RESTORATION AT THE BOUNDARY:
A SOCIO-ECOLOGICAL PERSPECTIVE ON MANAGEMENT
IN THE GREATER EVERGLADES ECOSYSTEM

By

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ABSTRACT

How will conservation areas in South Florida continue to change because of ongoing restoration efforts? Ecosystem restoration practitioners in the Global North aim for adaptive management during a time of increasing uncertainty. To reconcile competing socio-ecological futures in South Florida, this project integrates discursive narrative analysis, spatial modeling, and intuitive data visualization to guide a holistic monitoring approach during the restoration of the Florida Everglades. Projects like the East Coast Buffer (ECB) and the Western Everglades Restoration Project (WERP) represent ongoing attempts in Everglades restoration to acquire and protect degraded landscapes adjacent to protected areas, such as Everglades National Park and the Big Cypress Preserve. This interdisciplinary framework seeks to build a socio-ecological model to monitor ecosystem restoration to holistically track affected cultural landscapes at the periphery of the built environment.

Insights provided through this research suggest that panarchy as a conceptual tool best facilitates the co-production of knowledge in large-scale restoration projects threatened by environmental amnesia. A landcover change ranking system through expert knowledge consultation, remote sensing, and GIS is provided to give context to the narratives of Everglades restoration explored and understand the shifting physiognomic structure of landscapes affected by restoration activities in the ECB. I bridge this modeling framework into the content of WERP to showcase how ecosystem restoration evolves as actors continue to challenge the role of wilderness in South Florida. The insights provided through this investigation also guide the ongoing development of an ArcGIS Story Map, which serves as a boundary object to showcase my research and provide an interactive platform. This online spatial presentation platform integrates the research components of my project into a place-based narrative intended to assist with collaboration, education, and planning.

Restoration at the Boundary:

A Social-Ecological Perspective on Management in the Greater Everglades Ecosystem

A Dissertation
Presented to the Faculty of the Department of Coastal Studies East Carolina University

In Partial Fulfillment of the Requirements for the Degree
Doctor of Philosophy in Integrated Coastal Sciences

By

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DEDICATION

I dedicate this project to the Miccosukee and Seminole Tribes of Florida, the traditional stewards of the Greater Everglades Ecosystem. Your deep connection to this region's land, water, and spirit guides its preservation and resilience. The price of "progress" has not historically valued the impact of indigenous communities since time immemorial. This document marks my initial step toward honoring your enduring legacy and commitment to safeguarding this sacred and globally unique landscape

I also extend my heartfelt gratitude to Michael Elfenbein and the Gladesman community of South Florida, whose knowledge, lived experiences, and access granted me the rare opportunity to witness the politics of paradise unfold in real-time. Your unwavering dedication to the Everglades and other remaining wild places drives me to appreciate what *was* and never to stop fighting for what *could* be.

To all who call the Everglades home or find meaning in its restoration, this research is an attempt to reflect your voices, histories, and visions for the future of this iconic conservation landscape.

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A special acknowledgment goes to the Water Resources Center at East Carolina University for providing essential resources and a collaborative environment that enriched my research. The support and opportunities offered by the center were critical to completing this work.

Finally, I want to express my heartfelt appreciation to my beloved partner, Alexandra Stevenson. Her unwavering love, patience, and example carried me through dark and most uncertain times. This achievement would not have been possible without her steadfast support and belief in me. Boop, your presence alone is a constant source of hope and a reminder of what it takes to affect meaningful change; for that, I will never be able to thank you enough.

To all else who contributed to this endeavor—directly or in passing—your investments in me as a scholar and member of the global community continue to inspire me. This work is a testament to the collective effort and support I received in Eastern North Carolina, the Greater Everglades Ecosystem, and beyond.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I | Introduction

1.1 PROJECT OVERVIEW

Conservation lands at the interface between South Florida's protected areas and the built environment are integral to achieving the Greater Everglades Ecosystem's (GEE) long-term hydrological, ecological, and cultural restoration. These buffer sites secure regional water resources by recharging the underlying Biscayne Aquifer, serving as a transition in land use, and providing flood control for coastal communities. Understanding how ecosystems return to a prior state or improve in their functionality and value to society is a complex but necessary endeavor to foster resilient coastal communities. A resilient total environment requires functionality and connectivity between its human and non-human parts. Recognizing those intangible aspects of ecosystem functionality and *the human dimensions* entails adaptive planning that considers historical context and the landscape values of current and future communities. These conservation lands play an unparalleled role in safeguarding the total environment in South Florida. Beyond presenting a data-driven way to communicate ongoing progress in restoring this iconic conservation landscape, this research provides a more holistic means to assess the multiple, often competing social and ecological futures for components of the GEE bounded by wilderness and development. To better connect the guiding narratives of Everglades restoration to the effects of its local projects, I propose an interdisciplinary approach utilizing an exploratory research design that aims to connect anthropological and geospatial methods.

The socio-ecological value of a landscape connects not only past, present, and future land but also institutional memory and the significance of these landscapes to the local, national, and global communities. At multiple spatial scales, restoration decision-making unintentionally determines winners and losers in resolving various conservation conflicts, the perception of which appears strongly augmented by environmental claims-making (Garvoille, 2013). At the periphery of formally protected areas like Everglades National Park (ENP) and the Water Conservation Areas (WCA), the success of these complex projects relies on land acquisition aiming to provide a continuous buffer between urban development and protected natural areas—this manifests itself on both maps and the landscape as what the South Florida Water Management District (SFWMD) refers to as the East Coast Buffer (Figure 1.1). Ensuring the preservation of these land tracts is vital to long-term restoration efforts because these wetland buffer zones protect critical wellfields and provide seepage management for the major levees in western Miami-Dade County (SFWMD, 2006). Alongside the perceptions and utility of wilderness, contemporary policymaking is deeply embedded in a region's socio-cultural setting. I argue through his research that it is crucial to meaningfully decompose and communicate the project progress so that restoration practitioners and stakeholders better understand the role of these interconnected landscapes. This is necessary to continue navigating the complexity of a project on the spatial and temporal scale of Everglades restoration.

Connecting adaptive management to past land use and evolving attitudes on wilderness areas offers a more comprehensive evaluation of managed areas, which provides practitioners and other stakeholders with a more holistic portrayal of legacy landscapes critical to restoration goals (Cronon, 1996; Sharpe et al., 2021). The role social scientists have played in evaluating this conservation conflict lacks when compared to studies on the biophysical aspects of this setting.

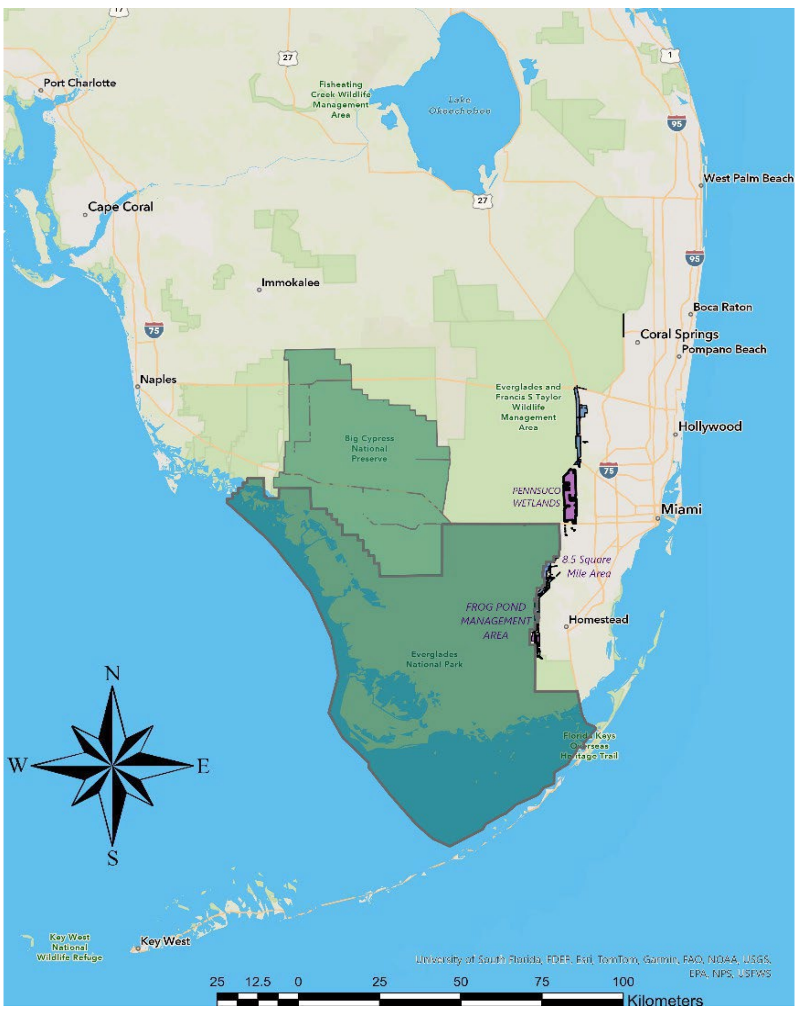


Figure 1.1 South Florida, the East Coast Buffer, and the Greater Everglades Ecosystem (Created with data hosted on the World Database on Protected Areas, IUCN 2024).

Within the interdisciplinary toolset, political ecology has demonstrated its ability to bridge disparate ways of understanding environmental conflicts with implications for sustainable land management (Turner & Robbins, 2008). While the power to promote and implement these large-scale conservation initiatives has historically belonged to state water managers, the United States Army Corps of Engineers (USACE), and growth-oriented stakeholders in the region, the institutional space to hold a more equitable dialogue on Everglades restoration emerged in the last decade. Absent a dynamic modeling framework capable of assessing these underemphasized interactions among restoration planning, land use policy, and community attitudes in South Florida, anticipating just where targets for restoration will ultimately land and to what benefit socially and ecologically remains increasingly uncertain. Assessing the long-term trajectory of Comprehensive Everglades Restoration Plan (CERP) projects seeking to create or revitalize wetlands ecosystems in urban proximate natural areas—including the Pennsuco Wetlands, the 8.5 Square-Mile Area (8.5 SMA), and Picayune Strand State Park—demands interdisciplinary approaches geared toward addressing the expectations of existing and future stakeholders. Securing land rights, recreational access, and a transparent framing of the Everglades' evolving state to the public all depend on proactive, holistic monitoring of on-the-ground conditions as obtained through policy, restoration plans, public forums, and remotely sensed data.

The potential impact of climate change on lands already jeopardized by invasive species and increasingly common flooding events within and at the periphery of protected areas in South Florida also play an important role in resilient environmental planning. Currently, few resources exist that organize and display these hazards along with the policies and plans designed to mitigate them in accessible and interactive ways to stakeholders across the GEE. As socio-economic factors continue to pressure a shift in the Urban Development Boundary (UDB) westward into the GEE, Miami-Dade western ecotone (a socio-ecological interface between types of land use and vegetation communities) risks further degradation as these marginal wetlands and agricultural lands important for environmental integrity and recreation face further compartmentalization (Leon, 2021). Moreover, these places do not represent *wilderness* in the romanticized sense of an uninhabited place: legacy landscapes such as the Pennsuco Wetlands and the 8.5-SMA in western Miami-Dade County, and the nearly developed Picayune Strand SP in Collier County, are all characterized by initially settled and thereafter fragmented (if not entirely dissolved) human and animal communities (Miami Herald Archives, 2020; Clark, 2020; Staletovich, 2021).Social learning is another key aspect of adaptive management (Gunderson & Light, 2006). Resources in the form of expertise are necessary now to track the feedback between restoration narratives and the complex non-linear socio-ecological responses. Failure to include these vital perspectives on restoration jeopardizes the success of its long-term goals. The planning-based paradigm dominant in Everglades restoration is often too rigid and does not afford the adaptive style of experimentation necessary to resolve environmental uncertainties (Gunderson & Light, 2006; Gunderson et al., 2019). The primary objective of this research is to holistically document the socio-ecological feedback that ties together landscape modification, fluctuations in environmental quality, and evolving perceptions of wilderness in South Florida. I aim to better understand this phenomenon across time and space related to the activities leading up to and during Everglades restoration. These communal relationships, directly and indirectly, inform ecosystem restoration in the context of the GEE over the past century and have the potential to better evaluate its progress through an integrative lens (Quandt, 2016).

1.2 RESEARCH DESIGN & GOALS

While various state and federal agencies review progress toward restoring the Florida Everglades since the CERP was authorized in 2000, few efforts effectively synthesize the complexity of both social and ecological conditions in a meaningful, interactive way. For this project, I develop a framework that guides the creation of a dynamic monitoring tool to evaluate Everglades restoration projects at the urban periphery in a more accessible, spatially explicit way. This holistic framework and the interactive Story Map-based platform it informs will allow environmental managers and other decision-makers in the region to reconcile gaps between cultural values and future land use. South Florida is infamous for its legacy of land dispossession, environmental degradation, and the ongoing compromises collectively seeking to "get the water right" at the expense of historically marginalized groups (Fortin, 2002; Ogden, 2008b; Garvoille, 2013; Amorino, 2020). Denying the connection between ecosystem management in South Florida with historic land use and evolving attitudes toward wilderness hinders a comprehensive evaluation of managed areas critical to restoration. Environmental restoration often drives an ecosystem towards a novel state with familiar and unknown conditions to the affected parties, regardless of the realization of restoration goals. Because this project seeks to facilitate a co-production of socio-ecological knowledge through integrating methods across domains of sciences, it provides a comprehensive evaluation of the potential results of its plans as they affect society and nature. To the extent that knowledge co-production has become contentious terminology, this project attempts to co-produce novel pathways for adaptive planning through an iterative development process that incorporates local ecological knowledge (Fabinyi et al., 2014). Thus, the socio-ecological model framework I develop here better captures the cultural value of wilderness areas while bridging localized restoration impacts to sustainable environmental governance. I argue that a political ecology framework offers the greatest potential to shed light on the shifting power dynamics underlying South Florida restoration initiatives and reconcile historically competing narratives on nature.

The two overarching goals of the proposed research, then, are: (1) to combine pre-existing qualitative and spatial datasets in addition to new field data in a meaningful way, enabling an efficient means for adaptive planning by environmental managers and other stakeholders; and (2) to develop a framework that evaluates restoration activities and progress through an integrative lens, further contributing towards the long-term resilience of the GEE. My three research questions ask:

1) Who has (and historically held) the power to promote and implement conservation initiatives to create a *second nature* in the Everglades?

2) How will conservation buffer areas in South Florida alter due to restoration activities?

3) What are the long-term implications of these restoration-related changes in boundary lands for community attitudes toward wilderness and access across the GEE?

I primarily rely on discursive narrative analysis to address the qualitative nature of Research Question 1 (RQ1), and I utilize geospatial methods common to geographic information system (GIS) and remote sensing to classify and quantify the land cover change modeling necessary to answer Research Question 2 (RQ2). Question 3 (RQ3) marks a difference from the direct approaches above as I attempt to provide a more dynamic answer through system scoping and integrative techniques prominent in critical geography and the digital humanities, as these are essential to applying the interdisciplinary approach necessary to connect and build from the prior research questions. In developing this workflow, my integrative process offers the potential to analyze and provide projections for the long-term biophysical and social conditions that underscore the governance of conservation buffer areas across the Global North.

1.3 A BACKGROUND OF FLORIDA'S EVERGLADES

South Florida's underlying karst geology, coupled with its largely subtropical climate and flat topography, contributes to a highly productive aquifer system and extensive hydrologic network of lakes, rivers, springs, and wetlands; all of which are unique in the world (Douglas, 1947). Pressures from an expanding coastal population in the past century led to the extensive modification of South Florida's surficial hydrology in the form of wetland drainage, affecting approximately half of the original Everglades ecosystem, alongside the installation of one thousand miles of dikes, canals, and levees by the Central and South Florida Flood Control Project from 1948–1965 (Ogden & Davis, 1994). While the GEE stretches from the headwaters of the Kissimmee River south of Orlando and runs some 250 miles to the southern extent of the state at the coast of Florida Bay, the Everglades watershed encompasses only the narrow area south of Lake Okeechobee west of the Fort Lauderdale-Miami metropolitan area, forming the ridge and slough freshwater wetland biome characteristic of much of the Everglades. This ecosystem terminates at the southern portion of ENP, one of North America's largest federally protected wilderness areas. Other components of the GEE consist of the Big Cypress National Preserve due east of Naples, and the Water Conservation Areas managed by the SFWMD.

Beyond its role in providing critical habitat and safeguarding South Florida from the impacts of climate change, Everglades restoration has a deep cultural and economic significance for many traditional communities. This region holds a deep meaning for Indigenous tribes like the Seminole and Miccosukee and remains a symbol of American heritage for the Gladesmen of South Florida. Restoring America's Everglades is about saving a critical ecosystem and protecting water resources, enhancing resilience to climate change, and preserving irreplaceable ecological and cultural assets for future generations.

1.4 DISSERTATION OVERVIEW

2 | The Human Dimensions of Everglades Restoration

In this chapter, I describe the results of my qualitative analysis of what I collectively refer to as "the human dimensions of Everglades restoration." I summarize perspectives on ecosystem management and Everglades restoration in narratives collected from archival media, policy documents, meeting transcriptions, and interviews with a diverse stakeholder audience, including 23 agency scientists, environmental advocates, recreators, and industrialists.

Taking a critical approach grounded primarily in political ecology, I examine these qualitative data covering historic trends in wilderness attitudes, the inner workings of restoration from various components of the GEE, and the interconnected policy-making process in South Florida. Of additional interest in this chapter is the role of boundary objects as they facilitate (or hinder) a shared understanding of a dynamic, coupled system. Most importantly, this chapter showcases the results of my socio-ecological model that tracks progress towards holistic restoration across time to inform participatory environmental governance and policymaking in the region.

Figure 1.3 The modern Greater Everglades Ecosystem. WCA = water conservation area (adapted from Schade-Pool & Muller, 2016).

3 | Monitoring South Florida's Boundary Lands: A Hybridized Geospatial Approach

Decades of environmental management across human-dominated and natural ecosystems bordering South Florida's formally protected areas has led to the installation of important conservation areas effectively serving as transitional boundaries for the region's two national parks, national preserve, and wildlife refuges. These wildlife corridors—also referred to as buffer zones throughout this dissertation—are essential to the wider restoration effort. Ecosystem managers understandably focus more on the protected areas given their federal status. Given time and access constraints, rapidly observing multiscale shifts in a landscape's ecology and hydrology amidst restoration efforts often requires remote sensing. This chapter showcases the results and significance of this portion of my research derived from regional planning maps, GIS data obtained from state agencies, and projections for South Florida's climate and demography going to 2050 and beyond.

4 | Towards a Socio-Ecological Model of Restoration

This chapter seeks to answer how an interdisciplinary scholar can more effectively integrate separate domains of knowledge to achieve a novel understanding emerging from the whole, given the complex nature of these phenomena amounts to more than the sum of its parts. To better connect the guiding narratives of Everglades restoration to the effects of its local projects, I present an interdisciplinary workflow that explores the combined advantage of qualitative and geospatial data used in tandem to understand the lived experience of stakeholders and the Everglades itself as an iconic conservation landscape undergoing a regime shift. The integration required to address environmental challenges in the Anthropocene amounts to an exceedingly complex task, and may not always be the best approach. This chapter outlines the research process and synthesis of information derived from my qualitative and quantitative modeling of Everglades restoration. In what I deem to be the total environment, the decomposed social and natural domains first charted out in chapters 2 and 3 now (re)combine to form a composite model that appreciates the smaller signals of restoration's effects on lifeways in South Florida to translate the progress of restoration the GEE more holistically. The chapter concludes with an overview of the design, implementation, and potential uses of the interactive platform-in-development this project directly informs: the StoryMap+.

5 | Conclusion

This chapter closes my dissertation project by first reflecting on this research experience and the role similar investigation should play in assessing the progress of region-scale ecosystem restoration projects. This reflection briefly summarizes the work in its respective theoretical and applied contexts. I also include sections covering the three research questions explored through this project and their condensed answers, the implications for ecosystem management achieved through this work, and conclude with suggestions for future integrative work in this restoration arena. Because this research does not live solely within my dissertation or online, I highlight the significance of this endeavor by virtual of the communities affected most by inequitable ecosystem restoration.

Figure 1.4 My attendance at the WERP Project Delivery Team Meeting in August 2023 (Photo Credit: Mike Elfenbein).

Chapter II | Navigating the Human Dimensions of Everglades Restoration

2.1 INTRODUCTION

In South Florida, ongoing conservation efforts are crucial for maintaining the vitality of the Greater Everglades Ecosystem (GEE). The implementation of restoration projects faces significant challenges, particularly concerning power distribution alongside the interconnected production and use of the underlying narratives driving these initiatives. While conservation buffers separating protected areas from development are vital for replenishing aquifers, maintaining ecological transitions in land use, and mitigating floods, the restoration process affecting these landscapes often neglects the interests and needs of historically marginalized groups. Restoration projects ultimately favor some communities over others. Within the Everglades watershed, diverse stakeholders; including state institutions, non-governmental organizations (NGOs), industries, recreational groups, and indigenous tribes, vie for control over restoration pathways and end objectives. My primary aim for this chapter is to holistically chart the socio-ecological dynamics connecting landscape modification, shifting ecological conditions, and evolving perceptions of wilderness in South Florida. In the process, I develop a scalable and streamlined method for monitoring progress toward restoration, with implications for long-term land management in buffer sites essential for safeguarding the hydrologic resilience and socio-ecological well-being of highly developed coastal areas. By identifying contrasting visions of nature and its resulting policy discourse, an interdisciplinary approach can identify pathways toward restoration of the Florida Everglades.

In this era of resilience-based governance, adaptive management dominates the ecosystem restoration literature while often failing to recognize its underlying social conflicts (Osborne et al., 2021; Ingalls & Stedman, 2016). Environmental decision-making produces interconnected social and ecological outcomes across landscapes frequently understood through narratives, or stories we use to make sense of the natural world. While political ecology and critical geography continue to inform adaptive management, there remains a gap in the implementation of social science within resilience-based planning. State institutions and powerful NGOs have significantly influenced the creation and implementation of regional restoration narratives (Quandt, 2016). Charting out power dynamics embedded into the ecosystem restoration arena from the ground up is a necessary part of bridging those insights reached through critical methods in social sciences to their applied use in adaptive planning. In this project, I follow the call by Ingalls & Stedman (2016) by incorporating resilience-based policy as a response to the resilience framework's lack of engagement with political ecology, one of its primary analytic weaknesses. Similarly, understanding the role of power is difficult under an ecology-driven resilience framework; thus, I attempt a theoretical bridging of these concepts through this investigation.

Political ecology as a critical interdisciplinary framework offers a potential bridge through which both social scientists and practitioners can reconcile the goals of ecosystem restoration with the inequity embedded in South Florida's *cultural landscape*—a geographic area highly modified by human activity (Waterman, 2019). The role social scientists have played in evaluating this conservation conflict is severely lacking compared to studies on the biophysical aspects of this setting. Common with many protected areas in the Global North, establishing Everglades National Park (ENP) required dehumanizing much of the landscape's legacy. While resilience-based research in the region continues, social scientists are well-positioned to contextualize South Florida's evolving environmental and social baselines through a holistic monitoring approach. In this chapter, I explore the implications for perceived naturalness and traditional use of two restoration projects at the edge of the GEE: the East Coast Buffer (ECB), lying closer to the Atlantic Coast; and the Western Everglades Restoration Project (WERP), connected to the Big Cypress Preserve and Gulf Coast. By examining the socio-ecological system underscoring the restoration of Florida's Everglades, this research highlights pathways through which environmental narratives influence the outcomes of ecosystem management. Acknowledging the diverse perspectives and values embedded in the Everglades cultural landscape ensures that restoration efforts benefit all stakeholders and honor the place-based values of current and future generations through culturally considerate adaptive planning. Recognizing those intangible aspects of ecosystem functionality and "the human dimensions" entails adaptive planning that considers historical context alongside the landscape values of evolving gateway communities (i.e., settlements lying near South Florida's protected areas).

The following sections provide a foundation for this investigation by charting growing research on ecosystem restoration, the role of political ecology in policymaking, and contextualizing the GEE. Through the lens of political ecology and utilizing discursive narrative analysis (DNA), this study examines evolving narratives in Everglades restoration as they inform management and conservation planning practices, and aid in conceptualizing "wilderness" under the anthropology of protected areas. I describe the results of my qualitative analysis of what I collectively refer to as "the human dimensions of Everglades restoration." Perspectives on ecosystem management and restoration were collected from archival media, policy documents, meeting transcriptions, and interviews with a diverse stakeholder audience; including 23 agency scientists, environmental advocates, recreators, and industrialists. My project showcases how emerging ideas in conservation structure restoration narratives and their impacts on the ecosystem restoration process in South Florida. In understanding these narratives, I ask: who holds the power to promote and implement conservation initiatives in South Florida?

2.2 LITERATURE REVIEW

Gunderson and Holling (2002) developed prominent ideas penetrating multiple research domains such as *resiliency* and *panarchy* following years of fieldwork and accompanying studies on ecological dynamics at the University of Florida and working in ENP, respectively. As they define it, resiliency refers to the capacity of an ecosystem or environmental system to absorb disturbances or stresses (such as natural disasters, climate change, or human activities) while maintaining its essential structure, function, and processes (Gunderson & Holling, 2002). Panarchy is a conceptual framework that describes the dynamic and interconnected nature of complex adaptive systems across different scales of time and space. In environmental management, panarchy emphasizes the idea that systems are not static but are continually evolving through adaptive cycles of growth, accumulation, restructuring, and renewal. This concept helps in understanding how ecological, social, and economic systems interact and influence each other, promoting a holistic approach to managing and sustaining ecosystems (Gunderson & Holling, 2002; Holling, 2004).

Resilience theory and its heuristic vision for the human-affected ecosystems portrayed as complex and adaptive socio-ecological systems influence many contemporary explorations into the applied role resilience in various forms plays in theory building and environmental management (Wakefield, 2017; Gunderson et al., 2018). In relating the resilience framework to complex adaptive systems, Gunderson and Holling (2002) draw from conventional domains of ecology, economics, and social systems summarizing as four phases: exploitation (*r*), conservation (*K*), release (Ω), and reorganization (α); a heuristic commonly referred to as the panarchic loop. Phases of the adaptive cycle are depicted along two axes—capital and connectedness—although adding resilience as a third axis makes the cycle truly adaptive when describing complex systems. Novel elements emerge in the "forward loop" (*r* and *K*) and seed the opportunity to learn from past disturbances in the system amidst the "back loop" (Ω and α), increasing overall resilience through experimentation and cycles of memory (Holling, 2004).

Resilience-based governance in the context of adaptive environmental management refers to a framework that aims to enhance the capacity of ecological and social systems to withstand and recover from disturbances while continuing to provide essential services (Horne, 2017). This approach recognizes the dynamic, complex, and interconnected nature of ecosystems and the human societies that depend on them. For restoration projects in the Global North, Florida's Everglades offers a rich platform for political ecological research while facilitating a multi-scalar investigation into landscape resiliency. Adaptive management broadly involves iterative decision-making, where policies and practices are continuously improved based on the outcomes of previous actions (Garmestani & Benson, 2013). This approach encourages *experimentation* and *learning* from both successes and failures—a critical consideration for Everglades restoration considering the unprecedented scale of its activities (Gunderson et al., 2012). To reinforce this for gateway communities affected by restoration, the data infrastructure must be in place to enable the continuous monitoring of environmental and social conditions, as these are used to assess the effectiveness of management actions and adjust strategies accordingly.

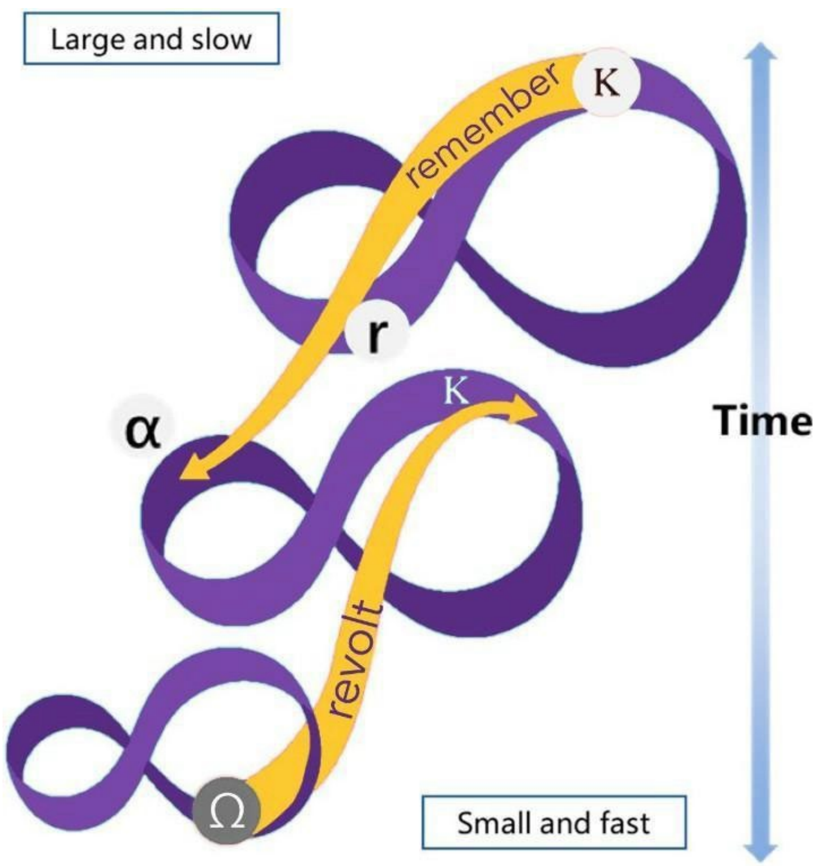


Figure 2.2 Cycle of Adaptive Change stylized in the "Panarchic Loop" (redrawn from Lieu et al., 2023). All four phases of the cycle are connected through the front loop ($r \rightarrow K$) or back loop ($\Omega \rightarrow \alpha$).

The evolving Anthropocene discourse suggests a recent paradigm shift in how we approach ecosystem restoration and environmental governance broadly. Wakefield (2017) questions whether our entry into the Anthropocene back loop manifests as a "tragedy to navigate." Instead, in this uncertain terrain lies "the possibility for a practical orientation with the Anthropocene" alongside the abandonment of other dated frameworks (2017, p. 1). Embracing this uncertainty in approaching our relationship with the more-than-natural world has consequences for the role of novelty as social scientists continue to chart coupled human-natural systems and their future possibilities. These opportunities for exploring new regimes provide a potential turn from less sustainable trajectories in rapidly developing regions. In escaping what they deem the "rigidity trap," Gunderson et al. (2019) more recently assert that the legal and organizational structures in place limit the type of experimental governance required to resolve conflicts in socio-ecological systems like the GEE. As opposed to avoidable surprises, crises can increase our overall adaptive capacity when understood properly with prior institutional structures and knowledge informing the resiliency of the greater system.

Following Escobar's definition, political ecology broadly studies biocultural structures—those existing and possible—as determined by the positionality of "actors, technologies, and practices" at sites of human:nature interaction (1999, p. 13). A systems approach to restoration has yet to successfully implement political ecology to highlight equitable pathways for of the total environment. Understanding how ecosystems return to a prior state or functionally improve their societal benefits is a complex but necessary endeavor to foster resilient communities (Brosius, 2006; Gruppuso, 2006; Ogden, 2008a; Bliss & Fischer, 2011; Kiik, 2019). Political ecology and adaptive management are interconnected in their approaches to addressing environmental issues, albeit from different angles. Political ecology focuses on the power dynamics, social structures, and political contexts that influence environmental outcomes, while adaptive management emphasizes learning and flexibility in managing ecological systems. Within critical humanist research on environmental conflicts, political ecology rarely examines the interplay among powerful, private landowners affected by restoration activities in the Global North and the agencies charged with leading these conservation initiatives. Investigations in political ecology can trace beliefs and tethered perceptions of the natural and social worlds to their roots in most cases. This exploration showcases how historical processes influence the trajectory of socio-ecological systems beyond a romanticized version of a nation's cultural and environmental history, something often accomplished via the homogenization of landscapes (Vacarro et al., 2013). In this way, a country asserts its administrative reach over territory by forging an "uninhabited," artificial origin. For Florida's Everglades, the evolving story of its relationship with human society remains ongoing. Communities continue to understand and adjust to the long-term impacts wrought by restoration projects contributing to regime shifts as conservation priorities evolve.

My critical approach to gathering and assessing the driving narratives of Everglades restoration juxtaposes against the generic mission of current ecosystem restoration efforts. This top-down examination of policies and narratives is directed at identifying pathways toward an idealized environmental baseline, something that is further clouded by competing (and imperfect) narratives of the past (Ogden, 2008a; Atisa, 2020; Bixler, 2021). In envisioning a more holistic and equitable form of ecosystem management that acknowledges the deep social ties to human-modified landscapes, my approach augments and could be argued to *disrupt* the formal knowledge production process. I accomplish this by illuminating how the landscape's human legacy drives the creation and utilization of environmental narratives. Addressing this research gap also continues earlier work by Ogden (2008b) and Cattelino (2015) that critically questions the role of people in South Florida's wilderness areas. As I seek to expand upon this role in the UN Decade on Ecosystem Restoration, my research considers how to question and reconcile with 170 years of state policy and other forms of institutional "work to make the Everglades seem like a wilderness without people," (2015, p. 241; UNEP, 2022). Social scientists look at sustainability transitions of this scale as a form of boundary maintenance in cases where narratives on marginalized groups are themselves forged through the dialogue and decision-making of powerful actors and state entities. Jessica Cattelino, a prominent sociologist examining the production of social relationships in the GEE remarks that "it takes work to make the Everglades seem like a wilderness without people—cultural work, conceptual work, physical work—and to render it an uninhabited swamp," or in this case, a tainted ecological space where "people should never have lived," despite clearly documented permissions from Miami-Dade County to the contrary (Fortin, 2002, Cattelino, 2015).

Adaptive management in ecosystem restoration literature fails to connect the preferred version of nature with the historically unquestioned legitimacy (or power) of South Florida's water management interests. This disconnect undermines the eco-centric values that are supposed to drive the core message of Everglades restoration today (Garvoille, 2013; Amorino, 2020). Reconciling these competing narratives on preferred versions of nature offers one equitable pathway towards securing a resilient socio-ecological future in South Florida. In doing so, a reconciliation of narratives charted through discursive narrative analysis identifies novel associations of environmental knowledge from diverse stakeholder perspectives. The reconciliation here describes how stakeholders and other community members utilize environmental narratives to support policy action or condemn the mission of powerful interest groups, including environmental NGOs and state/federal agencies. In this context, true knowledge co-production entails "iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce . . . pathways towards a sustainable future" (Norström et al. 2020, p. 182). The *ecosystem* and related concepts continue rendering through formal, scientific knowledge production (Zweig & Kitchens, 2010; Knox, 2013). Without a critical humanist discourse, relying on overwhelmed environmental planners and other decision-makers to address complex socio-ecological dynamics often leads to "new plan syndrome" (Brody, 2008), where plans are adopted without clear measures of progress.

For my project, *power* in the context of ecosystem restoration can be defined as a recognized measure of influence over social and environmental outcomes that result from realized conservation initiatives. This parallels the conceptualization of power offered by Ribot and Peluso (2003) as "the capacity of some actors to affect the practices and ideas of others" (p. 156). Put differently, power is amorphous and usually derivative from people, whereby the powerful "institutions and practices can cause people to act in certain ways without any apparent coercion" (Ribot & Peluso, 2003: 156). While power is a central theme in political ecology, it does not usually exist as an objective, discrete variable, although its study is paramount to understanding the nuanced and (dis)connected effects on environmental policy and the resulting well-being of both human and non-human communities. Absent this explicit conceptualization of power, it is difficult to trace at the institutional level how policymakers and ecosystem managers legitimize knowledge and their authority through creating narratives on environmental change (Bixler, 2021). Garvoille (2013) echoes this sentiment in declaring that anthropologists must document more critically the unequal benefits accrued to stakeholders in restoration projects given the local contingency of power and its many claims to nature—all of which are historically produced.

In social science, modeling takes on a variety of forms. However, many efforts contend with purely numerical models that often fail to capture the subtleties of real-world phenomena any better than textual or qualitative descriptions in most cases. The rigid mathematical foundation often employed in natural sciences to elucidate mechanistic behavior is limited in its explanatory role for social science when looking at emergent phenomena and other non-linear behavior (i.e., 'surprises'). As an example in socio-ecological systems, Mathias et al. (2020) emphasize the role of social and ecological "tipping points" as features that explain otherwise contradictory transition pathways in environmental governance. Social tipping points here describe the "perception of alarming ecological states," which drives actors to collectively respond to meaningful perturbations in the socio-ecological system (e.g., algal blooms following a weather event leading to legislation that prevents nutrient loading), thereby resulting in a regime change at scale. Other challenges in studies on human-environment interactions stem predominantly from scale-related issues, as well as from dependence on static, overly complex datasets that can lack meaningful interpretation in the context of multi-faceted, historically contingent conditions in complex adaptive systems like the GEE. When prioritizing different modes of modeling, Dowding (2018) argues that the decision for formal scientific models is seldom worth their effort when we prioritize their predictive potential, as the outcomes leave us with "boundaries of expectation" of the actual world. Narratives, as a more intuitive way to understand our observations, are typically easier to collect, being sourced from archival and interview data, and offer more dynamism given the "fuzzier" nature of stories. I attempt to identify these emergent pathways towards holistic ecosystem restoration through an examination of significant changes in community participation and the resulting governance structure of the GEE.

Guiding frameworks such as resiliency, panarchy, adaptive management, and other modeling approaches in critical social sciences do not solely rely on their textual contribution to conservation practices. The production of maps, figures, and planning heuristics which make abstract representations of complex socio-ecological systems does not occur in a cultural vacuum. Even when state and federal agencies appear to fail in their stewardship roles, pre-existing associations of power (the status quo in South Florida) reaffirms their authority to speak for the landscape primarily. In moving towards knowledge co-production, researchers in sustainability planning characterize presentation documents and other abstract tools–including panarchy–as "boundary objects" (Franco-Torres et al., 2020). In this project, boundary objects describe ambiguous information structures (abstract concepts like "ecosystem services" or models) that enable fluid communication across diverse institutional logics. These simultaneously respond to external stress or narratives through integration into understanding this stress, while allowing translation to a version suited for local use. While they are critical to bridge meaning across various institutional logics, boundary objects are necessarily incomplete despite their importance and intentional design. Franco-Torres et al. (2020) describe this boundary work as "the constructive effort to support communication across fences that separate communities" (p. 35).

Ogden (2008a) critically addresses this tendency for environmental science embedded in the interests of institutions to effectively legitimatize State power in the (not so) distant past. Guided by political ecology, intentional boundary objects can facilitate an adaptive management approach if restoration practitioners place greater emphasis on the role of knowledge production. As I explore further in Chapter 4, some of the more effective boundary objects in the ecosystem restoration arsenal include guided natural tours of affected lands alongside other immersive experiences afforded by Story Maps and the digital humanities more broadly (Cope et al., 2018; El Khatib & Schaeben, 2020; Roth, 2021; Gambrill et al., 2023). This implies incorporating not only a diversity of regional voices but also *how* and the extent to which these perspectives shift during the ecosystem restoration process through boundary work. Because reconciling competing narratives of environmental restoration is an active social process in policymaking, boundary objects, including these data visualizations, present opportunities to foster adaptive management as their visual interpretation alone could serve as a site for the production of knowledge (Drucker, 2020).

When human intervention in natural areas contributes to establishing novel ecosystem states, a primary concern in examining environmental governance asks: for whom are these places conserved, and from whom are they protected? Brosius (2006) suggests anthropologists are well-positioned to ask these questions because of their critical ability to recognize "not only the human impact on the environment but also how that environment is constructed, represented, claimed, and contested" (p. 683). The benefit of political ecology's "disruption" of conventional approaches to management extends from its ability to connect policymaking with value-laden assessments of the socio-ecological outcomes achieved in association with protected areas. According to geographer Paul Robbins (2016), political ecology's disruption only becomes legitimate if it "wears the mask of practice" capable of laying the foundation for lasting solutions. Addressing the power dynamics that influence ecosystem restoration and its underlying processes of environmental claims-making, therefore, relies on carefully charting out the fundamental beliefs and practices observed in iconic conservation landscapes by powerful actors. Garvoille (2013) outlines the concept of "second nature" as a concept that encompasses the ways in which human interventions and cultural practices shape and modify natural environments. I utilize this same designation in my primary research question addressed in this chapter (RQ1) because it reflects the intertwined relationship between human activities and the natural world, illustrating how ecological restoration efforts are influenced by social, cultural, and historical contexts.

