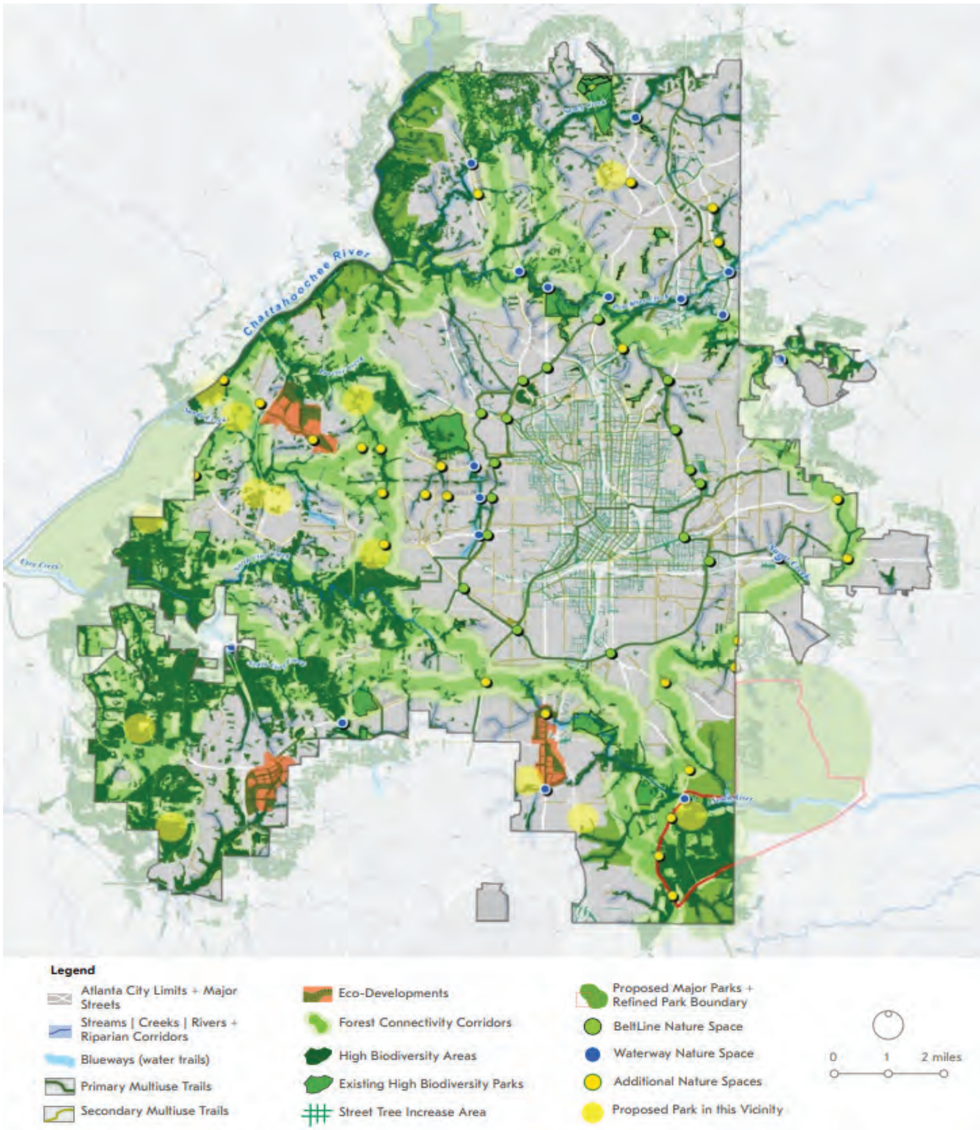

Figure 3.1: Atlanta City Ecological Patches and Hydraulic Network (Atlanta City Design: Nature, 2020)

be directly applied to some extent to Arlington, MA.

Another important tool for developing an accurate understanding of an urban landscape is to create an accurate map of the city's 'fabric'. This is done through the careful characterization of the landscape's surface components (pavement, grass, gravel, etc). This is incredibly important for understanding what areas are most vulnerable to the heat island effect, and which areas lack permeability (Akbari, & Rose, 2001). "Accurate characterization of the urban fabric would allow the design of implementation programs with a better assessment of the costs and benefits of program components. In addition, the results of such detailed analysis will be used in simulating the impact of heat-island reduction strategies on local meteorology and air quality (Akbari, & Rose, pg. 7, 2001)." This is one of the key mapping metrics that the Atlanta case study lacks. Without it, distinctions like a paved personal driveway vs. a yard cannot be made. This is extremely important for an accurate understanding of biodiversity, access to open space, permeability and heat island effect. Especially in suburban areas, private properties need to be taken into account (Atlanta City Design: Nature, 2020).

Unfortunately, creating an accurate city fabric map can be complex and costly, as the best means of doing so is using high-resolution aerial orthophotography, which smooths the natural distortion of photography (U.S. Geological Survey, 2015). This requires the use of an aircraft and specialized camera equipment. That said, in the case of the city of Atlanta, Georgia, or Salt Lake City, Utah, where the study was originally done, this use of technology would be needed due to size and scale of the project. At just under 5.5 square miles, Arlington could be categorized manually using satellite imagery.

3.2.1 Measuring and Monitoring Biodiversity

Measuring changes in biodiversity over time in urban and suburban areas is a key aspect of urban ecology. However, assessing biodiversity changes over time requires setting up scientific metrics and methods for analysis. This can be challenging, because biodiversity metrics for urban and suburban areas are not well established compared to metrics for wilderness (Honnay et al., 2000).

Heterogeneity and habitat connectivity are commonly utilized measurements of biodiversity and landscape services according to "Spatial Heterogeneity in Urban Ecosystems" (Cadenasso et al., 2007). While "Towards a monitoring method" proposes working with habitat diversity and species diversity metrics (Honnay et al., 2000).

In urban ecosystems, plant species, butterflies, amphibians, and birds can be used to determine biodiversity (Honnay et al., 2000). Habitat diversity is based on a predefined list of habitat units; for example, meadows, forests, and cultivated grass. These groups can be easily found and categorized by professional and citizen scientists, who are typically volunteers trained in basic scientific metrics for their task (U.S. Department of the Interior, 2021). An area's current state of biodiversity can be assessed using these flora and fauna categories as biodiversity indicators (Honnay et al., 2000). Periodically doing these surveys allows urban ecologists to track biodiversity progress.

The methods and calculations for determining habitat diversity are further explained in "Towards a Monitoring Method and a Number of Multifaceted and Hierarchical Biodiversity Indicators for Urban and Suburban Parks" (Honnay et al., 2000). The benefits of this work's methods are that they are adapted specifically for urban environments, unlike the majority of biodiversity studies (Honnay et al., 2000). While this type of field work is not within scope of our team's analysis, Arlington could use its already existing network of volunteers and this paper's framework to continuously monitor biodiversity in the landscape.

3.3 Integration of Urban Ecology into Planning

While reviewing case studies of specific urban ecology practices can be an important method for generating new ideas and solutions to local problems, ecology is location specific. Certain aspects of a case study in India or Utah could be applied to Arlington, but it is important to look at local strategies for applying urban ecology. In "urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design" the point is made that one of the key ways urban ecology should be integrated into planning is through collaborations between landscape ecologists, urban planners and designers to "advance an accepted working method for adaptive design or "learn-by-doing" (Aminzadeh, pg. 2, 2014).

Aminzadah asserts that integrating "safe to fail" builds into the planning practice will allow towns like Arlington to test the limits of their urban ecology practice and expand it. Furthermore, post-implementation monitoring is key to assessing outcomes and ecosystem services being provided by experimental builds (Aminzadeh, 2014). The importance of this experiment being incorporated into urban ecology is further described in other academic works. Evens states: “Experimental cities are thus truth-making machines that draw no distinction between the generation and application of knowledge; as both the condition and site of change are the boundary between field and lab” (Evens, pg. 231, 2011).

Both of these papers also indicated the need for urban ecology to be better integrated into the municipal planning and project design process. According to the research, the biggest gap in expanding the reach of urban ecology is that it needs to work in a “transdisciplinary mode with urban planners, designers, stakeholders and decision makers (Aminzadeh, pg. 3, 2014).” In an experiment in urban ecology, ecologists were recruited to assist in the redesign of a housing complex. Not only did they replace lawns with rain gardens to manage water, they also tracked amphibian migration patterns on the parcel. Using this information, they delineated the most sensitive habitat areas, which were reserved as wetlands. The project developer Tuxedo Reserve supported the research because it allowed them to build the number of homes they wanted, through negotiation with the planning board while reducing the proposed stormwater infrastructure costs. The planning board was able to use data to modify the project in a way that was minimally harmful to Tuxedo while still doing everything necessary to preserve wildlife and restore natural water flow (Felson, et al., 2013).

The literature argues for the integration of planning and ecology, from research through to policy (Alberti et al., 2003). It is this interaction of science, policy, and planning that needs to become the backbone of urban ecology. “Without it, socially relevant and ecologically accurate research will not materialize, policy decisions will be made without the full benefit of relevant scientific information, and cities will continue to grow in increasingly unsustainable ways (Alberti et al., pg. 1178, 2003).” Urban ecology cannot be “part of the process”, but needs to be integrated into the system of decision making from the research phase on.

3.4 Ecological Corridors

For over 100 years, Greater Boston has experienced rapid development that has left its lasting natural landscapes unconnected (Massachusetts Wildlife Climate Action Tool, 2017.). Wetlands, woods, and meadows that used to surround the urban Boston core have been raised in favor of houses and roads (Massachusetts Wildlife Climate Action Tool, 2017). Those areas that are not yet fully developed are patchworked across the landscape with no connection to each other (Massachusetts Wildlife Climate Action Tool, 2017).

This is bad for both flora and fauna in the area. Animals tend to move seasonally or with food patterns, and juveniles will often spread out in order to find and claim new territory. This movement is vital for not only the species’ well-being but also allows for the rescue of declining populations through natural movements (Parris et al., 2018). Furthermore, animals are the spreaders of many fungi and plant seeds, making their ability to move vital for all forms of life (Parris et al., 2018). Habitat fragmentation is a major barrier to biodiversity in urban areas, and work to undo it by creating ecological corridors is an important aspect of urban ecology.

Another case study from Tehran recommends that natural patches and corridors should be preserved and restored, and that built patches, such as planned garden areas or parks, can act as a connecting element between the natural areas (see Figure 3.2). These connected patches allow “natural flows” (Aminzadeh, 2014; Pickett, & Cadenasso, 2007). The study was done by analyzing natural and built patches, hydrological networks, and roads in GIS, to locate places in the city where creating ecological corridors would be most beneficial (see Figure 3.1). Atlanta's urban ecology planning also included a heavy focus on connectivity, with major parks and high biodiversity areas connected by forest corridors and nature paths (see Figure 3.1). Alongside terrestrial habitats, an effort was also made to connect waterways and other riparian habitats (see Figure 3.1).

It should further be noted that many of Atlanta's maps extended beyond the city perimeters, showing the area in its larger context. For urban ecology, considering ecological corridors and river habitats that extend beyond the arbitrary boundaries of city limits allows for better connectivity. While municipal authority may stop at the city border, exploring the city in the context of its surroundings created opportunities to consider more collaborative and interconnected planning approaches. While often quite challenging, these cross-scale approaches can be extremely valuable when planning for biodiversity because it naturally allows for more connectivity planning and reduces delays in plan implementation (Brodie et al., 2016).

