A SPATIAL-TEMPORAL ANALYSIS OF SECTION 404 WETLAND PERMITTING IN TEXAS AND FLORIDA: THIRTEEN YEARS OF IMPACT ALONG THE COAST

Samuel D. Brody[1], Stephen E. Davis, III[2], Wesley E. Highfield[1], and Sarah Bernhardt[1]

[1]*Department of Landscape Architecture & Urban Planning*

Environmental Planning and Sustainability Research Unit

Texas A&M University

College Station, TX 77845-3137

[2] *Corresponding author:*

Department of Wildlife and Fisheries Sciences

Texas A&M University

College Station, TX 77845-2258

E-mail: sedavis@tamu.edu

Abstract: Over the past 200 years, an estimated 53% (about 47 million ha) of the original wetlands in the conterminous United States have been lost mainly as a result of various human activities. Despite the importance of wetlands (particularly along the coast), and a longstanding federal policy framework meant to protect their integrity, the cumulative impact on these natural systems over large areas is poorly understood. We address this lack of research by mapping and conducting descriptive spatial analyses of federal wetland alteration permits (pursuant to section 404 of the Clean Water Act) across 85 watersheds in Florida and coastal Texas from 1991 to 2003. Results show that over half of the permits issued in both states (60%) fell under the Nationwide permitting category. Permits issued in Texas were typically located outside of urban areas (78%) and outside 100-year floodplains(61%). Over half of permits issued in Florida were within urban areas (57%) and outside of 100-year floodplains (51%). The most affected wetlands type were Estuarine in Texas (47%) and Palustrine in Florida (55%). We expect that an additional outcome of this work will be an increased awareness of the cumulative depletion of wetlands and loss of ecological services in these urbanized areas perhaps leading to increased conservation efforts.

Key Words: Clean Water Act, Section 404 permitting, coastal wetlands, urban development, dredge-and-fill activity, mitigation

INTRODUCTION

Naturally occurring wetlands are a vital component of this country's ecological infrastructure and provide essential ecosystem services to human communities. Ecosystem services including biodiversity support, water quality improvement, flood attenuation, and carbon sequestration are central landscape functions that are impaired when wetlands are lost or degraded (Zedler and Kercher 2005). Despite the importance of wetlands (particularly along the coast), the cumulative impact on these natural systems over large areas is poorly understood. There has been a longstanding federal policy framework meant to protect their integrity, yet very little is known concerning policy-related impacts over broad spatial and temporal scales. We address this lack of research by mapping and conducting descriptive spatial analyses of permits issued pursuant to Section 404 of the Federal Water Pollution Control Act ("Clean Water Act") across Florida and coastal Texas from 1991 to 2003.

The following section reviews the existing research on impacts of federal wetland protection under Section 404 of the Clean Water Act (CWA). Next, we describe the approach and methods used to couple Section 404 permit locations with other spatially derived variables. Finally, we provide spatially explicit descriptors of permit issuance over time and space and discuss how the results can help guide planners and policymakers concerned with wetland protection issues.

Research on the Impacts of Section 404

While an abundance of literature exists pertaining to the functions, values, and restoration of wetlands, there is a relatively small amount of empirical literature concerning the impacts of the Section 404 permitting program. Furthermore, the vast majority of the permitting literature compares permitted losses to compensatory mitigation (Kentula et al. 1992, Sifneos et al. 1992a, Cole and Shafer 2002, among others). Although our study does not explicitly address compensatory mitigation, when taken with the results of theses other studies, our data reveal the potential magnitude of impact associated with this environmental permitting program.

Sifneos et al. (1992a) examined the Section 404 program in numerous areas of the country. Results for the Texas study area found a net loss of 917 acres of wetlands in the Fort Worth District USACE between 1982 and 1986 that required compensatory mitigation. Additionally, 52% of the number of impacted wetlands (representing 35% of the area impacted) was located in the Dallas-Fort Worth metropolitan area. The authors' theorized that the real-estate market during this time period was growing, and furthermore expanding into the remaining riparian woodlands in the area (Sifneos et al. 1992a). A study on Section 404 permitting and mitigation in Oregon and Washington found comparable results. Kentula et al. (1992) found that over a 10 year period in Oregon (1977 – 1987) 74 ha of wetlands were impacted and 42 hectares were created; a net loss of 43%. In Washington from 1980 – 1986, 61 hectares of wetlands were impacted and 45 ha were created—a 26% net loss. Permitted activities in both states occurred near urban areas (Kentula et al. 1992). Owen and Jacobs (1992) conducted a similar study in Wisconsin, and found that 422 acres of wetlands were permitted while only 40 acres were created in the first 6 months of 1988. The authors also concluded that while the permitting program is, in effect, a land use control it performs poorly as such (Owen and Jacobs 1992).

Other empirical work concerning Section 404 permitting is centered on pre-permit and post-permit landscape conditions and cumulative impacts. Stein and Ambrose (1995) conducted an on-site study examining riparian areas in the Santa Margarita watershed in Southern

California. They concluded that while the Section 404 program had reduced overall project impacts, it had not minimized cumulative impacts. They also concluded that although NWPs accounted for only 21% of the impacted area, they contributed to 55% of the area that had substantial impacts. Thus NWPs accounted for proportionally more cumulative impacts despite the fact that they affect less total area across the watershed (Stein and Ambrose 1995). Additionally, this study appears to be one of the first to point out the high degree of correlation between population growth and cumulative permit actions. Using remotely sensed data in North Carolina, Kelly (2001) found net loss of wetlands under the Section 404 permitting program in addition to habitat fragmentation in 80% of areas adjacent to permit sites. This suggests additional 'nibbling' impacts associated with permitted activities that are not taken into consideration during individual permit review (Kelly 2001).

Evidence suggests that Section 404 permitting has and continues to cause at least some form of wetland impact if not altogether net wetland losses. This statement appears to hold despite federal policy of a "no net loss" of wetlands. Some of the literature concerning Section 404 does suggest that permitting activity is a direct result of urban growth and expansion. Other general research concerning wetland losses also suggests urban growth as the primary cause of wetland loss (Brady and Flather 1994, Holland et al. 1995, USGS 1996) while others have singled out navigational dredging and spoil banks as a primary driver (Turner 1997).

