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Determinants of Spatial and Temporal Patterns in Compensatory Wetland Mitigation

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Abstract Development projects that impact wetlands commonly require compensatory mitigation, usually through creation or restoration of wetlands on or off the project site. Over the last decade, federal support has increased for third-party off-site mitigation methods. At the same time, regulators have lowered the minimum impact size that triggers the requirement for compensatory mitigation. Few studies have examined the aggregate impact of individual wetland mitigation projects. No previous study has compared the choice of mitigation method by regulatory agency or development size. We analyze 1058 locally and federally permitted wetland mitigation transactions in the Chicago region between 1993 and 2004. We show that decreasing mitigation thresholds have had striking effects on the methods and spatial distribution of wetland mitigation. In particular, the observed increase in mitigation bank use is driven largely by the needs of the smallest impacts. Conversely, throughout the time period studied, large developments have rarely used mitigation banking, and have been relatively unaffected by changing regulatory focus and banking industry growth. We surmise that small developments lack the scale economies necessary for feasible permittee responsible mitigation. Finally, we compare the rates at which compensation required by both county and federal regulators is performed across major watershed boundaries. We show that local regulations prohibiting cross-county mitigation lead to higher levels of cross-watershed mitigation than federal regulations without cross-county prohibitions. Our data suggest that local control over wetland mitigation may prioritize administrative boundaries over hydrologic function in the matter of selecting compensation sites.

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Introduction

The impacts of land use change have had significant and irreversible effects on the extent and quality of wetlands around the world. In the contiguous United States, it is estimated that more than 53% of naturally occurring wetlands (more than 117 million acres or 47.4 million hectares; 1 acre = 0.405 hectare) have been converted into urban and agricultural uses (Dahl 1990). Since the 1980s, federal and local wetland regulatory programs have undergone significant changes. Most notably, the wetland mitigation program implemented by the U.S. Army Corps of Engineers (Corps) has progressively required compensation for smaller and smaller impacts.

To the best of our knowledge, no existing study has explicitly analyzed the extent to which spatial and temporal trends in mitigation patterns have been driven by changes in the regulatory framework. Similarly, only a few studies have considered the implications of increased regulator support for multiple user off-site mitigation methods, such as wetland banking and in-lieu fee mitigation (Environmental Law Institute 2002, 2006, Corps 2006). Finally, no work has compared the behavior of federal and local regulatory agencies in implementing compensatory mitigation. Such a comparison has important policy implications because recent legal challenges [*Rapanos v. United States* (126 S.Ct. 2208, 2006) and *Carabell v. US Army Corps of Engineers* (126 S.Ct. 2208, 2006)] will almost certainly lead to a further shift from federal to local control over wetland protection.

This study presents an analysis of 1058 wetland mitigation projects required by permits issued under local and federal regulations in the Chicago region between 1993 and 2004. Using a comprehensive geospatial and temporal dataset, we assess patterns in compensation method, regulatory authority, and changes in regulatory stringency over time. Here, we are able to test several research questions. First, how have the average wetland impact size, compensation method, and the resulting displacement distance during mitigation changed during our study period? Next, have there been differences in the usage of specific mitigation methods under the different federal and county agencies involved in our study? Finally, how have different regulatory agencies allowed wetland impacts to be mitigated in different counties and different watersheds?

We argue that the changing regulatory framework, along with legal challenges to federal authority, complicates the analysis of policy outcomes in a way that has not been captured in previous analyses of trends in the health and abundance of U.S. wetlands (Dahl 2006). Our results show that changing regulatory attitudes and frameworks have enhanced the viability of developer use of third-party mitigation techniques, including wetland mitigation banks and in-lieu fee programs, for small impacts. Conversely, compensation for large impacts has been largely unaffected by regulatory changes. We also show that local permitting agencies have behaved differently from the Corps in setting the spatial limits within which compensation can occur. Our results suggest that it is important to consider the permitting agency, regulatory framework, and development size in determining the current and future importance of wetland mitigation banking in the broader mitigation process.

We begin this article by outlining important background information on wetland policy and mitigation issues. We then introduce our Chicago study area, dataset, and the legal framework surrounding wetland mitigation programs throughout the region. Next, we present our analytical methods and results, looking at patterns in agency and developer behavior between 1993 and 2004. Finally, we discuss the implications of our results for researchers, resource managers, and environmental planners.

Background

The primary mechanism for allowing development of wetlands in the United States has been the permitting system run by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act (Scodari 1990, Kentula and others 1992, Gaddie and Regens 2000). This system requires a permit for anyone wishing to dredge or discharge fill material into wetlands.

During the three decades since the adoption of the Clean Water Act, legal challenges have significantly changed both the manner in which federal regulators are able to apply the law, and the scope of federal jurisdiction. In 2001, the Supreme Court issued a landmark ruling in *Solid Waste Agency of Northern Cook County v. Army Corps of Engineers* (commonly known as *SWANCC*; 531 U.S. 159), restricting federal regulatory authority over hydrologically isolated wetlands (Freeman and Rasband 2002). In *SWANCC*, the Supreme Court held that hydrologically isolated, intrastate, non-navigable waters (wetlands in this case) could not be considered part of the waters of the United States for purposes of Clean Water Act jurisdiction based solely on its use as habitat by migratory birds. Furthermore, the Court ruled that Congress did not have authority under the Commerce Clause of the U.S. Constitution to include isolated, intrastate, non-navigable waters as ''waters of the United States,'' and that the Clean Water Act was not intended to protect isolated, intrastate, non-navigable waters based solely on their use by migratory birds. The Court's reasoning implied that the Clean Water Act intended some ''connection'' between wetlands and navigability and that isolated waters need a ''significant nexus'' to navigable waters to be jurisdictional (Freeman and Rasband 2003).

This restriction eliminated a major portion of the wetland area under the Corps' jurisdiction in regions with an abundance of hydrologically isolated wetlands, necessitating alternative regulations at the state or local level in many areas. In flat, recently glaciated regions this ruling had a major impact, as a significant number of wetlands in the region have little or no surficial hydrologic connections to tributaries of navigable waterways.

More recent U.S. Supreme Court cases, most notably *Rapanos v. United States* (126 S.Ct. 2208, 2006) and *Carabell v. Corps* (126 S.Ct. 2208, 2006), threaten to reduce federal jurisdiction over wetlands further in the wake of the *SWANCC* decision. In 2006, the Supreme Court remanded the *Rapanos* and *Carabell* cases back to the appellate court, leaving the future regulatory status of isolated wetlands still uncertain. The Court's ruling was complicated, in part because the plurality included two separate opinions.

Under these decisions, federal agencies now have two tests for determining whether or not wetlands fall under the federal jurisdiction of the Clean Water Act: the so-called ''Scalia'' and ''Kennedy'' Tests. Under the Scalia Test, there must be a relatively permanent standing or flowing water connection between a wetland and a navigable-in-fact water, whereas under the so-called Kennedy Test, there need only be a demonstrable and significant nexus between the water quality of a wetland and a navigable-in-fact water, regardless of the existence or permanence of a standing or flowing water connection between the wetland and the navigable-in-fact water (see articles in *National Wetlands Newsletter 28(5)*).

As a result of the *Rapanos and Carabell* decisions, the extent of wetlands considered to be isolated (cut off from surficial hydrologic connection to navigable U.S. waters; Tiner 1997, Semlitsch 2000, Tiner 2003), and therefore not protected by the Clean Water Act, may increase considerably in the future, especially in areas where hydrologically isolated wetlands are abundant. As local and state governments face the need to regulate many wetland impacts formerly under the Corps' jurisdiction, their decisions will have a growing effect on the status and distribution of wetlands.

Methods of Compensatory Mitigation

As a condition of Section 404 permits, compensatory mitigation is often required, which usually involves the restoration of former wetlands on-site or elsewhere, to offset the effects of wetland loss (Brown and Veneman 1998, Environmental Law Institute 2002, Booth 2004). Mitigation encompasses a broad range of possible actions intended to preserve, maintain, or avoid damage to wetland resources, and if necessary, to produce functions similar to those being degraded or destroyed (Bedford 1996, National Research Council 2001, Hoehn and others 2003). Under both federal and local wetland regulations, developers are required to follow a ''sequence'' of mitigation steps if they believe that they may impact wetlands during the construction process (Corps and Environmental Protection Agency (EPA) 1990, Weems and Carter 1995, Kane County 2005, DuPage County 2006, Lake County 2006). Developers must initially attempt to avoid wetland impacts altogether, while minimizing impacts deemed to be unavoidable. Compensation can only be required for impacts that remain after all practicable avoidance and minimization efforts have been implemented, and is commonly achieved through the restoration, enhancement, creation, or preservation of alternate wetland areas.

