LOCAL ENVIRONMENTAL STEWARDSHIP AND SOCIAL-ECOLOGICAL BRIGHT SPOTS IN NEW YORK CITY

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ABSTRACT

Due to a wide range of benefits, some of which are highly visible, urban vegetation, including tree canopy, lawns, gardens, vacant lots, and urban agriculture, has become an important focus for urban sustainability planning. As many major cities such as New York invest large amounts of public funds into programs to increase urban vegetation cover, city planners require scientific understanding to help them determine effective and equitable greening strategies. Because cities are complex social-ecological systems, with a range of ecological, socioeconomic, and technological factors driving vegetation dynamics, developing this understanding will require new, multi-disciplinary thinking and tools to understand the many drivers of urban greening and the emergent interactions between them. In particular, in human dominated ecosystems such as cities, human visions, values, and the social relations that shape urban forests need to be incorporated into assessments of urban vegetation.

In this thesis, I examine the impacts of local environmental stewardship groups, an important part of environmental governance in many major US cities, on vegetation change and management in New York City.

In Chapter 1, I review the development of the field of urban ecology, outline the body of literature on environmental governance with a specific focus on local environmental stewardship, and discuss applications for urban vegetation modelling and management. In this review, I develop a framework that can be used to empirically assess the multiple complex drivers of urban vegetation change; integrate metrics of stewardship into urban vegetation modelling techniques; and learn from examples of stewardship success to identify best practices for stewardship group organizing and action.

In Chapter 2, I examine the relationship between the presence of neighborhood stewardship groups and vegetative change in New York City between 2008-2016. Using a combination of remote sensing methods and linear mixed effects models, I estimate the statistical effect of

stewardship presence on neighborhood-scale ecological change across the entire city. I found that the number of stewardship groups present in a neighborhood has a significant, positive relationship with decade-scale vegetative change in New York City.

In Chapter 3, I investigate bright spots of stewardship practice, neighborhoods with much better ecological outcomes than expected, by examining the enablers and barriers to capacity building that shape effective stewardship action in five New York City neighborhoods. To amplify the impact of effective stewardship actions, we must first understand the capacities that enable them and how capacity building can be best supported. Using a mixed methods approach combining modelling, interviews, and qualitative analysis, I examine three assets that contribute to stewardship group capacity. I show that stewards believe that their most effective actions are nurtured through the human-to-human relationships built with volunteers, policymakers, and communities, and that they are hindered through lack of access to knowledge, agency, and funding.

In Chapter 4, I investigate which characteristics of stewardship are generalizable and which are tied to specific local contexts through a comparison of the capacity building processes of stewardship groups in urban New York City and suburban Greater Montreal. Using qualitative content analysis, comparing results from identical interviews in both systems, I found that stewardship groups in each context resemble each other, but work within vastly different contexts and ultimately, via vastly different processes. I hypothesize that key differences between stewardship communities can be further understood by the mediation of demographic contexts present.

Overall, I show that local environmental stewardship groups play an important role in urban vegetation change in New York City and highlight the importance of incorporating the many ways of understanding stewardship in managing complex social-ecological systems.

RÉSUMÉ

Grâce à une grande variété d'avantages, certains très visibles, la végétation urbaine, incluant le couvert des arbres, les cours, les jardins, les terrains vacants et l'agriculture urbaine, est devenue un objectif important de la durabilité urbaine. Comme plusieurs grandes villes ont investi des fonds publics dans des programmes pour augmenter la végétation urbaine, les urbanistes ont besoin de connaissances scientifiques pour les aider à déterminer des stratégies de verdissement efficaces et équitables. Les villes sont des systèmes socioécologiques complexes, donc le développement de ces connaissances nécessitera des outils et pensées multidisciplinaires pour comprendre les facteurs urbains et les interactions émergentes entre eux. En particulier, dans les écosystèmes dominés par les humains, comme les villes, les valeurs, visions et relations humaines qui façonnent la gouvernance des forêts urbaines doivent être incorporées dans les évaluations de la végétation urbaine.

Dans cette thèse, j'examine les impacts des groupes locaux d'intendance environnementale, une partie importante des réseaux de gouvernance de plusieurs villes majeures aux É.-U., sur la gestion et le changement de la végétation dans la ville de New York.

Dans le chapitre 1, je révise le développement de l'écologie urbaine, je décris l'ensemble de la littérature sur la gouvernance des ressources naturelles avec un accent particulier sur l'intendance environnementale locale et je discute ses applications à la modélisation et la gestion de la végétation urbaine. Dans cette revue, je développe un cadre qui peut être utilisé pour étudier empiriquement les multiples variables complexes qui influencent le changement de la végétation, pour intégrer les paramètres de gouvernance et intendance dans les techniques de modélisation standard et pour apprendre d'exemples réussis d'intendance pour comprendre les meilleures pratiques pour organiser des groupes d'intendance.
Dans le chapitre 2, j'examine la relation entre la présence des groupes d'intendance de quartier et le changement de végétation à New York entre 2008 et 2016. Utilisant une combinaison de télédétection et des modèles d'effets mixtes linéaires, je fournis une estimation de l'effet statistique de la présence de l'intendance sur le changement écologique à l'échelle du quartier

à travers la ville. J'ai trouvé que le nombre de groupe d'intendance présent dans un quartier avait une relation positive et significative sur le changement de végétation à l'échelle de la décennie à New York.

Dans le chapitre 3, j'enquête sur les histoires de succès de l'intendance en examinant les catalyseurs et les obstacles au renforcement des capacités qui permettent les actions d'intendance efficaces dans 5 quartiers de la ville de New York. Utilisant une approche de méthodes mixtes combinant la modélisation, les entrevues et l'analyse qualitative, j'examine trois facteurs qui contribuent à la capacité des groupes d'intendance. Je démontre que les intendants croient que leurs actions sont soutenues par les relations humaines bâties avec les bénévoles, les décideurs politiques et les communautés, et qu'elles sont entravées par un manque d'accès aux connaissances, l'agence et le financement.

Dans le chapitre 4, je détermine quelles caractéristiques de l'intendance sont généralisables et quelles caractéristiques sont liées à des contextes locaux en comparant les procès de renforcement de capacité des groupes d'intendances de New York et Montréal. Utilisant l'analyse de contenu qualitative, j'ai trouvé que les groupes d'intendances dans chaque contexte se ressemblaient, mais travaillaient dans des contextes très différents et à travers des procès différents. Je postule que les différences entre les communautés d'intendance peuvent être mieux comprises par la reconnaissance des contextes démographiques présents.

Cette thèse démontre que les groupes locaux d'intendance environnementale jouent un rôle important dans le changement de la végétation de New York et souligne l'importance d'incorporer les diverses façons de comprendre l'intendance lors de la gestion de systèmes socioécologiques complexes.

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This thesis is dedicated to the stewardship, urban agriculture, and environmental justice communities in New York City. Their work, practice, and organizing has taught me a new depth of ecological thought. The seeds planted by organizers now will help us grow a radical new future by rethinking and dismantling our current systems of oppression.

This work took place on the unceded traditional territory of the Lenape people, who were violently forced off their land and displaced by American colonial forces in the 1860's to make way for the development of what we now call the greater New York City area. The writing of this thesis took place on the unceded traditional territories of the Kanien'kehá:ka and Algonquin peoples.

Of course, the utmost thanks to my supervisors Dr. Elena Bennett and Dr. Timon McPhearson. Since welcoming me into her lab as an undergrad honors student, Dr. Bennett has provided me with helpful guidance, unwavering support, and lots and lots of editing. In particular, I am deeply thankful for her encouragement to pursue engaged, impactful science that tells an important story. Dr. McPhearson provided me a home away from home at the Urban Systems Lab in New York City and has been a trusted collaborator and mentor throughout this project. I couldn't ask for a better supervisory team! In addition, I am thankful of the mentorship of Drs. Michelle Johnson, Erika Svendsen, and Lindsay Campbell from the USDA Forest Service and Drs. Karina Bennessiah and Jeff Cardille from McGill University.

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> ***Each of you should use whatever gift you have received to serve others, as faithful stewards of God's grace.***
> *1 Peter 4:10*

PREFACE

This thesis is manuscript-based and presented as four chapters, and therefore has some necessary repetition between chapters. Each chapter explores a different aspect of the influence of local environmental stewardship on urban vegetation in New York City, using a wide variety of interdisciplinary methods. Chapter 1 is a literature review and is not intended for publication at this time. Chapter 2 is prepared as a manuscript for submission to *npj Urban Sustainability* and has been formatted accordingly. It is currently under preparation for resubmission. Chapter 3 is prepared as a manuscript for submission to *BioScience* and again, is formatted accordingly. Chapter 4 is a report for distribution to colleagues and research participants and is not intended for publication at this time.

In Chapter 1, I review the development of urban ecology frameworks, and specifically their application to urban vegetation and canopy cover modelling. Following a review of literature on governance and stewardship, I make connections between urban ecology and governance to begin to shape methods to incorporate governance considerations in urban vegetation modelling. In Chapter 2, I explore and apply these connections empirically, presenting a study on the statistical influence of local environmental stewardship on NDVI change in NYC between 2008-2016. In Chapter 3, I assess the enablers and barriers to stewardship group capacity that build, shape, and mobilize effective stewardship action in five diverse neighborhoods in NYC with surprisingly positive vegetation outcomes. Drawing a comparison between a highly populated urban system, NYC, and a less populated suburban system, Greater Montreal, in Chapter 4 I present a report on which aspects of local environmental stewardship are generalizable across contexts and which are tied to hyperlocal contexts. Finally, I summarize and synthesis conclusions from the past four chapters, presenting main takeaways and policy recommendations, along with opportunities for future research.

CONTRIBUTIONS OF CO-AUTHOURS

Dr. Elena Bennett is a co-author on Chapters 2 and 3. As one of the two co-supervisors of this thesis, Dr. Bennett provided important input at every stage, including in the conceptualization of research questions and design, field work, and data analysis, as well as provided extensive editing on each chapter in this thesis.

Dr. Timon McPhearson is a co-author on Chapters 2 and 3 and is also a co-supervisor of this thesis. Dr. McPhearson was highly involved with the conceptualization and formulation of both research projects, provided important support during the research process including funding and workspace in New York City, and assisted in the preparation of manuscripts with edits and literature.

Dr. Karina Benessiah is a co-author on Chapter 3. Dr. Benessiah provided important support in the development of the research questions, qualitative data analysis, and manuscript editing.

The candidate, Juno Garrah, was responsible for leading the conceptualization of the research, all data collection, field work, and analysis, and writing of all chapters. She is the sole author of Chapters 1 and 4.

TABLE OF CONTENTS

ABSTRACT 2

RÉSUMÉ 4

ACKNOWLEDGMENTS 6

PREFACE 8

CONTRIBUTIONS OF CO-AUTHOURS 9

LIST OF TABLES 12

LIST OF FIGURES 12

THESIS INTRODUCTION 13

Case Overview 14

Research Design and Methodology 16

Chapter 1: Planting the Seeds: Towards an Understanding of Governance and Stewardship in Urban Vegetation Dynamics, Modelling, and Planning 18

INTRODUCTION TO URBAN ECOLOGY 18

MODELLING URBAN VEGETATION COVER 20

THE ROLE OF GOVERNANCE AND STEWARDSHIP 28

Governance 28

Stewardship 30

LEARNING FROM BRIGHT SPOTS 31

CONCLUSIONS 32

CHAPTER 1-CHAPTER 2 CONNECTING STATEMENT 34

Chapter 2: Sowing the Seeds of Urban Sustainability: Local Environmental Stewardship Groups Help Make New York City Greener 35

ABSTRACT 35

URBAN ENVIRONMENTAL STEWARDSHIP 35

STEWARDSHIP AND URBAN GREENING 36

GAPS AND IMPORTANCE 37

STUDY APPROACH 38

METHODS 39

Orthoimagery Analysis 39

Data Collection 40

Statistical Analyses: Estimating Drivers of NDVI Change 40

Statistical Analyses: Evaluating Impact of Governance Drivers 42

RESULTS 42

Spatial Distribution of NDVI Change in New York City, 2008-2016 42

Baseline Model of NDVI Change 43

Assessment of Stewardship Groups 44
DISCUSSION 46
ADDITIONAL CONSIDERATONS 47
CONCLUSIONS 48
CHAPTER 2 - CHAPTER 3 CONNECTING STATEMENT 49
CHAPTER 3: Human Relationships Nurture Stewardship Practice: Examining Capacities of Stewardship Groups in the Urban Vegetation Bright Spots of New York City 51
ABSTRACT 51
INTRODUCTION 52
Box 1: Categories of Capacity Assets 54
METHODS 55
Quantitative Analysis of Capacities 56
Qualitative Analysis of Capacities 56
RESULTS AND DISCUSSION 58
Financial Assets 59
Social Assets 62
Human Assets 64
Synthesis 65
CONCLUSION 66
CHAPTER 3 – CHAPTER 4 CONNECTING STATEMENT 68
CHAPTER 4: Local Environmental Stewardship Actions Are Shaped by Local Processes: A Comparison Study of Local Environmental Stewardship in New York City, NY and Greater Montreal, QC 69
ABSTRACT 69
STUDY BACKGROUND 69
METHODS 72
Sample Strategy 72
Interview Development 73
Interview Analysis 73
RESULTS AND DISCUSSION 74
Key Characteristics 74
Context Mediates Stewardship Characteristics 75
CONCLUSION 79
SYNTHESIS, FUTURE DIRECTIONS, AND CONTRIBUTIONS TO KNOWLEDGE 81
Synthesis 81
Future Directions 82
Contributions to Knowledge 83
Works Cited 84

LIST OF TABLES

Table 1 : Key drivers of urban vegetation distribution and change. SETS frameworks and contemporary urban vegetation modelling place the greatest emphasis on social and economic drivers, representing the forestry management decisions made within a city.....22

Table 2 Drivers of Urban Vegetation with indicator data used to create models of NDVI change in New York City, 2008-2016. All data were obtained from Open Data Sources.....41

Table 3 Results for model estimating the drivers of NDVI Change, including the influence of the number of local environmental stewardship groups in each neighborhood.....44

Table 4 List of organizations interviewed.....59

Table 5 Comparing five communities studied in NYC with five communities studied on the West Island of Montreal.....77

LIST OF FIGURES

Figure 1 Standard Deviation of NDVI Change for Neighborhood Tabulation Areas across New York City, 2008-2016. 43

Figure 2 Visual representation of two linear mixed effects models.....45

Figure 3 Bright spot neighborhoods designated for each borough of the city, with office locations of groups meeting our criteria and working in at least one of them shown as red points. 58

Figure 4 Multivariate regression modelling produced expected NDVI change values (on x-axis) which were compared with actual observations derived from high-resolution orthoimagery taken in 2008 and 2016 (see Garrah et al. in review). 60

Figure 5 Characteristics of stewardship for New York City and Greater Montreal.....75

THESIS INTRODUCTION

As the proportion of the global population living in urbanized areas continues to rise, cities are increasingly becoming sites of important questions regarding resilient and effective ecosystem service management (McPhearson et al., 2016). Large, growing, and high density urban areas represent unique leverage points for sustainability action and innovative ecosystem management in the Anthropocene, with changes and positive outcomes affecting a significant population (Rosenzweig et al., 2010). Policymakers can embrace the city's potential as a site for innovative sustainability action by working with researchers to determine effective leverage points that can shape pathways to a more sustainable future (Grimm et al., 2008).

Tackling urban sustainability will require new thinking and new tools, harnessing interdisciplinary teams to create a framework that shifts urban *ecology* into a new urban *science*, embracing the complexity of cities and their potential for transformative sustainability action (Alberti et al., 2018; Pickett et al., 2020). Contemporary ecological conceptions of cities have shifted over the last two decades from applying frameworks and methods developed in non-urban systems to study ecology *in* cities to thinking of the city as a complete social-ecological system, developing an ecology *of* cities. Today, urban ecology recognizes the complexity of urban systems, with emergent properties and social, ecological, and technological components, incorporating social hierarchies (Pickett et al., 1997), governance, culture (Grimm et al., 2000), and urban forms (McPhearson et al., 2016).

Urban ecology frameworks are frequently used to inform urban vegetation management plans. Due to its wide range of benefits and highly visible impacts, urban vegetation, including lawns, gardens, vacant lots, and urban agriculture, has become an important focus for urban sustainability planning (Campbell, 2017; Keeler et al., 2019). Urban Tree Canopy (UTC) and other forms of vegetation provide a wide range of benefits, including improvements in air quality and carbon sequestration (McPherson et al., 2011) as well as public health and neighborhood quality of life improvements (Lovasi et al., 2008; Salmond et al., 2016). The dynamics that affect the provisioning, distribution, and mediation of these benefits depend on

the distribution and dynamics of the vegetation and canopy *itself*, which is driven by both ecological and socioeconomic drivers, as well as the built environment of the urban system (Locke et al., 2016; McPhearson et al., 2016). However, in human dominated ecosystems, such as cities, there is an additional factor at play which mediates the influences of and interactions between all other known drivers: governance. Governance refers to the power relations, values, culture, and policy decisions that shape and construct the urban forest (Muñoz-Erickson et al., 2016).

