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

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*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 more than 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%). More than half of permits issued in Florida were within urban areas (57%) and outside of 100-year floodplains (51%). The most affected wetlands types 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, coastal wetlands, dredge-and-fill activity, mitigation, Section 404 permitting, urban development

## INTRODUCTION

Naturally occurring wetlands are a vital component of the United States' 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.

### 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. 1992, 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. (1992) examined the Section 404 program in numerous areas of the country. Results for the Texas study area found a net loss of 371 ha 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. 1992). A study on Section 404 permitting and mitigation in Oregon and Washington found similar results. Kentula et al. (1992) found that over a 10-year period in Oregon (1977–1987), 74 ha of wetlands were impacted and 42 ha were created; a net loss of 43%. In Washington, from 1980 to 1986, 61 ha 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 171 ha of wetlands were permitted while only 16 ha were created in the first six 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 (1998) 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 Nationwide permits (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 1998). 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) comprised largely of palustrine and estuarine wetlands (Dahl 2000). 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 (Mitsch and Gosselink 2000). Since the 1700s, 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 1,216 people per km (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

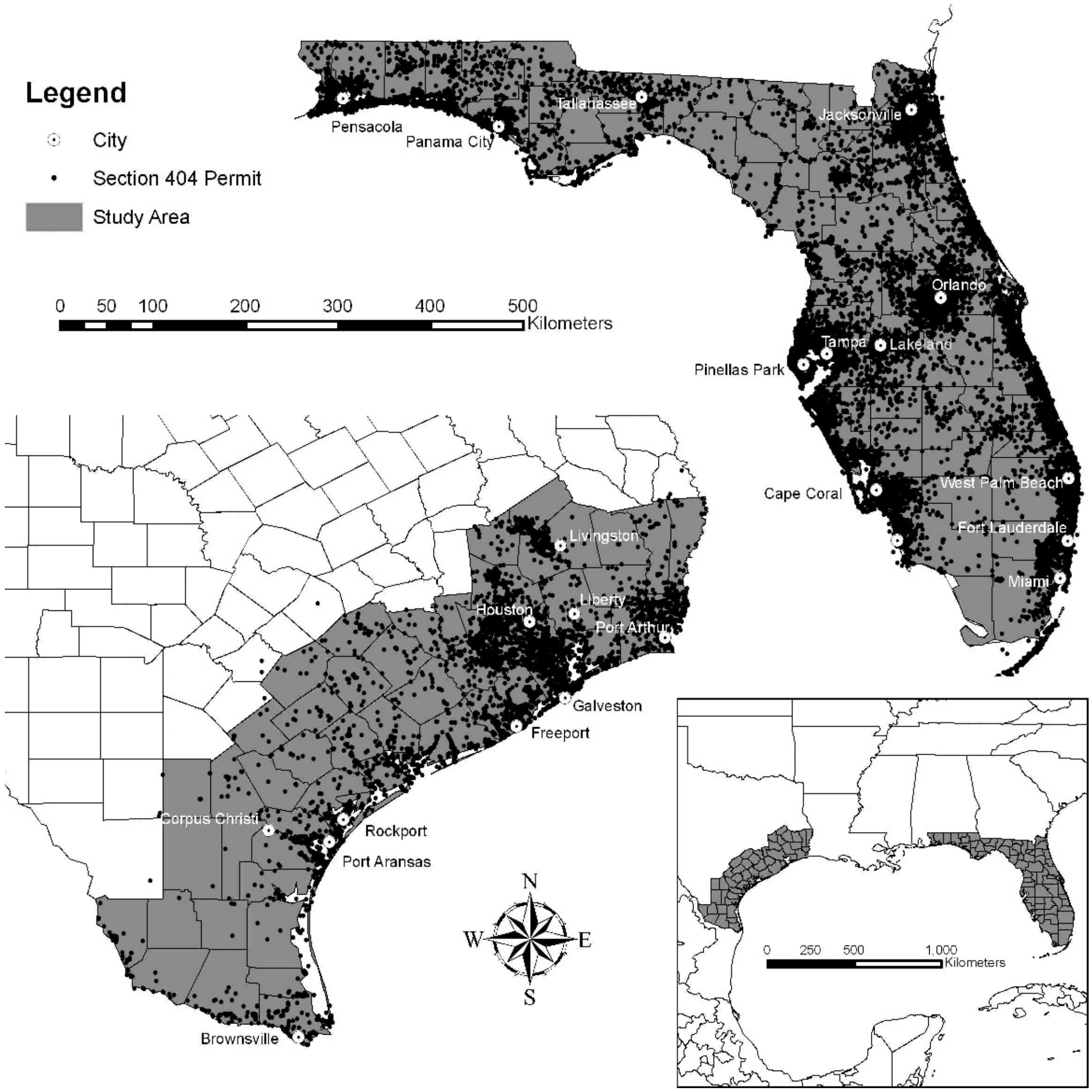


Figure 1. Map of greater Gulf of Mexico region with study areas of Texas and Florida highlighted. Expanded maps show major metropolitan areas of Florida and coastal Texas and Section 404 permit locations from 1991 to 2003.