While Arlington could apply the same methodology to create a map of potential ecological corridors, it is important to note that both Tehran and Atlanta are much larger in area, and therefore the connectivity maps included in this literature review consider larger regions. In order for a connectivity map to be of use to Arlington, it would also have to be regional. A regional ecological corridor of the entire Mystic Watershed or greater area could be incredibly useful, but because this report is focused on the Town of Arlington, a connectivity map is outside the scope of our research.

3.5 Private Gardens

Private yards and gardens can be difficult to include in an urban ecology plan or framework, as the effort requires individual homeowners to participate in the planning, maintenance, and

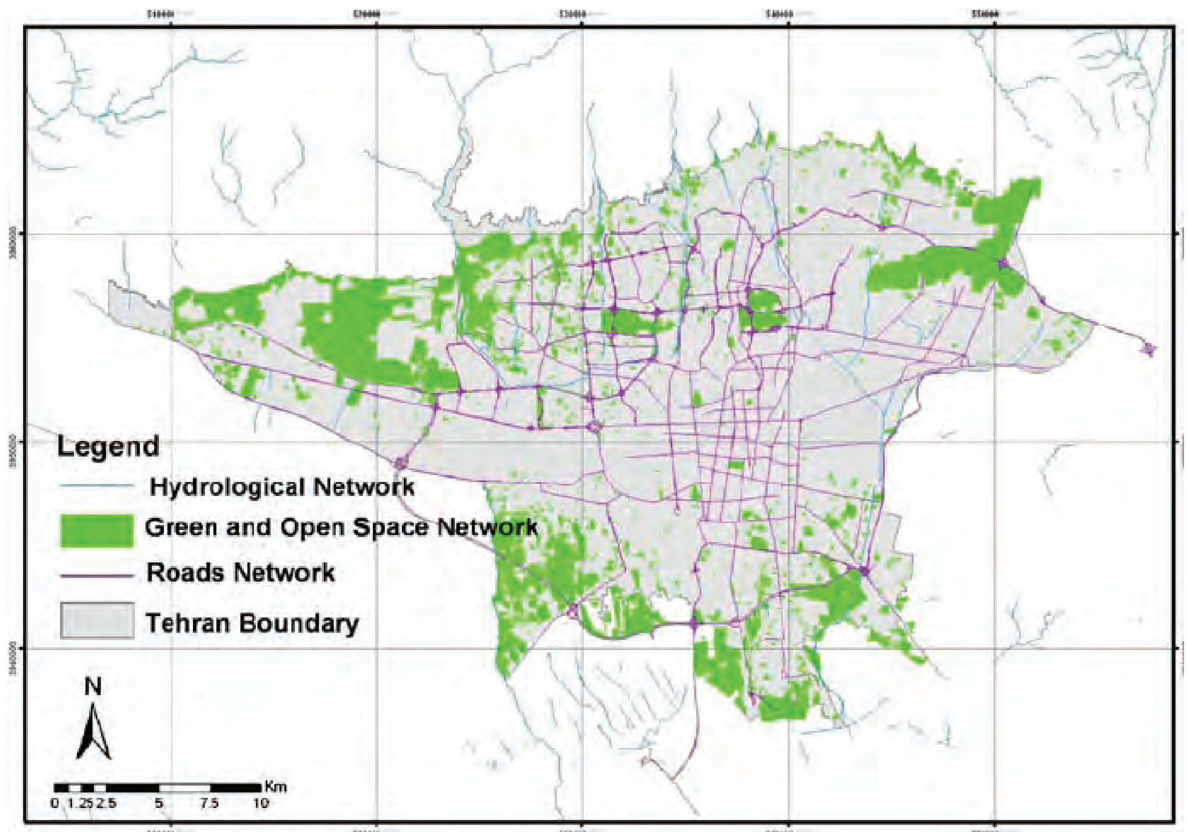

Figure 3.2: Map of Tehran's Green and Open Space Network (Aminzadeh, pg. 28, 2010)

ecological surveying of their property. However, especially in areas with a more suburban landscape, the potential value of private yards for increasing biodiversity and connectivity, should not be discounted (Lerman, et al., 2001).

Gardens can reduce hotspots and exposure to high winds, insulating houses against temperature extremes and allowing them to limit domestic energy use (Cameron, et al. 2012). While less beneficial for biodiversity due to their generally smaller size, private yards are extremely important for connectivity. The Paris study looking at bat habitats found that while private gardens made up only 36% of the total green areas, they still contribute up to 47.9% of bat habitat availability, while another study found that simply having homeowners reduce their mowing had a positive impact on biodiversity for the entire area (Mimet et al., 2019).

A survey of Boston area landscape connectivity found that 60.95% of total tree canopy is situated on residential land (Ossola et al., 2019). Since most of the existing tree canopy fragments are located on private property, it may be more cost-effective and efficient for the municipality to focus on connecting these fragments rather than creating new corridors from scratch.

Figure 3.3: Private residence in Concord, MA whose landscape was designed by Richard Burke Associates using principles from the Concord SLH (Hand, 2019)

Conversely, gardens can be a potential source of greenhouse gas emissions, and other problems leading to the loss of biodiversity and ecosystem health. Green lawns are often fertilized and chemically treated, leading to runoff which has the potential to negatively impact local water bodies. Additionally, gardens have been known to serve as a gateway for the introduction of invasive species and pests into the surrounding environment (Cameron, et al. 2012).

In regards to Arlington, future mapping could consider including private greenspaces when trying to figure out how to create and enhance connectivity. It could also be beneficial for Arlington to provide materials for their residents similar to those provided by Concord (see Figure 3.3).

3.6 Water

A case study from Kolkata, India, shows unique management of floodlands in a semi-urban system. Kolkata is effectively sustained by its wetlands, and they act as the city's primary source of sewage treatment. It recycles 810 million liters of wastewater generated by the city of 14 million people, on a daily basis (Mukherjee, 2015). Kolkata does not have a separate sewage treatment plant; the wetlands provide a service that would have otherwise cost the city approximately US $80 million yearly (Mukherjee, 2015).

The process is derived from local-Indigenous knowledge used in Kolkata, which involves feeding sewer water into pisciculture or controlled fish breeding grounds, where fish are able to consume waste products, thereby cleaning the water while also providing a food source (Mukherjee, 2015).

This case is one of the largest scale versions of floodplains being used to treat water and is a good example of how large scale this type of urban ecology planning can be. However, there are other smaller projects that use similar techniques to mitigate runoff in urban and suburban areas. For example, Arizona has used built wetlands to treat sewer and lawn runoff successfully for decades (Gelt, 1997). Not only do these wetlands treat runoff water everyday, they also reduce sewer and water cleaning costs to below that of traditional facilities (Gelt, 1997). An added advantage to these built wetlands is that they naturally enhance habitat connectivity (Donati et al., 2022)

3.7 Tree Cover

A case from Rome highlights the important role of trees as ecosystem service providers and highly beneficial to human societies and the ecological systems they propagate (Capotorti et al., 2017). Trees have been widely recognized as the main provider of ecosystem services in urban areas (Roy et al., 2012). In the instance of the Rome case study, researchers analyzed specific aspects of trees and urban forests that play an important role in the quality of urban ecosystems in combination with the provision of ecosystem services. Specific ecosystem services were selected, and for each service, researchers identified the tree and forest traits/species that influenced service provision. They subsequently integrated ecosystem service research with information available on plant diversity, including species distribution, conservation interest, and potential vegetation. The next stage involved selecting features that were critical to urban forest and tree conservation based on scientific literature and knowledge of local drivers of biodiversity loss. At the conclusion of their research, they developed a ranking system for each ecosystem service and provided three tiers for each service, detailing the species or morphological features that would positively influence each service's provision. In addition to the ranking system, they provided suggested actions for integrating biodiversity values into green infrastructure initiatives in Rome. These recommendations included: proactive conservation focusing on tree types that are most representative of local vegetation; facilitating passive restoration and propagating natural dynamics; controlling the spread of invasive species along with the site-specific non-native replacement with natural vegetation; and active restoration of seed source to enhance function connectivity (Capotorti et al., 2017).

The results of the Rome case study reinforce the importance of trees and urban forests because of the quality of ecosystem services they provide and for their use as indicators of ecosystem health. Researchers in Baltimore conducted a similar study where they identified five clusters of trees, taking into account canopy conditions (high or low) and the direction of canopy change (increase or decrease) (Anderson et al., 2021). Leveraging long-term data, they found unique patterns of canopy structure and biodiversity across the five clusters. Residential clusters supported high biodiversity and areas with increasing canopy were "dominated" by native species. Additionally, decreasing canopies were "dominated" by non-natives. It is notable that canopy trajectory results were consistent across land-use types (Anderson et al., 2021). The residential cluster results are particularly useful to Arlington, as one of its main goals is to utilize private gardens to improve habitat connectivity and enhance ecological resilience. Moreover, the consistency of results across land use types will allow the Town to continue their tree-planting efforts without having to take into account the present land-use. The results of the Baltimore and Rome cases emphasize the importance of increasing canopy cover in Arlington. The inclusion of private gardens in these plans will likely improve connectivity, ecosystem services, and significantly reinforce native species, which will further aid pollinator population health, an aspect we identify as lacking in many cases and in the Concord Sustainable Landscaping Handbook.

3.8 Increasing Biodiversity

Once a baseline understanding of an area's biodiversity is established, and a plan for monitoring progress is put into place, developing steps to enhance and protect that biodiversity becomes the priority. In "The Seven Lamps of Planning for Biodiversity in the City," seven major facets of enhancing biodiversity in urban areas are laid out (Parris et al., 2018). This paper's recommendations are concrete and backed by other scientific works. Using this framework, and incorporating additional source material, the following major categories have been outlined for enhancing biodiversity:

Protection

The easiest, often cheapest, and most straightforward way to preserve biodiversity is to start by preserving what exists in natural high-diversity ecosystems (McKinney, 2002). In order to do this, where and what those ecosystems are first needs to be ascertained, which can be done using the techniques outlined in the Measuring and Monitoring Biodiversity section of this paper.

Connectivity

The importance of connectivity is outlined in the ecological corridors section of this paper. "The Seven Lamps of Planning for Biodiversity in the City," distinguishing it as one of seven key factors only highlights just how important it is for biodiversity (Parris et al., 2018). Without connectivity flora and fauna are trapped in land patches, where they are more vulnerable to food shortages, overpopulation, and development (Parris et al., 2018).

Construction

Urbanization tends to cause habitat loss (Alberti, 2003). It is only natural that cutting down woods or paving meadows would do this, but it does not mean planners should accept this unintended consequence. Because urbanization clears an area of natural habitats for certain species, it is important to try and recreate and replace those habitats as much as possible (Alberti, 2003). Building with habitat creation and structural diversity in mind allows for these habitats

Figure 3.4: A bee brick incorporated into a building (Cloke, 2022)

Figure 3.5: Close up image showing a bee entering a bee brick (Souza, 2022)

to get replaced (Lundholm, 2006). Birdhouses, bee bricks, and green roofs are all examples of how those habitats can be recreated during the construction process (see Figure 3.4, 3.5, and 3.6) . However, constructing ecosystems can have negative consequences. The process to build an ecosystem in an urban space can require significant time and money and can exacerbate negative outcomes like habitat fragmentation (Pataki, 2015). Therefore, it is important not to rely solely on building ecosystems and habitats as an alternative to protection. Balancing natural recovery with green infrastructure initiatives is important to maximize urban ecosystem health as well as avoid unintended consequences as biodiversity efforts continue to scale to larger cities.

