SPATIAL PATTERNS AND EQUITY IMPLICATIONS OF WETLAND MITIGATION IN WESTERN WASHINGTON

by

Trace M. McKellips

A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
June, 2017

This Thesis for the Master of Environmental Studies Degree

by

Trace M. McKellips

has been approved for

The Evergreen State College

by

Edward A. Whitesell, Ph. D.
Member of the Faculty

Date

ABSTRACT

Spatial Patterns and Equity Implications of Wetland Mitigation in Western Washington

Trace M. McKellips

Under the Clean Water Act, regulatory agencies require developers to offset wetland impacts through wetland mitigation. Wetland mitigation research has thus far centered on the ability to restore or create functioning wetlands, yet little attention has focused on the spatial distribution of wetland relocation. With no spatial tracking system firmly in place, regulatory agencies know little about the aggregate distribution of wetland losses and gains. Using an environmental equity framework, this research examines if wetland mitigation transfers wetlands and their ecosystem services from urban to rural environments within a three-county area in western Washington State. In addition, this research examines socioeconomic and racial equity within wetland mitigation. Using 2010 Census data, this research collected population density data, socioeconomic indicators, and racial demographics within a ¾ mile buffer of each impact site and its corresponding mitigation site. This research then tested for a difference in mean values between these sites. Findings indicate that wetland mitigation relocates wetlands and their ecosystem service benefits along a pronounced urban-rural gradient. Population densities are, on average, 926 people per square mile greater near impact sites than mitigation sites. Mitigation sites have higher median incomes and higher percentages of minority populations. To address the difficultly of linking spatial data between impact and mitigation sites, this research recommends that regulatory agencies maintain a spatial database of all wetland mitigation projects in order to better link the distribution of wetland losses and gains, analyze spatial trends in wetland relocation and assess how this relocation relates to human populations.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I owe my gratitude to so many people that assisted me throughout this project and throughout my time in the Masters of Environmental Studies (MES) program. First and foremost, Dr. Ted Whitesell served as my attentive and enthusiastic thesis reader. Ted was in tune to my intellectual development throughout the process, listened thoughtfully in our conversations, and gently nudged me in the directions I needed to go. His timely and constructive feedback throughout the writing and research process improved the final product immensely.

Mike Ruth helped me review my spatial analysis methods and provided important points to improve my data management. As an adjunct faculty member, Mr. Ruth was by no means obliged to assist me with my requests. Nevertheless, like with so many other students, he offered his time with his already hectic schedule to help me overcome numerous geospatial challenges.

I also want to express my gratitude to the Department of Ecology Wetlands Team at their headquarters in Lacey for creating an internship and work space. All the Wetlands staff—in particular, Dana Mock, Kate Thompson, and Teri Granger—were generous with their time in orienting me to their wetland mitigation data. They also facilitated a number of introductions to agency partners that were helpful. Lauren Driscoll deserves thanks for completing all the necessary paperwork for my position. Thanks to Megan Webb from King County Mitigation Reserves Program who provided GIS data for their In-Lieu Fee program. Many folks spent time with data requests that did not end up in the final analysis due to incomplete spatial data. The Army Corps of Engineers assisted me with multiple Freedom of Information Act requests in a timely manner. The Washington State Department of Transportation, Clark County, Snohomish County, and Pierce County also fielded requests. Across the board, agency personnel handled my requests in a timely and professional manner.

I would like to thank all the MES core and adjunct faculty who work so hard for the program and its students. MES Director Dr. Kevin Francis embodies the spirit of inclusiveness, intellectual curiosity, and reflection that makes the MES program and The Evergreen State College a great place to learn. I also want to thank Writing Assistant Michael Radelich for his guidance during my early drafts. Thanks to the various members of my MES cohort who offered written and verbal feedback this past year.

Finally, I owe my gratitude and love to my family. To my parents, who have always encouraged me to follow my interests—even when they were unsure where that would lead. And to my wife Katrina, who supported me the past two years during this important time in my professional development. I aim to emulate her extraordinary dedication and resolve to be the best she can be.

Acronyms

ACOE – Army Corps of Engineers

CWA – Clean Water Act

DOE – Department of Ecology

EPA – Environmental Protection Agency

FWPCA – Federal Water Pollution Control Act

FOIA – Freedom of Information Act

FWS – Fish and Wildlife Service

NEPA – National Environmental Policy Act

NLCD – National Land Cover Database

RHA – Rivers and Harbors Act

RIBITS – Regulatory In-lieu Fee and Banking Information Tracking System

USDA – United States Department of Agriculture

USGS – United States Geological Survey

WSDOT – Washington State Department of Transportation

WTP – Willingness-To-Pay

CHAPTER 1: INTRODUCTION

Wetland value appears to be maximum when distributed spatially across a landscape that is not dominated either by cities or agriculture, but one that balances nature and human enterprises.

Mitsch & Gosselink (2000)

For the first two centuries in the United States, Americans drained and filled wetlands to make way for agriculture, cities, industry, and infrastructure. Initially, the vast majority of Americans viewed wetlands as unproductive ecosystems with few benefits to local populations (Hansen, 2006). Federal and state laws reinforced this prevailing attitude by incentivizing the conversion of wetlands to other land uses (Vileisis, 1997). By the 1780s-1980s, research estimated that Americans had converted a staggering 53% of wetlands in the lower 48 states to other uses (Dahl, 1990).

While initially not well understood, wetland degradation has impacted aquatic resources that have had adverse impacts on human populations (Vileisis, 1997). Wetlands can be defined as "an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the substrate," (NRC, 1995). Wetland habitats provide myriad benefits to human populations. These human benefits derive from ecosystems and the processes can be referred to as ecosystem services (MEA, 2005b). Ecosystem service benefits are not just the sweet sounds of the songbirds that inhabit these systems, but real economic benefits. Wetlands improve water quality by filtering toxic chemicals and impurities, reducing expensive costs for stormwater treatment. Wetlands reduce peak flows of storms that cause damages to public and private infrastructure. Additionally, wetlands provide cultural ecosystem services such as educational opportunities, recreation, and spiritual values.

While understanding of wetland ecosystem services' importance grew throughout the 20^{th} century, their decline continued. President George H.W. Bush articulated a plan to reverse this trend. In 1988, President Bush promulgated the country's first national wetland conservation strategy, calling for a "no net loss" of the country's wetlands. The no-net-loss plan however did not advocate halting all damage to existing wetlands. Rather, under the powers of the Clean Water Act (CWA), the Army Corps of Engineers (ACOE) and the Environmental Protection Agency (EPA) would regulate wetland impacts by requiring developers to replace wetlands and their ecosystem services. This regulatory process is known as wetland mitigation and is composed of a three-step sequence. Developers of a project must first avoid and secondly, minimize and finally compensate for wetland impacts. Clare, Krogman, Foote and Lemphers (2011) have critiqued this sequence as preferential tothe final step of compensatory mitigation to achieve no-net-loss objectives and maintain the country's aquatic resources.

Compensatory mitigation uses an ecosystem-services framework to trade wetlands from an impact site—where wetlands are damaged—to the mitigation site—where wetlands are preserved, enhanced, restored, or created. In addition to acreage, regulators assess specific ecosystem services (e.g., improved water quality, wildlife habitat) provided at the impact site so there can be a commensurate transfer to the mitigation site. This arrangement is predicated upon on the assumption that wetland ecosystem services have equal values regardless of geographic location. This assumption, however, is flawed. A wetland's multi-dimensional benefits, its position within a landscape, its hydrologic connection with other aquatic resources, and its position in relation to human populations all interfere with an equal transfer of ecosystem services from one location to another (Salzman & Ruhl, 2001).

In relation to human populations, wetlands provide ecosystem services at different spatial scales. Figure 1 displays human benefits from wetland ecosystem services at individual, community, and global scales. At the community and individual levels, proximity to wetlands affects a group or individual's ability to incur these benefits. Moreover, at the community level, many benefits are evenly dispersed to the population at large, representing local public goods (Mitsch & Gooselink, 2000).

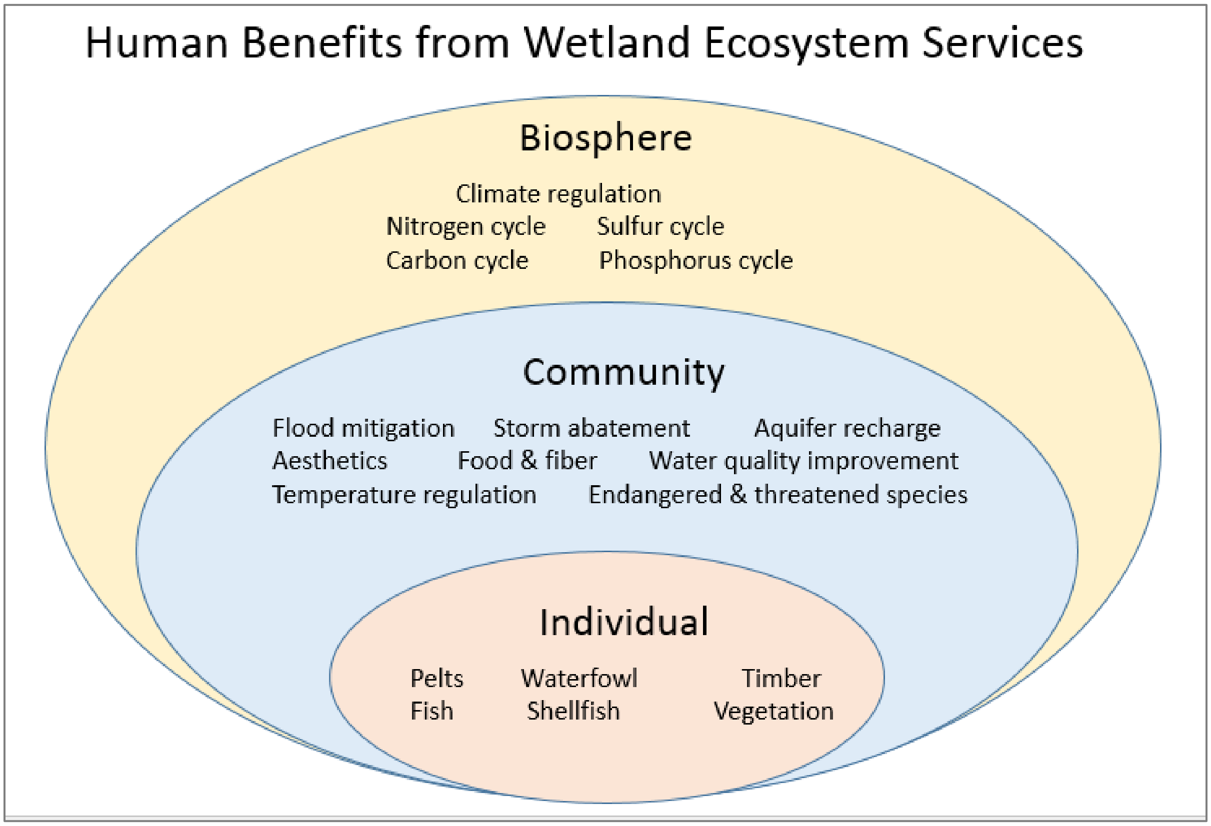


Figure 1. Human benefits derived from wetland ecosystem services, adapted from Mitsch and Gooselink, 2000.

As mitigation relocates wetlands across a landscape, this process produces outcomes in which one population loses wetland functions and another population gains wetland functions. But who is losing wetlands and who is gaining them? How far are wetlands being relocated across the landscape? Acknowledging the host of benefits human populations receive from wetlands, are there any issues of equity with respect to wetland relocation? These questions are all inquiries into the nature of wetland mitigation, but only a handful of previous researchers have addressed the spatial issue of wetland relocation and its potential impacts on human populations.

These studies have identified one consistent trend: wetland mitigation relocates wetlands from higher population densities to lower population densities (BenDor, T.K., & Bruzovic, N., 2007; BenDor, T.K., Brozovic, N., & Pallathucheril, V.G., 2007; BenDor and Stewart, 2011; Brass, 2009; King & Herbert, 1997; Robertson & Hayden, 2008; Ruhl & Salzman, 2006). King and Herbert (1997) first identified this relocation of wetlands along an urban-rural gradient. While this research uses the term "urban-rural gradient," this term is not a dichotomous distinction. Rather, the gradient falls along a continuum of urban, suburban, peri-urban and rural environments with varying population densities.

Three potential factors may be driving wetland relocation away from urban areas. These factors include the availability of land, economic incentives, and ecological performance of wetlands in urban environments. First, the availability of land is an important determinant for mitigation sites. Urban environments contain high percentages of built infrastructure. Rural areas, by their nature, have more available land for potential wetland restoration than urban areas.

As a second factor, economic incentives also influence wetland trading (Robertson, 2004). While regulated, wetland mitigation involves trading wetlands through a free-market system. Developers and private businesses have no rational economic incentive for conducting wetland mitigation on high-demand real estate. Rather, individuals acquire lowpriced land as they are permitted, acting in their own economic self-interest (Heal, 2000). Cheaper land, in most cases, correlates to rural locations.

A third factor is based on ecological grounds; urban wetlands function poorly (Azous & Horner, 2001; Kentula, Gwin, & Pierson, 2004). Burdened with an excess of pollution, prior land use legacies, invasive plant colonization and habitat fragmentation, choosing mitigation projects in urban areas often requires additional time and resources. One criterion that potential mitigation sites are based upon is their likelihood to be self-sustaining after site maintenance and monitoring ends. Excessive urban perturbations—or disturbances—decrease the likelihood of self-sustaining sites. The National Research Council's (2001) influential review of compensatory mitigation recommended mitigation sites away from urban areas with prior land use disturbances that could adversely affect mitigation site performance.

Prioritizing rural site selection however has not been universally accepted. A counterpoint to this logic argues that precisely because of urban disturbances, wetland functions are more needed and their relative values are greater in urban environments (Ruhl & Salzman, 2006). Mitsch and Gooselink (2000) conceptualize the relationship between increasing wetland values and higher population densities in Figure 2.

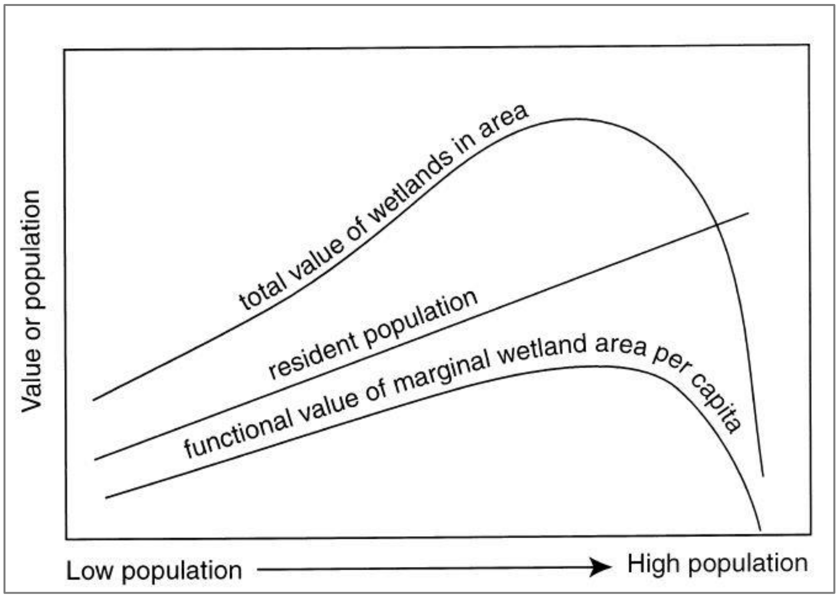


Figure 2. Wetland values along an urban-rural gradient (Mitsch & Gooselink, 2000).

With more people in urban environments and a greater scarcity of wetlands, the marginal value per unit of wetland increases. At an unknown tipping point, wetlands are overwhelmed with the excesses of urban populations and their ecosystem functions collapse. While this graph recognizes that the potential adverse urban influences overwhelming the functional state of wetlands noted by the NRC (2001), it also conveys the increased marginal value of urban wetlands. Wetland mitigation site selection exists with this tension between balancing benefits to human populations and wetland functioning.

Attempting to quantify specific values of wetlands, however, continues to challenge economists and ecologists (Boyd & Waigner, 2002). Not only do wetlands provide multi-dimensional benefits, their values are also dependent on the surrounding environment and cultural value systems (Mitsch & Gooselink, 2000). For example, a rural wetland may be valued for duck hunting, which is not feasible in an urban setting (Brass, 2009). The high degrees of variability hinder an agreed-upon valuation of wetlands. While land use planners and regulators understand the overall range of wetland ecosystem services, integrating these values within developed landscapes remains an elusive goal.

Many land use challenges facing urban and urbanizing western Washington communities relate to the scarcity of ecosystem services that wetlands provide. During rain events, impervious surfaces limit rainwater infiltration of stormwater into underground aquifers. Instead, roads and underground piping serve as the network of stormwater conveyance, which transports stormwater from the asphalt straight into waterways. This conveyance bypasses the process of water coming in contact with soil, which acts to purify the water from many of chemicals it picks up along the way (Trombulak & Frissell, 2000). When stormwater pipes flow into creeks and rivers, this system of conveyance exacerbates peak flows and its corresponding flooding. Not only is this water lost for future human use, this stormwater can be perilous for aquatic life, particularly for anadromous fish whose spawning cycles are triggered by rain events (Alberti et al., 2007; Scholz et al., 2011). As a habitat type, functioning wetlands moderate these aquatic impacts. Wetland ecosystem services are not strictly confined to managing water, however. Human populations enjoy wetlands for their many cultural ecosystem service benefits such as aesthetics, recreation, and educational opportunities (Manuel, 2003).

Proximity to wetlands influences populations' ability to incur and enjoy their ecosystem service benefits. Given this spatial dynamic, wetlands should be dispersed in the landscape so as not to exclude any social group. This dispersion is a central tenet of environmental equity, defined as "the proportionate …distribution of environmental benefits and risks among diverse economic and cultural communities. It ensures that the policies, activities and the responses of government entities do not differentially impact diverse social and economic groups" (DOE, 2013 p. 1-2). There is good reason to apply an environmental equity lens to wetland mitigation. First, research has argued that equitably distributing green infrastructure projects could promote urban poverty alleviation (Dunn, 2010). Second, a growing literature has analyzed the inequitable distribution of parks and open spaces among different social groups (Jennings, Gaither, & Gragg, 2012) but few have extended this analysis to wetlands.

With an average of 8,000 acres of permanent impacts to non-tidal wetlands annually (IWR, 2015), the success of current wetland mitigation hinges on the ability to relocate wetlands from one location to another. This relocation results in a transfer of wetland ecosystem services that could affect human populations near the impact sites—where wetland impacts occur—and mitigation sites, where wetlands are restored, preserved, or created (Mitsch & Gooselink, 2000). Unfortunately, this spatial redistribution of wetlands and its relation to human populations remains poorly understood (BenDor, Brozovic, & Pallathucheril, 2008). Principally, state and federal regulators do not maintain a spatial database to track where wetland losses and gains are occurring. Rather, regulatory personnel manage wetland mitigation projects on a project-by-project basis without knowledge of aggregate spatial patterns. As impact and mitigation sites are dispersed throughout the built environment of human populations, the distribution of wetland mitigation losses and gains and their relation to communities represent a significant knowledge gap.

Several academic studies have collected base data that examines wetland mitigation and human populations. The geographic study areas in previous analyses included Florida (King & Herbert, 1997; Ruhl & Salzman, 2006), North Carolina (BenDor & Steward, 2011), a three-county area in northeast Illinois (BenDor, Brozovic, & Pallathucheril, 2007;

Roberston & Hayden, 2008) and a three-county area in central Oregon (Brass, 2009). These past study areas represent a very small sample of wetland mitigation projects in the United States.

Spatial relocation of wetland mitigation and its equity implications on human populations lay the foundation of this research project. To better understand spatial patterns of wetland relocation through the mitigation process, this study examines a three-county study area of Clark, King, and Snohomish counties in western Washington. These counties have urban-rural population gradients that serve as an apposite natural laboratory to examine site selection patterns.

The central research question in this thesis examines if wetland mitigation relocates wetlands and their ecosystem service benefits from urban to rural areas. In addition, this research examines socioeconomic equity and racial equity in wetland mitigation. To accomplish this, this research analyzed 139 wetland mitigation projects across three counties in western Washington State with diverse urban-rural gradients. Using a ¾ mile buffer around each impact site and its corresponding mitigation site, this research analyzed differences in the human populations affected by wetland mitigation projects. The results from this study conclude that wetland mitigation in western Washington relocates wetlands in the following manners:

- Along a pronounced urban-rural gradient
- From lower to higher income populations
- From lower to higher percentages of minority populations

Results from this study advance our understanding of wetland mitigation's spatial redistribution of wetlands and its equity implications on human populations. Viewed in tandem with previous studies, these spatial tendencies advance our knowledge of diminishing urban wetland resources. While Western Washington manages a growth boom, planning for urban landscapes that balance human populations and ecological resilience remains a major challenge for decision-makers at the city, state, and federal levels (Godschalk, 2004). As market-based strategies for trading ecosystem services expands, research needs to critically analyze both its ecological and social impacts. Improved knowledge of the process of wetland mitigation and the degree to which it is relocating ecosystem services across landscapes will help regulatory bodies examine their guidelines and the potential adverse effects on urban environments. Increased understanding of these spatial and social characteristics should inform future guidelines that instruct wetland mitigation site selection.