In any given city, the decisions made by residents, governments, businesses, developers, and other local actors are an important factor shaping local change (Logan and Molotch, 2007). Urban planning literature has well-articulated this idea in the context of urban growth and development, but the idea of *governance* is less established in the fields of sustainability science and ecology (Armitage et al., 2019). Broadly, governance is defined as "processes involving collective action for resource allocation and use across multiple societal actors, *not just the state*" (Muñoz-Erickson *et al.* 2016, emphasis mine). To successfully translate urban ecological science into effective municipal policy, ecologists must incorporate and understand the governance dynamics at play in cities, incorporating people's values, visions, and social relations into our models of urban sustainability (Muñoz-Erickson et al., 2016).

One example of an institution that has been an important influence in the governance of many major American cities are local environmental stewardship groups - citizen organizations that work to protect, conserve, or transform social-ecological systems (Bennett et al., 2018). Management that includes the actions of stewardship groups has been proposed as a strategy to shape environmental governance strategies that are more flexible, adaptive, multi-scalar, and respondent to the needs of local communities than management with government actions alone (Muñoz-Erickson et al., 2016).

Case Overview

Environmental stewardship groups have played an important role in recent urban greening initiatives across New York City (NYC), NY, where the city aims to increase the city's tree canopy

by 20% (Svendsen, 2010; Campbell, 2014, 2017). New York City, the largest city in the United States and considered a world capital of finance and culture, is home to 8,622,698 people and has a land area of 783.8 km² across five boroughs (NYC Department of Planning, 2017). A diverse array of ecosystems lie within the city, from typical human-constructed urban forest, such as parks, to important sand dunes, salt marsh habitat areas ,and migratory bird sanctuaries (NYC Department of Parks and Recreation, 2017). New York City has a long history of grassroots environmental stewardship and activism, with guerilla gardening and community gardening initiatives springing up in underserved neighborhoods in the mid-20th century to provide food security and community autonomy to residents (Campbell, 2017). New York City's history of radical environmental stewardship continues today in the work of active stewardship groups in all five boroughs of Manhattan, The Bronx, Queens, Brooklyn, and Staten Island.

Local environmental stewardship groups in NYC use a wide variety of strategies to steward their community land, ranging from high level policy advocacy to small scale plot gardening. For example, in Harlem, NY, a historic Black neighborhood in Northern Manhattan, Black-led environmental justice and stewardship groups contributed important local perspectives on the development of a city-wide sustainability plan, PlaNYC (Campbell, 2017), moving plans beyond simple measurable metrics (Shepard et al., 2008) and resisting the potential impacts of green gentrification and development (Checker, 2011). In the South Bronx, NY, another low income neighborhood, a strong coalition of community groups have created the influential Bronx River Alliance, transforming the previously unusable Bronx River into a hub of community recreation, education, and ecosystem service provision through policy advocacy, but also through organizing community cleanups, riparian plantings, canoe flotilla protests, and building gathering space on previously unusable land (Pryor, 2018). Smaller scale projects, such as community gardens occupying vacant land, make up a large portion of stewardship groups in NYC, often focusing on making change at a block or street level. For example, the Q Garden in Brooklyn formed when a group of volunteers began planting vegetables on an unused piece of land belonging to the MTA, eventually gaining rights to the land (while being charged rent) and currently operating an open-harvest garden where community members are free to enter and

access vegetables, herbs, and compost (see Ch. 3). The variety of strategies, scales, and networks engaged in NYC stewardship community makes it an effective tool for social-ecological change and a well-situated case study for interdisciplinary sustainability research.

Research Design and Methodology

In 2007 and 2017, the USDA Forest Service conducted two censuses of local environmental stewardship groups in New York City (STEW-MAP), finding 754 active, responding groups (an 11% response rate from the 7000 groups contacted) in 2017 (Svendsen et al., 2016; USDA Forest Service, 2018; Landau et al., 2019). These censuses mean that, for the first time, we have a complete database of local environmental stewardship group characteristics and locations, allowing for scaled up analyses of their role in the wider urban social-ecological system, along with a replicable survey method that can be applied in other cities, communities, and systems (Svendsen et al., 2016). Using STEW-MAP to develop data-driven approaches is an important research frontier to understand more deeply the role of stewardship in driving ecological and social outcomes in urban ecosystems beyond case studies.

Building off of the STEW-MAP New York City database, I employ mixed methods approaches to understand both the statistical and relational aspects of local environmental stewardship (Bennett et al., 2018). Using methods that are "inherently mixed" – such as qualitative content analysis and geographic information systems (Bazeley, 2012), I am able to contextualize the results of the large scale STEW-MAP survey at a neighborhood scale, looking at measurable impacts (Chapter 2) and stories that describe what enabled effective stewardship action for each group (Chapter 3). I approach my research by looking at "bright spots", systems that are performing much better than expected from modelling given set ecological conditions (Bennett et al. 2016). This approach, described in the mixed methods behavioral science literature as "exploring deviant cases" (Bazeley, 2012), has been used in conservation research to explore the social-ecological drivers of coral reefs (Cinner et al., 2016), agricultural landscapes (Frei et al. 2019), and freshwater lakes (Garrah et al. 2019). As this research inherently involves both statistical modelling and work with human participants, my approach was reviewed by the McGill University Research Ethics Board and is covered under REB File #478-0419.

In this thesis, I examine the influence of local environmental stewardship on vegetation change in New York City. In Chapter 1, I review the development of contemporary urban ecology with a focus on drivers of vegetation change and bridge this work to literature on stewardship and governance. In Chapter 2, I present a manuscript of an empirical study connecting metrics of stewardship to vegetation change in New York City between 2008-2016 using remote sensing and statistical modelling. In Chapter 3, I provide a deeper dive into the inner workings of successful stewardship groups, examining enablers and barriers to capacity that build, shape, and mobilize effective stewardship action in NYC. In Chapter 4, I report on a comparative analysis between two very different stewardship communities from urban NYC and suburban Greater Montreal to explore which aspects of stewardship are broadly generalizable and which are tied to local contexts. Through this work, I use highly interdisciplinary tools to create a framework for a science of urban stewardship. From this framework, I produce evidence for quantitative connections between stewardship and ecological change while incorporating and embracing the complexity of human relationships and stewardship organization. A more complete picture of urban stewardship and the role that stewardship groups play in the urban system will inform sustainability planning policy that can support stewardship groups, build community, and shape pathways to more sustainable cities.

Chapter 1: Planting the Seeds: Towards an Understanding of Governance and Stewardship in Urban Vegetation Dynamics, Modelling, and Planning

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INTRODUCTION TO URBAN ECOLOGY

As the proportion of the global population living in urbanized areas continues to rise, cities are increasingly becoming sites of important questions regarding resilient and effective ecosystem service management (McPhearson et al., 2016). Large, growing, and high density urban areas represent unique leverage points for sustainability action and innovative ecosystem management in the Anthropocene, with changes and positive outcomes affecting a significant population (Rosenzweig et al., 2010). Policymakers can embrace the city's potential as a site for innovative sustainability action by working with researchers to determine effective leverage points that can shape pathways to a more sustainable future (Grimm et al., 2008).

Urban ecosystems provide essential ecosystem services including air and water filtration (Lundy and Wade, 2011), heat mitigation (Ziter et al., 2019), and public health improvements (Salmond et al., 2016). Although urban ecosystem services were addressed in major global ecosystem services frameworks, such as the Millennium Assessment (Millenium Ecosystem Assessment, 2005) and The Economics of Ecosystems and Biodiversity (Kumar, 2011), urban services remain less represented in the body of ES literature than ecosystem services in rural areas, working landscapes, or protected areas (Gómez-Baggethun et al., 2013). The complex nature of urban systems require research methods that move beyond traditional ecological studies of systems and services (Grimm et al., 2008).

To better understand urban ecosystem services, urban ecology has shifted over the last two decades from regarding cities as areas void of ecological or 'natural' value to thinking of the city as a complete social-ecological system, with complex emergent properties and social,

ecological, and technological components (McPhearson et al., 2016). Pioneering ecological studies in cities – studies that have been described more recently as looking at ecology *in* cities – applied the science of observing classical ecological theories and dynamics within the urban landscape and assessing differences from 'natural areas' (e.g. (McPherson et al., 1997). Long Term Ecological Research (LTER) Network studies in both Baltimore, Maryland (Pickett et al., 1997, 2001, 2008) and Phoenix, Arizona (Grimm et al., 2000) have advanced the field of urban ecology, shifting from ecology *in* cities to an integrative ecology *of* cities that incorporates social hierarchies (Pickett et al., 1997), governance, culture (Grimm et al., 2000), and urban forms (McPhearson et al., 2016). As Grimm et al. (2000) state, simply put, ecological theories presuming absence of human intervention are inappropriate for urban environments (Grimm et al., 2000). Grimm and Pickett's studies in Phoenix and Baltimore, respectively, both heavily emphasize the ecological role of human impacts in urban systems: spatial heterogeneity based on social stratification mediates resource flows and fluxes in ways that are analogous to natural patch ecology dynamics (Pickett et al., 1997). LTER Network studies have shown that a new, integrative ecology is needed for cities that explicitly addresses decisions, culture, institutions, and economics to inform sustainable urban planning and natural resource management (Grimm et al., 2000; Pickett et al., 2001) .

Today, many urban ecologists work with the city as a complex adaptive system (Alberti et al., 2018). This framework, based on the body of social-ecological systems literature (Berkes et al., 2008), is one that brings transdisciplinary, systems-focused methodologies into urban ecology. Contemporary research in urban ecology stretches the social-ecological systems framework one step further, introducing *technological* drivers – for example, built infrastructure and urban form – as central factors of the system, moving towards complex social-ecological-technological systems (SETS) (McPhearson et al., 2016). Emergent properties arise from the interactions between the three main system components and importantly, the agents that constitute the governance network of a city, who shape urban resource flows and the environmental impacts of development (Alberti et al., 2018). Advancing this framework represents yet another major shift in urban ecology, moving from ecology *of* cities to ecology *for* cities: producing research to

inform governance actors on best practices for sustainability planning, advocating for environmental justice, and building urban resilience to climate change and Anthropocene crises (McPhearson et al., 2016).

To properly shape a framework of ecology *for* cities, we must build upon the conceptual framework of the city as a SETS to more explicitly incorporate the important role of *governance* as a mediator of social-ecological dynamics, resource flows, and agency in decision-making (Muñoz-Erickson et al., 2016). Decisions on urban governance are made by multiple actors within the urban system, including city government planners, private developers, individual citizens, as well as local environmental stewardship groups, who play a major role in sustainability planning in many major American cities (Svendsen, 2010; Svendsen et al., 2016). For decisionmakers to shape actions best suited to their social and ecological context, researchers must conduct appropriate studies of these systems, generating knowledge on urban system dynamics and pathways to positive outcomes.

In this review, I focus on the application of urban ecology frameworks, specifically, SETS frameworks, to the management of urban vegetation. In the following sections I will cover drivers and management of urban vegetation change, the governance of urban vegetation, and the role of local environmental stewardship in urban vegetation management. I find connections between these bodies of work to bridge them through empirical studies in later chapters of this thesis.

MODELLING URBAN VEGETATION COVER

Due to its wide range of benefits and highly visible impacts, urban vegetation, including lawns, gardens, vacant lots, and urban agriculture has become an important focus for urban sustainability planning (Keeler et al., 2019). Urban vegetation, including trees, lawns, gardens, vacant lots, and urban agriculture, provides air and water filtration (Lundy and Wade, 2011), urban heat island mitigation (Ziter et al., 2019), public health improvements (Salmond et al., 2016), and other important ecosystem services in cities (Keeler et al., 2019). The benefits that urban vegetation affords are dependent on the distribution of vegetation throughout the city

(Locke et al., 2016). For example, populations in urban neighborhoods with higher vegetation cover have significantly lower rates of asthma than those in neighborhoods without vegetation cover (Salmond et al., 2016; Nardone et al., 2020)

Predicting how urban canopy grows and changes has been an issue for foresters, planners, and governments investing in ambitious programs to increase urban canopy (Landry and Chakraborty, 2009; Young, 2011; Campbell, 2014). To shape management programs that increase urban canopy cover, researchers have applied frameworks of urban ecology to model urban vegetation outcomes (Locke et al., 2016). In order to build better models to inform successful greening programs, understanding the multiple drivers of urban vegetation and the emergent dynamics from their interactions has been a key focus of urban ecology and sustainability planning over the past two decades (See Table 1).

In the late 1990's, important work by foresters and ecologists brought an understanding of forest management to urban vegetation planning. The frameworks developed by Zipperer, McPherson, Nowak, and others are based on empirical understandings of patch dynamics and disturbance ecology, building off of research done in non-urban forests (McPherson et al., 1997; Zipperer, 1997; Nowak et al., 2008). To the forest scientists moving their work into the city (an example of ecology *in* cities, see above), the main factors driving vegetation change were the physical parameters of a given site (i.e. soil and climate), characteristics of tree species (i.e. seed dispersal and growth rates), and local nutrient cycling patterns (Zipperer, 1997). Developing a mechanistic understanding of urban tree cover patterns was considered a key research direction by many with the goal of understanding the control mechanisms of urban forest patches on fluxes of water, nutrients, carbon, and biodiversity that could be generalized beyond city limits (Zipperer, 1997; Williams et al., 2009).

Table 1 : Key drivers of urban vegetation distribution and change. SETS frameworks and contemporary urban vegetation modelling place the greatest emphasis on social and economic drivers, representing the forestry management decisions made within a city.

DRIVER	CATEGORY	DIRECTIONALITY	DESCRIPTION	KEY REFERENCE
Population Density	*Socioeconomic*	*Negative*	For urban vegetation to increase, space is needed for growth and new planting. As an area becomes more settled, vegetation can be displaced by the addition of grey infrastructure and quality destroyed by negative human activities.	(Grove et al., 2006)
Housing Density	*Socioeconomic*	*Positive*	As more housing units exist, more vegetation can co-exist to serve the needs of a larger population.	(Grove et al., 2014)
Income	*Socioeconomic*	*Positive*	As income rises, so does the ability to create elaborate gardens, contribute to community greening, and the ability to move to more desirable, green areas.	(Grove et al., 2006; Luck et al., 2009)
Inequality	*Socioeconomic*	*Negative*	Although income is indeed an important predictor of vegetation, the level of income inequality in an area can affect the governance processes and area characteristics that can be assumed in an area of high income. For example, a highly unequal, but rich, area may be one undergoing	(Luck et al., 2009)

			gentrification or transition processes, rendering the vegetative community different from a leafy, wealthy, equal suburban area.	
Home Ownership	*Socioeconomic*	*Positive*	Home ownership has been hypothesized as a strong motivation for vegetation maintenance, as homeowners have potential for economic gain from investing in their property and neighborhood maintenance, driving a positive impact on vegetative cover.	(Luck et al., 2009)
Percent Minority	*Socioeconomic*	*Negative*	Urban vegetation is highly dependent on investment, maintenance, and action from the city government. Environmental justice theory would assert that this action is unevenly distributed, with the majority of investment funneled towards higher income and whiter communities, leaving lower income, minority communities with less to maintain robust urban vegetation.	(Landry and Chakraborty, 2009)
Median Gross Rent	*Socioeconomic*	*Positive*	Areas with a high median rent value are assumed to have more abundant green amenities due to the fact that vegetation adds value to a	(Chuang et al., 2017)

			home's value, whether owned or rented.	
Vacant Land	*Ecological*	*Positive*	Vacant lots have been identified as both key sites of ecosystem service production within New York City (McPhearson et al., 2013) as well as sites that are important to the work of local environmental stewardship groups (Fisher et al., 2012; Connolly et al., 2014). By including the amount of available vacant lot space, additional variation in urban vegetation change may be explained.	(McPhearson et al., 2013)
Street Length and Street Width	*Technological*	*Positive*	In a case study of Montreal, Pham et al. (2017) found that street length had a positive correlation with the percentage of the street that was covered by tree canopy. Conversely, street width was found to be negatively correlated with street tree canopy. These findings may be explained that these street characteristics are confounded with street types and management decisions, for example, arterial roads may be both wider and deprioritized in municipal planning initiatives.	(Pham et al., 2017)

Median Construction Age	*Technological*	*Positive*	Due to the nature of vegetation cover developing over time, housing age is proposed as a metric to reflect the elapsed development and growth time available to the vegetation cover in the area. However, as homes age and fall into disrepair, vegetation can be subject to less upkeep and maintenance, reducing its potential for growth and discouraging new planting.	(Grove et al., 2006; Locke et al., 2016; Pham et al., 2017)
Traffic Volume	*Technological*	*Negative*	Street trees, as well as other forms of urban vegetation, are sensitive to the ongoing survivorship conditions in the area in which they are planted, which includes aspects of transportation infrastructure. As cars and trucks move through a neighborhood, they damage adjacent vegetation with physical stressors, air pollution, and road salt deposits.	(Lu et al., 2010)

Early frameworks based on site-based observations are influential guides for planting programs implemented by city governments (McPherson et al., 1997, 2011; Morani et al., 2011). Using ecological frameworks, city sustainability planners decide where to plant new trees, how to maintain trees through their lifespan, and importantly, to determine the costs and benefits associated with planting programs. To assess the benefits of Chicago's UFCP, McPherson et al. (1997) look at the biological characteristics of the individual trees that make up the "ribbons of life meandering through a largely artificial landscape" (McPherson et al., 1997) to quantify the resultant energy savings and regulation of hydroclimate, runoff, and air quality. More recently, Morani et al. (2011) used numerical modelling of air quality and soil to determine quantitatively ideal planting locations for NYC MillionTrees project. Early ecological frameworks of urban vegetation cover provided rigorous, replicable methods that have been helpful in informing science-based ecosystem management in cities, but stress that ultimately, "humans decide patterns through ecosystem decisions" (Zipperer, 1997). To form a complete understanding of urban vegetation dynamics, ecological frameworks must be linked to socioeconomic dynamics in cities and a deeper understandings of urban governance (Zipperer, 1997; Grimm et al., 2000; Pickett et al., 2001).