Compensation is often carried out using one of four methods that fall into two categories: permittee-responsible mitigation (PRM) and third-party mitigation (Corps and EPA 2006). Permittee-responsible methods imply that a developer undertakes mitigation on their own, usually by individually contracting with an environmental restoration consultant (Robertson 2004). In these cases, developers may create or restore wetlands on the project site (on-site) or at another site that the developer either owns or can access for wetland restoration activities (off-site). Regulators may inspect mitigation sites at least once over the 5-year period during which developers are required to monitor hydrologic, soil, and vegetative functions.

Under third-party mitigation methods, parties impacting wetlands pay to transfer the responsibility of providing compensatory mitigation to another entity, often an entrepreneur, governmental agency, or nonprofit organization. During the last 10 years, policies adopted by the EPA and Corps indicate a gradual shift away from the preference for on-site compensation expressed in the 1990 Memorandum of Agreement (Corps and EPA 1990), towards an acknowledgment of the advantages of third-party, off-site compensation (Corps and EPA 1995, 2000, Shabman and Scodari 2005). This shift has been an acknowledgment that on-site compensation for urban wetlands often produces small, extremely low-quality wetland remnants. Additionally, a number of studies have argued that permittee-responsible wetland restoration projects inefficiently use funds that could be better applied to restoring larger, higher quality wetlands that often have a greater chance of success (Mitsch and Wilson 1996, Race and Fonseca 1996, National Research Council 2001).

Mitigation banking has become a common type of third party mitigation since 1995 (Environmental Law Institute 2002), drawing broad support from both regulators and ecologists. Banks were originally defined as mitigation constructed *prior* to wetland impacts (Corps and EPA 1995), although regulators have not strictly enforced this concept (Corps 1997, Robertson 2004). Supporters have banking as a means for facilitating ecologically sound wetland restoration (Etchart 1995, Dennison and Schmid 1997). Under mitigation banking guidelines, third-party entrepreneurs restore a large, contiguous tract of wetlands and sell developers the right to use the bank as a means of meeting mitigation requirements (Environmental Law Institute 2002). Banks are usually used as compensation for multiple impacts, because many individual developers can purchase ''credits'' (acres of wetlands) from an individual bank. Because banks concentrate mitigation in one place, regulators are able to devote more resources to inspection and to the enforcement of ecological standards (Marsh and Acker 1992, Etchart 1995, Environmental Law Institute 2002). For example, regulators usually only allow the placement of banks in locations with biophysical characteristics suitable for maintaining high-quality wetlands (Ruhl and Gregg 2001, Shabman and Scodari 2004, Thomas and Lamb 2004, Shabman and Scodari 2005).

The other major third-party mitigation method, in-lieu fee (ILF) mitigation, allows developers to compensate for impacts through the transfer of funds to a government or nonprofit agency. This payment is pooled with other payments from developers over time by agencies for use in future wetland restoration projects as compensation (Environmental Law Institute 2002). When eventually constructed, ILF sites are often large, contiguous mitigation areas, similar to banks. However, ILF sites are usually constructed well *after* developers have impacted wetlands and restoration capital funds have collected (Urban et al. 1999).

Most regulations governing off-site wetland mitigation stipulate penalties for relocating wetlands between watersheds, also known as ''cross-watershed mitigation.'' These penalties commonly come in the form of a higher amount of compensation (acreage) required per acre of wetland impacted (the ''mitigation ratio''). These penalties are present due to the watershed perspective of wetland protection taken by federal authorities, postulating that wetlands play important hydrologic roles within watersheds. Uncompensated removal of wetlands from their original watersheds has been found to lead to flooding, sedimentation, habitat reduction, and a slew of other ecological and hydrologic problems (Thomas and Lamb 2004).

Prior Spatial Studies of Wetland Mitigation

Although many studies have analyzed and criticized wetland mitigation practices for a variety of reasons (Kentula and others 1992, Allen and Feddema 1996, Cole and Shafer 2002, Robb 2002, Goldman-Carter 1992, Turner and others 2001, Tolman 2004, Dahl 2006, King and Herbert 1997, King 1998, Salzman and Ruhl 2000, 2004, Ruhl and Salzman 2006), empirical data on aggregate longitudinal trends in mitigation programs and policy are very limited. Although calls for such data collection have been issued repeatedly (King and Herbert 1997, National Research Council 2001), only recently have efforts materialized to construct geospatial datasets containing information on the location, dates, and area of impact and mitigation sites as they have been negotiated with local and federal regulatory agencies (National Research Council 2001, Salzman and Ruhl 2004, Ruhl and Salzman 2006). Datasets containing information on wetland location have primarily focused on wetland alteration and mitigation banking in Florida (Ruhl and Salzman 2006, King and Herbert 1997) and Chicago (Robertson 2004). To date, the most comprehensive work connecting impact and mitigation sites has been the Florida-wide study of mitigation banking detailed by Ruhl and Salzman (2006). This study used simple analysis of a geospatial dataset to demonstrate that mitigation banking drives a systemic migration of wetlands from urban to rural areas. Unfortunately, data from several previous studies have not allowed for the comparison of on- and off-site mitigation policies (Robertson 2004, Brody and Highfield 2005, Ruhl and Salzman 2006). Ruhl and Salzman (2006) collected high-quality geospatial data on mitigation transactions, but only focused on mitigation banking. In the case of King and Herbert (1997), the spatial resolution of the data made clear demographic analysis difficult. Here, the authors obtained wetland banking impact and mitigation spatial data on the zip-code level. As a result, their dataset did not contain the geospatial point/polygon data necessary for high-resolution demographic analysis.

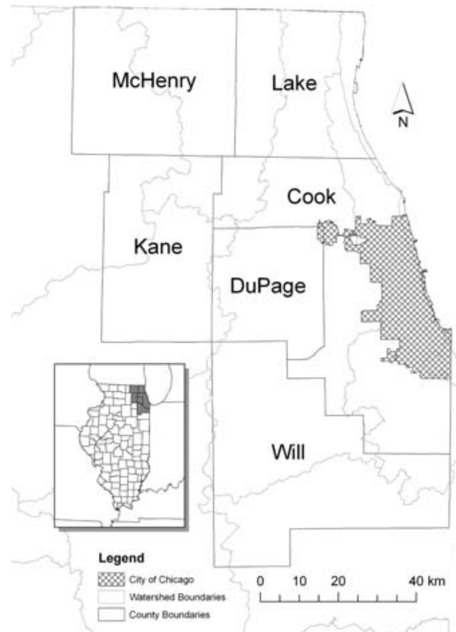

Fig. 1 Chicago study region

Study Area

The analysis presented here is based on data collected through Freedom of Information Act requests for wetland impact permits granted in the Chicago region between 1993 and 2004 (Fig. 1). This region consists of six counties that comprise both the Chicago District of the Army Corps of Engineers and the Northeastern Illinois Planning Commission area. During the last 20 years, the Chicago region has been affected by a complex and changing web of mitigation regulations. Additionally, the region has experienced tremendous spatial and population growth over the last 10 years, adding more than 830,000 new residents (11.4%). This growth has been almost entirely focused on the western and northern suburban areas of the region, including Lake and DuPage Counties.

After considerable flooding in 1986–1987, state legislation authorized counties in the Chicago region to create storm water management plans, programs, and projects (Metropolitan Water Reclamation District of Greater Chicago 2005). As a result, DuPage (in 1994), Lake (in 2002), and Kane (in 2001) counties established wetland permitting and mitigation ordinances and programs. Although the Kane and Lake County ordinances were both responses to the *SWANCC* decision, DuPage County's ordinance was enacted far in advance of this decision. As of April 2006, McHenry County had finalized a wetland ordinance, while Will and Cook county were still in drafting stages (Metropolitan Water Reclamation District of Greater Chicago 2005). Currently, Lake and Kane Counties issue permits for isolated wetlands only, because the Corps still exerts jurisdiction over nonisolated wetlands in these areas. In DuPage County, the Corps has relinquished nearly all permitting responsibilities for wetland impacts (isolated and nonisolated), citing the County's stringent ordinance and satisfactory mitigation requirements (Corps 2000b, Metropolitan Water Reclamation District of Greater Chicago 2005).