This research project proceeds in the following manner: Chapter 2 provides a brief overview and history of wetland management in the United States. This background chapter includes a brief history of widespread wetland degradation, important regulations, shifts in public perceptions of wetlands' utility, efforts to preserve and protect aquatic resources, the development of wetland mitigation, how mitigation has evolved over the past four decades, and Supreme Court rulings on mitigation jurisdiction. Chapter 3 reviews the academic literature relating to the spatial influences and societal impacts of wetland mitigation, synthesizing relevant studies in ecosystem services, economic valuations, and the trading of environmental goods and services. Chapter 4 reviews methods used in this study to determine the extent of wetland relocation in western Washington, including data acquisition, geographic information systems (GIS) analysis using ESRI software, and statistical analysis using JMP software. Chapter 5 presents results from this study. These results include maps of spatial distribution and tests of statistical significance in determining differences between impact and mitigation sites, and variance by mitigation type. Chapter 6 discusses the findings in the preceding chapters, how these results compare to previous studies, and the implications for wetland mitigation. This chapter also surveys the limitations and constraints of the present study. The thesis ends with a concluding section, synthesizing the main points found in this research and stating recommendations for future research.

CHAPTER 2: WETLAND MANAGEMENT IN THE UNITED STATES

Researchers and planners have yet to construct systems that enable them to address the basic question as to whether wetland mitigation contributes to social disparity and inequity.

BenDor, Brozovic, & Pallathucheril (2008)

Introduction

The central question in this research asks if wetland mitigation relocates wetlands and ecosystem services from urban to rural locations. Corresponding to this question, this research examines the equity implications of local populations surrounding impact and mitigation sites. To understand how wetland resources are being relocated throughout the landscape, this chapter reviews past wetland management in the United States.

Over the past 250 years, over 100 million acres of wetlands have been drained and converted for other uses (Hansen, 2006). By acre, the majority of these historical wetland drainages and fills were to increase agricultural production, but also included drainages to make way for urban and rural development, transportation infrastructure, and industry. Throughout the 20th century however, increased knowledge of wetlands' importance created a movement to improve management of our country's aquatic resources. The CWA advanced a paradigm shift in federal policies, reversing trends of widespread wetland conversion. Halting wetland loss, however, did not happen overnight. Due to a number of technical challenges and oversight limitations, the first decades of wetland mitigation often failed to replace wetland functions and their ecosystem services (NRC, 2001; Turner, Redmond, & Zedler, 2001). To improve site performance, shifts in guidelines have recommended greater percentages of off-site mitigation. The effects of these guidelines—greater wetland relocation—reinforce the need to develop an integrated geospatial system to track and analyze the redistribution of important wetland resources.

This chapter first chronicles wetland management in the early years the republic, marked by widespread degradation that coincided with the country's burgeoning population. The second section examines the landmark legislation of the Federal Water Pollution Control Act of 1972, later amended as the Clean Water Act of 1977, which established the wetland mitigation process. The third section describes the national goal of no-net-loss of wetlands and how compensatory mitigation efforts have been used to achieve this goal. The specific approach of mitigation available and their potential effects on wetland relocation are examined. Fourth is a section describing the mitigation sequence developed to reduce the impacts to aquatic resources. Since the final step of the sequence—compensatory mitigation—is the only step that relocates wetlands, the fifth section details the complexity and nuances of this step. In 2001, the National Resource Council (NRC) assessed how well compensatory mitigation was performing and made recommendations for future efforts. Given the report's influence on current mitigation practices, the sixth section reviews these findings. The last section reviews how the Supreme Court interpreted two important cases involving the CWA and wetlands. As wetland management has progressed to the present, wetland loss has slowed considerably. For its part, mitigation relies on the relocation of wetlands across landscapes to help achieve national no-net-loss objectives. To better understand why maintaining the country's aquatic resources remains imperative, this research first surveys wetland degradation in the early years of the American republic.

Wetlands in the Early Years of the Republic

Throughout the Unites States' nearly 250-year history, Americans' relationship with wetlands has changed dramatically, from policies encouraging the draining and filling of wetlands to the current regulatory environment seeking to increase total wetland acreage.

Complex tradeoffs between economic gains from wetland impacts and wetland ecosystem service benefits have been debated at each level of wetland management, from local to federal. While this research presents only a tip-of-the-iceberg account of wetland history, for a comprehensive account of wetland policy and history, see Vileisis (1997).

In the early years of the republic, government policies encouraged wetland drainage through incentive programs to increase agriculture and harness previously inaccessible land for urban and rural development. Known as the Swamp Land Act, Congress passed the first major piece of wetland legislation 1849. The Swamp Land Act ceded federally owned wetlands to the states. In turn, states could sell these lands in order to fund levee construction and building drainage infrastructure to decrease flooding, a perennial problem for communities built on the banks of undammed rivers. As Vileisis (1997) notes, this piece of legislation also brought one of the first public debates about defining wetland boundaries, functions, and benefits to the national stage (p. 73-74). Nevertheless, early settlers poorly understood wetland benefits at this time. In the view of most settlers, wetlands hindered progress (Dahl, 1990). Understanding that drained wetlands provided rich agricultural land strongly incentivized wetland draining and filling. In total, this program converted an estimated 26 million hectares of wetlands to non-wetland uses (Mitsch & Gooselink, 2015). Not until the Rivers and Harbors Act of 1899 (RHA, 1899) did the federal government begin to regulate dredge and fill operations.

The initial intent of the RHA was to ensure navigability of U.S. waterways. Regulated by the Army Corps of Engineers (ACOE), this agency granted permits to ensure dredge and fill operations did not block navigable routes. The jurisdiction of the RHA did not extend to "waters of the United States." Rather, jurisdiction was confined to navigable waters—a much narrower geographic area than the future CWA. During the 20th century, the ACOE also was charged with building hydropower, dam, and levee infrastructure—all duties that dramatically altered riverine and riparian wetlands (Vileisis, 1997). Thus, while the ACOE managed water, protecting wetland resources was not their top priority.

Through pressure from another federal agency, the Fish and Wildlife Service (FWS), the ACOE began addressing environmental degradation through the RHA in 1967 (Hough & Robertson, 2009). With growing recognition of rampant industrial pollution and polluted water resources, the ACOE instated a public interest review to assess a proposed project's suitability. This new review assessed projects not only for effects on the navigability of waters, but also for effects on "fish and wildlife, conservation, pollution, aesthetics, ecology, and the general public interest" (quoted in Downing, Winer, & Wood, 2003, p. 477). Even with these new policies, momentum was building for stronger environmental protections at the federal level.

Clean Water Act

Despite a presidential veto, Congress passed the Federal Water Pollution Control Act Amendments of 1972 (FWPCA, 1972), creating the strongest legislation to date to protect aquatic resources. This agreement came just five years after the ACOE had adopted more stringent review measures, soliciting worry that the new regulations would simply be duplicating regulations in the RHA (Hough & Roberston, 2009). Nevertheless, the FWPCA found purchase with Congress as consciousness grew around the impacts industry and development were having on the nation's aquatic resources. The stated goal of the FWPCA was to "restore and maintain the biological, chemical, and physical integrity" of navigable waterways (FWPCA, §230(1)). While still maintaining the same geographic reach of navigable waterways, the purpose of the legislation expanded to protect the important ecosystem services of aquatic resources.

In 1977, Congress made key amendments to the FWPCA that still guide wetland mitigation today. These amendments also marked when the law attained its modern-day title, the Clean Water Act. (Henceforth, this study refers to the FWPCA by its colloquial title, the CWA). It is important to note that the initial FWPCA did not contain "wetlands" anywhere in the legislation. The 1977 amendments changed the jurisdiction from navigable waters to "waters of the United States," which included adjacent wetlands, isolated wetlands, and tributaries of major rivers. This expansion can be attributed to the growing understanding of hydrological connections—often underground—between wetlands and other aquatic resources like lakes, rivers, and aquifers. Including wetlands within §404(1)(b) greatly increased the regulatory scope of the CWA. Figure 3 shows the disproportionate impacts to non-tidal wetlands compared with other aquatic resources.

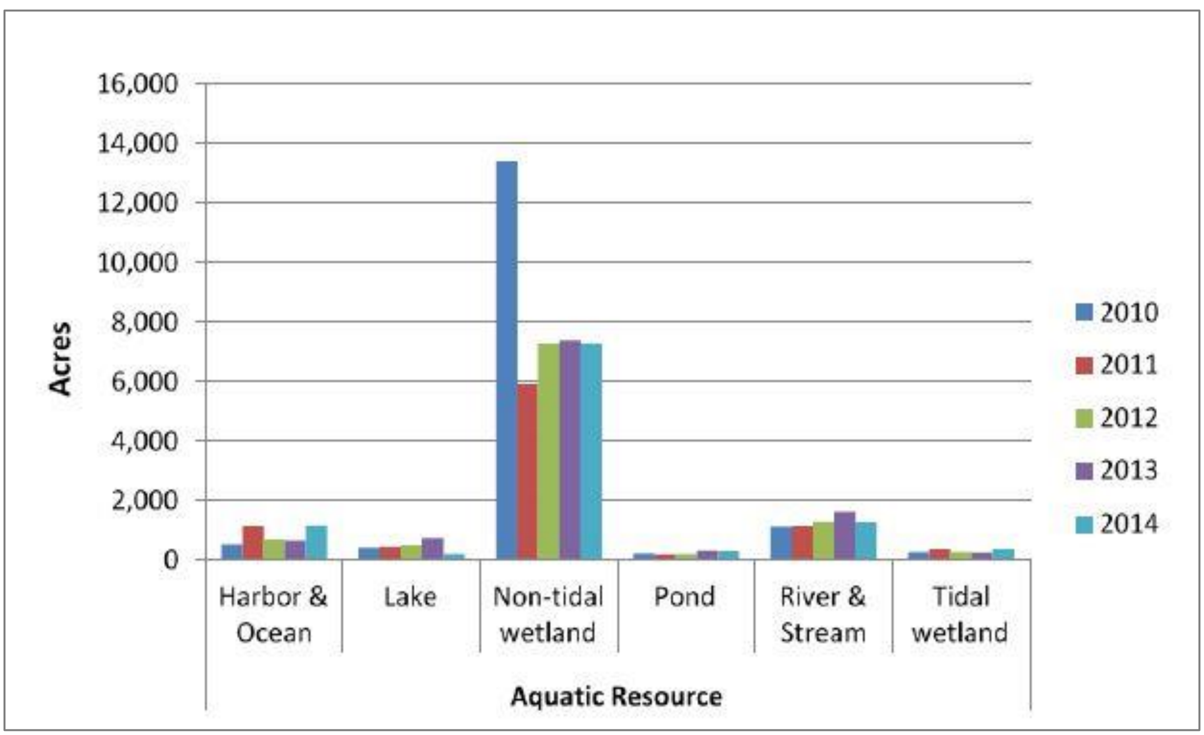


Figure 3. Permanent impacts to aquatic resources from 2010-2014 (IWR, 2015).

Protecting aquatic resources required offsetting impacts to wetlands through wetland mitigation, a complex regulatory system to ensure the CWA replaces essential ecosystem services. Mitigation under the CWA follows a three-step sequence—avoid, then minimize, and lastly, compensate—to moderate the impacts to wetland resources. The sequence order prioritizes each step *before* moving on to the next step. With this reasoning, regulators prefer the first step, avoidance, above all else. If avoidance cannot happen, regulators favor the next option, minimizing wetland impacts. Only after exhausting these first two options can compensatory mitigation be considered an option. While this process ostensibly limits the role of compensatory mitigation, research has argued that the mitigation sequence leans too heavily on this final step (Clare et al., 2011).

With this new legislation, the ACOE no longer solely held the regulatory reigns. Rather, the ACOE would oversee the day-to-day permit application process to impact wetlands—known as §404(1)(b)—while the EPA would oversee compliance and issue compliance guidelines. In addition, if the EPA had the power to exercise veto powers over ACOE decisions the EPA disagreed with, limiting the broad discretion the ACOE previously held. This new oversight role by the EPA created inter-agency tension, as the EPA and ACOE struggled to bilaterally manage mitigation programs (Hough & Robertson, 2009).

The ACOE, familiar with management under the RHA, resisted adopting an organizational mentality that strongly protected aquatic resources. After the CWA passed, many assumed the law would lead to a rejection of permit applications that damaged wetlands. As it turned out, the ACOE denied few permits. When the EPA exercised its veto power, the ACOE initially resisted this oversight. Before the passing of the CWA, the ACOE had sole jurisdiction to regulate the RHA. The CWA changed this dynamic, with the EPA overseeing ACOE decisions. Even after an out-of-court settlement from *National Wildlife Federation v. John O. Marsh Jr.* (1981) in which the ACOE agreed that EPA mitigation guidelines were binding, the ACOE released an internal guidance document days later stating the contrary, that the EPA guidelines were advisory only (ACOE, 1984). Despite disagreement, the EPA did little to exercise its veto authority. Rather, the two agencies failed in their respective capacities to curb wetland impacts. The ACOE showed little propensity to deny permit applications while the EPA failed to use its veto power to challenge the ACOE's decisions (GOA, 1988). While the agencies struggled to come together with a shared purpose, developers had little regulatory clarity to follow.

Turning the broad objectives of the CWA into an effective regulatory mechanism proved to be an ambitious task. Chief among the challenges was aligning all federal agencies—not just the ACOE—with dubious histories in wetland management to follow the CWA goal of protecting the integrity of U.S. waters. The Department of Agriculture (DOA), for instance, had long subsidized wetland drainage to increase agricultural acreage and productivity. From 1940–1977, an estimated 23 million hectares of wetlands were converted through the DOA's Agricultural Conservation Program (Mitsch & Gooselink, 2015). Incentives continued after Congress passed the CWA, creating a situation in which one federal agency subsidized wetland drainage and another agency that penalized it. In 1985, the Food Security Act cut these agricultural subsidies. Known as "swampbuster" programs, these initiatives helped unify federal agencies in the protection of wetlands.

Nevertheless, the 1970s and 80s marked a slow start to curbing wetland conversion. Even as the DOA halted their wetland conversion programs, the ACOE resisted a strong interpretation of protecting wetland resources. It would be another five years until the agency came to an agreement on the intent and administration of the CWA. This period also aligned with President George H.W. Bush's national wetlands goal.

No-Net-Loss

In the late 1980s, President George H.W. Bush's wetland initiative brought wetlands and their ecosystem service benefits into the national spotlight. While President Nixon and President Carter had issued Executive Orders directing federal agencies to increase wetland protection, President H.W. Bush upped the ante for American wetland protection by proposing to reverse the net loss of wetlands. President Bush adopted his pro-conservation attitude after national wetland inventories estimated that Americans had converted over 50% of wetland resources (Tiner Jr., 1984). Another assessment estimated annual wetland loss between the 1950s and 1970s at 439,000 acres per year (Frayer, Monahan, Bowden, & Graybill, 1983). In light of these assessments, the National Wetlands Policy Forum in 1987 set forth a new agenda to protect wetlands. The top recommendation advised a "no-net-loss" national policy. Through halting wetland conversion and investing in wetland restoration, the United States could set a trajectory for long-term wetland gain (Hough & Roberston, 2009). Speaking at a Ducks Unlimited gathering, President Bush embraced this no-net-loss framework and beckoned his countrymen to support strong environmental protections.

> I want to ask you today what the generations to follow will say of us 40 years from now. It could be they'll report the loss of many million acres more, the extinction of species, the disappearance of wilderness and wildlife; or they could report something else. They could report that sometime around 1989 things began to change and that we began to hold on to our parks and refuges and that we protected our species and that in that year the seeds of a new policy about our valuable wetlands were sown, a policy summed up in three simple words: "No net loss." And I prefer the second vision of America's environmental future.
>
> Bush, G.H.W., 1989

The no-net-loss goal set forth the goal that for every acre of wetland damage, at least one acre had to be replaced. To achieve no-net-loss, federal regulations needed a robust method to account for wetland loss in order to increase wetland acreage elsewhere. Wetland mitigation under the CWA fit this framework of tracking wetland loss and gains to achieve no-net-loss standards.

After nearly two decades of disagreement about jurisdiction within the CWA, the ACOE and EPA jointly published a memorandum of understanding (MOA) in 1990 (EPA, 2017a). The MOA ended the conflicting agency goals and clarified the mitigation sequence still practiced today. The choices made in the mitigation sequence determine the extent in which wetland mitigation will relocate wetlands across the landscape. Since the 1990 MOA, these preferences have not been stagnant. Rather, updated mitigation guidelines have resulted in higher proportions of wetland relocation. The next section describes the complex regulatory framework known as the mitigation sequence, which forms the basis for maintaining wetland resources and for wetland relocation though permitted wetland impacts.

Wetland Mitigation Sequence

The mitigation sequence follows three distinct steps. This first step to mitigate wetland impacts is avoidance. If alternatives for a project exist without damaging wetland resources, CWA guidelines instruct developers to seek these alternatives. Avoiding impacts altogether would be the most efficient way to protect existing wetland resources. Research in Canada however, which has a similar regulatory framework to the United States, critiqued the efficacy of the avoidance policy (Clare et al., 2010). This research attributed lack of avoidance measures to the lack of clarification on what “avoidance” means, not prioritizing high-value wetlands, undervaluing wetlands in economic valuations, and an over-confidence in the capabilities of restoration ecology to restore and create wetlands.

In between avoidance and compensation rests the second step of minimization. If wetland impacts cannot be avoided, then developers should seek to reduce wetland impacts to the extent possible. These steps, outlined in Section H of the §404(1)(b) guidelines, resemble best management practices (BMP) when dealing with dredged or fill material. Examples of minimization include covering materials to prevent erosion, changing the timing of project work to avoid spawning or nesting seasons, and using appropriate technology such as employing mats under heavy equipment to avoid compaction (Gardner, 2005). Like the first step of avoidance, minimization has received little attention as an alternative to compensatory mitigation (Hough & Roberston, 2009). As Clare et al. (2010) argue, "The language that allows compensation if avoidance or minimization 'is not practicable' becomes a de facto loophole in its non-specificity, allowing developers to skirt the intent of the law and move directly to compensation," (p. 169).

As a means to protect existing wetland resources, regulators should prioritize the first two steps of the mitigation sequence. These two steps rely on naturally-occurring hydrological cycles and other wetland functions already established. As has been documented, wetland restoration and creation have often produced mixed results (Zedler, 1996). As one EPA employee remarked, "In my view, nature has a remarkable track record in creating wetlands, and developers do not," (as quoted in Vileisis, 1995, p. 324). While advances in restoration ecology have improved site success, weak implementation of the first two steps represents a missed opportunity for wetland protection. Rather, mitigation has been structured around compensatory mitigation, the third—and least preferable—step in the sequence.

Compensatory Mitigation

As the name implies, compensatory mitigation requires developers to compensate for their damage to wetlands. This final mitigation sequence step requires restoration, establishment, enhancement, or preservation to replace wetland functions. Since mitigation requires more than a 1:1 replacement of wetlands, compensatory mitigation should create a net gain of wetland acreage. In compensatory mitigation, developers can choose between three primary mitigation methods—also referred to as approaches—to fulfill their mitigation requirements. These approaches include permittee-responsible mitigation (PRM), In-Lieu Fees (ILF), or mitigation banking. Figure 4 displays the different approaches to compensatory mitigation.

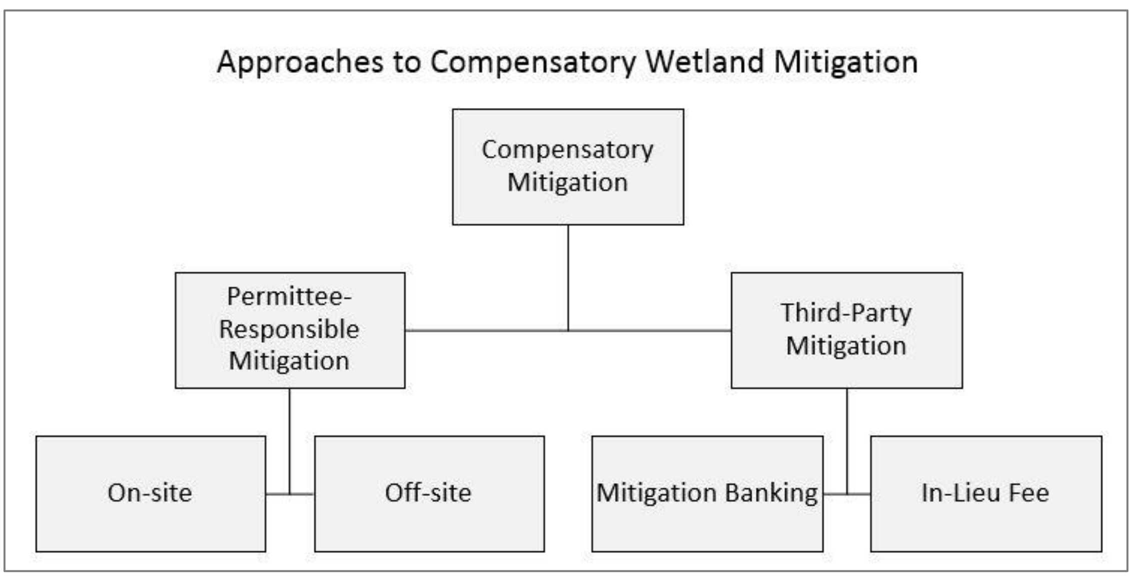


Figure 4*:* Approaches to compensatory wetland mitigation.