Recent advances in urban ecology have built upon early frameworks by incorporating the strong role of social, economic, and governance drivers of urban ecological change. Important foundations for this work came from the Human Ecosystem Model, which conceptually linked human social systems (institutions, social cycles, and social orders) to resource systems (ecosystem processes and patterns) (Pickett et al., 1997). Pickett et al.'s (1997) conceptual framework for human ecosystems emphases that humans must be considered "important ecological agents" with "powerful capacities for social and spatial organization" that ultimately change ecosystem processes.

Quantitative modelling of the Human Ecosystem Model confirmed the early hypotheses of foresters such as Zipperer (1997), showing that the influence of both ecological and socioeconomic drivers explains greater variance than relying on biophysical characteristics

alone (Grove et al., 2006; Landry and Chakraborty, 2009; Luck et al., 2009). Working in Australia, Luck et al. (2009) found that the strongest predictor of vegetation cover in each census division of a mid-sized town was the percentage of residents with a university degree, which has a positive correlation with percent vegetative cover. The model that accounted for the most variation in vegetation cover included education levels and housing density as well as the ecological drivers of elevation and soil fertility. Importantly, Luck et al. (2009) found that time lag variables – the socioeconomic characteristics of the neighborhood a *decade* earlier – were important predictors of vegetation cover.

Socioeconomic characteristics act as proxies, representing human behavior, preferences, and management strategies that affect vegetation cover. In many quantitative models, human preferences are represented through metrics of 'lifestyle behavior' that range from census demographic data to more complex categorizations (Grove et al., 2006, 2014, 2014, 2016, 2018). In 2006, Grove et al. used PRIZM data, proprietary data of marketing research which characterize socioeconomic demographics at a census block-scale, as a predictor of urban vegetation cover in Baltimore, finding that these categorical assessments of "lifestyle" were the strongest, most significant predictors of distribution (Grove et al., 2006). In 2014, this time working in New York City, Grove et al. model an "ecology of prestige", finding that a group identity shaped around developing an appearance of wealth on the streetscape with additional vegetation and landscaping was also a strong driver of vegetation cover (Grove et al., 2014). To categorize census block groups into particular "group identities", Grove et al. again used marketing data from PRIZM. These results were replicated in Philadelphia in 2016 by Locke et al., using finer scale multilevel models to show non-stationary interactions between lifestyle behaviors drawn from PRIZM, ecological characteristics such as terrain and percent pervious area, as well as indicators of urban form and space (Locke et al., 2016). Locke et al. (2016) urge development of more sophisticated modelling strategies for urban vegetation cover that more fully capture the complex interactions that shape its distribution and dynamics.

The development of modelling strategies by Grove, Locke, and others as part of the Baltimore Ecosystem Study (Pickett et al., 2008) constitute a shift away from focusing on solely on ecological or socioeconomic characteristics towards attempts to model the emergent interactions between the city, its vegetation cover, and the human values, visions, and social relations that drive it, the latter of which being what Muñoz-Erickson et al. (2016) define as *governance* (Muñoz-Erickson et al., 2016). Lining up with the school of urban ecology *for* the city, research has found that to properly understand urban vegetation cover an additional factor is needed to move beyond SETS frameworks, incorporating explicit understanding of the power relations, governance network actors, and policy decisions that shape and construct the urban forest.

THE ROLE OF GOVERNANCE AND STEWARDSHIP

Governance

In any given city, the decisions made by residents, governments, businesses, developers, and other local actors are important factors shaping urban development (Logan and Molotch, 2007). Urban planning literature has outlined many of the major actors and key decision-making processes in cities, but the idea of *governance* is less established in the fields of sustainability science and ecology (Armitage et al., 2019). Broadly, governance is defined as "processes involving collective action for resource allocation and use across multiple societal actors, *not just the state*" (Muñoz-Erickson et al., 2016). To successfully translate urban ecological science into effective municipal policy, ecologists must incorporate and understand the governance dynamics at play in cities, incorporating people's values, visions, and social relations into our models of urban sustainability (Muñoz-Erickson et al., 2016).

Much of the conversation around governance in sustainability science over the last half-century stems from Garrett Hardin's Tragedy of the Commons (Hardin, 1968), which theorizes ecological collapse of shared resource units due to humans' hypothesized desire to maximize their own benefit. Hardin recommends governance strategies, including privatization of property and state control, to reduce or avoid resource conflicts, which have been implemented in cities (Brinkley, 2020). Elinor Ostrom (1990), in her seminal work on governance of common pool resources, reflects that many policies based on Hardin's theory

are, in fact, more harmful than they are helpful, and can create unexpected "remorseless tragedies" and increased social inequality. Ostrom lays out a set of eight design principles that she observed in several long-enduring sustainable governance institutions – one of which is clear rights of users to devise their own institutions and management decisions free of government interferences (Ostrom, 1990). This design principle is not often found in cities: struggles to create solutions to common resource governance problems though strong government regulation and interference have been at the heart of urban sustainability decisions over centuries of city planning (Brinkley, 2020).

Neither relying solely on the state nor the market has been uniformly successful in solving sustainable resource problems. However, there have been multiple examples of communities exercising a right to form their own institutions to self-govern their own systems without government interference, producing many examples of relative success (Ostrom, 1990). A networked governance structure, incorporating state, market, and other institutions, has been recognized as a key governance feature of a sustainable city, integrating knowledge, monitoring, and decision-making that can occur at multiple spatial and temporal scales for more flexible, adaptive management (Pickett et al., 2013; Plummer et al., 2013). It's important to note, however, that there is not one idealized form of institutional arrangement, but rather multiple different forms of arrangements that coexist within social-ecological systems producing unique, emergent governance strategies (Ostrom et al., 2007; Muñoz-Erickson et al., 2016).

Local environmental stewardship groups, citizen organization that work to protect, conserve, or transform social-ecological systems (Bennett et al., 2018), are one example of a user-led, self-governance institution (that fits Ostrom's Principle of the Right to Organize (Ostrom, 1990)) that *have* been an important influence in the governance networks of many major American cities. By engaging with both social and ecological drivers within their focus area, management that includes the actions of stewardship groups has been proposed as a strategy to shape environmental governance strategies that are more flexible, adaptive, multi-scalar, and

respondent to the needs of local communities than management with government actions alone (Muñoz-Erickson et al., 2016). An adaptive, multi-scalar governance network that includes stewardship groups is well positioned to amplify the desired goals of sustainability plans in many cities, including increases to local ecosystem services (Andersson et al., 2014), as well as to strengthen communities (Tidball and Stedman, 2013) and sense of place (Enqvist et al., 2019).

Stewardship

Examples of outcomes from stewardship groups' actions that have amplified sustainability efforts, both social and ecological, can be seen in diverse systems from Harlem (Shepard et al., 2008; Checker, 2011) and the South Bronx (Pryor, 2018) in New York City, to rural landscapes in South Africa (Cockburn et al., 2019) and freshwater lakes in Canada (Garrah et al., 2019). In Harlem, NY, environmental justice and stewardship groups contributed important local perspectives on the development of a city-wide sustainability plan, PlaNYC (Campbell, 2017), moving plans beyond simple measurable metrics (Shepard et al., 2008) and resisting the potential impacts of green gentrification (Checker, 2011). In the South Bronx, NY, another low income neighborhood, a strong coalition of community groups have created the influential Bronx River Alliance, transforming the previously unusable Bronx River into a hub of community recreation, education, and ecosystem service provision (Pryor, 2018). These two neighborhoods represent important cases of stewardship action in New York, a city with a large and active environmental stewardship network with actions occurring in all five boroughs and a wide diversity of neighborhoods (Campbell and Svendsen, 2008).

In 2007 and 2017, the USDA Forest Service conducted two censuses of local environmental stewardship groups in New York City (STEW-MAP), finding 754 active, responding groups (an 11% response rate from the 7000 groups contacted) in 2017 (Svendsen et al., 2016; USDA Forest Service, 2018; Landau et al., 2019). For each responding group, STEW-MAP delineated a focus area, termed stewardship *turf*; organizational characteristics such as budget, number of staff, and active volunteers; main focus of actions; motivating factors; and network connections (Landau et al., 2019). STEW-MAP is an impressive undertaking – for the first time, we have a

complete database of local environmental stewardship group characteristics and locations, allowing for scaled up analyses of their role in the wider urban social-ecological system, along with a replicable survey method that can be applied in other cities, communities, and systems (Svendsen et al., 2016). Using STEW-MAP to develop data-driven approaches is an important research frontier to understand more deeply the role of stewardship in driving ecological and social outcomes in urban ecosystems beyond case studies.

Using STEW-MAP data, studies have focused thus far on the social network that stewardship builds (Connolly et al., 2013, 2014; Jasny et al., 2019), showing that the number of stewardship groups working in a neighborhood is an important indicator of a functioning, effective network (Johnson et al., 2019). To examine what drives collaboration between stewardship groups in New York and Philadelphia, Jasny et al. (2019) used Exponential Random Graph models to show that groups in Philadelphia collaborated mainly around shared social issues, while groups in NYC collaborated mainly around shared land use and geographic proximity. In New York, Johnson et al. (2019) used data from STEW-MAP to examine the influence of contextual factors – organizational, environmental, and social – on the number of groups present in neighborhoods and census block groups (CBGs). The *organizational landscape* of both neighborhoods and CBGs was the most influential contextual factor in predicting a high number of groups, with Johnson et al. encouraging future research on the interorganizational aspects of urban stewardship (Johnson et al., 2019). Furthermore, Locke et al. (2014), in analyzing stewardship and landscape change in New York City, showed that neighborhoods with positive vegetation change were more likely to have larger numbers of active stewardship groups (Locke et al., 2014). It remains unclear, however, whether stewardship groups have an impact on driving significant, city-wide vegetation trends.

LEARNING FROM BRIGHT SPOTS

To understand the positive impacts that local environmental stewardship can have, we can learn from examples of neighborhood successes, where stewardship groups have contributed to creating management strategies that shape social-ecological outcomes exceeding management by government alone (Muñoz-Erickson et al., 2016). A way of learning from

positive outliers – successful situations that exceed predicted expectation – is through the lens of bright spots (Bennett et al., 2016; Cinner et al., 2016). Bright spots are ecosystems that are substantially better than expected, given the environmental condition and socioeconomic drivers present (Cinner et al., 2016). By learning from the novel strategies management strategies and creative bottom-up scenarios that bright spots represent, we can articulate pathways towards a more positive future that can be adapted and applied to a variety of contexts and systems (Bennett et al., 2016). Building on empirical applications of a bright spots lens in coral reefs (Cinner et al., 2016), agricultural regions (Frei et al., 2018), and freshwater lakes (Garrah et al., 2019; Kovalenko et al., 2019), finding bright spots of local environmental stewardship action in cities presents a way forward in understanding successful governance schemes and organizing strategies. By implementing this framework in a complex urban system for the first time, we can identify commonalities across bright spots neighborhoods and the groups working within them. From examples of positive change, planners can formulate policy that plays into the strengths of successful stewardship groups, better supporting their capacities, actions and communities.

CONCLUSIONS

Managing urban forests better can build more sustainable cities by amplifying ecosystem services, benefiting public health, and contributing to climate change adaptation (McPhearson, 2011). The decisions made by governments, residents, and other actors matter for how vegetation changes in an urban landscape (Muñoz-Erickson et al., 2016). Incorporating people's values, visions, and social relations into the management and planning of the urban forest will create better outcomes through increased diversity and flexibility in decision-making. To achieve this goal, research is needed to further develop our knowledge on the role of local environmental stewardship groups in driving urban greening.

Stewardship groups are able to alter the social, ecological, and technological factors that drive urban vegetation. Evidence of this capacity comes from case studies that have documented the important impacts of stewardship on neighborhood sustainability in a few places. Qualitative, neighborhood examples are important but establishing a more quantitative relationship between stewardship action and city-wide vegetation change is an important step to help cities

understand the importance of local stewardship action and how to incorporate stewardship into city sustainability plans. For stewardship groups to be incorporated into city planning, they must have government support in building sufficient capacities for action. However, what these capacities look like for stewardship groups is not well established, and so far, formulating support has been a messy, experimental process.

In this thesis, I use interdisciplinary tools to create a framework for a science of urban stewardship, blending remote sensing, statistical modelling, and qualitative analysis. I aim to deepen knowledge of the multiple complex drivers of urban vegetation change; integrate metrics of governance and specifically, stewardship, into urban vegetation modelling techniques; and learn from bright spots of stewardship success to understand best practices for stewardship group organizing and action. By bridging multiple bodies of literature and diverse methodologies, this work aims to benefit governance stakeholders who make decisions on urban ecosystems in New York City and beyond.

CHAPTER 1-CHAPTER 2 CONNECTING STATEMENT

In Chapter 1, I reviewed literature from the fields of urban ecology, natural resources governance, and environmental stewardship, highlighting connections that can inform research on the influence of local environmental stewardship on urban vegetation change. There are numerous examples of local environmental stewardship generating positive outcomes, for example the work done by the Bronx River Alliance in the South Bronx, NY (Pryor, 2018), yet stewardship action remains a minimal consideration in urban vegetation modelling and in sustainability planning more broadly. With an understanding of stewardship's role in the urban system, cities will be able to better formulate effective support plans to amplify sustainability goals through collaborative management. However, to properly inform stewardship's place in modelling and planning, there is a need to move beyond case studies into data driven, empirical landscape-scale studies (Cockburn et al., 2018).

Therefore, in Chapter 2, I provide an empirical study of local environmental stewardship in New York City, NY, investigating the influence of stewardship on neighborhood-scale vegetation change between 2008-2016. Using 6-inch resolution orthoimagery, I create a spatially explicit landscape model of NDVI change between 2008-2016 and develop mixed effects models of known drivers of urban vegetation change along with varying governance metrics, including the number of active stewardship groups in each neighborhood. Through remote sensing and statistical analysis, I establish a quantitative connection between stewardship organizing and positive ecological outcomes, providing insight on stewardship's role in the complex urban system.

Chapter 2: Sowing the Seeds of Urban Sustainability: Local Environmental Stewardship Groups Help Make New York City Greener

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ABSTRACT

Local environmental stewardship groups are important sustainability decision-makers in many major American cities. Urban greening is particularly suited to management by local stewardship groups, since people are densely located alongside "green" features that are important to their well-being in cities. Stewardship groups are able to alter the social, ecological, and technological factors that drive urban vegetation. Evidence of this capacity comes from case studies that have documented the important impacts of stewardship on neighborhood sustainability in a few places. Qualitative, neighborhood examples are important but establishing a more quantitative relationship between stewardship action and city-wide vegetation change is an important step to help cities understand the importance of local stewardship action and how to incorporate stewardship into city sustainability plans. We examined the relationship between presence of neighborhood stewardship groups and vegetative change in New York City between 2008-2016 alongside well documented drivers of vegetation change. We found that the number of stewardship groups present in a neighborhood is a significant, positive driver of decade-scale vegetative change in New York City. Results quantitatively suggest that stewardship can be an important driver of urban greening and a key component of governance for urban sustainability.

URBAN ENVIRONMENTAL STEWARDSHIP

Local environmental stewardship groups, citizen organizations that work to protect, conserve, or transform social-ecological systems (Bennett et al. 2018), are important sustainability decision-makers in many major American cities (Romolini et al., 2016). Stewardship groups

connect with communities and engage with both social and ecological drivers in their neighborhoods (Wolf et al., 2013). Common stewardship actions such as tree care, government advocacy, and educational programs have the potential to create positive impacts in neighborhoods that include, and go beyond, the desired goals of many sustainability plans (Bennett et al., 2018; Murphy et al., 2019). Incorporating neighborhood stewardship groups into city sustainability plans as partners has been proposed as a strategy to shape environmental governance strategies that are more flexible, adaptive, and respondent to the needs of local communities (Young, 2011; Muñoz-Erickson et al., 2016).

Stewardship groups are known to have had important impact on urban sustainability in many places, including Harlem (Shepard et al., 2008; Checker, 2011) and the South Bronx (Pryor, 2018) in New York City. In Harlem, NY, environmental justice and stewardship groups contributed local perspectives on the development of a city-wide sustainability plans (e.g. PlaNYC) (Campbell, 2017), moving plans beyond simple measurable metrics (Shepard et al., 2008) and resisting the potential impacts of green gentrification (Checker, 2011). In the South Bronx, NY, another low income neighborhood, a strong coalition of community groups have created the influential Bronx River Alliance, transforming the previously unusable Bronx River into a hub of community recreation, education, and ecosystem service provision (Pryor, 2018). These two neighborhoods represent important cases of stewardship action in New York, a city with a large and active environmental stewardship network with actions occurring in all five boroughs and a wide diversity of neighborhoods (Campbell and Svendsen, 2008). With demonstrated success in many neighborhoods, the community management strategies that stewardship groups implement can be a key component of sustainability policy moving forward.