Cycles

Not only does urbanization disrupt habitats, but it can also disrupt the natural cycle of water, nutrients, and energy in that area. Removing organic tree waste or redirecting water flow alters natural cycles that are often important for maintaining the flora and fauna living in that area (Parris et al., 2018).

Benevolence

Construction should not just strive to create habitats, but also to reduce harm. There are many unforeseen consequences of buildings that can interfere with and even harm the flora and fauna communities of that area. While sometimes these aspects of urbanization cannot be avoided, for example, cars harming animals crossing roads, many can be avoided through simple design changes.

Figure 3.6: A green roof (Smart Cities World, 2021)

For example, modifying windows can reduce bird strikes on glass windows, and dimming lights in key areas can reduce the impact of artificial lights on animal circadian rhythm (Ogden, 2014). Even accidental animal killings on roads can be greatly diminished by adding wildlife bridges and tunnels (Machemer, 2020). While much of our infrastructure strives to be green through energy use or construction materials, we need to also incorporate the protection of what exists outside the building and consider the communities of flora and fauna that may interact with it (Parris et al., 2018).

3.9 Urban Ecology Vision/ Future

As the world continues to rapidly urbanize, policy efforts to protect and enhance biodiversity and ecosystem services must be deliberate and continuous. The interconnectedness of these systems makes singularly oriented policy solutions ineffective. Multiple policy approaches that embrace the diversity of conservation instruments are critical. Singapore has been at the forefront of holistic policy that recognizes the connectivity of urban systems (see Appendix A). In collaboration with the Convention for Biological Diversity, the country developed their own tool to evaluate a city's biodiversity conservation efforts by covering a broad range of indicators like governance, biodiversity management, and native biodiversity (Convention on Biological Diversity, 2021). The resulting "City Biodiversity Index" tool has been adopted globally for cities to evaluate their current conservation efforts, set priorities, and allocate budgets by prioritizing 28 indicators of urban biodiversity (Convention on Biological Diversity, 2021).

In 2008, the Singapore government established the Inter-Ministerial Committee on Sustainable Development (IMCSD) to "formulate a national strategy for Singapore's sustainable development in the context of emerging domestic and global challenges'' (Ming, 2018). Singapore's National Biodiversity Strategy and Action Plan is guided by five encompassing strategies, one being the integration of biodiversity into policy and decision-making. The establishment of the IMCSD and the integration of conservation into decision-making addresses the main challenges facing biodiversity policy. Establishing collaborative, interdisciplinary committees involving multi-stakeholder participation has been identified as a key solution to overcoming challenges such as lack of a sound-scientific basis, highly complex decision-making, and fragmented interests (Matsumoto et al., 2020). All of Singapore is surrounded by water, creating multi-sectoral use of coastal and sea-space. The system has become increasingly complex, so the need for balance in development, conservation, and public health has increased. The Technical Committee on Coastal and Marine Environment (TCCME), which is composed of members from different agencies and sectors, was established to address these issues and adopt an integrated coastal management approach. In its thirteen years of existence, the TCCME has effectively managed seawater quality and pollution, and perhaps more importantly, provided a platform for relevant agencies and actors to achieve a greater understanding of what is necessary to propagate biodiversity (Ming, 2018).

The coastal management aspects of this case do not directly apply to Arlington due to the absence of marine ecosystems. However, the multi-disciplinary and collaborative principles built on communication, transparency, and exchange of information are aspects Arlington policymakers could consider. Moreover, the top-down approach taken by the Singapore government can deter the legitimacy of community input in these processes. Arlington may want to make it a priority to effectively engage community stakeholders to maximize policy implementation because they can provide valuable input based on their lived experiences (Organization for Economic Development and Cooperation, 2013).

Policy Inventory Review

Based on the methods for enhancing biodiversity and urban ecology frameworks analyzed found in the literature review, a table of Arlington's completed actions in each plan were categorized in the Policy Inventory Table (Table 4.1). From the literature review and case examples, we analyzed several themes which we used to create a rubric to investigate how Arlington's current plans align with urban ecology.

4.1 Results

After analyzing the table, we found that none of Arlington's plans have completed actions for all urban ecology elements identified in the literature review. However, it is important to note that not all elements are applicable to every plan, and the plans were not developed with these specific categories in mind. The element found to be most lacking in Arlington's current plan was the incorporation of urban ecology into the planning process itself. As of now, there have been no plans that have completed actions or done work to incorporate urban ecology into future planning, design, or decision-making. Only the Public Land Management Plan incorporates urban ecology into its planning framework at all by developing a Green Streets Master Plan which gives a set of goals that will optimize investments in trees, utilities, green infrastructure, and drainage systems (Public Land Management Plan, 2022). While this plan does not directly incorporate the concept of urban planning, it does give a set of goals in line with urban ecology goals and principles (Parris et al., 2018). This finding is not unexpected as the very reason for this report is in order to have the baseline knowledge needed to incorporate urban ecology into planning in the first place. In fact, this project was taken on with the assumption that Arlington was lacking urban ecology as part of its planning. However, by adding this element into the rubric now Arlington can track their progress integrating urban ecology into planning over time.

So far, Arlington's measuring and monitoring of urban ecology baselines and metrics have been limited, with only the monitoring of the spy pond in the Public Land Management plan having been completed (Public Land Management Plan, 2022). There are a few planned measuring and monitoring urban ecology efforts in the Public Land Management Plan, including mapping canopy characteristics: overstory canopy coverage, understory light, gap sizes, viable regeneration openings, as well as site characteristics: moisture, slop, and solar aspect (Public Land Management Plan, 2022).

Despite limited urban ecology metrics, monitoring, and mapping, there has been quite a bit of work done to measure and monitor biodiversity. The Public LandManagement, Open Space & Recreation Plan, and Municipal Vulnerability Plan have all successfully rolled out a monitoring system for biodiversity. These initiatives included encouraging volunteer groups to monitor and control invasive plants, monitoring spy ponds and reservoirs and treating invasives and taking other actions to manage vectors and invasive species (Public Land Management Plan, 2022 & Open Space & Recreation Plan, 2022, & The Municipal Vulnerability plan, 2018). It is also notable that there seemed to be no strong correlation between incorporating monitoring, and management of biodiversity into a plan and successful biodiversity enhancement actions. However, it should also be noted that the Public Land Management Plan, which is the only plan to incorporate measuring and monitoring both biodiversity and urban ecology metrics also had the most urban ecology enhancement categories built into its plan (reference: see the Policy Inventory Review table).

Elements of Urban Ecology	Plan					
	Mill Brook Corridor	*Hazard Mitigation Plan*	*Tree Management Plan*	*Public Land Management Plan*	*Open Space and Recreation Plan*	*Municipal Vulnerability Plan*
Measures, Monitors, or Maps Urban Ecology Metrics	No actions taken	Does not apply	Does not apply	Actions taken	No actions taken	No actions taken
Enhances Connectivity	Actions taken	No actions taken	No actions taken	No actions taken	Actions taken	No actions taken
Incorporates Natural Water Management or Restored Flow	Actions taken	Does not apply	No actions taken	No actions taken	Does not apply	No actions taken
Enhances Tree Cover	Actions taken	Actions taken	Actions taken	No actions taken	Actions taken	No actions taken
Incorporates Private Property into Planning	Actions taken	No actions taken	No actions taken	No actions taken	Actions taken	No actions taken
Integrates Urban Ecology into Planning Process	No actions taken	No actions taken	No actions taken	No actions taken	No actions taken	No actions taken
Meausures or Monitors Biodiversity	Does not apply	No actions taken	No actions taken	Actions taken	Actions taken	Actions taken
Enhances Protection Areas	Does not apply	No actions taken		No actions taken	Actions taken	No actions taken
Includes Constructed Habitats	No actions taken	No actions taken		No actions taken	No actions taken	No actions taken
Preserves Natural Cycles	Actions taken	No actions taken		Actions taken	No actions taken	Actions taken
Constructs with Benevolence	No actions taken	No actions taken		No actions taken	No actions taken	No actions taken
Other Biodiversity Enhancement	Does not apply	No actions taken	No actions taken	Actions taken	No actions taken	No actions taken

Table 4.1: Policy Inventory Table, from current and ongoing actions found in Town Plans, sorted into urban ecology elements based on the Literature Review (Information compiled by the Team, table designed by Deandra Boyle)

Actions taken

No actions taken

Does not apply

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Spatial Analysis

5.1 Introduction

The goal of spatial analysis in this project is to identify suitable areas for biodiversity enhancement. As the project lays the foundation for urban ecology in Arlington, the Team chose to conduct a suitability analysis of potential biodiversity to identify prioritization areas within the Town of Arlington that could benefit from urban ecology framework. Furthermore, a suitability analysis could be the first step to conducting a more comprehensive corridor analysis for future study (Peng et al., 2017).

5.1.1 Slope

From the slope input layer (see Figure 5.1), it was apparent that the eastern third of Arlington was relatively flat – this includes the East Arlington and Arlington Center neighborhoods. The rest of the Town had varied topography, particularly in the aptly named Arlington Heights in the north, near the Winchester border – the highest point in Arlington is located here at an elevation of 377 feet. The steep inclines required to get to relatively flatter land, as seen by the brown-yellow-green gradient, indicates that the hilly landscape may pose an obstacle to wildlife. Some issues associated with steep grades above 10% include erosion, poor drainage and less productive soils (Centre County, n.d.).

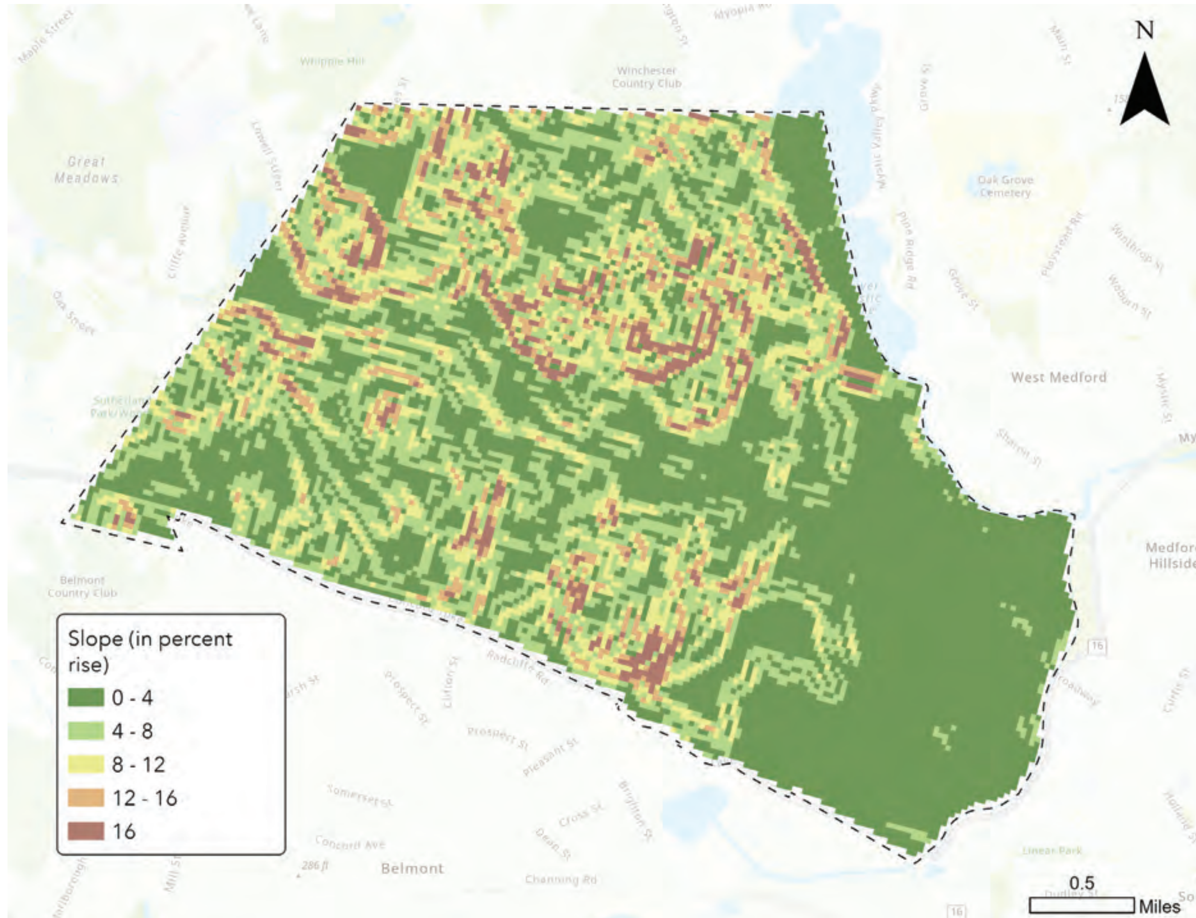

Figure 5.1: Map of Slope (created by Deandra Boyle & Tiffany Wu)