Permit applicants can achieve these requirements on-site, which compensates for impacts at the same location as the wetland impacts, or off-site, which relocates compensatory efforts in a different location. This choice of mitigation site selection features prominently in determining wetland relocation. Figure 5 provides a graphic to visualize how each mitigation approach relocates wetlands across a landscape.

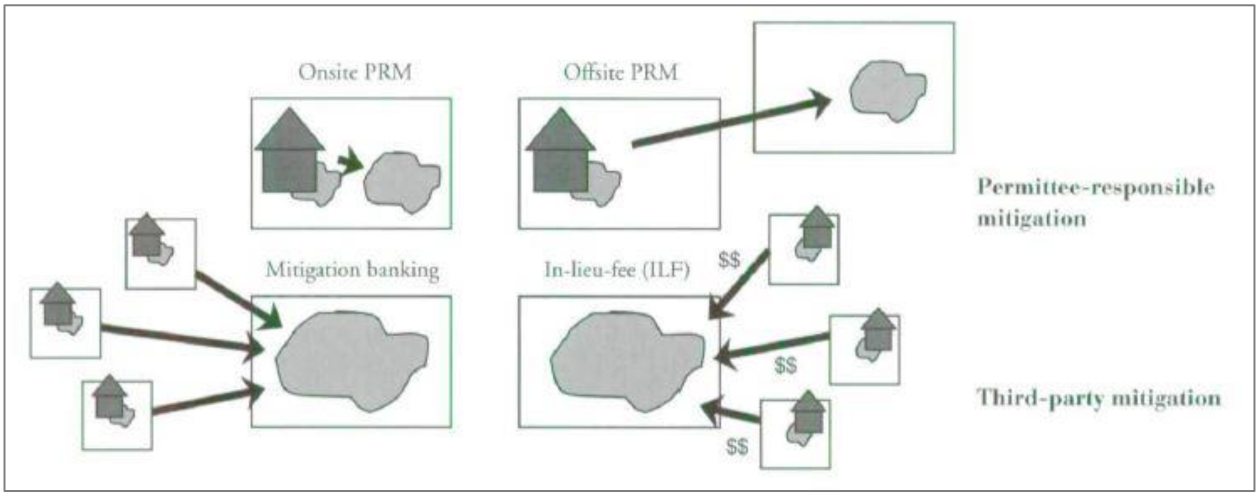


Figure 5. Wetland mitigation approaches and wetland relocation (BenDor et al., 2007).

The second avenue allows developers to pay a commensurate fee for third-party mitigation. Third-party mitigation can take two forms, mitigation banking or in-lieu fee (ILF) programs. Mitigation banks have one large mitigation site, called a mitigation bank, which mitigates for multiple impacts. Developers purchase wetland "credits" before a development project begins. For each mitigation bank, regulatory agencies determine the total credits within the mitigation bank, each credit's monetary value and define the service area, the geographic area where wetland impacts can occur. When regulators approve a project, the credits are debited into the banking ledger, which tracks all impacts and credit usage. For a potential developer, buying wetland credits for a project can be a cost-effective and timesaving choice. For conservationists interested in protecting wetland resources, wetland banks allow strategic site selection of one large restoration site that can provide a variety of wetland ecosystem benefits (NRC, 2001). With one large mitigation site and many impact sites, wetland relocation across the landscapes is more pronounced. If a wetland bank is located adjacent to high population densities, this should provide a host of wetland ecosystem services to adjacent populations. If the wetland bank is located in an area with a low population density, relatively fewer people may benefit from this bank's ecosystem services.

ILF mitigation, on the other hand, differs from wetland banks in its form of currency. While wetland banks use a credit currency, an ILF permittee pays a fee commensurate with the wetland impacts to a government agency or non-profit with restoration expertise. These programs however have struggled to link payments with wetland mitigation (ELI, 2006). Without clearly defined objectives, ILF funds often went to expenditures other than wetland mitigation (Hough & Robertson, 2009). At one point, the ACOE and EPA even considered eliminating ILF as a form on compensatory mitigation (ELI, 2006). Nevertheless, the initial shortcomings have been identified, adjustments have been made to better link ILF with targeted mitigation, and ILF continues to be an option. To date, the DOE has approved three ILF programs in Washington.

Despite their differences, wetland banks and ILF programs share many attributes. Both of these two forms were designed to improve outcomes for mitigation sites. Both approaches reduce temporal loss in wetland mitigation. Temporal loss refers to the lag time when a wetland is impacted and the time it takes to restore wetland functions (i.e. ecosystem services) at a mitigation site. Both approaches involve off-site mitigation that allow multiple impact sites to go toward one, larger mitigation site. Both approaches will likely grow as recommendations have shifted from on-site to off-site mitigation (NRC, 2001).

In the first decades after the CWA, wetland mitigation failed to replace wetlands ecosystem services across landscapes. As a way to track progress in wetland mitigation, the

National Resource Council (NRC) began a comprehensive study, per the request of the ACOE and EPA. In a telling decision of the regulatory agencies' priorities, the report only assessed compensatory mitigation, leaving out assessments for the first two steps in the mitigation sequence. The report's first conclusion did not mince words. "The goal of no net loss of wetlands is not being met for wetland functions by the mitigation program, despite progress in the last 20 years," (NRC, 2001, p. 2). The NRC attributed mitigation's no-net-loss failures to myriad organizational and procedural shortcomings.

National Research Council Findings

Maintaining the ecological functions of compensatory mitigation sites to be self-sustaining over time remains one of the greatest challenges for wetland mitigation (Zedler, 1996). To address this challenge, the NRC (2001) recommended a watershed approach. A watershed approach identifies the host of biotic and abiotic features of the landscape to be considering when selecting a mitigation site. These include climate, topology, hydrology and soil conditions. In the context of this thesis, one critical recommendation warns against selecting mitigation sites in "seriously degraded or disturbed sites" (p. 5). Increasing levels of urbanization yield more disturbed sites. Thus, this recommendation gives preference to rural areas of low population densities over urban areas with high population densities. Further, the report details that mitigation sites with floral communities not yet fully established are susceptible to the perturbations of population growth and human influences. In Washington State, this approach has been adopted by the DOE in their guidance, "Selecting Wetland Mitigation Sites Using a Watershed Approach" (Hruby, Harper & Stanley, 2009).

The NRC also identified other shortcomings of compensatory mitigation, many of which make it difficult to assess wetland relocation across landscapes. First, unclear performance standards impede compliance with mitigation requirements. If a mitigation site exhibits reduced ecosystem service benefits compared to an impact site, this divergence complicates assessing the functional equivalency of wetlands. This lack of equivalency between impact and mitigation sites also hampers assessing the redistribution of ecosystem service benefits to human populations. Current understanding of the complex nature of wetland dynamics prevents certainty about the transfer of ecosystem services.

Finally, tracking how compensatory mitigation programs affect wetland resources across the landscape remains low. The NRC (2001) recommended maintaining a database to properly track mitigation progress. In 2007, the ACOE developed the Regulatory In-lieu fee Bank Information Tracking System (RIBITS). This database captures ILF and wetland banking programs, although PRM is absent. The impetus for developing the system was to provide developers easily accessible information by which to know if using any mitigation service areas were contained within their proposed development. RIBITS could also present a spatial representation of where wetland impact and mitigation sites are located. Another database called ORM2 has also been developed to track all types of §404(1)(b) permits. While the ACOE tracks impacts with ORM2, site location data within the protected database does not contain coordinate data for mitigation sites, preventing geospatial analysis (R. Haines, personal correspondence, April 26, 2017). The ACOE shares database information only through Freedom of Information Act (FOIA) requests.

Supreme Court Interpretations of the CWA

While much of the discussion in this section has centered on the ACOE and EPA, the Washington State Department of Ecology (DOE) also plays a prominent role in compensatory mitigation by sharing permit responsibilities with the ACOE. Recent court decisions have limited federal authority of the CWA, creating a larger role for state agencies. This shift first began with the Supreme Court hearing of *Solid Waste Agency of Northern Cook County (SWANCC) v. Army Corps of Engineers* (2001).

In a 5-4 decision, the Court ruled that the ACOE overreached their jurisdiction by applying isolated wetlands used by migratory bird species to the CWA. While waters adjacent to rivers and other interstate water bodies were within their jurisdiction through the Commerce Clause, the Court pointed out that regulating isolated wetlands—wetlands without direct hydrologic connections to other aquatic resources—misinterpreted the original text of the CWA. The Court's decision questioned the broad interpretation of waters of the United States, bringing the question of applying navigable waterways back into the spotlight. This questioning went against actions governing the previous decades, which sought to protect the biological and hydrological integrity of U.S. waters (Downing et al., 2003).

Rapanos v. United States (2006) further limited federal oversight of isolated wetlands. While the Court failed to issue a majority opinion (4–1–4), Justice Kennedy's lone interpretation has been most influential. With four Justices narrowly interpreting CWA jurisdiction to include wetlands with a surface connection to navigable waters and the other four Justices interpreting tributaries and adjacent wetlands, Justice Kennedy took the middle of the road, citing the term "significant nexus" used in *SWANCC v. Army Corps of Engineers.* In his words:

> Wetlands provide the requisite nexus, and thus come within the statutory phrase "navigable waters" if the wetlands, either alone or in combination with similarly situated wetlands in the region, significantly affect the chemical, physical, and biological integrity of other covered waters more readily understood as "navigable." When, in contrast, wetlands' effects on water quality are speculative or insubstantial, they fall outside the one fairly encompassed by the statutory term "navigable waters."
> Justice Kennedy opinion, *Rapanos v. United States*, 2006, p. 779-780.

Challenging regulators to examine this nexus acknowledges the complex interactions wetlands have with underground aquatic resources. Indeed, Craig (2008) argues the nexus standard should lead to integrating ecosystem services within CWA regulation. In particular, this nexus highlights the regulating service of filtering sediment and pollutants from the surface waters. While not explicitly defining the term, Justice Kennedy's words underscore the importance of wetlands in combatting nonpoint source pollution. The CWA originally identified point-source pollution, or pollution coming from one source that can be geographically isolated. CWA amendments in 1987 included non-point sources as well. As the name implies, non-point source pollution cannot be traced back to one location. Rather, non-point source pollution comes from myriad sources throughout the landscape. Examples include accumulated chemicals from stormwater, pesticides from agricultural runoff, or urban areas with high percentages of impervious surfaces. Capturing non-point source pollutants before entering the Puget Sound or Columbia River is a critical ecosystem service that wetlands provide in urban environments in western Washington.

Conclusion

Since European colonization of the United States, wetland resources have been drained and filled to increase economic productivity. Chief among these converted uses have been agriculture and urban development. Government programs consistently incentivized wetland conversion, such as when the federal government granted wetlands to state governments to sell in order to combat frequent flooding. With policies such as these, an estimated 53% of the United States' wetland resources were converted in a span of 200 years (Dahl, 1990). Industrialization also began severely polluting our nation's waterways. In response to the degradation of U.S. waters, Congress passed the landmark legislation in 1972 that paved the way for the CWA. However, not until the Swampbuster programs of 1980's did federal policy align to prioritize wetland protection.

The CWA charges the ACOE and the EPA with protecting the "biological, chemical, and physical integrity" of U.S. waters. Taking this broad language and turning it into an agreed-upon regulatory program has proved challenging. First, the ACOE and EPA themselves have disagreed upon jurisdiction and procedure. The Supreme Court and lower courts continue to interpret the CWA, altering wetland management. Nevertheless, wetland mitigation currently administered under the CWA presents an intricate regulatory program to protect aquatic resources and their underlying ecosystem services. While a complete freeze on damaging wetland resources is considered incompatible with economic development, wetland mitigation has developed to offset the adverse impacts to wetland resources. The mitigation sequence has three distinct steps, but it is the last step of compensatory mitigation that assumes the most prominent role in practice. Compensatory mitigation has evolved during the past decades, from an initial preference for on-site wetland mitigation to a preference for off-site mitigation. This off-site mitigation relocates wetlands and their benefits from one location to another.

This thesis research examines this aspect of off-site, compensatory mitigation. Nationwide, the CWA impacted an average of 13,300 acres of wetlands annually from 2007-2014 (IWR, 2015). With the preference for off-site mitigation, this causes thousands of wetland acres to be relocated annually. Over time, what effects might aggregate relocation have on the local ecology and, in turn, local human populations? If wetland losses occur within one specific land use type (e.g., urban areas), this may reduce the resilience of the local environment.

This chapter presented a brief history of wetland management in the United States, with particular attention to specifics of wetland mitigation regulated under the CWA. The following chapter will present a review of the pertinent scientific literature, including a focus on ecosystem services, wetland valuations, spatial influences of wetland values, and the societal impacts of wetland mitigation. This review will examine theoretical and applied research on wetlands and their ecosystem services. Understanding these two aspects of wetlands and ecosystem services will contextualize the ensuing analysis.

CHAPTER 3: LITERATURE REVIEW

The projected continued loss and degradation of wetlands will reduce the capacity of wetlands to mitigate impacts and result in further reduction in human well-being.

Millennium Ecosystem Assessment (2005)

Introduction

Wetland mitigation regulated under the Clean Water Act (CWA) permits thousands of acres of permanent wetland impacts each year (IWR, 2015). To compensate for these impacts, mitigation creates, enhances, preserves, or restores wetlands, often at a different location than the wetland impacts. Accordingly, human populations near these sites gain or lose wetlands and their ecosystem service benefits depending in part on their proximity to impacts and mitigation projects. However, only a handful of studies have examined spatial dynamics and environmental equity of wetland loss and gain through CWA mitigation.

The purpose of this chapter is to review relevant literature centered upon environmental equity in the relocation of wetlands and their ecosystem services. Ecosystem services play a crucial part in this research; they are the very reasons why human populations benefit from wetlands and why regulatory agencies across the country spend time and resources centered on wetland management. Understanding the ecosystem services framework that environmental managers now use will contextualize how this research applies this framework to wetland mitigation. This literature review will first examine the rise to prominence of ecosystem services and efforts to accurately assess their benefits to human populations. As recognition of ecosystem services' importance has grown, economic markets have attempted to integrate ecosystem services into commodity markets. The second section details how wetland mitigation uses this framework to commodify and trade ecosystem services within a neoliberal economic system across spatial and temporal scales.

In particular, this chapter surveys the challenges of trading complex habitat types like wetlands across these scales.

The third section examines different methods of wetland valuations. This research presupposes benefits to human populations living near wetlands. Researchers and economists use a wide variety of valuation techniques to measure these benefits. While these valuation techniques can lack both precision and accuracy (Boyer & Polasky, 2004), understanding different valuation frameworks will increase understanding of the complexity of valuing wetlands with multiple ecosystem services and the nuance of how wetlands' position in a human-influenced landscape can alter these valuations.

The final two sections will examine past research influential in developing methods for this study. These sections will review previous studies on the equitable distribution of wetlands within mitigation. Specifically, this section surveys environmental equity within three parameters: urban-rural equity, socioeconomic equity, and racial equity. The final section positions this research within these previous studies and articulates the need for further studies to increase our understanding of wetland mitigation spatial dynamics and its relation to human populations.

The Rise of Ecosystem Services in Environmental Management

While ecosystem services has risen to prominence within a conceptual framework in natural resource management, researchers still disagree about a precise definition. The Millennium Ecosystem Assessment (MEA), the most comprehensive global analysis of ecosystem services to date, states simply that ecosystem services are the "benefits humans obtain from ecosystem services," (MEA, 2005c, p. v). The scope of this definition encompasses an extraordinary breadth of the earth's processes. For example, the MEA recognizes that ecosystem services include provisioning services such as food, fiber, water, and genetic material; regulating services such as climate regulation, water purification, natural hazard regulation, hydrology regulation and erosion control; cultural services such as spiritual, recreational, aesthetic and educational benefits; and supporting services such as nutrient cycling and soil formation. [See Appendix A for a more complete list of ecosystem services types.]

Increased interest in ecosystem services stems from the recognition that human activities threaten critical regulating and provisioning ecosystem services requisite for human health and well-being (MEA, 2005c). Attempting to put a price on these services yields immense values. A landmark study (Costanza et al., 1997) estimated these services on a global scale, approximating their values to be in the range of US$16-54 trillion annually. To put these numbers in context, global gross national product (GNP) at this time was US$18 trillion. As the authors readily admitted, their study presented many assumptions and conceptual limitations, extrapolating values from existing literature on small-scale ecosystem valuations to account for the entire planet's land mass. Nevertheless, the article stimulated immense interest in ecosystem service valuations and remains the most cited article in the field of ecological economics (Costanza, Stern, Fisher, He, & Ma, 2004). The high estimates garnered further interest in capturing the value of earth's processes and functions in economic valuations. Integrating the earth's dynamic ecosystems into an economic framework remains ecological economists' primary challenge.

Ecological Economics

Ecological ecologists combine elements of two fields—neoclassical economic theory and natural systems—but lack of consensus has prevented a unified set of tenets for practitioners to follow study (Bockstael, Freeman, Kopp, Portney, & Smith, 2000; Dorman, 2004; Morino-Saul & Roman, 2012). On one hand, neoclassical economists apply foundational principles such as cost, benefit, supply and demand, and monetization of goods and services. Marginal, or incremental values, follow linear relationships when adding units of value (Heal, 2000). On the other hand, natural systems follow few of these principles. Instead of using a reductionist approach, ecologists embrace the complexity of interconnected relationships and feedbacks. Natural systems are also observed to be nonlinear, with links between human well-being and ecosystems "indirect, displaced in space and time, and dependent on a number of modifying forces" (MEA, 2005a, p. 2). In general, ecological-economists accept non-market (i.e., non-monetary) values, such as the intrinsic value of nature and human rights. They also believe in the non-substitutability of natural capital, often referred to as "strong sustainability (Merino-Saum & Roman, 2012). In the context of wetlands, strong sustainability principles regards human-made features that mimic wetlands as inferior, such as water treatment plants that filter pollutants.

Different approaches within the two disciplines have also divided the field. On one side, neoclassical economists traditionally value natural resources for the physical products harvested, such as food or timber. On the contrary, Costanza et al. (1997) recognized this approach misses the valuation of natural capital, which provides not just a one-time payoff, but a continual flow of services spanning generations. While attempting to capture the value of these services, this methodology does not deviate from traditional neo-classical monetization into a cost-benefit framework. Once these services are properly valued, proper measures can be taken to account for—or to internalize the negative externalities of—ecosystem degradation (Merino-Saum & Roman, 2012).

Using economic valuations as a tool to conserve natural systems and ecosystem services has elicited strong debate on its merits (Lele, Springate-Baginski, Lakerveld, Deb, & Dash, 2013). On one side, ecosystem service valuation proponents argue that the process corrects for externalities, items or consequences not accounted for in a cost-benefit analysis of development projects (MEA, 2005b). Properly valuing these services accounts should reduce negative externalities by accounting for lost services and supports government regulatory bodies in prioritizing their protection with increasing resource scarcity (Daily et al., 2000). Wetland mitigation is embedded within these ecosystem service valuation principles.

A counter perspective argues that far from enhancing environmental protection, these valuations precipitate their decline (Robertson, 2004). While comprehensive valuations underpin ecosystems importance, valuations also pave the way toward commodification. Economic valuations are then framed within the context of neoliberalization and free trade. A cornerstone of capitalism rests upon the free flow of capital in the forms of goods and services; mitigation attempts to trade these ecosystem services within this economic system through environmental trading markets, or ETMs (Heal, 2000). These markets now extend to carbon sequestration, clean air regulation, and biodiversity preservation (Walker, Brower, Stephens & Lee 2009) in addition to wetland mitigation.

The Problem with Currency in Trading Wetlands

For a functioning market to be in place, users must be able to trade these goods with an agreed-upon currency. Therein lies another challenge in setting up a market for ecosystem services. Salzman and Ruhl (2001) contend that any currency must be traded equally across type, space, and time. The authors refer to this interchangeability across these scales as fungibility. While this research centers itself on issues of spatial equity, this section addresses issues of equity that also present themselves when traded across different types and temporal scales. When examining the currency of natural capital, the ecosystem services themselves influence their fungibility. With one specific ecosystem service, market users are more likely to assume a roughly equal trade.

For carbon sequestration, the currency is measured in metric tons of carbon dioxide (CO_2). Specialists can measure how much CO_2 a stand of trees sequesters, which can be protected as an offset for emissions CO_2 elsewhere. Notwithstanding other benefits provided by trees, CO_2 sequestration represents a currency that is measured and has approximately the same value over space and time. With multi-benefit habitats, their fungibility becomes questionable. For example, research suggests that trading land properties for biodiversity protection fails to properly understand the ecological and spatial diversity in these land values (Walker et al., 2009). Wetland mitigation faces similar challenges.

Currencies used for wetland mitigation fail the fungibility test on all three parameters of type, space, and time. For wetland type, Cowardlin, Carter, Golet, and LaRoe (1979) classified the county's diverse wetland types. Each wetland type is a highly-adapted system that has proved difficult for humans to relocate (Turner, Redmond, & Zedler, 2001). These types depend on the inputs, or controls, that relate to its geomorphic location, water source and hydrodynamics (Hruby et al., 2009). In some cases, relocation precludes the possibility that wetland type can be matched in the diverse landscape of Washington. Teasing apart the intricate, inter-connected web of relationships and ecosystem services within each wetland type to determine their value and equal transfer remains an elusive, if not impossible task.