Environmental scientists in the Global North often encounter difficulty applying critical social science perspectives in their "own backyards." This inspired many scholars of political ecology to advise restoration practitioners to reconcile with their "comfortable but perhaps superficial or biased familiarity with cultural and ecological patterns" essential to achieve lasting success for sustainable land management and outright ecosystem restoration (Bliss & Fisher, 2011, p. 141). Understanding the effects of *environmental amnesia* is key to tracing the underlying pressures and motivations inherent in conservation conflicts in landscapes characterized by deeply rooted cultural positions and claims (Kahn, 2002; Garvoille, 2013). Environmental amnesia describes the tendency for younger generations to slowly lose the association of environmental phenomena with place over time; policymakers effectively seem to "forget" the past conditions absent mechanisms for remembering. Often associated with what ecologists call shifting baseline syndrome, psychologist Kahn (2002) coined "environmental generational amnesia" to describe the evolving expectation of ecological conditions shifting on human timescales to the detriment of our long-term awareness of how our landscapes should appear and function. This perspective on environmentally contested spaces holds that large-scale reclamation projects in legacy landscapes— including the Florida Everglades—become framed as beneficial and even *virtuous* endeavors despite the obvious, uneven distribution of benefits for the wider community. In most instances, decaying social memory undermines the deep cultural significance of these contested spaces with newly formed narratives serving state or corporate agricultural interests, effectively passing such extensive interventions with the land off as needed (if not destined) "deliveries" from uninhabited wastelands (Grunwald, 2007; Grupposo, 2018).

2.3 BACKGROUND

Because South Florida serves as the conduit for recharge of the Biscayne Aquifer, over five million Floridians and an abundance of non-human life rely on freshwater delivery south of Lake Okeechobee (Grunwald, 2008). As restoration actors reconcile competing narratives in the GEE, the Comprehensive Everglades Restoration Plan (CERP) projects continue taking form across the landscape. Furthermore, the inclusion of communities historically denied participation during the conservation planning process is necessary to achieve more equitable social and ecological outcomes. As recognition of the greater Everglades ecosystem's deterioration became widespread in the 1980s, several grassroots movements and accompanying legislature emerged in response to historic droughts, fires, seagrass die-offs, and the proliferation of invasives throughout the GEE. South Florida comprises landscapes venerated and contested by the state institutions responsible for managing the environment, NGOs, the agricultural and mining industries, the recreational community, and two federally recognized tribes (The Miccosukee and Seminoles Tribes of Florida)—among generations of private landowners. Grunwald (2007) infamously described this restoration arena as "the politics of paradise." Anthropologists and other social scientists have criticized Everglades restoration broadly due to the unequal benefits of its activities, its tendency to reinforce pre-existing power dynamics, and its general failure to achieve the ecological outcomes promised (Ogden, 2008a; Ogden, 2008b; Garvoille, 2013; Cattelino, 2015; Amorino; 2020; Bixler, 2021). This section covers key events leading to the formation of policies and other ideas important to the social background of ecosystem restoration.

Along the policy-conservation interface, traditional ecological knowledge (TEK) embodies ways of understanding and relating to the landscape beyond the positivist scientific tradition prominent in contemporary environmental management (Berkes et al., 2000; US FWS, 2011). Because this information remains personal and often belongs to historically marginalized groups, collecting field data in the form of nuanced environmental narratives is a critical step in understanding not only which actors command the authority to introduce novel ecosystem states (i.e., what I refer to as a "second nature"), but for which social and historical reasons community members hold these beliefs. As widespread awareness of shifting environmental changes gave way to pressures to protect what was left of the GEE, the Florida Everglades Forever Act of 1994 was ratified at the onset of ecosystem restoration at the state level (Grunwald, 2007). This act formally mandated the reduction of phosphorus levels entering the Everglades in addition to outlining a framework for funding and implementing water quality improvement projects (Gunderson et al., 2018). Conservation in South Florida became most galvanized when Congress authorized the CERP in 2000 to envision the unprecedented scale of planning, constructing, and tying together more than 60 projects in the region (SFWMD, 2019). The CERP is a federal-state partnership aimed at restoring, protecting, and preserving the water resources of central and southern Florida, including the traditional interior region of the Everglades. Additionally, the Central Everglades Planning Project (CEPP) was approved in 2014 to accelerate the restoration of the Central Everglades by improving water flow and habitat connectivity. These policies collectively represent significant steps toward addressing the ecological challenges and ensuring the long-term sustainability of the Everglades, although ongoing criticism complicates much of the original unifying vision of CERP (Grunwald, 2007; Gunderson et al., 2017; Atisa, 2020).

The conceptualization of wilderness also bears significant consequences for the lived experience of stakeholders in the GEE today as this wilderness rhetoric continues to evolve. The

1964 Wilderness Act defines it as:

> An area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. [It is a place] without permanent improvements or human habitation, [absent] the imprint of man's work. (Wilderness Act, 16 U.S.C. § 1131-1136, 1964).

Wetland drainage and its realized consequences across the contiguous 48 states renewed the wilderness concept as places not previously considered "sublime"; for example, ENP was established in 1947 on the merit of its biodiversity as opposed to the breath-taking geology of the original western parks (Ogden, 2008b). Wilderness with a capital 'W' embodies the federal designation for many stakeholders in the GEE today and oftentimes, more protection and regulation are counter to the original mission of wilderness. Even for those regions of South Florida where many claim true wilderness remains a challenge in this definition emerges considering the wider American notion of access to protected areas: modern *wilderness* as a concept centers on its role as a recreational, aesthetic, and even spiritual resource when the Everglades found protection in the environmentalist spirit of biological uniqueness (Wilhelm, 2013). Ultimately, Nash (2014) resolves that the passive allowance of wilderness to define itself may better structure its consequences for policy. He posits that its historical temptations lead us "to accept as wilderness those places people call wilderness" because "it is not so much what wilderness is but what men *think* it is" (Nash, 2014: p. 5).

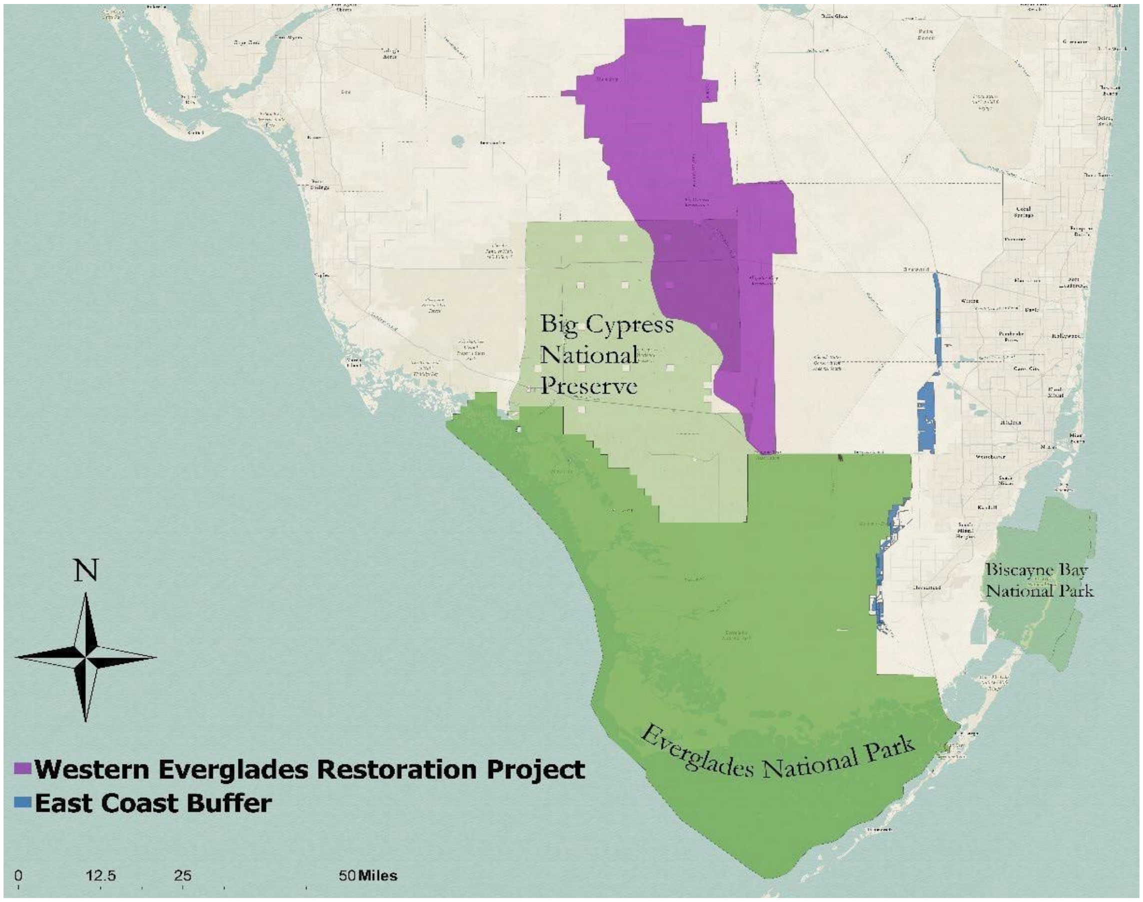


Figure 2.3 Boundary Lands & Protected Areas in South Florida. Drawn using spatial data provided by the National Park Service (2019) and South Florida Water Management (2022).

Everglades restoration broadly seeks to return much of the region's hydrology and ecology to its primeval condition. South Florida's underlying karst geology, subtropical climate, and flat topography result in a highly productive aquifer system. This unique hydrologic network of lakes, rivers, springs, and wetlands is integral to over five million in South Florida and many iconic species of birds, reptiles, and mammals found nowhere else (Ogden & Davis, 1994). This landscape is globally significant because Florida's Everglades are the most extensive subtropical wetland in North America, with recognition as a RAMSAR Wetland of International Importance and a UN Biosphere Reserve, as well as the protection it receives as a national park under the United States Department of the Interior (Keddy et al., 2009). As Davis and Arsenault (2005) document, pressures from an expanding coastal population in the past century led to the extensive modification of South Florida's surficial hydrology to accommodate the needs of agricultural and urban development. This manifested most clearly as wetland drainage, affecting approximately half of the original GEE, alongside the installation of one thousand miles of dikes, canals, and levees via the Central and

South Florida Flood Control Project from 1948–1965 (Davis & Arsenault, 2005). Because the regimes of ecology and hydrology in South Florida occur on scales exceeding generational memory or even human lifespans for some variables, understanding where and how “natural” environmental conditions compare to baseline or social “memory” continues to be challenging for a region undergoing a massive demographic shift and the accompanying growth. This also bears important implications for planning as access to wetlands and their resulting biophilic value to community members can influence how and where they are restored in urban contexts (Villagra et al., 2024). CERP recognized from its onset that communities across the GEE will continue living in a heavily managed system. Because periods of calm weather create a perception of lower risk, urban development in areas prone to storms or flooding often encounters little resistance (Chen et al., 2016; Wakefield, 2020). This occurs because there are no social mechanisms to remember and internalize serious disturbances, such as tropical storms, algal blooms, infrastructure failures due to disasters, and the proliferation of invasive species such as pythons and Melaleuca trees. Common with the existential threat introduced by climate change to Earth systems and societies, the global mandate to restore human-modified ecosystems, too, could be framed as a *wicked problem*. These describe complex "interdependent, unstructured, and pervasive” conflicts in social policy that introduce serious ethical dilemmas for actors of diverging worldviews (Franco-Torres, 2019, p. 34).

Despite the clear, uneven distribution of benefits within the wider region, humanist literature on ecosystem restoration projects criticizes powerful actors for portraying them as helpful and necessary environmental interventions (Vileisis, 1997; Brosius, 2006; Gruppuso, 2006). Through the research presented in this chapter, I examine stakeholders’ perspectives on the source and nature of the power used by restoration practitioners (local decision-makers, SFWMD, and the Army Corps) to transform landscapes and ultimately determine conservation outcomes. This approach allows me to shed light on the underlying power dynamics in contested, iconic conservation landscapes like the GEE (Ogden, 2008a; Garvoille, 2013; Amorino; 2020; Bixler, 2021). The timeline below (Figure 2.3) highlights major events and policies leading to the current era of Everglades restoration extracted from policy documents, research articles, and seminal texts (Douglas, 1947; Grunwald, 2007).

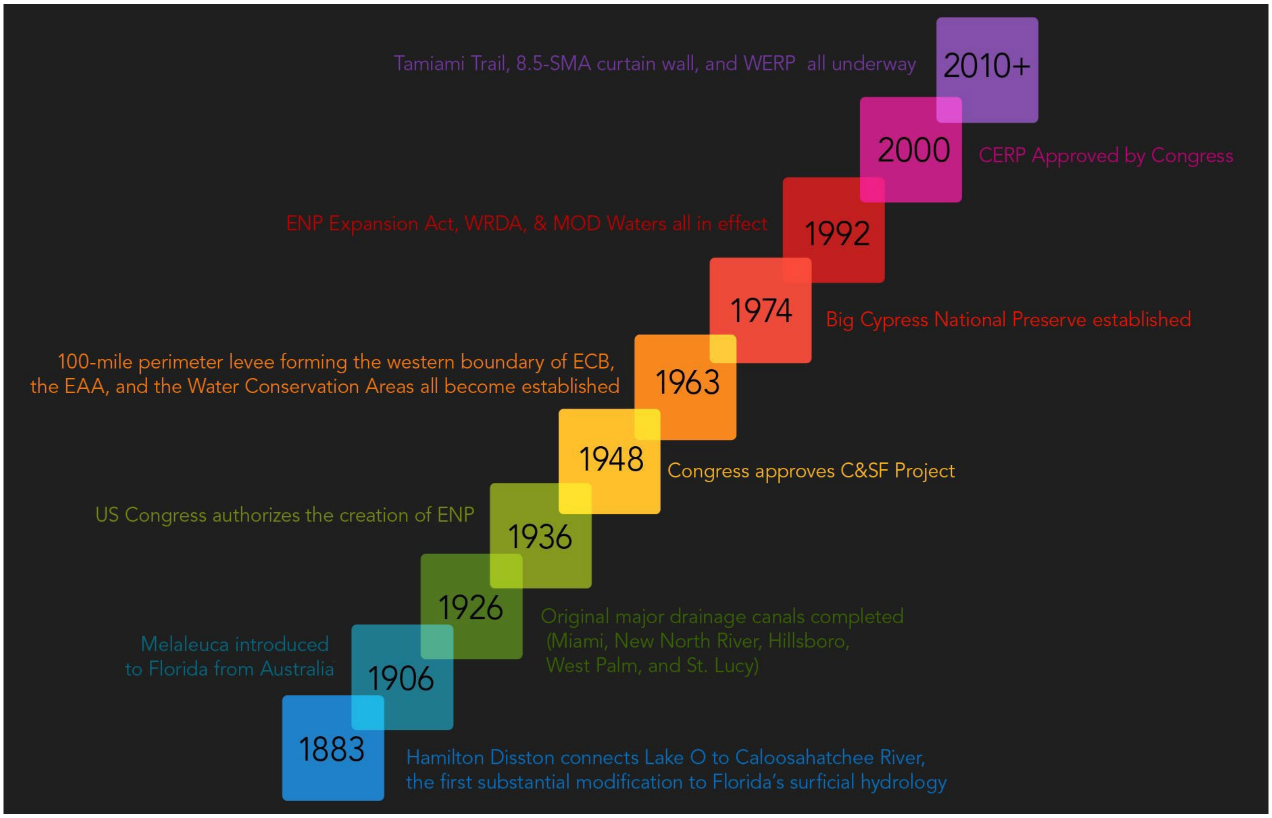


Figure 2.3.1 From draining the swamp to restoring the flow: a timeline of events in the Everglades' recent history as it relates to the major policies, projects, and other landscape interventions discussed in this chapter. This timeline helps temporally organize a response to RQ1 in the Discussion (Section 2.6).

2.4 METHODOLOGY

2.4.1. *My approach to gathering narratives on restoration*

The current model framework I describe in this chapter adopts a political-ecological take on Anthropocene conservation capable of integrating the place-based significance of restoration activities. Through the analysis of qualitative data collected from agency meetings, public comment forums, archival records, and semi-structured interviews, qualitative researchers can observe emerging themes that help contextualize community members' deep associations with geographic spaces. This is important because the *places* imagined and interacted with through the production of local environmental narratives provide insight into a stakeholder's attachment to the place. Due to this focus on the underlying social dynamics of actors and their positionality in a landscape, my primary research question asks: who has (and historically held) the power to promote and implement conservation initiatives to create a "second nature" in the Everglades? (RQ1). Supporting inquiries include:

A) How do different stakeholder perspectives on the management of protected areas by agencies in South Florida affect ecosystem restoration goals?

B) What boundary objects facilitate the co-production of knowledge by diverse stakeholders navigating the Anthropocene "back loop?"

	Nature for itself	*Nature despite people*	*Nature for people*	*People and Nature*
Era	1960–1970	1980–1990	2000–2005	2010+
Key Concepts	Species, Wilderness, Protected Areas	Extinction, threatened species, habitat loss, pollution	Ecosystems approach, economic values	Resilience, climate change, socio-ecological systems
Scientific Focus	Species, Habitats, Wildlife ecology	Population biology, natural resource management	Ecosystem functions, environmental economics	Interdisciplinary social and ecological sciences
Boundary Objects	Maps, linear graphs, wilderness designation	Systems framework, pristine nature	Ecosystem services, ecological baselines, sustainability	Panarchy, cultural landscape, Story Maps, mixed-reality experiences

Table 2.4.1 Boundary objects explored in this research framed around conservation eras. While the boundary objects mentioned have associated time period due to the contemporary technology and theory, older forms continue onward (adapted from Sanborn & Jung, 2021).

2.4.2 *Data Collection & Analysis: Pilot Data*

I first conducted thorough coding and analysis of relevant documents to identify the main issues related to Everglades restoration and to determine the primary stakeholders involved. With the help of East Carolina University's *One Search* database, I queried relevant news articles concerning the ECB project emphasizing the Pennsuco Wetlands and the 8.5 Square-Mile Area (SMA), in particular. The ECB and WERP represent active restoration projects (albeit at different points in their timelines) taking place in "boundary lands"— sites affected by Everglades restoration that have consequences for human communities (and vice-versa) based on their proximity to developed areas. These two components of the ECB represent key boundary lands whose debates were foundational to my investigation into the local significance of Everglades restoration. The Pennsuco Wetlands is the largest component of the ECB separating South Florida's built environment from Water Conservation Area 3B. Further south, ongoing flooding in the 8.5 SMA community adjacent to ENP has consumed three decades of debate over land acquisition and project planning processes to ensure flood mitigation efforts and vegetation treatment meet conservation goals in the region (SWFMD, 2008).

My query resulted in a collection of 18 popular news articles released from 1985–2021 that coincide with the planning of ECB restoration sites. In addition to these data, I incorporated two public comment transcriptions from SFWMD governing board meetings in December 2021 and March 2022. After coding these documents for recurrent themes central to restoration rhetoric, several themes emerged with four aligning with insights derived during background investigation on South Florida's legacy of ecosystem restoration. The thematic hierarchy of restoration themes was visualized as a dendrogram using NVivo's 12 Cluster Analysis toolset to Pearson correlation (Lumivero, Denver, USA). Cluster analysis helps to organize important restoration themes by tiers of relative significance and coding connectivity (Macia, 2015). These primary themes included wilderness values, property rights, uncertainty (as it relates to restoration planning), and views on "natural" landscapes. For my pilot study (ECU IRB approval 19-002099), I also conducted 11 semi-structured interviews in the summer and fall of 2021 with individuals I recruited based on their contributions in the public comment sessions concerning the 8.5 SMA at SFWMD Governing Board meetings from 2020 and 2021.

My interview guide addressed participants' background in Everglades restoration, as well as their views on institutional responses to system shocks, perceptions of resilience and wilderness, land acquisition, the impact of environmental amnesia, and their overall motivation. All interviews were conducted at public locations chosen by the participants. After audio recording interviews and uploading them into an online transcription service, I proofread and coded all transcripts derived from these semi-structured interviews in NVivo through the spring of 2022. Coding summary metrics in NVivo highlighted several emergent themes that aligned with my archival document analysis and helped to simplify the context of new interview guides. In this investigation, I define "themes" as semantic patterns that emerge from the data during analysis (Guest et al, 2012). Compared with narratives, these elements support the wider story being told, whereas narratives are composed of multiple themes and are typically structured as a sequence of events (Clarke, 2005). Altogether, findings from my pilot study were central to adjusting the scope of my research questions to ensure they were not too broad to elicit meaningful responses. For instance, I added the subset of two questions concluding Section 2.4.1 when it became clear that management and the fluid use of "resilience" still dominated much of the discourse in restoration today (Gunderson & Holling, 2002; Zweig & Kitchens, 2010; Garvoille, 2013; Atisa, 2020). I also found it helpful to ground my socio-ecological systems (SES) approach by ensuring I did not omit key aspects of the Everglades SES from my interview questions when creating new interview guides based on stakeholder feedback.

These initial conversations guided the focus of my remaining investigation through exploratory visualization in NVivo as well as augmented the guides for each stakeholder cohort (n = 5) based on recommendations offered by my research participants. In this way, the themes of restoration as understood by stakeholders organize themselves by their tier of importance and relative similarity as it derives from my overlapping and connecting coding schemes (Figure 2.4), I frame the results of my qualitative analysis in NVivo around four primary narratives and their connected themes based on 23 semi-structured interviews. I address my primary research question concerning the utilization of power to promote conservation initiatives thematically as understood by stakeholders under four dominant narratives of restoration.

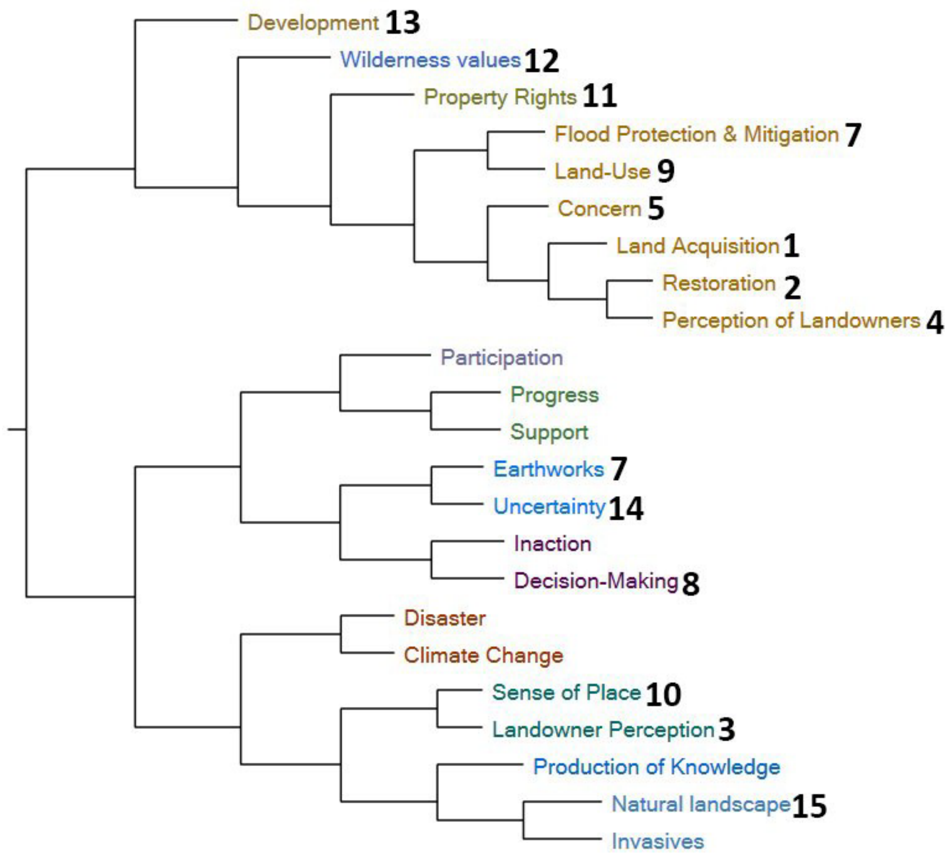


Figure 2.4. Dendrogram visualizing the hierarchical organization of queried restoration themes created in NVivo 12. Theme locations indicate association while bold numbers enumerate theme frequency from articles and transcriptions.

2.4.3 *Data Collection & Analysis: Semi-structured interviews*

Gathering narratives on Everglades restoration is an in-depth process driven by long-form dialogue between individuals with personal and professional ties to its greater ecosystem, and therefore, biased sampling is necessary to conduct this research (Bernard, 2011). From my pilot study points of contact, snowball sampling allowed me to recruit 11 additional restoration stakeholders actively contributing to public discussions on current restoration projects. The rhetoric I observed during public forums influenced other narratives of interest explored through this research as well as confirmed the prominence of themes explored during my pilot study analysis. After attending several meetings virtually about current CERP projects, I contacted all prospective interview participants via email, organizational phone number, or using social media (Facebook or Twitter). As before, I allowed research participants to determine their stakeholder identity by describing how they perceived their role in terms of a career or an enduring relationship with the landscape. While the eleven participants I initially interviewed included restoration practitioners (e.g., individuals associated with conducting science at state agencies or academic institutions), environmental policy advocates, and recreators, the additional stakeholders added perspectives from planning and industry, including mining and agriculture While this was a subjective process given some stakeholders identified as belonging to two cohorts, I ultimately placed them where I determined their experience and contribution best warranted.

The topics discussed in these interviews again included their background and involvement in conservation, how they view institutional responses to system shocks such as hurricanes or fires, their perceived meaning of resilience and wilderness, their views on land acquisition for conservation, the role of environmental amnesia, and ongoing motivation for their role in Everglades restoration. Interviews were audio recorded and conducted in person at their preferred sites where possible from July–November 2022, although some interviews were conducted virtually (teleconference or phone call) to suit the needs of research participants. Interview guides remained similar among the stakeholder groups to ensure proper comparison across their roles and the narratives gathered, although some questions were adjusted to better suit specific stakeholder groups (e.g., landowners and scientists understand the land differently). Table 2.4.2 shows the total number of interviewees from each stakeholder cohort, including agency scientists, environmental advocates, private landowners, industry and planning representatives, and recreators.

Stakeholder Cohort	Code	Participant Count
Recreator	RE*x*	4
Advocacy & Policy	AP*x*	5
Landowner	LO*x*	4
Agency Scientist	AS*x*	6
Industry & Planning	IP*x*	3

Table 2.4.2 Stakeholder cohort summary. Codes are utilized when quoting specific participants.

Finally, I incorporated one transcription for further coding extracted again from a public comment session for the October 2022 meeting of the South Florida Ecosystem Restoration Task Force (SFERTF) to continue tracking restoration progress for the duration of my analyses (EvergladesRestoration.gov, 2022). As restoration priorities shifted since I began my preliminary observations, I shifted my focus from single-instance news media articles and individual conversations towards the public meeting forum as a site for producing meaning in the GEE. Required by law in the State of Florida, these meetings serve as a real-life “stage” for actors vying for participation and control in the restoration arena, thus their underlying dynamics are key to outline alongside a critical interpretation of stakeholder-specific narratives. After observing this shift in prioritized restoration projects, I began pursuing the next phase of my research which examines how competing restoration narratives could be compared and visualized in the context of WERP.

Using the heuristic organization developed during my pilot study, all new interview data were coded and analyzed in NVivo using discursive narrative analysis, a component of grounded theory in social science (Strauss & Corbin, 1998; Taylor & Littleton, 2006; Bixler, 2021). In qualitative research, discursive narrative analysis is an approach that focuses on how narratives—the stories we use to understand the world around us through conversation or text—are constructed and used to make sense of social phenomena. This method views narratives not just as storytelling, but as social practices through which individuals or groups construct meanings, identities, and social realities. It also shows how speakers' biographical accounts are shaped and constrained by the meanings that prevail within the larger society and effectively inform a stakeholder’s identity (Chamaz, 2006; Taylor & Littleton, 2006). In this research, discursive narrative analysis explores how language and discourse shape and are shaped by power dynamics, social structures, and cultural norms (Bixler, 2021). While many themes emerged during my analysis, four narratives appeared to be the most relevant across interviews: access, decision-making, environmental amnesia, and knowledge production.

NVivo assisted my final analysis of these data by organizing the narratives on a conceptual plane using the relative strength of association between narratives and research participants based on coding summary metrics, including the word count and coding similarity for major themes. I juxtaposed the priorities of stakeholder cohorts using the Plotly 2.18.0 package for data visualization with Python. To visualize the relative weight of narratives as a reflection of stakeholder emphasis, I used Plotly to generate a ternary plot with wordcount data from my coding analysis with a priority on recreators, agency scientists, and policymakers due to their historic polarity on most Everglades issues (Grunwald, 2007; Ogden, 2008a); although, the colors indicate the narratives of primary concern for all five stakeholder cohorts as I found still important to visually highlight the narrative trends of all stakeholder groups. This data visualization technique primarily comes from geoscientific research, yet ternary plots in social science are increasingly present in demographic studies (Schöley, 2021). Visualizations like ternary plots can help identify the differences and similarities in attitudes among the three main stakeholder cohorts. Understanding this breakdown proved vital for deciding which narratives and their subthemes mattered most for this stage of my qualitative data analysis and subsequent visualizations.

2.5 RESULTS

Charting the trajectory of the socio-ecological system in terms of its progress toward fundamental social or environmental goals requires a holistic perspective of the total environment and its actors. Enabling traditional communities a means to compete with powerful institutions such as the Everglades Foundation, which have been associated with using their political power and funding to lead the primary narratives of restoration under a significant bias for the built environment, or the National Park Conservation Association, a group that continually reinforces the exclusionary model of fortress conservation, remains an ongoing component of this mission (Garvoille, 2013; pers. comm, 2021). The table below (Table 2.5.1) summarizes major narratives in restoration based on the analysis of all interview data. Discursive narrative analysis guided by the summary products produced in NVivo, including the dendrogram and ternary plot, helped me determine the most compelling and contentious narratives of Everglades restoration based on their community association and relevance in the restoration arena over the past two decades. These products also helped me generate the timeline table (Table 2.5.2.), which contextualizes many of the interview participants' commentaries from the top-down.

While the early analysis of archival records, meeting transcriptions, and newspaper articles afforded me a regional perspective on the primary issues in restoration, discursive narrative analysis allowed me to triangulate the observed themes and narratives of restoration within this deeper social context. This often revealed that various actors in Everglades restoration may hold similar views but for different, often ahistorical reasons. For instance, both agency scientists and policy representatives are concerned with the barrier of environmental amnesia and issues presented by shifting baselines in the GEE, yet the means to pass down information via networks of TEK was rarely emphasized by those engaged in the formal production of scientific knowledge at state agencies such as SFWMD or the Florida Fish and Wildlife Commission (FWC).

Narrative	Primary Stakeholder	Concern	Quote / Example	Offered Solution
Access	Recreators	Traditional access to project areas threatened by measures framed as environmental "protection"	"When something is declared wilderness, the gates are closed and people are omitted."	Management and recreational planning considerate of traditional uses by the Gladesmen & Tribes
Decision-making	Recreators, Agency scientists	Participation and rate of planning fail to meet the expectations of South Florida's communities	"They've never seen this place . . . the decision they make will never have any impact on their lives."	Increasing participation, ensuring landowners are consulted with, slowing down plan implementation
Environmental Amnesia	Agency scientists, Advocacy & Policy	Shifting demographics and "fuzzy" cultural memory complicates how natural conditions should be	Outrage at the implications for restoration projects absent the historical context	Safeguarding cultural and institutional memory, embracing the Cycle of Adaptive Change in policy
Production of Knowledge	Agency scientists, Recreators	Concepts supporting power structures in the GEE invented via ecological gatekeeping	Key concepts such as "nature" or "restoration" or normal conditions formally designated by those in power	Open collaboration up to the use of local and traditional ecological knowledge fostering adaptive management of the socio-ecological system

Table 2.5.1 Narratives of Everglades Restoration

Although the participants recognized the complexity of restoration conflicts—often declaring multiple factors at times— enough variation for each stakeholder cohort captures the general discourse of a narrative associated with their identity (Bixler, 2021). The four dominant narratives observed in this research manifest below as summaries for each narrative tethered by direct quotes from interviews and a 2022 SFERTF public comment session. As a reminder, these results primarily express the synthesized connection I observe between stakeholders experiences and personal opinions and the evolving rhetoric of Everglades restoration in the past century.

2.5.2 *Key Narratives of Everglades Restoration*

Access

Where human use is concerned in remote wetland ecosystems, recreational access, and spatial proximity equate to some of the most important yet underprioritized determinants for their protection and restoration (Villagra et al., 2024). "Access" here refers to the ability or permission to enter, use, or participate in a particular place, activity, or resource. For stakeholders across the GEE, access to natural areas like those being restored is crucial to fostering a strong connection with nature and promoting environmental stewardship (Keddy et al., 2009). One industry representative, native to Miami, was supportive of many restoration projects, stating:

> When I think "wilderness," I think of out west. I don't think of the Everglades (chuckles). I mean, it is kinda wilderness, but the Everglades is not a real accessible wilderness . . . unless you've got an airboat, you can't really get out in the Everglades. Even if you have one, there's a lot of times where it's not a very hospitable place. [IP3]

While he finds difficulty in ascribing to South Florida's remote interior a status typically reserved for the scenic, geologically vast vistas revered in western North America, this participant recognizes the historical nature of wilderness areas as primarily utilitarian. For most participants, their *wilderness perception* appears to largely frame human access as integral to their perceived value of natural places while also distinguishing wilderness from protected areas. The only resistance to this idea came from an indigenous activist who places a significant value on *all* landscapes in the GEE, beyond formally protected areas such as ENP and the Big Cypress.

Safeguarding traditional access for South Florida's historically marginalized communities or providing sites for new recreational opportunities remains a goal of Everglades restoration as declared by the state and federal agencies (U.S. Congress, 1999). Unfortunately, it is apparent that "*recreation* is not compatible with restoration" when looking closer at buffer zones or other natural areas under active management [LO4]. While the Gladesman culture is federally recognized, traditional practices related to sustaining a connection with the landscape and holding onto a livelihood in the River of Grass are claimed by interview participants to be threatened by development and restricted access today more so than in the past. For natural scientists, access significantly influences the production of knowledge because it contributes to field assessments that seek to understand ecosystem functioning and significance. As opposed to the remote yet highly visited natural areas out west, I observed that the recreational community in South Florida recognizes wilderness in the Everglades by virtue of its inaccessibility. A prominent recreator and public commentator active in the region's waterfowling community echoed this notion of a second nature present in recent years:

> When something is declared *wilderness*, the gates are closed and people are omitted. And when you take the people out of what is called "wilderness," you really no longer have

> wilderness. You have a zoo . . . worse than a zoo, because the animals overpopulate. And today's concept of wilderness by radical environmentalists is that man is excluded except as an observer. He cannot participate. That's not natural. That's not "real" wilderness. [RE4]

This common complaint by the recreational community see management as acting contrary to maintaining a "balanced ecosystem" due to higher conservation priorities like charismatic megafauna. For these stakeholders historically denied a seat at the table, I observed from our conversations that *motivation* for their tireless and often unpaid organizational roles can be traced to early memories in the GEE. Community members desire to maintain their lifelong connection to these places because of the meaningful time spent interacting with these landscapes, with most expressing the hope that their children could know a similar future. As environmental management in South Florida has shifted its priorities increasingly towards a preservation-oriented approach or simply one that only safeguardes water resources, the power to limit access to wilderness areas across the GEE has been claimed by interview participants to strongly associated with CERP. Members of the South Florida's traditional communities expressed that this began decades prior to CERP when the southern-most Gladesmen and remaining indigenous communities were evicted from their homestead to make way for ENP in 1947.

Decision-Making

Until recently, Everglades restoration suffered from a lack of *participation* by affected community members in restoration planning (Amorino et al., 2020; pers. comm, 2023). Understanding the pathways toward equitable decision-making for restoration planning, both in the years following CERP and in previous restoration projects, appears to be crucial for institutions aiming to maintain landscape resilience during their transition into novel ecosystem states. While agency efforts continue to emphasize science education as technology and social media dominate public interactions on the restoration stage today, research participants often appeared to be skeptical about the effectiveness of science education and outreach for its own sake when it often trivializes the lived experience of those affected most by CERP projects. For optimal community impact, interview participants and the ecosystem restoration literature covered in Section 2.3 suggest that project goals should align with stakeholders' needs; thus, decision-makers should prioritize knowledge sharing and collaborative management to ensure fairness and effective outcomes.

Following my review of water management priorities, the agency spearheading Everglades restoration—the SFWMD– officially state that their mission is to (a) sustain water supply and (b) provide flood protection above any specific environmental concern (SFWMD, 2021). Despite this, stakeholders across the GEE continue to express their deep concern with the rate at which restoration projects are planned and come online, often in an institutional vacuum. I often heard during my fieldwork observations that project impacts are often communicated by state and federal agencies to stakeholders in ambiguous terms. As an ironic response to a period of stagnation taking several years after CERP's onset and delays on many critical projects, one scientist involved with restoration design on the East Coast invoked the notion of "rushing" observed by many private landowners in the WERP footprint today:

> Politicians are always in a real big hurry. So you can't ever do the kind of detailed design research you would normally do. [AS1]
>
> Haste makes mistakes. And I know you guys [the Army Corp and the SFWMD] really want to get this done, but you're doing it at haste and you're doing it under the radar of the landowners. [SFERTF, 2022]

Another historic albeit less obvious threat to restoration progress is the rotating authority by decision-makers tasked with such an extensive, multi-decadal project. As explained by one interview participants, they mentioned that the time spent on any one project by an individual is typically just long enough to acquaint themselves with the "important" players and the overarching landscape concepts simply because careers evolve. The framing of benefits by agency staff to stakeholders (often through an accelerated planning timeline) can foster the support necessary to initiate restoration projects, albeit at the expense of their ultimate success. And where accountability stood, leadership changes were easier to satisfy quasi-governmental environmental NGOs than developing lasting solutions for complex issues not wholly understood by any one group, as a retired Collier County commissioner highlights:

> That's why you can't rely on politicians for this whole thing because politicians are short-lived. They're only here for maybe four to eight years, sometimes twelve, like I did. But most of the time, it's shorter than that. You need something that's more solid. [IP2]

Regarding a governor's decision to highlight the perceived success of one coastal wetland project for the sake of demonstrating that the State was making progress, a retired scientist laments hollow victories such as a "restored" Deering Estate on Biscayne Bay:

> Now all the wetlands that we have thousands if not tens, maybe hundreds of thousands of acres of wetlands that could use the water . . . he creates a wetland on top of a ridge which is totally artificial, requires 100% management. That's one of my pet peeves: they don't do things fast enough and then, regardless of what we say sometimes, things get done that aren't necessarily good. [AS1]

Since my initial observations, I shifted my focus towards the public meeting forum as a site for producing meaning in the Everglades ecosystem. Required by law in the State of Florida, these meetings serve as a real-life "stage" for actors in the restoration game. A private landowner from the 8.5 SMA recalls the strange experience of attending these because "it's not like real life . . . it's almost scripted the way people interact, even the environmentalists." [LO3] An outspoken recreator heavily involved with the promotion and planning of many conservation initiatives in the Western Everglades comments on *accountability* as those historically powerless understand it today:

> If you never meet your goals and objectives and your responsibility is the preservation and conservation of the resource, at what point is there any kind of recourse? Who holds anybody accountable for that? Where does the American public have the opportunity to say to the government, "We've entrusted you with the management of our lands and you've failed to do so," right? [RE3]

In South Florida, traditional resource users like the Gladesmen and indigenous groups—the Miccosukee and Seminole Tribes of Florida—are viewed as having been denied access to the decision-making table by several interview participants and notable authors writing on the GEE (Grundwald, 2008; Ogden, 2008a). As in the past, affected community members continue seeking tangible proof of the benefits of tradeoffs sought by these government actors seeking various permissions from private landowners. Much of the concern again relates to the perceived positionality of the decision-makers themselves, as indicated again by this recreator:

> I think they forget their place. Not in a personal way, but I think that they forget that working for the federal government means working for the people of the United States of America, right? They forget that. And they intentionally keep things from you because they know it'll make you upset or mad or cause some kind of concern that they're going to have to deal with. And most of the people in the federal agency that make the ultimate decision have never been here, and will never be. They've never seen this place. And at the end of the day, whatever decision they make will never have any impact on the rest of their lives or their family's lives. [RE3]

Most of the interviewees highlighted trust in the decision-making process as something not only earned but maintained over time, even by those in mining and agriculture, industries historically prioritized in restoration planning. As one engineering consultant questioned in our interview in the face of so many broken promises and exaggerated claims, "How do you believe anything they tell you?" [IP3]

One of the earliest messages in the rhetoric of Everglades restoration—sending water south to rehydrate ENP—continues to blindly drive the vision for a more resilient hydrologic system at the expense of South Florida's primeval condition. Following 23 conversations with key actors in the GEE, I view this message and its accompanying rhetorics as a form of institutional boundary maintenance. Private landowners reflect on their concern for restoration decision-making during a public comment session and in one interview:

> You can't send historical volumes of water through an area that's half the size without raising the water level to an unnatural level. 60 days of inundation kills Tree Islands. This is not a slough area. This is a rain-driven hardwood hammock with pines and palmettos. I think that we're looking more at creation than restoration when we're sending unnaturally high levels of water south just to "send water south." [SFERTF, 2023]
>
> There can't just be an overtake because, "you get one foot in the door, then they take all of it," is my perspective. I don't want this to stop completely. If you can prove to me, it does restore the Everglades properly and take care of the rest of the land as well—the Oak hammocks and all the other parts of Florida—then great. But until you can prove that to me, I'm going to have to fight back, because I don't want just the Everglades. I want all of it. [LO1]

Ultimately, there is no guarantee that restoration projects will operate as intended once they reach completion or under future demographic and environmental scenarios. While decision-making has reveal to be vital to the ecosystem restoration process as demonstrated through this narrative, community members may continue to challenge the justifications for its top-down approaches to management. This power problematic in political ecology connects with RQ1 given I seek to identify which entities have addressed environmental conflicts and continue to influence conservation outcomes (Quandt, 2016). Given the extent to which planning continues to prioritize economic growth and water storage at the expense of traditional lifeways, these contributions make salient the idea that resource users themselves still hold only a minor influence in the production of novel ecosystem states in South Florida. As public commenters have voiced in the recent conversation surrounding WERP, multi-generational landowners understandably do not desire to take part in this "science experiment" on a landscape scale.