METHODS

Selecting Florida and coastal Texas as study areas in which to examine the pattern of wetland alteration provides an ideal basis for comparison. Both states border the Gulf of Mexico and rank among the top five in terms of total wetland area (estimated at 4.5 million ha for Florida and 3 million ha for Texas) comprising largely of palustrine and estuarine wetlands (Dahl 1990).

Florida and Texas are also among the five most populous states—currently estimated at nearly 18 million and 23 million, respectively (U.S. Census Bureau). However, their different geography, policy climates, and development patterns also make for a powerful comparative analysis.

Florida has experienced one of the largest percentages of wetland loss of any state in the country (Mitch and Gosselink 2000). Since the 1700's drainage for agriculture, channelization for human water supply, and most recently urban and suburban development have contributed to the conversion of more than half of the original wetland acreage. Rapid population growth and associated development over the last decade has resulted in a concentrated pattern of wetland alteration in the fringe or outside of urban areas (see Brody and Highfield 2005).

In contrast, coastal Texas has not yet experienced the same degree of urban and suburban development, except for the Corpus Christi and Houston-Galveston metropolitan areas. Most of the Texas coast is relatively undeveloped such that the natural hydrological structure of its watersheds is more intact compared to Florida. While Texas has a relatively small percent of the total U.S. coastal population, population by shoreline mile is expected to double between 1960 and 2010 to 1,956 people per mile (Culliton et al. 1990). These trends indicate that the Texas coast will become one of the fastest growing coastal regions in the country. Projected increases in tourism and recreation, commercial and industrial projects, and second home ownership within the state's coastal zone will inevitably result in accelerated wetland alteration and potential corresponding problems with watershed flooding.

We selected for analysis all federal permits issued under Section 404 of the CWA to alter a naturally occurring wetland from 1991 to 2003 within 100 miles of the nearest coastline. This area encompassed the USACE Jacksonville District—covering all of Florida—and the USACE

Galveston District—spanning the entire coastal zone in Texas (see Figure 1). Each permit record included the permit type (based on the four categories described above), the date issued, and the geographic location of the permit (latitude and longitude). We geocoded the permit database using the given latitude and longitude coordinates in a geographical information system (GIS) to graphically and statistically describe the pattern of coastal wetland alteration. Of the 45,897 permits received from the USACE during the study period, 7,294 had insufficient geographic information due to data entry errors or lack of geographic information altogether.

(Insert Figure 1 here)

We constructed several additional measures to descriptively analyze the permit record. Permits were categorized by state, year and the four types permitted under Section 404 of the CWA: Individual, Nationwide, Letter of Permission, and General (for more information on wetland permitting, see Brody and Highfield 2005, Highfield and Brody 2006). We also used GIS analytical techniques to estimate the type of wetland being altered according to the most recent National Wetland Inventory (NWI) database. The Texas NWI data was based off of imagery collected from 1992 – 1993; Florida NWI data was based off of imagery collected from 1972 – 1982. We categorized the following five wetland types: estuarine, lacustrine, marine, palustrine, and riverine. Because positional accuracy varies in both the NWI and the permit dataset, permit locations did not always fall directly on an NWI-delineated wetland. In this case the nearest NWI polygon attributes were transferred to permit locations up to 1 km in distance. Permits with no NWI wetland within 1 km were dropped from this part of the analysis. Finally, we used GIS to measure two locational variables. First, we calculated the number and percentage of permits in urban areas as defined by the U.S. Census to gauge the degree to which development is occurring close to city centers. Second, we measured the number and percentage of permits within the FEMA-defined 100-year floodplain. Previous studies show that wetland alteration within floodplains may exacerbate local flooding and associated property loss (Highfield and Brody 2006). It is important to note that due to lack of digital FEMA data, 100 permits in Texas could not be associated with a particular floodplain.

RESULTS

Of the 38,603 federal wetland alteration permits analyzed in Texas and Florida, approximately 60% were categorized as Nationwide, 22% General, over 13% Individual, and only 8.4% Letters of Permission (Table 1). The vast majority of these permits were granted in Florida (71 %) where rapid growth and development has occurred over the last several decades. A majority of nationwide permits (60% versus 45%) and a slightly larger percentage of Individual permits were issued in Florida compared with Texas. In contrast, almost twice the percentage of General permits were issued in Texas involving mostly small-scale individual projects located outside or on the fringe of major urban areas.

(Insert Table 1 about here)

As shown in Figure 1, wetland alteration permits in Florida are concentrated within coastal urban areas, particularly in the southeast portion of the state stretching from the Keys north to West Palm Beach. The western coastline from heavily urbanized Pinellas County south to Naples is also heavily dominated by wetland alteration. The south central part of the State has comparatively fewer permits due to the presence of large protected areas associated such as the Everglades and Big Cypress ecosystems that act to buffer sprawling development. Permits to spill over into central portions of Florida in and around the Orlando area where protected areas are not as prevalent.

As illustrated in Figure 1, wetland alteration in coastal Texas also coincides with heavily urbanized areas, such as Houston/Galveston, Beaumont, and Corpus Christi. Due in part to the lack of protected areas and the sprawling nature of development along the Texas coastal margin, the distribution of wetland permits is more dispersed compared to Florida, particularly when considering areas between Houston and Corpus Christi.

(Insert Figure 1 about here)

The temporal trend of permit issuance indicates the scale and type of wetland alteration for a given year. In both states, the number of wetland alteration permits steadily increased each year until the middle of the study period, and then began to decrease in the late 1990s. In Florida, the number of granted permits peaked in 1995, and then gradually decreased until 2000. The most intense wetland development occurred between 1994 and 1997 (Figure 2). The end of the study period saw an upward shift in both the number of Nationwide and General permits. In Texas, the number of granted permits follows a more erratic trend (Figure 3). The issuance of General permits spiked in 1996 and 2001. Nationwide permits increased steadily until 1996, then gradually decreased only to abruptly increase again in 2002 and 2003.