Trading across temporal scales also poses serious limitations due to the lag time that often exists between an impacted wetland and its restoration or creation. During a development project, wetlands are often damaged *before* restoration begins, creating a net-loss in wetland functions during that time. To compensate, the Washington Department of Ecology (DOE) requires a higher fee in this scenario to address this time lag (Department of Ecology, 2013a). Uncertain ecological trajectories also pose a problem for trading wetlands (Zedler & Calloway, 1999).

Research continues to examine not only if relocating wetlands can be achieved, but also if practitioners can control with any degree of accuracy the types of ecosystem services supplied by mitigation efforts. Generally, there is a five or ten-year monitoring period are required by the DOE and the United States Army Corps of Engineers (ACOE). How wetlands and their ecosystem services develop after this monitoring and maintenance period remains poorly understood, as few researchers have conducted longitudinal studies on site performance. While this research focuses on spatial equity in wetland mitigation, temporal equity is a relevant issue, particularly with unknown trajectories that affect the flow of wetland ecosystem services,

The final ingredient for a currency to function is the ability of actors to trade commodities equally across space. This dimension proves the most problematic for wetland mitigation and is the primary focus of my research. Before examining spatial components of wetland ecosystem trading, this study reviews attempts to quantify wetland ecosystem services through different valuations. As the studies indicate, populations' spatial proximity to wetlands and wetlands' place within the landscape both influence valuations.

Wetland Valuations and Ecosystem Services

Per acre, wetland systems such as estuaries, floodplains, and tidal marshes are among the most valuable and productive habitat types in the world (Costanza, Farber, & Maxwell, 1989). Society places value on wetlands because they provide a wide array of ecosystem services that benefit populations at localized, regional and planetary scales (Mitsch & Gooselink, 2000). While these services provide stability for economic well-being, the extent of human influence around the globe threatens the delivery of many of these services on which humans depend (MEA, 2005a).

One response to this threat has been to conduct wetland valuation studies. Many researchers concede these studies do not produce values that can be applied to wetlands in other locations (Brander, Florax, & Vermaat, 2006). Rather, the threshold for successful valuations should be if they assist decision makers in choosing policy actions and land use recommendations (Boyer & Polasky, 2004). As research indicates however, wetland valuations fail to produce clear findings, with studies often producing wildly variable figures. This variation stems from two primary causes. First, variation exists in wetlands themselves due to their performed functions and place within the landscape (Mitsch & Gooselink, 2000). The second reason rests in the shortcomings of valuation techniques themselves (Boyer & Polasky, 2004). These valuation methods include contingent valuation, travel cost, hedonic pricing, production functions, and replacement cost, among others (Brande et al., 2006). See Appendix B for a full list of valuation methods and descriptions.

The hedonic method measures the value of a good—in this case, wetlands—by using existing prices as a proxy. Housing and land sales prove to be an effective measure. In urban areas, proximity to wetlands positively corresponds to wetland values in the three studies reviewed by Boyer and Polasky (2004). Research in Portland, Oregon showed an increase of

$436 in housing prices when houses were moved from 1.6 kilometers to 300 meters to the nearest wetland (Mahan, Polasky, & Adams, 2000). Studies in rural areas have lacked conclusive results. Reynolds and Regalado (2002) found wetland type to be a determining factor whether proximity yielded positive or negative values. The preference of shallow ponds over forested wetlands, for example, suggests rural residents may prefer hunting and aesthetic values to other benefits. Loss in agricultural production as well may cause rural landowners to prefer non-wetlands lands to wetlands. After all, settlers have been converting wetlands for agricultural purposes since European settlement began in earnest in the 1700's (Dahl, 1990). While the hedonic valuation method can show trends, scale limits these studies, as they measure values only in close proximity to wetlands.

A hedonic study of a three-county area in North Carolina, for example, found that proximity up to ¾ of a mile to natural wetlands steadily increased property values by roughly $3,100 (Kaza & BenDor, 2013). When examining restoration projects through the state-run Ecosystem Enhancement Program (EEP) however, land values varied. Interestingly, land within .0125 miles of EEP sites had average values $15,500 less than land not in proximity to EEP sites, suggesting a negative relationship. Given the assumed social benefits of wetlands, results from this study contradict conventional thinking. A key—and I would argue, flawed—assumption in this study supposes that these sites were not initially chosen based on land values, but rather suitability for wetland restoration or preservation. This assumption repudiates research that indicates private entrepreneurs in wetland mitigation identify profit as the primary reason for opening a mitigation site (Kaplowitz & Bailey, 2008). As many EEP sites were bought directly from private mitigation companies whose profit depends on a difference between the amount recouped for restoration credits and the initial land price, initial land prices may have had *everything* to do with where wetland mitigation sites are located.

Replacement cost is another valuation technique that estimates the price to substitute a good that is no longer available. Many municipal planners use this method in determining how best to provide safe drinking water. In the Puget Sound, long-protected upper watersheds in the Cascade Mountain Range and from Mount Rainier provide clean, consistent drinking water with few filtration costs (Seattle Public Utilities, 2013; Tacoma Public Utilities, 2008). New York City infamously faced this decision in the 1990's, with development in the nearby Catskills Mountains threatening to decrease water quality standards so that costly filtration plants would be needed. Instead, planners chose to increase protection for the watershed and associated wetlands, as the $6-8 billion estimated replacement cost of building purification plants dwarfed the cost of watershed protection to increase the watershed's natural water infiltration and purification ecosystem services (Chichilnisky & Heal, 1998). This large-scale watershed protection preserved existing wetlands, forests, and their respective ecosystem service benefits for rural populations, while also supplying the most-populated city in the country with its drinking water.

For fish and wildlife, economists can use production methods analysis to estimate how much a particular wetland increases fish production. Unfortunately, economists rarely apply this type of research to urban settings, despite good reasons to do so (Boyer & Polasky, 2004). For example, a growing body of research indicates that polluted urban waterways may be severely disrupting salmon populations as they enter fresh water system to spawn, the final stage in their life cycle (Scholz et al., 2011). While isolating the effects of increased riparian wetlands would be difficult to isolate in an urban setting, applying production methods analysis could improve understanding of the link between degraded urban rivers and the economic—or production—loss due to a river's riparian wetland loss.

Researchers have also applied contingent valuation to urban wetlands. Contingent valuation uses hypothetical values and asks respondents if they would be willing to pay that amount for a given service or good (Brander et al., 2006). By using different amounts, researchers average respondents' preferences to determine willingness-to-pay (WTP). This methodology has three primary limitations. First, dealing with hypotheticals may not accurately predict if respondents would actually pay (Boyer & Polasky, 2004). Saying one would pay $40/acre for restored wetlands is one thing; handing over the money is quite another. This method may artificially increase WTP. A meta-analysis of wetland valuation, for example, found that contingent valuation methods yielded greater estimates than other methodologies (Brander et al., 2006).

Second, incomplete knowledge may also hinder contingent valuation of wetlands. This ignorance has led to the opposite effect, a decrease in wetland values, as indicated in a different meta-analysis (Woodward & Wui, 2000). Given wetlands' complexity and their dispersed benefits, contingent valuation studies often ask to value just one specific ecosystem service such as improved water quality. This process also undervalues wetlands (King, 1998).

Third, socioeconomic factors influence perceived valued of wetlands, as indicated by (Brander et al., 2006). If mitigation relocates wetlands spatially, this will likely result in a population with different socioeconomic characteristics. In turn, these socioeconomic differences will attach different perceived values to wetlands. For example, a low-income community may produce starkly different estimates than an upper-middle class community, despite performing the same functions.

While instructive in noting public perceptions, contingent valuation's limitations restrict its application in wetland relocation. Noting the wide variability, the NRC (2001) recommended mitigation guidelines absent from valuation studies based on human perceptions. These studies lack of precision and accuracy prevents their integration in the mitigation process. Nevertheless, these studies point to differences in perceptions of wetlands and wetland uses among populations. These differences are important to deliberate when examining environmental equity occurring within the spatial relocation of wetlands and their ecosystem services because of wetland mitigation.

Spatial Influences on Wetland Values

Proximity to wetlands influences perceived values of these systems among human populations (Brander et al., 2006). Known as spatial discounting, this theory states that resources located farther away from populations will decrease its perceived value (Perrings & Hannon, 2001). Accordingly, resources located in close proximity to human populations are more highly valued. Wetland mitigation, therefore, has the power to increase or decrease the perceived value depending on wetlands relative proximity to human populations. Research by Manuel (2003) indicated that small, urban wetlands are valued for aesthetics and contribute to perceptions of place among local populations. This research indicates that local residents value cultural ecosystem services—aesthetics, education, recreational, spiritual, and the landscape as a sense of place—more than regulating and provisioning services whose benefits are more dispersed and less understood by the surrounding population.

Manuel (2003) recognized that the size of wetlands influence local perceptions of wetlands. With small wetlands, the author recognizes their size is unlikely to galvanize a community over potential impacts. As Figure 6 indicates, the vast majority of projects requiring mitigation are less than one-tenth of an acre.

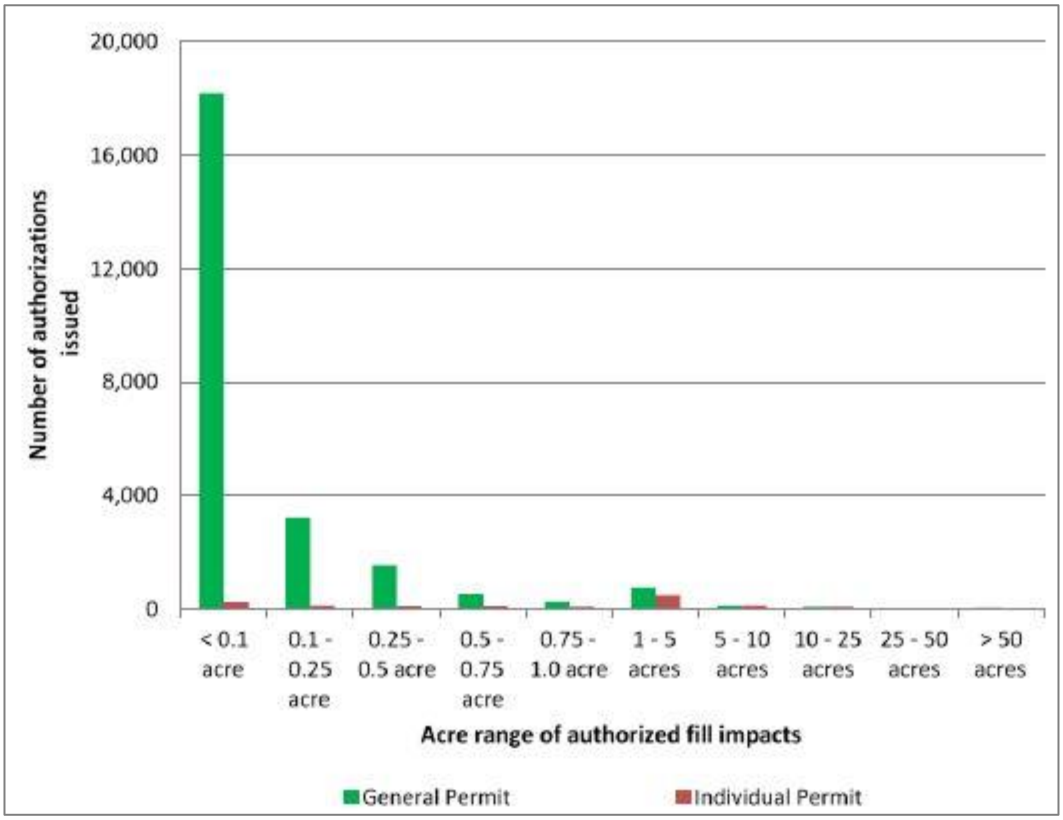


Figure 6. Acre range of national wetland impacts from 2010-2014 (IWR, 2015).

As wetland mitigation approaches one-half century in the United States, these small impacts will likely continue. These small-scale impacts add up to thousands of wetland impacts every year. From 2010-2014, regulatory agencies granted an average of roughly 8,000 acres of permanents impacts to non-tidal wetlands nationwide (IWR, 2015).

Recent studies have taken a broader and more critical look at spatial dynamics of wetland mitigation that may affect local populations, yet this remains an understudied area of research. King and Herbert (1997) were the first researchers to analyze wetland impact sites and mitigation sites in regards to human populations. This first study of Florida Department of Transportation (DOT) sites recognized a strong urban-rural shift in wetland mitigation placement. Nearly ten years later, Ruhl and Salzman (2006) continued research on Florida wetland mitigation sites and incorporated population densities into their analysis. Overlaying population density with site location, their analysis found that mitigation bank areas had low population densities while impact sites had much higher densities. BenDor, Bruzovic and Pallathucheril (2007) studied the impacts of wetland mitigation in four counties in the greater Chicago area, assessing if mitigation type and size correlated with population densities. Mitigation banking in particular moved wetlands along a strong urban-rural gradient. This study also examined demographic data to note environmental equity within the *types* of people living near impact and mitigation sites. These researchers analyzed differences in ethnic and racial percentages between impact and mitigation sites to measure racial equity. To examine socioeconomic equity, the researchers measured average household income and households in poverty. These types of analysis assessing the potential impacts on human populations of a widespread government program were what President Clinton intended when he signed an executive order to address environmental justice within government programs.

Environmental Equity within Wetland Mitigation

Executive Order No. 12898 (1994) from President Clinton asked that "each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States" (p. 1). Nevertheless, current regulatory guidelines do not address if cumulative impacts of wetland mitigation augments social disparity (BenDor, Brozovic & Pallathucheril, 2008).

Researchers and regulatory agencies have examined ecological functions in relation to human populations. Due to the high levels of human perturbations that may augment project costs, regulatory agencies recommend mitigation sites away from urban areas (NRC, 2001). Washington State, in turn, has followed these recommendations by using watershed boundaries as parameters for site selection. Hruby et al. (2009) with the Washington Department of Ecology (DOE) specify that using a watershed approach does not set any limits on the distance of wetland relocation, as watershed basins can cover large areas. However, altered hydrologic regimes found disproportionately in urban areas may cause increased flooding, eutrophication of local waters, poor water quality, bank erosion and loss of habitat (p. 14).

Current regulatory recommendations for wetland placement fail to take human populations into account (BenDor et al., 2008). Wetlands likewise have thus far failed to garner the attention that the equitable distribution of parks and other green spaces have. In practice, site selection with parks and wetlands starkly contrast each other. While environmental equity advocates seek to maximize urban green spaces for underserved communities (Jennings et al., 2012), the low fungibility of wetlands prevents adopting this same framework; previous land legacies may lead to poor site wetland functioning. For this reason, site selection for wetlands recommends low population densities to achieve ecological maximum benefits (NRC, 2001).

Nevertheless, the previous studies that examined urban-rural equity within wetland mitigation also examined socioeconomic and racial equity. Results do not indicate any clear trends across the studies. BenDor and Stewart (2011) found a movement from more White and higher income populations to populations with higher percentages of minorities and lower incomes in North Carolina. These findings were consistent with earlier work from the same author, BenDor et al. (2007), which found more White populations and higher incomes population living near impact sites. However, Brass (2009) found different findings in Oregon, with populations living near mitigation banks having higher incomes and higher percentages of White populations. The average distance between the sites also varied, ranging from 13.5-31.2 miles. The researchers hypothesized that relocation distance may be attributed to whether mitigation is managed at the local, state, or federal level (BenDor & Steward, 2011). While these studies captured valuable data, this limited range represents a significant data gap nationwide in wetland mitigation. Further studies conducted at the state and county level will help fill the gap in spatially analyzing mitigation trends to advance our understanding of environmental equity in wetland relocation.

Need for Further Research

With the small number of geographic areas analyzed for wetland mitigation trends, replicating methodologies from previous research will enhance baseline spatial and socioeconomic data for wetland mitigation. Choosing the paired t-test method by BenDor, Brozovic and Pallathucheril (2007) offers a succinct analysis of differences between mitigation and impact sites. Using data from King, Snohomish and Clark counties—three counties in Washington State that have pronounced urban-rural gradients—this research will examine if wetlands are relocated from urban-to-rural environments. In addition, this research will examine racial and socioeconomic equity within the distribution of wetland impact and mitigation sites.

No one has yet to complete this type of study in Washington State. As ecosystem service markets gain acceptance and expand to account for adverse environmental impacts, regulators and researchers must examine how this system affects both local ecology and human populations. This research examines how these three Washington counties are administering their wetland mitigation plans and if this regulatory process is being implemented equitably to human populations across spatial scales.

While the regulatory framework of the Clean Water Act (CWA) has enabled impacts to wetlands to occur for decades, determining the spatial relationship between wetland losses and gains has received little attention. Examining the spatial distribution of wetlands is important because of wetlands' many localized benefits for human populations. In the urbanized environment of the Western Washington, flood mitigation, storm abatement, and improved water quality all benefit the ecological health of sensitive aquatic resources. Wetlands also provide food and fiber, regulate temperature, and provide aesthetics (MES, 2005). Mitsch and Gooselink (2000) recognized that urban areas and their populations benefit greatly from these services due to the relative scarcity of wetlands. Despite the increased marginal value of wetlands in urban areas, guidelines have directed site selection away from urban areas (NRC, 2001). The NRC made these recommendations based on the relative low success rate of urban mitigation sites, noting that previous disturbances in urban areas often alter soil composition or hydrology to prevent wetland conditions from re-establishing. Perturbations such as invasive plant colonization also increase the likelihood of continued maintenance costs. As conceptualized by Mitsch and Gooselink (2000), wetland functions may have a tipping point, where previous land use legacies or continuing perturbations may cause wetland function to cross a tipping point and overwhelm their functional viability.

Therein lies the tension within this urban versus rural wetland mitigation site selection. On one hand, urban environments stand to benefit the most from wetlands and their ecosystem services. On the other hand, ecological conditions, land value prices, and the availability of land all favor mitigation site selection in rural areas. By comparing population densities surrounding impact and mitigation sites, this study will examine if wetlands are being relocated along an urban-rural gradient in Western Washington. By comparing socioeconomic and racial composition surrounding impact and mitigation sites, this study examines how different socioeconomic and racial groups are distributed near impact and mitigation sites. Results from this study will assist in closing the data gap in understanding how wetland mitigation relates to human populations.

CHAPTER 4: METHODS

No actor in the [mitigation] banking process takes steps that would allow us to test the policy implications of the phenomenon—i.e., tracks the redistribution of wetlands, estimates the effects thereof on ecosystem service values, notifies the affected public, and provides opportunity for public input.

Ruhl & Salzman (2006)

Introduction

This research surveys the spatial and socioeconomic characteristics between wetland impact sites and mitigation sites within three counties in Western Washington. Specifically, this research asks if wetland mitigation relocates wetlands and their ecosystem services from urban to rural environments. Closely linked to the spatial analysis is understanding what types of populations are losing and gaining wetlands. While regulatory agencies emphasize ecological functioning of wetlands, this framework overlooks the distribution of wetlands among human populations. Environmental justice literature has linked green spaces to improved human health (Jennings et al, 2012). This research extends this logic to wetlands to examine how site selection may be equitably or inequitably redistributing wetlands. While only a handful of studies have looked at socioeconomic characteristics of populations, results have been mixed across sites. This research aims to increase the knowledge of spatial dynamics in wetland mitigation projects and examine how wetland relocation may affect human populations.

This chapter describes the methods used to survey the spatial distribution and socioeconomic attributes of populations affected by wetland mitigation. The organization follows the chronological sequence in which the research was conducted. First, this section describes the criteria for choosing the study area. Second, the details of data acquisition from state, federal and county agencies are outlined. Third, this study establishes rationale for the many decisions of spatial scale that were made within this research. Next, methods of the geospatial analysis are described. These analyses include determining the urban-rural gradient, the relocation distance between impact and mitigation sites, and the socioeconomic characteristics of the populations surrounding these sites. After the geospatial analysis methods are defined, the challenges of acquiring data are reported. The final section outlines the limitations within the dataset.

Choosing the Study Area

Three counties were selected from Western Washington to be included in the study area. These counties are King, Snohomish and Clark. King and Snohomish are adjacent to each other, are located within the Puget Sound Basin within the Seattle greater area. Clark County borders the Columbia River within the Portland, Oregon greater metro area. Both Seattle and Portland have undergone significant population growth in recent decades; this growth has influenced changes in land use changes throughout these counties. See Figure 7 for map of the study area.