The Chicago region also contains a large number of mitigation banks (more than 24 active, sold-out, or proposed banks, including some of the earliest in the country), as well as both federally supported and county-based ILF programs. Between 1999 and 2001, the Corps supported an ILF program operated by the Corporation for OpenLands (''CorLands''), a nonprofit Chicago restoration organization. Additionally, county ILF programs are currently operating in DuPage and Kane Counties.

Dataset

Table 1 summarizes data sources, composition, and dates for which data are available. This dataset only includes transactions requiring permits between 1993 and 2004 that required mitigation, and includes wetland location and size information for impact and mitigation sites. Our dataset breaks apart permits into individual database records when permits refer to more than one impact site or more than one mitigation type or location. As a result, our dataset models mitigation as a set of individual transactions of wetland area throughout the region.

Permits and database records are delineated in Table 1, as some permits reference more than one impact or mitigation site in distinct, spatially separated (and identifiable) areas. The majority of permits were derived from the Chicago Corps' Regulatory and Analysis Management System (RAMS) database, which contains information that is entered as agency personnel review permits. Of the more than 3100 permit records obtained in the original RAMS dataset, only a small fraction actually included wetland impacts that required mitigation. In identifying these sites, we discovered that more than 420 records (13.5%) contained either missing or inaccurate impact location points. Additionally, over 620 records (19.9%) contained no useful Public Land Survey System location information (quarter sections that give a positional accuracy of one-quarter mile). Because RAMS has no systematic way of presenting or storing mitigation site location, we collected Corps digital correspondence documents and permits to assist with filling in more information about impact and mitigation site locations and sizes (hardcopy data often were not readily available).

The Corlands ILF program did not contain information on how funds were transmitted from individual impacts to specific mitigation sites. However, using a list of sites that were restored through this program that was obtained from the Chicago District of the Army Corps of Engineers (see third dataset in Table 1), we were able to identify mitigation sites by assuming that funds gained from impacts were used for mitigation purposes at the closest ILF mitigation site within the same watershed. Additional details on the construction of this dataset can be found in BenDor and others (2007).

Regulatory Framework and Local Implementation

The Corps has historically issued two types of permits: Standard Permits and General Permits. As concern over the cumulative effects of wetland degradation has increased (Stein and Ambrose 1998), regulators have gradually lowered the minimum impact size (*de minimis*) for which developers must obtain permits. This type of increasing regulatory stringency has most visibly affected Nationwide Permits, the category of General Permits created by the Corps in 1977 for routine types of wetland impact in order to reduce paperwork and permit evaluation time. Nationwide permits comprise the overwhelming majority of federally issued permits, and has been reformulated several times since the passage of the Clean Water Act in 1977 (65 Fed. Reg. 47, 12819). Although many Nationwide Permits require compensatory mitigation, some do not; by contrast, most of the more complicated Individual Permits require mitigation and are issued much less frequently.

Between 1977 and 1984, many impacts went unrecorded as unlimited fill of wetlands in headwaters and isolated areas were allowed under ''after-the-fact'' NWPs without prior notification to the Corps. Table 2 illustrates how the reach of federal regulation has extended to smaller and smaller minimum regulated wetland impact sizes during the last 15 years. Here, we see both the minimum impact size for which notification to the Corps was required (*de minimis*) as well as the minimum size for which compensation was required (minimum mitigated impact

Table 1 Summary of data sources for this study

Data source	Dataset collected	Time period	Raw data	Cleaned data
	RAMS dataset: all federally permitted impact sites. Locations, sizes, and date permit granted. All electronic correspondence documents to permittees.	1993–2005	2721 permits 3104 records	660 permits 729 records
Chicago District Army Corps of Engineers	Mitigation bank transactions requiring federal oversight. Impact site sizes and impact date.	1994–2004	214 permits 214 records	N/A
	Corporation for OpenLands (Corlands) ILF program. Impact site sizes and impact date.	1999–2001	65 permits 65 records	N/A
	Robertson (2004) survey of Corps' Chicago District mitigation bank transactions Geospatial point dataset containing census of mitigation bank transactions overseen by Corps. Impact and mitigation site locations, sizes, and impact date.	1994–2002	238 permits 238 records	40 permits 40 records
DuPage County Department of Environmental Concern, Stormwater Management Division	All county permitted wetland impact and mitigation sites. Locations, site sizes, and impact date	1993–2005	263 permits 272 records	200 permits 204 records
Kane County Division of Stormwater Management	All county permitted wetland impact and mitigation sites. Locations, site sizes, and impact date.	2001–2005	27 permits 29 records	18 permits 19 records
Lake County Stormwater Management Commission	All county permitted wetland impact and mitigation sites. Locations, site sizes, and impact date.	2002–2005	154 permits 160 records	60 permits 66 records
Final dataset	Geospatial point dataset Impact and mitigation site locations, sizes, and impact date.	1993–2004	N/A	938 permits 1058 records

Our dataset breaks apart permits into individual database records when permits refer to more than one impact site or more than one mitigation type or location. As a result, our dataset models mitigation as a set of individual transactions of wetland area throughout the region

Table 2 Changes in regulated impact size from 1993 to 2004 (acres)

<table>
<tr><th colspan="14">Timeline</th></tr>
<tr><th>Agency</th><th></th><th>1993</th><th>1994</th><th>1995</th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th></tr>
<tr><td>Corps</td><td>MMIS</td><td colspan="4">10.0</td><td colspan="3">3.0</td><td>0.5</td><td colspan="4">0.25</td></tr>
<tr><td></td><td>de min.</td><td colspan="4">1.0</td><td colspan="3">0.3</td><td>0.1</td><td colspan="4">0</td></tr>
<tr><td>DuPage</td><td></td><td colspan="12">N/A</td></tr>
<tr><td>Kane</td><td></td><td colspan="8">N/P</td><td colspan="4">0.25</td></tr>
<tr><td>Lake</td><td></td><td colspan="9">N/P</td><td colspan="3">0.25</td></tr>
</table>

N/A: DuPage County has not employed a mitigation *de minimis* during the lifetime of their program. However, impacts less than 0.1 acre do not require evidence that the developer has attempted to avoid impacts (Falsie 2006, personal communication)

N/P: No mitigation program was in place during these years
MMIS: Threshold at which mitigation became mandatory—minimum mitigated impact size
Notify: impact size threshold requiring notification to the Corps (*de minimis*). Mitigation was not always required for impacts over this size

Table 3 Dataset categories and size classes by size and time period

Timeline													
A. Categories	n	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
[>10]	16	←	—	—	—	—	—	—	—	—	—	—	→
[>3]	45					←	—	—	—	—	—	—	→
[>0.5]	244								←	—	—	—	→
[>0.25]	228									←	—	—	→
[<0.25]	238	←	—	—	—	—	—	—	—	—	—	—	→
B. Size classes													
[10 +]	16	←	—	—	—	—	—	—	—	—	—	—	→
[3 – 10]	35					←	—	—	—	—	—	—	→
[0.5 – 3]	225								←	—	—	—	→
[0.25 – 0.5]	60									←	—	—	→
[<0.25]	238	←	—	—	—	—	—	—	—	—	—	—	→
All data	1058	←	—	—	—	—	—	—	—	—	—	—	→

Data categories and size classes given in acres as specified in 65 Fed. Reg. 47, 12818-12899 and Corps (2000a, 2000c, 2005)

size, MMIS). In 2001, the Corps Chicago District instituted a regional permitting program that required permits and mitigation for all impacts over 0.25 acres. In 2005, the MMIS was decreased to 0.1 acre (Corps 2005). Kane and Lake Counties both established minimum regulated impact sizes of 0.25 acres when passing their respective storm water ordinances, whereas DuPage County did not create an MMIS or *de minimis*.