(Insert Figures 2 and 3 about here)

The location of permits issued to alter a naturally occurring wetland is also important because it indicates the pattern of development and corresponding impact on the natural environment over time. For example, in Texas, 78% of wetland permits were issued outside of urban areas, reflecting sprawling growth patterns associated with coastal development (Table 2). Interestingly, the disparity between permits granted in and out of urban areas increased over the study period. When considering areas vulnerable to flooding where naturally occurring wetlands have been shown to be most valuable as flood mitigation devices (Highfield and Brody 2006), results show that 38.5% of permits in coastal Texas were issued within the 100-year floodplain. This development pattern remained relatively consistent throughout the study period. Florida tells a different story when examining the location of wetland alteration (Table 3). Over 57% of permits were issued within urban areas, suggesting a more confined overall spatial pattern of development compared to Texas. In terms of development in areas most vulnerable to flooding, almost half (48%) of the permits issued in Florida were located within the 100-year floodplain.

(Insert Tables 2 and 3 about here)

By spatially tying permits to the National Wetland Inventory data, we are able to estimate both the degree of wetland alteration over time and the type of wetland system being impacted by various development activities. In coastal Texas, the majority of wetland permits are associated with estuarine systems (Table 4). Estuarine or tidal fringe wetlands are usually found between the open saltwater of the bays or Gulf and the uplands of the coastal plain and barrier islands. This finding reflects the concentrated development patterns adjacent to coastal waters, particularly around Galveston and Corpus Christi Bays. Palustrine wetlands also comprise a significant percentage (almost 36%) of wetland alteration permits in Texas. These development activities most likely take place further inland off the direct coastline in non-tidal areas or tidal areas where salinity due to ocean-derived salts is below 0.5%. Over 72% of altered palustrine wetlands are supported by Nationwide permits, indicating these wetland systems are being impacted cumulatively from smaller-scale developments symptomatic of sprawl. In Florida the majority of permits are associated with impacts to palustrine wetlands, primarily through the Nationwide category (Table 5). Again, alteration of this wetland type appears to be the result of individual residential projects dispersed over time and space that have a cumulative effect on wetland loss.

(Insert Tables 4 and 5 about here)

DISCUSSION

By mapping and analyzing wetland alteration permits, we gain a better understanding of how development activities are impacting wetland systems at relatively large temporal and spatial scales. These findings can provide guidance to ecological planners and wetland scientists on how and where to minimize losses of naturally occurring wetlands in the future. First, our results indicate a more intense and widespread pattern of wetland alteration than previously expected. In Florida, an average of 2,111 permits was granted per year from 1991 to 2003, mostly in coastal urban areas. We could not ascertain the precise acreage of wetlands altered during this time period, but Individual permits alone accounts for at least 2,000 acres. In coastal Texas, wetland alteration occurred over a surprisingly large area in and around the Houston metropolitan area where palustrine wetlands were heavily impacted. Even though the heaviest growth in the region is yet to come, over 857 permits per year were granted for the Texas study area. Texas also granted more General permits which is a special category of Nationwide. These permit types are most likely associated with oil and gas production activities pervasive in parts of eastern Texas. A general permit category may be providing industry with the rapid authorization needed to constructing pipelines, wells, and other oil and gas activities. In general, both the intensity and spatial pattern of wetland alteration via the Federal permitting process should serve as a warning sign to policy makers interested in protecting the value of existing wetlands for future generations. These trends also highlight the need to increase the effectiveness of compensatory wetland mitigation.

It is important to note that while wetland alteration under federal guidelines is almost always accompanied by mitigation at a ratio of 2:1 or higher, the ecological efficacy for restoration or replacement is questioned by many wetland scientists. In many cases, vegetative characteristics in created wetlands begin to resemble wetlands over a relatively short period of time (i.e., months to years), especially where planting activities have facilitated this establishment (Seabloom and van der Valk 2003). However, there is growing evidence that created wetlands do not function as natural wetlands, even after several decades post-creation (Cole and Brooks 2000, Brusati et al. 2001, Campbell et al. 2002, Cole and Shafer 2002). Moreover, there are studies documenting the failures of previous attempts at wetland mitigation. The bulk of these failures seem to be associated with inappropriate hydrologic conditions (e.g., ponding or deepwater as opposed to shallow or intermittent flooding) or an insufficient monitoring program to fully assess the development of mitigated wetland ecosystems through time (Erwin 1991, Gallihugh and Rogner 1998, Cole and Brooks 2000, Cole and Shafer 2002).

Another problem with mitigation efforts is that they are not necessarily aimed at replacing the functionality of the permitted wetland (i.e., the lost wetland type). When a particular wetland type is destroyed, mitigation does not always require restoration or creation of that same wetland type (Cole and Shafer 2002). Kentula pointed out this skewed nature of mitigation in her breakdown of natural wetland types versus mitigated wetland types in the northwestern United States in Keddy (2000). This analysis provided strong evidence that cheaper, easy-to-create wetlands (i.e., depression wetlands) were being created in favor of geomorphologically complex or rare wetland types (e.g., slope or riverine wetlands; Keddy 2000). Lastly, mitigation is often off-site, away from the location of the permitted wetland, so any functionality contributed by the mitigated wetland has been exported to another location, where it may or may not be of similar use or value. For example, in Florida, we found the average distance between wetland mitigation banks and the nearest cluster of wetland alteration permits was over 30 miles.

Second, our results suggest that sprawling development primarily from residential projects is escalating in coastal areas. Data trends indicate increasing development of palustrine wetlands via Nationwide permits located outside of urban areas. This phenomenon is particularly visible in coastal Texas around Galveston and Corpus Christi Bays towards the end of the study period where: a) there are no large protected areas to buffer outward growth as is the case in southern Florida, and b) there are no mandated growth management or comprehensive planning regulations that could help concentrate growth in urban areas. The implications of our results are that palustrine wetlands will increasingly be altered from smaller-scale, residential development projects, particularly since coastal Texas is projected to be one of the fastest growing areas in the country over the next several decades (Crosset et. al. 2004). As a result, the value derived from this type of wetland will continue to be lost including: flood attenuation (see Brody et al. 2007), recreation, and critical habitats for fish and wildlife.