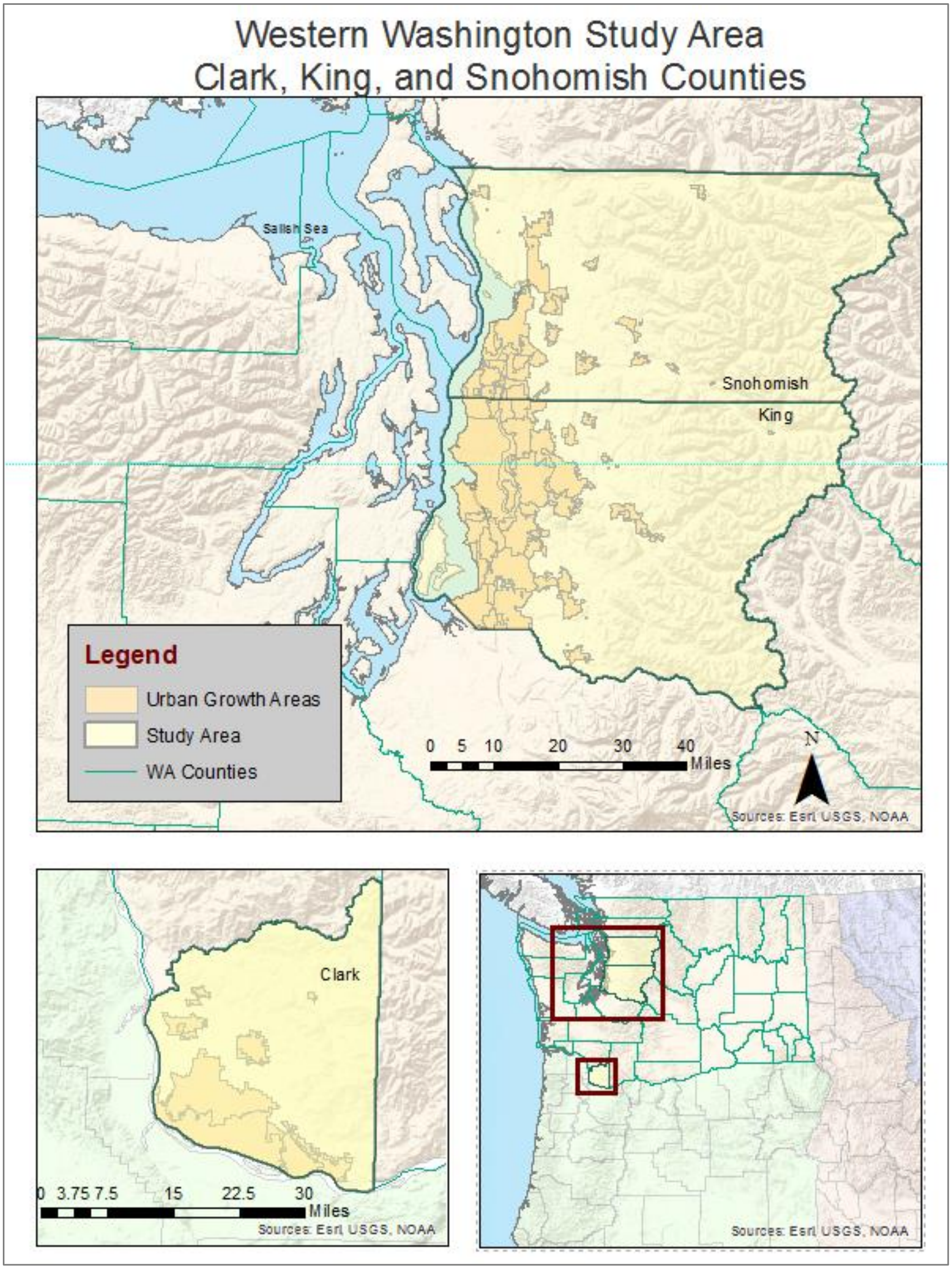


Figure 7. Three-county study area. This map illustrates the study area within western Washington and western United States.

These counties were selected based on two primary criteria. First, each county had a distinct urban-to-rural gradient, which was a necessary condition for the research question posed in this thesis. Second, these counties possessed a large number of wetland mitigation projects, also a requisite for this research. In the past fifteen years, these counties have experienced significant growth with increasing urbanization. See Table 1 for population trends in these counties from 2000-2015.

Table 1. Population estimates and growth rates from 2000 to 2015 in the three-county study area (United States Census Bureau, 2017).

Table 1

Population Increases by County

Census Year	2000	2015	% growth from 2000 to 2015
Clark	345,238	442,800	28.26
King	1,737,034	2,045,756	17.77
Snohomish	606,024	746,653	23.21

According to the Puget Sound Regional Council (2016), 95% of new housing in 2013 was centered in cities and urban areas. These findings are consistent with national trends that indicate robust urban growth while rural populations remain flat (EPA, 2017b). Figure 8 displays population trends in the United States over the past 200 years. In this research, the greater Seattle and Portland metro areas are these urban centers influencing regional growth. Predictably, this growth led to a higher rate of wetland mitigation permit requested under the Clean Water Act (CWA) due to development and growth pressure. For example, of the 286 statewide mitigation sites for Washington State Department of Transportation (WSDOT) transportation projects, 178 were found within the three-county study area. Selecting these counties enabled an adequate sample size from which to draw.

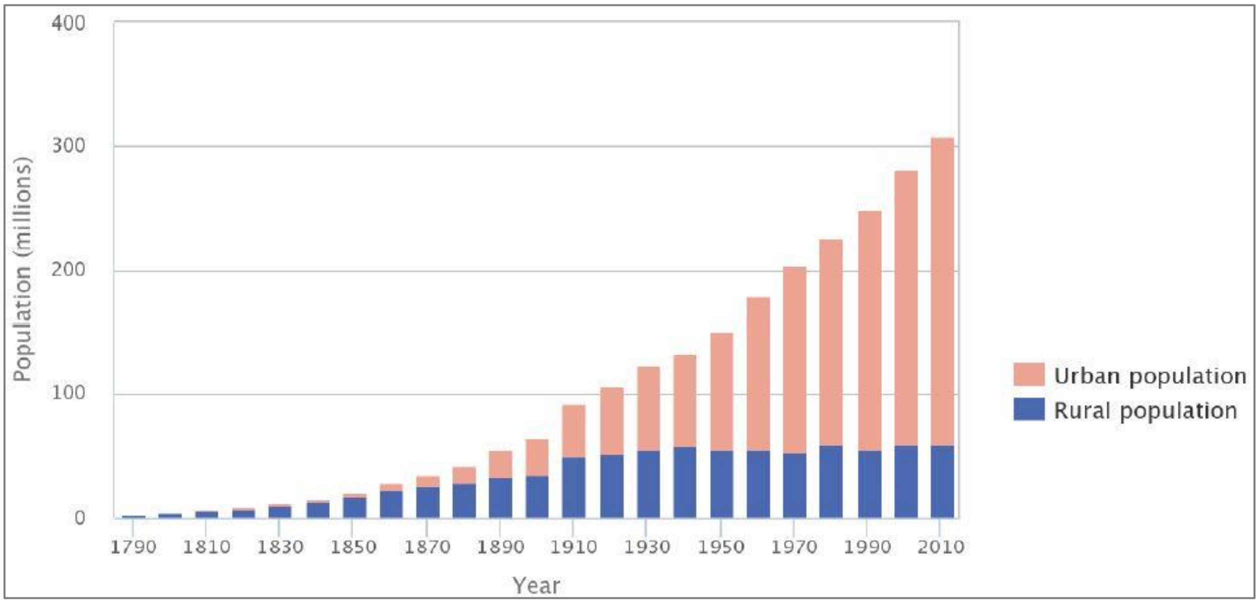


Figure 8. Urbanization and population trends in the United States (EPA, 2017b).

The study area chosen includes Clark County, the only county not within the Puget Sound Basin. While not geographically adjacent to the other counties, Clark County has in fact been undergoing the fastest growth in the state. This growth can largely be attributed to the expanding Portland, Oregon metro area, which borders Clark County to the south. Clark County also has unique features that enrich the data set. For example, it is the only county within the study area with a mitigation bank for impacts to a river system (e.g. Columbia River). In sum, Clark County exhibited a large number of mitigation projects, an urbanizing population, and a unique landscape setting to examine wetland mitigation.

Wetland mitigation projects often cross county lines. As long as the mitigation site was located within the three-county study area, this study analyzed cross-county mitigation projects, regardless of whether its corresponding impact fell within the study area. For example, the Columbia River Wetland Mitigation Bank's service area includes three counties, even though the actual bank is located in Clark County. Excluding sites that crossed over into different counties would have limited this study's full ability to assess spatial relocation within wetland mitigation. Since this research is interested in the geographic relocation of wetlands, including sites outside the study area was pertinent information and allowed for a more complete spatial analysis.

Acquiring Data

This analysis required three distinct types of data. The first type of data was information on wetland mitigation data. In order to complete the spatial analysis, coordinate information for both impact and mitigation sites was requisite. In addition, the mitigation approach (mitigation bank, ILF, or PRM) enabled this research to examine the characteristics of each approach. Socioeconomic data was the second type of data. The United States Census Bureau and ESRI, the computer mapping and spatial data analytics software company, maintain detailed spatial socioeconomic data. Once sites were geospatially located, these sources could provide site data on population, economic, and ethnic characteristics. Map layers were the third data type that enabled me to properly display the data. These layers included county boundaries, urban growth areas, and water bodies.

Acquiring wetland mitigation data involved contacting numerous state and county agencies involved with wetland mitigation. My primary source of data came from the Washington State Department of Ecology (DOE). Upon request, DOE staff at their headquarters in Lacey, WA granted access to their mitigation files to compile appropriate geospatial and site-specific data. King County Mitigation Reserves Program also provided GIS files with georeferenced locations. WSDOT and the ACOE both provided data, but only included mitigation site data. I was not able to track down impact site data for either of these sources. Requests were sent to Clark County and Snohomish County for county mitigation files, but these requests did not yield any site information.

In total, this research analyzed 139 wetland mitigation projects. For each project, there is one impact site and one mitigation site, referred to as a paired project. Mitigation banks accounted for 108—or 78%—of the 139 paired projects. A mitigation banking ledger contains addresses or some reference to physical locations to their impact sites. The DOE had a partially completed GIS layer for their bank impacts. For the remaining sites, addresses were georeferenced with Google Maps to obtain coordinate data. A small number of ledgers contained parcel numbers, which were georeferenced using county websites. If location could not reasonably be determined, sites were omitted. This often occurred with utility companies that work in areas without street addresses. As each purchaser of wetland credits provides the site location, a high diversity of address types were listed.

For socioeconomic data, the Census Bureau and ESRI were the primary sources of data. The Census Bureau completes a nationwide census every ten years that tracks demographic data. The last census was completed in 2010. Data from the ten-year census provide the public with detailed sociodemographic information. In addition, they track demographic changes using the American Community Survey, which assesses demographic patterns in between the ten-year census. Using three different area scales—census blocks, block groups, and census tracts—Census Bureau data can be spatially analyzed using geographic information systems (GIS). In addition to storing spatial census data, ESRI tracks socioeconomic data of their own that they make available through their online platform, ArcGIS Online. While ESRI calculates new layers for each year, these estimates are based off initial 2010 census data.

Importance of Scale

Measuring socioeconomic and population characteristics near impact and mitigation sites requires determining an appropriate scale. Given the fact that different wetland ecosystem services benefit populations at different scales, determining scale presented challenges (Mitsch & Gooselink, 2000). I used ArcGIS to create a ¾-mile buffer around each site. This methodology closely follows Brass (2009) which utilized a 1-mile buffer to study mitigation banks in Oregon. This buffer should not be interpreted as an agreed-upon perimeter in which a population therein achieves maximum benefits of wetland ecosystem services. Rather, this buffer provides the means to examine indicators near the immediate surroundings of impact and mitigation sites.

The scale used in this research is smaller than previous studies analyzing socioeconomic and population density characteristics of wetland mitigation. In previous studies, census tracts have been used to examine socioeconomic characteristics (BenDor et al, 2007; BenDor & Stewart, 2011). Census tracts with low population densities however can have large surface areas. Thus, census tracts may not properly evaluate the population near the site. The tradeoff with the methodology used in this study, however, was low populations at some sites. Eight impact sites had no population within their ¾-mile buffer. Since there was no population to draw from, these sites were excluded from differences in racial equity analyses.

Given the small acreage of most wetland impacts, these sites were saved as a point feature in ArcMap. Wetland mitigation banks in this study area, however, are 100-225 acre sites. To address these larger sites, mitigation banks were saved as polygon features. Saving these banks as a point feature may have artificially lowered the totals, since part of the buffer would have been within the mitigation bank itself.

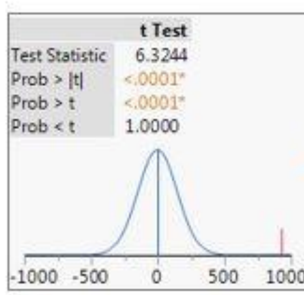
Spatial Analysis

This section describes the methodology used after impact and mitigation data and coordinates were collected. Figure 9 presents a simplified workflow of this analysis. First, site data were transferred into ArcMap. Since these sites were saved with an exact coordinate, a ¾-mile buffer was added to each site using the Buffer tool. As was previously stated, mitigation banks were saved as a polygon feature class, but the same Buffer tool was used to create a ¾-mile buffer. After the buffering step, GIS layers were transferred into ArcGIS Online, where data enrichment from Census data were applied.

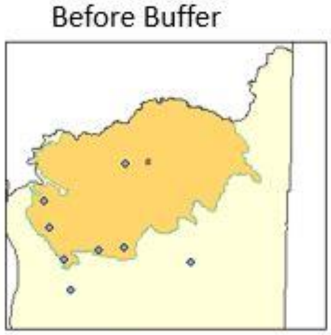
Compare Across Sites

Site Code	Mitigation or Impact	Distance	Population Density	Difference in population density	Latitude	Longitude
3501	I	13.3	18.7	-877	48.0017	-122.1362
3501	M		895.7		48.0017	-122.1362
3502	I	31.2	257.2	-638.5	47.7091	-121.3587
3502	M		895.7		47.7091	-121.3587
3503	I	31	252.1	-643.6	47.7087	-121.3621
3503	M		895.7		47.7087	-121.3621

Test for Statistical Significance using Paired T-Test



Before Buffer



After Buffer

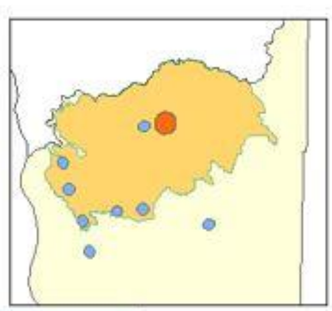


Figure 9. Workflow of spatial analysis after obtaining and organizing wetland mitigation data.

Data enrichment by ArcGIS Online enabled this research to procure site-specific data for each ¾-mile buffer area for a range of population and socioeconomic variables. Enriched data included the following:

1. **Urban-rural variables:** Population density, percent developed, relocation distance
2. **Economic variables:** median household income, number of households in poverty, median home value
3. **Racial/Ethnic variables:** Included populations of Whites (non-Hispanic), Hispanic, Black, Asian, Native American, Pacific Islander, Minority Population, and Diversity Index

Data that were analyzed independent of the data enrichment services on ArcGIS Online included whether a site was located within urban growth areas (UGA) and the average distance between impact and mitigation sites.

Urban-Rural Equity

Three variables were used to assess whether wetland mitigation relocates wetlands from urban to rural areas: population density, presence within a UGA, and the percent developed land according to the United States Geological Survey (USGS) National Land Cover Database (NLCD). The NLCD defines four varying levels of development within their definition. For the lowest level of development, impervious surfaces average less than 20%. For high intensity development, on the other hand, impervious surfaces average 80-100% (USGS, 2017). Since this research was interested in human populations affected by wetland mitigation, comparing population densities was the primary indicator to assess differences in impact and mitigation sites. Nevertheless, the suite of three indicators provide a more complete picture of wetland relocation.

Population density and percent developed were calculated using enrichment data. Presence within a UGA was calculated using the “Select by Location” function on ArcMap, using the UGA layer to select all sites contained within UGA. These sites were coded with a 1. Sites outside of UGA were given a 0.

The average relocation distance between impact and mitigation site is another spatial variable. The average relocation context adds context to how and where wetlands are being relocated through mitigation practices. Calculating distance was achieved by two different methods. For mitigation banks that exhibited a many-to-one mitigation scheme, the “Point Distance” tool was used. This calculated distance in feet between the mitigation bank and impact site. A separate column was created to convert this value to miles, which dividing all values by 5280, the number of feet in a mile. For PRM sites, the “Measure” function was used to mileage between sites. King County had already calculated distances between their ILF sites.

Economic Equity

Three variables were used to calculate the economic status of populations, including median household income, number of households in poverty, and median home value. These were all calculated using data enrichment, but their sources came from a variety of sources. Median household income and median home value came from 2016 ESRI data. Households below the poverty level came from 2010-2014 American Community Survey.

Racial Composition

With 2010 Census data, population estimates from multiple racial groups were used to calculate racial composition within wetland mitigation. These categories included the following: White (non-Hispanic), Hispanic, Asian, American Indian Pacific Islander, Black, and minority. Hispanics are not defined as a race, compared with the others. Rather, the Hispanic designation is defined as an ethnicity. Minority populations are defined as containing any of the following categories: Black, American Indian, Asian, Pacific Islander, Other, and Two or More races. Using enrichment data, total inhabitants from each category was calculated. In order to adjust for different population totals, totals for each racial category were divided by the total population within each buffer, which created the percentage of each racial group.

Measuring Difference in Means and Statistical Significance

Each impact and mitigation site had values for the aforementioned variables within the ¾-mile buffer surrounding each site. ArcGIS Online used Census data to extrapolate the values within each buffer. Measuring the difference between impact site values and mitigation site values provided the requisite data to determine environmental equity within wetland mitigation. The null hypothesis in this scenario is the difference in means should be close to zero, with averages across the sites balancing each other.

After enrichment, the data tables were brought into Microsoft Excel. In addition to the site name and coordinates, two features increased the facility of analyzing each site. First, each paired project was given a unique site code. Second, a column contained an “I” or “M,” indicating whether it was an impact or mitigation site. This organization enabled easy reference during analysis.

.

For each variable, the impact site value was subtracted from the mitigation site value. Thus, positive values indicated higher values at impact sites. Negative values indicated higher values at mitigation sites. The differences from each impact and mitigation site were added and then divided by the total number of sites. Finally, using JMP 12.1 statistical software, differences in means between impact and mitigation sites were analyzed using a paired t-test. Since this research aims to increase overall understating populations living near impact and mitigation sits, this research used a two-tailed test to note differences in either direction.

Limitations

Several limitations need to be acknowledged that may limit generalizing results. These limitations include a sample heavily weighted by wetland mitigation banking, treating every mitigation project the same, regardless of impact size, and receiving wetland benefits far from its geographic location.

Despite efforts to collect a balanced sample between mitigation approaches, over 77% of paired mitigation projects were from wetland mitigation banks. The Snohomish mitigation bank alone accounts for over 1/3 of all paired projects. This reliance on mitigation banking limits the ability to generalze findings for ILF and PRM projects. This fact also needs to be considered when reviewing the overall findings. While ILF and PRM projects were included in the overal sample, the overall findings should not be misconstrued as broadly representing wetland mitigaiton in general. To address this limitation, findings are presented by mitigation approach as well as individual mitigation bank to note the differences.

The extent of wetland benefits also limits this study. While a ¾-mile, buffer was used to examine populations living near areas of wetland gain and wetland loss, the range of benefits may expand or shrink depending on the ecosystem service provided. Thus, while this research informs of population differences in the immediate vicinities surrounding wetland loss and gain, this methodology simplifies the nuance of wetland ecosystem service benefits at spatial scales.

The methods employed in this study also treats each mitigation project as equal, despite different magnitudes of wetland impacts. While most wetland impacts are under 0.1 acres, there is a wide variance of impact and restoration acreage. The relative impacts to surrounding populations will vary largely due to the size or acreage. Hence, a wetland impact of .05 acres may have a small impact on the population surrounding the wetland damage. On the other hand, the ecosystem service benefits from a 200-acre mitigaiton bank would be substantially higher. While this variance is substantial, this research does not factor in wetland impact sizes.

One of the primary challenges with wetland mitigation analysis was finding information that links impact sites and mitigation sites. This challenge was not an isolated challenge for a thesis project. Rather, this problem continues to be an institutional limitation within the state and federal regulatory agencies. Some of the institutional challenges that resulted in a small sample size include the following:

- Agency personal do not prioritize keeping an updated database of wetland mitigation projects. As individuals are in charge of reviewing dozens—sometimes hundreds—of mitigation sites, staff prioritize single site evaluation. Little time remains for updating a database or spreadsheet. Multiple members from the DOE expressed interest in maintaining a more reliable and up-to-date database both for internal and external use.

- Coordinate information for wetland impact and mitigation sites may not be accurate. The DOE maintains a publicly accessible geographic information system (GIS) layer entitled “Facility/Site” that attempts to display all permitted site locations across the state, including those for wetland mitigation. Unfortunately, some of these sites are not accurately georeferenced, or linked to a geographic place from a coordinate system (Georeference, n.d.). Instead of taking coordinates with a global positioning system (GPS), the township and range code is often used instead. When inputted into the GIS layer, the site location will display the center—or in GIS parlance, *centroid*—of the township. This prevents accurately mapping site locations. Research conducted in Oregon also identified this problem (Brass, 2009). In instances where the centroid was used, a maximum of 0.7 mile error was calculated.
- Data sets copy coordinate information for impact and mitigation site, even when occurring off-site. Through a Freedom of Information Act (FOIA) request, I obtained a data set containing all mitigation projects overseen by the ACOE over a five-year period within the three-county study area. This file contained 776 individual rows of separate wetland impacts. While projects were separated between impacts and mitigation sties with coordinates for both, upon further examination, the coordinates listed for impact and mitigation sites were the same, regardless if the mitigation occurred on- or off-site. The remaining data were remarkably complete, signifying a unified dataset with compiled indicators such as acres affected, credits used, wetland classification, project start date, and type of project initiated. With accurate

coordinate data for both impact and mitigation sites, this database could be used by developers to know if wetland credits are available in a mitigation bank service area that many have advocated for previously (Martin and Brumbaugh, 2011). This act would also improve the ability to analyze spatial patterns of wetland mitigation.