There have been significant changes in MMIS over time (Table 2). As a result, the proportion of impacts requiring mitigation has also varied through time. Failure to account for this variation when comparing across regulatory periods may result in sample selection bias (as well as statistical conclusion bias). Thus, in order to analyze true changes in the mitigation process for a given size of development, it is necessary to categorize our dataset based on the year a permit was granted and the corresponding MMIS used at that time.

We divide our data into distinct distributions under which permits granted usually required compensatory mitigation. For example, mitigation was required for nearly virtually all permitted impacts more than 0.25 acres between 2001 and 2004 (see Table 3 for the sizes and date ranges for all categories). The inclusion of impacts less than 0.25 acres during this time period would include only a partial set of the permits actually granted, many of which did not require mitigation. This could potentially introduce sample selection bias into our analysis because our dataset would cross two separate distributions (permits always requiring mitigation versus permits sometimes requiring mitigation). We can look at all permits granted for impacts more than 10 acres between 1993 and 2004 because they would have been treated similarly (always requiring mitigation) during this period. However, permits granted for impacts of 1 acre would be treated differently in 1997 than they would be in 2004. By including only permits that nearly always required mitigation in our analysis, we can decouple the effects of changes in the urban development process and changes in regulatory framework. Additionally, we can compare samples over periods with a consistent MMIS, allowing us to decouple trends in the data from the decreasing trend in MMIS.

In order to analyze the effect of impact size on use of specific mitigation types and cross-watershed relocation, we divide our categories into the size classes shown in Table 3B. These classes allow us to distinguish between groups of impacts of different sizes that occurred *within* a given time period with a constant MMIS. By doing this, we can not only detect the effects of changing regulations, but also we can see how changing regulatory support and developer behavior have changed throughout the region.

Given the rapid increase in compensation requirements for wetland impacts, we must determine whether the implementation of third party off-site alternatives, such as banking, is actually driving urban to rural wetland migration, or whether banking is simply being used to mitigate small impacts that would not have been mitigated before. Economic logic would dictate that decreasing size thresholds for compensation would discourage development, making it more expensive to impact small amounts of wetlands. Here it is important to determine whether bankers are encouraging urban development on wetlands, or whether they are taking advantage of the decreasing MMIS that has required compensation for more wetlands and required more permits.

Analysis

We consider five main objectives in our analysis of mitigation transactions in the Chicago region. First, we determine whether average impact size has changed during our study period. Second, we study whether the displacement distance associated with off-site mitigation has increased over time. Third, we determine whether use of specific compensation types has changed over time within the region. Fourth, we focus on the differences in support given to specific mitigation methods by the different federal and county agencies involved in our study. Fifth, and finally, we look at the relative rates at which the agencies allow impacts to be mitigated in different counties and different watersheds. Taken together, these analyses allow us to dissect the relative effects of urban development and changing regulatory framework.

Here, it is important to note that watersheds can take on a range of definitions, depending on the scale of observation. For this analysis, we consider wetlands at the level defined by the eight-digit hydrologic unit classification of the U.S. Geological Survey (Seaber and others 1987), rather than at the scale delineated by regulatory agencies in the region as discussed in Robertson (2006).

Results

Between 1993 and 2004, at least 1544.2 acres of wetlands were impacted in the Chicago region. This area was compensated for with the creation, restoration, or preservation of 2634.2 acres of wetlands. Examination of the data reveals major differences between individual mitigation methods, including variation in gross impact and mitigation acreages, displacement distances, and frequency of use over time. The data also reveal major differences in the behavior of permitting agencies in the region. Table 4 summarizes the data by mitigation method.

Of 1058 observations, 462 (40.6%) were found to be mitigated on-site, with 638 (59.4%) being mitigated off-site, using off-site PRM, mitigation banking, ILF mitigation, or the Corlands ILF program.

Average Impact Sizes Changes

Our first research objective addresses the pattern of average impact size over time. When the whole dataset is considered, the average impact size in the region decreases significantly over time (Fig. 2). However, we find no significant difference in impact size within each stable regulatory period (period with a constant MMIS).

For the stable MMIS period between 1993 and 1997, no significant differences in impact sizes were found (1993 versus 1997, two sample t-test, $p = 0.153$). Likewise, the periods 1997–1999 ($p = 0.492$) and 2001–2004 were found to have no significant differences in impact size ($p = 0.161$).

Displacement Distance Changes

Our second question relates to the pattern in which mitigation has historically displaced wetlands across space. As the MMIS has decreased, more small impacts have required mitigation. Figure 3 demonstrates the extent to which small wetland impacts have driven up the average displacement distance. Impacts in categories including small impacts less than 0.25 acres during the entire study period, more than 0.25 acres from 2001 to 2004, and more than 0.5 acres from 2000 and 2004, contributed most to the increasing average displacement distance trend shown in Figure 3. In particular, the average displacement distance for impacts under 0.25 acres grew to over 40.4 km in 2004, pulling up the average displacement distance of all impacts to over 27.5 km. Between 1993 and 2004, the average bank displacement rose from just over 11.5 km to 43.1 km.

Although there was a significant increase in the average displacement distance between 1993 and 2004 for the aggregate dataset ($p < 0.0001$), this seems to have been driven largely by impacts under 0.25 acre ($p < 0.0001$; longest interval with sufficient data for test is 1996–2004). All other impact categories failed to yield an increasing average displacement distance over time (p values all in excess of 0.502).

Shifts in Mitigation Method Usage

The period between 1993 and 2004 was characterized by a shift in the dominant modes of wetland mitigation. In the early years of this period, the majority of mitigation was performed on-site as PRM, while the remaining impacts almost exclusively used off-site PRM. Figure 4 demonstrates the rapid decline experienced by on- and off-site PRM.

Here, we see that small impact size classes (<0.25, 0.25–0.5, and 0.5–3 acres) heavily used banks, sometimes at rates between 60% and 70% (0.25–0.5 acres). ILF programs were also consistently used at rates between 20% and 50% to mitigate these same types of small impacts.

With smaller impacts creating most of the demand for bank mitigation, we must note the variation in average displacement distances exhibited by each mitigation method. The federal Corlands ILF program and mitigation banks displaced wetlands significantly further than off-site PRM ($p < 0.0001$; Table 4). The county ILF programs and off-site PRM did not differ significantly in their displacement distances ($p = 0.667$).

Table 4 Descriptive statistics for mitigation dataset given for individual mitigation methods

	N	Minimum	Maximum	Mean	Median	Std. Dev.
Impact size (acres)	1058	0.001	46.810	1.460	0.690	3.283
Type						
On-site PRM	430	0.001	46.810	1.960	0.955	3.970
Off-site PRM	90	0.050	45.500	2.873	1.142	6.096
Banking	371	0.002	19.670	0.947	0.620	1.390
ILF	88	0.001	2.840	0.319	0.100	0.592
Corlands ILF	79	0.110	4.515	0.782	0.610	0.784
Mitigation size (acres)	1058	0.001	105.000	2.490	1.050	6.071
Type						
On-site PRM	430	0.001	105.000	3.520	1.590	7.640
Off-site PRM	90	0.050	68.250	5.315	2.268	11.043
Banking	371	0.003	10.000	1.365	0.950	1.426
ILF	88	0.001	7.140	0.540	0.150	1.156
Corlands ILF	79	0.120	5.540	1.132	0.800	1.099
Displacement distance (km)	1058	0.000	117.384	12.880	4.896	19.785
Type						
All off-site	628	0.015	117.384	21.699	16.015	21.639
Off-site PRM	90	0.190	75.193	11.788	5.954	16.653
Banking	371	0.015	117.384	25.619	17.724	24.671
ILF	88	0.514	36.363	12.629	11.336	7.871
Corlands ILF	79	2.972	81.777	24.682	23.030	14.243
Mitigation ratio	1058	0.076	7.810	1.780	1.500	1.011
Type						
On-site PRM	430	0.200	7.810	1.960	1.504	1.330
Off-site PRM	90	0.633	5.556	1.978	1.583	0.938
Banking	371	0.076	6.000	1.605	1.500	0.658
ILF	88	0.750	4.706	1.706	1.500	0.609
Corlands ILF	79	0.274	3.000	1.466	1.500	0.409

Many of the low minimum sizes are due to voluntary wetland mitigation or to individual permits for wetland impact that do not fall under Corps Regional Permit or County mitigation specifications (Corps 2005). It was not possible to determine displacement distances for on-site mitigation because data did not incorporate a high enough resolution to study relocation on the parcel level. As a result, on-site mitigation is assumed to have a negligible displacement distance

PRM: permittee-responsible mitigation, ILF: in-lieu fee

Permitting Agency Behavior and Patterns

We now shift our attention toward the permitting agencies in the region. Figure 5 shows the distribution of permittee responsible and third-party mitigation methods by regulatory agency. In particular, note the high rate at which counties have used third-party mitigation in comparison to the Corps. No significant difference between third-party and PRM mitigation based on impact size was found in Kane (two sample t-test comparing average impact sizes of PRM and third-party mitigation; $p = 0.526$) and Lake ($p = 0.586$) Counties. However, under DuPage County ($p = 0.008$) and Corps ($p < 0.001$) permits, PRM (mostly on-site) is clearly preferred by developers for larger impacts, whereas third-party mitigation (mostly banks) is preferred for smaller impacts.