Environmental Amnesia

In the case of South Florida, what I identify as environmental amnesia is reported by many interview participants outside of the Industry and Recreational cohorts to be fundamental in addressing the community perception why the current state of the environment appears "normal," even if it has been significantly degraded from previous generations due to shifting ecological conditions and human activity. Stakeholder concerns sometimes emerge from an almost mythicized past that tends to simplify local environmental conditions. Reflecting on the nature of this issue from enough perspectives can highlight the way it manifests locally along with guidelines to combat it. One agency scientist working in the Big Cypress described a significant issue for communicating pathways to restoration as extending from a biased cultural memory:

> A lot of agencies want the restoration because they realize the whole goal is to try to get the Everglades back to a pre-drainage hydrologic level. But the problem that has occurred over time is that a lot of the people that utilize their land, their memory of the Everglades' hydrology is probably from the 1950s to the 1970s, a timeframe that was heavily drained . . . a lot of people don't really understand even though they're for restoration, they don't really want the restoration pre-drainage, they want the restoration to kind of mimic what they view as from their childhood. [AS6]

This landowner traced the problem to a lack of institutional capacity for relating to the landscape:

> People forget and people die off. But I think it's really up to us, to the people that have lived this to teach the youngsters and pass this along. The problem is government doesn't allow for it. [LO4]

An outspoken indigenous activist on the East Coast framed traditional ecological knowledge as another means of coping with a degraded landscape:

> The elders, like they can tell you what the baseline was when they were children. We talk about my grandparents growing up in a situation where . . . they enjoyed all the flocks of birds that block out the sun and how abundant those species were. And now today we can talk about "Everglades Minimalism," like the absence of these animals. And still, you can find a sense of beauty or inspiration in a barren landscape. [LO2]

Drawing from multiple domains of knowledge to capture system-wide behavior seems to be a promising route as the honest recollections of agency scientists and program directors from SFWMD and the Army Corps reminds us in terms of expectations for both managers and stakeholders:

> We'll never be done because we're basically 'gardening.' And there's a lot of things that aren't self-sustaining . . . because the resilience isn't there. We're working to build it. When we 'get it right', it doesn't always mean that we end where they might have thought they wanted to be. [AS2]

One scientist working on the landscape ecology around Picayune Strand Preserve commented on the ephemeral nature of his property, hinting at the inevitable disaster waiting to return a dehydrated landscape back into the open, wet prairie historic to the area in claiming that, "These trees do not belong here, and they're going to go away one of these days" [AS4]. If community members only recall the extreme, this participant implies that the urgency of fostering a resilient landscape can only be realized by decision-makers through further disasters. At the very least, disasters appear to be both predictable yet inevitable across the GEE. At face value, this implies a wildfire devastating large tracts of Naples' hinterland—the context for the last quote on the drainage-induced proliferation of cabbage palms around Picayune Strand—would ultimately benefit the GEE. Despite the widespread recognition of shifting baseline syndrome in ecology, the institutional resilience of water management and the NGOs involved with environmental claims-making reveal the complexity underlying boundary work that seeks to facilitate true knowledge co-production in the GEE. I believe the absence of integrative boundary objects in policy and planning designed to tackle environmental amnesia has only recently begun to shift. This ties to my research sub-question B and highlights the significance of combating environmental amnesia in South Florida because establishing baselines through local ecological knowledge helps to reduce the influence of powerful (yet locally disconnected) actors in evolving conservation landscapes, (Kahn, 2002; Garvoille, 2013).

Production of Knowledge

On an equal tier in the dendrogram hierarchy within the *decision-making* narrative is the *production of knowledge*. Pathways for more equitable knowledge co-production have generally increased in the past decade as evidenced by widespread opportunities provided to stakeholders to publicly support or condemn capital improvement projects and other earthworks planned in the name of restoration (pers. comm.). Based on my interviews, private landowners, in particular, seem hesitant to trust the "quick-and-dirty" proceedings of many of these accelerated operations. The resulting power dynamics in the restoration area appear to be multi-faceted and more nuanced than many participants frame it. As one project advocate working in restoration planning for the Army Corps expressed:

> When you put those events of ecological significance and you overlay them on what may be a changing society of South Florida . . . we relate to our environment in a different way. And so, in my experience in South Florida, the value judgments that we make every day with water and with our environment are directly related to how people are connected to them and then specifically how our economies are connected to them. I would say it's both of those forces. It isn't one or the other. [AP2]

For those holding these protected areas in reverence, multiple "worlds" in conservation reflect the significant differences in the desired environmental outcome by institutions that otherwise appear to act for the same motivation. The ability to "accept that more than one thing can be true in this work" [AP2] has impacted the institutional resilience embedded in the social structure underpinning federal agencies such as the Army Corps. For a project such as WERP, a conventional approach to planning failed due to lacking community representation in the planning stages. The Army Corps representative above provides the example of a conventional aerial map with abstracted lines and symbols as being "the worst thing you can do" in Tribal interactions because of the way they relate to the landscape. Different ways of knowing the landscape appear to finally emerge at the highest level of restoration planning as boundary work continues within Everglades restoration.

To facilitate adaptive ecosystem management, improving the transparency of the planning process is crucial. Practitioners and researchers can address the uncertainty that restoration practitioners often face in the early stages through real-time project monitoring and communication. Because many of these trends oscillate on the scale of decades, interview participants suggest that active feedback could help assure that skeptical resource users are not discouraged by oversimplifications of landscapes intimately familiar to them. Given that learning from the past as social and ecological systems shift to new regimes entails a fair degree of experimentation, the social and technical infrastructure must be in place to properly observe and communicate this phenonena. One landowner's ongoing complaint of agency science conducted to provide baseline environmental data in the Western Everglades scorned their confidence when discussing the absence of in-person observations of the areas impacted by these projects; much of their research instead results from archived satellite imagery and brief flyovers in state-funded aircraft. Interestingly, I found narratives emphasizing a partial picture to not necessarily be counterproductive in evaluating restoration conflicts. An older agency scientist working to inform on-the-ground restoration work in Picayune Strand speaks to the pitfall of framing the narrative of Everglades restoration as central in the fight for *resilience*—or against *climate change*:

> I've got a lot that I can bring to the discussion because of what I know from all the years I've worked here on the natural system; as much as we can maintain the natural system that's out here. And so, there's a lot of things like climate change and resilience and the like that I haven't put a lot of effort into trying to understand because I don't think there's really a lot of people that are all on the same page anyway. Given that I'm 80 years old, it's not the best use of . . . whatever time I have left to try and get into that discussion. [AS4]

This statement embodies a common motif communicated in many interviews: the "big picture" is not always so relevant to local inspiration. So then, how should policymakers and ecosystem managers incorporate the type of nuance here into the idealized and awe-inspiring messages driving the progress of ecosystem restoration in South Florida? Perhaps paradoxically, it no longer seems worthwhile to stress the all-encompassing benefits of a GEE returned to Eden while the unifying messages of its work neither originate from nor can be consistently supported by less-powerful actors— the same actors that must live with the consequences of these "misdrawings" in perpetuity. Many of these actors represent marginal groups that historically suffered due to these acts of "creation." The ability for stakeholders to understand ecosystem restoration as a collective process that leaves room for participation and space to co-create and even challenge projects remain vital to securing the effective transformation of human communities and nature. One of the more experienced Industry and Planning representatives interviewed defined Everglades restoration for me as "this big, nebulous, undefined, inevitable government process" [IP3]. His decades of involvement in South Florida before and during the CERP era left him no longer expecting the initial promises government agencies made over two decades ago to reach fruition.

Looking at research sub-question B, competing perspectives on the management of protected areas affect ecosystem restoration goals by framing them around agenda-setting promises. These promises often form the basis of the sacrifices necessary to secure a supposedly more resilient future for South Florida because of the shift regional wilderness narratives have taken since the beginning of CERP. Therefore, I argue that this research application and similar approaches utilize a critical perspective to identify pathways toward equitable conservation outcomes and provide opportunities to question what sort of resilience (and for whom) is being offered through critical approaches in the social sciences.

2.5.3 *Ternary Plot & Summary Table*

One of the unique visual contributions of my qualitative research was the creation of a diagram that quantitatively summarizes all interviews based on the narratives discussed. The three-part structure of the following ternary plot (Figure 2.5) intuitively highlights the dichotomies between participants from the *Recreation* (pink), A*gency Science* (red), and *Advocacy & Policy* (green) cohorts in this diagram. I chose to focus on these three groups because their views are typically the most opposed based on my literature review and due to the higher representation of research participants, although every cohort is represented on this diagram. As I cover in the Background section (2.3), a ternary plot is a useful tool in social science research for visualizing the proportions of three variables that sum to a whole—in this case, all interview codes across 23 stakeholders (Schöley, 2021). Each point (or bubble) on the plot represents a share of emphasis on the three variables. For my analysis, these three variables are the aforementioned stakeholder cohorts whose participation in my project was highly representative. Based on coding summary metrics, a narrative's accompanying word count corresponds to the relative size of the plotted bubble. The location of narrative bubbles on this plot indicates the proportion of coded text belonging to a particular stakeholder cohort. For example, Recreators and Agency Scientists both emphasize narratives like *Access* or *Environmental Amnesia* to a similar degree based on bubble sizes, yet the bubble location relative to the labeled corners of the ternary plot indicates a stronger stakeholder association with a given narrative. The relative proportions of the variables determine the position of points. The insights gained from interpreting ternary plots and similar diagrams save time by summarizing massive volumes of text helpful for policy creation.

One can quickly identify through visual examination how more extreme positions correlate to a greater share of the "total conversation" linked to narratives expressed by my research participants. Similarly, the bubbles rendered closer to the center showcase which themes are shared concerns amongst all stakeholder cohorts in this research. One interesting summary point is that the stakeholder cohorts largely conform to their own portions of the plot. Perhaps unsurprisingly, the space allotted to speaking towards narratives such as *Access* and *Participation*—largely consumed by the Recreational community—are? intermeshed in much of the spaces taken up by private landowners (blue bubbles). Even without the cohort distinction, my qualitative analysis reveals that this textually rich approach reflects the hybrid identity held by many stakeholders in the GEE. This is to say that narratives cluster in some parts of the diagram more than others, almost pre-determining the stakeholder positionality based on their role in producing the narratives of access, decision-making, environmental amnesia, and production of knowledge.

Utilizing the ternary plot (Figure 2.5) to decipher the most significant points of stakeholder divergence, the recreational community emphasizes *Participation* and *Access* as dominant themes above all other stakeholders, an element in Everglades restoration that has shifted since its inception. Towards the plot's lower center, Advocacy/Policy and Agency Science representatives shared a near-identical value for *Production of Knowledge*. Yet the narrative emphases lacking from most cohorts that connect directly to legacy restoration projects, *Wilderness Perception* and *Environmental Amnesia,* indicate that monitoring restoration activities requires ongoing intervention into the political ecology its localized impacts. Because reconciling competing narratives of environmental restoration is an active social process in policymaking, data visualizations like these foster adaptive management as their visual interpretation alone could serve as a site for the production of knowledge (Drucker, 2020). An interactive version of this chart is hosted on the Story Map covered in Chapter 6. By graphically ranking narratives offered by different restoration actors, I quantitatively highlight with this boundary object the extent to which competing perspectives on management affect the outcomes sought after in Everglades restoration. As these cohorts here all appear vested in the *Production of Knowledge*, the incorporation of narrative-aligned suggestions could ensure a unified mission as ecosystem restoration continues to march forward in South Florida.

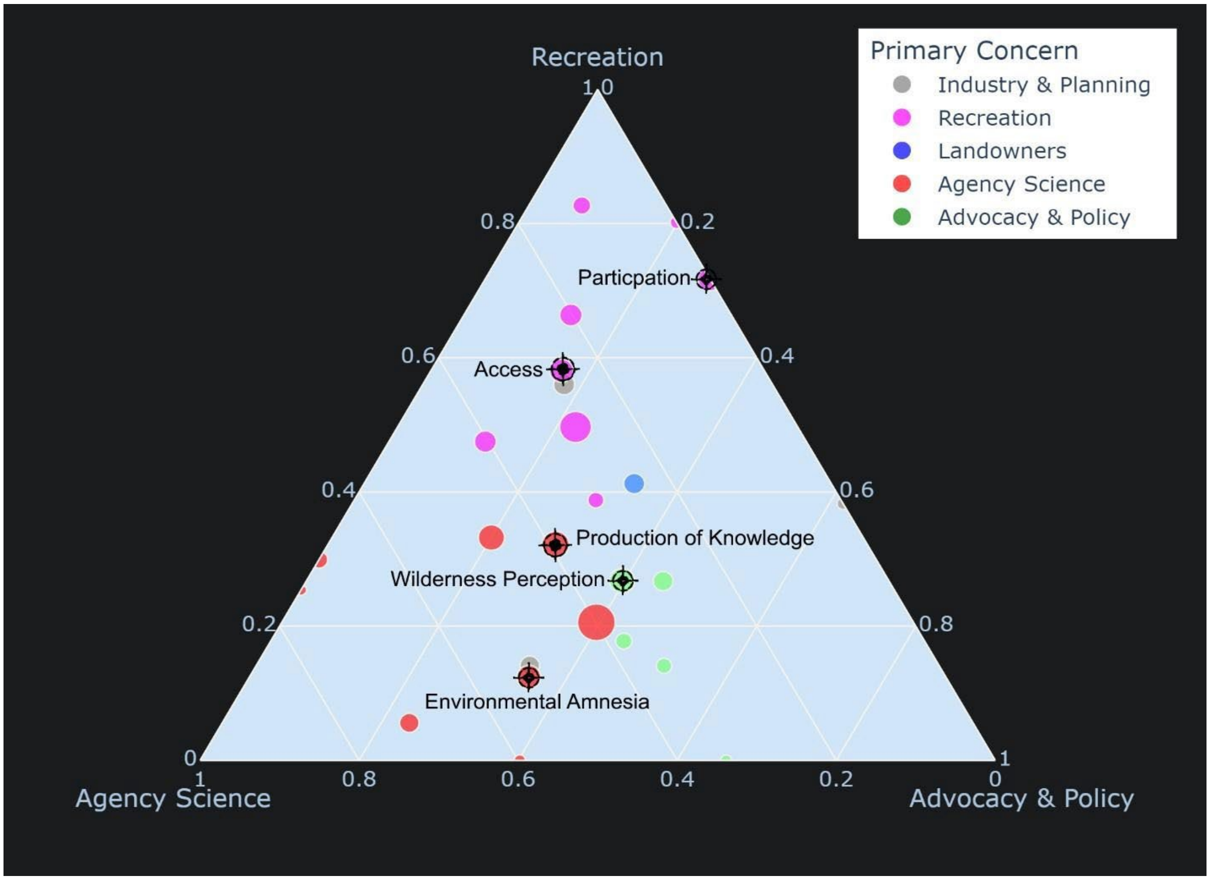


Figure 2.5 Ternary plot of narrative emphasis by stakeholder cohort. This figure was created using the Plotly package for data visualization in Python utilizing the narrative metrics from all interviews. Colors correspond to stakeholder cohort as indicated in legend. Bubble size reveals greater association with given narrative and location on chart reveals proportion of concern for three larger stakeholder cohorts (i.e. Recreators, Agency Scientists, and Advocacy & Policy representatives).

Beyond the generalized positionality of stakeholder narratives visualized in my ternary plot, I am also providing a summary graphic that updates and expands on my event timeline (Figure 2.3.1). Utilizing the results produced through my qualitative analysis, the below table (Table 2.5.2) connects key events and decisions of Everglades restoration in terms of the key actors, and consequences observed across the socio-ecological landscape. I also mark events for key narratives of restoration based on the influence of the ternary plot above to highlight potential sequences in Everglades restoration that demonstrate opportunities to study shifts in South Florida's participatory governance based on the framework proposed through this research.

ERA	Events/Policies	Powerful Actor(s)	Socio-ecological Consequences	Related Narrative(s)
1905–1938	Drainage and diversion for agriculture & flood management after storms	– US Army Corps – State of Florida	Everglades drainage district formed, land dispossession	*Access*
1948–1960	Everglades National Park, Everglades Agricultural Area, C&SF Project established	– Department of Interior – State of Florida	Early ecosystem fragmentation, spread of invasives and high influx of nutrients	*Wilderness Perception*
1963–1970s	Big Cypress National Preserve, the Water Conservation Areas, and SFWMD are all established as part of Water Resources Development Act	– State of Florida – US Army Corps	Kissimmee River channelized, rapid urban development, BiCy access restricted, Everglades Coalition formed	*Production of knowledge, access*
1980s–1994	Seagrass die offs in Florida Bay, algal blooms in Lake O, Melaleuca wildfires, ENP Protection & Expansion Act, MOD Waters, Everglades Forever Act	– Department of Interior – State of Florida – Environmental NGOs	Feds sue Florida over pollution in Loxahatchee Wildlife Refuge, boundary land acquistion	*Production of knowledge, participation, environmental amnesia*
2000s	CERP approved, early projects underway, Accelr8, ECB forms	– US Army Corps – State of Florida – Environmental NGOs	Environmental lawsuits, changes in land tenue for traditional land stewards	*Access, participation*
2015+	Kissimmee River restored, 8.5-SMA curtain wall approved, Hurricane Irma, WERP planning underway	– US Army Corps – State of Florida – Environmental NGOs – Private landowners	Restoration progress framed around climate change, opportunities to understand ecosystem resilience emerge, stakeholders delay project plans	*Production of knowledge, participation, environmental amnesia, wilderness perception*

Table 2.5.2 Timeline of power & policy in Everglades restoration (1905–2025)

2.6 DISCUSSION

In the GEE, restoration efforts have historically produced uneven benefits to resource users due to their long-term implications for the cultural landscape, including threats to traditional modes of access and land tenure regimes driven by indigenous land stewardship. The regional effort to revitalize critical ecosystem functioning in South Florida corresponds with a global mission to restore natural areas to sustain human well-being and mitigate climate change. The next ten years (2021–2030) of projects finishing or coming online in Florida's Everglades coincide with the UN Decade on Ecosystem Restoration (UNEP, 2022). Examining the political ecology of on-the-ground practices conducted in the name of this grand endeavor often paints a picture of failure as many nations are failing to meet their goals, with some managing to ironically worsen the social and ecological conditions they intended to improve through these extensive interventions (Osborne et al., 2021). This section examines the importance of my research findings considering the region's political ecology literature and the human dimensions of ecosystem restoration more broadly.

2.6.2 Research Question 1

My qualitative analysis of Everglades restoration focuses on the narratives utilized by actors and NGOs in South Florida and at the national level of conservation to understand who wields the power to transform the South Florida landscape. As competing ideas on nature compel scholars to render future environmental conditions as something "new," then the current state of the GEE can be described as "a second nature," with the *first* nature embodying the Everglades' primordial condition before European contact (Zweig & Kitchens, 2010; Garvoille, 2013; Wakefield, 2020). It implies that novel ecosystems transforming the ecological and social landscapes that have come to define South Florida face further uncertainty as the effects of climate change progressively manifest in the 21st century. The power of government agencies and special interest groups to rally well-funded environmental organizations, decision-makers, and key stakeholders from industry and planning behind seemingly eco-centric causes is instrumental in the introduction of novel ecosystem states. While environmental knowledge produced during the later stages of the restoration process can serve to justify future projects and determine performance measures, *where* and *how* stakeholders fit into the implementation of this inevitable practice is a mission that must continue past the planning process. To summarize my multi-faceted answer to RQ1 in the content of the evolution of the GEE across time and space, I provide Table 2.5.2 to organize how key events in the timeline of Everglades restoration (Figure 2.3.1) directly correlate with the transfer of power necessary to implement conservation efforts on a regional scale.

My findings collectively revolve around four primary narratives of restoration: access, decision-making, environmental amnesia, and knowledge production. Although elite actors in the restoration arena, such as SFWMD and the Army Corps, continue leveling the playing field through participatory governance, efforts to effectively communicate the historical and ongoing value of the places worth saving are hindered by powerful NGOs sponsored by interest groups tied to South Florida's political and industrial landscape. Participatory governance has substantially transformed decision-making in the Everglades, moving it beyond a purely bureaucratic approach to one that increasingly reflects the concerns and values of local communities, indigenous groups, and environmental advocates. Fortin's (2002) work represents one of the earlier critical takes on the human dimensions of Everglade restoration in addressing the bureaucratic challenges that residents of the 8.5 SMA faced, showing how participation from diverse communities, while beneficial, often collides with entrenched bureaucratic structures that nearly impossible to navigate in the 1990s and early 2000s. Fortin argues that while participatory governance offers a platform for local voices, it is not always sufficient to counteract bureaucratic inertia. Local communities can feel helpless in the face of governmental policies that are slow to change and often prioritize bureaucratic objectives over grassroots concerns. Ogden further (2008a) emphasizes that participatory governance has allowed for a wider range of perspectives, challenging traditional scientific and governmental authorities that previously dictated Everglades management. This shift has democratized the process, allowing diverse stakeholders to influence decisions about restoration and conservation. In her other prominent contribution to earlier political-ecological investigations in the GEE, Ogden (2008b) also illustrates that participatory governance has led to the Everglades being viewed as a contested space where multiple, sometimes conflicting, visions of ecological preservation and cultural value come to the fore as various forms of knowledge on the environment compete in technologically facilitated forms of its representations interact.

Cattelino (2015) expands on this by exploring the significance of cultural politics in water governance, noting that participatory governance has amplified indigenous voices, such as those of the Seminole Tribe, who emphasize their historical, cultural, and sovereign rights over water resources. This inclusion has complicated decision-making, but it has also enriched it by foregrounding the social and cultural stakes involved in Everglades management, moving beyond purely ecological considerations to include issues of social justice and equity. Together, these sources illustrate that while participatory governance has introduced critical new dimensions to Everglades decision-making that allow it to be more inclusive and representative, challenges remain in balancing these diverse interests within a complex bureaucratic system. The policy narratives produced today are compounded by the existential threat of climate change and its accompanying sea level rise, which planners anticipate to affect South Florida in this century (Wakefield, 2018).

When examining whose agenda actively promotes and implements conservation initiatives to create a second nature in the Everglades today, the State—of Florida and the U.S. government—continue to maintain the most power to transform this landscape and enable access to protected areas in South Florida. Across almost two decades of negative press around the 8.5 SMA and governing board meetings by the SFWMD, land acquisition as a means of solving these issues at the literal and figurative boundary of environmental restoration and human well-being was finally abandoned by the state as water managers now look to other ways to restore historic water flows through the eastern Everglades (pers. comm., 2022). As my research indicates, this did not occur in a cultural vacuum. The ongoing situation with WERP has evolved into a display of indigenous and traditional sovereignty that has successfully stalled the planned wilderness designation in the Big Cypress National Preserve (pers. comm., 2022; SFERTF, 2023). This is where we identify limits to the seemingly unlimited power wielded by the State. This situation is worsened by rampant environmental amnesia among planning interests and the evolving population as Florida continues to grow over the next decade, and I return to this idea in the following section.

Using a political ecology lens to analyze and interpret my data enabled me to frame these results as an objective survey of the current state of Everglades restoration. Several of these insights align with and update other investigations into the political ecology of South Florida. Looking at the roots of WERP's conflict through past scholarship, multi-species conservation has recently shifted management towards a landscape approach for much of the region. This entails consideration for South Florida's native plant communities and important species of wading birds such as the wood stork and roseate spoonbill. Amorino (2020) reflects that it was due to an eco-centric value for restoration activities early on that shifted water away from the Western Everglades to hydrate nesting grounds for the Cape Sable Seaside Sparrow, a contentious iconic species associated with conflicts between the NPS and US Fish & Wildlife over the past two decades (pers. comm, 2022). After I interviewed the same conservation biologist Amorino (2020) cites his influence as the reason the culturally sacred tree islands in the WCAs above ENP were drowned in 2019, this biologist's message became clear: it was the impression of the scientific community that Indigenous groups at the boundary (and, in the way) of restoration were "not living traditional lifestyles," as though their modern condition somehow negated the need to preserve sacred places in the name of ecosystem restoration (pers. comm.). The ability to claim this as a community outsider and authority on conservation, too, is an example of the institutional power utilized by restoration practitioners to downplay or outright ignore neo-colonial practices produced as a response to state interventions with nature (Ogden, 2008; Bliss & Fisher, 2011; Cattalino, 2015).

2.6.3 *Stakeholder Cohort Divergence*

Stakeholders agree on the socio-ecological decline of protected areas and their boundary lands. However, political ecology analyzes how power shapes and reinforces specific types of knowledge in these nuanced areas of narrative divergence. (Bixler, 2021). This confrontation with the popular discourse on Everglades restoration matters more today than in the recent past due to the way evolving communities learn about conservation practices thanks to technology and the accompanying uncertainty by competing stories on the natural world. As Garvoille (2013) so elegantly states in addressing her primary concern with the dominance of the leading message of "getting the water right":

> [this idea] changed the way the Everglades is managed and understood as a place, recasting it as a water management system and raising new questions about the proper place for people in this waterscape . . . the majority of literature on Everglades restoration takes a narrow view of restoration as a principally ecological, legal and technical process, largely ignoring how Everglades restoration is the site of potent social struggles and uneven power relations that seek to define the proper boundaries between people and nature. (p. 13)

Based on my analysis of interview data and the core message underscoring humanist research on protected areas, my results reinforce the notion that it lies in the interest of state agencies and environmental NGOs to maintain these physical and immaterial boundaries under the guise of "ecosystem revitalization for all." As SFWMD documents and staff remind us, their priorities lie in water security and flood protection; all other amenities are secondary. However, in 2024 (only two decades into CERP) the logo of the SFWMD proudly (and anachronistically) bears the subtitle "Protector of the Everglades Since 1949." Some of my research participants would not second guess the significance of such symbolism. It remains useful to, therefore, examine why different communities and stakeholders in South Florida interpret and use these narratives in different ways to achieve similar end results.

Ternary plots like the one I created (Figure 2.5.) are useful for initially assessing mass volumes of qualitative data to highlight the relationship and accompanying conceptual "distance" between stakeholders and environmental narratives. As observed during my interview analysis, another major divergence in these narratives' role for stakeholders includes a mounting yet often under-emphasized threat to Everglades restoration: environmental amnesia. As the ternary plot indicates, environmental amnesia is emphasized almost equally between Agency Scientists and Policy Advocates with little attention given by the recreational community, many of whom also identified as landowners in the region. Does this imply that traditional ways of knowing the landscape and daily interactions with it obfuscate the need for externally "remembering" how environmental conditions used to be? While understanding the reason for this trend exceeds the scope of what my data currently inform, shifting baselines as a formal ecological concept reminds us that restoration asks a backward-facing question in trying to understand the (technically uncertain) target conditions these projects strive to meet. In terms of what Recreators do speak to environmental amnesia, there is hope for the growing awareness by restoration practitioners that exposure to their lived experience continues to profoundly impact the efforts to spread awareness of complex processes of ecological deterioration. Therefore, we may identify power as the privilege to ignore or deny this personal exposure to decision-makers who otherwise remain detached from South Florida's landscapes unless actively motivated to experience the Everglades in the form of "field trips." As I mentioned in the Literature Review (Section 2.2), the anomalous ways that power structures adapt in the face of uncertainty can provide key windows for regime shifts in the Everglades SES/ Leveling restoration's playing field through interventions with key decision-makers can shift historical power contingencies and increase the likelihood of a more equitable novel ecosystem state.

2.6.4 *Research Sub-Questions*

While the research participants interviewed collectively embrace the need for knowledge co-production in the GEE, highlighting pathways to achieve this on a regional scale should dominate the early stages of project planning. Two sub-questions that seek to build upon this qualitative investigation are worth exploring now in the contextual narratives of (a) access and (b) the co-production of knowledge:

a) How much do different perspectives on the management of protected areas in South Florida affect ecosystem restoration goals?
b) What sorts of boundary objects best facilitate the co-production of knowledge for communities crossing into the "back loop" of the cycle of adaptive change?

I discuss each of these in turn.

The analysis reveals that different perspectives on managing protected areas in South Florida significantly affect ecosystem restoration goals. Initially, government agencies and well-funded NGOs, influenced by political and industrial interests, promote a "second nature" approach that prioritizes new ecosystem states and large-scale restoration projects. On the other hand, Indigenous and local communities, whose cultural and traditional ties to the land are often overlooked or undermined, resist these efforts, especially when restoration activities threaten sacred spaces or livelihoods. This conflict highlights the power dynamics in restoration decision-making, where elite actors often dominate, but resistance from marginalized groups, such as Indigenous communities, exposes limits to state control. These diverging perspectives challenge the implementation of restoration goals and complicate efforts to achieve balanced, inclusive conservation outcomes. Environmental scholars trace this often paradoxical, institutional failure to manage natural areas prominent in the North American discourse to "wilderness ideologies" especially prominent in settler colonial societies such as the United States for reasons of "property, indigenous dispossession, and sovereignty" (Cattelino, 2018). Most individuals or institutions no longer seem adequate to address these significant shifts given the complexity of incorporating local knowledge and people back into a heterogeneous landscape at the regional scale. Agencies place extensive effort in establishing and summarizing so-called "resiliency metrics" for public consumption often without context for their long-term implications to community members or acknowledgments for the uncertainty (SFWMD, 2021). When agencies designate protected areas without considering the impact of neighboring landscapes, proximity to highly altered water management zones and South Florida's developed areas complicate efforts to establish sustainable land-use transitions (SFWMD, 2006). After all, bars on access to these places prevent the critical management activities demanded by restoration from taking place, and even monitoring progress at the local level becomes difficult (pers. comm., 2022).

Water management from the top down is highly determinant of ecosystem restoration goals, although it may be better framed as *hydrological restoration* if we take agency perspectives seriously. The positionality of agencies charged with carrying out the bulk of restoration activities—the U.S. Army Corps and the SFWMD—introduces a potentially permanent obstacle to stakeholder collaboration. The decision by the SFWMD governing board members to approve a curtain wall construction theoretically solves the need for flood mitigation, yet this still resonates with a tradition of technoarrogance in the region. As one governing board member warned during a pivotal meeting on the fate of the 8.5 SMA, engineering their way out of a situation that "technical expertise" put themselves in did not appear to be in the community's best interest. Yet the GEE is heavily managed, and often, where it is too late to undo the impacts of growth, nature-based solutions to return the Everglades to its mythical, primordial state are impossible. The manner through which the 8.5 SMA and other communities at the restoration boundary are portrayed to decision-makers and the public consistently emphasizes why sacrifices were necessary to "fix" the Everglades. In her ethnography on the legacy of the 8.5 SMA as a "pariah" in the face of state-sanctioned ecosystem restoration, Fortin (2002) explains that early failures in the inclusion of stakeholder perspectives in the planning stages of projects derive from aggressive policy influence from special interest groups behind closed doors. As she argues, "this is a game of who has access to the people who control the decision-making process" (2002, p. 71). Where physical access is key in the GEE to best understand, connect with, and relate to the landscape, institutional access serves perhaps best as a proxy for the chance of shifting an exceptionally resilient (and by extension, *rigid*) social system.

In discussing sub-question B, I highlight the importance of boundary objects, both theoretical (such as panarchy) and practical (like field trips), in co-producing knowledge in the GEE. While ecological resilience is widely accepted, applying the resilience framework in ecosystem management faces social challenges due to its roots in ecological theory (Ingalls & Stedman, 2016). Recent research advocates for incorporating political ecology to better address these issues. Gunderson et al. (2018) argue that failing to integrate diverse stakeholder perspectives with hydrologic investments under a flexible management approach weakens adaptive governance and sustainability. The use of boundary objects like maps reveals the priorities of restoration agencies, often exposing a disregard for communities that may suffer from unequal environmental outcomes. However, regime shifts linked to human capital have led to ongoing legal disputes in the GEE. Panarchy, as a resilience concept, helps explain the balance between change and persistence although its analytic potential has limitations (Gunderson & Hollings, 2002). Panarchy's "creative destruction" phase (K phase) reflects the instability caused by environmental litigation. For example, the federal government sued Florida for failing to maintain the water management system, leading to the 1989 ENP Protection and Expansion Act, which aimed to revitalize the Everglades. The Army Corps later launched the 1992 Modified Water Deliveries project, but it did so with little consideration for 8.5 SMA area, despite mandates from the Expansion Act to consider local communities affected by changes to these natural areas (Gunderson & Hollings, 2002; Fortin, 2002).

Beyond theoretical implications, I observe more practical manifestations of boundary work in the form of ongoing field trips offered to decision-makers and influential NGO representatives via airboat and swamp buggy. Particularly among South Florida's recreational community, there is a strong desire to get those most removed from the restoration arena directly involved in ways that figuratively and literally get their boots wet. As WERP continues to evolve through planning delays, stakeholders have effectively showcased what places stand to suffer from proposed plans in the Western Everglades in shifting water out of the Tribal lands before it flows into ENP. The experiences leave lasting phenomenological impacts on the powerful actors and appear to move them more than the insights arrived in the formal settings of a laboratory or conference ballroom. The social context of knowledge production and environmental claims-making often impacts project outcomes from their inception. Cases of "restoration resistance" are not uncommon, as I encountered while reaching out to conduct my pilot study with some tribal members. Oddly, this same "resistance to progress" mirrors the paradoxical benefits of access encountered by the recreational community in Picayune Strand where petitioned off-road vehicle use prevented a massive development in Collier County and effectively prevented restoration plans (Swartz, 2016).

Looking at the utility of various boundary objects as communities cross tipping points in sub-question B, I suggest that future planning can benefit the inclusion of panarchy because it facilitates the co-production of knowledge on restoration projects threatened by environmental amnesia. We also must remember that theoretical concepts have their limits beyond the academy, thus, practitioners of ecosystem restoration should continue striving for ways to identify the GEE as a total environment of shifting ecological, hydrological, and social conditions in a time of increasing uncertainty and experimental management. In doing so, interdisciplinary scientists can provide a more transparent platform through which to co-produce claims about the Everglades socio-ecological system, especially given what is at stake during this next decade.

2.7 CONCLUSION

In examining the human dimensions of Everglades restoration, this chapter explored how local environmental narratives slowly shift the power dynamics underlying hard-fought conservation outcomes. My political-ecological research approach questioned the role of traditionally powerful restoration actors via ethnographic study and extensive qualitative analysis of the guiding narratives and rhetorical patterns of placemaking in South Florida. The goals of this chapter were to utilize critical social science approaches to identify pathways towards the socio-ecological restoration of boundary lands in South Florida as they face continual modification during the ecosystem restoration process. Developing deeper questions to ask emerging from the region's legacy of political ecological research is another short-term benefit of this project. I believe this could enhance the role of current resilience-based approaches to management as complex social and natural systems undergo transition across non-linear boundaries of stability. This section concludes my qualitative research efforts speaking with and working alongside key stakeholders in the GEE by reviewing the primary research outcomes, the limitations of this research, future directions in political-ecological work, and final reflections that position the importance of these types of inquiries in the wider North American perspective on the roles of wilderness and protected areas.

Ultimately, my results suggest that the social context of knowledge production and environmental claims-making influences project outcomes from the start. Different conceptualizations of wilderness and protected areas shape management approaches, with access playing a key role in this history. In settler colonial contexts like the U.S., this is linked to issues of property, indigenous dispossession, and sovereignty. Agencies often create "resiliency metrics" without long-term community context, raising concerns about sustainability, particularly concerning artificial wetlands that serve to remediate long-term environmental conditions. Hydrological restoration is prioritized by management over broader ecosystem goals, with physical access to these places and institutional rigidity posing less obvious challenges. A lack of stakeholder inclusion has hindered the resilience framework here, although its related concept of panarchy helps explain the tension between change and persistence, particularly in ongoing legal disputes in the South Florida social landscape. Direct encounters with the natural landscape via field trips into the Everglades influence decision-makers more effectively than formal processes, showcasing the importance of on-the-ground experiences to *know* places in restoration planning and communication efforts. Better integrating boundary objects like panarchy into future planning could help address "restoration resistance" and environmental amnesia by co-producing knowledge across diverse communities and environmental contexts. Additionally, incorporating more intuitive data visualization to empower active public participation could help ensure the transparency of project planning. These research takeaways provide several pathways for social scientists and community members to co-produce or even *challenge* claims about the state and trajectory of the GEE.

In terms of limitations to this study, my positionality as an institutional and cultural outsider to much of the science, recreation, and other traditional modes for the production of meaning in the GEE constrains my perspective of ecosystem restoration based on a well-developed relationship with the "natural" world in more temperate, less populated settings. In this research, I attempt to leave behind much of the biases and assumptions that have thus far jeopardized progress towards an efficient and equitable restored Everglades ecosystem. As opposed to "picking a side," political ecology allows us to improve the justness of a particular deliberative process (Robbins, 2016). I faced difficulty incorporating better representation from indigenous communities due to a perception of restoration bias, something I encountered from one tribal liaison when recruiting research participants. This impacted the comprehensive representation of my analysis because I still lacked inclusion from all stakeholder communities directly affected by WERP and other current restoration projects. Better understanding these aspects before conducting my investigations might have shifted the way I framed research questions and where I recruited participants to interview. In my experiences working on two projects during my ethnographic study of agency science in the region, I found that while most actors shared a deep passion for landscapes under study, a general sense of uncertainty could be gleaned from several casual field conversations: where was all of this data going? Who would be tying it all together? How would it be used? For many younger scientists in the GEE, the questions would not be answered until their roles had long ended.

Future research should continue to assess the power dynamics of actors across the GEE as new benchmarks for environmental conditions, and demography manifest due to issues of historic inequity, the interconnectedness of social and ecological systems, and because these examinations influence policy and management decisions that produce transformations at the landscape scale. Understanding how ecosystem managers utilize boundary objects to communicate complex phenomena to end-users, especially stakeholders historically denied seats in the decision-making process, is also integral to achieving holistic restoration. Conflicts have arisen in the GEE due to differing values between management and the local communities impacted by restoration efforts, often related directly to their relationship with nature. Many CERP goals remain vague, leading to outcomes that may conflict with the preferred conditions of different communities. While the GEE provides immense biophysical support to South Florida's communities and non-human nature, the abstraction of *place* allows the driving discourse of Everglades restoration to favor economic interests, often under the façade of conservation. This challenges the potential of socio-ecological restoration given that even much of the prioritized components of its landscapes will never be restored (Knox, 2013). The continuation of CERP depends on demonstrating tangible progress to decision-makers to secure ongoing government funding for environmental transformation. Competing narratives of nature further complicate our understanding of past social realities, as legislation solidifies values tied to preferred ecological regimes (Gunderson et al., 2018).

I recommend using this research in policymaking to identify bottom-up approaches to advocating for a resilient socio-ecological future in the region and elsewhere in the United States through established social pathways. These approaches should target and support more grassroots movements already connected to local communities to foster equitable conservation outcomes at a regional scale. Reinforcing local efforts to identify strategies that safeguard the native ecology and traditional lifestyles in South Florida allows holistic ecosystem restoration to compete with elite NGOs in the region. The international role bestowed upon the GEE early, coupled with the resistance of its traditional stewards, offer ways to catalyze a holistic restoration of the Everglades socio-ecological system in ways that mirror much of the early 20th-century grassroots initiatives by Marjory Stoneman Douglas and other iconic conservation activists in the region. As Garvoille (2013) concludes, the hidden role of identity politics and property relations continues to inform environmental claims-making in the region, although today, the extent to which these relations operate in the dark is now obvious to the benefit of many private landowners on both sides of the GEE.