5.1.2 Water Proximity

Arlington is fortunate to be in close proximity to many waterways and bodies of water. From our analysis, the vast majority of the Town was within 1600 meters of a mapped water body, with more than half within 800 meters (see Figure 5.2). The only exception to proximity to water was the small portion of town in the southwest, near the Concord Turnpike. This comprises a small portion of the Poet's Corner neighborhood. From our April site visit, the Team noted that many different species of wildlife, ranging from shorebirds to turtles, were spotted in or near these bodies of water.

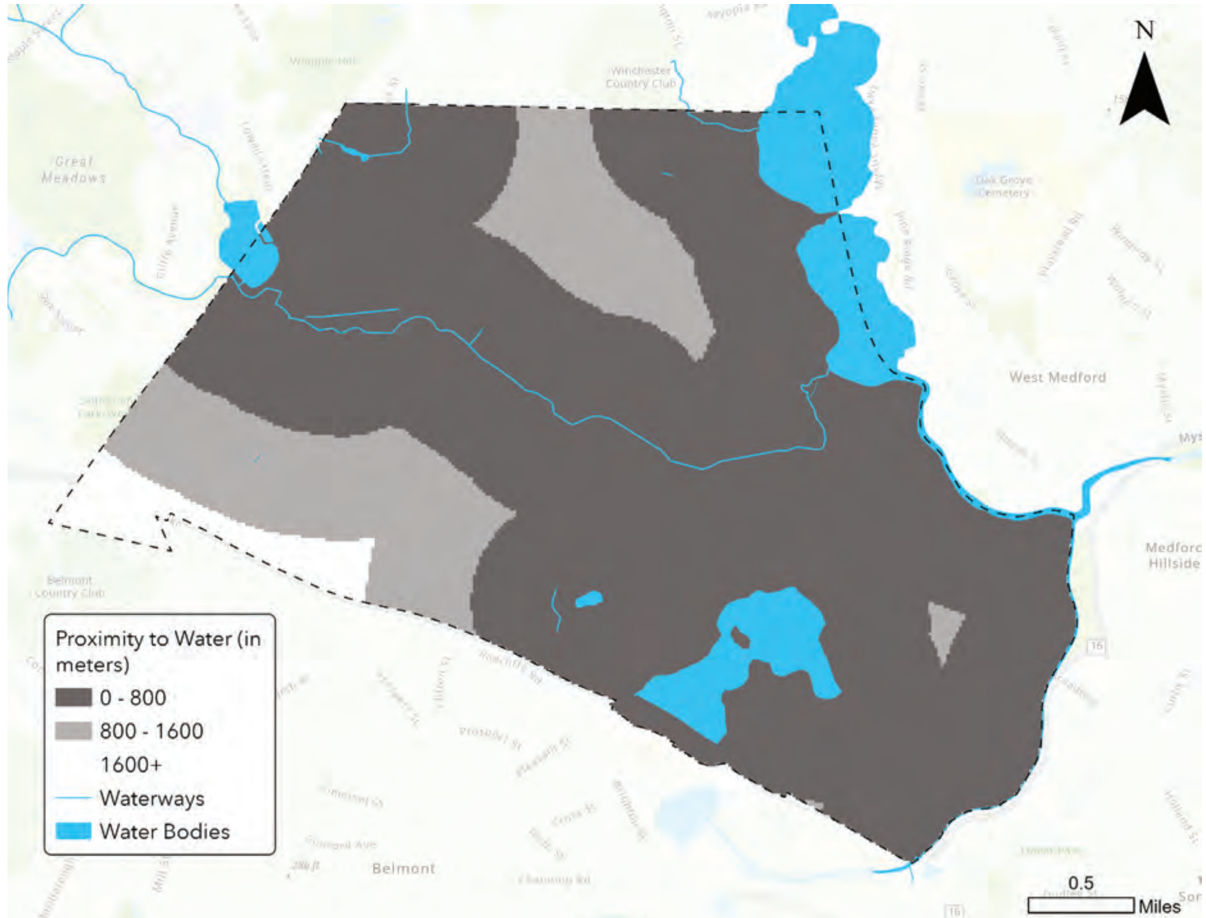

Figure 5.2: Map of Proximity to Water Bodies (created by Tiffany Wu)

5.1.3 Road Proximity

Being close to Boston, the Town of Arlington is fairly dense and has a network of roads that reflect this reality (see Figure 5.3). Major thoroughfares such as Massachusetts Avenue, Mystic Street (Route 2), Highland Avenue and the Concord Turnpike can contribute to landscape fragmentation, which was noted as a major barrier to biodiversity (see Section 3.4 of the Literature Review). The strengths of the Town do not necessarily lie in the distance of its backyards and open spaces from paved roads. With that said, it is not the only factor that contributes to the ability of flora and fauna to thrive.

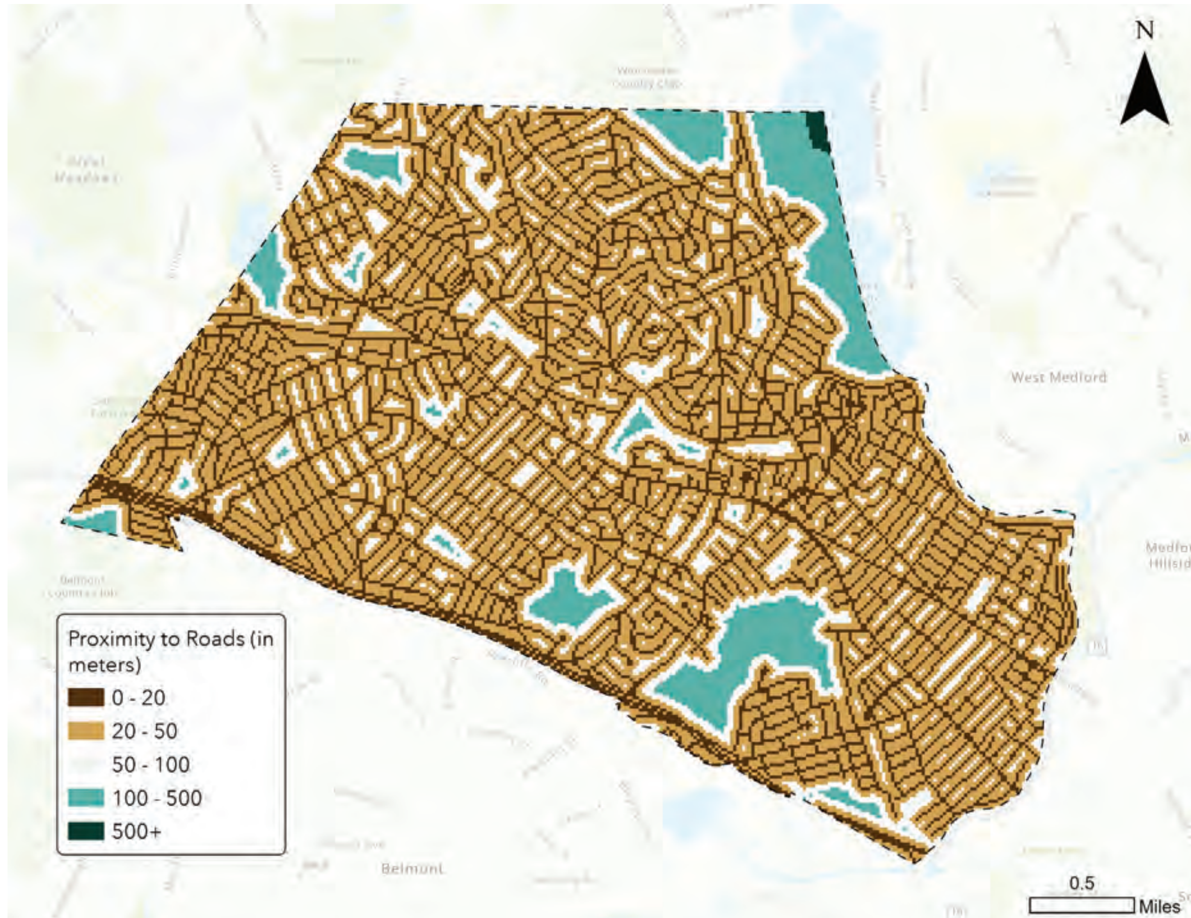

Figure 5.3: Map of Road Proximity (created by Deandra Boyle & Tiffany Wu)

5.1.4 Species Richness

Observations from iNaturalist were witnessed all over Arlington, a welcome sight. From our kernel density map, it appeared the areas around open spaces had the most clustering of wild plants and wildlife (see Figure 5.4 and Figure 5.7). These species-rich areas are capable of supporting the most biodiversity due to their ability to provide shelter, nesting or breeding grounds, serve as ecological corridors, and allow wildlife to forage freely. Some of the most common iNaturalist animal observations the Team noted included Mallards (Anas platyrhynchos), Eastern Cottontails (Sylvilagus floridanus), Common Eastern Bumblebees (Bombus impatiens), and American Robins (Turdus migratorius). On the plant side, some of the most common observations included Black Swalloworts (Vincetoxicum nigrum), Garlic Mustard (Alliaria petiolata), Japanese Knotweed (Reynoutria japonica), and the Oriental Bittersweet (Celastrus orbiculatus).