Cross-County and Cross-Watershed Mitigation Patterns

Our final analysis looks at how off-site mitigation relocated wetlands between counties or watersheds (eight-digit basins under the U.S. Geological Survey hydrologic unit classification system; Seaber and others 1987). Throughout the region, nearly 156 acres of wetlands were relocated outside of their original watersheds, and replaced with 255 acres elsewhere through the mitigation process (1.6:1 mitigation ratio). Strong differences emerged between agencies, with Kane and Lake Counties mitigating impacts

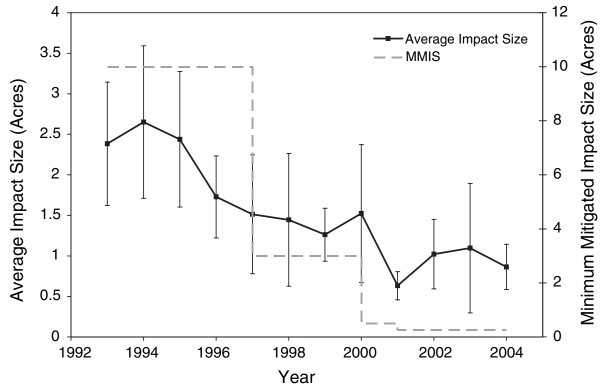

Fig. 2 Average impact size and minimum mitigated impact size (MMIS) changes over time. Dark line depicts behavior of full dataset (n = 1058); average impact size shown with 95% confidence interval. Gray line shows changes in minimum impact size always requiring mitigation under federal permits

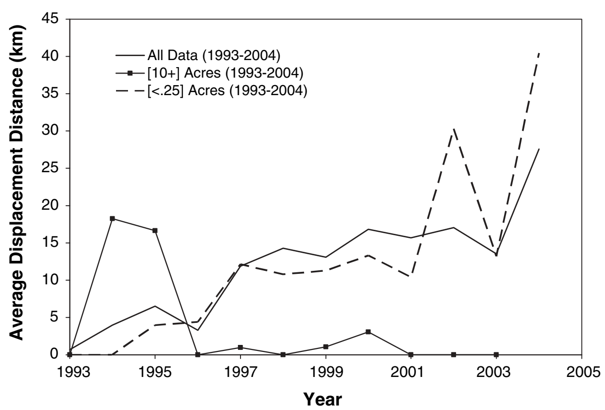

Fig. 3 Changes in displacement distance. This figure shows behavior of large impacts, small impacts, and dataset as a whole and includes on-site mitigation to demonstrate the effects and frequency of on-site mitigation. Analysis of transactions only utilizing off-site mitigation shows similar results. Note that impacts over 10 acres do not experience off-site mitigation after 2000

across watersheds at a rate of 20% and 30%, two to three times higher than the Corps, and four to six times higher than DuPage County.

As shown in Table 5, although cross-county mitigation does not occur under the county programs, Kane and Lake Counties employ significantly higher rates of cross-watershed mitigation than the Corps ($p = 0.0029$ and $p = 0.0008$, respectively). Conversely, DuPage County's cross-watershed mitigation rate is significantly lower than that of the Corps ($p = 0.0014$). We determine this using a two sample z-test for proportions, given the total number of transactions (n_i) and the proportion employing cross-watershed mitigation (p_s) (Healey 2005).

Within the distribution of impacts across agencies and across mitigation methods, we find no clear relationship between impact size and the propensity to move across watershed boundaries.

Discussion

The finding that nearly 60% of the wetland impacts during the study period involved some type of off-site mitigation seems unexpected, given the historic regulatory inclination for on-site mitigation (Corps and EPA 1990, National Research Council 2001). Additionally, our dataset shows a dramatic increase in the use of mitigation banking, with nearly 35.1% of impacts having been mitigated through banks over the 12-year study period. However, this figure matches well with the 33% nationwide banking rate found by Corps (2006), a number that was highly surprising both to regulators and the banking community.

The rise of banking and other off-site mitigation has been largely attributed to the growing regulatory acceptance of third-party mitigation options, especially mitigation banking as laid out in the 1995 Federal Guidance for the Establishment, Use and Operation of Mitigation Banks (Corps and EPA 1995). An additional boost for banking came from the National Research Council (2001), which noted that banking had the *potential* to solve some of the characteristic problems of compensatory mitigation (this claim is still under active debate; see Sibbing 2005 and Mogensen 2006). Over this period, a growing ecological and economic literature has supported banks and market mechanisms in environmental policy (Anderson and DeCaprio 1992, Lewis 1992, Etchart 1995, Albrecht and Wenzel 1996, Dennison and Schmid 1997, Neal 1999, Stein and others 2000, Farber 2004).

An appealing explanation for the decreasing average impact size trend is that the successful application of the mitigation sequencing guidelines has gradually caused developers to avoid and minimize previously unavoidable impacts. However, this explanation does not take into account the decreasing federal MMIS or the fact that sequencing guidelines are not enforced for Nationwide Permits. We contend that the declining aggregate trend (1993–2004; $p < 0.001$) in wetland impact size is largely a result of changes to the regulatory minimum shown in Figure 2.

Rather than being attributable to developer avoidance and minimization of wetland impacts, this trend appears to be driven by the inclusion of progressively smaller, previously unregulated impacts between 1997 and 2004. As shown in Table 1, until 1997 small wetland impacts (less than 1 acre) did not require permits (or even notification to the Corps), meaning that they were not recorded by federal authorities. This lack of early reporting ensures that current and future regulations, which act to broaden the set of