Third, our results show that a large percentage of wetland alteration permits in both states were issued within the 100-year floodplain (Florida has a higher percentage due to more floodplain area and more people living in the floodplain). This finding has significant policy implications because wetland alteration within floodplains increases impervious surface area and reduces or eliminates a wetland's ability to capture, hold, and store water runoff. For example, Highfield and Brody (2006) found that wetland alteration permits within the FEMA designated 100-year floodplain significantly increased reported flood damage in Florida, even when controlling for biophysical and socioeconomic factors. Disrupting the natural hydrological system can exacerbate flooding or create flood problems in areas not originally considered vulnerable to this hazard. Thus, developments initially considered safe from flood threats become an unexpected target of expensive flood damage over time. Assuming some development will occur within the floodplain, it should not be allowed to adversely impact or eliminate wetlands of high hydrological value. The planning goal in this case is to allow development to proceed without compromising the hydrological function and value wetland systems. Planning to mitigate floods clearly has benefits when consider property damage and human casualties. Despite having more floodplain area, people living in the floodplain, wetland alteration permits, impervious surfaces, annual precipitation, and valuable structures vulnerable to flooding, Florida has a lower number of flood events and flood casualties than coastal Texas (see Brody et al. 2007). A major difference between the two states is that Florida is twice as prepared to mitigate the adverse impacts from floods as measured through its mandated comprehensive plans and FEMA Community Rating System scores.

This study should be considered only a starting point towards a more comprehensive research agenda focused on several fronts. First, we do not consider compensatory wetland mitigation, which may be an important aspect of maintaining the values of wetland systems. Future work on this topic should systematically review the type, location, and extent of mitigation for each permit issued. Second, our study does not investigate the factors driving permit issuance. Additional research should seek to explain which socioeconomic, demographic, and political variables are most important in influencing the pattern of wetland alteration over time. Third, we only examine a thirteen-year period of wetland alteration across two states. Future work should track wetland impacts over longer time periods and larger regions to form a more complete picture of how wetland systems are being affected. Fourth, as is the case with any secondary data, the accuracy of both permit locations and NWI data is not ideal. The permit locations utilized in this analysis were those provided by the permit record itself; they were not accompanied by any statements of positional accuracy. In addition, NWI data is a remotely-sensed spatial product and may be subject to errors despite attempts to reduce or eliminate them. Although no alternative to either of these datasets currently exist at this scale of analysis, future research conducted at smaller scales could more comprehensively rectify potential differences between these two datasets. Finally, more work needs to be done on the area and type of wetland being altered and how this may affect flooding, water quality, critical habitats, and other ecosystem services provided by naturally occurring wetlands.

Despite this lack of information, our results show the importance of tracking wetland alteration not on a site-by-site basis, but over large spatial and temporal scales. Such an approach can help public decision makers better understand the cumulative impacts of development and view the "big picture" in terms of wetland loss. With information about the timing, extent and location of wetland alteration, planners can more effectively implement proactive policies to buffer against future adverse impacts to coastal ecological systems.

ACKNOWLEDGEMENTS

This article is based on research supported in part by the U.S. National Science Foundation Grant No. CMS- 0346673. The findings and opinions reported are those of the authors and are not necessarily endorsed by the funding organizations or those who provided assistance with various aspects of the study.

LITERATURE CITED

Brady, S. J. and C. H. Flather. 1994. Changes in wetlands on nonfederal rural land of the conterminous United States from 1982 to 1987. Environmental Management 18(5):693-705.

Brody, S. D. and W. E. Highfield. 2005. Does Planning Work? Testing the Implementation of Local Environment Planning in Florida. Journal of the American Planning Association 71(2):159-176.

Brody, S. D., W. E. Highfield, H. C. Ryu, and L. Spanel-Weber. 2007. Examining the Relationship between Wetland Alteration and Watershed Flooding in Texas and Florida. Natural Hazards 40(2):413-428.

Brusati, E. D., P. J. DuBowy, and T.E. Lacher, Jr. 2001. Comparing Ecological Functions of Natural and Created Wetlands for Shorebirds in Texas. Waterbirds 24(3):371-380.

Campbell, D. A., C. A. Cole, and R. P. Brooks. 2002. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management 10:41-49.

Cole, C. A. and D. Shafer. 2002. Section 404 wetland mitigation and permit success criteria in Pennsylvania, USA, 1986-1999. Environmental Management 30(4):508-515.

Cole, C. A. and R. P. Brooks. 2000. A comparison of the hydrologic characteristics of natural and created mainstem floodplain wetlands in Pennsylvania. Ecological Engineering 14:221-231.

Costanza, R., R. d'Arge, D. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Crozier, G. E. and D. E. Gawlik. 2002. Avian response to nutrient enrichment in an oligotrophic wetland, the Florida Everglades. The Condor 104:631-642.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, C. M. Blackwell, and J. J. McDonough. 1990. 50 Years of Population Change Along the Nation's Coasts: 1960-2010, A Special Earth Week Report. Rockville, MD: DOC, NOAA. (Coastal Trends Series No. 2).

Dahl, T. E. and C. E. Johnson. 1991. Wetlands: status and trends in the conterminous United States, mid 1970's to mid 1980's. U.S. Fish and Wildlife Service/U. S. Dept. of the Interior. 28 pp.

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986-1997. U.S. Dept. of the Interior, Fish & Wildlife Service, Washington, D.C. 82 pp.

Danielsen, F., M. Sorensen, M. F. Olwig, V. Selvam, F. Parish, N. D. Burgess, T. Hiraishi, V. M. Karunagaran, M. Rasmussen, L. B. Hansen, A. Quarto, and N. Suryadiputra. 2005. The Asian tsunami: a protective role for coastal vegetation. Science 310:643.