- Linking impact sites and mitigation sites for permittee-responsible mitigation (PRM) remains vexing. This research required linking impact sites and mitigation sites. However, the current regulatory framework does not incentivize coupling these two areas. Rather, an initial assessment by regulatory agencies at the impact site determines the amount of mitigation required. From there, developers decide an appropriate course of action for mitigation. As mitigation plans develop, impact site information is often not included. During personal conversations with both permittees and regulators, this challenge was consistently acknowledged. These challenges are not as acute for mitigation banks and in-lieu fee (ILF) programs. These two types of mitigation benefit from having just one large mitigation site. Owners of mitigation banks keep a running ledger of impact sites to track how many credits can be released at a given time.

A final limitation of this data recognizes on-site mitigation. While my research question addresses off-site mitigation, permittees can also mitigate for wetland impacts on-site. With disparate data, there was no easy method to assess how many impacts are mitigated on-site and how many are relocated off-site. In mitigation banking for example, the credit-debit system is utilized only for off-site relocation. A percentage of mitigation may (or may not) be conducted on-site, but the credit/debit system does not capture these actions. Recent directives from federal and state authorities recommend off-site mitigation however

(Hruby et al., 2009; ACOE & EPA, 2008). Without having this information, no conclusions can be drawn for on versus off site mitigation. DOE staff acknowledged this difficulty in compiling complete information that assesses the totality of wetland mitigation from beginning to end (Kate Thompson personal correspondence, Feb 17, 2017).

CHAPTER 5: RESULTS

Urban development stresses the landscape and may compromise environmental quality. Since some communities are disproportionately impacted by changes in land use and land cover, understanding the environmental justice implications of changing the landscape is important. Likewise, the additive effects of degraded landscapes and decreased environmental quality have human health implications.

Jennings et al. (2012)

Summary

For this analysis, 139 paired impact-mitigation projects within the three-county study area were analyzed. These sites included wetland banks, In-Lieu Fee (ILF), and off-site Permittee-Responsible Mitigation (PRM). First, results are listed for the entire 139 paired projects. Second, results are listed for individual mitigation bank programs, ILF, and PRM projects. The small sample size in many of the individual programs increases the likelihood the sample mean deviates from the population mean, decreasing the probability of finding statistically significant trends at the 0.05 level. However, the variability and spatial context of these programs warrant their own analysis. This section presents the findings of the analysis. The proceeding Discussion chapter explores the implications of these results.

Complete Study Area

Results indicate that over the three-county study area, mitigation relocates wetlands along a pronounced urban-rural gradient, from lower to higher income neighborhoods, and from sites with a higher percentage of White populations to sites with higher percentages of minority populations.

For urban-rural indicators, population densities are 926 people higher per square mile near impact sites than mitigation sites. Impact sites are 8.5% more developed than mitigation sites. On average, wetland mitigation relocates wetlands and their ecosystem services 11.3

miles. These findings confirm previous research that wetland mitigation does in fact relocate wetlands away from high-density population areas to less-populated locations.

For economic indicators, median income is on average, $9,032 higher at mitigation sites. The median home value was $43,250 higher at mitigation sites. These findings were consistent with research by Brass (2009), who found more affluent populations near mitigation sites. On average, there are 26 more households in poverty near impact sites than mitigation sites. However, households in poverty were not weighted with population densities.

Indicators on racial equity indicate that minority populations are 3.7% higher near mitigation sites. Conversely, White populations are 3.7% higher at impact sites. For individual racial categories, Black populations are, on average, 3.4% higher at mitigation sites. Native American populations are, on average, 0.3% higher at mitigation sites. Pacific Island populations are, on average, 0.2% higher near mitigation sites. No significant differences are noted in Asian or Hispanic populations between impact and mitigation sites.

These summary statistics can be found in Table 2. Since the mean difference was calculated by subtracting impact site values from mitigation site values, positive numbers indicate impact sites have a greater mean average. Negative values indicate mitigation sites having a greater mean average.

Table 2. Summary statistics of study area. Positive values signify greater values at impact sites. Negative values indicate greater values at mitigation sites.

Three-County Study Area (n=139)		
Indicator	**Mean Difference**	**P-value**
Population Density	926	0.0001
Developed Land	8.5%	0.0001
Median Household Income	-$9,032	0.0027
Median Home Value	-$43,250	0.0067
Households in Poverty	26	0.0299
White population	3.7%	0.0053
Minority population	-3.7%	0.0053
African-American	-3.4%	0.0001
American Indian	-0.3%	0.0188
Asian population	0.6%	0.2838
Pacific Islander	-0.2%	0.0335
Hispanic population	-0.5%	0.4182

Urban Growth Areas (UGA) provide a signpost for developed landscapes. For impact locations, 89 out of 139 sites were located within UGA. With the presence of mitigation banks and ILF programs that represent many-to-one mitigation, there were fewer mitigation sites. However, each paired project was considered one impact site and one mitigation sites. For mitigation sites, 45 out of 139 were located within UGAs.

The average relocation distance varied by approach and location. Over the complete study area, the average relocation distance was 11.3 miles. Mitigation banks and ILF programs showed greater relocation distances than PRM projects. However, the uneven sample between different mitigation approaches prevent any strong conclusions on variation between them. See Table 3 for a summary of average relocation distances between mitigation approach and locations.

Table 3. Average relocation distance by approach and location.

NAME	Avg. Relocation Distance (In Miles)	Mitigation Approach
All Sites	11.3	All
Col River	6.7	Mitigation Bank
EFL	11.7	Mitigation Bank
ILF	13.0	ILF
PRM	1.5	PRM
Skykomish	16.2	Mitigation Bank
Snohomish	15.3	Mitigation Bank
Springbrook	3.4	Mitigation Bank

Findings by Approach and Location

The following section displays summary findings for the individual mitigation banks, ILF, and PRM programs within the study area. Since many of the sample sizes and populations numbers for some racial categories are very small, only White and minority populations are listed in the summary data. These findings are also displayed geospatially. See Figures 10-15.

Mitigation Bank Summary Results

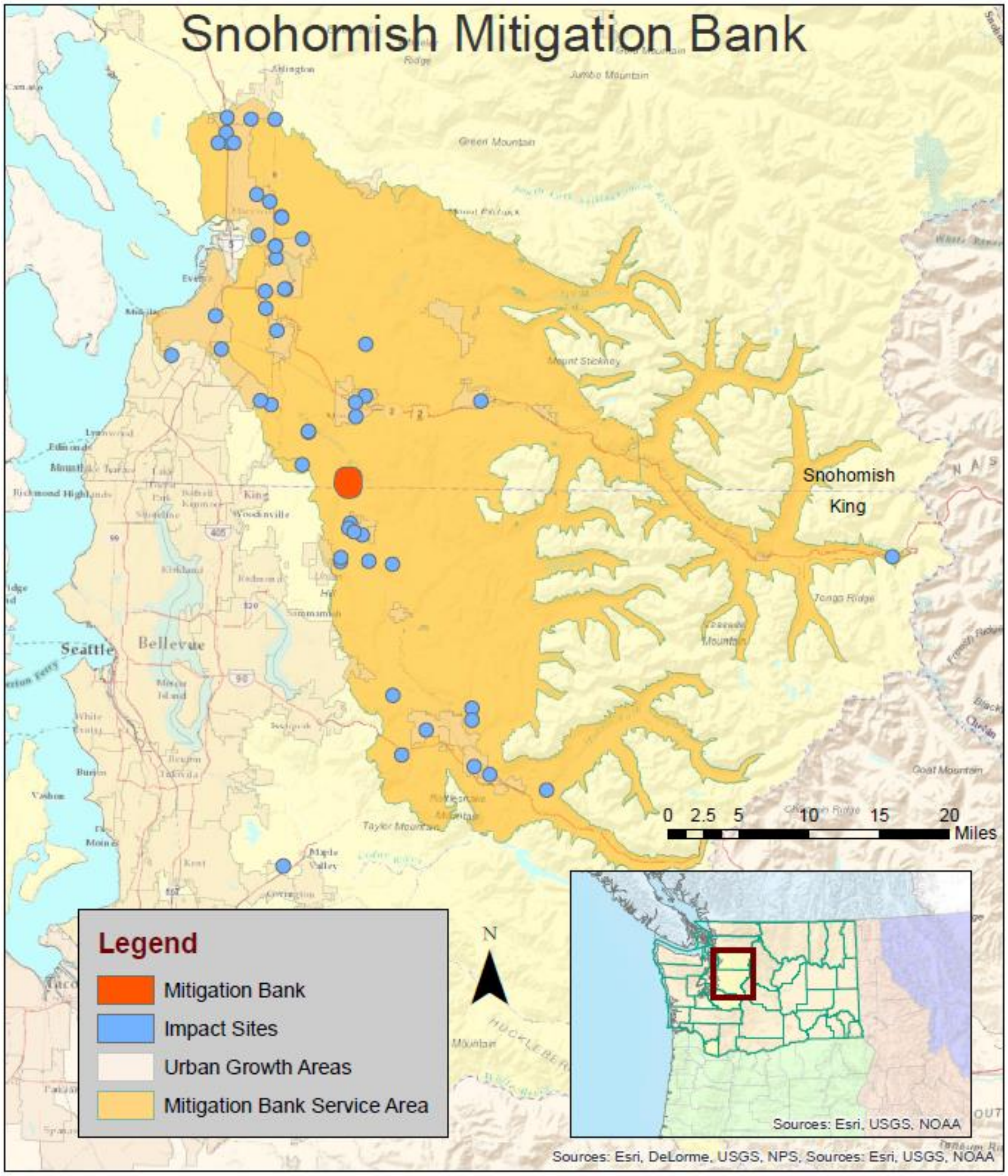


Figure 10. Map of Snohomish mitigation bank impact and mitigation sites.

Table 4. Summary statistics for Snohomish mitigation bank.

Snohomish Mitigation Bank (n=52)		
Indicator	**Mean Difference**	**P-value**
Population Density	1,336	0.0001
Developed Land	14.2	0.0001
Median Household Income	-$28,097	0.0001
Median Home Value	-$180,806	0.0001
Households in Poverty	25.5	0.0001
White population	-3.6%	0.0024
Minority population	3.6%	0.0024

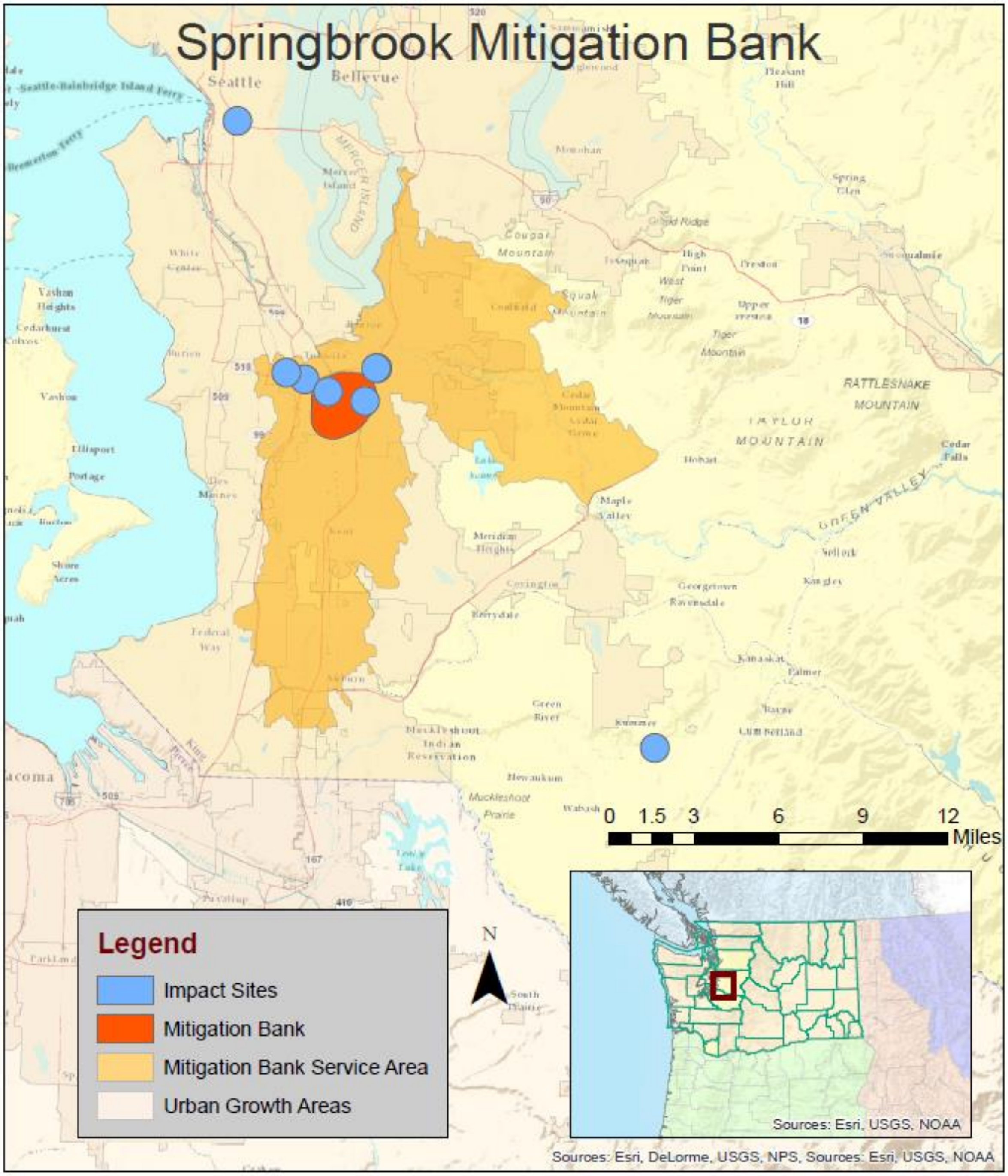


Figure 11. Map of Springbrook mitigation bank impact and mitigation sites.

Table 5. Summary statistics for Springbrook mitigation bank.

Springbrook (n=8)		
Indicator	**Mean Difference**	**P-value**
Population Density	2,905	0.0170
Developed Land	-9.5	0.2720
Median Household Income	-$34,973	0.0104
Median Home Value	-$53,348	0.0276
Households in Poverty	218.1	0.0921
White population	37.5%	0.7950
Minority population	50.0%	0.7950

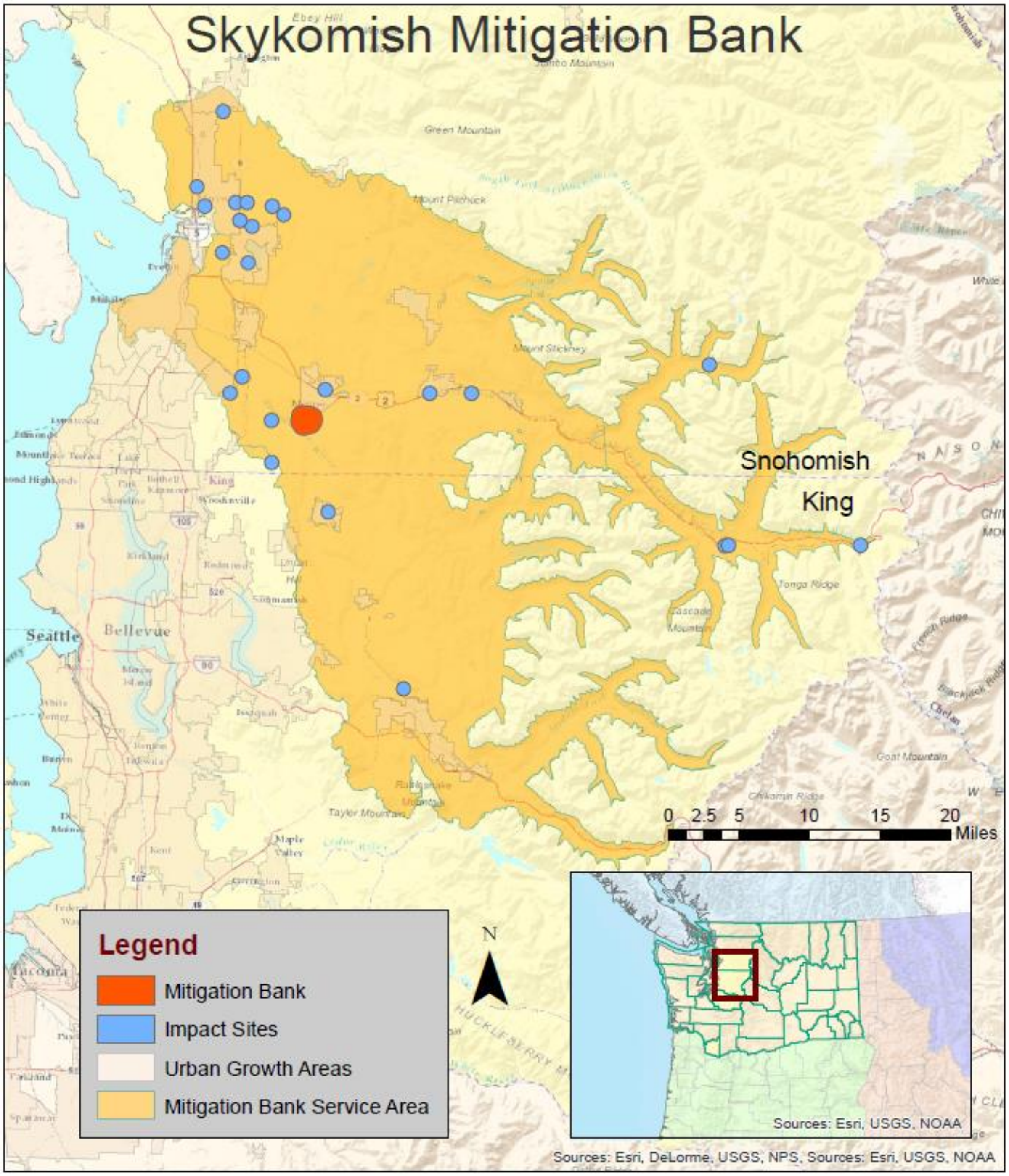


Figure 12. Map of Skykomish mitigation bank impact and mitigation sites.

Table 6. Summary statistics for Skykomish mitigation bank.

Skykomish (n=25)		
Indicator	**Mean Difference**	**P-value**
Population Density	122	0.4181
Developed Land	16.5	0.0001
Median Household Income	-$5,723	0.6227
Median Home Value	$45,540	0.0686
Households in Poverty	-24.6	0.1002
White population	17.8%	0.0001
Minority population	-17.8%	0.0001

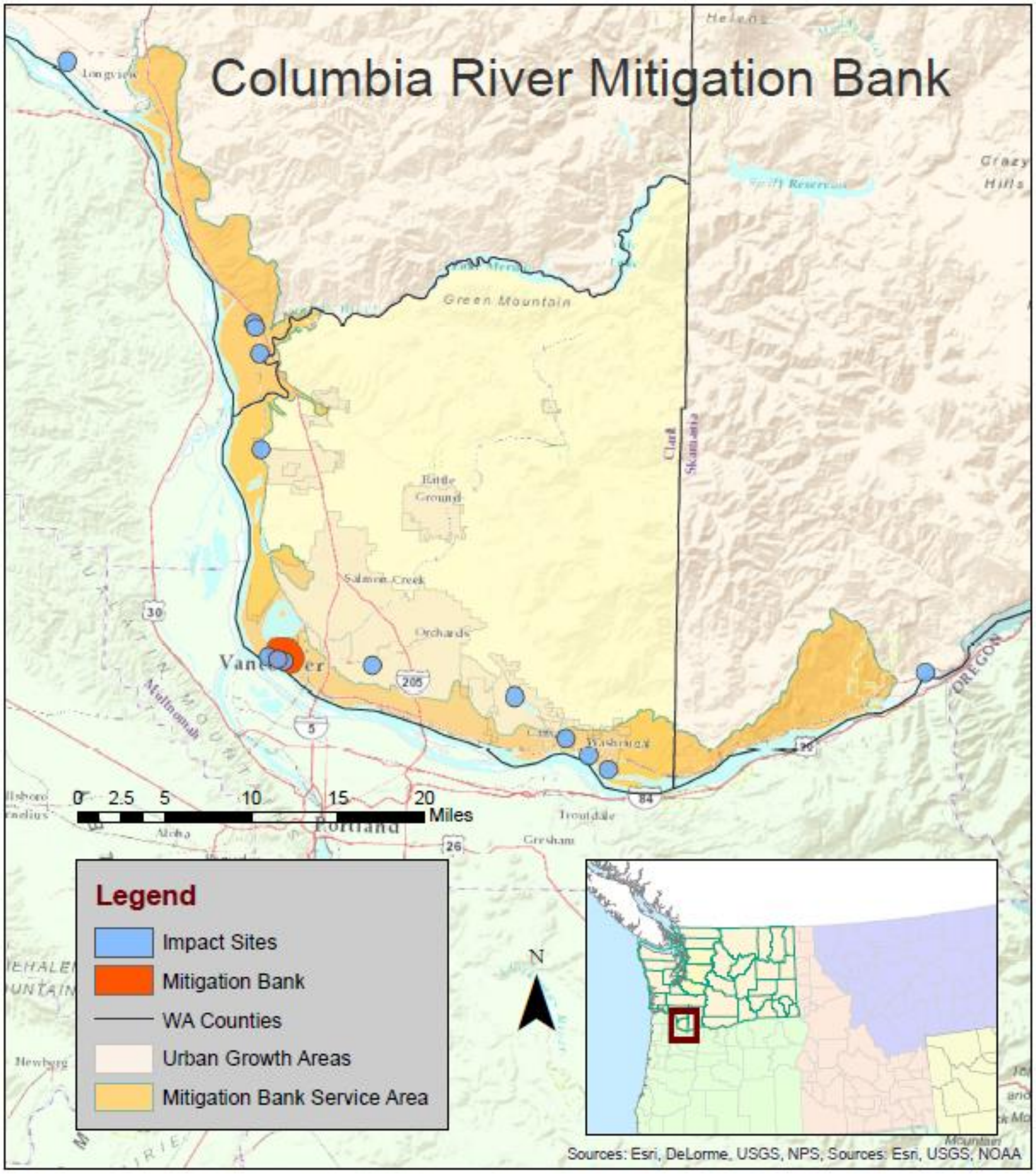


Figure 13. Map of Columbia River mitigation bank impact and mitigation sites.