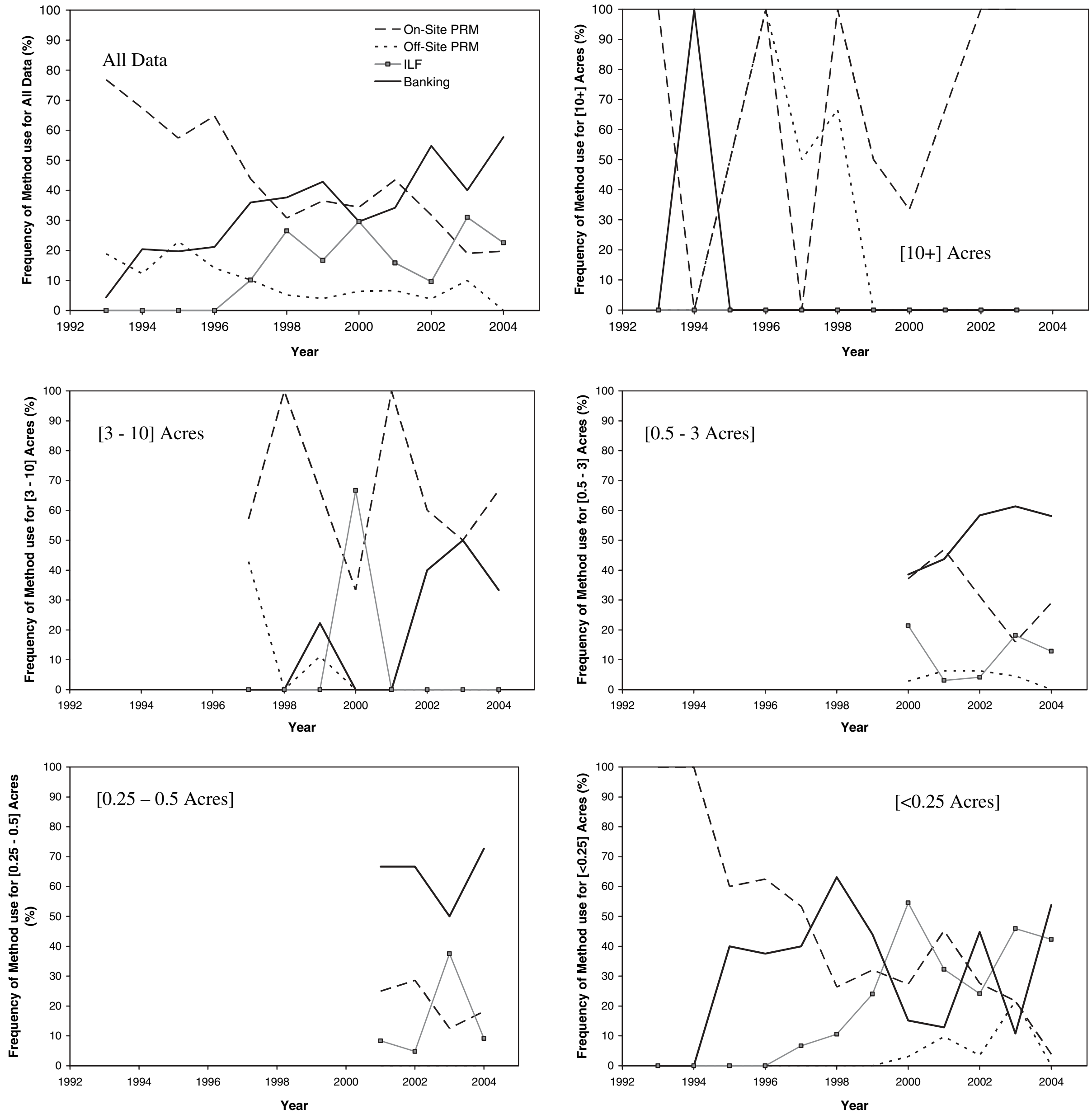

Fig. 4 Shifting usage of mitigation methods. Size classes follow those given in Table 3. The steady decline in all on-site permittee-responsible mitigation (PRM) follows the decline of on-site mitigation for small wetland impacts. It also mirrors the niche growth in banking for the same sets of small impacts. The steady decline in off-site PRM demonstrates regulator disfavor with quality control and monitoring at these sites. This trend also may highlight ethical conflicts on the part park and forest preserve districts in providing access to their land for mitigation activities. Steady growth of mitigation banking has been supported by smaller impacts, mostly those less than half an acre. Only one impact over 10 acres has utilized a bank (1994). Includes transactions using both in-lieu fee and Corlands mitigation

impacts requiring compensation, will appear to have reduced average impact sizes.

Our data also demonstrate an inverse relationship between average impact size and displacement distance. This is seen in the correlation between the changing requirements for small impact compensation and the increasing average displacement distance between 1993 and 2004 for the aggregate dataset ($p < 0.0001$; Figure 3).

Here, we are interested in the potential interplay between urban development and changing regulations in relocating wetlands. We believe that these findings offer an additional explanation for the growth of the banking industry, as well as an alternative (and perhaps more nuanced) explanation for the work of Salzman and Ruhl (2004) and their recent empirical findings (Ruhl and Salzman 2006).

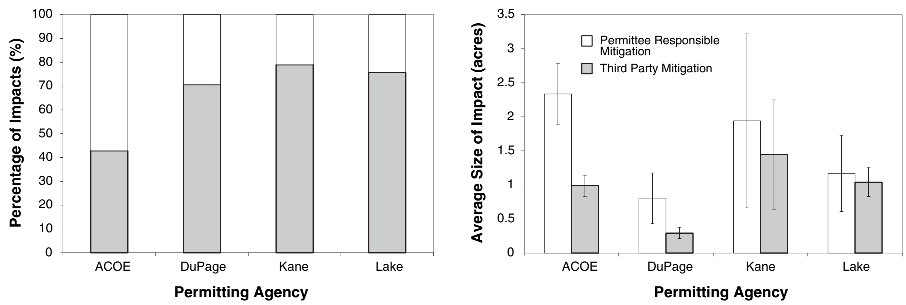

Fig. 5 Distribution of mitigation methods among agencies and impact sizes. Left panel: Percentage of impacts encountering permittee responsible (on- and off-site) and third party mitigation (in-lieu fee, Corlands, and banking). Right panel: Average impact size for permittee responsible and third-party mitigation (95% confidence interval shown). The large interval for Kane county is due to low number of observations (N = 19)

Table 5 Rates of Cross-Watershed and Cross-County Mitigation (%)

		% Cross-watershed				% Cross-county [a]
		Corps	DuPage	Kane	Lake	Corps
Size classes (acres)	>10	13.3	0.0	N/A	N/A	13.3
	3 – 10	6.7	0.0	100.0	0.0	0.1
	0.5 – 3	10.0	3.8	20.0	28.3	26.7
	0.25 – 0.5	16.3	0.0	0.0	27.3	27.9
	<0.25	9.2	7.1	28.6	0.0	28.6
	All	11.1	4.9	31.6	24.2	22.1
	N	85	10	6	16	170
	N_{total}	769	204	19	66	769

Cross-watershed and cross-county mitigation rates for both aggregate dataset (''All'') and size classes. N: Total number of impact mitigated cross-watershed and cross-county, N_{total}: Total number of impacts (N_{total}), N/A: Kane and Lake Counties did not have any impacts mitigated in this size category

[a] Kane and Lake Counties each provide mitigation for one out-of-county impact

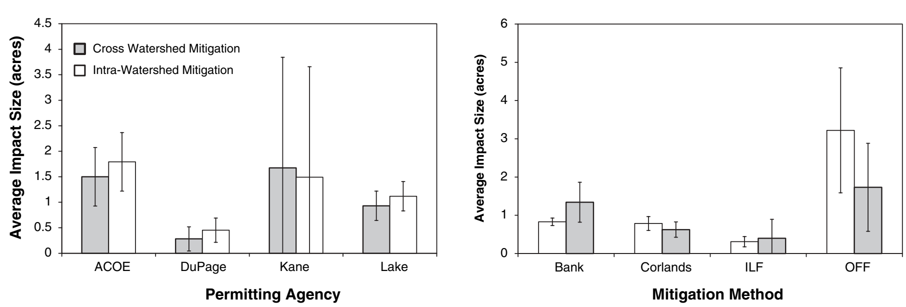

Fig. 6 Comparisons of intra- and cross-watershed mitigation behavior. Left panel: Analysis of entire dataset by permitting agency (n = 1058; 95% confidence interval shown). The wide variation for Kane County is due to the low number of observations (n = 19). Right panel: Analysis of entire dataset by mitigation method (n = 1058). Both panels include on-site mitigation transactions. ACOE, Army Corps of Engineers; ILF, in-lieu fee

Salzman and Ruhl (2004) hypothesized that low bank prices could stand as a major factor in lowering the financial barriers to wetland impacts, thereby simplifying the process of development on wetlands. This simplification (lower prices through market efficiency) could be construed (although this would be difficult to test) to mean that banks could facilitate impacts that would have otherwise been minimized or altogether avoided. The authors' empirical work (2006) offers evidence that supports this hypothesis, showing that banks frequently have been located in areas with low land values (usually at the urban periphery), thereby enabling them to offer low credit prices, which in turn has compelled developers to choose banking over other mitigation methods.

However, by isolating periods of consistent regulatory treatment, we believe that our data provide another possible explanation for bank industry growth in the Chicago region. Here, we argue that banking does not necessarily facilitate development, but rather takes advantage of the influx of small impacts that now require compensation due to the steadily decreasing MMIS.

King and Bohlen (1994) found that wetland restoration activities exhibit scale economies, whereby a 10% increase in project size commonly leads to a decline of approximately 3.5% in the per acre cost of nonagricultural projects. We theorize that large impacts will tend to be mitigated on site or at off-site PRM locations, because the large mitigation acreage creates the same type of scale economies associated with banks. These scale economies make PRM cost effective for large impacts and allow developers to avoid payments to a third party and manage their own mitigation. Conversely, developers responsible for small wetland impacts lack economies of scale in mitigation and therefore have to pay a third party with appropriate expertise to manage mitigation.