STEWARDSHIP AND URBAN GREENING

The vast majority of stewardship groups in New York City work on actions related to urban greening (Fisher et al., 2012). Due to its wide range of benefits, urban greening has also become an important focus for government sustainability planning in cities (Campbell, 2017). Urban vegetation, including trees, lawns, gardens, vacant lots, and urban agriculture, provides air and

water filtration (Lundy and Wade, 2011), urban heat island mitigation (Ziter et al., 2019), public health improvements (Salmond et al., 2016), and other important ecosystem services in cities (Keeler et al., 2019). Because of its importance, many major cities have invested large amounts of money into programs to increase urban vegetation, although these programs often fall short of intended target goals (Checker, 2008, 2011; Campbell, 2017). As increased vegetative cover is a shared goal of both government planners and local environmental stewardship groups, incorporating stewardship management into vegetation plans is a promising strategy to improve greening outcomes and meet canopy goals (Young, 2011).

GAPS AND IMPORTANCE

Although stewardship groups have high potential to make important contributions to urban greening, they are often under-supported by governments (Cockburn et al., 2019). To work effectively, stewardship groups need financial and material support, the ability to make decisions in their neighborhood and provide input into development plans, as well as recognition of their advocacy work (Bennett et al., 2018). Increasingly, stewardship groups are only included in sustainability planning as an instrumental tool of free or low-cost maintenance labor (Young, 2011), a key procedural injustice issue (Bullard, 1994; Checker, 2011) that also reduces their potential for effective management, even amidst growing evidence of the multiple positive outcomes stewardship can have on a neighborhood (Checker, 2008; Svendsen, 2010; Wolch et al., 2014; Pryor, 2018)

Evidence thus far comes from case studies that have documented the important impacts of stewardship on neighborhood sustainability in New York City and elsewhere. Moving from qualitative, neighborhood examples into a quantitative relationship between stewardship action and city-wide vegetation change is an important step to help cities understand how to incorporate stewardship into city sustainability plans. A quantitative relationship can begin to show where and how stewardship groups need support and provide recognition to their work that resonates with governments, scientists and policymakers.

Recently, large-scale data collection by the USDA Forest Service STEW-MAP project (Svendsen et al., 2016) has allowed for analysis that moves beyond qualitative case studies to examine the role of local environmental stewardship in the urban system. In 2017, STEW-MAP identified 754 active, responding stewardship groups in New York City (Landau et al., 2019). Analyses using these data have focused thus far on the social network that stewardship builds (Connolly et al., 2013, 2014; Jasny et al., 2019), showing that the number of stewardship groups working in a neighborhood is an important indicator of a functioning, effective network (Johnson et al., 2019). Furthermore, Locke et al. (2014), in analyzing stewardship and landscape change in New York City, showed that neighborhoods with positive vegetation change were more likely to have larger numbers of active stewardship groups (Locke et al., 2014). It remains unclear, however, whether stewardship groups have an impact on driving significant, city-wide vegetation trends.

Modelling has shown that social drivers are the most important factors impacting urban vegetation change (Landry and Chakraborty, 2009; Luck et al., 2009), along with ecological (Zipperer, 1997; Berland et al., 2015) and technological factors (Pham et al., 2017). Locke et al. (2016) recommend the use of all three of these categories of drivers in the context of urban social-ecological-technological systems (McPhearson et al. 2016), along with metrics of lifestyle behavior, as a way of indicating the decisions, values, and desires of residents in mixed effect multilevel models to predict urban tree canopy. STEW-MAP data provide an opportunity to include stewardship groups in models as a potential driver of urban vegetation alongside known predictors (Landau et al., 2019). Successfully incorporating stewardship groups as a dependent variable in standard modelling techniques would provide a quantification of their relationship with urban greening.

STUDY APPROACH

In this study, we investigated whether stewardship groups and their actions had a measurable quantitative impact on city-wide vegetation change. We asked: does the number of local environmental stewardship groups working on a neighborhood scale in New York City influence city-wide changes in urban vegetation? To answer this question, we integrated stewardship into standard urban vegetation modelling techniques to estimate the influence of the number

of local environmental stewardship groups on changes in New York City's urban vegetation between 2008-2016 alongside other known social, ecological, and technological drivers of change. Our goals include clarifying the role stewardship plays in the urban system quantitatively to help inform policies that appropriately support stewardship groups' efforts to green their cities.

METHODS

To examine how urban vegetation changed over 2008-2016, we used high resolution orthoimages to calculate Normalized Differential Vegetation Index (NDVI), a measure of landscape greenness, in 2008 and 2016, and produced a model that estimated the effects of multiple social, ecological, and built environment drivers of change. We added the metric of number of local environmental stewardship groups to the model to assess its relative influence on vegetation change, ultimately creating two models: one that included stewardship groups, and one that left them out. We then compared the models to determine the effect of measures of stewardship in influencing ecological outcomes in New York City.

Orthoimagery Analysis

To observe overall vegetative change across New York City at the beginning of the sustainability push introduced by PlaNYC in 2007 and a decade later, we created a spatially explicit landscape model of NDVI from two sets of high-resolution (6-inch), four-band orthoimagery collected by the New York State Orthoimagery program in the springs of 2008 and 2016 (City of New York, 2020). These years were selected due to data availability of orthoimagery that included infrared bands. We downloaded both sets of computer-corrected orthoimagery data from NYC Open Data Portal. NDVI, a general measure of greenness, was used to capture the wide variety of vegetation types used by various actors in NYC sustainability action, including garden plots, riparian vegetation restoration, and rooftop greening (Campbell, 2017), following successful use in similar studies of urban vegetation (Morawitz et al., 2006; Li et al., 2015). We calculated NDVI across all images, subtracting spatially corresponding images to find NDVI change from 2008-2016. We used the Zonal Statistics tool from the rasterstats package to compute the mean change in NDVI for each Neighborhood Tabulation Area (NTA, n=175 after data clean) across

the city, a unit made up of census blocks that has policy relevance for city sustainability planning. To focus on the impacts of stewardship in residential neighborhoods, we removed NTAs representing major parks in each borough from this analysis.

Data Collection

We collected data on the ecological, social, and built aspects of the city, available through the City of New York's Open Data Portal, to predict changes in NDVI (see Supplemental Information for data table). Ecological predictors (SO_2 and NO_x concentrations, average summer temperature) were collected from citywide raster datasets with surface temperature measures taken in summer 2011. We drew data for social predictors of NDVI change (median household income and income inequality) from the American Community Survey 2006-2010 estimates, centering the estimates on 2008 (Spielman et al., 2014). To assess aspects of the built environment in each NTA that may predict NDVI change (new construction and average annual traffic density), we processed data from the NYC MapPLUTO dataset for 2017 and the New York State Department of Transport. We represented the influence of stewardship by recording the number of local environmental stewardship groups with active 'turf area' in each NTA, as delineated in the NYC STEW-MAP 2017 Survey (Svendsen et al., 2016), following the metric used for stewardship in past studies (Locke et al., 2014; Johnson et al., 2019).

Statistical Analyses: Estimating Drivers of NDVI Change

Selecting from a wide range of social, ecological, and technological variables, we built a model assessing drivers of NDVI change between 2008-2016 across all of New York City. We determined the best possible model by using a stepwise regression test; selecting air quality, temperature, income, inequality, construction, and traffic as dependent variables (Table 1). We then used a linear mixed effects model to estimate relationships for various drivers of NDVI change in each neighborhood (Zuur, 2009). We selected the model with the lowest Akaike Information Criterion, corrected (AICc), even if some other models had a higher conditional R^2 (Hurvich and Tsai 1989). All analyses were performed in R 3.5.0.

Table 2 Drivers of Urban Vegetation with indicator data used to create models of NDVI change in New York City, 2008-2016. All data were obtained from Open Data Sources.

Driver	***Indicator***	***Units***	***Year(s)***	***Source***	***Reference***
Air Quality	Concentrations of SO_2, NO_2	ppm	2009	NYC Dept. of Health	Steele and Wolz 2019
Heat Island Effect	Summer Surface Temperature	Degrees Celsius	2011	NOAA	Steele and Wolz, 2019
Income	Median Household Income	Dollars	2008	American Community Survey 2006-2010	Grove et al. 2014
Inequality	Gini Index	Ratio	2008	American Community Survey 2006-2010	Martinez-Harms et al. 2018
Infrastructure Disturbance	Average Annual Traffic Density	Average Daily Traffic	2008	NYS Dept. of Transport	Lu et al. 2010
Development	New Construction	Square Feet	2008-2016	NYC Dept. of Planning MapPLUTO	**Locke et al. 2014**
Governance	New Street Trees Planted	Count	2005-2015	NYC Parks	Campbell 2017
Governance	Number of Stewardship Groups	Count	2007	USDA Forest Service	Svendsen et al. 2016

The borough of New York in which a neighborhood was located was used as a random effect in the model, accounting for variations in policy, geography, and development history. Our spatial analysis focused on neighborhoods, the unit with which most NYC residents and stewardship groups strongly identify (Campbell, 2017; Johnson et al., 2019), allowing for easier identification of stewardship groups. NTA's, created by the NYC Department of Planning by amalgamating census blocks, provided an approximation of neighborhood boundaries with abundant available data.

Statistical Analyses: Evaluating Impact of Governance Drivers

We evaluated the influence of governance on NDVI change by creating an additional model including the number of stewardship groups in each neighborhood. Along with the original model that excluded stewardship, we calculated the R^2 and AICc for each model and performed scaled difference chi-squared tests (Bryant and Satorra, 2012). By comparing the models, we were able to determine the importance of the additional variable representing stewardship.

RESULTS

Spatial Distribution of NDVI Change in New York City, 2008-2016

Mean NDVI change was negative in the majority of the city's NTAs, with 163 of 190 NTAs (86%) undergoing a loss of vegetation between 2008 and 2016. Just 35 NTAs had a positive change in mean NDVI, mainly in Staten Island, the Rockaways, and in Eastern Queens. The average NDVI change value for all NTAs was -0.04698. The largest decreases were seen in Midtown Manhattan (mean NDVI change = -0.2) while the largest increases were seen in Mott Haven, Bronx (mean NDVI change = 0.11) (see Fig. 1).

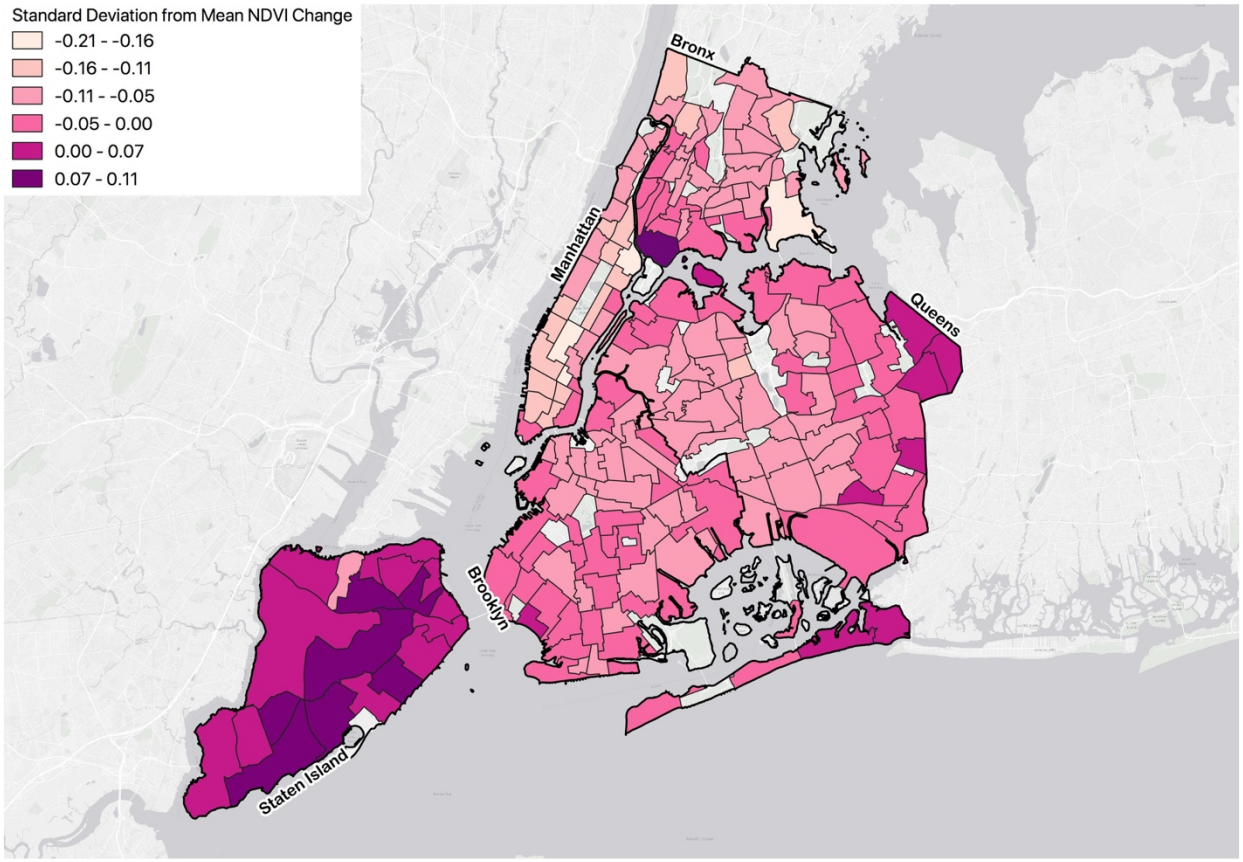

Figure 1 Standard Deviation of NDVI Change for Neighborhood Tabulation Areas across New York City, 2008-2016.

Neighborhoods in darker purple, around the outer ring of the city and on Staten Island, were performing much better than average, while neighborhoods in lighter pink, mostly in Manhattan and The Bronx, were performing below average.

Baseline Model of NDVI Change

In our baseline model of ecological, social, and built environment drivers of NDVI change, both variables representing air pollution (SO_2 and NO_X concentrations) were statistically significant and negatively correlated with vegetation change. Temperature was also negatively correlated, although not significant. Both social variables (income and inequality) were also negatively correlated and insignificant. Built environmental drivers were slightly positively correlated, although strongly insignificant (Table 2). This baseline model, which did not incorporate stewardship, had a conditional R^2 of 0.48 and AICc of 415 (Fig. 2).

Table 3 Results for model estimating the drivers of NDVI Change, including the influence of the number of local environmental stewardship groups in each neighborhood.

	Mean NDVI Change 2008-2016		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	0.06	-0.28 – 0.40	0.722
Average Annual Traffic Density	0.05	-0.06 – 0.16	0.335
Number of Stewardship Groups	**0.22**	**0.09 – 0.34**	**0.001*** **
Concentration of SO_2	-0.27	-0.52 – -0.01	**0.042** **
Concentration of NO_2	-0.29	-0.53 – -0.04	**0.021** **
Median Household Income	-0.03	-0.17 – 0.11	0.630
Summer Surface Temperature	-0.08	-0.21 – 0.05	0.207
GINI	-0.08	-0.24 – 0.09	0.385
New Construction	-0.07	-0.20 – 0.05	0.265
Random Effects			
σ^2	0.45		
$\tau_{00\ borough}$	0.13		
ICC	0.23		
$N_{\ borough}$	5		
Observations	172		
Marginal R^2 / Conditional R^2	0.370 / **0.514**		
AIC	**405.230**		

Assessment of Stewardship Groups

The number of stewardship groups per neighborhood was a statistically significant, positive indicator of NDVI change when included in the model (see Table 1, coefficient estimate = 0.22, p = 0.001***). Comparing the model with and without stewardship groups using scaled difference chi-squared testing and with AICc estimates, we found that the model that

incorporated stewardship accounted for the most variation in NDVI change over time (R^2 = 0.52) and had the most explanatory power (AICc = 408) (Fig. 2).