Table 7. Summary statistics for Columbia River mitigation bank.

Columbia River (n=14)		
Indicator	**Mean Difference**	**P-value**
Population Density	669	0.0958
Developed Land	-13.1	0.0459
Median Household Income	31600	0.0301
Median Home Value	210838	0.0047
Households in Poverty	42.2	0.0118
White population	13.8%	0.0060
Minority population	19.4%	0.0060

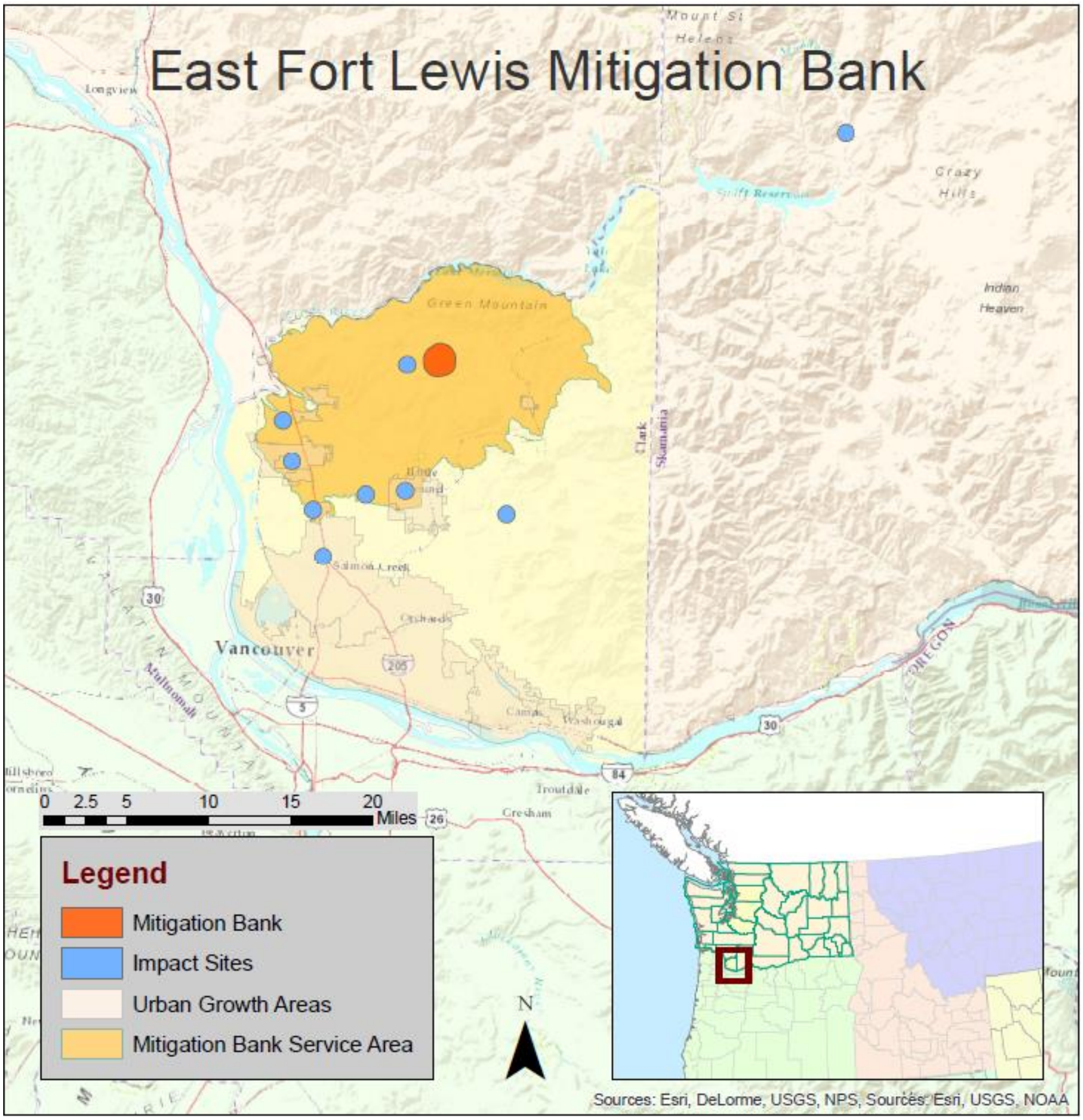


Figure 14. Map of East Fort Lewis mitigation bank impact and mitigation sites.

Table 8. Summary statistics for East Fort Lewis mitigation bank.

EFL (n=9)		
Indicator	**Mean Difference**	**P-value**
Population Density	904	0.2055
Developed Land	14.6	0.0639
Median Household Income	$11,309	0.0290
Median Home Value	5589	0.8397
Households in Poverty	10.9	0.4152
White population	-4.1%	0.0186
Minority population	4.1%	0.0186

In-Lieu Fee Summary Results

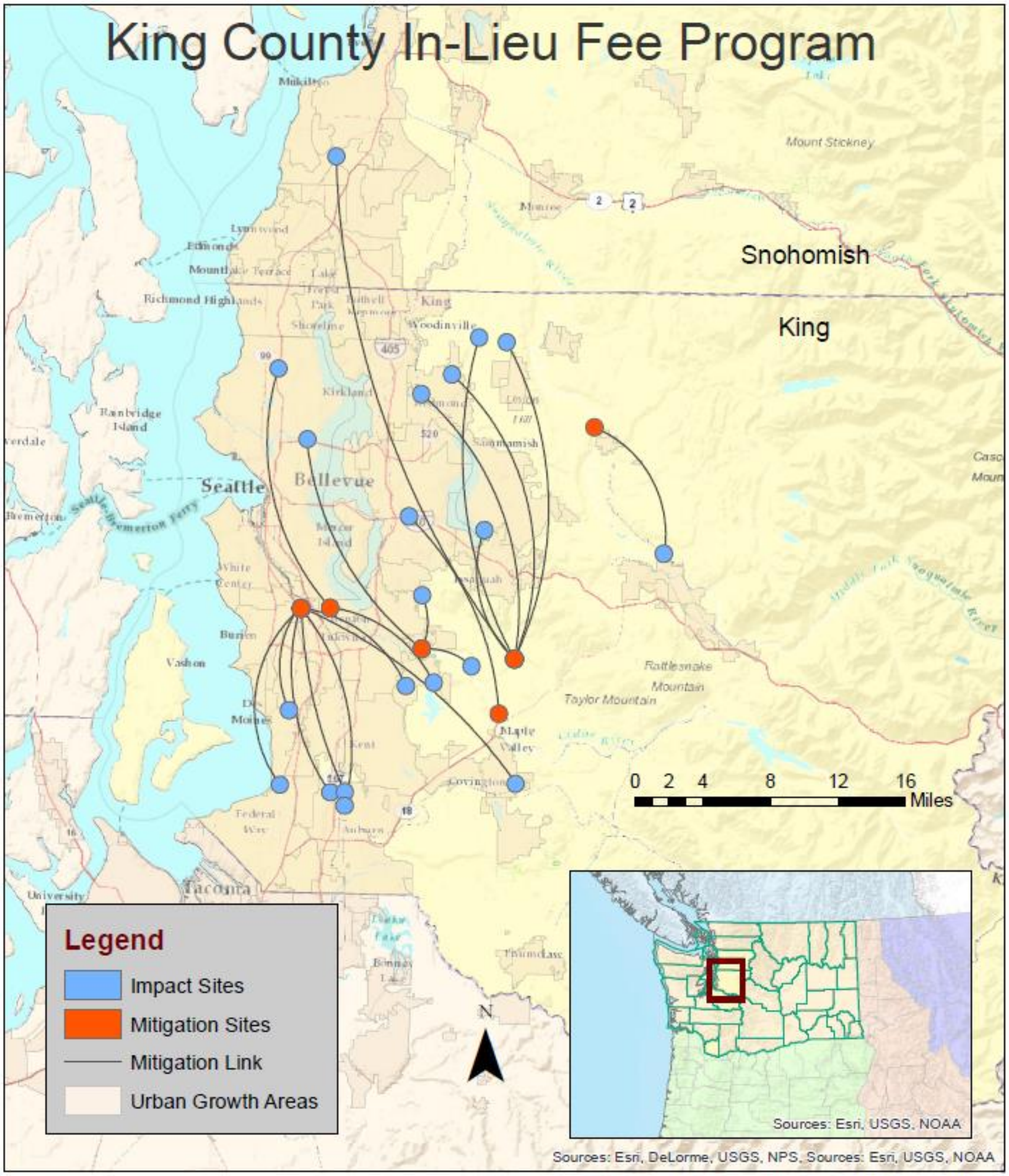


Figure 15. Map of King County In-Lieu Fee Program's impact and mitigation sites.

Table 9. Summary statistics for King County In-Lieu Fee program.

ILF (n=20)		
Indicator	**Mean Difference**	**P-value**
Population Density	329	0.5405
Developed Land	7.8	0.1727
Median Household Income	$14,101	0.0512
Median Home Value	$460,907	0.1888
Households in Poverty	47.8	0.3434
White population	7.2%	0.2070
Minority population	-7.2%	0.2070

Permittee-Responsible Mitigation Summary Results

Minimal average distances of 1.5 miles between impact and mitigation sites posed a challenge to represent PRM programs cartographically. For this reason, the map is omitted. See Table 10 below for the summary table.

Table 10. Summary statistics for Permittee-Responsible Mitigation.

PRM (n=11)		
Indicator	**Mean Difference**	**P-value**
Population Density	805	0.0941
Developed Land	0.2	0.0001
Median Household Income	-$16,561	0.1360
Median Home Value	-$13,252	0.1690
Households in Poverty	113.3	0.0791
White population	-2.5%	0.2168
Minority population	2.5%	0.2168

CHAPTER 6: DISCUSSION

Planners and legislators will not respond to the impacts of individual losses that they perceive to be small and insignificant, but they may respond to the collective value, and the impact of cumulative loss, of many small natural amenity environments in the urban landscape.

Manuel (2003)

Introduction

Results from this study strengthen research that indicates wetland mitigation relocates wetlands and their ecosystem services along urban-to-rural gradients. This study supports previous research that has examined the landscape effects of wetland mitigation (BenDor, Brozovic, & Pallathucheril, 2007; BenDor & Stewart, 2011; King & Herbert, 1997; & Ruhl & Salzman, 2006). In relation to socioeconomic equity, average household incomes were nearly $9,032 higher near mitigation sites. However, these results were not uniform; two mitigation banks and the King County ILF program all had higher incomes near impact sites. In examining racial equity, mitigation relocated wetlands to areas with higher percentages of minority populations.

Urban-Rural Equity

The results in this study confirm previous studies finding that wetland mitigation favors mitigation site selection in less densely populated areas. For example, Ruhl and Salzman (2006) found wetland migration along an urban-rural gradient in 19 of the 24 mitigation banks they surveyed, averaging 2,419 more people/sq. mi. near impact sites. In addition, Bendor et al. (2007) found that on average, 359 more people/sq. mi. lived near impact sites than mitigation sites when assessing all off-site compensatory mitigation programs. In a study of wetland banking in four Oregon counties, Brass (2011) found population density to be, on average 1,060 people/sq. mile more near impact sites. See Table 11 for a comparative summary of key findings including the results from this analysis.

Table 11. Comparative summary statistics of differences in population densities.

Study	**Year**	**Study Area**	**Precision**	**Mitigation Type**	**Population difference people/mi^2**	**P-value**
Ruhl & Salzman	2006	Florida	Zip codes	wetland banking	2,419	N/A
Bendor et al.	2007	Four counties in northwest IL	Census tracts	off-site compensatory mitigation	355	<.01
Brass	2011	Four counties near Eugene, OR	1 mile buffer using Census Block data	wetland banking	1,060	0.0038
BenDor & Stewart	2011	North Carolina	census tracts	wetland mitigation	1,082	<.01
McKellips	2017	Three counties in western WA	.75 mile buffer using 2010 Census data	off-site compensatory mitigation	926	<.0001

When assessing previous research, mitigation approaches with “many-to-one” mitigation (e.g. wetland banking and ILF) tend to increase the difference in population densities. BenDor and Stewart (2011), for example, found ILF programs to exhibit the greatest difference, followed by mitigation banking. PRM mitigation, with one-to-one mitigation showed the lowest differentials in population densities. While sample sizes in this study for ILF were low (n=20), ILF sites showed lower differences in population densities, averaging 164 people/sq. mi. at each site. Mitigation banking exhibited the greatest difference in population densities, ranging from 328-720 people/sq. mi.

The area of developed land serves as another indicator to understand mitigation site location. Overall, mitigation sites were 8.5% less developed than impact sites. Some sites may have low population densities, but still be located in highly developed industrial landscapes. Summary statistics for two mitigation banks, Columbia River and Springbrook, exhibited higher percentages of development but lower population densities at impact sites. For the Columbia River mitigation bank, this its proximity to the Port of Vancouver may explain the high-development percentage, but low population findings.

Socioeconomic Equity

Results from this study indicate that on average, wetland mitigation relocates wetlands away from populations with lower home values and lower median household incomes. On average, home values were $43,250 greater where wetland mitigation (i.e. wetland gains) were taking place. These findings however varied considerably among the different mitigation approaches and between mitigation banks. For example, the King County ILF program, Columbia River, East Fort Lewis, and Skykomish mitigation banks, which comprise nearly half of the 139 projects, had higher home values near impact sites (n=68). The differential in home values was disproportionately influenced by the Snohomish mitigation bank, where the median home value was $541,667. Values at this site had a large influence in the overall mitigation data, as replicate data from the mitigation bank were used to compare with each of the 52 impact sites.

Median household income displayed similar variance. While on average, incomes were $9,032 lower near impact sites, the King County ILF program, Columbia River and

East Fort Lewis mitigation banks had higher incomes at the impact sites (n=43). The Snohomish mitigation bank also significantly influenced this variable, with an average of over $28,000 greater income at mitigation sites. The degree of variability between the mitigation banks points to a more nuanced conclusion of socioeconomic equity than the summary data indicate.

With the exception of Skykomish mitigation bank, the total number of households in poverty are greater near impact sites than mitigation. Given there are, on average, 926 more people per square mile near impact sites than mitigation sites, one expects a corresponding increase in households in poverty. Across the 139 sites, the average difference of households in poverty is 26. These households would have the least resources to soften the impacts of a proposed development project requiring mitigation, whether through loss of wetland ecosystem services or other consequences of a project, such as increased housing prices. While this study quantitatively identifies the number of households in poverty near impact and mitigation sites, determining the aggregate effect of households in poverty in the study area is beyond the scope of this study. Further research could examine at a finer scale how proposed mitigation projects affect households in poverty.

Racial Equity

This research supports the claim that a greater percentage of minority populations are living closer to mitigation sites than impact sites, indicating that wetland mitigation equitably distributes wetlands and their ecosystem services to minority populations. These findings were consistent across all minority racial groups, with the exception of the Asian population. However, the Asian population was also the only racial population to not show a significant difference between impact and mitigation sites ($p=0.2838$). In general, the large majority of

White populations posed a challenge when looking at the minority racial populations, since minority population numbers and percentages are low to begin with. While instructive to examine individual racial groups, combining these groups under minority population—particularly with the small sample size in this study—created a clearer picture of racial equity.

With minority populations having higher populations near mitigation sites, it follows that more White populations live near impact sites. Thus, mitigation inequitably distributes wetland ecosystem service benefits to White populations. This finding supports research by BenDor and Stewart (2011) that found higher percentages of White populations near impacts sites but counters findings in northeast Illinois (BenDor et al., 2007) that observed higher White populations near more rural mitigation sites. While off-site compensatory wetland mitigation causes wetland relocation from one population to another, results from across these studies do not indicate that wetland site selection strongly favors one racial population over another.

It is worth noting that these findings appear to stand in contrast to the racial income gap in the United States. This gap shows that among working families, minorities are 24% more likely to be low-income or poor than non-Hispanic Whites (Povich, Roberts, & Mather, 2015). However, this dataset does not link household income to specific racial groups. Thus, while minority populations are observed to have higher percentages near mitigation sites with higher incomes, this fact does not per se indicate that minority populations are the populations with these higher incomes.

Limitations

This research examined populations living near impact and mitigation sites through CWA wetland mitigation to address equity in the relocation of wetland resources. Using a ¾-mile buffer enabled a snapshot of populations living nearby these wetland losses and wetland gains. However, the fact that wetland ecosystem services benefit human populations at larger spatial scales than ¾-mile limits this research's ability to fully capture populations affected by wetland relocation. For example, the ecosystem service benefits of improved water quality and aquifer recharge occur at a watershed or regional level. In addition, increased wetlands and floodplains along rivers provide the ecosystem service of reduced flood risk many miles from its location. Furthermore, many of the adverse effects of increased urbanization and degraded wetland resources are addressed at the watershed and regional level. Past hedonic studies point to populations valuing cultural ecosystem services such as aesthetics and recreation within a ¾-mile buffer, but wetlands' variability makes measuring the extent of their multiple benefits decidedly demanding.

One assumption embedded within this research presumes that human populations benefit from proximity to wetlands. The same logic assumes populations incur adverse effects as wetland resources diminish. Undoubtedly, this logic simplifies this relationship. For example, a proposed development that damages wetlands may represent an economic investment in a community. To use a clear example, a proposed health clinic may represent a public good whose benefits to the surrounding population outweighs the impacts to wetland resources. The wetland mitigation sequence permits these developments to occur while not losing net wetland acreage or ecosystem services.

The anthropogenic lens of this research should also be acknowledged. This study scarcely acknowledges wildlife and land conservation goals. While human populations benefit from wetlands, urban wetlands present more potential dangers (e.g. car traffic, eutrophication) to wildlife. When done in tandem with broader goals, wetland mitigation could increase habitat connectivity and wildlife corridors that benefit non-human populations. Of course, human populations value wildlife and its corresponding habitat as well. Many existing federal policies such as the Endangered Species Act require prioritizing existing habitat and habitat connectivity. Thus, rural wetland site selection may have benefits outside the parameters discussed in this research.

Future Research

The results from this study analyzed aggregate wetland mitigation projects in a spatial context. While individual mitigation projects follow site selection criteria, regulatory agencies rarely spatially analyze aggregate wetland mitigation in a region. Rather, regulatory agencies provide total acreage lost and gained through mitigation to track no-net-loss objectives but cannot fully evaluate these projects in a spatial context (Boyd & Wainger, 2002). Over time, annual wetland relocation could affect aquatic resources at the landscape level. In turn, this relocation may affect populations losing and gaining aquatic resources and their ecosystem service benefits. Maintaining accurate data on how wetlands are moving across the landscape can help land use planners understand changes in wetland resources over time. Accurate, up-to-date data also enables analyses of environmental equity among different populations. The current permitting structure does not emphasize linking impact and mitigation sites or geospatially maintaining data. Integrating these two initiatives would greatly increase the facility to conduct future research.

Future research should seek to further target spatial dynamics and how it relates to wetland mitigation. There are two principle areas where research can be refined. Integrating quantitative and qualitative wetland data into GIS will support spatial analyses. While the ACOE data set did not contain linked impact and mitigation sites, the ORM2 database from which the data set came contained organized site characteristics. For example, each site indicated if the mitigation was in-kind (same type of wetlands) or out-of-kind (different type of wetlands) and wetland class, which classifies a wetland's functionality. These characteristics should be examined spatially. Acreage should be included as part of the analysis. Linking wetland acreage with mitigation would enable future research to assess the relative influence of each project. Linking sites could solve some of the challenges dealing with impacts that mitigates impacts at multiple sites.

In addition, socioeconomic characteristics surrounding wetland mitigation projects should increase. Due to the small impacts of individual projects, wetland mitigation projects do not often initiate strong opposition, even though they are valued by local residents (Manuel, 2003). Precisely because these impacts are small and often under the radar of local citizens, regulatory agencies have even more responsibility to ensure the aggregate impacts are not adversely affecting local populations.

Conclusion

The results from this study contribute to the growing body of research examining the effects that wetland mitigation has on wetland relocation along an urban-rural gradient and on local populations. Determining the full effects on local populations remains elusive, given that wetlands provide multiple ecosystem services, these ecosystem service benefits accrue to the public at large and wetland area is not always an accurate indication of wetland value and wetland functions are variable, which often times are influenced by human perturbations (Mitsch & Gooselink, 2000).

Despite the difficulty—if not the impossibility—of pinning down specific wetland values, the cumulative importance of wetlands in this country has been recognized under the no-net-loss policy of the first Bush Presidency and supported by every proceeding administration. While slow to coalesce, government agencies such as the EPA, ACOE and DOA have united to administer and promote wetland protection, enhancement, and restoration. To maintain healthy wetland resources, wetland mitigation under §404(1)(b) of the CWA represents the most important piece in the puzzle. This law sets up the framework to avoid, minimize, and compensate for wetland impacts. Through compensatory wetland mitigation, hundreds of thousands of wetland acres have been restored, enhanced, created, or preserved. Wetland mitigation also represents the largest ecosystem service market in the country (Salzman & Ruhl, 2001).