It is evident from our data that certain impact size groups have driven the increasing aggregate trend in displacement distance observed between 1993 and 2004 (Fig. 3). Evidence of this can be seen in the high rate at which on- and off-site PRM, rather than banking, is used with larger impacts (3–10 and 10+ acres). Conversely, small impacts have an especially high rate of using banks and ILF sites. These mitigation sites tend to be further away (confirming the work of Ruhl and Salzman 2006), which means that small impacts are being relocated further across the landscape than larger impacts. This is a particularly important finding for Kane and Lake Counties, whose wetland permitting programs have been particularly willing to accept third-party mitigation methods as a means of compensation. Unfortunately, given the current regulatory framework and economic incentives for mitigation, a reliance on third-party mitigation (particularly banking) may mean that these agencies are facilitating the urban to rural wetland migration criticized for its potential creation of social disparity and inequity by King and Herbert (1997) and Ruhl and Salzman (2004, 2006).

Finally, we believe that the high rate of cross-watershed transactions present in the County programs is due in part to the high number of watershed divisions present in Kane and Lake Counties (each county falls into four separate watersheds, whereas DuPage County falls into parts of only two). Furthermore, given the rapid rate of development in Lake County, the lack of mitigation banks in the Chicago River and Lake Michigan watersheds may be necessitating mitigation transactions into neighboring watersheds (Fig. 6). Here, the land values in some impact watersheds may be high enough to exceed the cost of cross-watershed mitigation at higher mitigation ratios. The limited displacement distances associated with county agencies are likely due to county prohibitions on locating mitigation outside of county boundaries (DuPage County 2006, Kane County 2005, Lake County 2006). By delimiting potential compensation areas using county boundaries, county programs may be preventing the migration of wetlands out of their respective jurisdictions, but at the expense of inviting the hydrologic problems caused by cross-watershed mitigation discussed earlier.

Conclusions

This study used 12 years of wetland impact and mitigation data to explore spatial and temporal trends in wetland mitigation in the Chicago region. During the study period, changes in the regulatory framework mean that trends in the aggregate data may be confounded by selection bias; to avoid this problem, we analyzed data by impact size class and within consistent regulatory intervals.

Spatial analysis of individual wetland mitigation transactions reveals several behaviors present in Chicago wetland mitigation programs that have not been previously described. In particular, within a consistent regulatory interval, we cannot reject the hypothesis that there is no time trend in the aggregate impact size data. Thus, we argue that the observed declining average impact size is likely a function of changing standards governing the amount and type of impacts regulated. Without more information on the sizes and types of impacts proposed, we cannot say whether or not these patterns also reflect a change in the development process rather than a fundamental change in the development process. Additionally, we have demonstrated that the rising average displacement distance over time is primarily driven by the mitigation of small, previously unregulated impacts in wetland banks.

Our data demonstrate that preferred mitigation type varies with impact size. Large impacts are primarily mitigated on-site, whereas small impacts are primarily mitigated using third-party methods. The decreasing compensation threshold has increased the relative number of small impacts, whose developers have preferentially used mitigation banks. We contend that banks may be taking advantage of the high transaction costs associated with on-site PRM for small developments. As impacts grow, on-site mitigation becomes increasingly feasible due to scale economies associated with wetland restoration. Finally, our analysis shows that impacts permitted by local regulators have lower displacement distances and are less likely to cross county boundaries, but more likely to cross watershed boundaries, than impacts permitted by the Corps.

There are two sets of implications for this work. First, we have shown that changing regulations have had significant effects on the patterns associated with mitigation programs in the Chicago region. In order to avoid mischaracterization of spatial and temporal trends, future research on mitigation transactions should account for changes in the types and sizes of impacts for which regulators require compensatory mitigation. We speculate that regulators have assisted the rapid growth in the banking industry by requiring compensation for smaller impacts that are not economical for permittees to mitigate themselves, thereby helping to increase the potential customer base of banks.

Second, our analysis can inform wetland mitigation policy in several ways. Recent U.S. Supreme Court decisions handed down in *Rapanos v. United States* (S.Ct. No. 04-1034) and *Carabell v. Corps* (S.Ct. No. 04-1384) may limit Corps jurisdiction over certain isolated wetlands. If the shift toward local control over wetland regulation continues (as it did after *SWANCC*), many new county and municipal units across the country may create their own permitting processes. We have shown that some Chicago counties prohibiting cross-county mitigation experience higher rates of cross-watershed mitigation. It is clear that regulations requiring in-county mitigation are likely to lower displacement distance and maintain wetland resources within the county. However, we have shown that these regulations may come at the expense of replacing wetlands outside of their original watersheds; this is a troubling pattern if watersheds are the appropriate scale for wetland preservation. Stakeholders should consider this outcome of local control when working with local regulators in establishing new policies and ordinances.

This work also presents significant avenues for further research on wetland mitigation and, more generally, ecosystem service trading issues. The major constraint of the research presented here lies in the availability of accurate data for assessing the behavior of regulators and developers in compensating for wetland losses. Data collection is difficult, although new data collection infrastructure being adopted by the Corps will hopefully rectify the current lack of reliable information on mitigation projects (Olson 2004, 2005). Additional data and analyses could answer an important group of questions emerging from this study. Given the apparent divergence in behavior between developers responsible for small and large impacts, how can regulators increase compensation quality? How do developers minimize the full set of costs (not just compensation) associated with minimizing and mitigating development impacts? We suggest that a much more thorough discussion of the nature of watershed-centered compensation regulations is warranted. For example, what are the implications of prohibiting wetland mitigation across political boundaries at the potential cost of increased rates of cross-watershed mitigation? Answers to these questions will enhance the ability of regulators to establish successful programs for protecting against the loss of our nation's valuable wetland resources.

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References

Albrecht V, Wenzel M (1996) A view from the private sector. In: Marsh LL, Porter DR, Salvesen DA (eds.) Mitigation banking: theory and practice. Island Press, Washington, DC, pp 77–87

Allen AO, Feddema JJ (1996) Wetland loss and substitution by the Section 404 Permit Program in Southern California, USA. Envir Manage 20:263–274

Anderson R, DeCaprio R (1992) Banking on the Bayou. Natl Wetlands Newslett 14:10

Bedford BL (1996) The need to define hydrolic equivalence at the landscape scale for freshwater wetland mitigation. Ecolog Applic 6:57–68

BenDor T, Brozovic N, Pallathucheril VG (2007) Assessing the socioeconomic impacts of wetland mitigation in the Chicago region. J Am Planning Assoc (in press)

Booth TE (2004) Compensatory mitigation: what is the best approach? Baltimore J Envir Law 11:205–221

Brody SD, Highfield WF (2005) Does planning work? Testing the implementation of local environmental planning in Florida. J Am Planning Assoc 71:159–175

Brown S, Veneman P (1998) Compensatory wetland mitigation in Massachusetts. Massachusetts Agriculture Experiment Station, University of Massachusetts, Amherst, MA

Cole CA, Shafer D (2002) Section 404 wetland mitigation and permit success criteria in Pennsylvania, USA, 1986–1999. Envir Manage 30:508–515

Corps (U.S. Army Corps of Engineers) (1997) Interagency coordination agreement on wetland mitigation banking within the regulatory boundaries of Chicago District, Corps of Engineers. Chicago District of the U.S. Army Corps of Engineers. [Online]: 12/1/2005. http://www.lrc.army.mil/co-r/ica_all.htm

Corps (2000a) Corps facts: background of nationwide permits. U.S. Army Corps of Engineers Regulatory Program. [Online]: 5/4/2006. http://www.usace.army.mil/inet/functions/cw/cecwo/reg/press/background.pdf

Corps (2000b) DuPage County programmatic general permit (RP-25). Chicago District of the U.S. Army Corps of Engineers. [Online]: 5/4/2006. http://www.lrc.usace.army.mil/co-r/rpglist.htm

Corps (2000c) Talking points: Corps NWP revisions (March 6, 2000). U.S. Army Corps of Engineers Regulatory Program. [Online]: 5/4/2006. http://www.usace.army.mil/inet/functions/cw/cecwo/reg/press/talking.pdf