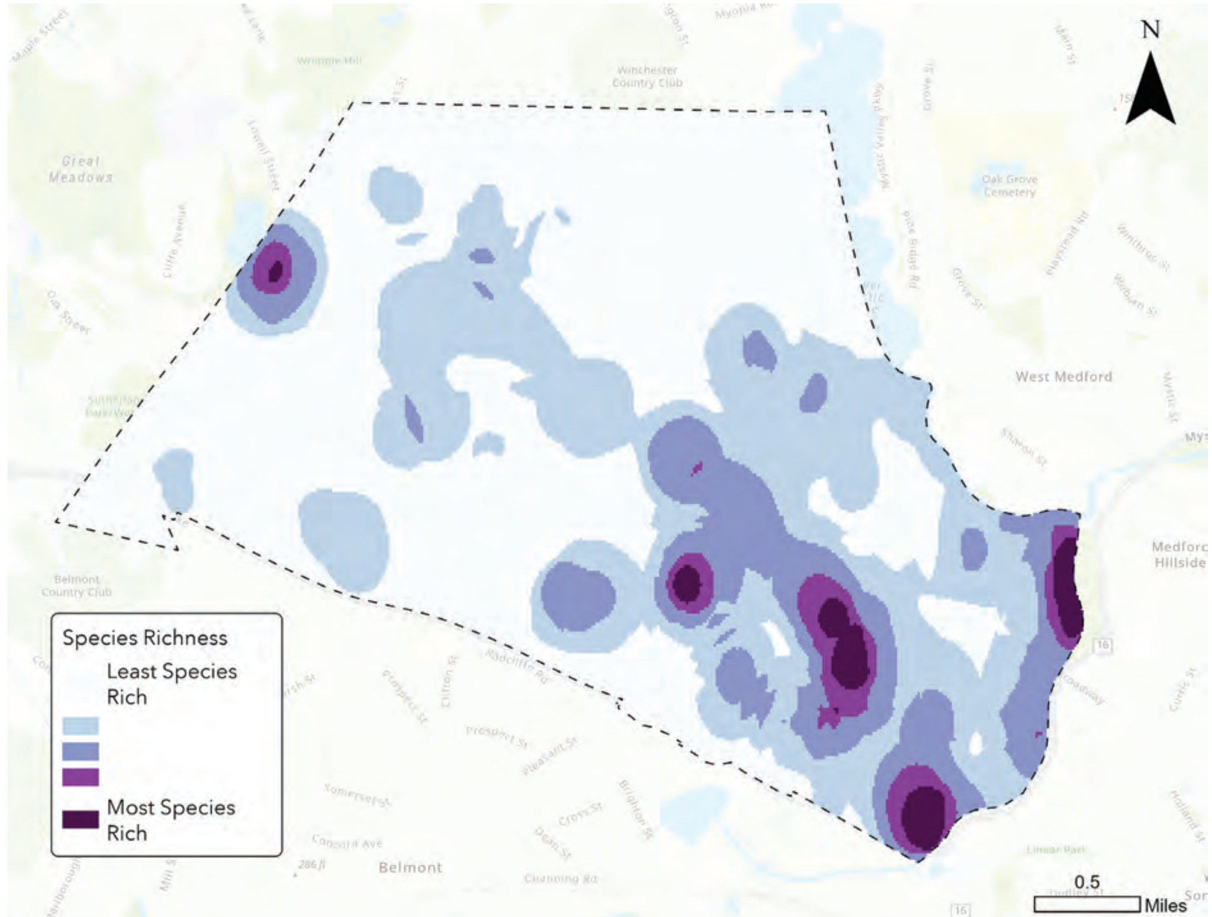

Figure 5.4: Map of Species Richness from iNaturalist data (created by Deandra Boyle)

5.2 Results

From our preliminary analysis using the unweighted suitability map, one can see that the areas most suited for biodiversity are located in the eastern part of the Town, particularly near Spy Pond and Alewife Brook (see Figure 5.5). Biodiversity suitability scores near bodies of water were consistently higher than in surrounding regions, including Upper and Lower Mystic Lake and the Arlington Reservoir near the Lexington border.

Based on the weighted suitability map (see Figure 5.6) , there are a couple of key findings regarding biodiversity suitability in Arlington. Our suitability map 'weighted' the four factors differently, which produced a more dynamic map that can be used for analysis (see Section 2.3 and Figure 2.2 for more details). As expected, the areas that have the most potential for biodiversity include Spy Pond and Arlington Reservoir (see Figure 5.6). These areas had scores as high as 17, which was the highest resulting score from the suitability map. Perhaps unsurprisingly, these are the places in Arlington that already serve as a biodiversity hotspot based on existing data.

Regions within the Town that contain the least potential for biodiversity are the areas where the areas are zoned

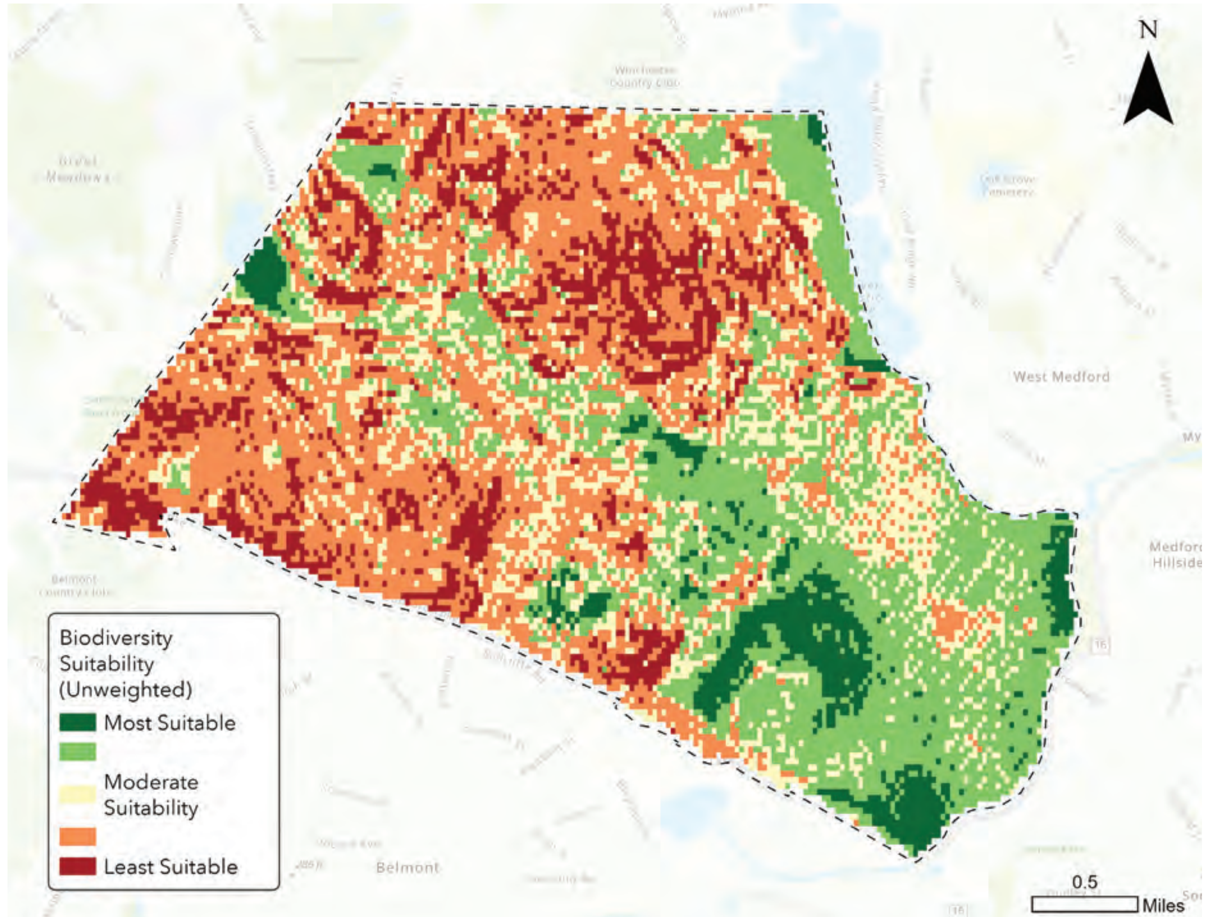

Figure 5.5: Unweighted Biodiversity Suitability Map (created by Deandra Boyle & Tiffany Wu)

for housing, particularly single-family housing (see Figure 5.8). Impervious surfaces can comprise up to 65% of residential lots and 85% of commercial lots (University of Delaware NEMO, n.d.), and the presence of human activity may also pose an obstacle to biodiversity. The scores for these areas in the northern third and western portions of the Town were as low as 5 in composite.

Analyzing the results layer by layer, the hilly topography of Arlington was apparent, with large swaths of the Town's northwestern and western portions unsuitable for biodiversity based on scores of 1 and 2 for slope. Even though some municipal open space just north of Massachusetts Avenue was located in these steep areas, the significant change in grade made them less unsuitable for biodiversity based on our analysis. In contrast, the eastern third of the Town was relatively flat, and there was little change in percent rise of elevation detected. This part of Arlington largely scored a 5.

The greatest species richness for mammals, birds, insects and plants appeared to be around the Spy Pond corridors and various parks, with scores of moderately suitable and above (see Figure 5.7). There were extremely few sightings of wildlife or wild plants noted in residential areas, leading to scores of

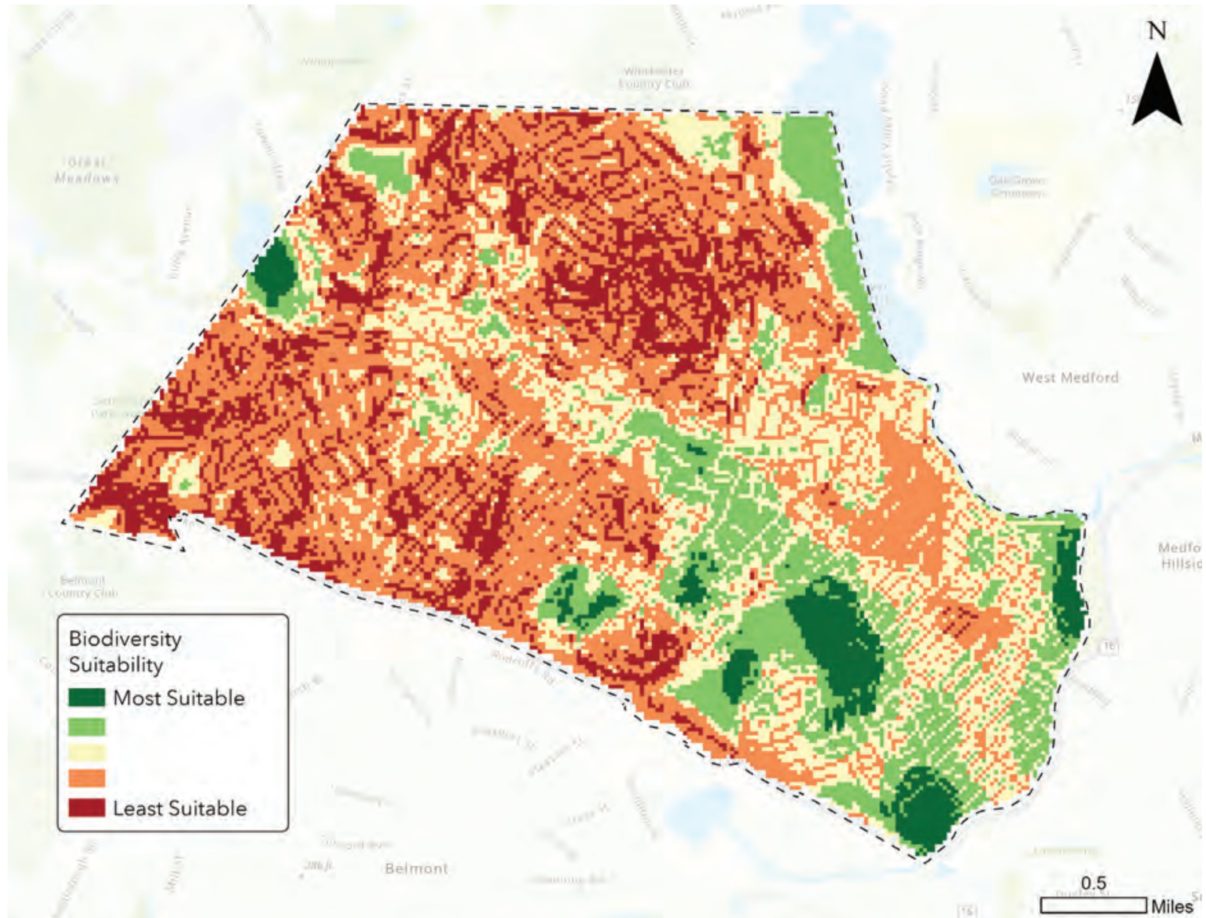

Figure 5.6: Weighted Biodiversity Suitability Map (created by Deandra Boyle & Tiffany Wu)

1 and 2 in these parts, although this may reflect a lack of reporting or uploading to the iNaturalist database as opposed to an absence of biodiversity altogether. Residents are more likely to record interesting sightings at places of interest, such as local parks, instead of their own backyards, although greater outreach regarding citizen science practices encouraging additional reporting could change that. Regardless, we were able to corroborate this species richness information with a map layer from the University of Massachusetts, Amherst's Designing Sustainable Landscapes Lab (see Appendix B), which suggested largely the same results.