Two final reflections from the literature deserve mention. Cronon (1996) cautions today's environmentalists in their tendency to fetishize retreats from urban life recreating in seemingly wild places as if nature merely plays a passive role in the historical process, reinforcing the paradox of wilderness. An unrealized connection with nature absent any meaningful form of co-habitation lessens the impact of these buffer zones peripheral to the federally managed and formally protected spaces of ENP and the Big Cypress National Preserve. When narratives and policymaking privilege some natural areas over others, the resulting power dynamic reinforces maladaptive practices as evolving communities celebrate an ahistorical (and disconnected) nature in South Florida as the antithesis of daily interaction in their own backyard. To the detriment of cultural landscapes, this conventional take on the environment reinforces a human:nature duality when wilderness narratives position us *outside* of its ontological boundary (1996, pp. 16–17). In time, I believe interventions such as those recommended in this research shift attitudes and management so places beyond those heavily guarded as natural areas count as "true" wilderness worthy of saving or appreciating.

Wilhelm, too, challenges the notion of wilderness in the Everglades when looking back to the formation of its modern concept as it revolved around a recreational, aesthetic, and spiritual resource—instead, "the Everglades was protected for biocentric reasons, a rationale for preservation typically thought of as a product of modern environmentalism" (2013, p. 153). A growing interest in restoring the GEE and other vast, wetland complexes in the past few decades established an inherent value beyond anthropocentric use; preservation for its own sake thus dominated the narrative of protected areas and their restoration when viewing its importance through the formal production of knowledge driving conservation initiatives in the Global North. This requires holistic reframing and relating to stakeholder ontology to inform more productive policy and improve socio-ecological outcomes at the local and regional scales. As Wilhelm warns us, "This wilderness was not to be a wilderness for people; this wilderness was for the birds" (2013, p. 157). Political ecology offers one pathway to ensure that Florida's Everglades—among other iconic conservation landscapes—do not break ties with the human element often critical to their continued vitality. Contextualizing the role of local environmental narratives within restoration activities is necessary to understand how shifting power relations, attitudes on wilderness, and management regimes resulted in the creation of this second nature in South Florida and beyond.

Chapter III | Monitoring South Florida's Boundary Lands: A Hybridized Geospatial Approach

3.1 INTRODUCTION

Within the United Nations Sustainability Goals, the Group on Earth Observation (EO) envisions an Anthropocene where open-access environmental data plays a crucial role in informing decisions and actions for the benefit of humankind, enabled by coordinated, comprehensive, and sustained Earth observation information and services. (GEO, 2019). This requires that complex, large ecosystem restoration projects occurring throughout Florida's Greater Everglades Ecosystem (GEE) have robust monitoring protocols. Monitoring—the routine empirical assessment of an area based on pre-determined metrics—is vital to ensuring that protected areas are effectively managed and remain on track to reach sustainable development and environmental restoration goals (RAMSAR, 2014; Durgan et al., 2020). Restoration monitoring in projects like the Comprehensive Everglades Restoration Plan (CERP) aligns community aspirations with EO technologies, fostering sustainable environmental policy and adaptive management in urban growth areas. (Thatcher et al., 2016; Hakimdavar et al., 2020). This chapter outlines the literature on EO technologies utilized to capture environmental data related to ecosystem restoration projects. I cover the background of field sites in the East Coast Buffer (ECB) region of South Florida and provide a workflow for integrating multiscale imagery. Results include summaries of land cover change in areas subject to restoration activities under CERP. I connect my research findings to summary metrics used by federal oversight committees, including the South Florida Ecosystem Restoration Task Force (SFERTF) in terms of their annual system-wide indicator reports.

Notable examples of global monitoring include tracking the changes in global forest cover (Hansen et al., 2013), tracking carbon stores in deltaic systems (Lagomasino et al., 2019), the effectiveness of agricultural practices (Weiss et al., 2020), mapping burned area globally (Chuvieco et al., 2019), water depth and flood monitoring (Kim et al., 2014; DeVries et al., 2020), and rapidly assessing the impact of storm events to coastal ecosystems (Mondal et al., 2022).T he development of dynamic, spatially explicit models of landscape transformation is necessary to link localized events, such as flooding and landcover shifts, with informed restoration decision-making across the region (Mayer & Lopez, 2011; Klemas, 2013; Taddeo & Dronova, 2018; Wilson & Norman, 2018). In ecosystem management, remote sensing is powerful because it allows researchers and ecosystem managers to chart fundamental ecological and hydrological dynamics of these restoration-related processes at multiple spatial and temporal scales. A hybridized workflow utilizing satellite and uncrewed aerial imagery enables the continuous and rapid monitoring of conservation areas as required to connect these international efforts in spaceborne technology with stakeholder needs—something that has proven difficult for most cases (Zhu et al., 2019). While current EO-based monitoring has been ongoing in CERP, much less attention has been given to multi-scalar approaches to provide a more holistic understanding of conditions in conservation lands outside of protected areas at the boundary of urban-proximate wilderness.

Because this place-based monitoring of buffer areas remains largely unexplored by academic institutions and the state agencies involved in Everglades restoration, I seek to bridge this gap in rapid monitoring to render an intuitive understanding of landscape changes at restoration sites accessible to the public. By integrating imagery acquired from satellites and uncrewed aerial vehicles (UAV), I examine how restoration activities affect the composition of vegetation communities in South Florida's boundary lands. These boundary lands include state-managed buffer areas and other projects under the Comprehensive Everglades Restoration Plan (CERP) positioned in close proximity to growing metropolitan areas such as the East Coast Buffer (ECB) in Broward and Miami-Dade Counties, Florida (Figure 3.3.1).

3.2 EO APPLICATIONS IN WETLANDS

3.2.1 *Vegetation*

In providing comprehensive and accurate data that can be used to manage ecosystems, remote sensing primarily observes spectral features across the landscape reflected as energy signatures. These captured data are separated into bands not unlike the red, green, and blue (RGB) bands stored in normal color images. Over time, band associations have been confidently associated with most land covers; including plants, water, and developed surfaces. To assist with decoding the context of pixels composed of multiple bands, EO analysts have developed indices of environmental quality to track the extent and quality of vegetation and water in various wetland contexts over the past two decades. Approaches taken by Wilson and Norman (2018) to monitor vegetation recovery in restored wetlands include modeling the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Infrared Index (NDII)—two indices calculated using the red, near-infrared, and shortwave infrared bands present in most satellite multispectral imagery products. Using NDVI and NDII, EO scientists can observe changes as vegetation responds differently due to variations in land use or from different restoration-related activities (chemical treatment, burning, and replanting) or even animal grazing and variations in the presence of water. Wilson and Norman (2018) confirmed the benefits of using erosion control structures up and downstream from restoration sites when these two indices indicated improved vegetative heath and water quality over the same period due to these landscape modifications. Alternative vegetation indices such as the Soil-Adjusted Vegetation Index (SAVI) and the Enhanced Vegetation Index (EVI) have been developed to track more sensitive changes to the soil in diverse environmental contexts given they better handle the bias introduced by brighter soils as well as accommodate for distortions from chlorophyll saturation when similar spectral patterns of light confuse more generalized classifiers (Sims et al., 2006; NASA, 2020; Laonamsai et al., 2023).

Restoring wetland ecosystems often involves more than just enhancing overall health and moisture levels; it may prioritize removing specific plant species (Yagci et al., 2017). Throughout CERP, vegetation monitoring has heavily relied on manually interpreting large-scale aerial photographs, which consumes considerable resources. Despite these setbacks, satellite imagery has provided a basis for tracking the abundance of invasive and highly problematic Melaleuca trees (*Melaleuca quinquenervia*) for decades in South Florida (Capehart et al., 1977; Arvanitis & Newburne, 1984; Gordon, 1998; Fuller, 2008; Omar et al., 2020). Melaleuca caused the most widespread negative impacts on both human settlement and wildlife in the Everglades due to its rapid proliferation via fire and its tendency to increase soil elevation, reduce water flow, and generally displace native species in the interior freshwater marshes (Gordon, 1998). Research by Fuller (2008) initiated the first use of high-resolution multispectral IKONOS imagery alongside the Normalized Difference Vegetation Index (NDVI) to help detect the presence of these invasive trees. Recent studies on detecting Asian Melaleuca forests have demonstrated that a composite approach, which integrates the Soil-Adjusted Vegetation Index (SAVI) with the standard green and near- infrared bands captured by most sensors, is most effective for land cover classification (Omar et al., 2020). For these reasons, both the NDVI and SAVI (formulae found in Table 3.3.2) are implemented in my remote sensing workflow to address variations in the spectral signatures of different vegetation communities across the GEE.

More recently, studies by Zhang & Xie (2014) and Wendelberger et al. (2018) demonstrated that machine learning approaches utilizing high-resolution commercial imagery could achieve high success rates (i.e.,>80%) when classifying plant communities in the Coastal Everglades. However, relying on these data still presents challenges when discerning among species-specific plant communities absent more spectral information or even sub-meter resolution imagery. These types of imagery come with higher financial costs than most local institutions (e.g. regional universities or non-profits) can afford. Presently, a lack of studies investigating long-term vegetation shifts in conservation areas across the GEE through comparable means hinders restoration monitoring andaffects the management of buffer zones. Duncanson et al. (2022) present a global perspective on aboveground biomass using light detection and ranging (LiDAR) data to provide four delineations for plant functional types, although scaling this to the study area\leaves primarily two classes (Deciduous Broadleaf Tree and Evergreen Needleleaf Trees) less relevant to vegetation communities of interest in the GEE; including marshes, forests, woodlands, and other types difficult to distinguish with LiDAR-based methods at a regional scale. This deficiency represents a significant critique of the current integration of EO research in South Florida in that management often prioritizes vegetation mapping or classification techniques, often stopping short of outlining their practical applications to connect ongoing field and aerial observations with Everglades restoration efforts positioned to benefit both human and natural communities (Turner, 2003; Braun, 2021).

3.2.2 *Hydrology*

Effective hydrological monitoring is crucial for understanding the hydroperiod (the duration water remains on the landscape) and hydropattern (the spatial extent of water) of subregions within the Everglades. This involves tracking the depth, duration, and extent of water using EO in tandem with water gauges to validate spectral phenomena associated with the presence of water. Remote sensing research has demonstrated significant advancements in water detection, playing a crucial role in environmental restoration. Studies have employed indices like the Modified Normalized Difference Water Index (MNDWI) and the Normalized Difference Moisture Index (NDMI) to monitor water dynamics and vegetation moisture, essential for evaluating restoration efforts. For instance, the MNDWI has been particularly effective in detecting water in areas with mixed land-water signatures, which is common in wetlands and restored habitats (Xu, 2006; Singh et al., 2014). Research has highlighted the importance of understanding hydroperiods and hydropatterns for restoration projects, as accurate water monitoring informs the management of hydrological conditions necessary for ecosystem recovery (Guo et al., 2017; Wilson & Norman, 2018). Additionally, remote sensing has been pivotal in identifying the impacts of abnormal flooding on restoration sites, helping to optimize restoration strategies and improve the resilience of restored environments (Omar et al., 2020). These studies underscore the integral role of remote sensing in supporting and enhancing environmental restoration practices.

While helpful to start tracking the behavior of water across dynamic wetland ecosystems, these methods are not without their drawbacks. Given the spectral noise associated with coarser resolution imagery, the edge detection of water features becomes occluded in many of these standard analyses. More recently, Laonamsai et al. (2023) demonstrated the improved detection accuracy of the Automated Extraction Water Index (AEWI) and the Water Ratio Index (WRI), two novel hydrological indices that offer additional spectral flexibility in cases where different bands are available (e.g., drone imagery in the case of shortwave infrared and thermal bands). The detection and extraction of the subpixel waterline and similar techniques also enable sensitive monitoring in inundated areas. Thresholding methods aided by machine learning can bridge the gap in resolution when open-access imagery acquired by Landsat does not normally afford the precision necessary to track subtle changes (Donchyts et al., 2016; Bishop-Taylor, 2019; Vos et al., 2019).

Other tools exist to assist with initial management concerns. more conventional product also derived from Landsat-8 used to capture the extent of water is the Dynamic Surface Water Extent (DSWE), an optically derived product of "surface water inundation as detected in the cloud-, shadow-, and snow-free pixels" (USGS, 2020). This tool is composed of high-temporal resolution hydrologic products published by the United State Geological Survey (USGS) with several applications ranging from wetland delineation to flood-risk and inundation mapping, both of which are relevant to the monitoring needs of my research. Capturing the full range of these hydrologic dynamics in shallow, densely vegetated wetlands common in urban-proximate wilderness areas is essential to quantify the localized effects of restoration because even subtle alterations slowly impact the region in ways that are difficult to quantify from the ground or even through conventional aerial survey.

3.2.3 *Uncrewed Aerial Vehicles*

Spectral information at finer spatial scales aids in validating and understanding the dynamics of seasonal phenomena and can highlight the effects of recent management actions, enhancing decision-making (Quamar et al., 2023). Because not all satellites and the onboard sensors used to record images from above are created equally, researchers have begun reconciling with trade-offs in the spatial resolution and timing of imagery collected through uncrewed aerial vehicles (UAVs)—referred to commonly as *drones*—to bolster monitoring techniques in wetland ecosystems (Boon, 2016; Gray et al., 2018; Safa et al., 2019). The uncrewed aerial *system (*UAS) differs in its designation in that it refers to the entire system, including the UAV, GPS instruments, and flight control console operated by a remote pilot. López & Mulero-Pázmány (2019) identified five areas of UAV implementation in protected areas, including wildlife research and management, ecosystem monitoring, law enforcement, and disaster response; although the wider conservation benefits "remain fundamentally unexplored" (2019, p. 1). Less explored benefits in the literature could include expanding the best practices in UAS-based conservation through experimentation into novel territory such as rapid restoration monitoring. Research protocols should, therefore, advance with the pace of technological development and the policy to ensure EO technology can better realize the five beneficial areas at local scales (Freeman & Freeland, 2019).

Today, UAV imagery addresses a critical need to rapidly capture and assess conditions in sensitive terrestrial and aquatic areas where conventional EO techniques fail to perform. While their territorial reach is limited by battery life and access rights, Gray et al. (2018) showcased the strength of UAV imagery to train and validate data achieved from satellite platforms in the Rachel Carson Preserve, NC, USA. It is important to emphasize a hybridized multi-scalar workflow in the context of my project because UAV imagery addresses a critical need to rapidly capture and assess conditions in sensitive terrestrial and aquatic areas, although some limits remain for conservation applications. As of 2024, many restrictions remain in place for utilizing UAVs federally protected areas (NPS, 2017; 36 CFR 1.5, 1986). Over the past decade, there has been a significant increase in UAV-based research for wetland management and conservation. Jeziorska (2019) provides a comprehensive review of UAS applications in wetlands, covering UAS hardware, software, regulations, and best practices for data collection and imagery processing. Nearly all applications utilize sensors that capture visible spectrum light, not only for the higher resolution of UAV imagery but also because of the distinct differences in the reflected energy of vegetation, water, and their combinations. In estuarine environments, Gray et al. (2018) successfully integrated UAV imagery with satellite data, enhancing overall model accuracy through the training and validation of commercial satellite imagery. Similarly, Díaz-Delgado et al. (2018) harmonized UAV imagery with Sentinel-2 bands, enabling effective ground-truthing of inundation mapping and ensuring scalable hydrologic monitoring at long-term social-ecological research sites (LTSER) in Europe.

More recently, Durgan (2020) evaluated the use of UAVs in the restoration and management of the coastal Everglades, highlighting tradeoffs for various modeling goals. Her research demonstrated that flight configurations impact data quality depending on the objectives of wetland surveys. These studies above suggest a workflow where open-access satellite data initially identifies sites of interest that can be used to plan UAV surveys which serve to "zoom in" on phenomena less obvious at coarse spatial scales. By connecting drones with traditional EO technology, including aerial survey and satellite imagery, hybridized high-resolution datasets that detail patterns of hydrology and vegetation.

3.3 METHODOLOGY

3.3.1 *Site Descriptions & Regional Significance*

After the ENP Protection and Expansion Act of 1989 was passed, the eastern limits of Everglades National Park (ENP) were expanded. Consequently, the federal government acquired the area used for small-scale agriculture, rural housing, and eco-tourism adjacent to the east coast perimeter. These lands were originally connected by the Everglades' two key hydrologic conduits—Shark River Slough and Taylor Slough—with the latter's influence visible in the orientation of tree islands running north- south in Water Conservation Area (WCA) 3 (Figure 1), along with critical environmental space prioritized for its habitat connectivity beyond the expanding Ft. Lauderdale- Miami Metropolitan Area (Blyth, 2017). The South Florida Water Management District (SFWMD)—the state agency charged with leading Everglades Restoration—established the ECB over several periods of land acquisitions spanning the 1980s–2010s. As stated in their Land Management Plan, the mission was to increase the aquifer recharge rate to secure the storage of water, "protect urban drinking water wellfields [and] enhance the water supply for the Everglades to provide recreational opportunities" (SFWMD, 2006: p. 2). As of 2022, the ECB encompasses 5,730 hectares (ha) running north-south through Palm Beach, Broward, and Miami-Dade counties as 10 units (Figure 1).

Two of these units (Pennsuco Wetlands and Frog Pond) along with a third site positioned within WCA-3B) are the location of UAV surveys I conducted to visualize and validate restoration activities (see Figure 11), such as vegetation treatment and shifting the conveyance of water, at the site level The third site (Mack's Fish Camp) is on private property and serves as one of the last Gladesmen outposts east of Shark River Slough and remains important today for its local role in ecotourism. "Outposts" describe isolated dwellings or semi-permanent structures culturally important to South Florida's recreational Community because they enable access to interior wetlands in the Everglades and continue serving as important conduits for field trips used by recreational advocates to educate policymakers in the GEE (pers. comm., 2023).

I selected the Pennsuco Wetlands, Mack's Fish Camp, and Frog Pond to conduct UAV surveys for this study. All three sites vary in land cover, land use, and hydrology. The Pennsuco Wetlands and Frog Pond belong to the State of Florida, although Pennsuco was mostly characterized by invasive Melaleuca forests and restricted waterflow. Today, their extent has been successfully limited in portions of Pennsuco according to the record and as is visible from my UAV survey (SFWMD, 2023). Frog Pond is open to recreational use adjacent to ENP with more tree islands (isolated patches of upland plant communities surrounded by marsh) and bears a different assemblage of invasive plant species (see Table

3.3.1) (SFWMD, 2006; SFWMD, 2023). These field sites all represent ecologically degraded wilderness areas where restoration activities continue to modify the local hydrology and botanical composition to restore historic vegetation communities and hydrology or more ecologically resilient conditions. Table 3.3.1 details the species of concern (e.g., Melaleuca and Brazilian Pepper), treatment methods, and the date of restoration activities as determined by the SFWMD (2023). Due to their access by roads, these three sites were excellent candidates for the collection of UAV imagery as they showcase recent restoration activities that occurred at various stages of CERP These ECB sites also demonstrate variability in their land cover, a historical role for human communities, and enabled an efficient comparison of diverse land use gradients within the survey ability of the P4M drone chosen to acquire high-resolution imagery.

The long-term plans by the State of Florida for these buffer zones remain unclear. Chemical and fire treatment data, alongside interviews conducted with agency staff, indicate ongoing management of these lands in perpetuity (pers. comm., see Table 3.3.1). Land acquisition by the state remains ongoing as many private properties located in ECB components are beyond the control of former residents, where land scraping to lower artificial development on formerly owned private parcels and the removal of exotics is prioritized by the SFWMD and the Army Corps. Without more public involvement and access to these buffer areas as they recover, monitoring their progress in the wider picture of Everglades restoration remains disconnected absent a multi-scalar integration. Despite the weight placed on restoration activities and environmental planning in CERP, "it might be too late for changing land use," according to one hydrologist at a key environmental NGO in the region (pers. comm., 2023). For CERP goals, "sending water south" is the primary answer to rehydrate ENP and mitigate flooding despite changes introduced by reservoir flows in the northern system, all further compounded by shifting environmental baselines under climate change. To capture shifting conditions using multi-scalar imagery capturing landscapes at the interface of South Florida's protected areas and built environment, this project seeks to answer the following research question: *How will conservation buffer areas in South Florida alter due to restoration activities?* (RQ2). To understand these shifts, I analyze five eras of land cover changes in the ECB Region to visualize the effects of ongoing restoration activities better). The functionality of these boundary lands provides essential natural and cultural ecosystem services, and their role will become increasingly important as Everglades restoration progresses under a changing climate (Smith, 2022; Florida Climate Center, 2024).

SITE NAME	SUBREGION	SPECIES COMPOSITION	TREATMENT	TIME PERIOD
Mack's Fish Camp	WCA-3B	*Melaleuca sp., Schinus sp.*	Chemical	2013, 2015, 2016, 2021
Mack's Fish Camp	WCA-3B	N/A	Wildfire	2014
Pennsuco Wetlands	ECB	*Melaleuca sp.*	Chemical / Hack / Aerial	1998–2016, 2018, 2020, 2021
Pennsuco Wetlands	ECB	*Melaleuca sp.*	Fire / Wildfire	2011, 2014, 2015
Frog Pond	ECB	*Arundinaria, Salix, Pennisetum*	Chemical / Hack	2003, 2007, 2008, 2012–2014, 2016, 2018–2021
Frog Pond	ECB	Various	Fire / Wildfire	2011

Table 3.3.1 Vegetation treatment/event summary for UAV sites cataloged using spatial data analyzed using geographic information systems (SFWMD, 2023).

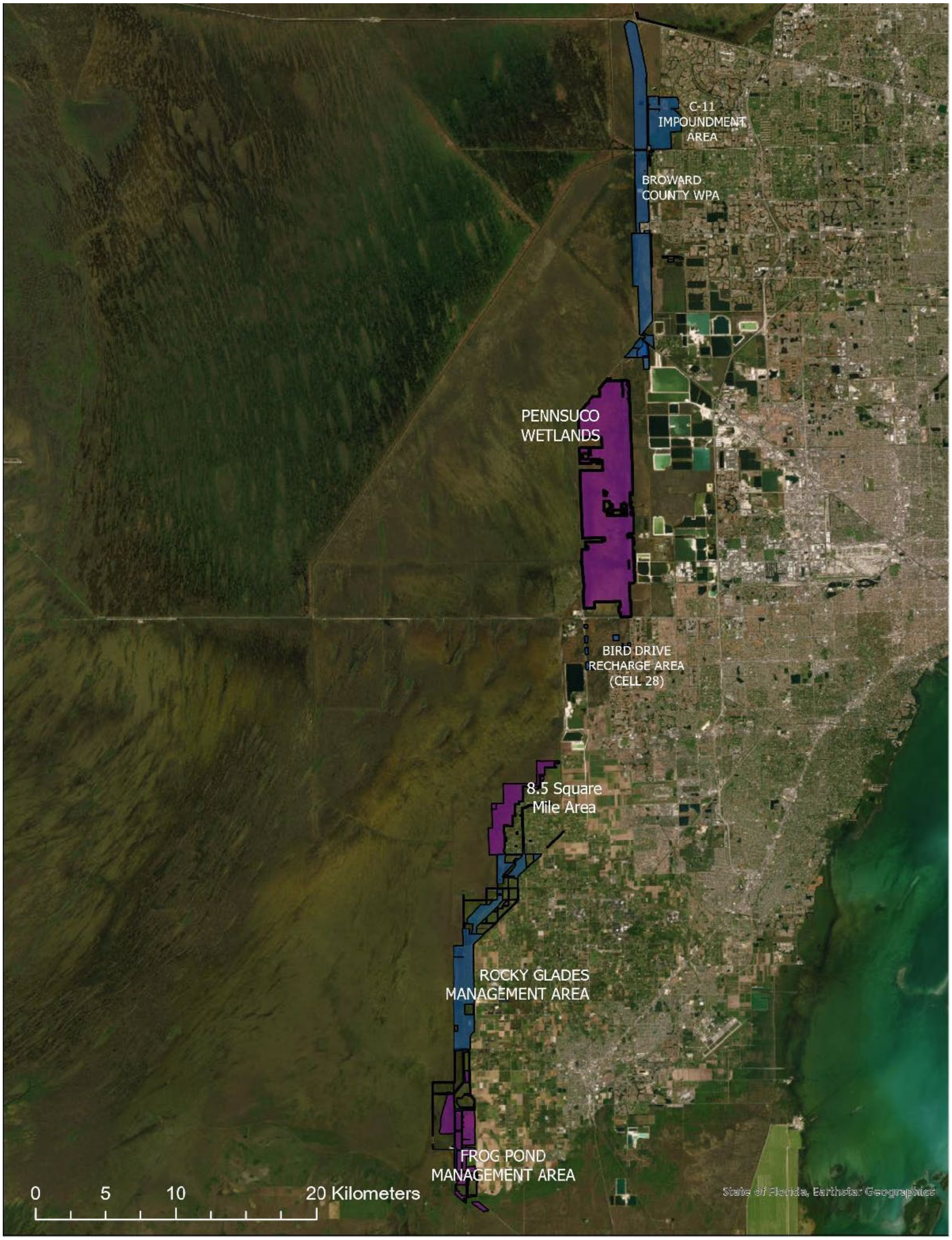


Figure 3.3.1 South Florida's East Coast Buffer. Positioned between the expanding Ft. Lauderdale-Miami metropolitan area and the remaining GEE, these managed areas represent ecosystem restoration sites along the edge of the built environment. Purple zones correspond to buffer sites mentioned in this research.

3.3.2 *Datasets & Analysis*

There were two primary sources for the imagery analyzed in this research. Initially, I acquired imagery via UAS in May and July 2023 using the Phantom 4 Multispectral Sensor (P4M) (DJI, Shenzhen, China). In the following spring, satellite imagery was downloaded for the Landsat 7 TM+ and Landsat 8 OLI sensors using Google Earth Engine (GeE). All satellite imagery ranged from 1999–2023 as this overlaps with the ratification of CERP and was, therefore, necessary to establish a baseline for tracking restoration activities associated with CERP as observed across South Florida. Until the past decade, many tools were not available to achieve the efficiency of analysis or foster collaborations using their cloud-based computational resources. GeE is unique in that it works with an open-source integrative development environment powered by JavaScript and that it draws data from a petabyte-scale catalog of global satellite imagery alongside other land use and other compiled datasets (Gorelick et al., 2017; Google, 2023).

This satellite imagery dataset was gathered to create a near-seamless time series of cloud-free, enhanced imagery for southeast Florida, allowing me to study the structure and change of vegetation communities and hydrologic variability. In general, spectral comparisons between different sensors are possible because of their close alignment but depending on the specification of the UAV and its sensor payload, some discrepancies exist beyond the spatial resolution alone (Gray et al., 2018). For this investigation, the spectral bands between the data from both Landsat missions (7 and 8) correspond to allow harmonization for use as a consistent product (TM+ does not have a Coastal Aerosol band for instance, the designation for Band 1 on OLI). The P4M utilizes similar bands (Blue, Green, Red, and Near-Infrared) but differs in its lower spectral resolution while adding the Red Edge band. Frampton and colleagues (2013) define this relatively novel spectral feature as positioned between the red absorption and near-infrared reflection peaks, an inclusion in more stable indices key to decoding finer responses in the chlorophyll production by plant species. As Durgan (2020) more recently demonstrated, successfully mapping vegetation communities within the GEE is viable at fine spatial scale using UAV imagery with limited spectral bands.

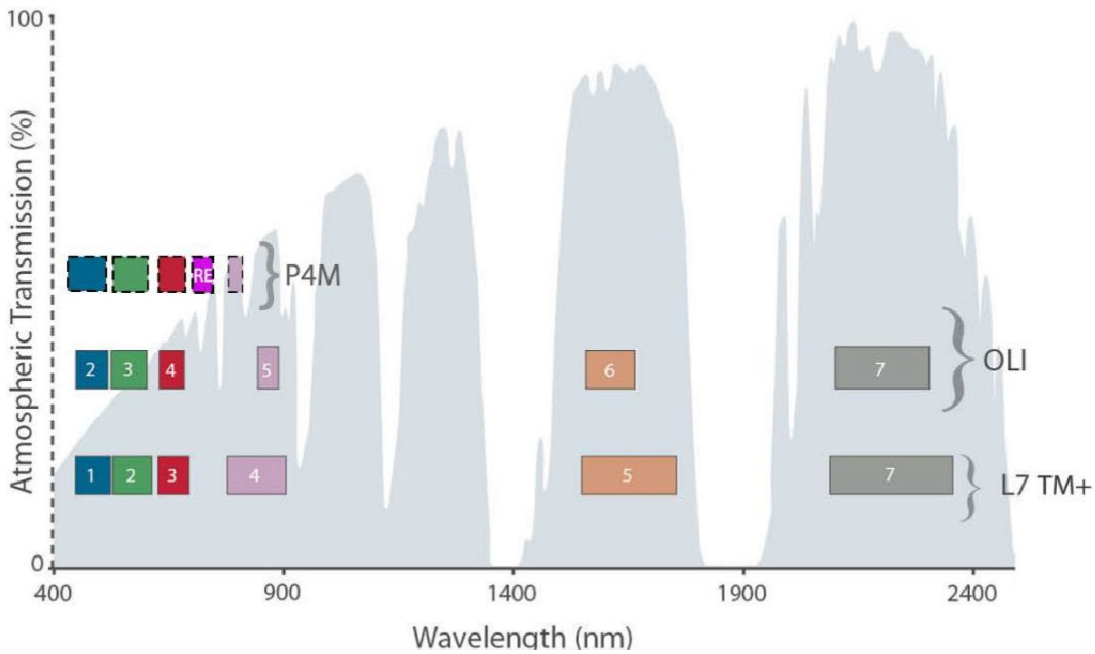


Figure 3.3.2 Band frequency (corresponding to bands 1–7) comparison for the sensors used on Landsat 7 (TM+), Landsat 8 (OLI) and the Phantom 4 Multispectral (P4M, 'RE' = Red Edge) (modified from NASA, 2012).

3.3.3 *Landsat imagery processing*

Preprocessing satellite imagery in GeE typically involves several standard steps starting from the reflectance data to ensure the end data are clean, accurate, and ready for analysis. The following workflow details steps taken to arrive at the final imagery layers used for my analysis of landcover change in the ECB Region. The surface reflectance data derive from the Level 2 Collection 2 for Landsat 7 and 8 (Crawford et al., 2023). All processing below was conducted using GeE's Application Programming Interface (API) (https://code.earthengine.google.com/). These steps describe how I develop the time slices (n = 5) used to classify landcover in the ECB Region of South Florida using open-access functions in Google's online platform (Amani et al. 2020; Gorelick et al., 2017; Wang et al., 2020). A primary consideration for the integrity of this imagery comparison is ensuring spectral consistency between the two sensors aboard Landsat 7 (ETM+) and Landsat 8 (OLI).

Data Selection: I collected satellite imagery based on the spatial and temporal resolution required for analysis, which included Landsat 7 TM+ and Landsat 8 OLI using their Blue, Green, Red, Near-Infrared, and two Shortwave Infrared bands (SWIR and SWIR2) see Figure 8 for a visual comparison). Because the OLI has enhanced radiometric resolution and utilizes narrower wavebands than the ETM+, I first must harmonize the two datasets prior to making an accurate temporal record following the Roy et al. (2016) technique of quantitative spectral reflectance using top of atmosphere reflectance values for calibration, as well as the root mean square difference between overlapping sensor observations and the reduced major axis regression. This allowed me to align six spectral bands (blue, green, red, near infrared, shortwave infrared 1, and shortwave infrared 2) of high agreement between both sensors in a way that enables the generation of continuous time series.

Filtering and Masking: All images were filtered to the region of interest, effectively encompassing South Florida from Lake Okeechobee south to Florida Bay with a date range of 1999–2021 focus on specific time periods. After defining an algorithmic cloud masking function using the QA_PIXEL band to identify minimal cloud cover in images (i.e. <10%) and thereafter filtering for pixel saturation with the QA_RADSAT band, I was left with a series of clear images from L7 and L8 totaling in 290 Landsat scenes or radiometrically corrected cloud- and glare-free imagery.

Image Enhancement: This includes adding additional bands to each image in the form of index calculation for my vegetation indices (e.g., NDVI & SAVI), water indices (e.g., NDWI & AEWI), that now gave each scene 10 bands in total. These were important to include because existing band data (n = 6) cannot adequately train robust machine learning classifiers. The combination of bands alongside remote sensing multiple indices is necessary because indices enhance and often provide meaningful information about specific characteristics of the surface features. Using an index with individual bands also helps to reduce redundancy in overlapping band information, enhance the single-to-noise-ration by normalizing data, and improve the overall robustness of the model, especially when utilizing ensemble methods in machine learning (Saini, 2022).

C*ompositing and Mosaicking*: The final transformation of this imagery collection was delineating the total series of scenes into five time slices that correspond with five-year intervals of Everglades restoration. I chose the years 2000, 2005, 2010, 2015, and 2020; although these time slices themselves represent average pixel values taken across a two-year imagery collection (i.e. "2005" corresponds to imagery collected from 01/01/2004–01/01/2006. I created composite images by averaging or selecting the best pixels over a period (e.g., median, maximum, average) to reduce noise and gaps. Mosaicking involves merging multiple images to create a seamless mosaic of the area of interest. In this case, the above time slices and their sources image counts are 2000 or "L7A" (n = 33), 2005 or "L7B" (n = 41), 2010 or "L7C" (n = 42), 2015 or "L8A" (n = 88), or 2020 = "L8B" (n = 86). The final scenes, therefore, consist of only five composite scenes corresponding to the years 2000, 2005, 2010, 2015, and 2020.

Land Cover Classification: Using the Random Forest Classifier (Google, 2023) to detect pixels belonging to six land cover classes (Marsh, Upland Forest, Upland Woodland, Wetland Shrubland) with the two classes selected manually using visual interpretation (Open Water and Anthropogenic/developed Area). The training data was provided by the SFCN from maps created using high-resolution aerial imagery and digital aerial sketch mapping conducted in 2016 (Ruiz et al., 2017). After using GIS to export this land cover dataset into my GeE repository as separate classes, I manually selected from these layers of categorical vegetation data area of pixels that overlapped with my Landsat scenes as individual polygons to use for training data. The polygon counts for each land cover class and their pixel area in square kilometers are as follows: Anthropogenic (n = 50, pixel area = 273.10 ha), Freshwater Marsh (n = 50, pixel area = 3757.59 ha), Open Water (n = 30, pixel area = 900.01 ha), Upland Forest (n = 30, pixel area = 174.80 ha), Wetland Shrubland (n = 30, pixel area = 294.37 ha), Wetland Scrub (n = 30, pixel area = 373.80 ha). The relative area of training data for each land cover class changes according to the availability of training data (i.e. classes such Open Water and Freshwater Marsh are well represented in this region with more homogenous areas compared to isolated patches of Upland Forest).

Exporting: The final step was exporting the images to GeoTIFF format for further GIS processing using ESRI's ArcPro. This enabled comparison with other datasets to corroborate the modeled results with UAV imagery and delineate three areas in the ECB region along a north–south gradient of adjacent (anthropogenic) land uses: residential, industrial, and agricultural (Figure 12). I explain the subsequent further delineation of these land uses into three socio-ecological ecotones (Protected, Buffer, Anthropogenic) to establish the nine zones finally used for my modeling (Section 5.4.3).

Index	Abbreviation	Formula
Normalized Difference Vegetation Index	NDVI	*(NIR – R) / (NIR + R)*
Soil Adjusted Vegetation Index	SAVI	*((NIR – RED) / (NIR + RED + 0.5)) * (1.5)*
Modified Normalized Difference Water Index	MNDWI	(GREEN - SWIR1) / (GREEN + SWIR1)
Automatic Extraction Water Index	AEWI	BLUE + 2.5 × GREEN − 1.5 × (NIR + SWIR1) − 0.25 × SWIR2

Table 3.3.3 Spectral indices used for mosaic images.

All layers of spatial information in this chapter were created, processed, and visualized using ESRI's ArcPro GIS 3.2 (Environmental Systems Research Institute, Redlands, USA). Other spatial datasets utilized in this research include as inputs for my training data include a vegetation map for ENP provided by the South Florida & Caribbean Monitoring Network (SFCN) to help select training data pixels for the land cover classification and a land cover/land use database updated during 2017– 2019 for South Florida (Ruiz et al., 2017; SFWMD, 2019). Figure 9 depicts an idealized workflow for rendering ecohydrological conditions of South Florida buffer sites. In this workflow, GeE exported all resulting layers as TIF images with geographic information embedded to help with processing using GIS-based methods. Strictly speaking, these layers are merely transforms of data and should not be interpreted by users as literal maps of vegetation or water given the real-world constraints of any model application, although these results correspond well with real-world land cover or hydrology upon further validation.

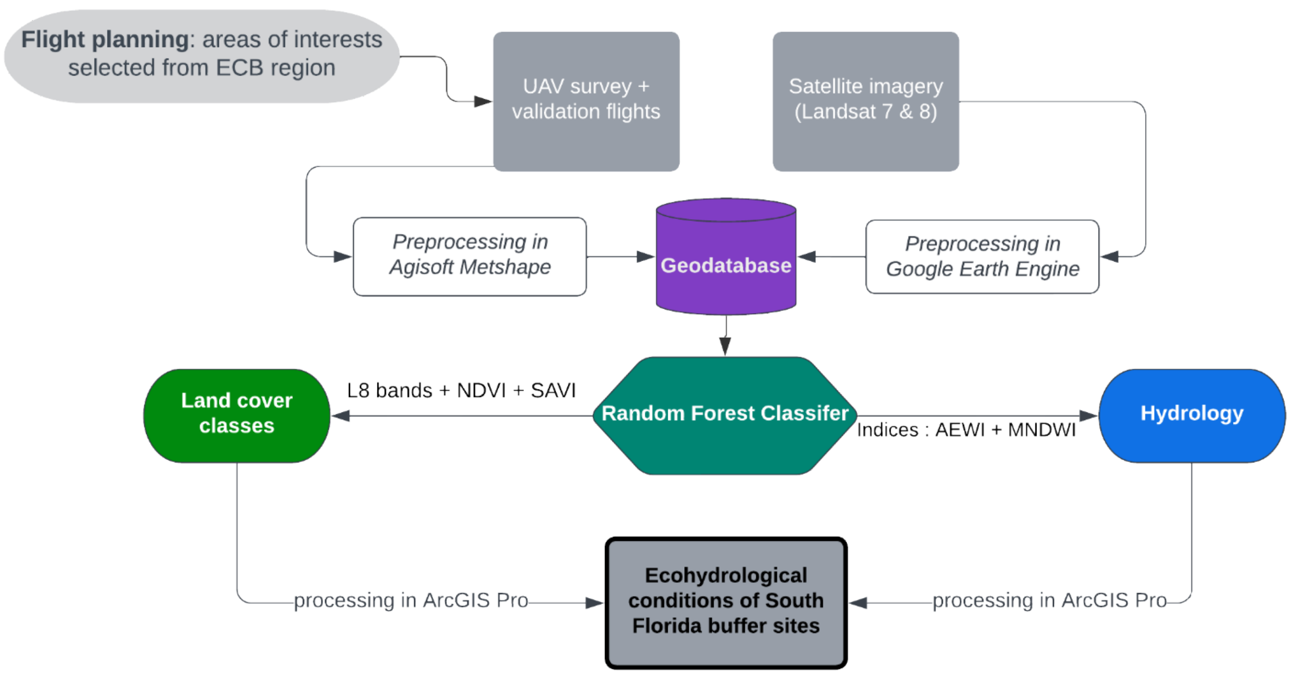


Figure 3.3.3 Geospatial workflow. This indicates how spatial datasets render the environmental conditions observed across the buffer sites of interest.

All layers of spatial information in this chapter were created, processed, and visualized using ESRI's ArcPro GIS 3.2 (Environmental Systems Research Institute, Redlands, USA). Other spatial datasets utilized in this research include as inputs for my training data include a vegetation map for ENP provided by the South Florida & Caribbean Monitoring Network (SFCN) to help select training data pixels for the land cover classification and a land cover/land use database updated during 2017– 2019 for South Florida (Ruiz et al., 2017; SFWMD, 2019). Figure 9 depicts an idealized workflow for rendering ecohydrological conditions of South Florida buffer sites. In this workflow, GeE exported all resulting layers as TIF images with geographic information embedded to help with processing using GIS-based methods. Strictly speaking, these layers are merely transforms of data and should not be interpreted by users as literal maps of vegetation or water given the real-world constraints of any model application, although these results correspond well with real-world land cover or hydrology upon further validation.