miles of the nearest coastline. This area encompassed the U.S. Army Corps of Engineers (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 previously described), 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.

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 were based off of imagery collected from 1992 to 1993; Florida NWI data were based off of imagery collected from 1972 to 1982. We categorized the following five wetland types: estuarine, lacustrine, marine, palustrine, and riverine. Because positional accuracy

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 | 3,512 | 31.5% | 1,284 | 11.5% | 1,237 | 11.1% | 5,116 | 45.9% |
| Florida | 4,963 | 18.1% | 3,959 | 14.4% | 2,027 | 7.4% | 16,505 | 60.1% |
| Total | 8,475 | 22.0% | 5,243 | 13.5% | 3,264 | 8.5% | 21,621 | 56.0% |

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, 56.0% were categorized as Nationwide, 22.0% General, 13.5% Individual, and 8.5% 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 46%) 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.

Wetland alteration permits in Florida were concentrated within coastal urban areas, particularly in the southeast portion of the state stretching from the Keys north to West Palm Beach (Figure 1). The western coastline from heavily urbanized Pinellas County south to Naples is also heavily dominated by wetland alteration. The south central part of Florida has comparatively fewer permits due to the presence of large protected areas such as the Everglades and Big Cypress ecosystems that act to limit sprawling development. On the other hand, the density of permitted sites was much higher in central Florida—in and around the Orlando area—where protected areas are not as prevalent.

Wetland alteration in coastal Texas also coincides with heavily urbanized areas, such as Houston/Galveston, Beaumont, and Corpus Christi (Figure 1). 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 the areas between Houston and Corpus Christi.

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 pattern (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.