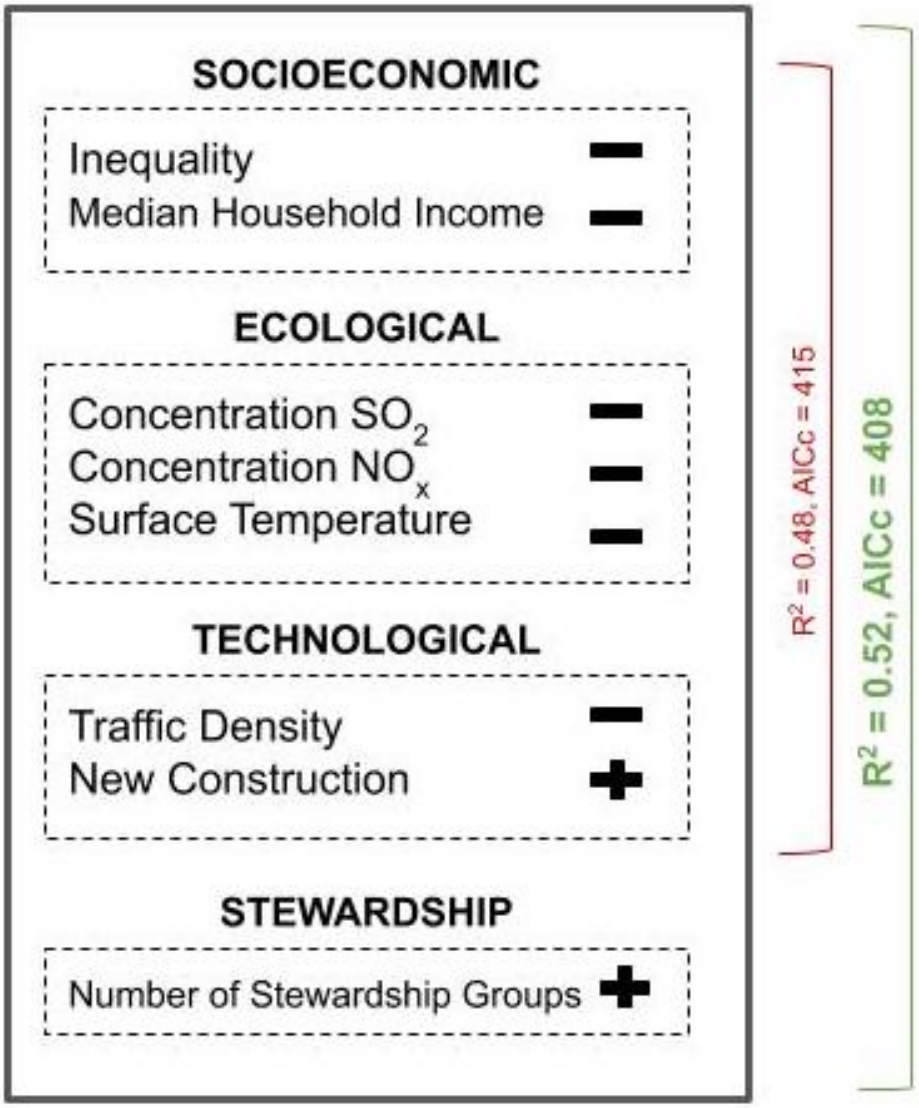

Figure 2 Visual representation of two linear mixed effects models.

Baseline parameters used in both models are shown in the social, ecological, and technological with additional stewardship parameter below. Crosses and dashes indicate positive or negative influence on NDVI Change. R2 and AICc results are shown to the right, baseline model in red and stewardship model in green. Including the number of stewardship groups produced the strongest model.

DISCUSSION

We found that the number of active local environmental stewardship groups is a statistically significant, positive driver of NDVI change in New York City neighborhoods. Our most parsimonious model without stewardship explained 48% of the variation in NDVI changes in New York City between 2008-2016, with differences mainly driven by air pollution concentration. Our best model that included stewardship explained an additional 4% of variation in NDVI change. While social variables, such as income levels, often have top-billing when it comes to predicting urban vegetation distribution (Locke et al., 2016), we found that stewardship groups and ecological conditions also have an influence on the way that urban canopy changes.

Case by case examples of positive impacts from local environmental stewardship has made supporting stewardship groups an important goal for urban sustainability (Bennett et al., 2018; Hölscher et al., 2019). However, there is still a need to quantitatively show the larger significance of urban stewardship groups and their relationship with greening efforts across a whole city (Cockburn et al., 2018). We demonstrated the positive influence of local environmental stewardship on urban vegetation change. For city planners, this result has practical policy implications. In many cities, while stewardship groups are consulted when creating sustainability policy, they are often not included as an important piece of the policy itself (Young, 2011; Campbell, 2017). Furthermore, cities rarely have a codified policy of support for stewardship (Andersson et al., 2014). As stewardship's role in urban sustainability is becoming clearer, city planners can support these groups to enable them to be more effective in their neighborhoods. For cities such as New York and Baltimore, where problems of young tree mortality have been a hindrance to major goals for increasing canopy cover (Lu et al., 2010), supporting stewardship may be part of a solution to encourage city-wide tree care to increase survivorship. Although this analysis positions city sustainability policy and local environmental stewardship as alternative strategies, they are in fact deeply intertwined and have the capacity to support and enhance one another (Campbell, 2017).

ADDITIONAL CONSIDERATONS

Our quantification of biophysical drivers, such as air pollution, also has practical policy implications for cities. The strong negative influence of air pollution on NDVI change points towards a negative feedback loop between air pollution and tree planting that has disproportionate effects on marginalized neighborhoods. Although many urban forestry programs are predicated on the notion that additional vegetation will help solve problems of urban pollution (Keeler et al., 2019), our modelling found that high initial concentrations of NO_x and SO_2 had a significant negative impact on urban vegetation. Both NO_x and SO_2 cause damaging soil acidification after deposition and can damage key tree tissues in gaseous form (Sieghardt et al., 2005). That might mean that some urban forestry programs will fail to successfully grow trees if initial pollution is high.

While abiotic environmental conditions have been noted as a factor in a city's vegetation (Steele and Wolz, 2019), critics of government sustainability planning have described a "curious contradiction" of strong focus on the addition of environmental benefits while neglecting to address existing burdensome environmental conditions (Checker, 2011). In many urban greening plans, low-income and low-vegetation neighborhoods are slated to receive more new trees as method of reducing pollution (Campbell, 2017). For many cases, the addition of urban vegetation is an effective strategy for mitigating harmful air pollution and improving public health (Salmond et al., 2016; Keeler et al., 2019). However, this strategy may work differently in areas (such as the South Bronx in New York City) affected by extreme levels of air pollution that are caused by a legacy of discriminatory zoning and environmental racism (Maciejczyk et al., 2004; Checker, 2008). Pointing towards a hypothesis of a human-induced urban ecological tipping point (Filbee-Dexter et al., 2018), extreme levels of air pollution may decrease dramatically the survivorship potential of vegetation, along with their potential to mitigate pollution (Lu et al., 2010). Future work investigating this hypothesis should lean on stewardship literature as one of many potential solutions, as well as other strategies that have the ability to simultaneously alter ecological dynamics through actions such as tree care, while altering the negative feedbacks in the system by advocating for larger scale changes, such as land use change.

CONCLUSIONS

Stewardship groups are important decision-makers in many major cities, including New York City. As community-management actors, they have the ability to alter both social and ecological aspects of their system, which is particularly well-suited to managing urban vegetation. We used large-scale ecological and social datasets to show a positive relationship between levels of stewardship activity and vegetation change across New York City. Our results suggest that the more groups that are present in a neighborhood, the more positive influence is put on vegetation change. Incorporating stewardship groups as partners in urban greening programs is a proposed strategy for amplifying program goals and meeting canopy targets. In New York City between 2008-2016, stewardship groups had a significant relationship to changes in urban vegetation at a city-wide scale. The number of groups predicts a positive influence on vegetation change, which interacts with other drivers to produce an ultimate outcome. Supporting stewardship groups and increasing their effects is a strategy to shape pathways towards positive outcomes. Future research on the contexts and processes shaping this relationship will provide the details needed for this to be adapted into a framework that can be used by planning officials and stewards in different contexts to support decentralized governance and local environmental stewardship in their own cities. Although further work needs to be done to clarify exactly how stewards work within the urban system, uncovering the important role they play quantitatively indicates the need to consider stewardship groups in city planning moving forward.

CHAPTER 2 - CHAPTER 3 CONNECTING STATEMENT

In Chapter 2, I established a connection between local environmental stewardship and ecological change in New York City by identifying the number of active stewardship groups as having a statistically significant, positive relationships with neighborhood-scale vegetation change. By reaching beyond case studies of positive change already established in NYC (Checker, 2011; Curran and Hamilton, 2012; Pryor, 2018), this quantitative link between local environmental stewardship and vegetation change helps inform our understanding of the important role stewardship plays in the complex urban system.

Modelling reveals the relationship between stewardship and outcomes, but it does not reveal how those outcomes are achieved. Stewardship groups are diverse, with diverse motivations, actions, and systems driving the ways that they work within their communities. Not all groups are created equal, and some groups are more effective than others. To support stewardship groups doing important sustainability work, there is a need to understand deeper the ways that stewardship groups work and the strategies that generate stewardship actions. Effectively, there is a need to fill the gap that modelling creates, moving beyond statistical relationships to the values, motivations, and social relations that construct them.

Therefore, in Chapter 3, I provide an examination of the enablers and barriers to capacity building that shape and mobilize effective stewardship actions in five diverse New York City neighborhoods with surprisingly positive vegetation outcomes. These neighborhoods are examples of places where we can learn from positive change and where stewardship groups are likely to have large established capacity or novel governance arrangements. I present the results of nine semi-structured interviews focusing around social, financial, and human capacities, and contrast interview results to quantitative assessments of group capacity. While quantitative assessments were useful guides to approach stewardship capacities, I found that the underlying relational values of stewards and their communities are important considerations in understanding capacity and stewardship processes.

CHAPTER 3: Human Relationships Nurture Stewardship Practice: Examining Capacities of Stewardship Groups in the Urban Vegetation Bright Spots of New York City

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ABSTRACT

Local environmental stewardship groups comprised of residents working to protect, conserve, or transform their local ecosystems, play an important role in ecosystem management and environmental governance in many major cities. To amplify the important sustainability goals proposed by urban greening plans in many major cities, policymakers are looking towards supporting stewardship groups as a strategy for supporting initiatives at a neighborhood scale. For stewardship groups to be effective, they must have support in building appropriate capacities for action. However, what appropriate capacity looks like for stewardship groups is not well established, and so far, formulating support has been a messy, experimental process. In this study we ask: what are the enablers of and barriers to capacity that shape and mobilize effective stewardship group actions in New York City? Using a mixed methods approach combining statistical modelling and on-the-ground interviews, we assessed the capacities and capacity building processes of stewardship groups working in neighborhoods with a history of positive ecological outcomes in New York City. We show that effective stewardship action is nurtured through the human-to-human relationships built between stewards, volunteers, policymakers, and communities and hindered through lack of access to key assets such as knowledge and funding. Helping to build the capacities of urban stewardship groups should be a priority for urban sustainability planners. Moving forward, this can be achieved by recognizing the importance of relationship building and employing collaborative planning approaches.

INTRODUCTION

Local environmental stewardship groups are citizen organizations that work to protect, conserve, or transform social-ecological systems (Bennett et al., 2018). Recent research in sustainability science and urban planning has identified the importance of stewardship groups for managing complex urban environments, with stewardship helping to shape the environmental governance of many major US cities through advocacy and direct action (Young, 2011; Connolly et al., 2014; Romolini et al., 2016). This importance stems from stewardship groups' ability to perform actions that mediate both the biophysical contexts of their systems as well as the social factors that drive them (Wolf et al., 2013). Management that includes stewardship groups has been proposed as a strategy to shape environmental governance to be more flexible, adaptive, multi-scalar, and respondent to the needs of local communities than management through government actions alone (Muñoz-Erickson et al., 2016). An adaptive, multi-scalar governance network that includes stewardship groups is likely to be well positioned to amplify the desired goals of sustainability plans in many cities, including increasing the supply of, and access to, local ecosystem services (Andersson et al., 2014), as well as to strengthen communities (Tidball and Stedman, 2013) and sense of place (Enqvist et al., 2019).

Positive outcomes from stewardship groups' actions can be found in diverse systems, from Harlem (Checker, 2011) and the South Bronx (Pryor, 2018) in New York City, to rural landscapes in South Africa (Cockburn et al., 2019) and freshwater lakes in Canada (Garrah et al., 2019). In Harlem, NY, environmental justice and stewardship groups contributed important local perspectives on the development of a city-wide sustainability plan, PlaNYC (Campbell, 2017), moving plans beyond simple measurable metrics (Shepard et al., 2008) and resisting the potential impacts of green gentrification (Checker, 2011). In the South Bronx, NY, another low income neighborhood, a strong coalition of community groups have created the influential Bronx River Alliance, transforming the previously unusable Bronx River into a hub of community recreation, education, and ecosystem service provision (Pryor, 2018). These two neighborhoods are important cases of stewardship action in New York, a city with a large and active environmental stewardship network with actions occurring in all five boroughs and a wide diversity of neighborhoods (Campbell and Svendsen, 2008).

To amplify the effects of stewardship groups' actions, policymakers in many cities include stewardship groups in sustainability planning decisions. However, so far, this has proved to be an experimental, messy process varying widely between regions, cities, and individual stakeholders (Bulkeley and Betsill, 2005; Bulkeley and Castán Broto, 2013). Given the complexity of urban systems and their sustainability governance networks, as well as the immense differences between individual cities, governments, and stewardship communities, it is difficult to scale up from case studies of stewardship to understand general principles of stewardship success.

Not all stewardship groups are created equal: some are more successful than others. To be successful, groups must build appropriate stewardship capacities: the ability of communities to steward their own resources, measured as a combination of *assets* that build a pool of capacity for any given stewardship group within a given environment (see Box 1) (Bennett et al., 2018). To generate successful outcomes, stewardship groups must be well supported by enablers that help bolster the assets that build their capacity while barriers to building capacity are overcome (Eakin et al., 2016). However, interactions between actors, ecosystems, and built environments, including political context, power dynamics, equity, and distributive justice (Checker, 2011; Campbell, 2017; Johnson et al., 2019) mediate how stewardship groups can use their assets to build capacity and create effective actions (Schuttenberg and Guth, 2015). Understanding a fuller picture of the enablers and barriers to how capacity is built for successful stewardship groups – for example combining measurements of assets with the relational factors that mediate them – would provide a key step for policymakers to able to support stewardship groups more effectively, thus amplifying the effects of stewardship groups' actions that drive positive social-ecological outcomes.

Previous work on stewardship group capacities has relied heavily on quantitative survey measurements of assets to inform regional censuses of stewardship (Landau et al., 2019), examine the influence of geographic context on organizational factors (Johnson et al., 2019),

establish a relationship between stewardship action and ecological change (Locke *et al.* 2014; Garrah *et al.* 2019, Garrah *et al. in review*), and create conceptual frameworks (Bennett et al., 2018). Studies using quantitative survey measurements provide important, scaled up analyses that demonstrate the role of local environmental stewardship in the urban social-ecological system. However, to fully understand the processes by which capacity is built, maintained, and used to drive effective actions, there is a need to understand deeper the relational processes of individual relationships, group deliberations, financial management, and larger scale networking that shape each survey metric.

Box 1: Categories of Capacity Assets

Bennett et al. (2018) break down stewardship capacities as consisting of assets from six categories. Categories bolded are considered in this study.

Cultural Assets	*Facets of culture, tradition, knowledge, and sense of place that support and encourage stewardship*
Financial Assets	***Financial resources available to support and fund stewardship actions***
Social Assets	***Relationships and connections that build trust and reciprocity***
Institutional Assets	*Agency and options derived through broader governance processes, including institutions (i.e. norms, laws, decision-making processes) and power structures.*
Human Assets	***Individual and group attributes related to human labor (e.g. education, age) supporting stewardship***
Physical Assets	*Technologies, infrastructure, and material tools that enable stewardship*

In this study we ask: what are the enablers and barriers of capacity that shape and mobilize effective stewardship group actions in New York City? To amplify the impact of stewardship actions, we must first understand the capacities that shape and mobilize them. When successful stewardship groups work on actions that drive positive social-ecological outcomes,

what do their capacities look like, and which combination of assets and enabling conditions are present?

Previous modeling of urban vegetation change in New York City revealed that the presence of more stewardship groups was correlated with positive vegetation change on a neighborhood-scale (Garrah et al. Chapter 2). We have since incorporated capacity asset metrics into our model to estimate quantitative relationships between assets and ecological outcomes. We then looked in-depth at each modelled relationship in the context of vegetation bright spots, neighborhoods with vegetation change that is seen to be much better than expected. To effectively shape policies and management strategies to support environmental stewardship, it is important to gain a better understanding of the processes that build the capacity of stewardship groups to act and impact their social-ecological environment. Through this study, we aim to provide a more complete picture of what capacity looks like, which forms of capacity building are most impactful, how capacity can be modelled, and how capacity building processes can be supported by policymakers and planners.

METHODS

We used a mixed methods approach to study stewardship capacity in areas of unexpectedly positive vegetation change in New York City with a quantitative, asset-based approach as well as a qualitative, relational approach. We employed a *bright spots* (Bennett et al., 2016) method, using an existing model of vegetation change (see Garrah *et al. in review*) to identify neighborhoods where vegetation change was positively outperforming model expectations (Cinner et al., 2016; Frei et al., 2018; Garrah et al., 2019). We then used a regional census of stewardship groups in New York City, USDA Forest Service STEW-MAP 2017 (Svendsen et al., 2016) to identify the stewardship groups working within those neighborhoods. We followed up by conducting qualitative semi-structured interviews with a representative from at least one stewardship group in each bright spot to discuss how their capacity is built and translated into action. Finally, we contrasted quantitative and qualitative results to see a fuller picture of enablers and barriers of capacity, how capacity is built, and how it shapes positive outcomes.

Quantitative Analysis of Capacities

We used a model of NDVI change, a measure of landscape greenness (Carlson and Ripley, 1997), across New York City between 2008-2016 at 6-inch resolution (see Garrah et al., *in review* for model details) to examine the relationship between variation in neighborhood-level stewardship capacity and ecological outcomes. We took measurements for neighborhood-level stewardship capacity from STEW-MAP 2017 (Svendsen et al., 2016) by aggregating assets in each neighborhood indicating the total number of stewardship groups (social asset), the average budget of all groups (financial asset), and the average number of staff and volunteers of all groups (human assets). We incorporated each asset measure into a multivariate regression model with additional drivers of urban vegetation change and calculated a model coefficient and p-value for each asset. All analyses were performed in R 3.5.0 (R Core Team, 2018).