In total, five UAV-derived orthomosaics were created during the end of the dry (n = 3) and beginning of the wet seasons (n = 2) (only the Pennsuco Wetlands and Mack's Fish Camp) due to weather constraints. Each survey covered an area of approximately 15 hectares (ha) with an average flight speed of <5 meters (m) per second, 50 m above ground level altitude, with vertical and horizontal overlaps of 80% and 70%, respectively. In general, a low sun angle (<60°) less cloud cover, and storm-free horizons enable the production of high-quality models; thus, all flights took place approximately halfway between sunrise and solar noon during overcast or sunny conditions when no precipitation was present. After I used all four batteries during a site visit, the data were migrated from a micro-SD card to a hard drive for later analysis. Some of the orthomosaic extents for corresponding surveys did not align perfectly or contained holes (Frog Pond and Mack's Fish Camp in the dry season), thus, direct comparisons for seasonal hydrologic fluctuation were not feasible. Following a visual validation of UAV images, I uploaded, aligned, and generated a photogrammetric dense cloud using Agisoft Metashape Professional 1.6 (Agisoft LLC, St. Petersburg, Russia.), which utilizes the structure from motion algorithm to generate an image- textured, (three-dimensional) 3D mesh from overlapping two-dimensional (2D) imagery data (Schönberger et al., 2016). I utilized the following five steps to generate orthomosaics of my three fields:

1) *Import Photos*: imports photos for a given survey, allows further removal of repeat or blury images and other artifacts encountered during the data acquisition phase.

2) *Align Photos*: stitches together photos to create a sparse point cloud (all parameters set to "High") which generates an approximate shape of your model to form. From here, I refined the sparse point cloud by filtering for points using *Gradual Selection*, with an additional step of *Optimize Camera Alignment* in between each filtering process.

3) *Build Dense Point Cloud*: generates a dense point cloud (3D mesh) from the aligned photos to effectively "fill" out the spare point cloud rendering a low-resolution 3D model.

4) *Build Texture*: generates a high-resolution textured model from imagery data.

5) *Build Orthomosaic:* creates an ortho-rectified mosaic from all images using the 3D mesh and texture data to produce a seamless, high-resolution image necessary for mapping.

This is necessary to create each site's 3D models, which are vital to landscape visualization at perspectives more relatable to those on the ground or viewing from low-altitude flights. 3D models are also necessary to produce orthomosaics, the multiband, high-resolution, geometrically corrected composite images for orthomosaics utilized in site visualization and predict site-level land cover predictions to validate the Random Forest classification performed in GeE. Figure 10 below showcases an example of the photogrammetric models produced for the Pennsuco Wetlands site. In contrast, Figure 11 indicates the region where each site is in addition to an example orthomosaic juxtaposed against the site using coarser Landsat 8 imagery. While Figure 10 provides a perspective view of the Pennsuco Wetlands, Figure 11 highlights this survey in the context of the region and compares the stark differences in spatial resolution.

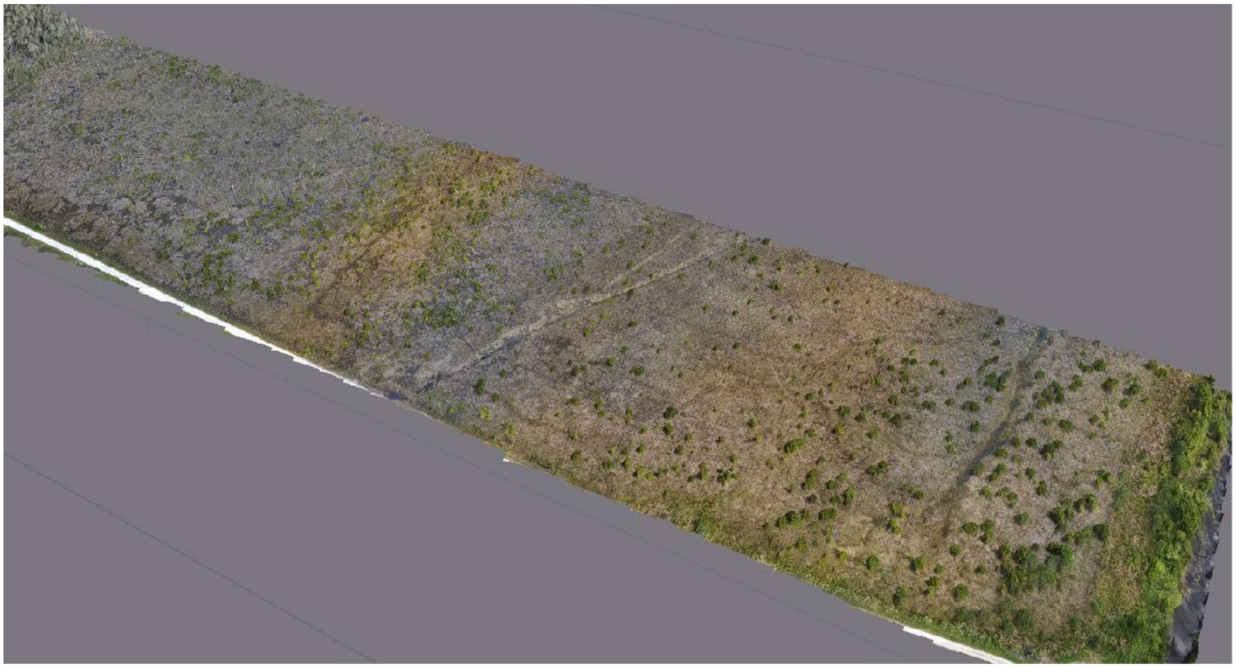


Figure 3.3.4 3D landscape model (aerial) of the Pennsuco Wetlands in Agisoft Metashape. This provides a unique landscape perspective helpful to understanding community patterns and local physiognomic structure.

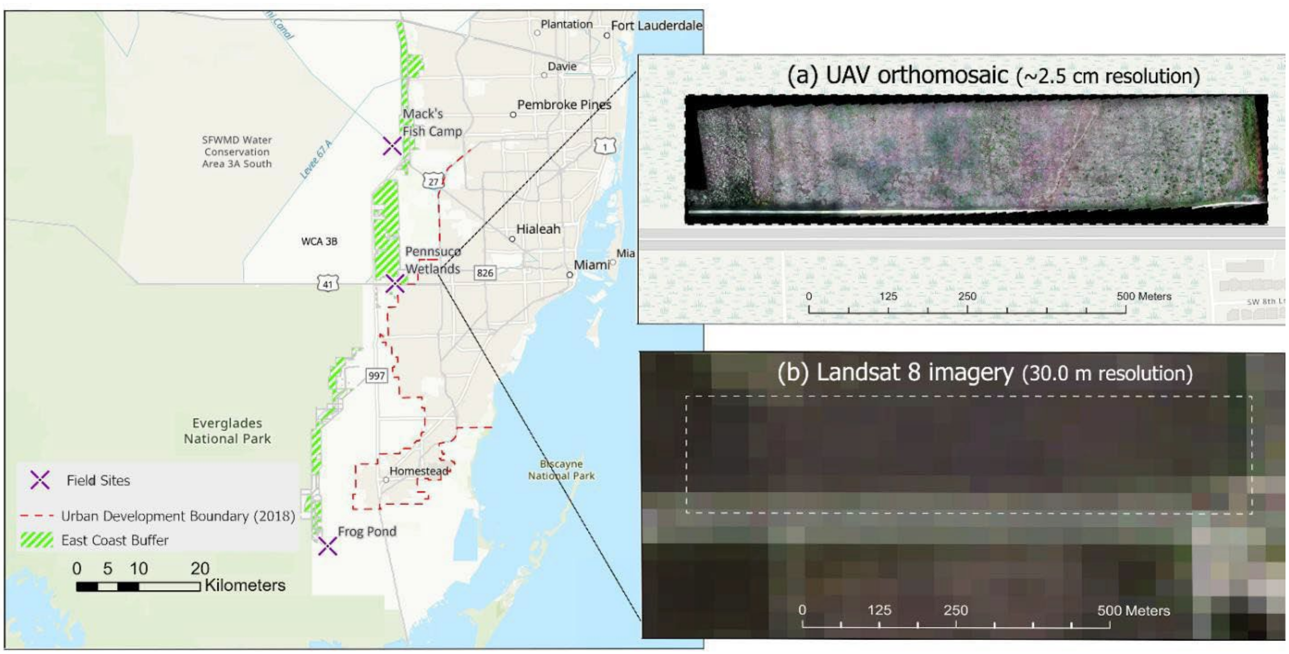
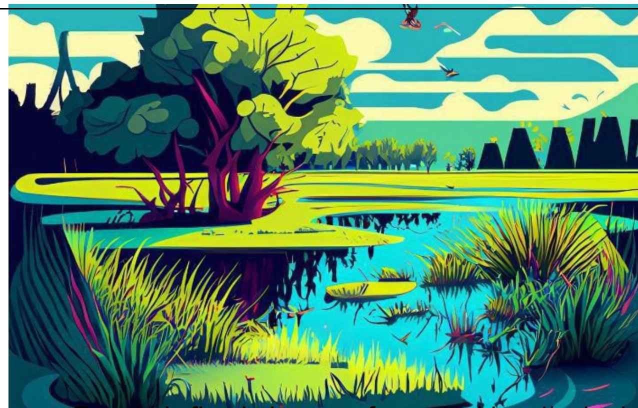


Figure 3.3.5 UAV fieldwork region with three sites indicated by purple X. (a) UAV orthomosaic of the Pennsuco Wetlands with (b) OLI satellite imagery of identical area for resolution comparison.

In essence, monitoring the progress of sites involves developing a protocol to measure these indicators against a control. What past conditions are the intended target? Over a century since initial major drainage attempts in the GEE and almost seven decades since the drainage and development radically transformed South Florida's surficial hydrology, presenting uncertainty for environmental baselines (Ogden & Davis, 1994). My analysis is key to independently measuring and understanding the long-term effects of 20+ years of ongoing restoration activities, as detailed in Table 3.3.1.

3.3.1 *Land Change Modeling: GIS layer preparation*

This project utilizes a hierarchical classification system developed by Rutchey et al. (2006) for use in the Everglades restoration footprint and the Florida Keys. This is known as the Vegetation Classification System for South Florida Natural Areas (Ruiz et al. 2017). Land cover classification for the ECB first required data to train the random forest algorithm in GeE (Breiman, 2001). Due to the spatial and spectral limitation of coarse resolution (30-meter) open-access satellite imagery, this analysis cannot accurately detect assemblages smaller than 0.09 ha or intermixed vegetation communities of multiple species. Therefore, I reduced the vegetation classification for ENP ecologically from 129 classes at Level 6 or 7 (L7) to 13 classes at Level 2 (L2) based on the NPS designation (Ruiz et al., 2017). This reduces the complexity (and rareness) of classes such as "Short Sawgrass Marsh-Dense" (L6) into the simplified L2 designation "Freshwater Marsh." After cross-walking the landcover classes to reduce the level of ecological detail and following the removal of vegetation classes underrepresented in the training data, my final land classification set consists of seven classes that correspond largely to L1 designations—the lowest level detail based on dominant physiognomy and structure provided by the recent vegetation map of ENP utilized for this analysis (Ruiz et al., 2017). Physiognomy refers to the general appearance of a landscape or its scenic quality and distinguishes fundamental types recognized by non-experts.

Freshwater Marsh	1	 Regularly flooded areas of graminoid and/or herbaceous vegetation	1812.9
Upland Forest	2	 Stands of trees (>5 m) that are of high density (>50% cover)	696.48
Wetland Woodland	3	 Briefly flooded low-density stands of trees	58.57

Wetland Shrubland	4	 High density Shrubs (<5 m) adapted to regularly flooded conditions	486.68
Wetland Scrub	5	 Low density Shrubs adapted to regularly flooded conditions	655.44
Anthropogenic	6	 Developed and cultivated surfaces such as roads, buildings, agricultural land & other infrastructure	9.14

Open Water	7	 Freshwater absent emergent vegetation or other structure	N/A*

Table 3.3.5. Land cover classes utilized and the corresponding area (ha) in ENP. I chose training pixels visually and confirmed with land use data (SFWMD, 2017). All example images were created with generative AI using Adobe Express in January 2024, using the class titles and the underlying description as prompts (Adobe, 2023).
* Omitting a measure for Open Water because training data from in ENP spectrally contrasts from freshwater color found throughout GEE.

While it is possible to utilize the finer-grained land classification levels (Level 4+) with higher-quality commercial satellite imagery, the financial limitations and complications encountered in acquiring that quality of data challenge the requirements of this open-access modeling framework (Boyle et al., 2014). Incorporating a classification scheme of the low ecological resolution, machine learning algorithms, and other classifiers in GeE significantly improve their detection of land cover in visible and infrared bands available through the multispectral imagery of Landsat or DJI's P4M drone (Cooper et al., 2021). Again, he allocation of training and test data came from splitting layers of vegetation data initially derived from the updated vegetation map for ENP created by Ruiz et al. (2017) into training and validation polygons. I used ArcPro in this geospatial processing, where the cells were dissolved and all vegetation classes were assigned to their L2 designation, leaving seven classes that stand out structurally and spectrally in the ECB. Land cover classes were characterized by their surface reflectance in the conventional Landsat bands, including Blue, Green, Red, Near-Infrared, SWIR 1, and SWIR 2, as well as the four indices mentioned in Section 6.3 (NDVI, SAVI, MNDWI, and AEWI) totaling 10 bands of spectral data. In GeE, I utilized Landsat 7 and Landsat 8 imagery spanning the history of Everglades restoration *(~1999--today)* into the random forest classifier. This works by splitting the machine decision-making into multiple decision "trees" that together resemble a forest (Breimen, 2001; Fawagreh et al., 2014).

I exported the training polygons from the SFCN map (Ruiz et al., 2017) containing pixels from the 2015 time slice into GeE and used them to train my random forest model using one of five time slices: 2000, 2005, 2010, and 2020 as detailed in the data analysis section (5.4.1). These

composites constitute 10 bands (spectral bands with indices detailed in Table 3.3.3 above). Training, therefore, took the pixels assumed under the training polygons for 2015, given the temporal proximity to the ENP vegetation map, and set the basis for classification applied to all five years with approximately half of all polygons used for validation in GeE. Due to issues with these polygons overlapping with comparable vegetation close to the ECB, I measured the final accuracy of this classification through a confusion matrix (Table 3.4.2) that compared 100 randomly generated points with high-resolution Google Earth imagery (McHugh, 2012).
I developed the following workflow to integrate the spectral data from my satellite imagery into the appropriate zones to use the Change Detection Wizard in ArcPro:

1) *Add Data* – opens the geotiff imagey (.tif) in ArcPro as *single* R, G, and B bands.

2) *Combine* (spatial analyst) – separately adds RGB bands to create a new feature layer.

3) *Reclassify* – changes the pixel value so they match the classification.

4) *Extract by Mask* – retains only the data found in the desired area and extent.

5) *Add Field* – associates the RGB combo classes as landcover types.

6) *Change Detection Wizard* – uses two time slices of text-based fields – select 'Categorical Change', Filter Method = 'ALL', – Save Result = 'Feature Class'

7) *Dissolve* – Each attribute table dissolves by Field = 'Classname' to summarize class changes (or lack thereof) across the area.

8) *Export Data* – Exports a table of the change detection analysis foreach year – Use '.csv' file ending or it will not write.

Nine unique zones were delineated within the ECB to test the effectiveness of restoration activities affecting the patterning of vegetation and hydrology. These zones contain buffer units established by SFWMD as well as take into consideration the ecotone established between predominantly three contrasting land uses in South Florida running north to south: residential, industrial, and agricultural, as the following map indicates through the delineation of nine zones. Beyond the buffer components managed by SFWMD South of the Broward Levee, the modeling area here extends outwards in a 2.5 km buffer on all sides. The eastern area overlaps directly with the three anthropogenic land uses with the westward stretch covering protected natural areas, including ENP and WCA-3B, effectively serving as the control. This zonation produces two north-south interfaces—the boundary between protected (untreated) area and the ECB and the boundary juxtaposing the ECB with the anthropogenic areas of Broward and Miami-Dade Counties—effectively separating three functional areas within the ECB region: "Protected Area" (zones 1, 4, and 7), "Buffer Area" (zones 2, 5, and 8), and "Anthropogenic Area" (zones 3, 6, and 9). Comparing the transitions in vegetation for these zones provides a regional sense of the trajectory of these boundary lands across a socio-ecological gradient from 2000–2020, visualized in Figure 12. I calculated the area of each land cover class from my classified map of the study area in hectares for the total area. In ArcPro's Imagery workspace, I analyzed change detection using the Change Detection Wizard for four eras as time slice transitions: 2000–2005, 2005–2010, 2010–2015, 2015–2020. These numbers are reported below, emphasizing the five top change categories (>50 ha) to isolate meaningful patterns and omit noise during classification.

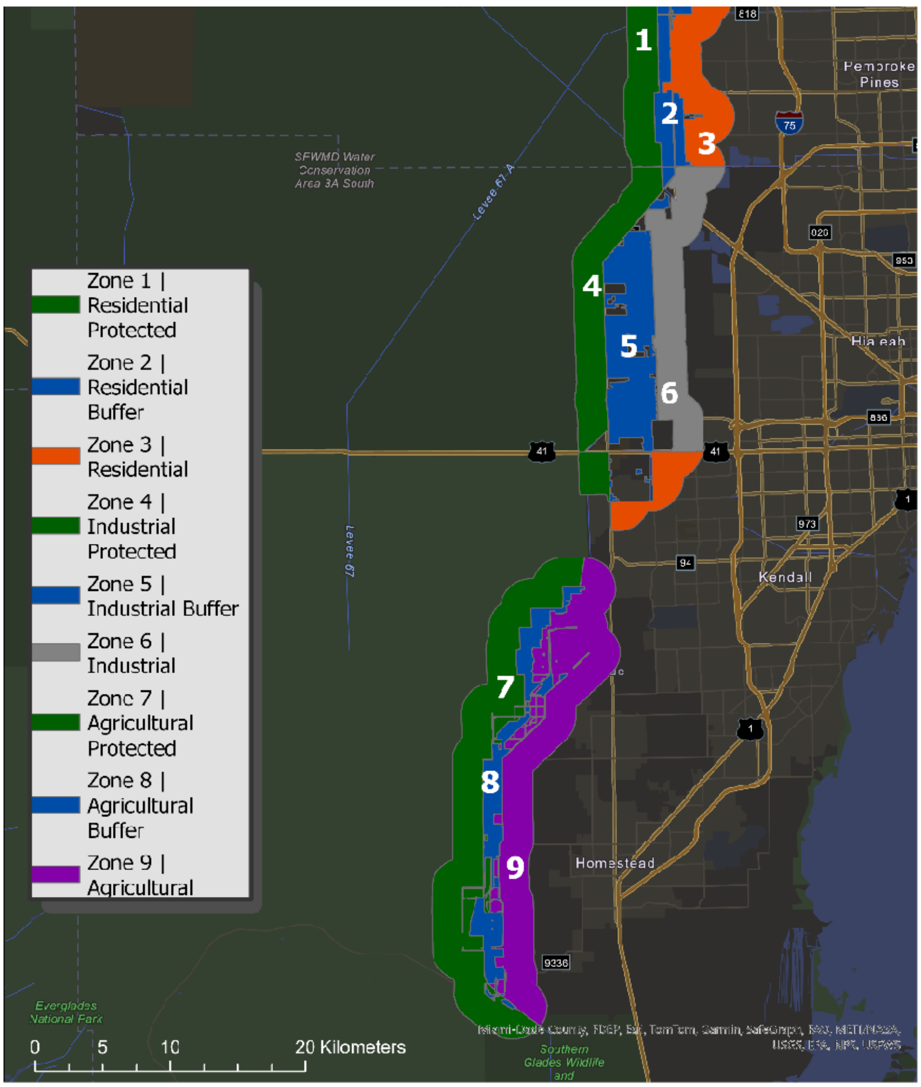


Figure 3.3.6 East Coast Buffer zonation compared with Landsat imagery overlaid by buffer components. This map was created using the methods described above with classification data generated using LandSat-7/8 imagery in Google Earth Engine.

In Agisoft Metashape Professional 1.6 (Agisoft, 2020), I created three orthomosaics composed of processed UAV imagery collected during field visits in the spring and summer of 2023. Using 50 visually referenced points on the true color UAV imagery to train a random forest classifier on the same seven land cover classes, I produced a validation map for the Pennsuco Wetlands and manually labeled areas around Mack's Fish Camp. These UAV-based land cover maps facilitate the assessment of fine vegetation gradients. To validate the accuracy of the random forest classifier utilized by GeE, 100 sample points for each land cover class were randomly generated and evaluated using high-resolution imagery on Google Earth. This validation process helps to understand the real-world efficacy of an ecohydrological monitoring protocol driven by open-access imagery. This resulted in a confusion matrix to validate the performance of the random forest models of land cover in the GEE, a recommendation measure to assess the accuracy of remote sensing classification models (Table 3.4.2). (Foody, 2005). The primary values I report through these results are the overall accuracy (OA) and the Kappa value to be contextualized in Section 5.5.

For this categorical change analysis, the weighted arithmetic mean was modified to accommodate the needs of this approach (Chelli et al., 2019). The weighted arithmetic mean is a measure of central tendency that takes into account the importance or frequency of each value in a dataset. Unlike the simple arithmetic mean, which treats all values equally, the weighted arithmetic mean assigns a specific weight to each value, reflecting its relative significance in the overall dataset. This is useful in situations where some values contribute more heavily to the final average than others, as is the case with preferential land covers assigned by management. I refer to this modification as the Weighted Rank Score (WRS), a composite measure used to rank overall change for each zone similar to the weighted arithmetic mean with further constraints important to this analysis. This derives from the assigned vegetation class change value using a simple system developed through expert consultation with ecologists at the SFCN and described in the following section (pers. comm, 2022).

The approach is beneficial for high-level comparisons of landscape physiognomy as it intuitively captures the most significant shifts in land cover through broad ecological description of vegetation community structure and functionality. This is critical because physical geographers acknowledge the "virtue in vagueness" arrived through the ability to map and understand landscapes in more generalizable terms, a challenge of increasingly accurate and diverse EO technology (Braun, 2021; Cullum et al., 2017; Braun, 2024) In the WRS, the Change Value (Vc) multiplies by the weighted area in hectares ($A\boldsymbol{w}$) for land cover class across all nine zones applying a more proportionate measure of overall change averaged from the top five change categories for each zone for five years. I express this mathematically as:

$$WRS = \sum^{nn} VV \cdot AA$$

Equation 1. The Weighted Rank Score, a function of proportional change averaged for the top five classes in a zone.

whereas $-6 \leq WRS \leq 6$, V_c is the value associated with the vegetation change type (see Table 5), A_w denotes the area of land cover change for its zone as a function of its proportional area in the ECB Region, with n denoting the mean of the top five weighted averages for land cover transitions in each zone. These five transition classes usually exceeded 100 ha and accounted for over half of the change in the ECB Region from 2000–2020. For an example, a positive change class such as "Wetland Scrub → Wetland Shrub" has a V_c of 3, thus its area of about 225 ha (considering 3.9% coverage in that zone) yields an A_w of 11.79; this is done for the top change classes (n = 5) and averaged to reduce noise from the classifier and to produce a clear signal of the trajectory of vegetation and its resulting physiognomic structure for every zone. Calculating the average (or arithmetic mean) with consideration to all five A_w values results in a WRS between –6 and 6, thus this method lessens the impact of outlier values in this zone.

The statistical model I incorporated to assess the significance of WRS for Protected, Buffer, and Anthropogenic Areas is Analysis of Variance (ANOVA) Repeat Measure Testing, a standard test to determine if the mean of a population differs significantly from the compared sets (Volcani et al., 2005). Regression analysis using ANOVA seeks to determine if there is a difference between the different groups of the dependent variable (WRS) concerning the mean observed across all populations. Running this statistical test helps to confirm whether there are significant differences between management areas. These metrics are reported towards the end of the following section along with other quantitative summaries of the modeling and its validation against land cover serving as the ground truth. Table 3.3.6 outlines the six change categories utilized in this modeling framework as well as provides core examples for each.

Vegetation Change Type	Change Value	Ecological Example
Development of any type (worst)	-3	Wetland Scrub → Anthropogenic (pavement or managed agricultural lands)
From graminoid vegetation to woody vegetation (low resilience)	-2	Freshwater Marsh → Wetland Shrubland
A change in structure tied to *increased* landscape entropy	-1	Forest → Shrubland or Scrub, or simply vegetated → non-vegetated area
A decrease in woody cover within marl prairies (historic marshes)	1	Upland Forest → Freshwater Marsh
From non-vegetated cover to natural vegetation cover	2	Anthropogenic cover or Open Water → any vegetation
A change in structure tied to *decreased* entropy (succession)	3	Wetland Shrubland → Upland Forest

Table 3.3.6 Vegetation Change Categories and associated change values.
This classification style was adapted from a ranking system developed for the SFCN project.

3.4 MODELING RESULTS

This section outlines the initial modeling results produced using replicable geospatial techniques and following the recommendations of expert scientists working in the region. During an internship with SFCN, my supervisors and I developed a simple change ranking system to categorize, measure, and summarize vegetation changes in the Southern Coastal Region of ENP.

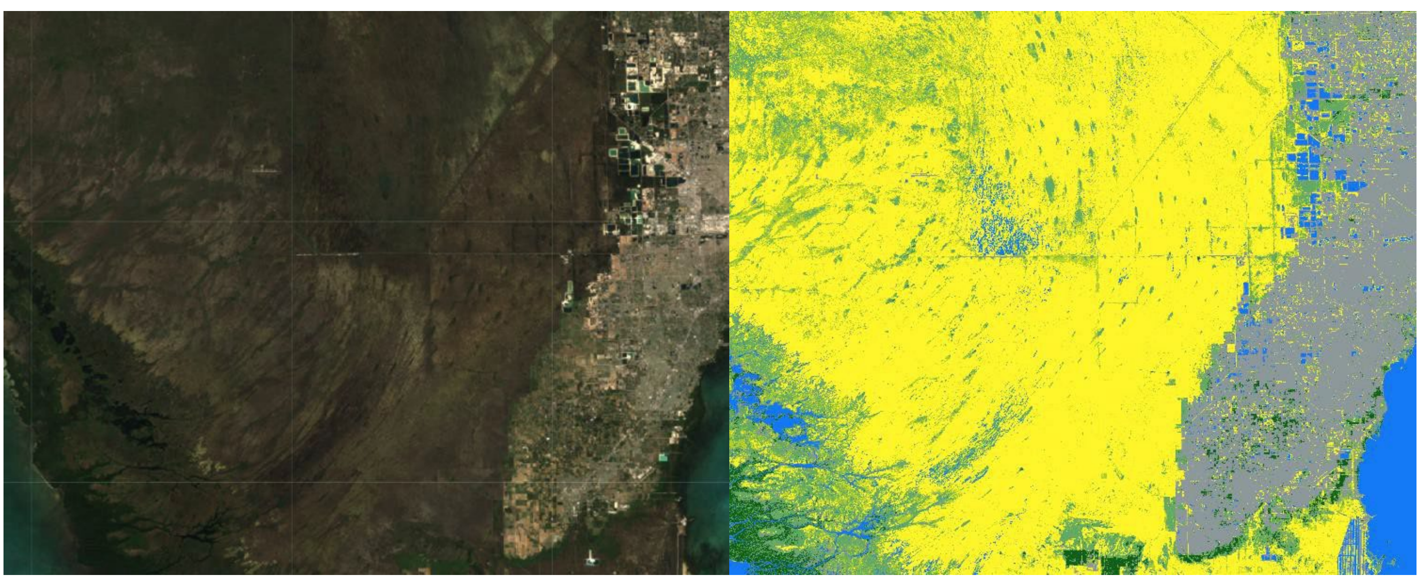


Figure 3.4.1 Comparison of Landsat 7 TM+ image of South Florida with Random Forest classification model for the year 2000. Land covers classified include Freshwater Marsh (burnt yellow), Upland Forest (dark green), Wetland Shrubland (light green), Wetland Scrub (yellow-green), Anthropogenic (gray), and Open Water (blue).

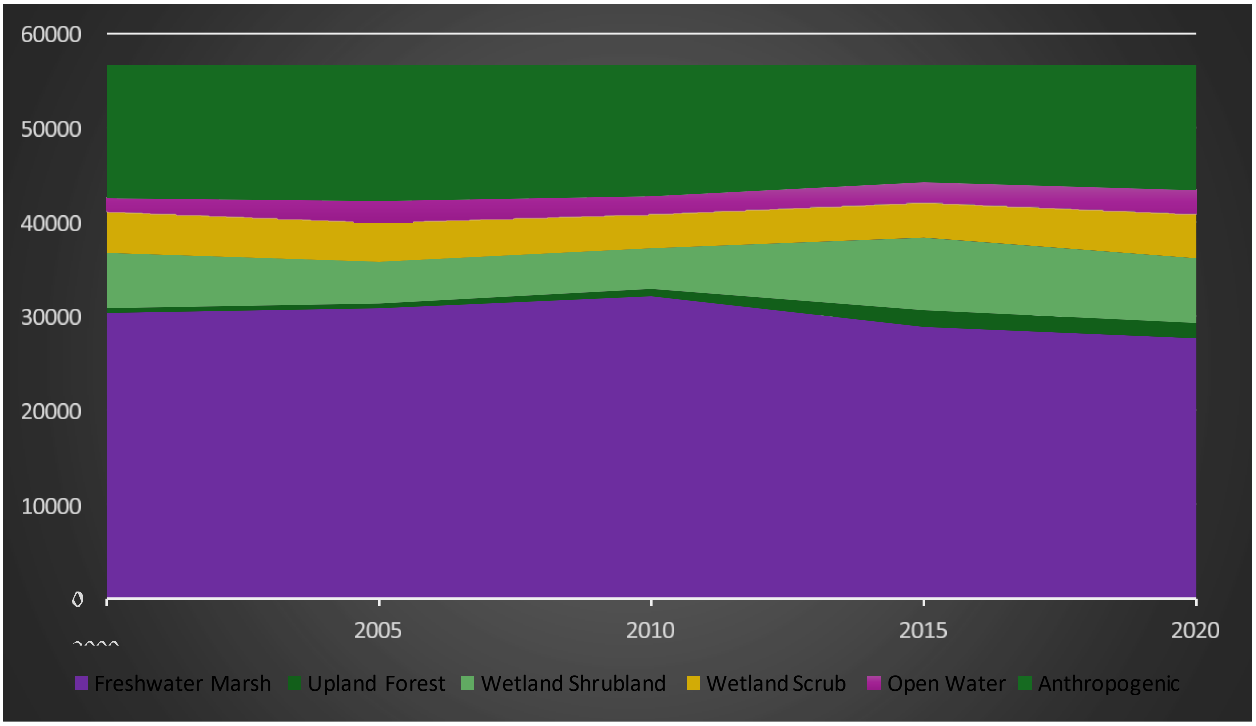


Figure 3.4.2 East Coast Buffer Region land cover area shift in hectares (ha) 2000–2020.

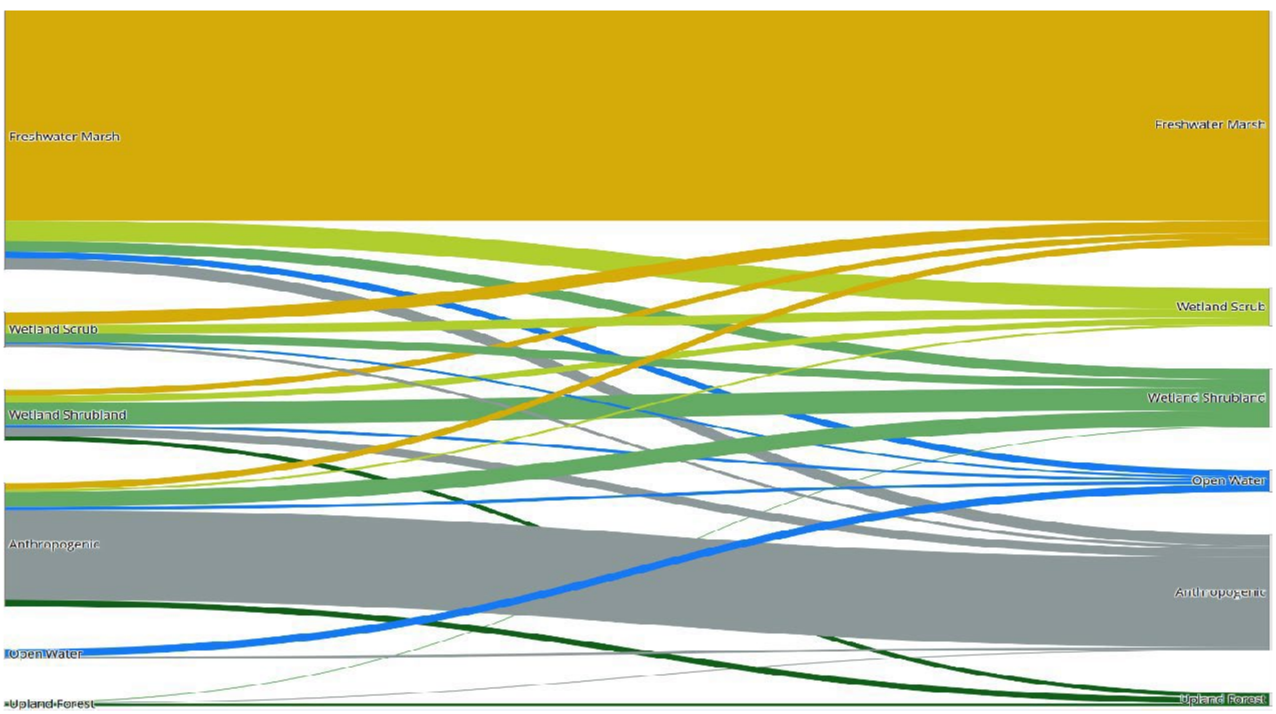
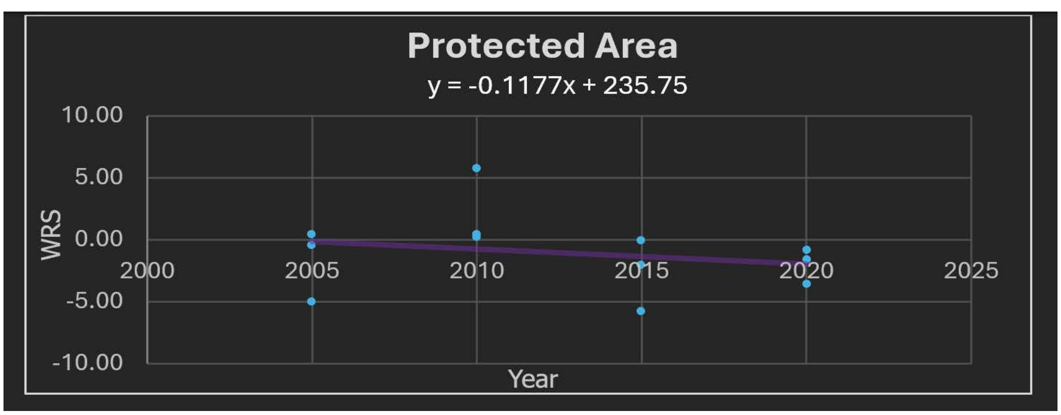


Figure 3.4.3 Land cover change (ha) pathways in the East Coast Buffer Region 2000–2020.
This Sankey diagram intuitively displays land cover swapping, including the extent and resulting classes for larger transitions.

Table 3.3.1 lists all WRS values for the Protected, Buffer, and Anthropogenic Areas within the ECB Region for the nine zones across four eras of management. The era of greatest fluctuation in terms of total WRS variance is 2005–2010 ($\sigma^2 = 7.949$) followed closely by 2010–2015 ($\sigma^2 = 7.494$), interestingly corresponding to a decade of highest intensity fire or chemical management (SFWMD, 2022). As indicated in Table 3.3.1, the greatest negative and positive WRS occur in zones 1 (WRS = - 5.792: 2010–2015) and 4 (WRS = 5.765: 2005–2010), respectively, together encompassing most of the *Protected Area* (zones 1,4, and 7). A comparison between zones alone is, therefore, not adequate for my purposes.

	2000–2000	**2005–2010**	**2010–2015**	**2015–2020**	**Ecotone**	**ECB Area**
Zone 1	-0.434	0.443	*-5.792*	-3.635	*Residential*	*Protected*
Zone 2	2.428	0.131	-2.858	-4.633	*Residential*	*Buffer*
Zone 3	-1.434	-3.037	3.678	-1.683	*Residential*	*Anthropo.*
Zone 4	-4.990	*5.765*	-2.081	-1.651	*Industrial*	*Protected*
Zone 5	-0.051	-0.151	-0.043	-0.656	*Industrial*	*Buffer*
Zone 6	-3.672	-1.136	2.037	0.240	*Industrial*	*Anthropo.*
Zone 7	0.398	0.159	-0.083	-0.850	*Agricultural*	*Protected*
Zone 8	0.379	5.122	-0.703	-5.076	*Agricultural*	*Buffer*
Zone 9	-1.225	-5.736	3.967	-0.920	*Agricultural*	*Anthropo.*

Table 3.3.1 Weighted Rank Score (WRS) by change era.



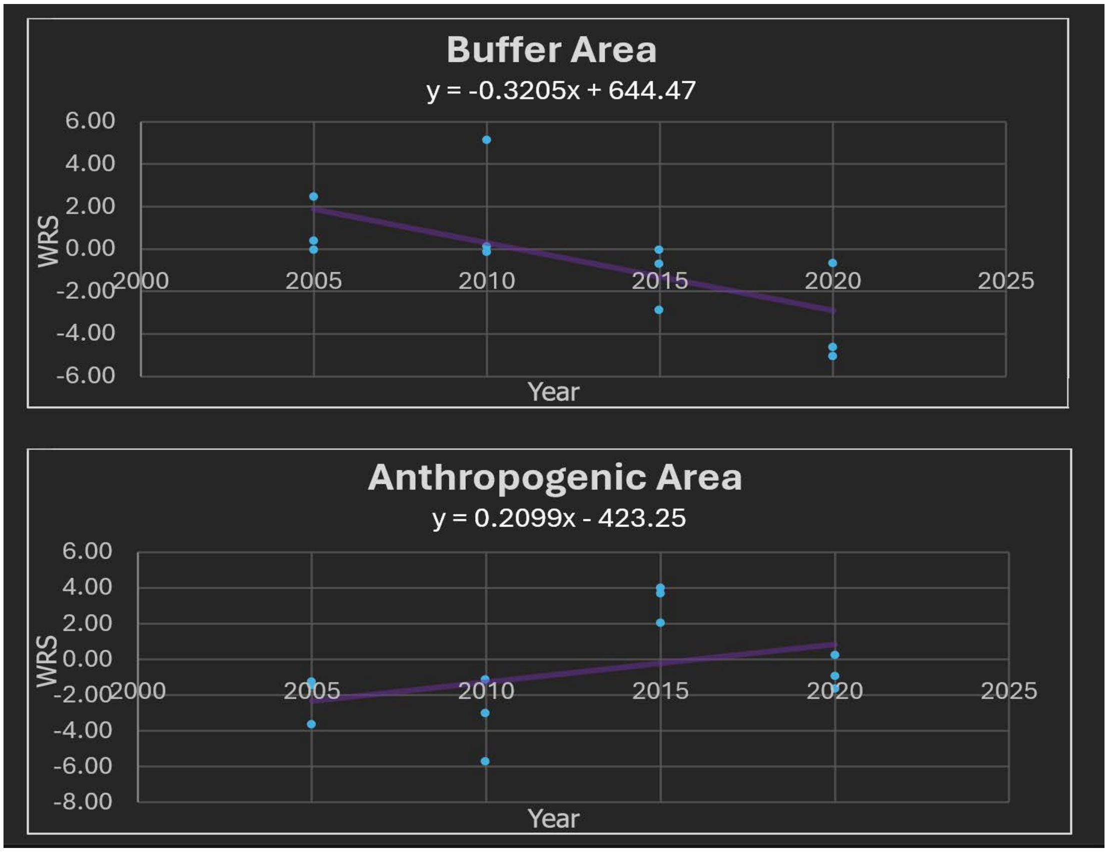


Figure 3.4.4. WRS Trendline Comparison for Three Areas in the ECB Region.
Results from the regression tests reside in Section X. Y-axis = WRS and X-axis = YEAR.

Comparing the WRS trendlines for the three areas in the ECB Region reveals that only *Anthropogenic Area* had an overall positive WRS trajectory. This trend derives from the WRS values of zones 3, 6, and 9 for 2000–2020. Because these values do not reflect a single moment but instead summarize changes through five years (era), trendlines need only remain parallel to the x-axis in the model to indicate progress towards restoring wildlife habitat and securing environmental resilience in conservation buffer areas. Due to each era providing a summary of five years, even a minor increase in WRS over time demonstrates an accelerating trend as the average score increases.