Day, J. W. Jr., J. Ko, J. Rybczyk, D. Sabins, R. Bean, G. Berthelot, C. Brantley, L. Cardoch, W. Conner, J. N. Day, A. J. Englande, S. Feagley, E. Hyfield, R. lane, J. Lindsey, J. Mistch, E. Reyes, and R. Twilley. 2004. The use of wetlands in the Mississippi Delta for wastewater assimilation: a review. Ocean & Coastal Management 47:671-691.

Downing, D. M., C. Winer, and L. D. Wood. 2003. Navigating Through Clean Water Act Jurisdiction: A Legal Review. Wetlands 23(3):475 – 493.

Erwin, K.L. 1991. An evaluation of wetland mitigation in the South Florida Water Management District, vol. I. Final Report to the South Florida Water Management District, West Palm Beach, FL. 124 pp.

Fenner, T. 1991. Cumulative impacts to San Diego County wetlands under federal and state regulatory programs 1985–1989. MA thesis. San Diego State University.

Frayer, W. E., T. J. Monahan, D. C. Bowden, and F. A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. Colorado State University, Ft. Collins, CO. 31 p.

Gallihugh, J. L. and J. D. Rogner. 1998. Wetland mitigation and 404 permit compliance study, Volume 2. U. S. Fish and Wildlife Service, Barrington, IL.

Gorham, E. 1991. Northern peatlands: role in the carbon cycle and probable responses to climatic warming. Ecological Applications 1:182-195.

Highfield, W. E. and S. D. Brody. 2006. The Price of Permits: Measuring the Economic Impacts of Wetland Development on Flood Damages in Florida. Natural Hazards Review 7(3):23-30.

Holland, C. C. and M. E. Kentula. 1992. Impacts of section 404 permits requiring compensatory mitigation on wetlands in California (USA). Wetlands Ecology and Management 2(3):157-169.

Holland, C. C., J. Honea, S. E. Gwin, and M. E. Kentula. 1995. Wetland degradation and loss in the rapidly urbanizing area of Portland, Oregon. Wetlands 15(4):336-345.

"Issuance of Nationwide Permits; Notice." 2005. Federal Register, 67(10):2019-2095.

Josselyn, M., J. Zedler, and T. Griswold. 1989. Wetland mitigation along the Pacific Coast of the United States. p. 1-35. *In* J. Kusler and M.E. Kentula, (eds.) Wetland creation and restoration: The status of the science. Environmental Research Laboratory. Corvallis, Oregon.

Kadlec, R. H. and R. L. Knight. 1996. Treatment Wetlands. CRC Press/Lewis Publishers, Boca Raton, FL. 893 pp.

Keddy, P. A. 2000. Wetland Ecology: Principles and Conservation. Cambridge University Press. Cambridge, UK. 614 pp.

Kelly, N. M. 2001. Changes to the landscape pattern of coastal North Carolina wetlands under the Clean Water Act, 1984-1992. Landscape Ecology 16(1):3-16.

Kentula, M. E., J. C. Sifneos, J. W. Good, M. Rylko, and K. Kuntz. 1992. Trends and patterns in section 404 permitting requiring compensatory mitigation in Oregon and Washington, USA. Environmental Management 16:109-119.

Crossett, K., T. J. Culliton, P. Wiley, T. R. Goodspeed. 2004. Population Trends Along the Coastal United States, 1980-2008, National Oceanic and Atmospheric, Administration Coastal Trends Report Series.

Kusler, J. A. and M. E. Kentula. 1990. Wetlands Creation and Restoration: The status of the science. Island Press, Washington, D.C. 594 pp.

Lewis, W. M. 2001. Wetlands Explained: Wetland Science, Policy, and Politics in America. Oxford University Press. New York. 147 pp.

Liu, P. L., P. Lynett, H. Fernando, B. E. Jaffe, H. Fritz, B. Higman, R. Morton, J. Goff, and C. Synolakis. 2005. Observations by the International tsunami survey team in Sri Lanka. Science 308:1595.

Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert. 2003. Crop Freezes and land-use change in Florida. Nature 426:29-30.

Middleton, B. A. and K. L. McKee. 2001. Degradation of mangrove tissues and implications for peat formation in Belizean island forests. Journal of Ecology 89:818-828.

Minello, T. J., K. W. Able, M. P. Weinstein, and C. G. Hays. 2003. Salt Marshes as nurseries for nekton: testing hypotheses on density, growth, and survival through meta-analysis. Marine Ecology Progress Series 246:39-59.

Mitsch, W. J. and J. G. Gosselink. 2000. Wetlands: 3rd Edition. Wiley & Sons, New York. 920 pp.

Mitsch, W. J., J. W. Day, J. W. Gillian, P. M. Groffman, D. L. Hey, G. W. Randall, and N. Wang. 2001. Reducing Nitrogen Loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to Counter a Persistent Ecological Problem. Bioscience 51(5):373-388.

Ogden, J. C. 1994. A comparison of wading bird nesting colony dynamics (1931-1946 and 1974-1989) as an indication of ecosystem conditions in the southern Everglades, p. 533-570. *In* S. Davis and J. Ogden (eds.) Everglades: the Ecosystem and its Restoration. Delray Beach, Florida, St. Lucie Press.

Owen, C. R. and H. M. Jacobs. 1992. Wetland protection as land-use planning: The impact of Section 404 in Wisconsin, USA. Environmental Management 16:345–353.

Race, M. S. and D. R. Christie. 1982. Coastal zone development: mitigation, marsh creation and decision making. Environmental Management 6:317-28.

Seabloom, E. W. and A. G. van der Valk. 2003. Plant Diversity, Composition, and Invasion of Restored and Natural Prairie Pothole Wetlands: Implications for Restoration. Wetlands 23(1):1-12.