Corps (2005) Chicago district regional permit program. Chicago District of the U.S. Army Corps of Engineers. [Online]: 5/5/2006. http://www.lrc.usace.army.mil/co-r/webrpp2004.pdf

Corps (2006) Draft environmental assessment, finding of no significant impact, and regulatory analysis for proposed compensatory mitigation regulation. U.S. Army Corps of Engineers, Washington, DC, March 13, 2006

Corps and EPA (1990) Memorandum of agreement between the Environmental Protection Agency and the Department of the Army concerning the determination of mitigation under the Clean Water Act section 404(b)(1) guidelines. [Online]: 3/30/2005. http://www.epa.gov/owow/wetlands/regs/mitigate.html

Corps and EPA (1995) Federal guidance for the establishment, use and operation of mitigation banks. 60 Fed. Reg. 228, 58605–58614. [Online]: 6/13/2005. http://www.epa.gov/owow/wetlands/guidance/mitbankn.html

Corps and EPA (2000) Federal guidance on the use of in-lieu-fee arrangements for compensatory mitigation under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. [Online]: 1/4/2005. http://www.epa.gov/owow/wetlands/pdf/inlieufee.pdf

Corps and EPA (2006) Draft regulation: compensatory mitigation for losses of aquatic resources. U.S. Army Corps of Engineers and U.S. Environmental Protection Agency: 71 Fed. Reg. 59, 15520–15556

DuPage County (2006) DuPage County Stormwater and Floodplain Ordinance (Rev. Feb 8, 2006). DuPage County Department of Environmental Concern, Stormwater Management Division. http://www.dupageco.org/stormwater/

Dahl T (2006) Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C

Dahl T (1990) Wetlands losses in the United States, 1780s to 1980s. U.S Department of the Interior, Fish and Wildlife Service, Washington, D.C

Dennison MS, Schmid JA (1997) Wetland mitigation: mitigation banking and other strategies for development and compliance. Government Institutes, Rockville, MD

Environmental Law Institute (2002) Banks and fees: the status of off-site wetland mitigation in the United States. Environmental Law Institute, Washington, DC

Environmental Law Institute (2006) 2005 status report on compensatory mitigation in the United States. Environmental Law Institute, Washington, D.C

Etchart G (1995) Mitigation banks: a strategy for sustainable development. Coastal Manage 23:223–237

Farber DA (2004) Mitigation banking: stemming the rising constitutional tide. Natl Wetlands Newslett 26:5–6, 27

Freeman GE, Rasband JR (2002) Federal regulation of wetlands in aftermath of Supreme Court's decision in SWANCC v. United States. J Hydraulic Eng 128:806–810

Gaddie RK, Regens JL (2000) Regulating wetlands protection: environmental federalism and the states. State University of New York Press, Albany, NY

Goldman-Carter JL (1992) The unraveling of no net loss. Natl Wetlands Newslett 14:12–14

Healey JF (2005) Statistics: a tool for social research (7th ed.). Thomson Wadsworth, Belmont, CA

Hoehn JP, Lupi F, Kaplowitz MD (2003) Untying a Lancastrian bundle: valuing ecosystems and ecosystem services for wetland mitigation. J Envir Manage 68:263–272

Kane County (2005) Kane County Stormwater Ordinance, Kane County Stormwater Management. http://www.co.kane.il.us/kcstorm/

Kentula M, Sifneos J, Good J, Rylko M, Kunz K (1992) Trends and patterns in section 404 permitting requiring compensatory mitigation in Oregon and Washington, USA. Envir Manage 16:109–119

King DM (1998) The dollar value of wetlands: trap set, bait taken, don't swallow. Natl Wetlands Newslett 20:7–11

King DM, Bohlen C (1994) Estimating the costs of restoration. Natl Wetlands Newslett 16:3–5, 8

King DM, Herbert LW (1997) The fungibility of wetlands. Natl Wetlands Newslett 19:10–13

Lake County (2006) Lake County Watershed Development Ordinance (Rev. Jan. 10, 2006), Lake County Stormwater Management Commission. http://www.co.lake.il.us/smc/regulatory/wdo/docs.asp

Lewis RR (1992) Why Florida needs mitigation banking. Natl Wetlands Newslett 14:7

Marsh LL, Acker DR (1992) Mitigation banking on a wider plane. Natl Wetlands Newslett 14:8–9

Metropolitan Water Reclamation District of Greater Chicago (2005) Our community and flooding. [Online]: 3/30/2006. http://www.mwrdgc.dst.il.us/Engineering/OurCommunityFlooding/OCFBody0104.htm

Mitsch WJ, Wilson RF (1996) Improving the success of wetland creation and restoration with know-how, time, and self-design. Ecol Applic 6:77–83

Mogensen RK (2006) Mitigation Banking: It's No Myth. Natl Wetlands Newslett 28:15–16, 21

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

Neal J (1999) Paving the road to wetlands mitigation banking. Boston College Envir Affairs Law Rev 27:161–192

Olson D (2004) The OMBIL Regulatory Module and Geographic Information Systems: an overview. Army Corps Eng Aquat Resource News 3:2–4

Olson D (2005) Advanced information system to support Corps' wetland regulatory program. Natl Wetlands Newslett 27:19–21

Race MS, Fonseca MS (1996) Fixing compensatory mitigation: what will it take? Ecol Applic 6:94–101

Robb JT (2002) Assessing wetland compensatory mitigation sites to aid in establishing mitigation ratios. Wetlands 22:435–440

Robertson MM (2004) Drawing lines in water: entrepreneurial wetland mitigation banking and the search for ecosystem service markets. Unpublished PhD Dissertation: University of Wisconsin at Madison, Department of Geography, Madison, WI

Robertson MM (2006) Emerging ecosystem service markets: trends in a decade of entrepreneurial wetland banking. Frontiers Ecol Envir 4:297–302

Ruhl JB, Gregg RJ (2001). Integrating ecosystem services in environmental law: a case study of wetlands mitigation banking. Stanford Envir Law J 20:365–392

Ruhl JB, Salzman J (2006) The effects of wetland mitigation banking on people. Natl Wetlands Newslett 28:1, 9–14

Salzman J, Ruhl JB (2000) Currencies and the comodification of environmental law. Stanford Law Rev 53:607–694

Salzman J, Ruhl JB (2004) ''No net loss'' and instrument choice in wetland protection. Natl Wetlands Newslett 26:3–4, 16–20

Scodari P (1990) Wetlands protection: the role of economics. Environmental Law Institute, Washington, D.C

Seaber PR, Kapinos FP, Knapp GL (1987) Hydrologic unit maps. U.S. Geological Survey, Washington, D.C

Semlitsch RD (2000) Size does matter: the value of small isolated wetlands. Natl Wetlands Newslett 22:5–6, 13

Shabman L, Scodari P (2004) Past, present, and future of wetlands credit sales. Resources for the Future, Washington, D.C

Shabman L, Scodari P (2005) The future of wetlands mitigation banking. Choices 20:65–69

Sibbing J (2005) Mitigation banking: will the myth ever die? Natl Wetlands Newslett 27:5–6, 8

Stein ED, Ambrose RF (1998) Cumulative impacts of Section 404 Clean Water Act permitting on the riparian habitat of the Santa Margarita, California watershed. Wetlands 18:393–408

Stein ED, Tabatabai F, Ambrose RF (2000) Wetland mitigation banking: a framework for crediting and debiting. Envir Manage 26:233–250

Thomas R, Lamb Z (2004) Scientific perspectives on a watershed approach to compensatory mitigation. Natl Wetlands Newslett 26:17–20

Tiner R (1997) Geographically isolated wetlands of the United States. Wetlands 23:494–516

Tiner R (2003) Estimated extent of geographically isolated wetlands in selected areas of the United States. Wetlands 23:636–652

Tolman J (2004) How we achieved no net loss. Natl Wetlands Newslett 19:1, 19–22

Turner RE, Redmond AM, Zedler JB (2001) Count it by acre or function: mitigation adds up to net loss of wetlands. Natl Wetlands Newslett 23:5–6

Urban DT, Ryan JH, Mann R (1999) A lieu-lieu policy with serious shortcomings. Natl Wetlands Newslett 21:5, 9–11

Weems WA, Carter LW (1995) Planning and operational guidelines for mitigation banking for wetland impacts. Envir Impact Assess Rev 15:197–218