In terms of major land cover changes, the extent of Freshwater Marsh overall reduces from approximately 57% of the area in the ECB Region to under half, while woody vegetation such as Upland Forest and Wetland Shrubland expand to cover almost one-sixth of the region. Most land covers are collectively being lost to Open Water with Anthropogenic cover falling closely behind, although Anthropogenic covers appear to be decreasing as many cultivated spaces near the ECB are returned to their historic state (Figures 14 and 15). These results ultimately suggest that restoration activities are ineffective given the significant negative WRS trend of *Buffer Area* over *Anthropogenic Area* or even *Protected Area*, the natural control for this analysis.

3.4.2 *Model Validation & Regression Testing*

A way to quickly measure classifier accuracy in land cover prediction models is to develop a confusion matrix to compare errors of omission (classes left out) and commission (classes incorrectly labeled) (Hsiao & Cheng, 2016). Table 3.4.2 depicts the predictive accuracy of the Random Forest classifier with summary metrics including Overall Accuracy (OA) and kappa (ϰ) value.

CLASSIFIER	1 Freshwater Marsh	2 Upland Forest	4 Wetland Shrubland	5 Wetland Scrub	6 Anthro	7 Open Water	VALID
Freshwater Marsh	98	0	0	0	2	0	100
Upland Forest	1	97	2	0	0	0	100
Wetland Shrubland	2	2	92	0	3	1	100
Wetland Scrub	1	2	5	94	0	0	100
Anthropogenic	2	1	12	7	78	0	100
Open Water	1	0	0	1	0	98	100
		OA =	92.53%	**Kappa** =	0.91	TOTAL	600

Table 3.4.2 Confusion matrix for displaying accuracy of modeled landcover validated with Google Earth. *n* = 100 sample points/class. A ϰ closer to 1 indicates high agreement between classifications and observations.

The ϰ value indicates the impact of chance agreements in measuring the interrater reliability for categorical items (McHugh, 2012). The provided validation data come from cross-examination of the above 600 sample points (Table 7) using high-resolution Google Earth imagery as well as further checking the proportionality of classes as it ranks with the SFWMD Land Cover/Land Use data scaled to the ECB Region (SFWMD, 2017). With a high OA and ϰ of 0.91, these models of land cover in South Florida closely resemble real-world physiognomic structure at the landscape scale from 2015–2020, suggesting results for the other eras are also reliable.

If statistically meaningful differences exist among WRS groups, we would expect the *Buffer Area* subregion to have an exceptionally high or low WRS trendline (indicated in Figure 16 slope equations), indicating that it is responding to external drivers of change, whether along a positive or negative trajectory. At the 95% confidence interval, regression results indicate a negative trajectory of land cover change in the Buffer Area WRS population was statistically significant and, therefore, unique in the three ECB subregions. I provide details of this ANOVA testing in Table 3.4.3.

ECB Subregion	Significance F	P-Value
Protected Area	0.47558973	0.477522
Buffer Area	*0.016897064*	0.7646
Anthropogenic Area	0.167058235	0.166384

Table 3.4.3 ANOVA testing results between WRS and areas of interest within the ECB Region. **Independent Variable** = Vertical subregions of the East Coast Buffer and its periphery (n = 3) composed of Zones 1– 9 and subdivided as "Protected Area" (WCA-3, ENP: Zones 1, 4, & 7), "Buffer Area" (SFWMD managed lands: Zones 2, 5, & 8), and "Anthropogenic Area" (developed/cultivated land west of UDB: Zones 3, 6, & 9). **Dependent Variable** = Change Periods (e.g. "2010–2015") (n = 4).

3.5 DISCUSSION

Understanding exactly why and to what extent the trajectories of land cover for the *Anthropogenic, Buffer*, and *Protected Areas* are directly associated with the management of the ECB exceeds the analytic scope of this spatial experiment. However, we can explore these relationships by comparing the WRS trendlines for the three areas. To assess whether restoration decision-making and other management activities in the ECB negatively impact adjacent natural areas or buffering the effects of land use practices in the *Anthropogenic Area*, more control data of higher resolution with finer spatial boundaries of treatment extent is needed. These control data would better characterize whether these activities and changes in land cover are meaningfully correlated in the eastern Everglades. Another motivation for this investigation is at the site level to determine if conservation buffers in South Florida effectively reduce their impacts on conservation lands prioritized for native vegetation communities, habitat, connectivity, and other ecosystem services outlined in the introduction (Section 3.1).

This research attempts to understand whether ongoing activities are worth their concomitant costs and growing opposition by gateway communities in the hinterland of developed coastlines like Miami and Naples, Florida. It remains exceedingly difficult to tease apart factors related to external forcing (climate change and land use) or determine whether changes in protected areas such as WCA-3 and ENP influence the changes observed in boundary lands over time. One limitation to this dataset and my mode of training the classifier was the lack of ability to detect Class 3 (Upland Woodlands) and mismatching Class 2 (Upland Forest), two vegetation communities undeniably present in the ECB region. I believe spectral artifacts result from some training data overlapping with salt-tolerant mangrove communities (most of the true forests in ENP) in NPS maps and accompanying datasets. Considering the differential results of WRS modeling in the ECB region, it is perhaps surprising to observe such a significant negative trend for WRS Buffer Area as the UDB marches westward and restoration activities remain ongoing albeit scattered. Even the trendlines for

Protected Area, with zones overlapping WCA-2 and ENP, indicated halted progress and eventually declines following 2010 as further hydrologic changes are introduced in the GEE along remote tracts of wilderness that otherwise receive less attention from agency staff. This may also indicate landscape-scale processes affecting the analysis area that render restoration site-level treatments trivial at this scale.

Addressing my research question—on how will conservation buffer areas in South Florida alter due to restoration activities—entails understanding how shifts in the eco-hydrological conditions altered landscapes in the Eastern Everglades during the first 20 years of CERP. Restoration efforts in the largest component of the ECB, Pennsuco, like other projects in the region, focus on enhancing a degraded ecosystem that will likely continue to deteriorate and impact nearby natural areas unless action is taken to control the spread of exotic Melaleuca trees and other species. If habitat enhancement, groundwater recharge, water quality improvement, and increased flood storage capacity all lead to the enhancement of the Pennsuco Wetlands via restoration of a higher quality sawgrass community, progress in this context should further the goals of Everglades restoration at local scales. My land cover change modeling results imply that counter to the primary goals of Everglades restoration, water storage, and habitat provision in the form of freshwater wetlands should be increasing in area compared to stands of invasive upland forests of Melaleuca or dehydrated scrublands and other problematic vegetation (Ross et al., 2014; SFERTF, 2022). While no model should be taken at face value, this land cover change analysis reveals that active management of the vegetation communities in the ECB region is impermanent and, at best, remains ineffective in the long-term without accompanying hydrologic interventions.

In terms of its importance for vegetation patterning in the GEE, hydrology primarily drives this process and is an integral element of ecosystem restoration in South Florida (Gunderson, 1989). As CERP increased water flows adjacent to ENP during the 1990s and more recently, monolithic pumps rehydrate and effectively flood stands of woody species and wet prairies historic to the region resulting in an unnaturally prolonged hydroperiod and associated changes to local soil chemistry. Ross et al. (2014) found via field survey in the Taylor Slough basin—a key conduit for the movement of water adjacent to these lower boundary lands—that vegetation change trajectories spanning 1992–2010 neatly track with shifts in the water supplied by connected detention ponds adjacent to the canals running along much of the east coast perimeter levee. This bears consequences for this limited geospatial approach in terms of quantitative reliability based on the size of the spatial buffer (2.5 km) used to generate comparative subregions for *Protected Area* for *Anthropogenic Area*. However, using the geospatial framework, I propose in this project, even medium-resolution open-access imagery provides an initial examination of the potential impacts of long-term restoration activities, albeit at a relatively coarse ecological resolution. As this study reveals, fluctuations in the WRS trajectory associated with recorded management activities, as well as water releases, correlate with the restructuring of vegetation in the ECB Region within a five-year window, as indicated by comparisons of treatment history in Table 3.3.1 and resulting WRS values in Table 3.4.1.

These eco-hydrological interactions, coupled with the direct treatment of invasive and nuisance plant species, bear significant consequences for the vegetation communities influenced by South Florida's microtopography. Because minor changes in the flat landscape produce stark differences in the hydropattern of sloughs in the GEE, minor shifts in water delivery correspond to major changes in the composition of wetland species along relatively brief timescales. Past work examining the dynamics of Everglades ecohydrology reveals that vegetation shifts can respond to local hydration on a scale of 3–5 years (Zweig & Kitchens, 2008). The scale and rate of this change vary according to the magnitude of both natural and management-induced alterations to the sub-surface water supply— major drivers for which are the result of upstream water management (Ross et al., 2014). For monitoring needs, implementing frequent UAV surveys at a scale reflecting dry-wet seasonality changes would dramatically improve upon our short-term ability to assess responses to recent fluctuations in water delivery and drought stress, as Wendelberger et al. (2018) demonstrate using multispectral imagery in the Southern Coastal Everglades. Introducing more frequent data acquisition intervals that better suit local managers' needs by providing intuitive visualization through a hybridized geospatial approach increases the confidence and transparency of restoration planning from the bottom up.

The SFERTF releases an annual report summarizing the status of region-wide indicators of restoration goals. In common with this chapter's concern, the response by native vegetation communities and invasive plants to treatment methods is a key consideration for the ongoing management of natural areas in the GEE. Due to the ecologic damage to natural areas associated with the presence of species like Melaleuca and Brazilian Pepper, their prevention and control are "key to restoration of the [Everglades] ecosystem" (SFERTF, 2022, p. 21) As of 2022, the ongoing progress for the invasive plants indicator fails to meet restoration targets in terms of their presence and in most reaches of the GEE. While I implement my land change modeling on a scale of five-year intervals and only identify major land covers based on their fundamental physiognomic structure and not in relation to the presence of specific species as the SFERTF report utilizes, I identify several important lines of comparison below.

Although it remains stable, the invasive plant indicator rating has been "Below restoration target" since 2018. The exception is in WCA-3B, where the status meets the restoration targets for 2021 and 2022. A difficult balance act emerges for management given that restoration activities affect invasive plant communities in the GEE in different ways. As the report implies, longer hydroperiods in tree islands could stunt the growth rates of Brazilian pepper while inadvertently improving habitat for Old World climbing fern. Land management efforts by state agencies such as SFWMD and the Fish and Wildlife Commission are also constrained by "limited resources, remote infestations, and in some cases inadequate control methods" (SFERTF, 2023, p. 25) UAV integration as a means for enhancing the reach of restoration efforts in remote areas could substantially improve monitoring for the detection of invasive plant communities before they impact local ecology where further intervention would be required (LeRoy et al., 2018; Sighn, et al. 2024). The northeastern region of ENP lying adjacent to the ECB Region analyzed for this project, is labeled explicitly as a problematic subregion for the control of invasive species. Looking at the abundance of Melaleuca remaining in the ECB Region, the Task Force recommends continued and frequent "sweeps" to eradicate Melaleuca trees before reproducing.

A final point of disagreement between my analysis and this SFERTF report was that the only rating that "Meets Restoration Goals" was the portion of WCA-3B categorized as Protected Area (Zone 1), despite my analysis revealing a significant negative trend in WRS (albeit for a brief overlap and not for the same period, i.e. 2015–2020 compared to 2018– 2022. This highlights an important difference in developing and utilizing monitoring protocols for native plant communities in the GEE. In their *East Coast Buffer Land Management Plan* (SWFMD, 2006, p. 48). used extensively for reference in this analysis, the SFWMD offers several long-term scenarios for these buffer components, including management trajectories that prioritize ecology and restoration for sites surveyed for my research, including Pennsuco (Zone 8) and Frog Pond (Zone 8) (Figure 17). Management reports that ongoing monitoring is in effect and the State of Florida will eventually produce detailed plans for future land use in these areas. This follows continued land acquisition, permanent infrastructure installation, and efforts to control the spread of exotics and use periodic prescribed fire Similarly, Frog Pond to the south seeks to restore native habits but differs from Pennsuco in that agricultural clearance devastated the area's Upland Forests (Pinelands and Tropical Hammocks). As Table 3.4.1 reveals, 2015–2020 showcases the worst era for land cover change for Zones 5 and 8 with WRS = –5.076 and -0.656, respectively, despite statements to the contrary for both sites. After almost two decades, even a minor positive trend would validate the nature of these activities to South Florida's gateway communities and the wider public. Current documents and data fail to render a clear future for these boundary lands positioned at ecosystem restoration's social and ecological periphery.

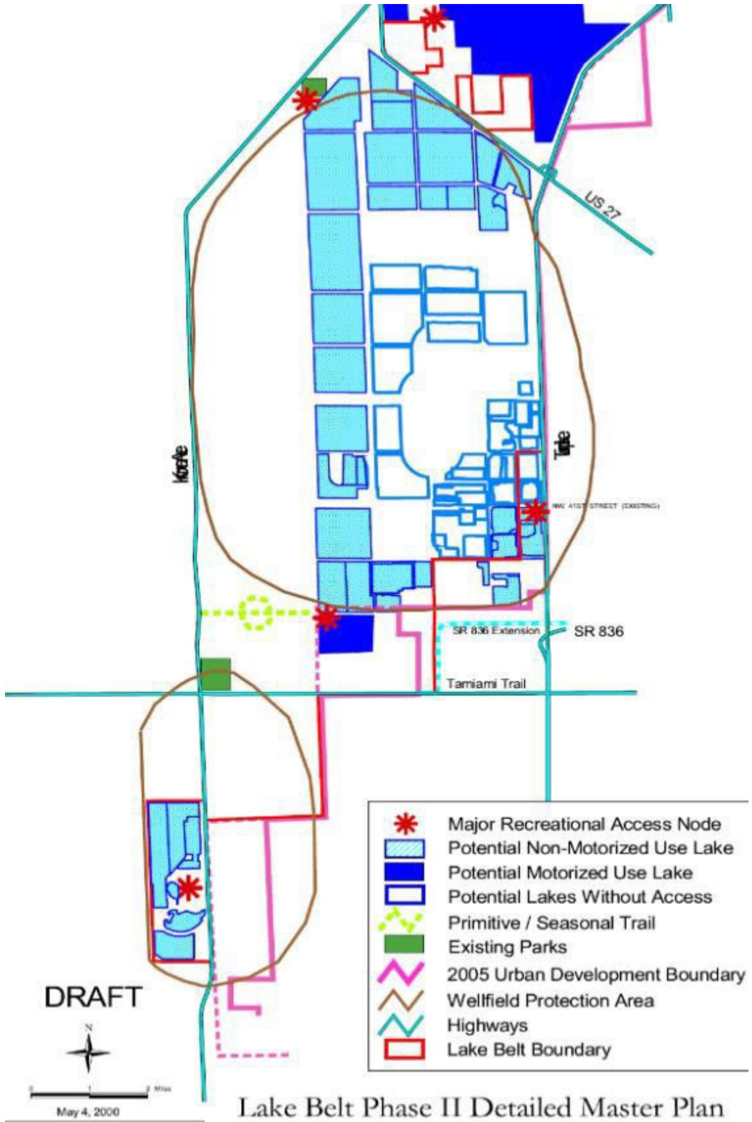


Figure 3.5 Recreation Scenario A for the Lake Belt Area, the industrial space adjacent to the Pennsuco Wetlands in Miami-Dade County (SFWMD, 2006). I include this as a reference because current plans no longer consider this future for the ECB.

Other considerations of my modeling approach using NPS data are worth mentioning. Due to fundamental ecological differences denoted by the broad Level 2 ranking, physiognomic structures observed in these botanical communities of ENP correspond well to original change categories after removing saline environments. For instance, mangroves and sand dunes are not a feature of the River of Grass. These change categories are necessarily incomplete, given a lower ecological resolution complicates finer decision-making and blurs the detection of the invasive (or nuisance) species sought for removal. All the same, such a simple approach establishes meaningful shifts in vegetation structure to isolate more nuanced phenomena worth exploring via UAS or ground survey. Understanding environmental shifts at the landscape scale presents numerous challenges, among them communicating how and what has meaningfully changed and for which reasons human communities should interfere with complex biophysical systems. This further opens opportunities to communicate long-term trends with stakeholders less familiar with other plant communities.

Revisiting my research question, an alternative wording relevant to the wider discussion of ecosystem restoration in South Florida asks: how are these areas changing, and how far from "natural" are these changes? This investigation provides one hybridized geospatial approach to track these shifts towards more favorable physiognomic structures using a simple change ranking system, yet other important factors remain to tease apart from underlying biophysical processes affecting the GEE. From these results, it appears that management activities do not generally produce obvious beneficial outcomes in the ECB Region. With modifications to the change ranking system this research proposes alongside the incorporation of frequent UAV surveys to capture seasonal fluctuations, monitoring efforts at the regional scale could better connect with localized shifts before they cross irreversible thresholds in their trajectory. A similar hybridized framework could be applied to other buffer areas in South Florida to rapidly assess shifting ecohydrological conditions at low costs with results more meaningful to stakeholders, including the ongoing Western Everglades Restoration Program (WERP) that seeks to hydrologically connect private and Tribal lands with the Big Cypress Preserve (Julian & Davis, 2024).

3.6 CONCLUSION & FUTURE DIRECTIONS

Connecting landscape modifications and their policy-driven goals is integral to the geospatial communication needed to serve local decision-makers, restoration practitioners, and community members across the GEE. Understanding ecosystem restoration requires more than merely establishing environmental baselines and planning for a mechanistic reversal of local processes. Managers and practitioners must explicitly chart restoration pathway-dependent variables, including the type and frequency of vegetation treatment methods and regional hydrologic operations that lead to the emergence of novel landscapes such as those emerging in South Florida's natural areas. If long-term conservation targets for these areas continue shifting, as is the case in Everglades restoration, South Florida's gateway communities face further uncertainty without monitoring tools available to advance their understanding of and participation in ecosystem restoration from the bottom-up. This becomes compounded by climate change-induced warming trends, rapid sea level rise, and impacts on water security that threaten both human and non-human resilience in the 21st century (EPA, 2016; Abiy, 2019).

In South Florida and other regions known for large-scale restoration projects, the end- user products offered to the public by institutions advocating for and planning restoration projects are often vague or too technical. They often do not communicate results clearly and remain accessible to the public only through technical documents and lengthy, frequently rushed presentations by agency representatives. To render more explicit and intuitive explanations for these shifting environmental conditions beyond presenting the basic outputs ofGIS analysis, an intentional research design for hybridized monitoring is necessary to ensure the long-term use of EO platforms aids management efforts while communicating clear results to community members. Ecosystem restoration missions, including water management and environmental protection, represent two of many applications possible, but these bear greater relevance here and, therefore, dominated my discussion. Land change influences regional precipitation, local biodiversity, and energy fluctuation across subtropical ecosystems, yet shifting what is left of the GEE into a resilient state ultimately requires the social will to sustain hydrological and geochemical interventions at immense scales across the region (Sklar et al., 2005) The interdisciplinary potential of rapidly relating on-the-ground progress of restoration projects captured through EO remains largely unrealized in Everglades restoration literature, thus my modeling endeavor presents itself as one of the first attempts in Everglades restoration to use land cover change modeling in tandem with existing vegetation datasets to rank shifts in the landscape's physiognomic structure in association with restoration activities. I believe similar approaches should be adopted in the future to better integrate UAS with understanding the site-level intricacies detected first via satellite imagery. My research also plans these measures for changes considerate of the cultural values inherent in ecosystems undergoing periods of socio-ecological transformation.

Managed landscapes at the periphery of urban development boundaries and protected areas present a unique opportunity to inform sustainable ecosystem management understood through geospatial modeling. Cloud-based toolkits such as the modeling framework I demonstrate in this chapter can be adapted and implemented to meaningfully track the long-term ecohydrological condition of conservation lands in South Florida and other restoration contexts. Currently, the connection between these models and accompanying tools with end-users remains weakened by the complexity of their operation, issues of scale, and the process of visualizing results in meaningful ways to different stakeholders. I argue that developing true adaptive management demands an intentional design regarding how these products deliver the information used to inform decision-making and how they can screen policy at varying scales upon confronting future environmental conditions. To enhance the resilience of novel ecosystem states shaped by past ecological consequences, management should implement a multi-scalar monitoring approach in common with the one presented in this research.

Chapter IV | Towards a Socio-Ecological Model of Restoration

> The system-wide perturbation caused by human domination places those alive today on the leading edge of a no-analog future. (Cosens & Gunderson, 2018)

4.1 INTRODUCTION

The restoration of Florida's Everglades is an ongoing, unprecedented socio-ecological process driven by environmental concerns, political pressure, and the production of scientific knowledge. These drivers are interconnected today through South Florida's hydrology, ecology, and culture. Due to the rigidity of water management framed through a monodisciplinary lens, the restoration of the Greater Everglades Ecosystem (GEE) continues to prioritize economic growth at the expense of environmental stability and the values of human communities at the gateway of South Florida's major protected areas: Everglades National Park (ENP) and the Big Cypress National Preserve (BiCy) (Ogden, 2008a; Garvoille, 2013; Wakefield, 2017; SFERTF, 2023). The inability of state and federal actors to balance competing interests in Everglades restoration, including the South Florida Water Management District (SFWMD) and the US Army Corps of Engineers (Army Corps), has significantly limited the emergence of adaptive governance in the GEE capable of addressing the pathways toward securing socio-ecological resilience for the total environment. Through this research, I explore one interdisciplinary pathway for envisioning an ecologically sustainable and socially equitable future for the GEE informed by approaches in integrative conservation and the geospatial humanities. Understanding how the management of protected areas shifts is important for this investigation, as these influence restoration projects at the periphery of South Florida's built environment. These relate to participatory governance in the GEE, wilderness designations, and the evolving rhetoric driving the original mission of the Comprehensive Everglades Restoration Plan (CERP).

This chapter aims to showcase how modeling efforts from two disparate fields—environmental anthropology and geosciences—can operate in tandem to critically produce insight into monitoring the conditions of dynamic conservation landscapes, like the Everglades, as restoration activities continue in the Anthropocene epoch. Charting out this process is key to demonstrating how integrative modeling efforts can operate in tandem because they offer a comprehensive approach to understanding and managing complex conservation landscapes. As restoration activities continue in the Anthropocene epoch, dynamic landscapes require ongoing monitoring and adaptive management. By combining various models, interdisciplinary researchers can more effectively analyze ecosystem conditions, anticipate future changes, and make the most informed and equitable decisions. Such a workflow also ensures that ongoing restoration efforts are resilient, remain responsive to evolving conditions, and align with broader conservation goals. Although stakeholder engagement is improving in South Florida, restoration planning remains contentious as indicated by the failure of institutional boundary objects that facilitate sustainability transitions (Franco-Torres et al., 2019). The involvement of environmental nongovernmental organizations (NGOs) and community stakeholders complicates this process as they continue to intervene across the interagency efforts required for ecosystem restoration at scale.

In this final component of my investigation, I ask the following research question in the context of South Florida's East Coast Buffer (ECB) and the Western Everglades Restoration Project (WERP): *What are the long-term implications of these restoration-related changes in boundary lands for community attitudes toward wilderness and access across the Greater Everglades Ecosystem?* (RQ3) I argue here that restoration practitioners should utilize interdisciplinary methods to reconcile narratives defining what is "natural" according to whom, and how this should translate into restoration policies and accompanying activities. To present this research as an interactive platform, this chapter is structured to showcase the development of a Story Map positioning my prior investigations and outcomes in Chapters 2 and 3. Although I cannot entirely answer the above research question without a fully functioning Story Map+ as described in the following sections, I make the case that it ultimately could answer RQ3 if properly utilized. This chapter, therefore, serves as a prototyping effort in support of narrative cartography to foster the adaptive management necessary to achieve holistic ecosystem restoration in South Florida and beyond.

4.2 BACKGROUND

4.2.3 *The Greater Everglades as a Socio-Ecological System*

The GEE embodies a unique regional system definable through diverse domains and understood by many communities, institutions, and theoretical frameworks as an iconic conservation landscape (Ogden, 2008a; Zweig & Kitchens, 2010; Gunderson et al., 2017). Socio-ecological systems (SES) describe a complex adaptive system structured by "strong connections and feedbacks within and between social and ecological components that determine their overall dynamics" (Biggs et al., 2021, pg. 5). The SES framework is useful for approaching projects on the spatiotemporal scale of Everglades restoration because merely addressing the biophysical needs of this complex process fails to secure the interconnectivity and longevity of the total system. Researchers can fundamentally decompose trajectories of non-linear systems like regional-scale wetland complexes undergoing restoration through *panarchy* and its analytic ability to examine cross-scale linkages (Gunderson &

Holling, 2002; Wakefield, 2017). Crafting policy solutions that can identify and apply lessons from modeling community responses to regime shifts in South Florida's ecology and governance requires an emphasis on the processes of claims-making and related utilization of boundary objects in the restoration arena (Harvey & Chrisman, 1998; Turnhout, 2009; Garvoille, 2013). This section provides an overview of the literature on pathways towards integrative monitoring in the GEE; including how to evaluate the role of key boundary objects in science policy, Everglades restoration in the age of digital conservation, and how applied work in critical geography can effectively identify pathways towards holistic ecosystem restoration for the greater public.

Anthropogenic climate change, biodiversity, and ecosystem degradation more broadly have led to global institutional responses as restoration science and practice continue transforming iconic conservation landscapes. Florida's Everglades and its CERP represent a keystone effort in the Global North well-situated to showcase how socio-ecological solution approaches will characterize 2021–2030 as the United Nations Decade on Ecosystem Restoration (United Nations Environment Agency, 2021). Departing from conventional ecological concerns, the uncertainty of the Anthropocene requires a biocultural approach to facilitate reintegrating human beings into the total environment (Fischer et al., 2021). A true socio-ecological model of Everglades restoration should incorporate how modeling approaches from the natural and social sciences operate together—and more interestingly—*could* operate in tandem. In common with the *ecosystem* concept in Everglades restoration, boundary objects like *resilience* and even *wilderness* are "meaningful to all relevant social worlds, although the meaning of that object will be somewhat different to every world it inhabits" (Lundgren, 2021; p. 94). As Zweig and Kitchens (2010) point out in the context of Everglades restoration, scientists and managers may struggle to recognize that restoring a system to a static historical moment is difficult to reconcile with the wider agenda, but also necessary to recover ecosystem functionality to the extent that is possible.

As an SES, the boundaries of the GEE are well-defined in the scientific literature by Gunderson et al. (2017), where they identify its qualities and ongoing regime shifts alongside five other major water basins in North America. Adaptive governance in South Florida's social-ecological system faces the most resistance through the ongoing litigation between special interest groups and government regulatory bodies like the SFWMD. What Gunderson et al. (2017) call "overly prescribed planning" and other disagreements complicate efforts to ensure a balanced recovery of the GEE that addresses water security, economic prosperity, and ecological concerns.

The original goals of Everglades Restoration were to affect "the quantity, quality, timing, and distribution of the water" to better emulate pre-drainage conditions prevalent in the region before the 1950s (Army Corps & SFWMD, 2000). These remain integral despite ongoing contentious claims concerning traditional rights of access and management approaches amidst the wider regional endeavor since CERP was ratified by Congress in 2000. With these goals in mind, one may recognize why the ephemeral conditions of local hydrology combine with the long-term restructuring of landcover (and as a result, *access*) to determine the cultural landscape continually produced (SFERTF 2000, 15, Catellino, 2018; Amorino, 2016). Put differently, the landscapes of South Florida and their significance to diverse stakeholders are not an obvious result of merely the biophysical *or* social processes underlying them but instead, emerge from an interconnected assemblage of human and non-human relationships (Ogden, 2008a). The choice of resilience assessments used to track ecosystem restoration progress can hinder true adaptive management. Surface-level management that appears successful may discourage open questioning of governance practices, as failure at this scale carries significant social and political risks for the actors involved (Gunderson et al., 2017). Using integrative practices in management can ensure that practitioners alike can apply lessons learned from community members at the gateway of restoration because, following project completion, they remain in these landscapes as local environmental stewards navigating this complexity at the precipice of non-analog futures (Cosens & Gunderson, 2018; Fischer, 2021).

Environmental models and other abstractions of landscape become quintessential to understanding the long-term outcomes of extensive interventions in South Florida's ecosystem. As stakeholders and decision-makers discover every year, these models are necessarily incomplete. CERP consists of 60+ projects on various timelines. As different stakeholder facets of the GEE demand a nuanced, community-centered approach to build upon the success of neighboring projects and their activities, the onslaught of environmental Big Data must be handled accordingly. Community members and social science researchers continue to make calls for transparency because the complexity of most models results in their utilization by only a few enlightened researchers. This leaves decision-makers with unrealistic expectations about the use of this scientific knowledge to maintain a collective endeavor on the scale of Everglades restoration on track because they cannot fundamentally participate in all stages of this research and planning process (Buytaert et al., 2012). As I begin to highlight in Chapter 2 regarding the human dimension of this restoration conflict in the GEE, it is through the co-production of models and frameworks by researchers, decision-makers, and stakeholders alike that opens the dialogue for the diverse perspectives required to navigate novel ecosystem states and their implications for the communities of South Florida (Lundgren, 2008; Wakefield, 2017; Cosens & Gunderson, 2018). The idea of non-analog futures is synonymous with novel ecosystem states, as discussed in Chapter 2. These phrasings generally suggest future environmental conditions without historical precedent or existing analogs. These are scenarios where ecosystems and climate patterns diverge significantly from anything observed in the past due to rapid changes brought on by human activity in the Anthropocene (Cosens & Gunderson, 2018). I believe an interactive platform best facilitates understanding how restoration impacts the benefits of "cultural ecosystem services." These represent the intangible social component of ecosystem services popular in the discussion of long-term plans yet often omitted during the policy formation process by policymakers and scientific advisors due to the methodological incongruity between natural and social science disciplines (Gosal et al., 2018).

The GEE remains a globally unique SES shaped by complex interactions among its ecological, economic, and social components, making it an ideal context for studying large-scale conservation efforts. Everglades restoration exemplifies these efforts by addressing the challenges of restoring water quality and distribution while balancing diverse stakeholder interests and navigating the nuanced pathways of adaptive governance. Given the vast scale of current restoration projects and the need for community-centered approaches to planning, integrative platforms that facilitate both transparent and participatory data modeling, analysis, and visualization are crucial to ensuring these landscapes accommodate diverse stakeholders facing South Florida's uncertain future.

4.2.4 *Critical Geography & Storytelling*

> Post-representational cartography is based on the idea that maps are never finished, but are rather always in the process of *becoming*
> (Caquard & Cartwright, 2014 [emphasis added])

In the participatory governance required to sustain CERP, the insights reached through adaptive management demand a specialized retention of the decisions, results, and public evaluations comprising the ecosystem restoration process. The intentional design and use of planning documents such as maps to challenge or convince stakeholders is one primary example. As Harvey and Chrisman (1998, p. 1684) remind us, "cartography changes how we understand geography." Decision-makers cannot successfully plan holistic ecosystem restoration without identifying and engaging the affected community members and other stakeholders (Sharpe et al., 2021). One interview participant noted during my pilot research that WERP "has stalled twice due to a lack of historical scientific data." An unavoidable hallmark of positivist science is that formal academic reporting often moves too slowly to reflect contemporary conditions in all components of a SES. Conventional research publishing

and record-keeping through databases do not wholly serve the institutional memory necessary to produce
a regime shift in the SES (Gunderson & Holling, 2002). Even the most effective boundary objects are ineffective in the wrong context. As one committee member (DL) asked me while drafting my geospatial research, "How wrong does a map have to be before it's not helpful in decision-making?" His question set the tone for this integrative exploration. This section provides background on how integrative approaches utilize geospatial boundary objects and storytelling to form a holistic basis for my analysis and, beyond this work, how they can craft ecosystem restoration as an equitable socio-ecological endeavor.

State forces continue to shape conservation in the digital age, with some humanists challenging the commodification of data, which can obscure community goals for ecosystem restoration (Cronon, 1999; Lundgren, 2020; Braun, 2021). Digital conservation encompasses a wide array of advancements where digital technology intersects with nature conservation (Arts et al., 2015). This may include everything from GIS to virtual reality (VR) applications (Markowitz et al., 2018). As Arts et al. (2015) note, more data does not necessarily lead to better decisions, as science and policy interact within rigid social structures (Gunderson et al., 2017). The proliferation of data, technologies, and modeling frameworks through which managers can attain meaningful information places conservation efforts in a difficult space while accelerating knowledge production. Braun (2021) describes this paradox as the "more accurate, less meaningful phenomenon," a consequence of geospatial advances that reveal how increasing accuracy comes with less application for many contexts of geography. In remote sensing and GIS, this implies that high-accuracy results are less informative in understanding the total landscape critical geography seeks to define. Given that scholars identify how geospatial technology affects sociopolitical outcomes (Turner, 2003; Thatcher et al., 2016), critical geographers may be best positioned to question the legitimacy of claims on nature and the underlying causes of environmental change from the perspective of the communities most affected by ongoing restoration plans.

Critical GIS is particularly interested in the digital humanities, which have directly confronted the contradictions between interpretative scholarly approaches common in humanistic fields and analytical computing paradigms largely developed by engineers to support capital accumulation and state power (Thatcher et al., 2016).To counter the pitfalls of ecosystem restoration, a critical people's science addresses the most serious societal impacts of conservation without giving into misleading "good news narratives" that counter reality (e.g., the displacement of indigenous people from their land, fortress conservation, or lacking stakeholder participation). Given that a way to connect this to a regional sense of resilience is through rendering the conceptual space defined by a system's resilience, potential, and connectedness, then an integrative toolkit borrowing insights from the adaptive cycle more broadly ought to incorporate ways of charting these metrics in explicit time and space from both the human dimensions and the natural sciences (Folke, 2016). Social scientists play a unique role in digital conservation by establishing who benefits most from these intentional and unintentional decisions that augment how information transfers. More specifically, my contribution to this research area could be framed as the *geospatial humanities* to the extent that it works across interdisciplinary domains to address textual, place-based narratives. This affords more experimental analyses that are difficult to conduct absent additional research interventions that incorporate participatory GIS (PGIS) or other approaches in the geospatial humanities to be explored in this chapter (El Khatib & Schaeben, 2020).

Informed storytelling is a fast-growing response to the conventional mode of planning that often produces uncertain models and socially sterile frameworks that fail to empower stakeholders. Spatial narratives instead enable knowledge co-production better suited to deal with concrete societal problems through digestible narratives (Roth, 2021; Gambrill et al., 2023; Pima et al, 2023). In practice, informed storytelling enhances spatial narratives by providing a deeper context to the geographic information, giving audiences an understanding of where events occur, why they matter, and how they relate to broader issues. Spatial narratives, in turn, bring informed storytelling to life by situating these stories within specific landscapes, allowing for an interactive and visually engaging experience that highlights the importance of place. Spatial narratives in this research describe the personal stories utilized by restoration practitioners or community members that can be understood through explicit representations of place, often producing a discrete sequence of events told in geographic terms.

Cartographic design as *visual storytelling* manifests in different forms, although for this application I adapt the methods covered in the following section (4.3) from recent work by Roth (2021), Gambrill et al. (2023), and Lima et al. (2023); as these authors examine spatial narratives in the popular form of *story maps*. Cope et al. (2018) describe these as "web applications that enable scientists, educators, and others to enhance interactive maps with text, figures, and multimedia content;" yet different digital platforms for their design exist (Lima et al., 2024). In my case, I utilize ESRI's ArcPro Story Maps (Environmental Systems Research Institute, Redlands, CA). Beyond simply storytelling, the ability of narrative cartography to capture and communicate traditional ecological knowledge (TEK) has allowed Indigenous communities to define territory through a Western spatial formalization process; something well-positioned to reverse the geographic reality established by former colonial interests in North America (Carquard & Cartwright, 2014, p. 102). From a post-representational cartographic perspective, a map (and its digital incorporation) is only as valuable as the diverse narratives that describe its context of appearance, production process, and the political or personal agendas it helps to advance. A remaining obstacle to Everglades restoration involves environmental claims-making and the distorted communication that complicates progress toward ecosystem recovery in the region (Garvoille, 2013; Knox, 2013; Catellino, 2020).

At present, two Story Maps appear when using Google to search for "Everglades Story Map": *Everglades History & Timeline* (NPS, 2021) and *Restoring America's Everglades* (NPS, 2022). My *StoryMap+* is stylized as such (and not merely "Story Map") because it stands apart from conventional Story Maps. To expand on the role a Story Map plays in assisting with monitoring and communicating restoration progress, my StoryMap+ excludes content that is already widely available in previous examples, such as a historical overview (pre-drainage, circa 1850), top-down summaries of federal policy initiatives in the region, a simplified spatiotemporal outline of restoration goals and major projects, and generalized portrayals of the Greater Everglades that overlook the ongoing social conflicts in South Florida. These surficial components are necessary to see "the forest" of Everglades "for the trees." Contrasting with these examples, however, I am creating an interactive Story Map more akin to National Geographic's *Ambassadors of the Amazon* project, which reaches deeper into a data-driven story-telling platform rooted in community conservation (Blue Water GIS, 2022). My hope is that this type of product will benefit diverse stakeholder groups concerned with restoration activities across the GEE similar to SERVIR, a global project already in place that connects remote sensing data products with end-users to address ongoing environmental issues (SERVIR Global, 2022). I ultimately believe this contribution to Everglades restoration is justified because the insights realized in Chapters 2 and 3 fall short of providing a dynamic solution capable of addressing my integrative research question (RQ3).

Utilizing the literature from SES research and critical geography enables me to reconcile research gaps that are difficult to bridge using singular methods in social or natural sciences alone. Critical GIS, intertwined with digital humanities, addresses the societal impacts of conservation without succumbing to misleading narratives. Integrative toolkits that consider resilience and connectivity can better chart the metrics of SES, while social scientists play a vital role in understanding the beneficiaries of information transfer. My research also dovetails with the emerging trend of geospatial humanities by bridging interdisciplinary domains to enrich place-based narratives through PGIS approaches. Informed storytelling and collaboration as spatial narratives can help empower stakeholders and provide a cultural context to growing geographic information, fostering knowledge co-production. Developing a cartographic narrative through my Story Map can capture TEK and challenge dominant narratives of land and access in the region. This StoryMap+ stands apart from similar platforms because it can continue to incorporate observations and other input from traditional land stewards in the GEE, including the indigenous and recreational communities of South Florida. Because the value of maps and other data visualizations lies in the diverse stories accompanying them, addressing environmental claims remains a significant obstacle to effective ecosystem recovery while the long-term implications for stakeholders remain vague, static, or uncontested.

4.2.5 *Formation of an Integrative Question: Research Question 3*

Through linking the realized lessons from different environmental disciplines—in my case, environmental anthropology and geosciences—I integrate the results of conventionally disparate domains of knowledge to arrive at my final research question:

RQ3: *What are the long-term implications of these restoration-related changes in boundary lands for community attitudes toward wilderness and access across the Greater Everglades Ecosystem?*

This Background section sets the stage for my approach to integrative research using a SES model to inform the design of a cartographic narrative tool using critical geography insights. Modeled restoration-related landscape changes discussed in Chapter 3 impact the five key stakeholder groups identified in Chapter 2: agency scientists, environmental advocates, planning and industry representatives, and recreators. Through my pilot study and interviews guided by RQ1, I gathered insights into South Florida stakeholders' perceptions of restoration activities. Leveraging a geospatial platform informed by approaches used to answer RQ2, I engage these narratives spatially and explicitly to highlight possible shifts in land access and the cultural values connected to restoration, effectively addressing RQ3. This approach applies political ecology methods to reconcile competing restoration narratives and provides a spatial story illustrating the ecohydrological conditions of protected areas and their surrounding lands. By using visual storytelling, this chapter moves beyond traditional scientific documentation, focusing on aspects of Everglades restoration that are more intuitively captured by the humanities while underpinned by a rigorous academic foundation. As Roth (2021, p. 83) notes, "Visual storytelling combines quantitative and analytical methods from journalism and visual analytics with qualitative, reflexive approaches from critical cartography, Indigenous mapping, and participatory GIS." As research on the human dimensions of Everglades restoration progresses, the success of these interactive platforms rests increasingly on the accommodation space created through effective storytelling design.

4.3 STORY MAP DEVELOPMENT: An Interdisciplinary Methodology

4.3.1 *Conceptual Overview*

This methods section describes the development of my Story Map. I aim for this platform to incorporate both the thematic and technical insights from Chapters 2 and 3 to craft an interactive place-based narrative on Everglades restoration. Its design sets the stage for the social and ecological landscapes under consideration, drawing from a literature review to establish the spatial, temporal, and conceptual boundaries addressed in earlier chapters. After consulting the human dimensions (Chapter 2) and geospatial analysis (Chapter 3) findings, I identified key information to showcase the GEE as an evolving, multi-faceted conservation landscape. This section outlines the workflow to move beyond a standard Story Map, creating a dynamic, data-driven toolkit supporting ongoing communication and public engagement: a StoryMap+.