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

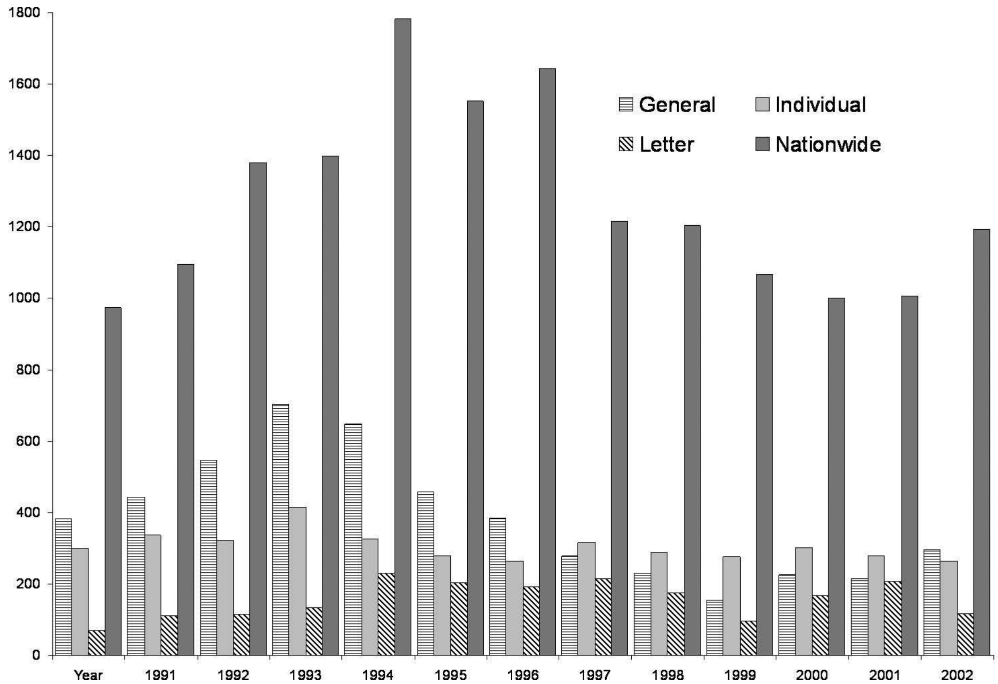


Figure 2. Histogram plot of Section 404 Permits issued in Florida by type and year: 1991–2003.

Texas were issued within the 100-year floodplain. This development pattern remained relatively consistent throughout the study period. When examining the location of wetland alteration in Florida (Table 3), the story is different. More than 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 those areas most vulnerable to flooding, almost half (48%) of the permits issued in Florida were located within the 100-year floodplain.

By spatially tying permits to the NWI data, we were able to estimate both the degree of wetland alteration over time and the type of wetland system

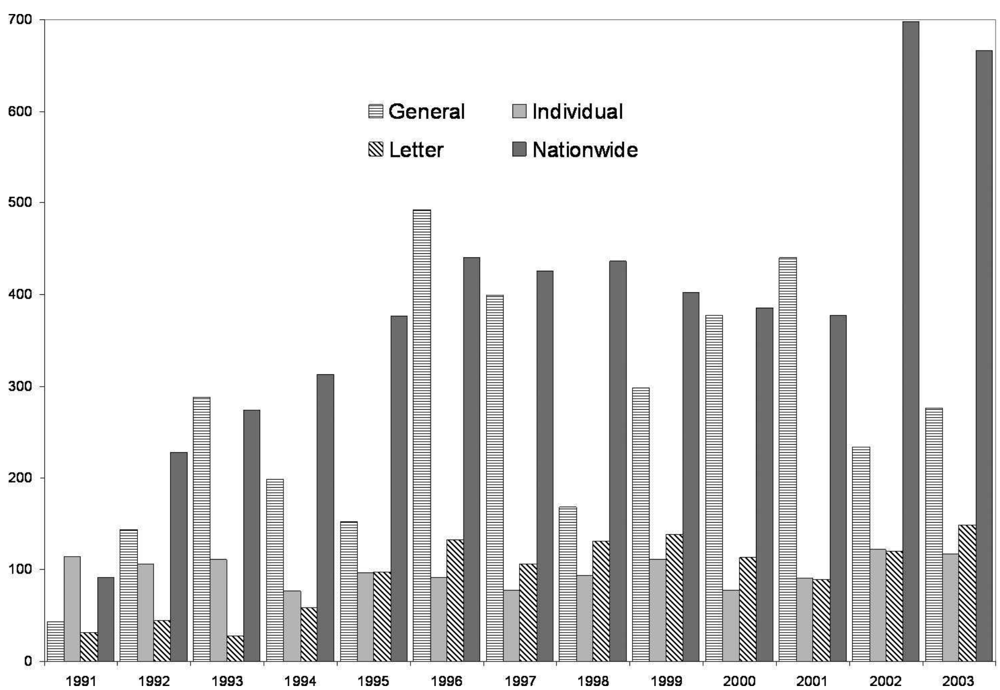


Figure 3. Histogram plot of Section 404 Permits issued in Texas by type and year: 1991–2003.