Due to the presence of Spy Pond, Upper and Lower Mystic Lake, Mill Brook, Arlington Reservoir, and other bodies of water, most of Arlington is in close proximity to at least one water source, indicating that insufficient proximity water should not pose an issue for wildlife or plants, who may utilize these places as nesting grounds or shelter. The vast majority of the Town scored a 4 or 5 with regards to proximity to water, meaning they were at most 1600 meters away from a mapped water source (see Figure 5.2)

Because of the highly urban nature of the Town, roads were present throughout, ranging from smaller residential roads to the Concord Turnpike, which forms the

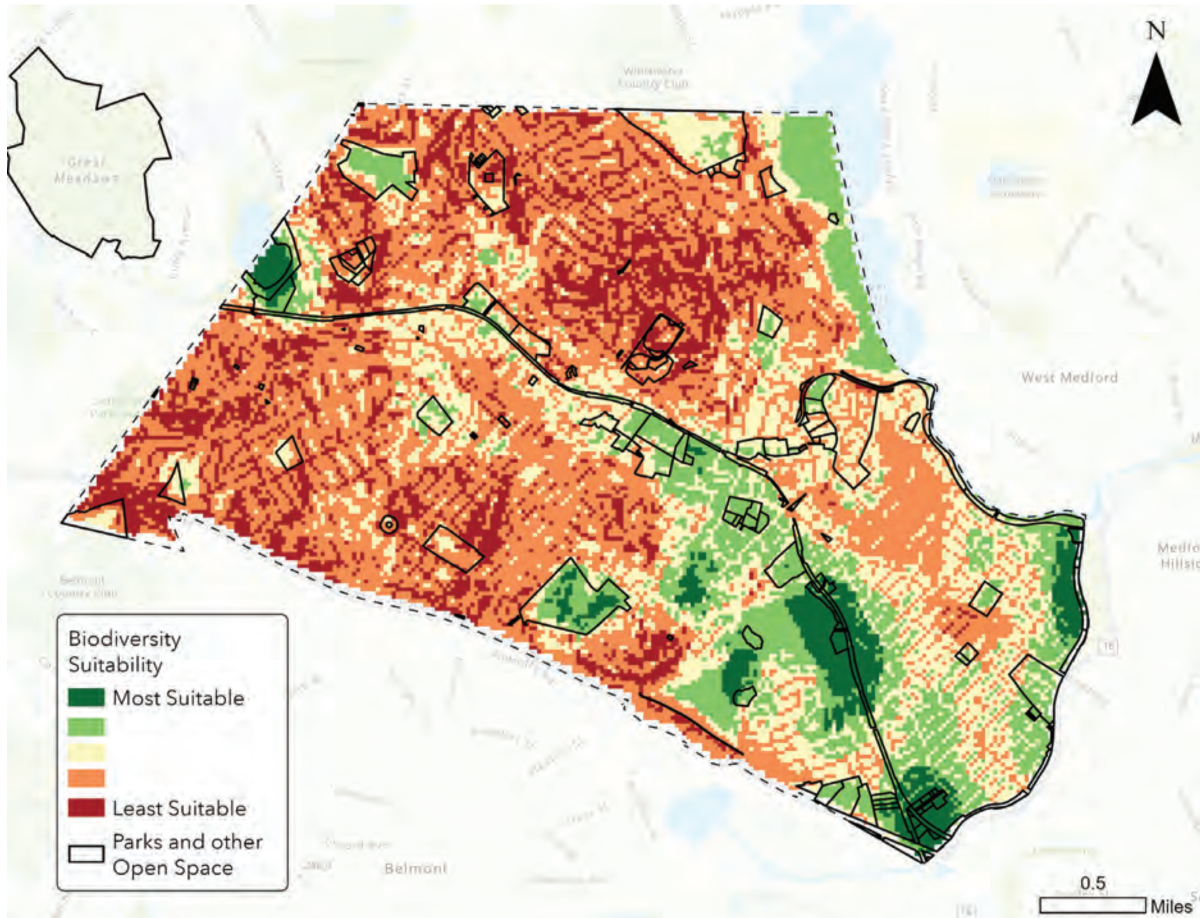

Figure 5.7: Weighted Biodiversity Suitability Map with Parks and Open Space Overlay (Created by Deandra Boyle)

southern border of Arlington. As such, the most suitable regions turned out to be lakes and ponds. The lot sizes in the Kelwyn Manor neighborhood south of Spy Pond appear to be slightly larger than the rest, but the difference from the analysis appears to be negligible. Most of the Town is zoned for residential use, particularly R0 (large lot single family) and R1 (single family), with the exception of the Massachusetts Avenue thoroughfare, which is mostly zoned for industrial and business use (Town of Arlington, n.d.). The biodiversity suitability map also revealed that areas within R0 and R1 zoning have the least potential for biodiversity (see Figure 5.8), which indicates that these are the areas that could benefit this most from biodiversity enhancement interventions.

The unweighted suitability map, which took all four raster layers into equal account, indicated moderate suitability for more of the Town as compared to the weighted suitability map (see Figure 5.5 and Figure 5.6). The weighted suitability map, on the other hand, clearly demonstrated the presence of steep terrain and roads made most of Arlington less suitable and the areas by Spy Pond and Menotomy Rocks Park highly suitable. The latter, which more accurately accounts for how various input layers affect wildlife by assigning a weight to each one, was seen as the optimal

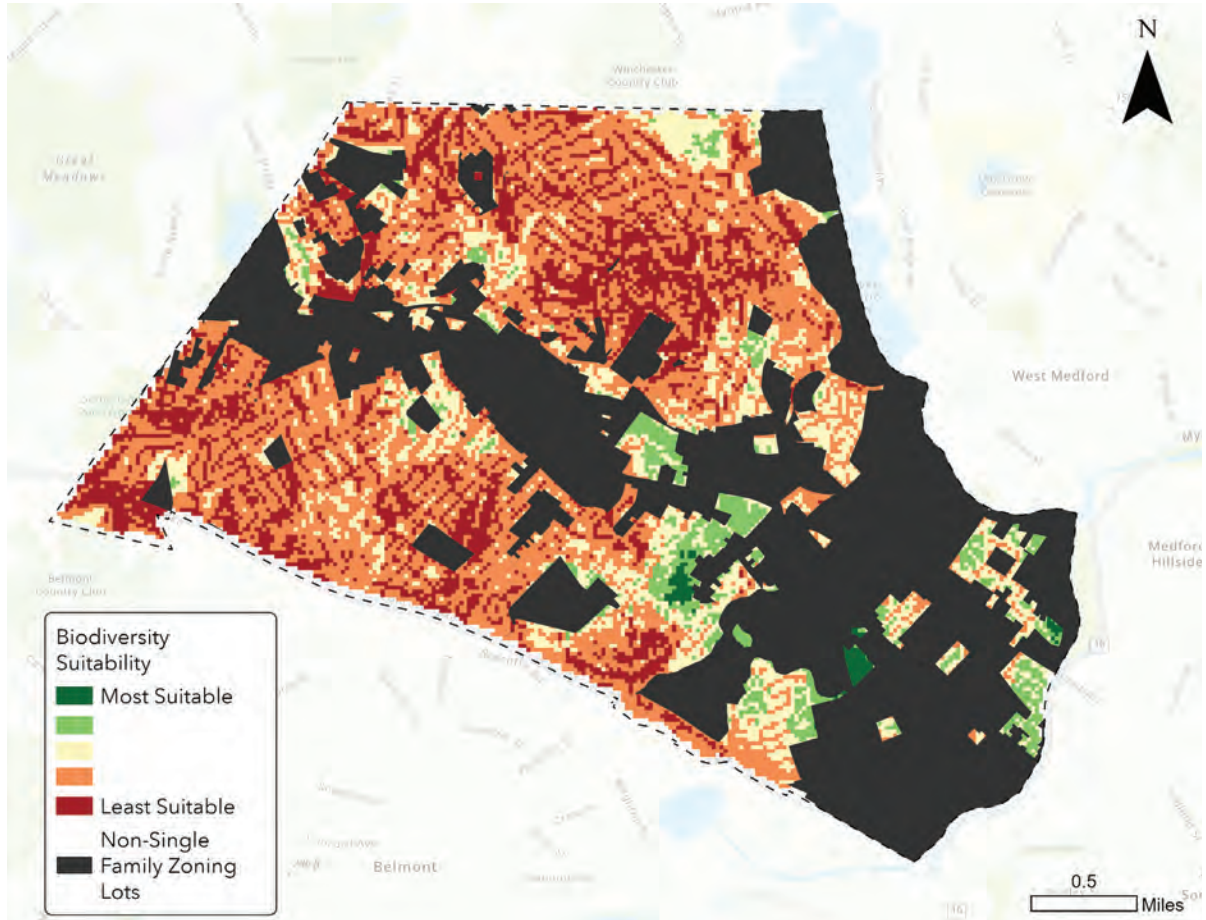

Figure 5.8: Biodiversity Suitability in Areas with Single-Family Zoning Lots (R0 and R1) (Created by Deandra Boyle)

approach. The site visit conducted by members of the Team also corroborated the suitability map's findings regarding these areas that were deemed optimal.

Addressing the Gaps: Analysis & Discussion

To gain a comprehensive understanding of the gaps in the Town of Arlington's urban ecology plans, the Team conducted a literature review, policy inventory review, and spatial analysis. While each research method uniquely provides insights into how Arlington can improve its biodiversity plans, together they create a holistic understanding of the urban ecology gaps in Arlington's current plans. To synthesize this information, the Team identified themes from the findings of the different research methods for further discussion below.