Truly integrative problem-solving describes how systems interact, assuming certain conditions and scales. Informed by frontier research in critical geography and storytelling (see Section 4.2.4), I organized content by domain and potential use within my Story Map. Through systems scoping, I extracted all relevant data from the subsequent components of my research and organized all content based on disciplinary approaches, methodological needs, and the conceptual dimensions necessary to showcase an integrative analysis of the Everglades socio-ecological system (Sitas et al., 2021). Table 4.3.1 summarizes the essential features of systems scoping as it guided the integration of my research findings from Chapters 2 and 3, highlighting how these components were integrated to support an interactive and continuous content output. The underlying functions of each Story Map section behave according to domain convention and perceived application.

Disciplinary Background	anthropology and geography, landscape ecology/geospatial science
Knowledge Type	descriptive, exploratory
Research Approach	analytical/objective, interpretive/subjective, collaborative/process
Purpose of Method	data collection/generation, System understanding, Stakeholder engagement, Policy/decision support
Temporal Dimension	recent past (1999+), present day (decadal)
Spatial Dimension	local (sites like Pennsuco Wetlands), regional (South Florida)
System Process	SES components, power relations, multi-scalar interactions, social learning, collaborative governance

Table 4.3.1 Summary of system scoping to design Story Map. Color codes link variables with disciplinary tradition.

This organizational table was adapted from a similar template created by Sitas et al. (2021).

The StoryMap+ developed in this research contextualizes the lived experiences of community members at the intersection of digital conservation and the "geospatial humanities" (El Khatib & Schaeben, 2020). During the geospatial analysis phase, I identified a gap between the qualitative investigation in Chapter 2 and the land cover change modeling in Chapter 3, prompting a need to integrate these approaches into a socio-ecological model of Everglades restoration as it covers the ongoing debate and planning revision process of WERP. By focusing on current restoration efforts to strengthen the link between research and actionable outcomes, this Story Map can facilitate a co-production of usable knowledge supported by institutional boundary objects. Through careful organization and development of boundary objects such as Story Maps or agency presentations, restoration practitioners can foster information exchange for policy development and assist with future restoration evaluations by community members (Biggs et al., 2019; Lundgren, 2020).

For this chapter, GIS technology serves as a means for critical landscape interpretation, providing a framework for participants to engage directly with restoration progress. I followed a post hoc PGIS approach to bridge the results from Chapters 2 and 3, though some aspects of the process were modified to accommodate time constraints and lacking active spatial input from participants. Re-analysis of interview data highlighted mentions of significant locations across the GEE, leading to the creation of a geodatabase with an annotated table of 35 specific sites or general areas, each labeled with stakeholder associations and wilderness character (WC) ratings based on descriptions from agency websites (Table 4.2.2). WC ratings were assigned according to a simple scheme informed by a literature review on the subject of wilderness character and inspired by methods used by Tricker et al. (2017). Additional context for the WC rating system and its application in the PGIS survey is discussed further in Section 4.4.2.

WC Quality	**Low WC**	**Moderate WC**	**High Wilderness**
Area	<2,500 acres	2,500 – 5,000 acres	≥ 5,000 acres
Development	Extensive presence of the built environment	Minor presence of the built environment	Virtually unmodified
Access	Low access beyond paved roads	Access points limited with some paved road	Traditional access points and modes accommodated
Ecology	Extensive presence of invasive species/ highly managed landscape	d ecology with minor management	Native species dominate with little to no management

Table 4.2.2 Conceptual wilderness character ranking system.

4.3.3 *Story Map Data Integration*

Initially, I planned for this interactive platform to organize storytelling components effectively, embedding tools for data visualization and cartographic experiences to guide users through the Everglades SES. The Story Map's structure closely mirrors the organization of this dissertation, while prioritizing the clear presentation of qualitative and spatial analyses. Post-processed results from these analyses feed directly into the data visualizations. I applied the organizational and storytelling principles outlined by Vollstedt et al. (2020) and Lima et al. (2024) to maximize clarity, storytelling flow, and utility for end-users. This design ensures that I convey complex information through this platform via an intuitive, well-structured interface accessible to diverse communities, with interactive visualizations and crowdsourcing features that enhance engagement and enable real-time geographic data updates. Once online, this will offer an additional external yet dynamic platform for exploring the uncertainty and scale of Everglades restoration.

To systematically incorporate all materials into the Story Map and establish a consistent means of construction for other researchers, I adapted and created the following workflow template informed by best practices in storytelling and research ethics (Roth, 2021). Building on Roth's (2021) work on cartographic design in map-based narratives and Pima et al.'s (2018) process flow diagram, I created Figure 4.3.3 to illustrate the Story Map publication process within the context of my research. This cartographic narrative approach supports ecosystem restoration by visualizing ecosystem complexities, integrating local knowledge, tracking temporal changes, enhancing stakeholder engagement, and reinforcing policy frameworks. By combining scientific, social, and historical data into a visual narrative, these cartographic tools help foster understanding and support for restoration, even amidst contested landscapes like South Florida (Turner, 2003; Thatcher et al., 2016; Braun, 2021). Although the Story Map presented here remains a work in progress, the link provided in the Results (Section 4.4) directs users to a preliminary version currently under development.

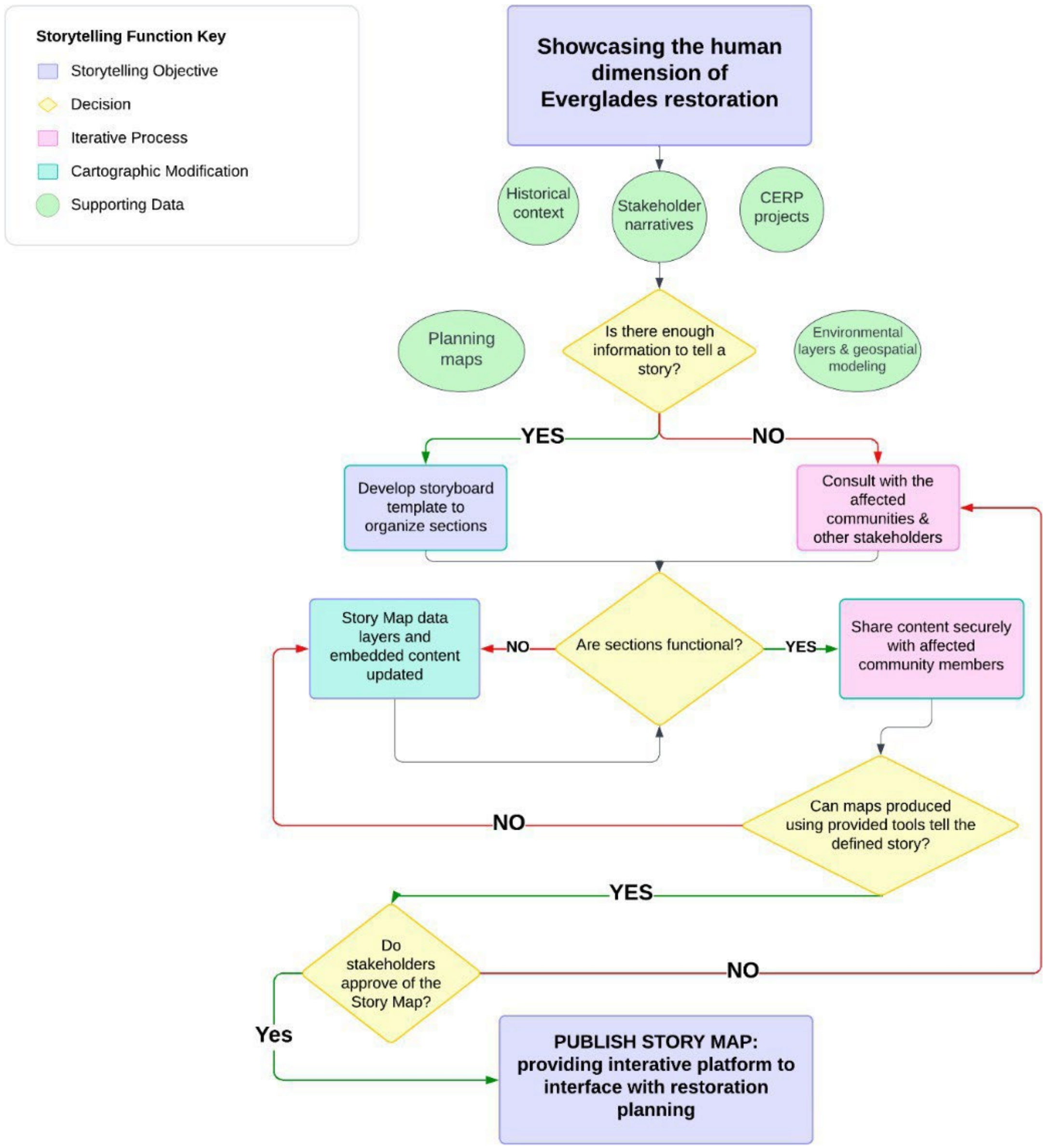


Figure 4.3.3 Story Map Design Flowchart
(adapted from Pima et al., 2018 with story elements derived from Roth, 2021).

The central thematic feature of the cartographic narrative will be an overarching interface that links various places and research themes, representing the narrative's timeline (Lima et al., 2024). Therefore, the thematic timelines guiding the storyboard navigation must align with the overall project scope to determine which datasets should be displayed to capture the most meaning from this interdisciplinary research. This ensures that the cartographic narrative flows in a way that accurately represents my investigation as positioned within the legacy of critical environmental scholarship in the region. Ongoing consultation with stakeholders regarding the platform's use will help anticipate users' emotional responses to different maps and images. A design template for this structure is provided in

the Results (Section 4.4) to break down the StoryMap+ organization.

Ultimately, this platform is designed to allow non-experts a means of identifying trends in the long-term conditions of conservation lands near restoration sites with personal observations from their local areas. Its unique contribution lies in its ability to continuously update imagery and spatial data related to land cover and project impacts and incorporate data-driven narratives that often reflect project timeline revisions and ecosystem changes. Eventually, users will be able to download observations, data projections, and visual comparisons of *what-if* scenarios, helping them evaluate potential policy changes and restoration activities in real time. Through this StoryMap+ and its connected Google Earth Engine (GeE) applications, users can conduct on-the-fly analyses and answer RQ2—regarding how boundary lands are shifting in ecological composition—with increasing precision as more restoration projects reach their long-term phases. Because the presentation of these results matters as much as the mixed-data analysis itself, I will consult with key informants from my pilot study on the displays and functionality of my Story Map as more of its features come online during 2025. The following section summarizes the organization and intent of a Story Map and findings derived from my interdisciplinary research on Everglades restoration.

4.4 INTEGRATIVE RESULTS & DISCUSSION

The end product of this chapter will be a fully functioning Story Map that not only updates the ongoing legacy of Everglades restoration but encapsulates and operationalizes the results of my prior investigation into the human dimensions and geospatial modeling encompassing my Everglades restoration research. While the StoryMap+ is not fully functioning at the time of writing this dissertation, access is still available using this link. Before showcasing the primary results of this chapter, I will first briefly review responses gathered from five interview participants included in the analysis of Chapter 2. This is an important introduction to framing my results because a committee member (LG) suggested I inquire into stakeholders' perceived positionality within the cycle of adaptive change and where they figured the GEE would also situate. This brief interaction with some interview participants highlights a persistent issue in reconciling the worldviews of Everglades restoration stakeholders. It also underscores the challenge of aligning these perspectives within a resilience framework that often fails to account for cultural contextual observations and responses to local environmental change or identify socio-ecological indicators of resilience (Quandt, 2008; Wakefield, 2017; Cosens & Gunderson, 2018).

While a resilience-based toolkit helps frame restoration planning for scientists and practitioners, I observed inconsistencies among stakeholders' self-perceptions based on their position within the adaptive change cycle are inadequate for understanding local connections in utilizing resilience theory alone. Consequently, it is not always positioned to effectively guide the development of adaptive governance in social-ecological systems (SES) or promote more equitable outcomes in all environmental scenarios. Working from this realization, I present the following findings to outline a data-driven pathway for producing an interactive platform. Integral to this section is explaining the functionality, significance, and online hosting of two central components within my Story Map: the PGIS survey and the dynamic landscape visualization critical to sustaining intuitive restoration planning efforts in the age of digital conservation. Following this introduction, my integrative chapter showcases the design and organization of the StoryMap+, emphasizing two interactive components developed through interdisciplinary synthesis: a PGIS survey and a dynamic landscape visualization portal. I frame the latter portion of this Results section around a fruitful way to answer RQ3 and the formation of an idealized SES model framework inspired by this integrative modeling endeavor. Because other sections of my Story Map are undergoing further development, I cover the remainder of this process towards the end of the Results. This section begins with an overview of my Story Map with a detailed outline of all sections and the associated content.

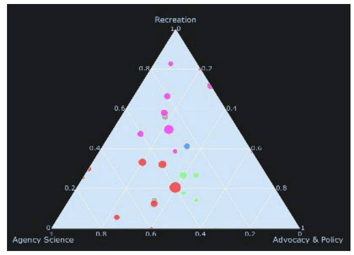
4.3.4 *Overview of the StoryMap+*

For now, the primary contribution of this interdisciplinary research is to provide an applied roadmap to address the coupled dilemmas of ecosystem restoration through a critical geographic approach to storytelling in the GEE. I accomplish this computationally using a workflow connecting GeE web applications and open-source Python libraries that embedded interactive data visualizations derived with the results of Chapters 2 and 3. This Story Map will reflect the research explored in this dissertation as well as highlight trends reported by stakeholders and detected through EO to enable a dynamic, iterative co-production of knowledge (Vollstedt et al., 2020). Because I cover the methods and results underpinning the first three components in prior chapters of this dissertation, the following sections instead focus on the contents of Story Map Section 4 (Integrative Restoration). This Section contains the PGIS survey and dynamic landscape visualization portal explained following the Story Map design template and outline below (Figure 4.4.1 and Table 4.4.2, respectively). Story Map Sections 5 and 6 correspond to the thematic highlights of this Chapter's Discussion (Section 4.5) and Conclusion (Section 4.6).

Everglades cultural landscape

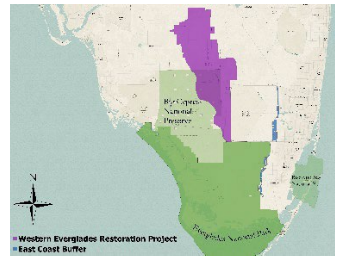
- Background and what other Story Maps on the Everglades omit
- The role of "boundary lands"
- Framing restoration as an SES

Human dimensions research



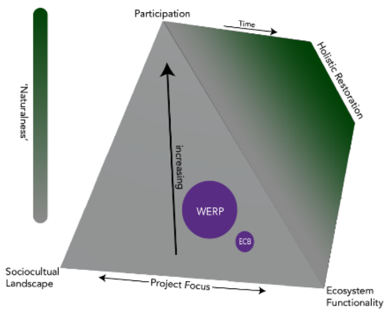
- Political ecology in the Everglades
- Stakeholder worldviews
- Understanding restoration narratives

Geospatial modeling



- Monitoring restoration progress
- Understanding land cover change
- Landscape visualization

Integrative restoration approach

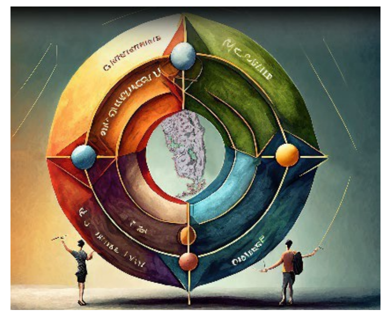


- Intentional boundary objects
- Participatory GIS survey
- SES model development

Rethinking Wilderness in BiCy

- Application of SES for W. Everglades
- Framing restoration as an SES

"Second Nature" in South Florida



- How nature is co-produced
- Community implications of projects
- Everglades in the Anthropocene

Figure 4.4.1 StoryMap+ design template for major sections with content headings.

Story Map Section	Thematic Component and Content Form
1 | Everglades cultural landscape	○ What other Story Maps omit – Everglades are "globally unique," yet the full story is complicated by competing narratives surrounding ecosystem restoration in the region – Positionality statement and declaration of research project goals – Primary graphic/function: composite evolution from first map to recent SFWDM to establish evolving representation of South Florida spatially ○ The role of "boundary lands" – Definitions and policy implications of their use – Goals of buffer sites with example map with inset images of projects – Primary graphic/function: thematic SF map + ECB flyover video ○ Framing restoration as an SES – Outlining this concept in virtue of Gunderson & Holling (2004) – Primary graphic/function: panarchic loop

2 | Human dimensions research	o Political ecology in the Everglades – Positioning this research within critical environmental literature – RQ1 + historical context of conservation in South Florida – Primary graphic/function: historical images (immersive box car scroll) o Stakeholder worldviews – Florida's Everglades & the politics of paradise overview – Traditional wilderness values vs. goals of 'environmental resilience' – Primary graphic/function: pie chart breaking down interviews by stakeholder cohort, references to archival research, and archival audio to showcase the complexity of socio-ecological interactions in South Florida
	o Understanding restoration narratives – Overview of knowledge production and discursive narrative analysis – Breakdown of anthropological investigation and four narratives – Primary graphic/function: ternary plot to narrative breakdown
3 | Geospatial modeling	o Monitoring restoration progress – Contextualization of RQ2 – Overview of datasets: land cover layers and UAV site orthomosaics – Primary graphic/function: GIS/RS workflow diagram o Understanding land cover change – Why do tracking changes matter? [melaleuca treatment example] – Definition & role of physiognomic structure, change ranking system – Primary graphic/function: interactive map of SF with landcover classes delineated based on modeled information
4 | Integrative restoration	o Intentional Boundary Objects – The limitations of static maps and other data visualization – Addressing RQ3 and pathways toward observations on- and offline o Participatory GIS survey – How this stems from my research and continues its original mission – Primary graphic/function: embedded Survey123 portal o Dynamic Landscape Visualization – Connecting EO with the subjective experience understood by community members, getting beyond mere science communication –Primary graphic/function: two embedded Sketchfab portals o SES Model Framework Development – Charting out restoration trajectory for the total environment – Primary graphic/function: summary framework figure
5 | Rethinking Wilderness in the Big Cypress Preserve	o Application of SES for W. Everglades – Showcasing evolving attitudes of wilderness in South Florida – Primary graphic/function: Big Cypress Restoration Alt-Maps and images mined from social media
6 | Emergence of a "Second Nature" in South Florida	o How nature is co-produced – Understanding ecosystem restoration as a social process – Reconciling with environmental claims-making with novel ecosystems – Primary graphic/function: images from the 2022 WERP presentation o Community implications of projects – Timeline animation with project images – Geovisualization that overlays WERP impacts on the cultural landscape – Primary graphic: flooded ranch GIF from Wingate Mill o Everglades in the Anthropocene – Where do we go from here? Conclusion, alternative resources – Applications in the Pantanal & and other conservation landscapes

4.3.5 *Participatory GIS Survey*

As I utilize it here, PGIS is a fundamental bridge through which restoration practitioners can better integrate TEK into environmental policy (Berkes, 2003; Roth, 2021). While Chapter 2 examines the relationship between powerful conservation interests in the GEE and the evolving socio-ecological condition of South Florida's protected areas, RQ1 and its derivative questions seek to understand competing management perspectives' role in determining ecosystem restoration goals. In arguing that landscape values and attitudes on wilderness have historically driven these narratives, I develop a tangible, cartographic rendering of the stakeholder views through this integrative process. This is critical for the wider discussion of wilderness in South Florida, given that only two congressionally designated wilderness areas exist in South Florida today: the Marjory Stoneman Douglass Wilderness Area in ENP and the Florida Keys Wilderness (Wilderness Connect, 2024). However, lacking information on the indirect measures of changing wilderness conditions in places outside of formally protected areas, such as those mentioned above, complicates a conventional visualization of the narratives gathered from my qualitative research in explicit geographic terms. To accommodate this need, I am utilizing ArcGIS Survey123 (ESRI, Redlands, CA) to work within the Story Map so users can submit observational data and record survey responses, which will better quantify and geolocate points of concern or support as restoration activities continue.

This component will be hosted in Story Map Section 6 (Table 4.4.1), concerning *Integrative Restoration*. Through this method, users can place multiple pins representing significant places in the GEE and, using a Likert scale for values 1–5, they can rate the effectiveness of restoration activities. Data will be captured in ArcGIS Online, and any responses with missing scores will be removed. The latitude, longitude, and score for each point can be imported back into ArcPro and later integrated into my Story Map to overlay with habitat maps or other project plans. This PGIS survey portal is an important contribution to my integrative monitoring efforts because it opens a virtual access point for ongoing, remote collaboration between restoration practitioners, community members, and interdisciplinary storytellers in a way that rapidly and more effectively extract spatial meaning from user perspectives. As the StoryMap+ currently demonstrates, its user navigation will emphasize the spatially explicit nature of my research narratives and other qualitative information offered through the public commenting process. In common with the dynamic landscape visualization discussed in the following section of these results (Section 4.4.3), it represents one of the unique contributions from this chapter showcased in my Story Map.

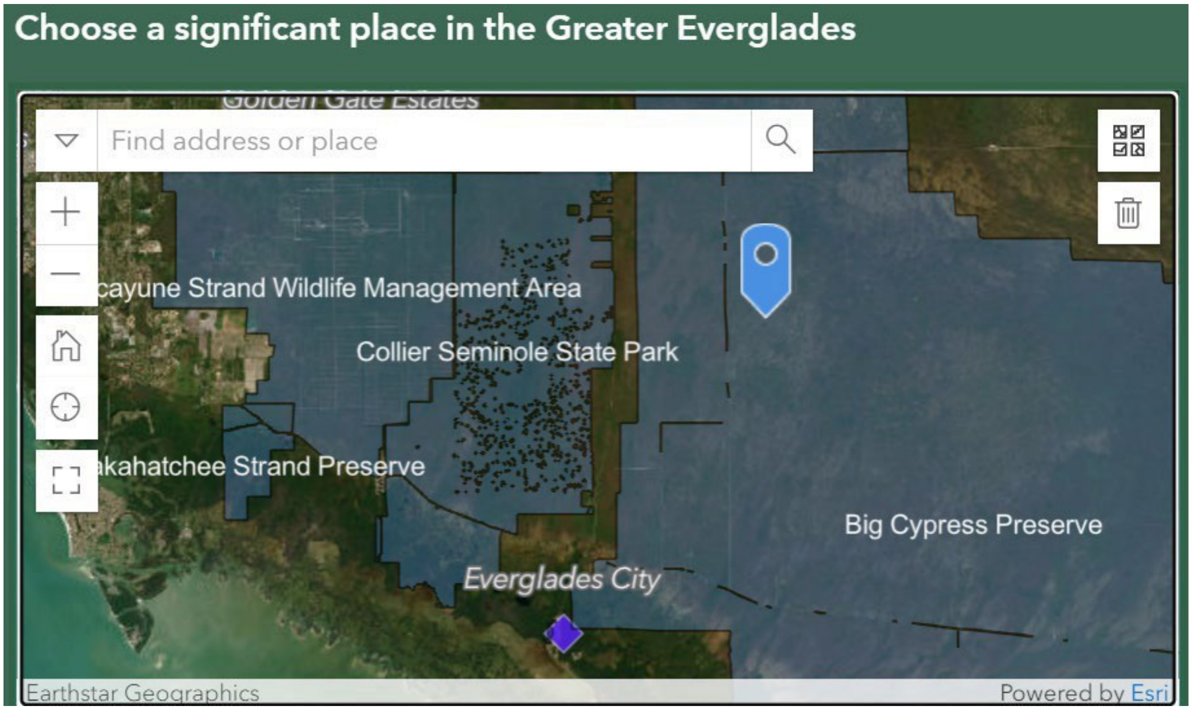


Figure 4.4.2 Webmapping survey included towards the beginning of StoryMap+. This was created using Survey123 (a mapping tool available through ArcGIS Online) and can be accessed directly using this link.

By conducting the mapping survey and performing a preliminary spatial analysis using the composite WC ranking system (Table 4.2.2) as developed from my findings in Chapters 2 and 3, I demonstrate the opportunity for research synthesis by offering derivative inquiry to further refine RQ3. This example showcases how PGIS can be employed in other questions relevant to equitable planning as:

If significant places in the Greater Everglades Ecosystem (GEE) diverge from conventional wilderness concepts held by diverse South Florida communities, what social pathways must shift to achieve equitable outcomes in ecosystem restoration planning? Addressing these emergent questions through co-produced boundary objects such as cartographic narrative remains an ongoing goal of my Story Map's dissemination and use. Although this initial analysis is foundational, it highlights the robust functionality of PGIS to incorporate more detailed data from an expanded participant pool and multiple sites. As Everglades restoration efforts progress and more interdisciplinary spatial data become available, PGIS can foster richer, more nuanced cartographic narratives. The limited dataset derived from prior interviews and public comment transcripts yields two initial insights that this Story Map will help restoration practitioners continue to understand as Everglades restoration evolves:

1) Important places in the GEE encompass over 1/3 of South Florida's area contain *high* or the potential for high WC and;

2) The stakeholder cohort most vocal in their framing of these protected areas as containing intact wilderness were *agency scientists*.

4.3.6 *Dynamic Landscape Visualization*

My efforts supporting the capture, analysis, and visualization of real-world data enable landscape visualization hosted using SketchFab for use in the geospatial modeling portion of my StoryMap+. This online platform publishes and shares 3D content for augmented reality and VR applications. Restoration practitioners emphasize science communication as a consideration in many aspects of Everglades restoration planning and collaboration, however, the potential of such tools in ecosystem restoration remains largely unrealized owing to technical difficulties and the demands of contextualizing complex environmental changes through language and static images. Immersive experiences provided through VR and even large interactive displays facilitate an understanding of landscapes affected by restoration activities in more tangible ways than conventional learning allows (Markowitz et al., 2018). Care should be taken in the implementation of this technology. Digital representations of nature cannot possibly encompass the multi-faceted worlds experienced by community members affected by restoration activities, although this is a growing trend in conservation (Arts et al., 2015). While Mack's Fish Camp is one of many planned virtual landscapes significant to stakeholders in the GEE that will be hosted in my Story Map, it remains the only landscape model currently accessible to users in Story Map Section 6. Other locations will include other boundary restoration projects, a hunting camp in the BiCy, and a traditional Miccosukee camp north of ENP.

While an operational VR workflow rendering future conditions based on restoration progress for meaningful places in the GEE exceeds this project's scope, this StoryMap+ provides the foundation for more intuitive, place-based assessments of shifting environmental conditions. Such a practice will be important in preventing environmental amnesia in an era of exponential growth accompanying a rapid demographic shift (Kahn, 2002; FDEC, 2021). The following figure is a screenshot of a virtual guided tour of Mack's Fish Camp, an ecotourism site and famous Gladesmen outpost in Water Conservation Area 3B. The data used to visualize this 3D landscape model were originally captured and analyzed in Chapter 3. VR experiences of a landscape undergoing restoration can be a powerful tool for engaging community members in primarily two ways. VR allows community members to visualize the restoration process through means usually difficult to convey through traditional maps or photographs. By immersing them in a simulated environment, VR can illustrate what specific changes in the landscape will look like over time, helping people understand the goals and anticipated outcomes of the restoration efforts. Experiencing a landscape in VR can also evoke a sense of presence and emotional attachment to the area, even if individuals cannot physically visit it. This connection can foster a stronger commitment to conservation and restoration, as people can more vividly imagine the potential impact on the ecosystem and their community. For now, this portal is easily accessible to any device with internet.

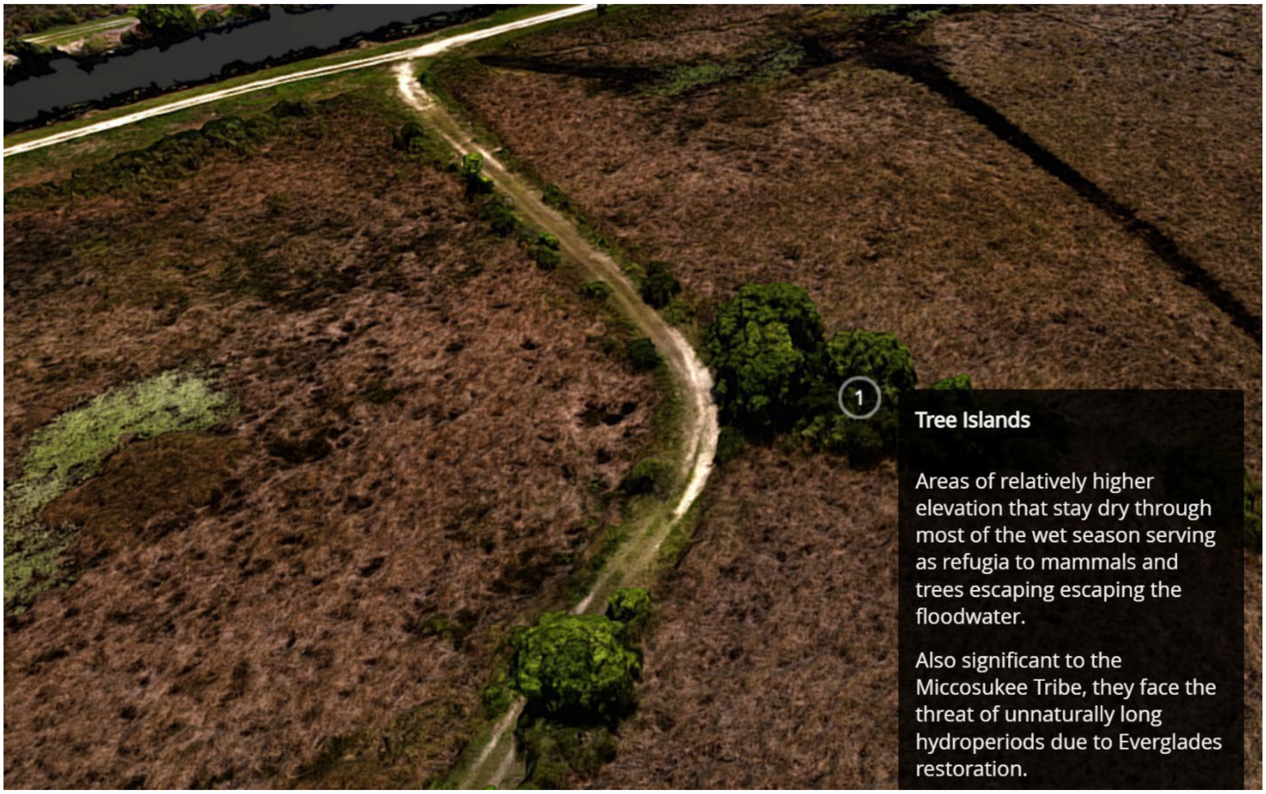


Figure 4.4.3 Example of Mack's Fish Camp as the interactive virtual landscape with educational annotations. I created this photogrammetric model using UAV imagery collected in the summer of 2023 and notes from my literature review.

4.3.7 *Addressing Research Question 3*

With its integration of PGIS and dynamic landscape visualization, this Story Map provides a vital tool for exploring my third research question: *What are the long-term implications of restoration-related changes in boundary lands for community attitudes toward wilderness and access across the GEE?* To understand the impact of these changes on community attitudes toward wilderness and access within the GEE, it is essential first to establish the historical context—how perceptions of naturalness have been linked to ecosystem restoration in South Florida. This involves revisiting past research on landscape preference and re-evaluating my qualitative and geospatial modeling workflows. As discussed in Chapter 2, the emphasis on access by the recreational community underscores a complex narrative. Rather than merely landscape aesthetics, access has been a primary motivator, with recreational opportunities being shaped by accessibility and the ability to engage directly with the landscape (Gosal et al., 2018). This perspective is particularly relevant in South Florida, where much of the interior is flooded and densely vegetated, limiting direct interaction with most natural areas.

The following figure summarizes key takeaways from landscape preference research to visualize the continuum of naturalness observed in terrestrial ecosystems with two examples from restoration projects in the GEE relevant to this research: the ECB and WERP. While both projects remain at different stages of completion with WERP approaching its final plans, charting the shifting emphasis between the ecohydrological conditions necessary to reach a restoration target in terms of functionality and efforts taken to preserve the sociocultural landscape is necessary for critical monitoring efforts. To reiterate Chapter 3's conclusion, long-term plans for the ECB remain unclear, although most of its components are unlikely to stabilize without continuous intervention. As research continues and more project data becomes available to the public via publications and crowd-sourced methods, users can compare the pathways of projects in four-dimensional space as extended, potentially overlapping pipelines. As envisioned below, holistic restoration requires approaches that consider the cultural landscape and ecosystem functionality, together enhanced by participation from affected communities (Figure 4.4.4).

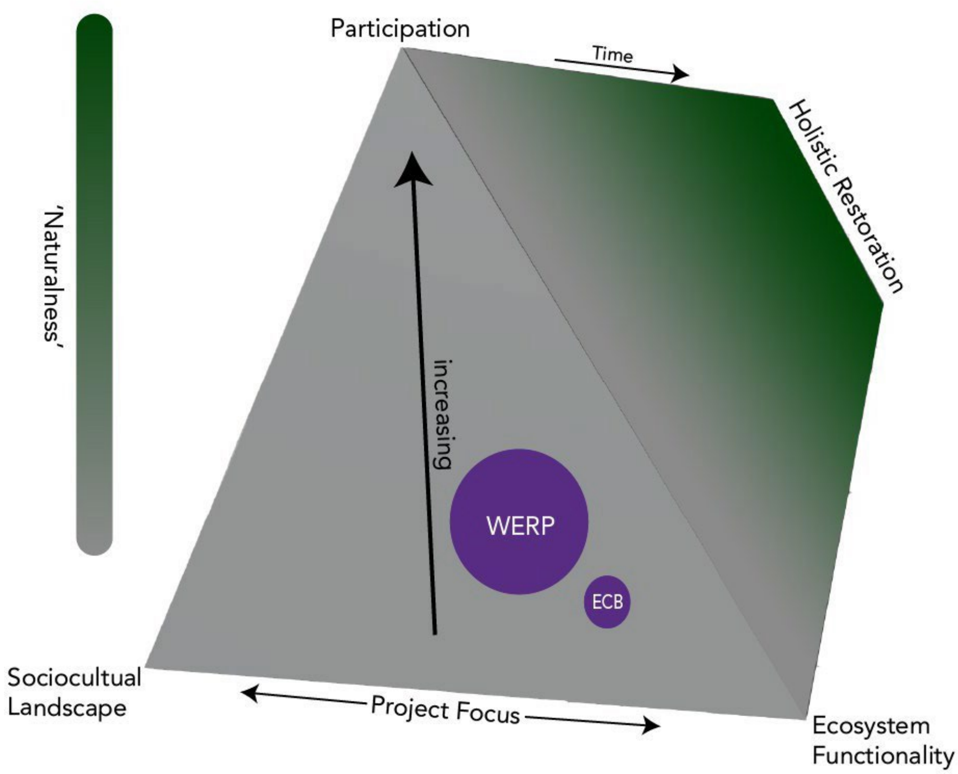


Figure 4.4.4 Socio-ecological model framework for Everglades restoration based on this research.

While it manifests here as a theoretical representation, this summary figure of my integrative research has several important features relating to real-world phenomena. The gray-green color gradient of the vertical scale on the left indicates "naturalness" as a composite of physiognomic structure and community attitudes that inform a landscape's WC. This is not to say that all projects eventually reach a point of more natural or pristine character over time, only that the color for a single time slice (rendered two-dimensionally as a triangle) would vary along the vertical gray-green axis. As provided in the methodology in Table 4.2.2, I structure WC around the relative area, modes of access, and extent of development along a generic low–high rating. In reality, these are gradual measurements, and so the accompanying scale reflects a lack of discrete breaks in the WC of South Florida's protected areas and associated boundary lands. As depicted in this figure, WERP is greater in the area but only improves marginally for stakeholder participation compared with the ECB, while its project focus offers more in terms of retaining and restoring the Western Everglades cultural landscape. WERP primarily promotes ecosystem functionality in common with other CERP projects based on this framework and other insights realized through my investigation, although the extent to which historic conditions of land cover and hydrology will be achieved in this area remains dubious when confronting current plans offered by SFWMD and the Army Corp. I make this claim based on my analysis of recent public commenting sessions (SFERTF, 2023), WERP boundary objects discussed further in the following section, and ongoing communication with key stakeholders. Therefore, a direct yet comprehensive answer to RQ3 is not yet possible, although my StoryMap+ can eventually answer RQ3 as monitoring data becomes available. Under my integrative approach, this framework more closely facilitates an abstract comparison of different CERP projects across time from a higher-level view.

4.3.8 *Situating this Story Map in the Future of Everglades Restoration*

Assessing the implications for restoration planning on South Florida's human and ecological dimensions is a complex but necessary task to foster more equitable conservation outcomes for the GEE. By exploring the relationship between the qualitative and quantitative aspects of my research journey, I provided a workflow through which interdisciplinary scholars can design interactive platforms, like a Story Map, to collaborate across communities and scales of management. The cartographic narratives of ecosystem restoration prototyped in this chapter illustrate how these interactive tools can serve as bridges between diverse knowledge systems. My results underscore important pathways for Everglades restoration that are also discussed in the literature on socio-ecological systems and critical geography. These findings suggest that integrative modeling can provide more insightful narratives to support data-driven, policy-based collaborations between restoration practitioners and local stakeholders affected by these projects. This section further situates my contribution to the growing body of ideas and practices in ecosystem restoration.

Navigating South Florida's transformation into a "second nature" through the lens of critical geography offers insights into the long-term implications of restoration-related changes in boundary lands within the GEE (Garvoille, 2013; Amorino, 2019; Catellino, 2020). As restoration efforts reshape both the physical and social landscapes, community perceptions of wilderness—historically tied to pristine, untouched areas—are shifting with a direct impact on the framing of "conservation-minded" federal policy aiming to set aside massive areas of the WERP cultural landscape. While I explore this further in terms of recent studies into BiCy in Section 4.5.1, my insights present an effective pathway for assessing the evolving role of nature in their lives of South Florida's Gladesmen and tribal communities through addressing the research questions explored throughout my results.

RQ3 is especially relevant at the time of writing this in restoration projects like WERP, which affect local identities and relationships with the land. The preliminary use of PGIS to build my Story Map's survey portal and the use of dynamic landscape visualization allows diverse users to explore these themes in high-fidelity cyberspace. As I hypothesized towards the end of Chapter 2, significant places in the GEE do not correspond primarily with traditional ideas of wilderness as represented by diverse communities in South Florida. Because of this, projecting the directions for social pathways affecting the thresholds necessary for SES shifts is fundamental to facilitating equitable outcomes in ecosystem restoration planning (Gunderson & Holling, 2002). My findings also suggest that these non-traditional wilderness areas hold immense cultural and emotional significance for native residents of South Florida, so their continued and expanded inclusion in restoration planning is vital. These places challenge conventional notions of wilderness and call for an expanded understanding of ecosystem services, including those tied to both ecological and cultural dimensions.

This research also attempts to shift the focus of South Florida's restoration away from limited environmental remediation and capital improvement toward a confrontation with the Anthropocene discourse shaping our future relationship with the natural world. Wakefield (2017, p. 2) offers a unique commentary here in terms of our positionality as scholars approaching complex environmental issues: "a critical engagement [with these updated frameworks . . . offers a way to see the Anthropocene as neither a crisis to avoid or manage nor a world of ruins, but rather as a time of dislocation and possibility that calls to be inhabited via creative, situated experimentation." Narrative-based uncertainties in ecosystem restoration often stem from environmental generational amnesia, an issue formally identified by the psychologists Kahn and Wiess (2017) and echoed in the interviews that inform the human dimension of this research. The following quote by a key recreational advocate frames the damage this amnesia invokes for those working in Everglades restoration:

> I think "restoration" was the wrong word. I think the idea and the goal were noble, but . . . I think maybe "rehabilitation" might have been the better word, right? Because you hear restoration, and everybody's mind goes

to a different idea of what it should be. When are we going back to; 1832, 1549? What are we restoring it to . . . what's the goal?

Dynamic landscape visualization, particularly through tools like Story Maps, plays a crucial role in bridging these gaps. One key landowner affected by WERP voiced a poignant concern when reflecting on the absurd use by many journalists and other public facing actors of restoration to rely on surficial "research" through Google Earth to make impactful statements on an environment they have not personally countered. That she did "not want the land that we love and consider family to be a science experiment and fail" lies very much at the core of landowner fears in the Western Everglades given how rapidly mis-management has already transformed things in the western fringes of the GEE. This sentiment encapsulates the emotional stakes for residents whose livelihoods and identities are intertwined with the landscape. Visualization tools not only help communicate the scientific and technical aspects of restoration but also enable these personal and cultural narratives to be integrated into planning processes. Incorporation of cultural ecosystem services requires methods that span natural and social sciences and even interpretive qualitative approaches from the humanities (Gosal et al., 2018). This naturally renders important considerations for the use of virtual interactions as key ways we understand long-term landscape dynamics. These approaches are particularly valuable in understanding the human dimensions of restoration, ensuring that these lands' cultural and historical significance is not lost amid ecological goals that also bring their own qualities of uncertainty.