Sifneos, J. C., M. E. Kentula, and P. Price. 1992a. Impacts of Section 404 Permits Requiring Compensatory Mitigation of Freshwater Wetlands in Texas and Arkansas. The Texas Journal of Science 44(4):475-485.

Sifneos, J. C., E. W. Cake Jr., and M. E. Kentula. 1992b. Effects of Section 404 Permitting on Freshwater Wetlands in Louisiana, Alabama, and Mississippi. Wetlands 12: 28-36.

Smith, L. C., G. M. MacDonald, A. A. Velichko, D. W. Beilman, O. K. Borisova, K. E. Frey, K. V. Kremenetski, and Y. Sheng. 2004. Siberian peatlands a net carbon sink and global methane source since the early Holocene. Science 303:353-356.

Stein, E. D. and R.E. Ambrose. 1998. Cumulative impacts of Section 404 Clean Water Act permitting on the riparian habitat of the Santa Margarita, California watershed. Wetlands 18(3):393-408.

Steiner, F., S. Pieart, E. Cook, J. Rich, and V. Coltman. 1994. State Wetlands and Riparian Area Protection Programs. Environmental Management 18(2):183-201.

Turner, R. E. 1997. Wetland loss in the northern Gulf of Mexico: multiple working hypotheses. Estuaries. 20:1-13.

United States Army Corps of Engineers (USACE). 2005. U.S. Army Corps of Engineers—Jacksonville District regional general permits, (http://www.saj.usace.army.mil/permit/permitting/general-permits.htm).

United States Geological Survey. 1996. National Water Summary on Wetland Resources. USGS Water-Supply Paper 2425. Washington, D.C.

Zedler, J. B. 1991. The Challenge of Protecting Endangered Species Habitat Along the Southern California Coast. Coastal Management 19:35-53.

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

Zedler, J. B. and S. Kercher. 2005. Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39-74.

Table 1. Breakdown of section 404 permits issued in Florida and Texas from 1991 to 2003 by permit type.

	Permit Type							
	General		Individual		Letter of Permission		Nationwide	
State	*n*	% of Total	*n*	% of Total	*n*	% of Total	*n*	% of Total
Texas	3512	31.5%	1284	11.5%	1237	11.1%	5116	45.9%
Florida	4963	18.1%	3959	14.4%	2027	7.4%	16505	60.1%
Total	8475	22.0%	5243	13.5%	3264	8.5%	21621	56.0%

Table 2. Breakdown showing number and percentage of Section 404 permits issued within urban areas and floodplains in Texas: 1991-2003. 100 permit locations in Texas did not have FEMA data and were not included.

	Urban		Floodplain	
Year	Within	Outside	Within	Outside
1991	76	193	93	185
	28.3%	71.7%	33.4%	66.6%
1992	140	381	167	349
	26.9%	73.1%	32.3%	66.7%
1993	165	536	249	448
	23.5%	76.5%	35.7%	64.3%
1994	163	483	223	421
	25.2%	74.8%	34.6%	65.4%
1995	217	505	264	456
	30.1%	69.9%	36.7%	63.3%
1996	205	952	457	695
	17.7%	82.3%	39.7%	60.3%
1997	222	787	414	593
	22.0%	78.0%	41.0%	58.8%
1998	208	620	336	491
	25.1%	74.9%	40.6%	59.4%
1999	236	713	390	556

	24.9%	75.1%	41.2%	58.8%
2000	196	758	387	566
	20.5%	79.5%	40.6%	59.4%
2001	176	821	389	603
	17.6%	82.4%	39.2%	60.8%
2002	219	955	475	694
	18.6%	81.4%	40.6%	59.4%
2003	223	985	454	744
	18.5%	81.5%	37.9%	62.1%
Total	2446	8689	4298	6801
	22.0%	78.0%	38.7%	61.3%

Table 3. Breakdown showing number and percentage of Section 404 permits issued within urban areas and floodplains in Florida: 1991-2003.

	Urban		Floodplain	
Year	Within	Outside	Within	Outside
1991	974	747	774	947
	56.6%	43.4%	45.0%	55.0%
1992	1130	856	1031	955
	56.9%	43.1%	51.9%	48.1%
1993	1418	945	1202	1161
	60.0%	40.0%	50.9%	49.1%
1994	1621	1026	1421	1226
	61.2%	38.8%	53.7%	46.3%
1995	1735	1253	1514	1474
	58.1%	41.9%	50.7%	49.3%
1996	1569	920	1159	1330
	63.0%	37.0%	46.6%	53.4%
1997	1498	985	1183	1300
	60.3%	39.7%	47.6%	52.4%
1998	1196	827	961	1062
	59.1%	40.9%	47.5%	52.5%
1999	1028	869	885	1012
	54.2%	45.8%	46.6%	53.4%

2000	784	808	680	912
	49.3%	50.7%	42.7%	57.3%
2001	869	824	762	931
	51.3%	48.7%	45.0%	55.0%
2002	863	841	741	963
	50.7%	49.3%	43.5%	56.5%
2003	1068	800	980	888
	57.2%	42.8%	52.5%	47.5%
Total	15753	11701	13293	14161
	57.4%	42.6%	48.4%	51.6%

Table 4. Texas Section 404 permits by nearest wetland system type: 1991-2003. 3,209 permits were within the area but lacked digital NWI data. 130 permits fell outside of 1 km boundary and were not included. The average distance from permit to NWI wetland = 78.9 m and median distance from permit to NWI wetland = 14.9 m.

Wetland Type	Permit Type				Total	% of All Permits
	General	Individual	Letter	Nationwide		
Estuarine	864	711	693	1463	3731	47.8%
	23.2%	*19.1%*	*18.6%*	*39.2%*		
Lacustrine	132	46	12	149	339	4.3%
	38.9%	*13.6%*	*3.5%*	*44.0%*		
Marine	3	16	5	28	52	0.7%
	5.8%	*30.8%*	*9.6%*	*53.8%*		
Upland	2	12	0	3	17	0.2%
	11.8%	*70.6%*	*0.0%*	*17.6%*		
Palustrine	335	323	119	2014	2791	35.7%
	12.0%	*11.6%*	*4.3%*	*72.2%*		
Riverine	356	51	107	366	880	11.3%
	40.5%	*5.8%*	*12.2%*	*41.6%*		

Table 5. Florida Section 404 permits by nearest wetland system type: 1991-2003. 53 permits fell outside of 1 km boundary and were not included. The average distance from permit to NWI wetland = 93.0 m and median distance from permit to NWI wetland = 43.6 m.