6.1 Opportunities to Incorporate Urban Ecology Elements in the Decision Making Process

A significant deficiency in urban ecology and ecological land management is its lack of integration into policy decision-making (Alberti et al., 2003). The interdisciplinary nature of urban ecology lends to its complexity and the need for trans-disciplinary collaboration. Singapore is a prime example of the inter-agency collaboration to promote urban ecology on a more national scale (OECD, 2013). However, there are examples at the local level that present a more replicable model for Arlington. Melbourne, Australia built an effective Green Factor Tool through interdisciplinary collaboration between architects, designers, policymakers, researchers, and community stakeholders (Bush et al., 2021). The close collaboration of practitioners, researchers, and community stakeholders encouraged transparent exchange of information and created a foundation built on peer-reviewed research (Bush et al., 2021). Arlington must similarly build urban ecology into the backbone of their decision-making process.

An important aspect of incorporating urban ecology into planning begins at a very early stage of the planning process, with the conception and drafting of the plan. This report does not assess the plan creation process, only the drafted or final plans themselves. It is clear based on the results of the Policy Inventory Table that Arlington's Town Plans have integrated many elements of urban ecology (see Table 4.1). Despite the plans not being created to address the categories generated by the literature review of this project, almost all categories were addressed at least once (see Table 4.1). This indicates that while each of these categories may not have been deliberately addressed, many of them may have been at least considered.

However, regardless of whether or not urban ecology was considered during the plan creation process, there is room for improvement, when it comes to the way urban ecology is affecting the decisions that are made after the plan is complete. It was found in the analysis of current plans that urban ecology was not being incorporated into continual decision-making, despite other aspects or urban ecology often being touched on in those same plans (see Table 4.1). This means that urban ecology is being addressed often through a set of hard and fast rules rather than goals, whose subsequent action is informed by urban ecology principles. For example, the public land management plan states that the municipality should "avoid topographical changes" and avoid mowing entire meadows in one year for habitat diversity (Public Land Management Plan, 2022). While these are likely done in order to meet a goal such as enhancing biodiversity or maintaining natural cycles, which are urban ecology metrics, they do not allow for changes in decision making as conditions change. Avoiding topographical change in one area could legitimately preserve that area's natural topography and erosion cycles, but in another it could be ignoring erosion. The environment is in a constant state of change, and not incorporating a mechanism to change approaches based on environmental conditions negates one of the fundamental points of urban ecology - to live with nature (Atlanta City Design: Nature, 2020).

It is clear that Arlington is moving in the correct direction in regards to incorporating some aspects of urban ecology into its planning. The direction that this report proposes in order to take urban ecology further in Arlington is a novel one, and the changes suggested will not happen overnight. However, in order for urban ecology to be further incorporated into town planning it is vital that a concerted effort be made to enhance local representatives and decision makers' understanding of urban ecology through educational resources and models developed through other communities. This report may act as foundational research to develop this education, but for urban ecology to be truly incorporated into planning, it must be championed by decision makers who will be present when plans are being created.

6.2 Private Property Considerations in Urban Ecology

One major gap that the Team's research has identified was the lack of private property considerations in planning for biodiversity enhancement, protection, and sustainable landscape practice. The spatial analysis revealed that areas with the least potential for biodiversity within Arlington are areas that are zoned for single-family residential housing (see Figure 5.9). At the same time, there are little to no considerations of private property in conservation land management, as evidenced by how few plans include private property management and policies (see Table 4.1). This gap in planning is important to highlight as Arlington owns only 9% of the 3500 acres of land in Arlington (Arlington Master Plan, 2015). If Arlington seeks to fully utilize an urban ecology framework, the planning department must consider how they can manage private property within this framework. This is especially important because private landowners conducting sustainable landscape practices are shown to significantly contribute to habitat availability and connectivity and in some cases, have a greater impact than public land (Mimet et al., 2020).

At the time of this project, Arlington is in a unique position to address this gap. In December 2022, the Town announced that they were awarded an Accelerating Climate Resilience Grant by the Metropolitan Area Planning Council (MAPC) to improve ecological integrity for private landowners. This project will produce a Sustainable Landscaping Handbook (SLH) that is adapted from the Concord Sustainable Landscaping Handbook, which can provide useful models that the Town can implement (Town of Concord, 2019). As such, there is an incentive for Arlington to create opportunities for private property owners to engage in sustainable landscape practices.

The Town has already taken measures to conduct sustainable landscapes workshops using the Accelerating Climate Resilience Grant, which allows interested citizens to learn about sustainable approaches to their yards, erosion control, and planting native species, among other topics (News | Town of Arlington, 2023). However, there are more ways than education to further include property owners to engage in sustainable landscape practices. Based on the Team's literature review, significant resources such as time and equipment are often required in order to practice sustainable landscaping effectively. To increase the number of citizens who can implement the sustainable practices outlined in the handbook, the Town of Arlington should consider establishing a shared equipment resource where landscaping tools can be rented and used communally. The same concept has been successfully applied in urban agriculture initiatives and there are guidebooks to inform effective practices (Gilbert, 2018).

6.3 Supporting High-Biodiversity Areas

While the spatial analysis can help identify areas to prioritize biodiversity enhancement in low-biodiversity potential areas, Arlington should also ensure that high-biodiversity potential areas are still being supported and that local wildlife can still thrive and not be disrupted. For example, the area surrounding Menotomy Rocks Park has a high potential to support biodiversity and urban wildlife, but the area is predominantly residential, where there is high prevalence of turfgrass which creates an artificial environment that presents little opportunity for native species to thrive. Furthermore, the liberal use of pesticides, herbicides, and synthetic fertilizers present an added threat to native plants and insects since they are designed to eradicate naturally occurring weeds and other plants (Hostetler & Main, 2010). Plants, animals, and insects do not recognize zoning borders, and it is important to establish a full-picture when supporting high-biodiversity areas and take into account the surrounding nature and built environments. During the Team's site visit to Arlington, the Team observed how the use of rat poison has resulted in the death of a Great Horned Owl in the Town (see Figure 6.1). This could also interplay with the second discussion point regarding

Figure 6.1: Poster discouraging the use of rat poison pinned on the Menotomy Rocks community board (Taken by Tufts UEP Field Projects Team on 4/12/23)

how private property plays an important role in maintaining habitats (Mimet et al., 2020).

Secondly, the Concord Sustainable Landscaping Handbook makes substantial notes on the importance of native species and reducing the presence of non-native and invasive species. Specifically, there is mention of propagating pollinators through pollinator gardens (Town of Concord, 2019). In the policy inventory table, the Town makes note of the pollinator gardens and planting native species (see Figure 4.1). This helps maintain the species-specific relationships between pollinators and invertebrates and propagates specialized-pollinator species since urbanization has been shown to reduce insect pollinator species richness and abundance (Bates et al., 2011). Installing beehives in high-biodiversity potential spaces such as Spy Pond or Menotomy Rocks Park would reduce the impact urbanization has on their populations and would also contribute to native plant-species genetic diversity since they would pollinate over a large area. Increasing genetic diversity is critical to population stability, without it the population is less resilient and robust, being unable to rebound from environmental pressures (Govindaraj et al., 2015). When deciding where to install hives, the Town should be aware of the spatial gaps required (typically 500 feet or ~.1 miles) to avoid resource competition (University of Georgia CAES, 2008).

6.4 Utilizing Biodiversity Metrics

The Town of Arlington has taken steps in their conservation efforts to measure and monitor different aspects of urban ecology. However, in the Town's plans, there is no clear connection as to how these measures translate into actions and how they affect the Town's planning process. In order to effectively propagate and conserve biodiversity, the Town should aim to measure a greater range of urban ecology metrics and utilize those metrics to implement successful biodiversity enhancement actions.

Establishing an accurate fabric map would provide greater depth to the Town's metrics that could directly translate into actions to enhance habitat connectivity and reduce threat of heat islands. A fabric map would clearly and precisely depict the distribution of impermeable surfaces in a given area (Akbari & Rose, 2001). Understanding the material distribution throughout the Town could be part of a greater system of gathering urban ecology metrics that would inform decision-making. However, it is key that these efforts are continuous as the literature highlights a limitation in biodiversity indicators is how they are observations from a certain place and time when biodiversity changes across space and time (Hill et al., 2016). The Town has systems in place to collect data like overstory canopy coverage, understory light, gap sizes, and viable regeneration openings. Collecting data on biodiversity metrics combined with existing data collection would help the Town understand their ecosystems and gain a clearer picture of their entire urban ecology. Overall, the gap analysis revealed to the Team that while Arlington measures some urban ecology metrics, they make no clear connection between their metrics and how they inform different biodiversity initiatives.

6.5 Collaborative Fronts

Our research of urban ecology frameworks frequently highlighted the important role of joint efforts between cities and municipalities (Atlanta City Design: Nature, 2020). Continuous measuring and mapping of urban ecologies is important to multi-generational management and changing management strategies as ecosystems continuously adapt. The City of Atlanta provides an excellent example of equitable access and biodiversity protection through effective mapping. While our GIS analysis can aid in understanding Arlington's current landscapes, it is essential to bring together community leaders and researchers to develop a similar strategy to Atlanta. Although mapping outside of its borders is challenging for Arlington, establishing open channels of collaboration with bordering towns like Belmont and Lexington would encourage information sharing and ensure that management practices and plans are as comprehensive and effective as possible. This is especially true when it comes to urban ecology, as the largest Town-owned parcel, the 183-acre Great Meadows preserve, is actually located in East Lexington (Arlington Land Trust, n.d.) – studying these places in tandem would be a thoughtful next step.

Because Arlington is a relatively small town in the Greater Boston area, it would also be prudent for the Town to partner with nearby municipalities on efforts expanding beyond technical analysis. From our in-person discussion with project partner David Morgan at the Arlington Town Hall, it seemed that the most successful grant applications and environmental planning endeavors were done in partnership with neighboring towns that faced the same issues, such as the aforementioned Winchester, Stoneham and Arlington MAPC award towards developing a sustainable landscaping handbook or the Wicked Hot Mystic urban heat island mapping initiative from the Mystic River Watershed Association, which includes a partnership of thirteen towns along the river (Resilient Mystic Collaborative, 2020).

6.6 Limitations

One of the limitations of the project was the lack of in-depth knowledge about the planning and creation process for the Plans covered by the policy inventory table. The analysis focused on the plans themselves rather than the process of writing the plans, which limited the ability to fully understand the context in which they were created. While the plans were assessed to see if they included any actions that would be relevant to the project's objectives, this only provided information on the outcomes of the plans, and not the process by which they were created.

Another limitation of this project was the lack of information regarding the town's budget and pricing for ecological initiatives. Without a clear understanding of the resources available to the Town, it was challenging to make specific recommendations for implementation or to assess the feasibility of proposed actions. This limitation underscores the importance of having access to comprehensive information on town budgets and resources when conducting ecological assessments and planning for the future.

Additionally, the project worked within the relatively small size of the Town of Arlington and the GIS team was limited in terms of availability of data on species and animals within the town. To overcome this challenge, the team used citizen science data from iNaturalist as a proxy for species richness. While this approach allowed for a broad assessment of biodiversity in the town, it may not accurately represent the full range of species present. Furthermore, because iNaturalist uses user observation data, the Team would like to acknowledge that the data may be skewed to areas where users are specifically looking for biodiversity. However, iNaturalist offers the best localized data for species through the Team's research. Thus, the lack of available data on species and animals within the town limits may have limited the scope of the project. Future studies may benefit from exploring additional sources of data or developing more targeted data collection efforts.