Finally, the storytelling embedded in these visualization tools holds great potential for helping community members and other stakeholders understand and adapt to future socio-ecological conditions in South Florida's boundary lands. By presenting these narratives in a way that is accessible and grounded in local values, restoration efforts can foster more inclusive and resilient outcomes that reflect both the ecological and social needs of the region (Arts et al., 2018). The integration of these diverse perspectives and methods into ecosystem restoration planning not only deepens our understanding of the GEE but also sets a precedent for how we approach restoration in other complex socio-ecological systems. As proposed through this integrative methodology, a StoryMap+ is not designed exclusively to serve the communities of South Florida or even iconic conservation landscapes in the Global North.

4.3.9 *Rethinking Wilderness in the Big Cypress National Preserve*

Beyond academic literature, a dialogue between recreators and the agencies leading ecosystem restoration efforts in South Florida manifests primarily through public forums like the South Florida Ecosystem Restoration Task Force (SFERTF) and the informal online blogging space (Repanshek, 2015). Towards the end of my qualitative analysis, involvement with stakeholders belonging to the recreational cohort of research participants (n = 4) led to a shift in emphasis from the ECB as a case study to WERP dominating the immediate utility of my research. This contentious matter relates to region-scale restoration activities adversely impacting the BiCy and its boundary lands under the historic domain of private landowners and South Florida's federally recognized tribes, the Miccosukee and Seminole of Florida. While the StoryMap+ best covers this ongoing conflict in the legacy of "the politics of paradise" (Grunwald, 2006) the remainder of this section discusses the implication of my findings for RQ3 and how my SES modeling framework holistically ranks scenarios proposed for the future of the Western Everglades.

After attending meetings and speaking to many restoration actors affected directly by the possibilities of a congressional wilderness designation in BiCy, much of the current planning contradicts earlier recreational accommodations present in CERP. Those areas once placed off-limits to offroad vehicles, and some that were even deemed suitable for a formal designation, have been observed on the newest maps, led many recreators to question restoration leadership. It has been suggested that some enlightened decision-makers were privy to the fact that these areas were far from "pristine nature" and remained headstrong in their idealistic commitment to "remove the scars caused by vehicles and recover a sustainable, self-regulating, self-organizing ecosystem" as stated in the 2000 Off-Road Vehicle (ORV) plan (National Park Traveler, 2015).

Given the relevance of wilderness perceptions to my project and the ongoing significance of WERP with its implications for BiCy under a formal wilderness designation, I believe the best use case for my socio-ecological model will be to assess these alternatives such that an interactive PGIS framework would be feasible for a more equitable inclusion of members of these "gateway communities." Evolving wilderness visions under a realism:idealism dichotomy is important because of the never-ending role of advocacy. A socio-ecological modeling framework considerate of stakeholder attitudes on wilderness more intuitively guides the role a change ranking system plays in monitoring holistic restoration. Such an approach is already empowering gateway communities in South Florida, yet the timeframe is uncertain and inefficient owing to powerful institutional barriers. In consideration of this dilemma and the recreational community who inspired and assisted me most during my fieldwork, I am positioning the WERP case study within the social-ecological model of restoration as a test of its analytic potential. The remaining figures in this section highlight the key components of its section in the StoryMap+.

In this era of wilderness management, the NPS states that they manage regions "of eligible and proposed wilderness in such a way as to protect their wilderness character" (NPS, 2022, p. 64). The idea that some protected areas contain more pristine regions than others based on their appearance originates in the North American tradition of land management (Nash, 2024). According to their 2022 Supplemental Draft Plan and Environmental Impact Study (EIS) for BiCy, their stated goal is to delineate portions of the original preserve considered eligible for a wilderness designation. Encompassing nearly one-third of South Florida's drainage basin, BiCy protects the Big Cypress Watershed: a western, more upland region critical to the vitality of the lower Everglades. Due to issues of "threatening wilderness character" in BiCy, the NPS envisioned future plans for access with varying delineations of federally protected wilderness through three scenarios.

According to many community members relying on local ecological knowledge and data collected by external partiers, parts of the Preserve historically significant to the recreational community in South Florida will face further deterioration through any formal designation in the BiCy. Many believe that current threats in the Preserve, including invasives and altered periods of flooding, stand to worsen under the hands-off approach to management that comes with a wilderness designation. Two of the three alternatives proposed in the EIS for BiCy are posed to ironically deteriorate many of these already affected landscapes in the hopes of maintaining or returning to their primitive character. If this is the case, BiCy may further devolve into a "wet desert" beyond remediation, as hydroperiod duration only increases inversely with opportunities for traditional lifeways to flourish in the Western Everglades under WERP.

Scenario	Implications
ALT 1: No Action	Continuing current Management, thus recreation does not thrive in its historical sense but "no areas would be proposed for wilderness designation in the original preserve" (p. x)
ALT 2: Moderate Access, More Wilderness	Proposes that Congress designate approximately 190,528 acres of land (32% of the original preserve and adjoining Western Addition) as wilderness & fewer ORV trails
ALT 1: Enhanced Access, Less Wilderness	Proposes that Congress designate approximately 147,910 acres of land (25% of the original preserve and adjoining Western Addition) as wilderness & more ORV trails

Table 4.4.6. Big Cypress Preserve alternatives summaries, ORV = off-road vehicle (NPS, 2023).

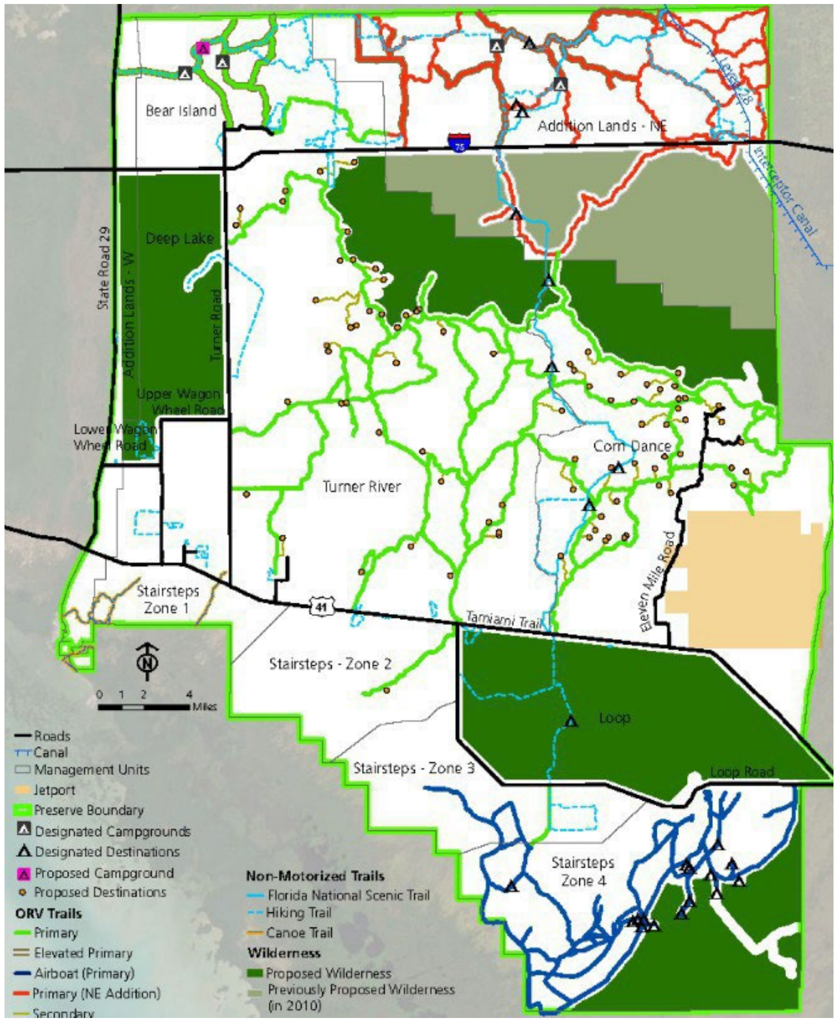


Figure 4.4.5. Map of "Alternative 3" for Big Cypress National Preserve, the NPS-preferred solution (NPS, 2002).

In looking at the maps and tables showcasing the spatialized realities of potential management regimes for BiCy, it is important to understand what these maps omit (Garvoille, 2013). Common with other boundary objects, there are tradeoffs in the interpretability of a map's abstraction of the dynamic and nuanced cultural landscapes they necessarily reduce. Clarity and simplicity are prioritized at the expense of communicating the uncertainty of project activities and long-term ecological shifts. When ideas are introduced to combat "climate change impacts" despite agency restrictions on the usage of identical rhetoric in recent memory, a critical take on these planning studies requires acknowledging the power relations that have increasingly come to influence the biophysical landscape given the weight placed on certain types of knowledge (Braun, 2021; Osborne, 2021). In the NPS document, the Everglades and restoration are mentioned often, yet this EIS fails to connect the potential of any scenario's role in the wider vision of a restored GEE. This may signify a deeply rooted failure by state actors to recognize other forms of resilience underscoring socio-ecological system (Ogden, 2008a; Garvoille, 2012). Many of the projects key to restoring the Everglades start appearing fractured when the lived experiences of community members along this socio-ecological boundary reveal that WERP impacts contradict adaptive management and policy mandates for sustainable public access. This represents another unrealized promise of Everglades restoration prominent in the 2020 SFERTF Meeting.

4.4 CONCLUSION: RESTORATION AS A SOCIO-ECOLOGICAL PROCESS

4.4.4 *Maintaining a "Second Nature" in South Florida*

Beyond understanding shifting perspectives on wilderness and the resulting production of knowledge driving conservation initiatives, this project seeks to understand the socio-ecological process through which novel states of nature emerge. There remains a high degree of uncertainty in projecting the long-term results of management regimes and the extent to which they affect the values inherent in cultural landscapes across the GEE. CERP aims to improve South Florida's water security by restoring the primeval "quality, quantity, timing, and distribution of water" and, by extension, the historic vegetation communities of the Greater Everglades, yet that appears neither viable nor clear any longer (Zweig & Kitchens, 2010). A *resilient* Everglades seems to trump all renditions of a *natural* Everglades when project plans and the rhetoric of powerful actors and agencies receive deeper scrutiny. Bearing this in mind, translating these implications for members of South Florida's gateway communities should be a primary undertaking for re-cognizing future regimes of the Greater Everglades SES. Wilderness perhaps lost its relevance in becoming conceptually resolved in terms of its deeper role to society alongside the benefits to both human and non-human nature, as many have expressed before (Lynch, 2006). We facing this dilemma in restoration today.

An emerging perspective in land management that provides some promise is that we move beyond monitoring the typical biophysical aspects of wilderness and instead describe, track, and elucidate our relationships with wilderness if our goal is to define and protect its character. The impact of climate change on wilderness character in protected areas globally is already significant. When confronting heavily degraded landscapes, the meaning of unrecognizable natural spaces poses an awkward challenge when "the images in the visitor's mind might be difficult to reconcile with the changed landscape before them" (Dvorak et al., 2009, p. 131). Most communities lack an agreed-upon baseline or quantification scheme necessary to make comparisons between restoration case studies feasible. Established thresholds worsen in the region absent knowledge co-production, especially when Western audiences generally prefer taller, densely vegetated forests without deeper context

(Kiley et al., 2017). This manifests most clearly in the proliferation of invasive Melaleuca forests in southeast Florida in the case of the Pennsuco Wetlands. These themes relate to broader perspectives on landscape preference under the assumption that "nature" is an invention of the Western mind. Instead, emerging platforms such as the Story Map explored in this chapter can facilitate storytelling in ways that address RQ3 when the social construction of boundary objects is subject to "constant renegotiation" (Harvey & Chrisman, 1998). William Cronon (1996, p. 17) famously remarked that the "paradox of wilderness" embodies a "vision in which the human is entirely outside the natural," a message that remains clear from the analysis of the various documents and conversations compiled to address the political-ecological investigation of Chapter 2.

4.6.2 *Final Thoughts: Where to go from here?*

While we remain earnest as scholars of the environments in commemorating the wilderness ideal as a reflection of our society, the inherent human:nature dualism leaves little room for experimentation toward the ethical and sustainable role we believe necessary to thrive in the Anthropocene (Cronon, 1996). To the best of our ability, social scientists working in environmental contexts have a moral and ethical obligation to embrace the insights of our research to achieve common goals. An adaptive modeling framework works in tandem with adaptive ecosystem management; thus, the continuous incorporation of new information accessible to a wider audience begets new knowledge. This fosters more virtual but ongoing interactions between stakeholders and enables transparency across the uncertainties of environmental decision-making. True restoration does not foresee an idealized end state; as opposed to being the goal, restoration is the means to achieve the structural changes necessary to produce sustainable and just land management in the long-term (Osborne et al., 2021). As I demonstrated with WERP, the ability for successful integration in the planning and outreach process and the monitoring protocol underscoring landscape modifications is critical to see restoration projects to fruition, whatever form they ultimately take.

A pipeline that integrates diverse information types iteratively, along with the appropriate management and communication of data, has the potential to adaptively guide restoration activities and align competing narratives within a regional narrative. The StoryMap+ developed in this project represents one attempt to build such an interactive platform, but its functionality meains limited. Stakeholder evaluation of its utility will serve as a vital test of its ability to address RQ2 and understand the long-term concerns raised by RQ3, that restoration projects pose significant challenges to access, evolving ideas on nature, and support for the status quo of environmental governance. Upon further consulting with the research participants interviewed, I will distribute this platform to organizations and communities connected to the GEE. While future experimentation with this dynamic medium could facilitate more immersive landscape visualization under various restoration scenarios in VR, the true strength of participatory approaches pushing digital conservation today stems from the potential of more accessible, high-resolution, co-produced knowledge of the natural world. Further uncertainties in this mission relate directly to the integration of these insights back into policy formation. For this reason, Buytaert et al. (2012) echo the need for planning critiques when public input challenges a model's results and decision-making process.

If South Florida takes seriously Cronon's (1996) notion of getting back to "the right nature," then managed landscapes hold the same potential for sustained ecosystem services as do iconic conservation landscapes like the National Park and Preserve. Future conditions in the GEE and beyond could be characterized by a more equitable, reciprocal relationship between society and non-human nature if an interdisciplinary approach to holistic ecosystem restoration grounded in digital conservation becomes realized. Because restoring America's Everglades bears the potential to serve as "a model for the world" (Grunwald, 2007), this project is well-positioned to apply the hard-won lessons of its success and failures in South Florida. Wakefield (2019) argues that a key question of the Anthropocene is deciding who gets to live what sort of life and under what conditions. Given the growing emphasis on the human dimensions of the CERP, this research additionally offers a more effective heuristic for navigating ecosystem restoration projects across ecologically and culturally significant landscapes.

Chapter V | Conclusion

This project sought to provide a more holistic means to assess the competing social and ecological futures for South Florida's protected areas and related zones juxtaposed by wilderness and development. More practically, I desired to prototype a culturally rich, data-driven means to communicate ongoing progress in restoring the iconic conservation landscape of Florida's Everglades, referred to throughout this document as the Greater Everglades Ecosystem. I adopted perspectives and methods from political ecology and critical geography to envision an interdisciplinary framework that effectively composites anthropological and geospatial methods, respectively, to understand narratives and activities underscoring Everglades restoration. This manifested as workflow over four years in the making that explored initial perspectives on restoration in the region, built upon past social science research on South Florida's politics of paradise, established a multi-scalar geospatial monitoring approach, and attempted to integrate the analytic strengths of conventionally unconnected domains of inquiry to synthesize a more equitable platform to the benefit of communities affected most by this long-term socio-ecological process. The remainder of this discussion reviews major lessons from my project and summarizes the key takeaways from all chapters in this dissertation. These summaries distill the theoretical and applied steps necessary to trace out how powerful interests in South Florida have effectively introduced a second nature, and to what extent the trajectory of current restoration projects will continue to succeed or fail in providing socio-ecological restoration of the total environment.

The current era of ecosystem restoration in the Global North embraces adaptive management, which means that the uncertainties of project outcomes—both ecological and social—are minimized by decision-makers. Opportunities for project transparency instead have been replaced by the agencies literally paving the way for progress with narratives that work in tandem with the same political rhetoric reinforcing these power structures (Fortin, 2002; Garvoille, 2013). Through past eras, Everglades restoration retains an unprecedented reputation for its scale in terms of area, cost, and individuals. The expanding communities of South Florida generally do not recognize the long-term implications of failing to secure the resilience of its landscapes. As I demonstrated through my qualitative research, the binary distinction between 'civilization' and 'wilderness' or non-human nature is an arbitrary social construct with socio-ecological consequences for boundary lands, including the East Coast Buffer (ECB), the Western Everglades Restoration Project (WERP), and Picayune Strand; despite the ongoing priorities of 'saving' charismatic megafauna in the region. The production of environmental knowledge matters more today than it once did. Historically marginalized communities most connected to these managed lands and their adjacent protected areas will not settle for state agencies and NGOs to celebrate wildness symbolically without taking the proper steps to preserve it.

To navigate the human dimensions of Everglades restoration, the reader should explore Chapter 2, where I primarily connect past scholarship in political ecology with the current state of affairs as it dominates South Florida's restoration game. The role of environmental amnesia, participatory governance, wilderness values, and access were explored in the context of restoration projects. Another major component of my theoretical modeling overview was the Cycle of Adaptive Change and its associated panarchy (Gunderson & Holling, 2004). This approach in the study of complex natural and social systems was important to frame for Everglades restoration to its role in not only historically serving as the ecosystem that resilience and panarchy were derived from but also because its ongoing regime shift represents one of the best opportunities interdisciplinary researchers have in North America. The remainder of this chapter effectively lays out the methods associated with my qualitative fieldwork and thereafter details the discursive narrative analysis to address who has (and historically held) the power to promote and implement conservation initiatives to create a 'second nature' (Garvoille, 2013) in the Everglades. I conclude with a discussion of the role of boundary objects and how they can be better informed and ultimately used to chart pathways for equitable environmental knowledge production in South Florida.

Earth observation (EO) and its predominance in ecosystem management dominate the background and execution of Chapter 3's contribution to this project. Here I cover remote sensing-based monitoring techniques and examples from around the world, but generally within the GEE. Again the indices and sensors relevant to my approach were covered with the review divided amongst vegetation, hydrology, and uncrewed aerial vehicles (UAVs or drones). My methodology then built a geospatial modeling framework I showcase as utilizing workflow of how data from the National Park Service (NPS), open-access satellite imagery (Landsat 7 and 8), multispectral UAV imagery, and software packages such as ArcGIS Pro and Agisoft Metashape work interactively to train a random forest classifier. I accomplished this using the cloud-based platform Google Earth Engine (GeE) to classify land cover across South Florida, although the area of interest for the land cover change modeling associated with CERP activities was limited to the geographic extent of ECB adjacent to the Ft. Lauderdale-Miami metropolitan area. Major land cover transitions were summarized for the ECB region. Change ranking was accomplished via expert consultation and comparative regressions established that Buffer Area, as compared to Protected Area (the control) and Anthropogenic Area, was characterized overall by a negative trajectory of restoration 'progress' in terms of the landscape's physiognomic structure despite being the most actively managed area in the region.

The final chapter's (4) contribution to this project evolves from an intentional integration of the primary takeaways from both the cultural (or qualitative) and geospatial (or quantitative) components of my research. I opened the chapter by covering the background of integrative methods in the realm of coupled human-natural systems. I built upon an evolving argument for why remote sensing and GIS have typically failed to be incorporated into social science and finished the background discussion with several interesting modes for integration in environmental policymaking. The methods covered primarily encompass data pathways for the style of socio-ecological modeling utilized in this research as the emerging subfield of critical geography (Braun, 2021) presents one of the best ways to tackle the issues of digital conservation raised by Arts et al. (2015, 2018). I allotted the remainder of this chapter to the way I believe best addresses RQ3, in trying to render meaningful the long-term implications of these restoration-related changes in boundary lands for community attitudes toward wilderness and access across the GEE. Systems scoping, the design of the StoryMap+, and how this interactive platform—itself a boundary object—functions and helps us collectively rethink the role of wilderness in restoring landscapes in the GEE and beyond dominate the results and discussion of my integrative chapter.

In conclusion, addressing the human-nature dualism that traditionally undermines holistic approaches to environmental management is essential for achieving sustainable restoration in the Anthropocene. Social scientists, through adaptive modeling and ecosystem management frameworks, play a critical role in fostering transparency, stakeholder collaboration, and continuous knowledge generation for region-scale ecosystem restoration projects such as CERP. A viable model for restoration focuses on structural changes rather than an idealized end state, enabling adaptive and equitable conservation outcomes for people and nature. The integration of diverse data and interactive digital tools built with critical storytelling in mind can advance participatory governance by enhancing accessibility and co-production of knowledge. As the Everglades restoration exemplifies, interdisciplinary approaches to ecosystem restoration present pathways towards a more realistic, culturally considerate novel ecosystem state for South Florida's protected areas. My research ultimately provides a multi-faceted, iterative workflow for scholars and practitioners navigating the uncertain terrain of ecosystem restoration. Cultural landscapes facing significant ecological and social consequences of these interventions will require our attention as the Anthropocene evolves.

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APPENDIX A

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Socio-Ecological Restoration at the Boundary:

Integrative Monitoring in South Florida's Protected Areas

Principal Investigator: John Edward Sabin III

Institution, Department or Division: Department of Coastal Studies

Address: Flanagan Building, Suite 250 Greenville, NC 27858

Telephone #: 252-328-6220

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?

The purpose of this research is to gather perspectives from diverse actors involved in Everglades restoration to guide the remainder research, aiming to facilitate more effective environmental planning in South Florida. You are being invited to take part in this research because you have demonstrated through your involvement at the local or state level a passion for the Everglades ecosystem as well as years of relevant experience in academic and/or applied settings. The decision to take part in this research is yours to make. By doing this research, I hope to gain insight into your expert perspective on the complex social and physical components involved with restoring Florida's Everglades.

If you volunteer to take part in this research, you will be one of about 30 **people to do so.**

Are there reasons I should not take part in this research?

Your participation in this study will consist of answering questions during an interview with a researcher from ECU. The interview will likely not last longer than 45 minutes and is not physically demanding. Only you, however, can determine your ability to participate. Other reasons to forgo participation in this study include if you are under 18 years of age, on medicine for depression, or feel that taking part in this study jeopardizes your personal or professional life in any manner.

What other choices do I have if I do not take part in this research?

You can choose not to participate with no consequence. You may also contact the research later if need be if you wish to contribute then.

Where is the research going to take place and how long will it last?

The research will be conducted across various sites in Florida. Some meetings may be virtual, but the choice of a public setting under your preferred circumstances remains yours. During this study, we will meet once and for less than one hour.

What will I be asked to do?

You will be asked to participate in one interview. These questions are open-ended and relate to your role in Everglades restoration and perception on common themes including ecosystem resilience, land acquisition, and the complexities of ecosystem restoration. All interviews will be recorded in order to transcribe our conversations, but the audio files will be erased thereafter.

What might I experience if I take part in the research?

I recognize no risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life, and likely less. I cannot promise you will benefit from taking part in this study. There may not be any personal benefit to you, but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?

We will not be able to compensate you for the time you volunteer while in this study.

Will it cost me to take part in this research?

It will not cost you any money to be part of the research

Who will know that I took part in this research and learn personal information about me?

ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

How will you keep the information you collect about me secure? How long will you keep it?

Non-identifying names (e.g., participant #1) will be used and only I will have access to the key. This document will be encrypted on our department drive to ensure data security. These data will be programmed to delete itself after three years following the completion of the project. Results will be reported anonymously and in aggregate format. No one other than the PI will have access to the data.

What if I decide I don't want to continue in this research?

You can stop at any time after it has already started. There will be no consequences if you stop, you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?

The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator via email (sabinj19@students.ecu.edu), calling or text at (404) 694-6816 on any day that you have a need. I am likely to answer or will make the best effort to respond within the same day.

If you have questions about your rights as someone taking part in research, you may call the University & Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914.

Is there anything else I should know?

Your information collected as part of the research, even if identifiers are removed, will not be used or distributed for future studies.

I have decided I want to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, declare this to the PI:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By verbally declaring consent, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

APPENDIX B

UMCIRB 21-001194
Semi-structured interview guide

Socio-Ecological Restoration at the Boundary:

Interdisciplinary Planning & South Florida's East Coast Buffer

1) How did you become involved in Everglades restoration (or environmental science broadly)?

2) How would you best identify the role you play? What are your responsibilities?

3) In your lifetime, which events triggered the most response by environmental managers and politicians?

4) What are the **top three issues** threating successful environmental restoration in South Florida?

5) What does environmental resilience mean to you? Does this relate to community resilience in your experience?

6) What does *wilderness* mean to you? Is this different than a 'protected area' in your eyes?

7) How can scientists, stakeholders, and decision-makers reconcile with different perceptions of wilderness?

8) What are your thoughts on land acquisition for the purpose of conservation? What are your thoughts on the East Coast Buffer (or other CERP projects at the periphery of the built environment)?

9) What aspects have changed since you became involved with Everglades restoration?

10) Where do you see environmental restoration headed in the 2020s? What shifts in the management of land, water, other conservation initiatives have the best potential to achieve restoration?

11) How have shifting environmental baselines affected the restoration goals in your agency? How is it being address, or how would you ideally address this 'environmental amnesia?'

12) What does a restored Everglades ecosystem mean to you? Describe some of the qualities you would personally expect as well as those your community would hope for.

13) What motivates you to continue fighting for the restoration of the Everglades despite the inherent complexity?

14) Is there anything you expected me to ask about that I did not?

APPENDIX C

East Coast Buffer Classification codes used for band mosaicking
and land cover training and detection in Google Earth Engine

```
// CLOUD MASKING FUNCTION FOR LANDSAT 8
// This example demonstrates the use of the Landsat 8 Collection 2,
Level 2
// QA_PIXEL band (CFMask) to mask unwanted pixels.

function maskL8sr(image) {
  // Bit 0 - Fill
  // Bit 1 - Dilated Cloud
  // Bit 2 - Cirrus
  // Bit 3 - Cloud
  // Bit 4 - Cloud Shadow
  var qaMask = image.select('QA_PIXEL').bitwiseAnd(parseInt('11111',
2)).eq(0);
  var saturationMask = image.select('QA_RADSAT').eq(0);

  // Apply the scaling factors to the appropriate bands.
  var opticalBands = image.select('SR_B.').multiply(0.0000275).add(-
0.2);
  var thermalBands =
image.select('ST_B.*').multiply(0.00341802).add(149.0);

  // Replace the original bands with the scaled ones and apply the
masks.
  return image.addBands(opticalBands, null, true)
      .addBands(thermalBands, null, true)
      .updateMask(qaMask)
      .updateMask(saturationMask);
}

/// Renaming bands for simplicity under Landsat 7 convention
var BLUE = 'SR_B1'
var GREEN = 'SR_B2'
var RED = 'SR_B3'
var NIR = 'SR_B4'
var SWIR1 = 'SR_B5'
var SWIR2 = 'SR_B7'


//
==========================================================================
=======================================================

// Sort and filter through the Landsa Image Collection and apply the
cloud mask function using .map
// Bring in L5 if artifacts appear in 2005 & 2010 timeslices
// CACULATE INDEX BANDS: NDVI, SAVI, MNDWI, & AEWI
// SAVI = ((NIR - RED) / (NIR + RED + 0.5)) * (1.5)
```

```
// MNDWI = (GREEN - SWIR1) / (GREEN + SWIR1)
// AEWI = BLUE + 2.5 × GREEN − 1.5 × (NIR + SWIR1) − 0.25 × SWIR2

var BandsIWant = [BLUE, GREEN, RED, NIR, SWIR1, SWIR2]

var addIndices = function(image){
  var addNDVI =  image.normalizedDifference([NIR, RED]).rename('NDVI')
  var SAVInum = image.select(NIR).subtract(image.select(RED))
  var SAVIden = image.select(NIR).add(image.select(RED).add(0.5))
    var addSAVI =
((SAVInum).divide(SAVIden)).multiply(1.5).rename('SAVI')
  var addMNDWI = image.normalizedDifference([GREEN,
SWIR1]).rename('MNDWI')
  var addAEWI =
image.select(BLUE).add(2.5).multiply(image.select(GREEN)).subtract(1.5)

.multiply((image.select(NIR)).add(image.select(SWIR1))).subtract(0.25).
multiply
                  (image.select(SWIR2)).rename('AEWI')

 return image.select(BandsIWant).addBands(addNDVI)
                                .addBands(addSAVI)
                                .addBands(addMNDWI)
                                .addBands(addAEWI)
}




// PULLED FROM LANDTRNDR SCRIPT - From GEE SUMMIT 2018
//------ L8 to L7 HARMONIZATION FUNCTION -----
// slope and intercept citation: Roy, D.P., Kovalskyy, V., Zhang, H.K.,
Vermote, E.F., Yan, L., Kumar, S.S, Egorov, A., 2016, Characterization
of Landsat-7 to Landsat-8 reflective wavelength and normalized
difference vegetation index continuity, Remote Sensing of Environment,
185, 57-70.(http://dx.doi.org/10.1016/j.rse.2015.12.024); Table 2 -
reduced major axis (RMA) regression coefficients
var harmonizationRoy = function(oli) {
  var slopes = ee.Image.constant([0.9785, 0.9542, 0.9825, 1.0073,
1.0171, 0.9949]);                                           // create
an image of slopes per band for L8 TO L7 regression line - David Roy
  var itcp = ee.Image.constant([-0.0095, -0.0016, -0.0022, -0.0021, -
0.0030, 0.0029]);                                       // create an
image of y-intercepts per band for L8 TO L7 regression line - David Roy
  var y =
oli.select(['SR_B2','SR_B3','SR_B4','SR_B5','SR_B6','SR_B7'],['SR_B1',
'SR_B2', 'SR_B3', 'SR_B4', 'SR_B5', 'SR_B7'])// select OLI bands 2-7
and rename them to match L7 band names
            .resample('bicubic')
// ...resample the L8 bands using bicubic
            .subtract(itcp).divide(slopes)
// apply the line equation - subtract the intercept and divide by the
slope
```

```
            .set('system:time_start', oli.get('system:time_start'));
// ...set the output system:time_start metadata to the input image
time_start otherwise it is null
  return y;
// return the image as short to match the type of the other data
};


var L7Acollection = ee.ImageCollection(L7)
                    .filterDate('1999-01-01','2001-01-01') // 'Year
2000'
                    .filterBounds(SF)
                    .map(maskL8sr)
                    .map(addIndices)
print(L7Acollection.size(),'Number of images in the L7A collection')

 var L7Bcollection = ee.ImageCollection(L7) // 'Year 2005'
                     .filterDate('2004-01-01','2006-01-01')
                    .filterBounds(SF)
                    .map(maskL8sr)
                    .map(addIndices)
print(L7Bcollection.size(),'Number of images in the L7B collection')


 var L7Ccollection = ee.ImageCollection(L7) // 'Year 2010'
                     .filterDate('2009-01-01','2011-01-01')
                    .filterBounds(SF)
                    .map(maskL8sr)
                    .map(addIndices)
print(L7Ccollection.size(),'Number of images in the L7C collection')


 var L8Acollection = ee.ImageCollection(L8) // 'Year 2015'
                     .filterDate('2014-01-01','2016-01-01')
                    .filterBounds(SF)
                    .map(maskL8sr)
                    .map(harmonizationRoy)
                    .map(addIndices)
print(L8Acollection.size(),'Number of images in the L8A collection')

 var L8Bcollection = ee.ImageCollection(L8) // 'Year 2020'
                     .filterDate('2019-01-01','2021-01-01')
                    .filterBounds(SF)
                    .map(maskL8sr)
                    .map(harmonizationRoy)
                    .map(addIndices)
print(L8Bcollection.size(),'Number of images in the L8B collection')


// PULLED FROM LANDTRNDR SCRIPT - From GEE SUMMIT 2018 --- CHANGE BAND
NAMES
//------ L8 to L7 HARMONIZATION FUNCTION -----
```

```
// slope and intercept citation: Roy et al. (2016) Table 2 - reduced
major axis (RMA) regression coefficients

var harmonizationRoy = function(oli) {
  var slopes = ee.Image.constant([0.9785, 0.9542, 0.9825, 1.0073,
1.0171, 0.9949]);        // create an image of slopes per band for L8
TO L7 regression line - David Roy
  var itcp = ee.Image.constant([-0.0095, -0.0016, -0.0022, -0.0021, -
0.0030, 0.0029]);     // create an image of y-intercepts per band for
L8 TO L7 regression line - David Roy
  var y = oli.select(['SR_B2','B3','B4','B5','B6','B7'],['B1', 'B2',
'B3', 'B4', 'B5', 'B7']) // select OLI bands 2-7 and rename them to
match L7 band names
             .resample('bicubic')
// ...resample the L8 bands using bicubic
             .subtract(itcp).divide(slopes)
// ...apply the line equation - subtract the intercept and divide by
the slope
             .set('system:time_start', oli.get('system:time_start'));
// ...set the output system:time_start metadata to the input image
time_start otherwise it is null
  return y.toShort();
// return the image as short to match the type of the other data
};

//===========================================================
// MERGING IMAGERY AND BANDS
// List of all bands to be used in the classification analysis
containing the 1. median, 2. maximum, and percentile + indices

//L7A
var L7AnewBands = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7',
                     'NDVI','SAVI','MNDWI','AEWI']

// add the bands from one image to another
var L7A_fullBands =
L7AcompositeMedian.addBands(L7AcompositeMax).addBands(L7AcompositePerce
ntile)
                  .select(L7AnewBands)

print(L7A_fullBands, 'L7A Image with the desired bands')


//L7B
var L7BnewBands =['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7',
                     'NDVI','SAVI','MNDWI','AEWI']
// add the bands from one image to another
var L7B_fullBands =
L7BcompositeMedian.addBands(L7BcompositeMax).addBands(L7BcompositePerce
ntile)
                  .select(L7BnewBands)

print(L7B_fullBands, 'L7B Image with the desired bands')
```

```
//L7C
var L7CnewBands = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7',
                     'NDVI','SAVI','MNDWI','AEWI']
// add the bands from one image to another
var L7C_fullBands =
L7CcompositeMedian.addBands(L7CcompositeMax).addBands(L7CcompositePerce
ntile)
                   .select(L7CnewBands)

print(L7C_fullBands, 'L7C Image with the desired bands')


//L8A
var L8AnewBands = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7',
                     'NDVI','SAVI','MNDWI','AEWI']
// add the bands from one image to another
var L8A_fullBands =
L8AcompositeMedian.addBands(L8AcompositeMax).addBands(L8AcompositePerce
ntile)
                   .select(L8AnewBands)

print(L8A_fullBands, 'L8A Image with the desired bands')


//L8B
var L8BnewBands = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7',
                     'NDVI','SAVI','MNDWI','AEWI']
// add the bands from one image to another
var L8B_fullBands =
L8BcompositeMedian.addBands(L8BcompositeMax).addBands(L8BcompositePerce
ntile)
                   .select(L8BnewBands)

print(L8B_fullBands, 'L8B Image with the desired bands')


//var landsat = ee.Image('users/premsocietyjs/SF_fullBands/IMAGE')
CHANGE YEAR BELOW
Map.addLayer(L8A,{min:0,max:0.3,bands:['SR_B3','SR_B2','SR_B1']},'Lands
at Image - 2015')

// List of the spectral and temporal bands you want to use in your
analysis -
var predictionBands =
['SR_B2','SR_B3','SR_B4','SR_B5','SR_B7','NDVI','SAVI','MNDWI','AEWI']

// All landcover shapefiles of ENP - Feature Collection of TRAINING
data

Map.addLayer(FreshwaterMarsh_TRAIN,{color:'#fff52b'},'MF',false)
Map.addLayer(FU_Train,{color:'#15721f'},'FU Train',false)
```

```
Map.addLayer(WU_Train,{color:'#64aa65'},'WU Train ',false)
Map.addLayer(SW_Train,{color:'#9fca62'},'SW Train',false)
Map.addLayer(CW_Train,{color:'#91ce3a'},'CW Train',false)

// All landcover shapefiles of ENP - Feature Collection of VALIDATION
data (Open Water, Anthropgenic, and Marsh classes absent because they
are obvious)
Map.addLayer(FU_Test,{color:'#15721f'},'FU Test',false)
Map.addLayer(WU_Test,{color:'#64aa65'},'WU Test',false)
Map.addLayer(SW_Test,{color:'#9fca62'},'SW Test',false)
Map.addLayer(CW_Test,{color:'#91ce3a'},'CW Test',false)


// Seven landcover types are *well-represented* in this area [change to
6 due to WU being non-existent in my model]

var trainingFeatures = FreshwaterMarsh_TRAIN  // CLASS 1
                        .merge(UplandForest_TRAIN) // CLASS 2
                        .merge(UplandWoodland_TRAIN) // CLASS 3
                        .merge(WetlandShrubland_TRAIN) // CLASS 4
                        .merge(WetlandScrub_TRAIN) // CLASS 5
                        .merge(Anthropogenic_TRAIN) // CLASS 6
                        .merge(OpenWater_TRAIN); // CLASS 7



//=================================================================
=========
// CART Classification and Regression Trees - Trained using the L8A
imagery (2015)
var classifierTraining = L8A.select(predictionBands)
    .sampleRegions({
      collection: trainingFeatures,
      properties: ['class'],
      scale: 30
    });

var classifier = ee.Classifier.smileCart().train({
  features: classifierTraining,
  classProperty: 'class',
  inputProperties: predictionBands
});
                                                            //Not used :(
var visOptions =
{min:1,max:7,palette:['#d5ab09','#125f1a','#9fca62','#64aa65','#b0ce2e'
,'#8c9899','#1579f6']}

var classified =
L8A.select(predictionBands).classify(classifier).set('classifier','CART
');
Map.addLayer(classified, visOptions,'Cart Classifier', false);
```

```
//=================================================================
=========
// RANDOM FOREST

var random_forest = ee.Classifier.smileRandomForest({
    variablesPerSplit: 2,
    numberOfTrees: 30
    })
    .train({
    features: classifierTraining,
    classProperty: 'class',
    inputProperties: predictionBands
    });

// Pass new YEAR TIMESLICE before .select AND change label year
var classRF =
L8B.select(predictionBands).classify(random_forest).set('classifier','R
F');
Map.addLayer(classRF, visOptions,'Random Forest Classification 2020');

// GET REGIONAL AREA STATS
// create a unique reducer you want to apply to your data
var myReducer = {reducer: ee.Reducer.sum(),geometry:ECB, scale:30}


// create a function that calculated the area of each class within the
ROI
var stats = function(img){
  var MFArea =
ee.Number(img.eq(1).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var FUArea =
ee.Number(img.eq(2).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var WUArea =
ee.Number(img.eq(3).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var SWArea =
ee.Number(img.eq(4).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var CWArea =
ee.Number(img.eq(5).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var OAArea =
ee.Number(img.eq(6).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)
  var OWArea =
ee.Number(img.eq(7).selfMask().multiply(ee.Image.pixelArea()).reduceReg
ion(myReducer).get('classification')).divide(10000)

  return img.set('Marsh_Area',MFArea)
            .set('UplandForest_Area',FUArea)
```

```
            .set('UplandWoodland_Area',WUArea)
            .set('WetlandShrubland_Area',SWArea)
            .set('WetlandScrub_Area',CWArea)
            .set('OpenWater_Area',OWArea)
            .set('Anthropogenic_Area',OAArea)
    }


    // Create a new image collection by combining individual images into a
    list.
    var modelCollection = ee.ImageCollection([classified,classRF])


    // Apply model to the image collection
    var imgWithStats = modelCollection.map(stats)
    print(imgWithStats,'Classification Model - Class Area Statistics')

    //============================================================
    // Taking Stratified Sampling Points

    // create a set of randomly selected points within specific integer
    values of an image (FIX THIS TO APPLY FOR WHOLE REGION)
    var ValidationPoints = classRF.stratifiedSample({
      numPoints: 100,
      classBand: 'classification',
      region: South_Florida,
      scale:30,
      geometries: true

    })

    print(ValidationPoints.size(),'Size of random points')
    Map.addLayer(ValidationPoints,{},'Stratified Validation Points')


    //============================================================
    // Export Random Points out of the cloud. Export to google drive and
    download the file to your computer

    Export.table.toDrive({
      collection:ValidationPoints,
      description:'ValidationPoints',
      folder: "GEE_Outputs",
      fileFormat: 'KMZ'
    })

    Export.table.toDrive({
      collection:randomPoints,
      description:'RandomPoints_CSV',
      folder: "GEE_Outputs",
      fileFormat: 'CSV'
})
```