Table 2. Breakdown showing number and percentage of Section 404 permits issued within urban areas and floodplains in Texas: 1991–2003. One hundred 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 | 2,446 | 8,689 | 4,298 | 6,801 |
| | 22.0% | 78.0% | 38.7% | 61.3% |

being impacted by various development activities. In coastal Texas, the majority of wetland permits were 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 pattern adjacent to coastal waters, particularly around Galveston and Corpus Christi Bays. Palustrine wetlands also comprised a significant percentage (almost 36%) of wetland alteration permits in Texas. These development activities most likely took place further inland in non-tidal areas or tidal areas where salinity is $< 0.5‰$. More than 72% of altered palustrine wetlands were supported by Nationwide permits, indicating these wetland systems were being impacted cumulatively from smaller-scale developments symptomatic of sprawl. In Florida, the majority of permits were associated with impacts to palustrine wetlands, primarily through the Nationwide category (Table 5). Again, alteration of this wetland type appeared to be the result of individual residential projects dispersed over time and space that had a cumulative effect on wetland loss.

## DISCUSSION

By mapping and analyzing wetland alteration permits, we gained a better understanding of how development activities are impacting wetland systems at relatively large temporal and spatial scales. Our 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 indicated 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

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

| Year | Urban | | Floodplain | |
|---|---|---|---|---|
| | Within | Outside | Within | Outside |
| 1991 | 974 | 747 | 774 | 947 |
| | 56.6% | 43.4% | 45.0% | 55.0% |
| 1992 | 1,130 | 856 | 1,031 | 955 |
| | 56.9% | 43.1% | 51.9% | 48.1% |
| 1993 | 1,418 | 945 | 1,202 | 1,161 |
| | 60.0% | 40.0% | 50.9% | 49.1% |
| 1994 | 1,621 | 1,026 | 1,421 | 1,226 |
| | 61.2% | 38.8% | 53.7% | 46.3% |
| 1995 | 1,735 | 1,253 | 1,514 | 1,474 |
| | 58.1% | 41.9% | 50.7% | 49.3% |
| 1996 | 1,569 | 920 | 1,159 | 1,330 |
| | 63.0% | 37.0% | 46.6% | 53.4% |
| 1997 | 1,498 | 985 | 1,183 | 1,300 |
| | 60.3% | 39.7% | 47.6% | 52.4% |
| 1998 | 1,196 | 827 | 961 | 1,062 |
| | 59.1% | 40.9% | 47.5% | 52.5% |
| 1999 | 1,028 | 869 | 885 | 1,012 |
| | 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 | 1,068 | 800 | 980 | 888 |
| | 57.2% | 42.8% | 52.5% | 47.5% |
| Total | 15,753 | 11,701 | 13,293 | 14,161 |
| | 57.4% | 42.6% | 48.4% | 51.6% |

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, more than 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

Table 4. Texas Section 404 permits by nearest wetland system type: 1991–2003. Within the area, 3,209 permits lacked digital NWI data and 130 permits fell outside of the 1 km boundary and these 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 | 1,463 | 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. Fifty-three 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.

| | Permit Type | | | | | |
|---|---|---|---|---|---|---|
| Wetland Type | General | Individual | Letter | Nationwide | Total | % of All Permits |
| Estuarine | 2,773 | 1,303 | 1,280 | 4,164 | 9,520 | 34.8% |
| | 29.1% | 13.7% | 13.4% | 43.7% | | |
| Lacustrine | 315 | 90 | 36 | 666 | 1,107 | 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 | 1,499 | 2,291 | 508 | 10,872 | 15,170 | 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% | | |

pervasive in parts of eastern Texas. A General permit category may be providing industry with the rapid authorization needed for constructing pipelines and wells, or for 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 (as reviewed in Keddy 2000; pp 523–24) pointed out this skewed nature of mitigation in her breakdown of natural wetland types versus mitigated wetland types in the northwestern United States. 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). 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 more than 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 (Crossett 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 habitat 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 floodplains). 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 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 after 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 of wetland systems. Planning to mitigate floods clearly has benefits when considering property damage and human casualties. Surprisingly, Florida has a lower number of flood events and flood casualties than coastal Texas despite having more 1) floodplain area, 2) people living in the floodplain, 3) wetland alteration permits, 4) impervious surfaces, 5) annual precipitation, and 6) valuable structures vulnerable to flooding (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.

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