Qualitative Analysis of Capacities

Sampling Strategy

We focused our interviews on stewardship groups working in neighborhoods of New York City with positive ecological outcomes over the study period of 2008-2016. Following a bright spots methodology, we calculated the deviance between observed NDVI change values measured from high-resolution orthoimagery (see Garrah *et al. in review*) and predicted change from a multivariate regression model. In each borough of NYC (Brooklyn, Bronx, Manhattan, Staten Island, Queens), we selected the neighborhood with the highest positive deviance as the borough's *bright spot*. By selecting a bright spot neighborhood within each borough of NYC, we sampled appropriate spatial and demographic representation across the city, accounting for the boroughs' distinct differences in land use, development history, and current planning (Ward and Zunz, 1997; Pham et al., 2013).

Next, we selected stewardship groups to interview in each bright spot neighborhood based on the area of their work, their main focus, and the time period in which they've been working. We used the spatial data in the STEW-MAP 2017 census of NYC stewardship to identify all stewardship groups that worked in at least one of our five bright spot neighborhoods,

disregarding city-wide groups who work in all five to account for between neighborhood variability in groups. Following identification of all possible groups working in bright spots, we sampled groups to contact for interviews by selecting only for those meeting the following criteria:

a) A focus on urban greening (selecting one or more of forests, community gardens, urban farms, street trees, vacant lots, residential building grounds, greenways, or green roofs as project sites)
b) At least 40% of organizational time and effort contributing to environmental stewardship
c) Working in the time before the NDVI analysis end point of 2016.

Interview Development

Following the interview protocols from Enqvist et al. (2019), we created a semi-structured interview guide with main thematic open questions and specific probes. We contacted groups via email and follow-up phone calls, conducting interviews in June and July 2019 at a group office, the location of stewardship activity (garden, park, or restoration site) or another appropriate location within the neighborhood (Figure 1). Groups self-selected their own interview representative based on the project description sent to them. The open, semi-structured nature of these interviews allowed for the insertion of narratives, making the interview a site of data production rather than simply collection (Elliott, 2005).

One-hour interviews began with a discussion of the group and who is involved, and then moved to a discussion of the actions and projects the group was undertaking. We then discussed with participants what they felt were the greatest enablers of their work (Eakin et al., 2016), along with significant barriers and challenges they've faced, which revealed key capacities and processes of building them. Finally, we engaged interviewees on their visions of a sustainable future for their neighborhood, as well as the allies and opponents that they find within and outside of local governance networks.

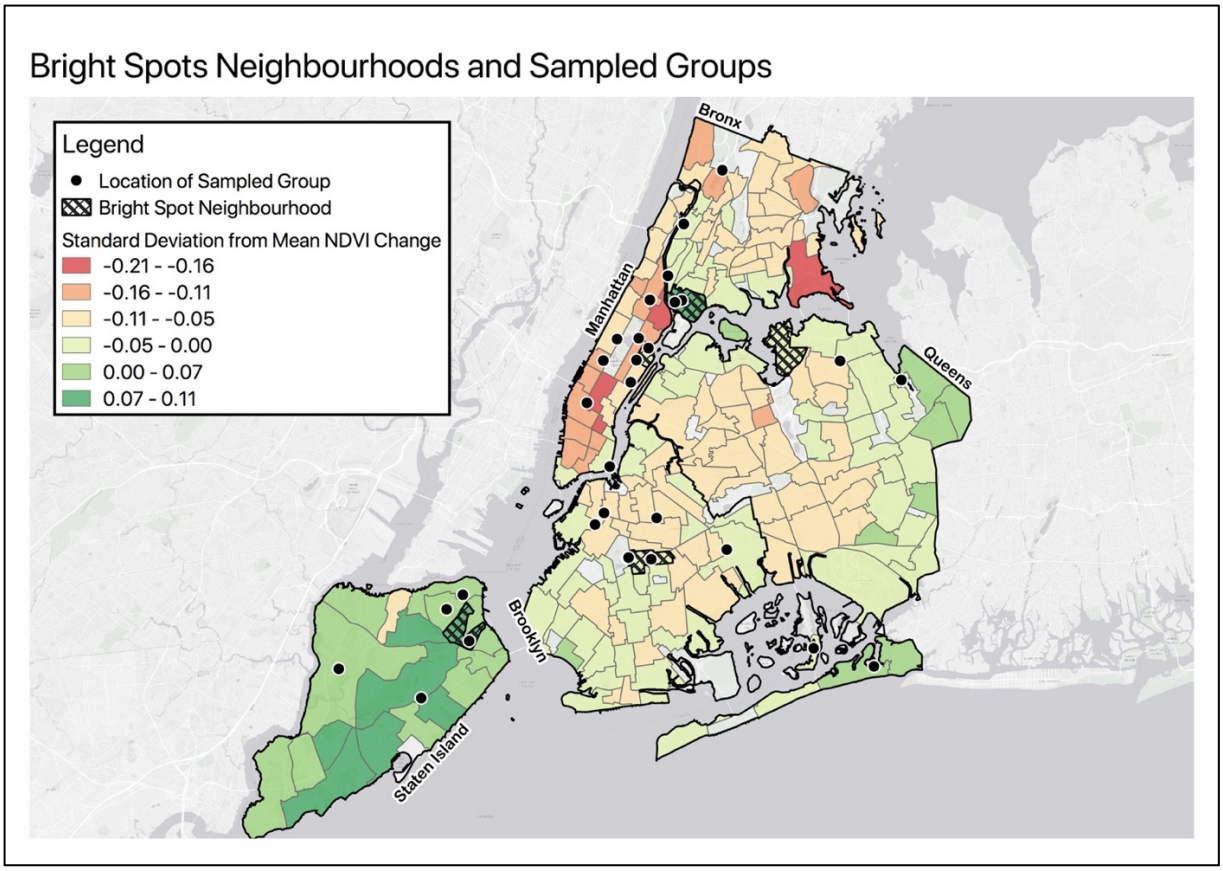

Figure 3 Bright spot neighborhoods designated for each borough of the city, with office locations of groups meeting our criteria and working in at least one of them shown as red points. Although offices of some sampled groups are not within a bright spot neighborhood, groups self-identified at least one bright spot as part of their focus area in STEW-MAP 2017 survey results.

RESULTS AND DISCUSSION

We identified five *bright spot neighborhoods* in New York City, one for each NYC borough: Mott Haven (The Bronx), Prospect-Lefferts Gardens (Brooklyn), Yorkville (Manhattan), Grymes Hill (Staten Island) and College Point (Queens) (Fig. 2). Of all stewardship groups working in at least one of these neighborhoods, 30 met our selection criteria for interviews, and nine responded to our requests for an interview (30% response rate). We selected and interviewed least one group working within each bright spot neighborhood, and we found that the sample of those groups interviewed was roughly representative of the city-wide mix of group sizes, professionalization levels, and action diversity (Fisher et al., 2012) (Table 1). Interviews generated data on three key assets that are important for understanding the capacities and

process of environmental stewardship, including: financial assets, social assets, and human assets.

Table 4 List of organizations interviewed.

Code used to refer to interview quotations in this study is indicated along with the bright spot neighborhood represented. Note that some groups have a turf that extends beyond the indicated neighborhood but self-declared the neighborhood as part of their turf in STEW-MAP 2017. Not all interviews are directly quoted in this paper, but results were generated as a product of coding all interviews.

Group Name	**Code Used**	**Neighborhood Represented**
Family 2 Family Community Initiative/Padre Plaza Community Garden	F2F	Mott Haven, The Bronx
Gowanus Canal Conservancy	GCC	Prospect-Lefferts Gardens, Brooklyn
Gowanus Dredgers	GD	Prospect-Lefferts Gardens, Brooklyn
Maple Street Community Garden	MSCG	Prospect-Lefferts Gardens, Brooklyn
Q Gardens	QG	Prospect-Lefferts Gardens, Brooklyn
Guardians of Flushing Bay	GFB	College Point, Queens
Upper Green Side	UGS	Yorkville, Manhattan
Lower East Side Ecology Center	LES	Yorkville, Manhattan
Friend of Eibs Pond Park	FEPP	Grymes Hill, Staten Island

Financial Assets

We found that average neighborhood stewardship budget, a common indicator of financial capacity, was not a significant indicator of NDVI change at a neighborhood scale. That is, there was no relationship between the amount of stewardship money invested into a neighborhood and the ecological outcomes produced (Coef = -3.408e-09, p = 0.08). This result runs contrary to

the dominant narrative that increasing funding is the primary leverage point to increase stewardship capacity (Connolly et al., 2013; Bennett et al., 2018).

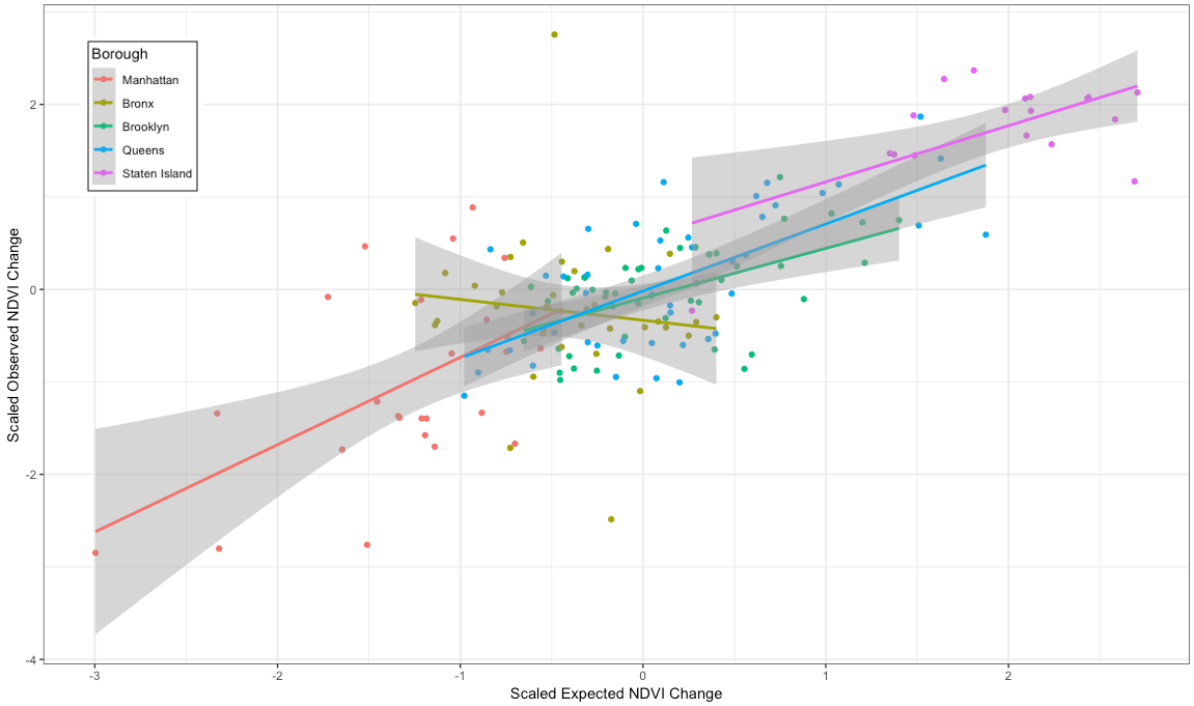

Figure 4 Multivariate regression modelling produced expected NDVI change values (on x-axis) which were compared with actual observations derived from high-resolution orthoimagery taken in 2008 and 2016 (see Garrah et al. in review).

A different average slope is seen for each borough to account for the random effects of jurisdictional differences and development history.

Our interviews revealed that how funding was distributed (its source and conditions attached) often mattered more than absolute amounts. Some small budget groups expressed contentment with their level of funding, with one interviewee working in a Brooklyn community garden explaining that she "just find[s] that [she] can do things on not much money" (QG, personal communication), even rejecting the need for a suggested one-time donation of 20$ from new garden members. The important leverage point that was expressed by the majority of interviewees (12 mentions by five of nine interviewees) was not the amount of funding they had, but rather their ability to manage the money they had and their access to grants, including having personal or institutional knowledge of granting processes. Most

interviewees considered their difficulty in managing budgets and participating in granting processes to be a significant barrier to their work. When it comes to available stewardship funding, interviewees described a funding situation where the majority of funds get distributed to larger, more politically connected groups: “everything is a competition, and [it’s] not because there isn’t enough for everybody” (F2F, personal communication). Interviewees described funding processes as being full of “more red tape… than people expect” (GCC, personal communication) making it so that “often, you can’t even do the work you want to do because there’s so many stipulations” (F2F, personal communication).

Increasing funding is often pointed to as a primary policy leverage point for supporting community stewardship (Connolly et al., 2014) but the situation vis a vis funding levels and success is far more complex. Groups need access to the *appropriate* budget for their work, along with resources, knowledge, and streamlined processes to make funding requests easy, efficient, and effective. We found that stewardship groups in New York City did not consider simply increasing the amount of external funding to be a major improvement in their ability to perform important management actions. In a very different context, working with community-based water management groups in the Colombian Andes, Murtinho et al. (2013) found that simply increasing external funding levels did not necessarily increase a management group’s adaptive capacity (Murtinho et al., 2013). Similarly, Murtinho et al. (2013) demonstrated that adaptive capacity was positively impacted when management groups had the ability to make their own funding requests and set their own agenda. In NYC, many stewardship groups expressed feeling that they could not set their own agendas, creating a major barrier to their ability to carry out stewardship work.

Our interviews revealed that more funding does not necessarily equate with immediate positive outcome. A more nuanced understanding of funding as an enabler/barrier is needed that takes into account the motivations and development trajectories of each stewardship group. It is not clear that our results would scale to larger groups. For example, city-wide groups typically have much larger budgets, up to hundreds of times larger than the groups we interviewed (Landau et

al., 2019). As groups' funding grows, however, they are more likely to act in a bridge organization role (Connolly et al., 2014), redistributing money outside of their own neighborhoods, empowering smaller groups, and acting as a point of connection between government and civic organizations. Stewardship funding networks must be diverse, focused on increasing the capacity of smaller groups and providing them with the agency and knowledge needed to achieve their goals, regardless of the source of funding (Murtinho et al., 2013).

Social Assets

Similar to other studies of stewardship groups in New York City (Locke et al., 2014; Johnson et al., 2019), Garrah et al. (Chapter 2) found that the number of groups working within a given neighborhood, representing social assets of capacity, is a significant, positive driver of decade-scale NDVI change (Coef = 1.697e-03, p = 0.001), Garrah et al., *Chapter 2)* Here, as the number of actors or groups working together within a system increases, so does their capacity for collaboration, learning, and diverse ideas (Connolly et al., 2014; Cockburn et al., 2019). Network approaches to urban stewardship have been an important research focus in resilience, urban greening, and sociology literatures, with social network analysis (SNA) used as a primary tool to "disentangle complexity" (Cinner and Barnes, 2019). For example, in the context of salmon environmental restoration, Sayles and Baggio (2017) used SNA to show that the types of relationships matter, finding that relationships among restoration stewardship organizations were significantly more productive when based on shared interests rather than based on mandated or funded relationships.

Interviewees also found that their social assets were key enablers of their stewardship work, but had a perspective moving beyond modelled relationships: to them, foundational to all the work they do, is the human-to-human relationships embedded in each node and each link of the network – entangling each one of them in complexity. Interviews revealed that relationships within, between, and beyond stewardship groups contributed to capacity building.

The complex relationships between in-group actors shape each individual stewardship group:

> *"I think the people who keep coming back are the ones to really find the work meaningful and feel really passionate about it. So definitely, creating relationships has been more impactful on our organization than just having tons of hands on deck."*
> (GCC, personal communication)

While other relationships shape the connections between stewardship groups and other governance actors:

> *"You know, ally is kind of a funny word in politics, but like, friends, family. People who we feel like we can send information to and who will really candidly tell us if they will or will not support something. [People who] will sign on to grants letters for us."*
> (GFB, personal communication)

Relationships also facilitate exchanging knowledge within stewardship groups and beyond: "I learned so much from other people [outside of our group]. And I, I feel like we lean on each other [within it]" (QG, interview). The process of stewardship itself can be viewed as a process of relationship building, with one interviewee drawing parallels between the work that she puts into a garden and what comes out of it, with embedded learning processes that reinforce both human-to-human relationships and social-ecological outcomes:

> *"[Gardening is] a process, just like relationships. Sometimes your best plannin' doesn't work out... like this [plant], maybe it didn't get enough water. So, yeah, you gotta be able [to learn and to adapt]. It teaches a lot of life lessons."*
> (F2F, personal communication)

For city planners, this result has an important implication: supporting the work of stewardship means supporting the work of relationship building among neighbors, activists, and governance actors. Care should be put into nurturing and fostering meaningful relationships based on shared motivations rather than ones based on institutional or financial requirements (Sayles and Baggio, 2017). Collaborative planning approaches – starting with relationship building

between stakeholders – shift urban planning from a task of 'making places' to one of fostering capacity for 'placemaking' among communities (Healey, 1998). Using planning strategies that begin with recognition of the importance of relationships and community agency in decentralized governance will help foster the connections necessary to build the capacity of stewardship groups to contribute to positive social-ecological change.