Wetland Type	Permit Type				Total	% of All Permits
	General	Individual	Letter	Nationwide		
Estuarine	2773	1303	1280	4164	9520	34.8%
	29.1%	*13.7%*	*13.4%*	*43.7%*		
Lacustrine	315	90	36	666	1107	4.0%
	28.5%	*8.1%*	*3.3%*	*60.2%*		
Marine	73	153	112	305	643	2.3%
	11.4%	*23.8%*	*17.4%*	*47.4%*		
Palustrine	1499	2291	508	10872	15170	55.4%
	9.9%	*15.1%*	*3.3%*	*71.7%*		
Riverine	297	103	86	445	931	3.4%
	31.9%	*11.1%*	*9.2%*	*47.8%*		

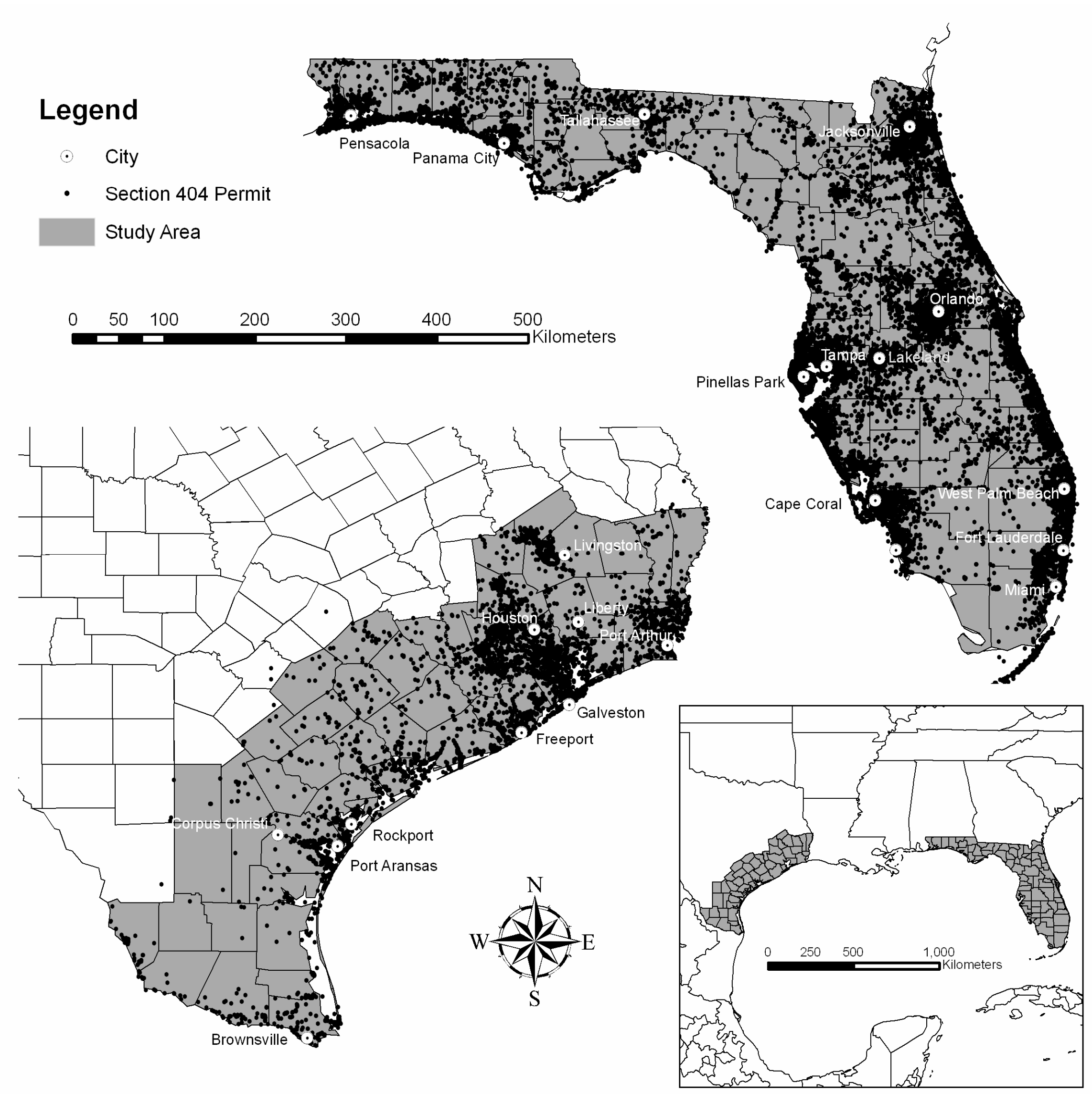
List of Figures

Figure 1. Map of greater Gulf of Mexico region with study areas of Texas and Florida highlighted. Expanded maps show major metropolitan areas of Florida and coastal Texas and Section 404 permit locations from 1991 to 2003.

Figure 2. Histogram plot of Section 404 Permits issued in Florida by type and year: 1991 – 2003.

Figure 3. Histogram plot of Section 404 Permits issued in Texas by type and year: 1991 – 2003.

1 Figure 1.


Legend
City
Section 404 Permit
Study Area
0 50 100 200 300 400 500
Kilometers
Pensacola
Panama City
Tallahassee
Jacksonville
Orlando
Tampa
Lakeland
Pinellas Park
Cape Coral
West Palm Beach
Fort Lauderdale
Miami
Livingston
Liberty
Houston
Port Arthur
Galveston
Freeport
Corpus Christi
Rockport
Port Aransas
Brownsville
N
W
E
S
0 250 500 1,000
Kilometers

2

Figure 2.