Finally, although Arlington has great natural resources such as Spy Pond and Mystic Lake, to get a comprehensive understanding of the town's biodiversity, it is necessary to look beyond its municipal boundaries. This is because the movement of animals and plant species is not constrained by political boundaries. Therefore, to gain a more complete picture of the town's biodiversity, it is essential to collaborate with neighboring towns such as Medford, Belmont, Somerville, and Lexington. By doing so, the project could benefit from a more extensive and collaborative approach to biodiversity analysis.

Recommendations

By analyzing case examples and frameworks, we can provide practical suggestions for improving Arlington's resilience to climate change and sustainable land management practices. Our evaluation has highlighted areas where the Town has made progress, but also where more work is needed. Our research shows that other towns facing similar challenges have effectively utilized nature-based solutions, including protecting vital ecological corridors, to combat the effects of climate change and preserve biodiversity. The next following subsections briefly summarize why the Team proposes these recommendations, and summarizes them into a table of actions (see Table 7.1).

7.1 Education and Outreach

We recommend that the Town of Arlington take steps to educate residents on urban ecology as the topic is relatively new. It is important to realize a shared understanding from both the perspective of the Town and its residents, in order to create effective goals and actions. These suggestions include outreach to schools, hosting educational events, and creating education materials in different languages to broaden audience reach.

7.2 Planning and Policy

Our second set of recommendations follows from the integration of urban ecology elements into plans and policy. Using the completed actions table, Arlington can understand their current position in biodiversity management and the metrics currently tracked. From this, they must depict a clear pathway on how their metrics inform and impact their decision-making. Additionally, the Town should initiate interdisciplinary collaboration across sectors like the Singapore Biodiversity Index, which shows how collaboration leads to effective biodiversity management under a set of unified missions and goals.

7.3 Private Property Incentives

Our third recommendation centers around the utilization of private property to enhance biodiversity and connectivity. Our gap analysis found that city plans do not capitalize on private property as a way to propagate biodiversity. Atlanta City Design: Nature did not mention private gardens and since the Town has recently received a grant to build its own SLH, the team sought ways for the Town to maximize its own SLHs effectiveness.

7.4 Data and Mapping

Our fourth set of recommendations can help Arlington utilize data and mapping to inform their management strategy. To deeply understand its ecologies, the Town should build the systems necessary to continuously track in-depth ecological data. Once that is achieved, the Town can look beyond its borders when mapping to understand its geographical context and how it can regionally collaborate to build regional management networks. The Town is still building its GIS capacity and should continue to do so to understand how its landscapes are changing over time.

7.5 Supporting and Creating High-Biodiversity Areas

Our final set of recommendations can help ensure that Arlington takes steps to preserve and continue to create high-biodiversity areas, areas that will be crucial if connectivity is improved. Site visits to Menotomy Rocks Park and Spy Pond showed the team areas where the Town can implement pollinator gardens and other ecological tools that propagate biodiversity, provide ecosystem services, and build a foundation for different management projects as the Town's metrics and ecologies change over time.

Themes	Actions
Education and Outreach	• Establish community gardens and wildlife habitat areas. • Host educational events and workshops with experts. • Partner with local schools and universities to educate youth and establish a network for future collaboration. • Create materials in non-English languages including but not limited to Spanish, Mandarin and Cantonese, and Portuguese to promote information accessibility.
Planning and Policy	• Create a plan that clearly depicts how biodiversity metrics and other data will be incorporated into decision-making processes. • Use the completed actions table categories as a checklist. • Incorporate feedback loops into plans based on urban ecology metrics.
Private Property Incentives	• Incentivize private property owners to incorporate sustainable landscapes by implementing incentives like rebates/reimbursements and a rewards/recognition program. • Create a shared resource/equipment program to increase accessibility and ease of participation.
Data and Mapping	• Create a connectivity map in collaboration with neighboring municipalities to contextualize regional ecologies. • Develop a system for ongoing monitoring and evaluation of the Town's ecological health, including regular assessments of water quality, soil health, and air quality. • Utilize technology such as GIS mapping and remote sensing to track changes in the Town's ecological landscape over time. • Develop an urban fabric map of Arlington using satellite imagery.
Supporting and Creating High Biodiversity Areas	• Implement measures such as pollinator gardens, bird-friendly habitats, or butterfly corridors. Areas on the edges of Menotomy Rocks Park and Spy Pond are unoccupied areas that can be utilized as a biodiversity haven as well as an education space. • Mandate the use of native plant species to provide food and shelter for local wildlife and permit the planting of invasives. • Mandate the use of native plant species to provide food and shelter for local wildlife and permit the planting of invasives.

Table 7.1: Summarized recommendations into themes and actions

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Conclusion

The world will continue to urbanize, with increased pressure on urban ecosystems. The role of biodiversity in the health of an ecosystem, including humans, cannot be overstated. Completing a policy inventory allowed us to accurately contextualize Arlington's current biodiversity management strategies and how they are addressing the Town's urban ecology. Examining existing plans and case studies in the literature review has shown effective strategies and science-based models that other cities have utilized. Additionally, it has highlighted gaps in current management practices and areas that Arlington can implement new strategies. The spatial analysis provided the geographic baseline that would be important in formulating our recommendations. Conducting a suitability analysis helped identify biodiversity preservation areas so we were able to tailor our recommendations to specific regions of the Town and areas that would be most beneficial to target conservation efforts. These three sections were each a critical piece of the gap analysis that helped the team form specific, precise, and science-based recommendations.

All things considered, the Town of Arlington has incorporated biodiversity into their plans, but they need to take steps to incorporate biodiversity and urban ecology into their decision-making processes. The Town collects data and measures aspects of their biodiversity, but does incorporate that data into their long-term planning and makes no clear connection between the data and their biodiversity enhancement actions. The spatial analysis revealed that the Town's biodiversity hubs are centered around their main bodies of water and those are also the areas that serve best to target efforts. Our analysis translated into recommendations encompassing accessibility, policy, measuring and monitoring, and actionable strategies. The most important step is integrating urban ecology into decision-making because it will maximize the effectiveness as well as unify efforts under the same mission. Effectively managing and propagating urban biodiversity requires a systems level approach, needing inter-departmental collaboration and public support. The Town of Arlington is laying the foundation for effective biodiversity management and is embracing the ecological challenges the Town faces in the future.

The Big Tickets

1 Examining the Town of Arlington's existing plans along with current literature highlighted the lack of integration of urban ecology into the Town's decision-making process, leading to scattered goals and an ambiguous path between metrics and management practices.

2 The spatial analysis allowed the team to create a baseline geographic understanding of Arlington and in tandem with the suitability analysis, helped us identify biodiversity hubs that are the ideal areas to target management efforts.

3 Combining the findings from our literature review and GIS analysis, our gap analysis created the science-based foundation for our recommendations, which center around accessbility, policy, measuring and monitoring, and actionable strategies.

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Appendix

A. Singapore National Biodiversity Action Plan 5 Guiding Strategies

1. Safeguard Our Biodiversity

This strategy aims at conserving Singapore's habitats and ecosystems for long-term sustainability so that Singaporeans can benefit from their multiple functions. Concerted efforts should be made to protect existing native species, habitats and ecosystems, and to re-establish species that once existed.

Actions:

i. Implement species conservation and recovery programmes
ii. Rehabilitate areas that have previously been degraded
iii. Extend green corridors to counter fragmentation
iv. Utilize parks for ex-situ conservation and to house or re-create ecosystems that have been lost

2. Consider Biodiversity Issues in Policy and Decision-Making

This strategy aims to conserve Singapore's habitats and ecosystems for long-term sustainability so that Singaporeans can benefit from their multiple functions. Concerted efforts should be made to protect existing native species, habitats and ecosystems, and to re-establish species that once existed.

Actions:

i. Incorporate biodiversity conservation considerations that include integrating coastal management principles into existing administrative processes
ii. Enhance biodiversity assessment capabilities
iii. Strengthen the current processes on access and benefit sharing, to ensure that biodiversity conservation is considered when granting access to Singapore's natural genetic resources

3. Improve Knowledge of Our Biodiversity and the Natural Environment

Keen knowledge of how the key ecosystems respond to our activities will enable us to conserve and use them in a sustainable manner. It is essential that we support taxonomic studies, document our biodiversity and conduct ecological research.

Actions:

i. Encourage and facilitate research, in particular on ecosystem and species-specific biodiversity conservation, the interactions between the biological components and their physical environment, biodiversity valuation studies and the impact of climate change on biodiversity
ii. Monitor the health of ecosystems and species as part of the management process
iii. Develop and maintain a central information portal on biodiversity to facilitate more informed decision-making
iv. Maintain a list of species with their conservation status (red data list)
v. Compile case studies on and assess best practices that have been implemented

4. Enhance Education and Public Awareness

Knowledge and awareness are prerequisites for action, hence communication on biodiversity issues are critical in driving public involvement. Effective communication will create greater awareness, interest in our natural heritage and instill a sense of national pride.

Actions:

i. Increase appreciation, awareness and understanding of Singaporeans for nature through public seminars, road shows and events
ii. Promote volunteerism through biodiversity interest groups
iii. Incorporate elements of biodiversity conservation into the curricula of all levels of education

B. Details of Spatial Analysis

Reclassification Process

The Reclassify tool in ArcGIS was used on all four of the input layers in order to simplify the data. The reclassification was done on a scale of 1 to 5, with 5 being the best. When reclassifying raster layers, the resulting output is simplified and can be analyzed on the same scale as other layers.

Raster Calculator

We used the Raster Calculator tool in order to create a combined raster layer which represents the weighted suitability map (see Figure 8.1). The symbology was modified on a gradient from red to green so that shades of green represented the areas with the highest suitability scores and shades of red represented the areas with the least. The highest output score possible from the Raster Calculator is thus 20 (5 + 5 + 5 + 5) whereas the lowest is 4 (1 + 1 + 1+ 1).

Designing Sustainable Landscapes Map

Using data from the University of Massachusetts, Amherst's Designing Sustainable Landscapes Lab (DSL), the Team was able to corroborate the preliminary findings that supported higher biodiversity suitability near water bodies in Arlington.

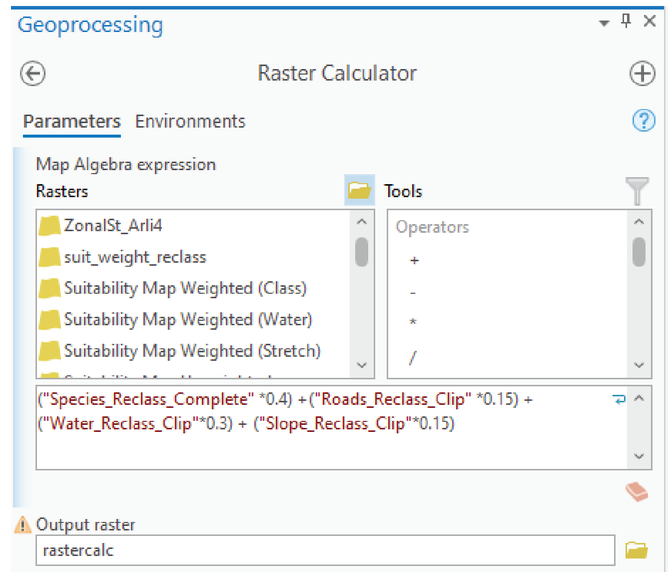

Figure 8.1: Raster Calculator for the weighted suitability biodiversity potential map, showing a 40% weighting on species density, 30% weighting on proximity to water, and 15% weighting on proximity to roads and slope.