Human Assets

Evaluating the human capacity of stewardship groups across New York City, we found that the average number of paid stewardship group staff, average number of volunteers, as well as average number of volunteered hours worked per month were all insignificant predictors of ecological outcomes (Staff: Coef. = 1.141e-04, p = 0.10; Volunteers: Coef. = -1.879e-07, p = 0.57). This result echoes what interviews revealed about social capacity – that there is a quality over quantity dimension to human capacity, where not all staff positions and volunteer hours are created equal, each contributing an uneven amount of labor into direct stewardship results (Rosol, 2012).

Stewards in New York City discussed human capacity as a result of the two previous discussed capacities: financial and social. To have effective human capital assets – committed volunteers and motivated, organized staff – stewardship groups must build strong human-to-human relationships with staff, volunteers, and community members while simultaneously securing appropriate funding to compensate for labor. For groups struggling to establish these capacities, lack of human capacity feeds into a positive feedback loop where often singular staff members get stretched beyond their personal ability to build relationships and secure funding: "It's difficult to maintain all those relationships alone. You know, it's hard for me to follow up with everybody" (GFB, personal communication). Without appropriate relationship building and secure funding, opportunity to hire extra help becomes unachievable, making it more difficult to increase capacity.

Although capacities are often thought of discrete pools of assets (Bennett et al., 2018), our interviews on human capacity produced conversations that discussed it as a product of, or at

least dependent on, two separate categories of capacity, financial and social. Asset pools are linked and not independent, causing discrete quantitative assessments of capacity to miss important connections. Although the idea of assessing capacities as linked bundles, and not in isolation, is well established in economics (Sen, 2004) and sustainable development (Scoones, 1998), it is less established in urban ecology.

Synthesis

We found that the key enablers nurturing effective stewardship practice in New York City were the human-to-human relationships built between individual stewards, decision-makers, and community residents. Similar results have been found elsewhere. Working in a very different context, examining collaboration networks of agricultural stewards and policymakers in South Africa, Cockburn et al. (2019) demonstrated that the relationships and trust built between landscape management actors facilitate the exchange of learning, knowledge, practices, funding, and resources, enabling greater capacity for action and social-ecological change. Similarly, in Baltimore, MD, and Phoenix, AZ, Locke et al. (2020) found that knowing more neighbors by name was positively correlated with a stated willingness to volunteer in support of water quality improvement. Building relationships and ultimately, trust, between environmental governance actors is a key motivator and capacity builder, prompting co-development of effective actions that drive positive social-ecological change.

The key barriers we identified in New York – namely, the *lack* of knowledge to access funding resources – is an important finding for policymakers and planners. By focusing on the key enabler of relationship building, policymakers may be able to help stewardship groups overcome this major barrier – through building collaborative relationships, stewardship groups will have greater access to knowledge and resources, learning opportunities, and ultimately, agency. Collaborative planning approaches that shift the task of planning to one of fostering capacity and codesigning approaches for placemaking within communities are key in embracing and enabling stewardship groups' role in creating sustainable urban futures (Scoones 1998). By employing collaborative planning approaches along with a diversity of interventions and policies well suited to each context (Selinske et al., 2017), for example, compensation for

stewardship initiatives (Chapman et al., 2019), stewards and government policymakers can co-produce potential pathways to sustainable futures for their cities.

Scholars are beginning to frame environmental stewardship as a concept that is able to bridge and capture many sustainability planning strategies, desired outcomes, and communities (Cockburn et al., 2018; Enqvist et al., 2018; West et al., 2018; Masterson et al., 2019b, 2019a). We demonstrated the importance of human-to-human relationships in building stewardship groups' capacity in five key vegetation bright spots in New York City by shifting the focus of our case study from measuring statistical correlations to exploring the relational values that shape them. For both social and financial capacities, it was not the amount of resources that stewards considered important, but rather what kind and quality of resources they had access to. Future research on stewardship capacity would do well to embrace the complexity embedded in each measurement, statistic, and network analysis to further shape an empirical picture of stewardship capacity building processes to inform effective and equitable sustainability planning.

CONCLUSION

We examined the capacities of stewardship groups working in five diverse neighborhoods in New York City with surprisingly positive vegetation change outcomes. For stewardship groups working around sites of positive ecological change (urban vegetation bright spots) in New York City between 2008-2016, we found that human-to-human relationships, which build social capacity, were a key *enabler* for shaping effective stewardship group actions and ultimately, positive ecological outcomes. This human capacity of stewardship groups emphasizes the importance of relationships between individual group members, community members, and governance decision-makers. Further, the majority of groups expressed that the most important *barrier* to building more capacity for change was the knowledge and skills needed for sound financial and administrative management. While quantitative asset modelling of capacity was a useful guide to arrive at our results, the full picture of how capacity is built and maintained was only captured once we explored relational values and hyperlocal contexts through qualitative interviews.

Our results, alongside a growing body of research, show that local environmental stewardship groups play an important role in shaping the future of urban sustainability (Svendsen et al., 2016; Enqvist et al., 2018). Helping to build the capacities of urban stewardship groups and networks should be a key priority for urban planners and policymakers moving forward (Cockburn et al., 2018) using collaborative planning approaches and including stewardship groups in decision-making processes. In particular, these goals can be achieved by recognizing and supporting the human-to-human relationships that build capacities for environmental stewardship and working to overcome barriers to knowledge and funding that restrict them. Building a healthy culture of local environmental stewardship facilitates residents to harness their own visions of healthy neighborhoods to achieve collective urban sustainability goals, benefiting us all.

CHAPTER 3 – CHAPTER 4 CONNECTING STATEMENT

In Chapter 3, I identified human-to-human relationships as the primary enabler of effective stewardship action in five diverse New York City neighborhoods and a lack of access to knowledge as a primary barrier. This result emphasizes the important role of relational values in building, shaping, and mobilizing effective stewardship actions in NYC. For urban planners and policymakers, this result points to the need to develop more effective collaborative planning strategies, placing emphasis on building relationships with local stewardship groups and enabling relationship building between community members themselves. However, can planners in other, extremely different systems, learn from this result and implement similar strategies effectively? Governance actors have much to learn from one another, but it is important to recognize the phenomenon of stewardship of one that is rooted in place and inescapably tied to the landscape (Cockburn et al., 2018). To learn from examples of successful stewardship and adapt lessons to different contexts and systems, it is an important direction of future research to recognize which aspects of stewardship are tied to and mediated by local contexts, and which are generalizable across them.

Therefore, in Chapter 4, I conduct identical semi-structured interviews in a very different system, suburban Greater Montreal, and present a comparative study between NYC and Greater Montreal stewardship communities. Through this comparison, I show that in urban NYC and suburban Greater Montreal, demographic, social, cultural, and physical contexts mediate characteristics of stewardship that differ in each location, as well as characteristics that appear to be similar. Stewardship is a landscape-rooted phenomenon that is heavily mediated by the surrounding social contexts as well as the preferences and values individual stewards themselves. When learning from far removed examples of successful stewardship and adapting lessons to inform local policy, decision-makers must consider their own contexts and individual stewards that shape stewardship and governance processes.

CHAPTER 4: Local Environmental Stewardship Actions Are Shaped by Local Processes: A Comparison Study of Local Environmental Stewardship in New York City, NY and Greater Montreal, QC

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ABSTRACT

The phenomenon of stewardship -- people caring for the environment that they are proximal to (Bennett et al., 2018) -- is an important governance process in many diverse systems. Some common aspects of stewardship are shared across systems, while some are tied to local contexts. Stewardship actors have much to learn from one another, but it is important to recognize the phenomenon of stewardship of one that is rooted in place and inescapably tied to the landscape. To learn from case studies of stewardship and adapt lessons to different contexts and systems, an important direction of future research is to recognize which aspects of stewardship are tied and mediated by hyperlocal processes and which are generalizable. Using a qualitative content analysis approach, comparing identical interview results in both systems, I found that stewardship groups in each context resemble each other, but work within vastly different contexts and ultimately, via vastly different processes and pathways. I hypothesize that key differences between these stewardship communities, and indeed, unpacked, nuanced differences between key similarities, can be further understood by the mediation of demographic, economic, and governance contexts present in each.

STUDY BACKGROUND

The phenomenon of stewardship -- local people caring for the environment that they are proximal to (Bennett et al., 2018) -- is an important governance factor in many diverse systems. Local environmental stewardship occurs on every sort of landscape, in every sort of context, from rural landscapes (Cockburn et al., 2019; Garrah et al., 2019), to suburban developments (Landau et al., 2019) and urban metropolises (Campbell and Svendsen, 2008). Different systems

often share some common characteristics of stewardship, while other characteristics are tied to local governance processes, cultural contexts, landscape structures, resource dependence and human capacities (Bennett et al., 2018; Cockburn et al., 2018). Although stewardship is a widespread phenomenon found in many systems, it is one that is rooted in place and inescapably tied to the landscape, making it a powerful strategy to shape local social-ecological change (West et al., 2018) through practitioners and knowledge holders that know their system best (Enqvist, 2017).

Increasingly, researchers and practitioners of urban and regional sustainability planning are aiming to increase support for local environmental stewardship in cities as a strategy to shape collaborative pathways to sustainable futures (Svendsen, 2010; Krasny and Tidball, 2012). Support is delivered to stewardship communities through city government programs often built on lessons learned from best practices implemented in other cities, focusing on enabling stewardship groups to build capacity through financial incentives (Young, 2011). However, so far, this has proved to be an experimental, messy process varying widely between regions, cities, and individual stakeholders (Bulkeley and Betsill, 2005; Bulkeley and Castán Broto, 2013). Given the immense differences between individual cities, governments, and stewardship communities, it is difficult to scale up from case studies of stewardship to understand general principles of stewardship success (Bennett et al., 2018; Lopez, 2020). To learn from case studies of stewardship and adapt lessons to different contexts and systems (Bennett et al., 2016), an important direction of future research is to recognize which aspects of stewardship are generalizable and which tied to and mediated by local processes.

Although the body of literature on urban stewardship is growing, with recent additions of conceptual frameworks (Bennett et al., 2018), large-scale reviews (Enqvist et al., 2018), and empirical studies (Jasny *et al.* 2019; Johnson *et al.* 2019, Garrah et al. *Chs 2, 3*), there is a need for future research to develop comparisons across case studies and scales to further develop generalizable conceptions of the phenomenon (Bennett et al., 2018; Lopez, 2020). Local environmental stewardship groups have wide, varied motivations, capacity building processes,

actions, and contexts (Fisher et al., 2012) while being intrinsically tied to their landscapes (Cockburn et al., 2018). Past research on capacities of local environmental stewardship groups – the ability of a group to steward their own resources (Bennett et al., 2018) -- has mainly focused on analyses of measurable asset metrics (Eakin et al., 2016; Johnson et al., 2019; Landau et al., 2019; Locke et al., 2020), although bridging an asset view of capacity with a qualitative understanding is becoming more common (Enqvist *et al.* 2018, 2019, Garrah et al. *in prep*). Bennett et al. (2018) conceptualize stewardship capacity as shaped by a group's assets, by also by the governance context of the system in which a group works (Bennett et al., 2018). To properly inform new stewardship support policies in cities across the world, it is important to address how local contexts, including governance, shape and mediate stewardship capacities and processes.

This chapter aims to begin investigating generalizable and local context-specific characteristics of stewardship by presenting a comparison study on the processes of stewardship groups in urban New York City, NY and suburban Greater Montreal, QC. Both study sites have active local environmental stewardship communities, but different geographies, governance, demographics, and economics, offering an opportunity to draw similarities and differences between the enablers, barriers, and processes encountered by each stewardship community. In New York City, we looked at stewardship groups operating in five highly dense, inner city neighborhoods that were considered bright spots of vegetation change. NYC stewardship groups often operate on a neighborhood-scale, grow out of other social movements (for example, anti-gentrification efforts), and work on advocacy with the dominant governance actor in NYC, the city government (Campbell, 2017). In Greater Montreal, we looked at stewardship groups operating in the suburban West Island region, a collection of affluent suburban cities, towns, and boroughs directly west of urban Montreal. On the West Island, stewardship groups often have a specific focus on conservation of a piece of unprotected land, form around advocacy for their focus-area, and work with a complex political geography involving multiple municipal, provincial, and federal bodies.

In this study, I ask:

1. Which aspects of stewardship processes are shared across very different context?
2. Which aspects of stewardship processes are affected by the mediating influence of governance processes, landscape structures, culture, and geographies?

The vast majority of research on local environmental stewardship focuses on groups operating in one, specific context – as a landscape rooted phenomenon, this is crucial to understanding how stewardship functions and produces outcomes. In this report, I provide a comparison study (of which there are a limited number in the field of stewardship (Chuang et al., 2017)) of two very different stewardship communities, operating in very different contexts. This does not provide a deep dive into how stewardship functions in each place, but rather will address how stewardship can be adapted and understood across system boundaries, creating deeper understanding of how policymakers and stewards can learn from successful examples and adapt lessons to their own specific systems.

METHODS

We conducted one-hour semi-structured interviews with representatives of nine stewardship groups in New York City and five stewardship groups in Greater Montreal, discussing landscapes, actions, motivations, and most importantly, capacity building processes and important enablers and barriers for each group. Next, we coded interviews using a grounded theory approach (Corbin and Strauss, 1990) for repeated themes and characteristics in each region. By comparing repeated themes in both study regions, we were able to draw similarities and differences between the two stewardship communities and observe mediating local factors that altered the way stewardship networks function.

Sample Strategy

Stewardship groups were selected for interviews following different methods in New York City and in Montreal, due to lack of available data for West Island stewardship groups. In NYC, we selected stewardship groups to interview in each bright spot neighborhood based on the area

of their work, their main focus, and the time period in which they've been working. We used the spatial data in the STEW-MAP 2017 census of NYC stewardship (Svendsen et al., 2016) to identify all stewardship groups that worked in at least one of our five bright spot neighborhoods, disregarding city-wide groups who work in all five to account for between neighborhood variability in groups. On Montreal's West Island, we used a snowball sampling approach, starting by identifying and contacting member groups of the Green Coalition, a regional umbrella group, and collecting referrals to other stewardship network contacts from responding interviewees. We contacted groups via email and follow-up phone calls, conducting interviews at a group office, location of stewardship activity (garden, park, or restoration site) or another appropriate location within the neighborhood. Groups self-selected their own interview representative based on the project description sent to them.

Interview Development

Following the interview protocols used in Enqvist et al. (2019), we created a semi-structured interview guide with main thematic open questions and specific probes. Interviews began with a discussion of the group and who's involved, moving to talking about the actions and projects the group was undertaking. We then discussed with participants what they felt were the greatest enablers of their work (Eakin et al., 2016), along with significant barriers and challenges they've faced, which revealed key capacities and processes of building them. Finally, we engaged groups on their visions of a sustainable future for their neighborhood, as well as the allies and opponents that they find within and outside of local governance networks. See Chapter 3 of this thesis for complete interview development process and protocols.

Interview Analysis

Using a blended coding approach (Saldaña, 2013) combining Bennett's Framework of Environmental Stewardship (2018) with Corbin and Strauss (1990)'s grounded theory approach, we coded for capacities already recognized by existing frameworks (Bennett et al., 2018; Enqvist et al., 2018) as well as identifying repeated additional capacities or underlying capacity building processes. Additionally, we coded repeated outcome goals across groups as well as repeated pathways of change and actions. All coding was performed in R with the R Qualitative

Data Analysis package (Huang, 2018). To compare across the two systems, we laid out repeated themes of capacity enablers and barriers, pathways to change, and outcomes for each study area on a flowchart, connecting commonalities in the middle and separating differences on either side (Figure 2).

RESULTS AND DISCUSSION

Key Characteristics

We found that the key enabler nurturing effective stewardship practice in both New York City and Greater Montreal were the human-to-human relationships built between individual stewards, decision-makers, and community residents. The key barrier shared between the different contexts was frustration with larger environmental governance processes restricting stewardship group agency and effectiveness (Fig. 1). In both regions, stewardship groups shared a tendency to focus on advocacy actions, lobbying all levels of governance and decision-making to implement sustainability plans. However, this tactic was far more developed, prevalent, and almost universally used in the West Island while in New York City stood as one of a wide variety of tactics utilized by stewardship groups (see Chapter 3).

A key difference between stewardship communities in New York City and Greater Montreal was the amount of knowledge of local governance processes held by stewards. In NYC, lack of knowledge was consistently cited as a key barrier to mobilizing effective actions and collaborating with larger scale governance actors. Meanwhile, on Montreal's West Island, interviewees expressed that their deep knowledge of governance and legal processes was a key enabler in producing effective advocacy and sustainability planning.

Yet another key difference between NYC and Greater Montreal stewardship communities was the distinctly different visions possessed by each for the areas and greenspaces they worked to steward. In NYC, stewardship groups often undertook their work in pursuit of community autonomy, gaining ownership of derelict land, and establishing an alternative governance regime for their hyperlocal contexts. Meanwhile, in Greater Montreal, stewardship groups worked towards the goal of government purchase and oversight of their turfs, moving them

into protected area status with government taking on the bulk of maintenance and planning tasks while stewardship groups are transformed into advisory councils, fundraisers, or 'Friends Of' groups. One interviewee, a longtime influential environmental activist on the West Island, went so far as to say: "We've never thought of it in terms of stewardship. We want our natural areas to become public, then the stewardship of course, shifts to the municipal government" (GC, personal communication).