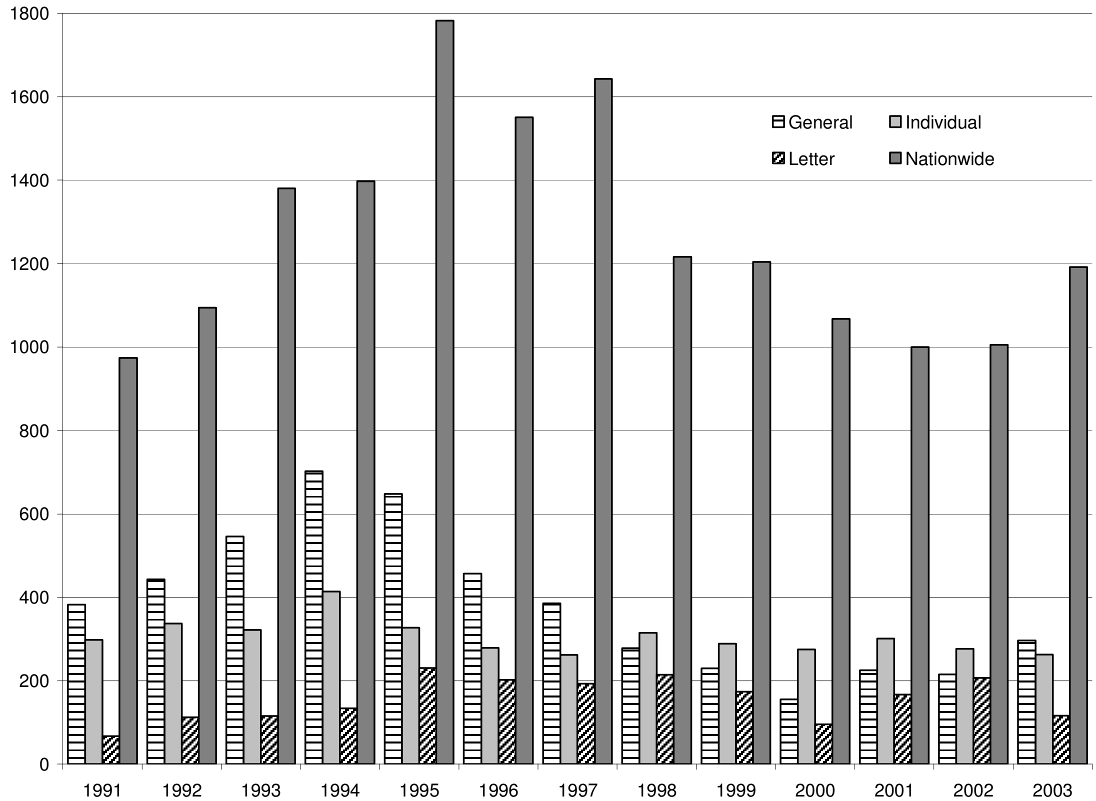
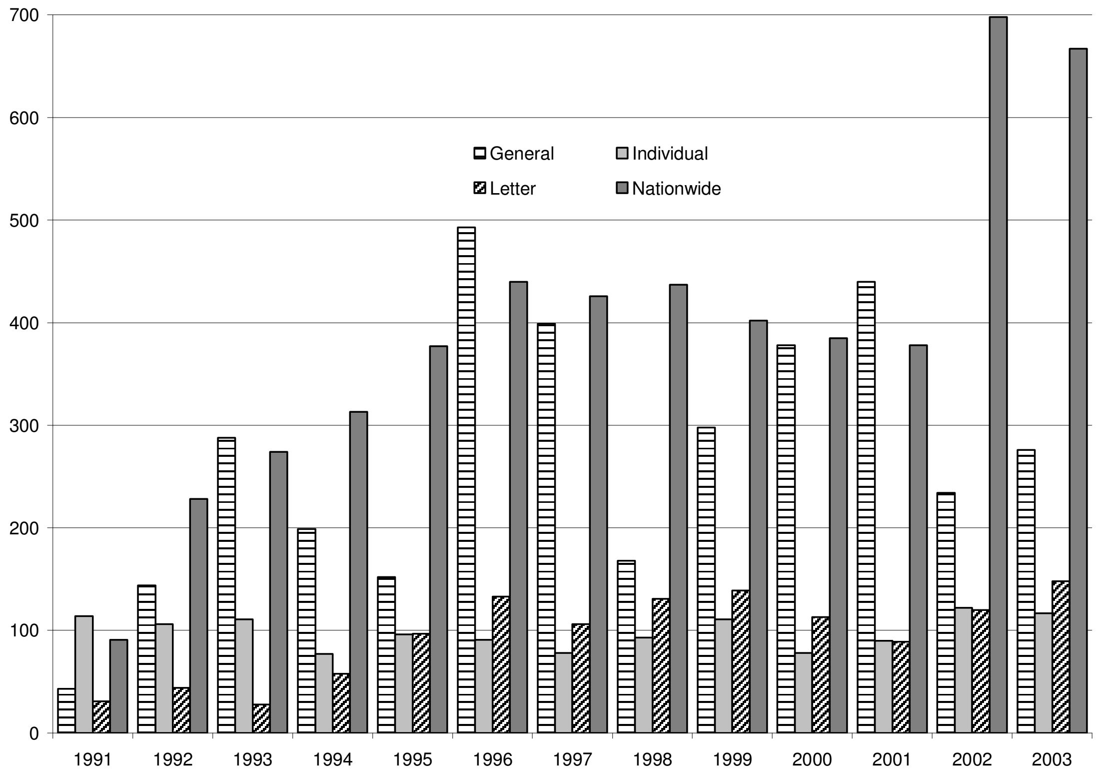

General
Individual
Letter
Nationwide
0
200
400
600
800
1000
1200
1400
1600
1800
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

Figure 3.


General
Individual
Letter
Nationwide
0
100
200
300
400
500
600
700
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003