Through the decades, regulators and policy makers have sought to amend mitigation practices to improve upon the many challenges of ecosystem service trading. Salzman and Ruhl (2001) recognized that in order to trade an ecosystem service, a common currency must be traded equally over space, time, and type. While scales of type and time have substantial challenges, this research addressed the challenge of trading wetlands over space. To address the challenges of spatial relocation of wetlands, EPA directives have moved from preferences of on-site mitigation and little relocation distances to favoring greater relocation distances through the development of "many-to-one" mitigation projects such as wetland banks and ILF mitigation. In addition to increasing the likelihood of site success (i.e., replacing wetland functions), this system also improves oversight from the ACOE and DOE charged with ensuring all off-site compensatory mitigation meet their performance standards (NRC, 2001).

While increasing efficacy of wetland management, these directives may also exacerbate the migration of wetlands from densely populated environments. Urban environments that lack wetlands are absent the many ecosystem services wetlands provide. In the Puget Sound, for example, die-offs of spawning Coho salmon (*Oncorhynchus kisutch)* increasingly point to stormwater pollution carrying toxic pollutants as the driver. Scholz et al. (2011) conducted stream surveys and found Coho die-offs linked to rainfall events. These die-offs, however, only occurred in urban areas, with *O. kisutch* in non-urban creeks being unaffected. Roads—a common source of wetland mitigation projects—in particular have shown to be a source of contaminants that disrupts aquatic biota (Trombulak & Frissell, 2000). Thus, wetland mitigation may impair natural resiliency in urban areas two ways, by relocating ecosystem services to less-populated areas and worsening non-point source pollutants. In order to improve upon the overarching goal of the CWA— to "restore and maintain the biological, chemical, and physical integrity" of U.S. waters," regulatory agencies should recognize the potential impacts to urban and urbanizing environments. In order to minimize these impacts, this research offers the following recommendations.

Recommendations

This research proposes three recommendations to increase understanding of spatial dynamics and improve environmental equity in wetland mitigation. First, where feasible, regulatory agencies should promote wetland mitigation banks in urban areas. Second, regulatory agencies should improve access to mitigation data to better understand aggregate effects of wetland relocation. Lastly, incentives to increase mitigation site selection in urban areas should be considered.

First, wetland mitigation should prioritize wetland bank site selection to benefit urban areas. To reduce the amount of urban-rural wetland relocation, wetland mitigation bank site selection should be evaluated to sustain wetland ecosystem services in urban areas. Wetland mitigation banks represent a system where one mitigation site accounts for multiple impacts across the landscape. With only one mitigation site, the site selection of mitigation banks provides a critical opportunity to sustain wetland ecosystem services within urban and urbanizing locations. On the contrary, if wetland bank site selection favors rural locations displaced from urban areas, the effect will exacerbate the urban-rural migration of wetlands.

Second, improving data management would improve overall understanding of landscape scale impacts of wetland relocation. Over the past few decades, hundreds of thousands of wetland acres have been relocated through compensatory wetland mitigation. While the ACOE tracks the total acres of permitted impacts and mitigation at national scales, narrowing wetland mitigation impacts to smaller scales proves difficult given the dearth of publicly available information. Requiring all wetland mitigation project to clearly link wetland impacts and wetland mitigation sites could vastly improve geospatial analysis. Given the growth of publicly available geospatial data from government and non-government agencies alike, coupling wetland mitigation data could increase collective knowledge of wetland mitigation patterns and trends. In particular, understanding population characteristics near impact and mitigation sites remain poorly understood. In one of the first analyses of its kind to document wetland relocation, Ruhl and Salzman (2006) lamented the significant data vacuum that exists within mitigation banks. These researchers identified include land values of sites and demographic data associated with banks as primary data gaps. Addressing the difficulty if wetland relocation along an urban-rural gradient has any significance, the authors wrote that "it is difficult to approach this question intelligently, since no actor in the banking process takes steps that would allow us to test the policy implications of the phenomenon—i.e., tracks the redistribution of wetlands, estimates the effects thereof on ecosystem service values, notifies the affected public, and provides opportunity for public input," (p. 10). This vacuum still exists today. Given the large amount of documentation required in wetland mitigation projects, changing guidelines to ensure regulatory agencies link wetland impacts and mitigation would facilitate increased understanding by regulatory agencies and the public at large of aquatic resources through §404(1)(b) permits.

Third, wetland mitigation guideline could change incentive structures to level playing field for urban-rural site selection. The current market-based structure does not take into account human populations. As over 2/3 of the United States' population now live in urban areas, urban areas and their growing populations could benefit greatly from functioning wetland ecosystem services. Since these considerations are not included in mitigation site selection criteria, any arguments that "efficient allocation" of resources under principles of market-based economies are rendered null, (Ruhl & Salzman, 2006). Rather, land prices have been identified as the prime criteria under which mitigation sites are selected (Kaplowitz & Bailey, 2008).

These recommendations maintain the core essence of the CWA. During the 40-year history of wetland mitigation, guidelines have changed to improve upon mitigation practices that prevents further degradation of our country's wetland resources. Taking into account surrounding human populations is an extension of this iterative process of improving wetland mitigation practices. As nationwide trends indicate increasing urban populations in the next century, I recommend that wetland mitigation address this new literal and metaphorical landscape to improve the equitable distribution of wetland ecosystem services to urban and urbanizing populations.

Works Cited

ACOE & EPA (2008). Compensatory Mitigation for Losses of Aquatic Resources; Final Rule. 33 CFR Parts 325 and 332 and 40 CFR Part 230. Published in *Federal Register* April 10, 2008.

ACOE (1984). EPA's role in determining compliance with sec 404(b)(1) Guidelines. Regulatory Guidance Letter 84-06, issued 26 March, 1984, Washington DC.

Alberti, M., Booth, D., Hill, K., Coburn, B., Avolio, C., Coe, S., & Spirandelli, D. (2007). The impact of urban patterns on aquatic ecosystems: An empirical analysis in Puget lowland sub-basins. *Landscape and Urban Planning*, *80*, 345-361.

Azous, A., & Horner, R. R. (Eds.). (2000). *Wetlands and urbanization: Implications for the future*. New York, NY: Lewis Publishing.

BenDor, T.K., & Bruzovic, N. (2007). Determinants of spatial and temporal patterns in compensatory wetland mitigation. *Environmental Management, 40,* 349-364.

BenDor, T.K., Bruzovic, N., & Pallathucheril, V.G. (2007). Assessing the socioeconomic impacts of wetland mitigation in the Chicago Region. *Journal of the American Planning Association*, *73*(4), 263-282.

BenDor, T.K., Brozovic, N., & Pallathucheril, V.G. (2008). The social impacts of wetland mitigation policies in the United States. *Journal of Planning Literature, 22*(4), 341-357.

BenDor, T.K., & Stewart, A. (2011). Land use planning and social equity in North Carolina's compensatory wetland and stream mitigation programs. *Environmental Management, (47)*2, 239-253.

Bockstael, N. E., Freeman, A. M., Kopp, R. J., Portney, P. R., & Smith, V. K. (2000). On measuring economic values for nature. *Environmental Science & Technology, 34*(8), 1384-1389.

Boyd & Wainger (2002). Landscape indicators of ecosystem service benefits. *American Journal of Agricultural Economics, 84*(5), 1371-1378.

Boyer, T., & Polasky, S. (2004). Valuing urban wetlands: A review of non-market valuation studies. *Wetlands, 24*(4), 744-755.

Brander, L. M., Florax, R. J., & Vermaat, J. E. (2006). The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. *Environmental and Resource Economics, 33*(2), 223-250.

Brass, T.W. (2009). Who is affected by wetland mitigation banking? A social and geographic evaluation of wetland mitigation banking in Benton, Lane, Linn and Polk Counties, Oregon (Unpublished Masters Thesis). University of Oregon, Eugene, OR.

Bush, G.H.W., (1989, June 8). *Remarks to Members of Ducks Unlimited*. Retrieved from The American Presidency Project, http://www.presidency.ucsb.edu/ws/?pid=17125

Chichilnisky, G., & Heal, G. (1998). Economic returns from the biosphere. *Nature, 391,* 629-630.

Clare, S., Krogman, N., Foote, L., & Lemphers, N. (2011). Where is the avoidance in the implementation of wetland law and policy? *Wetlands Ecological Management, 19,* 165-182.

Costanza, R., d'Arge, R., De Groot, R., Faber, S., Grasso, M., Hannon, B., ... & Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387,* 253-260.

Costanza, R., Farber, S. C., & Maxwell, J. (1989). Valuation and management of wetland ecosystems. *Ecological economics*, *1*(4), 335-361.

Costanza, R., Stern, D., Fisher, B., He, L., & Ma, C. (2004). Influential publications in ecological economics: A citation analysis. *Ecological Economics, 50*(3), 261-292.

Cowardin, L. M., Carter, V., Golet, F. C. & LaRoe, E.T. (1979). Classification of wetlands and deepwater habitats of the United States. *US Fish & Wildlife Service, FWS/OBS-79/31*.

Craig, R. K. (2008). Justice Kennedy and ecosystem services: A functional approach to Clean Water Act jurisdiction after Rapanos. *Environmental Law, 38,* 635-666.

Dahl, T.E. (1990). Wetlands: Losses in the United States 1780's to 1980's. *U.S. Department of the Interior,* Washington, D.C. 13 p.

Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P. R., ... & Levin, S. (2000). The value of nature and the nature of value. *Science*, *289*(5478), 395-396.

Department of Ecology (2013). *Non-Discrimination, Executive Policy 1-4.* Retrieved from http://www.ecy.wa.gov/jobs/DiversityPolicy.pdf

Dorman, P. (2004). Ecological versus environmental economics: What's the difference?" (Unpublished article). Olympia, WA.

Downing, D. M., Winer, C., & Wood, L. D. (2003). Navigating through Clean Water Act jurisdiction: A legal review. *Wetlands*, *23*(3), 475-493.

Dunn, A.D., (2010). Siting green infrastructure: Legal and policy solutions to alleviate urban poverty and promote healthy communities. *Environmental Affairs, 37(41),* 41-66.

Environmental Law Institute [ELI] (2006). The status and character of in-lieu fee mitigation in the United States. Washington, D.C.

EPA (2017a). Memorandum of agreement between the Department of the Army and the

Environmental Protection Agency. Retrieved from https://www.epa.gov/cwa-404/memorandum-agreement

EPA (2017b). Urbanization and population change. *Report on the Environment.* Retrieved from https://cfpub.epa.gov/roe/indicator.cfm?i=52

Exec. Order No. 12898, 3 C.F.R. 5 (1994).

Frayer, W.E., Monahan, T.J., Bowden, D.C., & Graybill, F.A. (1983). Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. *US Fish and Wildlife Service*: Washington, D.C.

FWPCA [Federal Water Pollution Control Act Amendments of 1972], 33 U.S.C. §§ 1251-1387 (1972).

Gardner, R.C. (2005). Mitigation. In Connolly, K.D., Johnson, S.M., & Williams, D.R. (Eds.), *Wetlands Law and Policy.* Chicago, IL: American Bar Association.

Georeference. (n.d.). In ESRI Online GIS Dictionary. Retrieved from http://support.esri.com/other-resources/gis-dictionary/term/georeferencing.

GAO [US General Accounting Office] (1988) Wetlands: the Corps of Engineers' administration of the Section 404 program. Report GAO/RCED-88-110. GAO, Washington DC.

Godschalk, D. R. (2004). Land use planning challenges. *Journal of the American Planning Association*, *70*(1), 5–13.

Hansen, L., (2006). Wetland status and trends. Wlebe, K., & Gollehon, N., eds. *Agricultural Resources and Environmental Indicators, 2006 Edition.* USDA.

Heal, G. (2000). *Nature and the marketplace: Capturing the value of ecosystem services*. Washington, DC: Island Press.

Hough, P., & Robertson, M. (2009). Mitigation under Section 404 of the Clean Water Act:

where it comes from, what it means. *Wetlands Ecology and Management, 17*(1), 15-33.

Hruby, T., Harper, K., & Stanley, S. (2009). Selecting wetland mitigation sites using a watershed approach. Washington State Department of Ecology Publication #09-06-032.

Jennings, V., Gaither, C.J., & Gragg, R. S. (2012). Promoting environmental justice through urban green space access: A synopsis. *Environmental Justice*, *5*(1), 1-7.

Kaplowitz, M.D., & Bailey, D. (2008). Wetland mitigation banking: The banker's perspective. *Journal of Soil and Water Conservation,* 63(3), 162-172.

Kaza, N., & BenDor, T. K. (2013). The land value impacts of wetland restoration. *Journal of Environmental Management*, *127*, 289-299.

Kentula, M. E., Gwin, S. E., & Pierson, S. M. (2004). Tracking changes in wetlands with urbanization: Sixteen years of experience in Portland, Oregon, USA. *Wetlands*, *24*(4), 734-743.

King, D. M., & Herbert, L. W. (1997). The fungibility of wetlands. *National Wetlands Newsletter*, *19*(5), 10-13.

King, D. (1998). The dollar value of wetlands: Trap set, bait taken, don't swallow. *National Wetlands Newsletter, 20,* 7-11.

Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., & Dash, P. (2013). Ecosystem services: Origins, contributions, pitfalls, and alternatives. *Conservation and Society*, *11*(4), 343.

Manuel, P.M. (2003). Cultural perceptions of small urban wetlands: Cases from the Halifax regional municipality, Nova Scotia, Canada. *Wetlands,* 23(4) 921-940.

Mahan, B.L., Polasky, S., & Adams, R. (2000). Valuing urban wetlands. A property price approach. *Land Economics, 76,* 100-113.

Martin, S., & Brumbaugh, R. (2011). Entering a new era: What will RIBITS tell us about mitigation banking. *National Wetlands Newsletter*, *33*(3), 16-18.

Millennium Ecosystem Assessment (2005a). *Ecosystems and human well-being: Health synthesis.* Washington, DC: Island Press.

Millennium Ecosystem Assessment (2005b). *Ecosystems and human well-being: synthesis*. Washington, DC: Island Press.

Millennium Ecosystem Assessment (2005c). *Ecosystems and human well-being: water and wetlands synthesis.* World Resources Institute, Washington, DC: Island Press.

Merino-Saum, A., & Roman, P. (2012). What can we learn from ecological economics? *Economics*, *1,* 1-7.

Mitsch, W. J., & Gosselink, J. G. (2000). The value of wetlands: Importance of scale and landscape setting. *Ecological economics*, *35*, 25-33.

Mitsch, W.J., & Gosselink, J.G (2015). *Wetlands (*5th ed.). Hoboken, New Jersey: Wiley.

National Research Council (1995). *Wetlands: Characteristics and Boundaries.* Washington, DC: National Academy Press.

National Research Council (2001). *Compensating for wetland losses under the Clean Water Act*. Washington, DC: National Academy Press.

National Wildlife Federation v. John O. Marsh Jr. 665 F2d 390. US Court of Appeals for the District of Columbia (1981).

Perrings, C., & Hannon, B. (2001). An introduction to spatial discounting. *Journal of Regional Science, 41*(1), 23-38.

Povich, D., Roberts, B., & Mather, M., (2015). Low-income working families: The racial/ethnic divide. *the working poor families project.* Retrieved from http://www.workingpoorfamilies.org/wp-content/uploads/2015/03/WPFP-2015-Report_Racial-Ethnic-Divide.pdf

Puget Sound Regional Council (2016). Growth in the Puget Sound Region. Retrieved from http://kingcounty.gov/~/media/depts/executive/performance-strategy-budget/regional-planning/GrowthManagement/GMPCMeeting033016/Growth_presentation_KC_GMPC_3-30-2016.ashx?la=en

Rapanos v. United States. 547 US 715. Supreme Court of the United States (2006).

Reynolds, J.E. & Regalado, A., (2002). The effects of wetlands and other factors on rural land values. *Appraisal Journal, 72*, 182-190.

Robertson, M.M. (2004). The neoliberalization of ecosystem services: Wetland mitigation banking and problems in environmental governance. *Geoforum*, *35*, 361-373.

Robertson, M., & Hayden, N. (2008). Evaluation of a market in wetland credits: Entrepreneurial wetland banking in Chicago. *Conservation Biology*, *22*(3), 636-646.

RHA [River and Harbors Appropriation Act of 1899], 33 USC § 401 *et. seq.*

Ruhl, J.B. & Salzman, J. (2006). The effects of wetland mitigation banking on people. *National Wetlands Newsletter, 28*(2), 7 p.

Salzman, J., & Ruhl, J.B. (2001). Currencies and the commodification of environmental law. *Stanford Law Review*, *53*, 607-694.

Scholz, N. L., Myers, M. S., McCarthy, S. G., Labenia, J. S., McIntyre, J. K., Ylitalo, G. M., ... & McMillan, B. (2011). Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urban streams. *PloS one*, *6*(12), e28013.

Seattle Public Utilities (2013). Water system plan: plan summary. Seattle, WA. Retrieved from www.seattle.gov/util/WaterSystemPlan

Solid Waste Agency of Northern Cook County v. Army Corps of Engineers. 531 US 159. Supreme Court of the United States (2001).

Tacoma Public Utilities (2008). Green River water management plan, Vol. II. Tacoma, WA.

Tiner Jr., R.W. (1984). Wetlands of the United States: Current status and recent trends. *USFWS, Department of the Interior*. Newton Corner, MA, 71 p.

Trombulak, S.C., & Frissell, C.A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology, 14*(1), 18-30.

Turner, R.E., Redmond, A.M., & Zedler, J.B. (2001). Count it by acre or function—Mitigation adds up to net loss of wetlands. *National Wetlands Newsletter, 23*(6), 5 p.

United States Census Bureau (2017). Population and housing unit estimates. Retrieved form https://www.census.gov/programs-surveys/popest.html

United States Geological Survey [USGS] (2017). 2011 National Land Cover Database product legend. Retrieved from https://www.mrlc.gov/nlcd11_leg.php

Vileisis, A. (1997). *Discovering the Unknown Landscape.* Washington, DC: Island Press.

Walker, S., Brower, A. L., Stephens, R. T., & Lee, W. G. (2009). Why bartering biodiversity fails. *Conservation Letters*, *2*(4), 149-157.

Woodward, R. T., & Wui, Y. S. (2001). The economic value of wetland services: A meta-analysis. *Ecological economics*, *37*(2), 257-270.

Zedler, J.B. (1996). Ecological issues in wetland mitigation: An introduction to the forum. *Ecological Applications, 6*(1), 33-37.

Zedler, J. B., & Callaway, J. C. (1999). Tracking wetland restoration: Do mitigation sites follow desired trajectories? *Restoration Ecology*, *7*(1), 69-73.

Appendices

APPENDIX A: Ecosystem Services by category, adapted from Millennium Ecosystem Assessment (2005c).

Ecosystem services	**Examples**
Provisioning	
Food	Production of fish, wild game, fruits, grains
Fresh water	Storage and retention of water for domestic, industrial, and agricultural use
Fiber and fuel	Production of logs, fuelwood, peat, fodder
Biochemical	Extraction of medicines and other materials from biota
Regulating	
Climate regulation	Source and sink for greenhouse gases, influences local and regional temperatures, precipitation
Water regulation (hydrological flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, storm protection
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Source of inspiration, religious and spiritual values
Recreational	Opportunities for recreation
Aesthetic	Beauty and aesthetic values
Educational	Formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling and processing of nutrients

APPENDIX B: Economic valuation methods used to estimate wetland values, verbatim from Brander, Florax, and Vermaat (2006).

Valuation Method	Short description	Welfare measure
Contingent valuation	Hypothetical questions to obtain WTP	Compensating or equivalent surplus
Travel cost	Estimate demand (WTP) using travel costs to visit site	Consumer surplus
Hedonic pricing	Estimate WTP using price differentials and characteristics of related products	Consumer surplus
Production function	Estimate value as an input in production	Producer and consumer surplus
Net factor income	Assign value as revenue of an associated product(s) net of costs of other inputs	Producer surplus
Replacement cost	Cost of replacing the function with an alternative technology	Value larger thanthe current cost of supply
Opportunity cost	Value of next best alternative use of resources (e.g., agricultural use of water and land)	Consumer surplus, producer surplus, or total revenue for next best alternative
Market prices	Assigns value equal to the total market revenue of goods/services	Total revenue

APPENDIX C. Definitions of Compensatory Mitigation Methods, verbatim from IWR (2015).

1. RESTORATION
The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource.

For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: reestablishment and rehabilitation.

1.1.RE-ESTABLISHMENT
The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. Re-establishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions.

1.2 REHABILITATION
The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.

2. ENHANCEMENT
The manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s). Enhancement results in the gain of selected aquatic resource function(s), but may also lead to a decline in other aquatic resource function(s). Enhancement does not result in a gain in aquatic resource area.

3. ESTABLISHMENT (CREATION)
The manipulation of the physical, chemical, or biological characteristics present to develop an aquatic resource that did not previously exist at an upland site. Establishment results in a gain in aquatic resource area and functions.

4. PRESERVATION
The removal of a threat to, or preventing the decline of, aquatic resources by an action in or near those aquatic resources. This term includes activities commonly associated with the protection and maintenance of aquatic resources through the implementation of appropriate legal and physical mechanisms. Preservation does not result in a gain of aquatic resource area or functions.