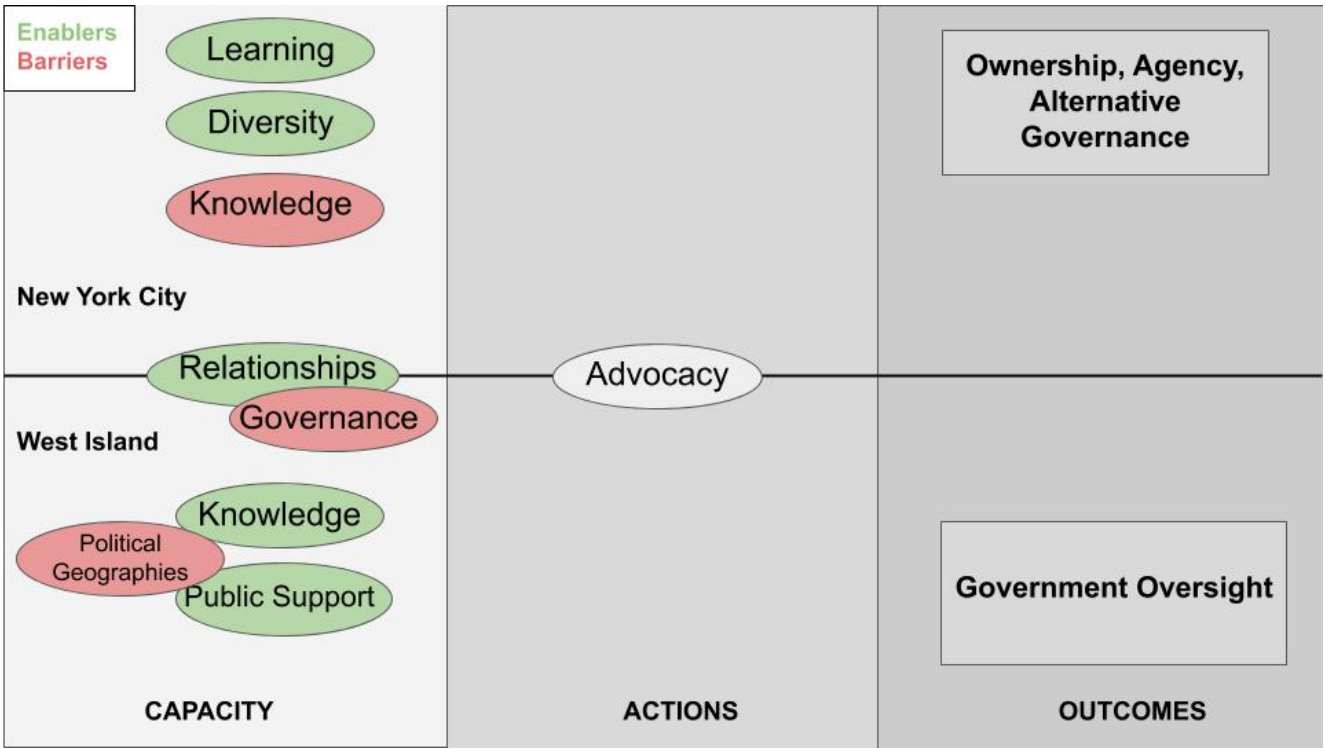

Figure 5 Characteristics of stewardship for New York City and Greater Montreal

Shown are characteristics of capacity (ability to steward resources), actions (what is done to steward resources), and outcomes (what is desired by stewards) shown for the stewardship communities of New York City (top) and the West Island of Montreal (bottom). Shared characteristics are placed in the middle (relationships, governance, and advocacy). For capacity processes, enablers to capacity building are shown in green and barriers in red. All groups followed a dominant action pathway of advocacy but aimed for divergent goals, shown in the boxes to right.

Context Mediates Stewardship Characteristics

We found key similarities between stewardship processes in both urban New York City and suburban Greater Montreal, along with distinct differences in knowledges and projected

outcome goals. Stewardship groups in each study system resemble each other, but work within vastly different contexts and ultimately, via vastly different processes and pathways. To fully understand the ways that stewardship groups in both NYC and Greater Montreal resemble each other and the ways that they differ, contextual evidence must be connected to each key characteristic presented in the previous section. For the key characteristics of access to knowledge and of desired outcomes, I will present connected contextual evidence to begin to understand how contexts mediate stewardship processes, working within the hypothesis that key differences between these stewardship communities, and indeed, unpacked, nuanced differences between key similarities, can be further understood by the mediation of demographic contexts (see Table 5).

Demographic context mediates the difference in access to knowledge of governance processes as an enabler or barrier to effective stewardship action. On the West Island, a region with a vast majority of affluent and highly educated residents, interviewees expressed a reliance on their backgrounds in legal processes, political participation, and real estate development as key enablers driving their stewardship strategies. As well, a key enabler on the West Island was close relationships with other highly educated professionals who provided legal services or publicity in local news outlets (FMP, Angell Woods, Technoparc, SLF, personal communication). In NYC, many of the interviewed stewards struggled with these same aspects of advocacy. As marginalized populations with lower levels of formal educational achievement, many stewards felt underprepared for participating in local governance and legal processes as well as gaining access to appropriate funding (see Chapter 3). Aspects of capacity building processes can manifest differently for different groups depending on the amount of knowledge they possess on how to navigate the legal and political systems involved in their work. Local contexts, including the factors that drive access to education in communities, is a factor contributing to the level influence stewardship groups can gain through capacity building and action. (Schuttenberg and Guth, 2015).

Table 5 Comparing five communities studied in NYC with five communities studied on the West Island of Montreal.

On average, communities in NYC are larger, with much lower levels of educational obtainment and income, while communities on the West Island are smaller, highly educated, and affluent. Additionally, NYC communities have a housing tenure that is heavily renter dominated while West Island communities are mainly made up of homeowners. Data is taken from 2013-2017 ACS for NYC and 2016 Canadian Census for the West Island

NEW YORK CITY	Population	Post-Secondary Ed.	MdHHInc (USD)	Owner-Occupied Housing	Percent Non-Hispanic White
Prospect Lefferts Gardens, Brooklyn	69 096	28.70%	46 922	17.70%	16.20%
Mott Haven-Point Morris, Bronx	54 617	9.10%	21 662	5.60%	2.10%
College Point, Queens	25 298	18.60%	57 276	46%	23.50%
Yorkville, Manhattan	82 432	80.40%	107 772	27.40%	75.20%
Grymes Hill, Staten Island	2 340	19.20%	55 401	49.00%	30.20%
Source: 2013-2017 American Community Survey					
WEST ISLAND	**Population**	**Post-Secondary Ed.**	**MdHHInc (CAD)**	**Owner-Occupied Housing**	**Percent Non-Hispanic White**
Senneville, QC	921	38.55%	138 069	88.41%	92.40
Pointe-Claire, QC	31 380	29.51%	80 242	70.3%	78.84
Beaconsfield, QC	19 324	39.02%	123 392	89.65%	87.30
Montreal-Ouest, QC	5050	43.17%	115 029	77.3%	82.67
Cote Saint-Luc, QC	32 448	31.97%	58 935	49.07%	80.82
Source: Canadian Census, 2016					

When we consider the demographic contexts of the communities studied, it becomes clear that local residents, and stewards themselves, are likely to have vastly different lived experiences

with and levels of trust in government, changing what a vision of a healthy, sustainable future looks like for each community. We found that both stewardship communities share, broadly, a common goal: a sustainable, healthy future for their city, town, neighborhood, or greenspace. However, the vision of what a sustainable, healthy future looks like is vastly different for each community. In New York City, stewardship groups advocate for community ownership and agency over local management and decision-making, while in Greater Montreal, stewardship groups advocate for government purchase, management, and legal protection of lands.

The majority of residents in four of the five NYC neighborhoods we studied (save for the wealthy Yorkville, Manhattan) were of a minority race or ethnicity (Table 1), a population with a long history of subjection to environmental racism (Checker, 2008; Grove et al., 2018) and inequities (Narcisse, 2017), producing a strong communal distrust of government intervention and management (Cordasco et al., 2007). After Hurricane Katrina devastated the city of New Orleans, LA, Cordasco et al. (2007) found that affected populations distrusted authorities' competency to manage the situation and felt that they were being treated unfairly, with other's best interests prioritized. The distrust demonstrated by Cordasco et al. (2007) ran so deep that interviewees felt like there was a lack of truthfulness and sincerity from authorities, and that they were consistently lied to. With many examples of authorities' failures to properly manage and respond to environmental disasters and management for low-income, minority populations in the United States, it is clear to see how the context of our studied NYC neighborhoods mediates the goal of environmental stewardship into one of autonomy, agency, and neighborhood self-governance.

Meanwhile, on the West Island of Montreal, all five communities linked to the environmental stewardship groups we studied were by far, majority white populations living in affluent suburbs with median household incomes far above neighborhoods studied in NYC (Table 1). In addition, all West Island communities were highly educated, with a high proportion of homeowners. Interviews with stewards on the West Island emphasized a deep *trust* in government, and a desire to "work within the system with available leverage points" (Society of

the Protection of Angell Woods, personal communication). For stewards from white, affluent communities, government has been an institution that works, facilitating social mobility, education, and wealth accumulation – resulting in a deep level of trust. Again, it is clear to see how this very different context again mediates the overarching goals of environmental stewardship into a goal focused on government purchase, oversight, and management.

Although I focused on two specific study areas with unique stewardship communities, I used replicable interviews to show that stewardship processes are highly context specific, although lessons and characteristics from wide ranging case studies can be used as a guide to approach learning about new stewardship communities. This research suggests that context is a more important factor in understanding stewardship than the majority of literature suggests. Similarly, comparing stewardship communities on a different scale – between neighborhoods in New York City – Johnson et al. (2019) found that development histories, demographics, and organizational characteristics played important roles in influencing the development of stewardship networks over time. Future research on the contexts and relational values shaping stewardship processes will provide the details needed to incorporate a better understanding of context-dependence into conceptual frameworks of stewardship that can be used by planning officials and stewards in different contexts to support decentralized governance and local environmental stewardship in their own cities.

CONCLUSION

Local environmental stewardship groups are an important consideration in creating pathways to sustainable cities, and city planners are looking to case studies of successful stewardship action to better support stewardship groups in their own cities. To know what is likely to be similar and what is likely to be different in various cities, there is a need to develop comparison studies to determine which aspects of stewardship are generalizable and which are rooted in specific landscapes, cultural contexts, and governance systems. Using two contrasting stewardship communities as examples, we showed that, in urban NYC and suburban Greater Montreal, place-specific contexts, including demographic contexts, mediate the characteristics of stewardship in each location, emphasizing the framing of stewardship as a landscape-rooted

process (Cockburn et al., 2018). When learning from far removed examples of successful stewardship and adapting lessons to inform local policy, decision-makers must consider their own contexts and stewards, using collaborative planning methods (Healey, 1998) to craft appropriate and effective support, creating more sustainable cities for all.

SYNTHESIS, FUTURE DIRECTIONS, AND CONTRIBUTIONS TO KNOWLEDGE

Synthesis

In this thesis, I set out to determine the influence of local environmental stewardship groups on urban vegetation change in New York City, focusing on finding examples of positive outcomes to inform future urban sustainability planning. In Chapter 1, I reviewed the development of frameworks of urban ecology and their applications to vegetation modelling and planning, how natural resources governance fits into urban vegetation planning, and the phenomenon of local environmental stewardship. By bridging literature from a variety of disciplines, I created a framework to approach the empirical study of governance, and specifically, stewardship, in driving urban vegetation change. In Chapter 2, I applied this framework to determine a statistical relationship between stewardship presence and NDVI change in NYC between 2008-2016, identifying the number of stewardship groups as a significant, positive factor at a neighborhood scale. In Chapter 3, I qualitatively examined the capacity building strategies of 9 stewardship groups in successful neighborhoods, finding that they considered human-to-human relationships as the key factor nurturing the action that underlies statistical relationships. In Chapter 4, I explored which aspects of NYC stewardship strategies were generalizable to other contexts by repeating interviews in the West Island of Montreal, finding that all results are deeply tied to demographic contexts. Throughout this thesis, I use a fundamentally interdisciplinary approach and draw on a wide variety of spatial, quantitative, and qualitative methods to build a larger picture of local environmental stewardship's contexts, motivations, actions, and outcomes. By better understanding the many aspects of stewardship, planners can better formulate policies that support and encourage healthy cultures of stewardship in their cities to build pathways towards a sustainable future.

For city planners, these results have important implications: stewardship can be an effective strategy to build healthy, sustainable neighborhoods, and supporting the work of stewardship means supporting the work of relationship building among neighbors, activists, and governance actors. For many communities, such as Harlem and the South Bronx, engaging in local environmental stewardship is an act of placemaking, with local residents using stewardship as a

way to create their own visions of a healthy sustainable neighborhood, incorporating ecological goals as well as social goals, such as widespread affordable housing and accessible employment (Checker, 2008, 2011; Wolch et al., 2014; Pryor, 2018). Many government sustainability plans, such as New York's PlaNYC, have been heavily criticized by stewardship groups for working against these goals by using a market-driven, neoliberal framing of a sustainable city to increase real estate values and attract wealthy, new residents from elsewhere (Shepard et al., 2008; Gould and Lewis, 2016; Campbell, 2017). Indeed, in addition to these plans not achieving the social goals desired by longtime residents, the ecological results often fall short of expectations (McPherson et al., 2011, see Garrah et al. Chapter 2). By moving towards collaborative planning approaches – starting with building relationships between stakeholders – urban planning can move from a task of 'making places' to one of fostering capacity for 'placemaking' among communities (Healey, 1998). My results show that this approach has the potential not only to strengthen neighborhood environmental stewardship – with outcomes strengthening community wellbeing and sense of place – but also to strengthen the ecological structure of urban systems. Using planning strategies that begin with recognition of the importance of relationships and community agency in decentralized governance will help foster the connections necessary to build the capacity of stewardship groups to contribute to positive social-ecological change.

Future Directions

Stewardship is a practical strategy for developing pathways towards urban sustainability that is of increasing interest to planners and researchers (Young, 2011; Bennett et al., 2018). However, it is also an embodied, landscape-dependent process shaped by relationships, culture, and governance (Enqvist et al., 2018; Cockburn et al., 2019). In this thesis, I bridge these two understandings of stewardship by first showing the practical positive impact of stewardship on a city-wide scale in Chapter 2 and then by investigating the relational factors shaping this impact in Chapters 3 and 4. Current research on local environmental stewardship, and in particular urban stewardship, often neglects one of these two crucial aspects of the phenomenon. To fully incorporate the voices of local stewards into urban sustainability planning and amplify positive impacts, future research must aim to incorporate flexible

understandings of the relationships that shape stewardship processes, as well as an understanding of the positive impacts generated from community stewardship, both social and ecological.

Helping to build the capacities of urban stewardship groups and networks should be a key priority for urban planners and policymakers moving forward (Cockburn et al., 2018) using collaborative planning approaches and including stewardship groups in decision-making processes. Researchers have an important role to play in this process by generating place specific as well as more generalized knowledge on stewardship to create integrative frameworks to inform policy development. In particular, it is crucial to take an interdisciplinary approach to local environmental stewardship, incorporating many aspects, approaches, and strategies to fully understand the multiple ways that stewardship can help shape a more sustainable urban social-ecological system. Moving forward, we cannot rely on quantitative or qualitative assessments alone -- as this thesis as shown, they only tell part of the story.

Contributions to Knowledge

I have shown that local environmental stewardship plays an important role in the social-ecological system of New York City. My results provide insight into the scaled up, system-level impacts of stewardship action on urban vegetation, as well as the underlying enablers and barriers to capacity building, including community relationships, that shape effective actions. In addition, I have shown that local demographic and governance contexts play an important role in mediating stewardship processes. Previously, case studies have described the important impacts of stewardship in particular New York City neighborhoods (Checker, 2008; Svendsen, 2010; Wolch et al., 2014; Pryor, 2018) while city-wide, data-driven studies have described the distribution of groups (Johnson et al., 2019), collaboration networks (Jasny et al., 2019), and landscape structure (Locke et al., 2014). I have combined these methodologies to incorporate a wide variety of complex drivers of urban ecosystem change to reveal the role of stewardship alongside these drivers in the urban system on a decadal, city-wide scale while providing in-depth qualitative interviews to understand effective stewardship processes in bright spot

neighborhoods. Mixed-methods studies of stewardship are crucial to inform a fuller understanding of local environmental stewardship both in New York City and across the world.

For city planners, my results have important implications. Firstly, I have built upon previous stewardship research in NYC to show, concretely, that stewardship action is an important strategy to harness when shaping sustainable cities and neighborhoods. By supporting stewardship, planners can amplify desirable ecological and social goals for longtime residents, potentially improving overall community well-being and health. Secondly, I have shown that supporting the work of stewardship means supporting the work of relationship building among neighbors, activists, and governance actors. Using planning strategies that begin with recognition of the importance of relationships and community agency in decentralized governance will help foster the connections necessary to build the capacity of stewardship groups to contribute to positive social-ecological change.

Overall, I have made contributions towards the development of a science of urban stewardship, deepening understanding of the role of stewardship in the complex urban system. I have provided evidence on the crucial importance of integrating the voices, goals, and desires of longtime communities of practice in NYC and elsewhere, who have been stewarding the ecosystem and generating positive change for decades, and who will be for decades to come. Those of us invested in shaping just urban futures would do well to follow their lead.

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