

2008

# A spatial-temporal analysis of section 404 wetland permitting in Texas and Florida: Thirteen years of impact along the coast

Samuel D. Brody

*Department of Landscape Architecture & Urban Planning Environmental Planning and Sustainability Research Unit, Texas A&M University*

Steven E. Davis III

*Department of Wildlife and Fisheries Sciences, Texas A&M University*

Wesley H. Highfield

*Department of Landscape Architecture & Urban Planning Environmental Planning and Sustainability Research Unit, Texas A&M University*

Sarah P. Bernhardt

*Department of Landscape Architecture & Urban Planning Environmental Planning and Sustainability Research Unit, Texas A&M University*

Follow this and additional works at: [https://digitalcommons.fiu.edu/fce\\_lter\\_journal\\_articles](https://digitalcommons.fiu.edu/fce_lter_journal_articles)

---

## Recommended Citation

Brody, S.D., S.E. Davis, W.E. Highfield, S.P. Bernhardt. 2008. A Spatial-Temporal Analysis of Section 404 Wetland Permitting in Texas and Florida: Thirteen Years of Impact Along the Coast. *Wetlands* 28(1): 107-116.

This material is based upon work supported by the National Science Foundation through the Florida Coastal Everglades Long-Term Ecological Research program under Cooperative Agreements #DBI-0620409 and #DEB-9910514. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

This work is brought to you for free and open access by the FCE LTER at FIU Digital Commons. It has been accepted for inclusion in FCE LTER Journal Articles by an authorized administrator of FIU Digital Commons. For more information, please contact [dcc@fiu.edu](mailto:dcc@fiu.edu), [jkrefft@fiu.edu](mailto:jkrefft@fiu.edu).

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

3

4 Samuel D. Brody<sup>1</sup>, Stephen E. Davis, III<sup>2</sup>, Wesley E. Highfield<sup>1</sup>, and Sarah Bernhardt<sup>1</sup>

5

6 *<sup>1</sup>Department of Landscape Architecture & Urban Planning*

7 *Environmental Planning and Sustainability Research Unit*

8

*Texas A&M University*

9

*College Station, TX 77845-3137*

10

11

*<sup>2</sup>Corresponding author:*

12

*Department of Wildlife and Fisheries Sciences*

13

*Texas A&M University*

14

*College Station, TX 77845-2258*

15

*E-mail: sedavis@tamu.edu*

16

17

18

19

20

21

1 *Abstract:* Over the past 200 years, an estimated 53% (about 47 million ha) of the original  
2 wetlands in the conterminous United States have been lost mainly as a result of various human  
3 activities. Despite the importance of wetlands (particularly along the coast), and a longstanding  
4 federal policy framework meant to protect their integrity, the cumulative impact on these natural  
5 systems over large areas is poorly understood. We address this lack of research by mapping and  
6 conducting descriptive spatial analyses of federal wetland alteration permits (pursuant to section  
7 404 of the Clean Water Act) across 85 watersheds in Florida and coastal Texas from 1991 to  
8 2003. Results show that over half of the permits issued in both states (60%) fell under the  
9 Nationwide permitting category. Permits issued in Texas were typically located outside of urban  
10 areas (78%) and outside 100-year floodplains(61%). Over half of permits issued in Florida were  
11 within urban areas (57%) and outside of 100-year floodplains (51%). The most affected  
12 wetlands type were Estuarine in Texas (47%) and Palustrine in Florida (55%). We expect that an  
13 additional outcome of this work will be an increased awareness of the cumulative depletion of  
14 wetlands and loss of ecological services in these urbanized areas perhaps leading to increased  
15 conservation efforts.

16

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

## 1 INTRODUCTION

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

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

19  
20 Research on the Impacts of Section 404

21 While an abundance of literature exists pertaining to the functions, values, and restoration  
22 of wetlands, there is a relatively small amount of empirical literature concerning the impacts of  
23 the Section 404 permitting program. Furthermore, the vast majority of the permitting literature

1 compares permitted losses to compensatory mitigation (Kentula et al. 1992, Sifneos et al. 1992a,  
2 Cole and Shafer 2002, among others). Although our study does not explicitly address  
3 compensatory mitigation, when taken with the results of these other studies, our data reveal the  
4 potential magnitude of impact associated with this environmental permitting program.

5 Sifneos et al. (1992a) examined the Section 404 program in numerous areas of the  
6 country. Results for the Texas study area found a net loss of 917 acres of wetlands in the Fort  
7 Worth District USACE between 1982 and 1986 that required compensatory mitigation.  
8 Additionally, 52% of the number of impacted wetlands (representing 35% of the area impacted)  
9 was located in the Dallas-Fort Worth metropolitan area. The authors' theorized that the real-  
10 estate market during this time period was growing, and furthermore expanding into the  
11 remaining riparian woodlands in the area (Sifneos et al. 1992a). A study on Section 404  
12 permitting and mitigation in Oregon and Washington found comparable results. Kentula et al.  
13 (1992) found that over a 10 year period in Oregon (1977 – 1987) 74 ha of wetlands were  
14 impacted and 42 hectares were created; a net loss of 43%. In Washington from 1980 – 1986, 61  
15 hectares of wetlands were impacted and 45 ha were created—a 26% net loss. Permitted  
16 activities in both states occurred near urban areas (Kentula et al. 1992). Owen and Jacobs (1992)  
17 conducted a similar study in Wisconsin, and found that 422 acres of wetlands were permitted  
18 while only 40 acres were created in the first 6 months of 1988. The authors also concluded that  
19 while the permitting program is, in effect, a land use control it performs poorly as such (Owen  
20 and Jacobs 1992).

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

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

12 Evidence suggests that Section 404 permitting has and continues to cause at least some  
13 form of wetland impact if not altogether net wetland losses. This statement appears to hold  
14 despite federal policy of a “no net loss” of wetlands. Some of the literature concerning Section  
15 404 does suggest that permitting activity is a direct result of urban growth and expansion. Other  
16 general research concerning wetland losses also suggests urban growth as the primary cause of  
17 wetland loss (Brady and Flather 1994, Holland et al. 1995, USGS 1996) while others have  
18 singled out navigational dredging and spoil banks as a primary driver (Turner 1997).

## 19 METHODS

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

1 Florida and Texas are also among the five most populous states—currently estimated at nearly  
2 18 million and 23 million, respectively (U.S. Census Bureau). However, their different  
3 geography, policy climates, and development patterns also make for a powerful comparative  
4 analysis.

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

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

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

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

8 (Insert Figure 1 here)

9 We constructed several additional measures to descriptively analyze the permit record.  
10 Permits were categorized by state, year and the four types permitted under Section 404 of the  
11 CWA: Individual, Nationwide, Letter of Permission, and General (for more information on  
12 wetland permitting, see Brody and Highfield 2005, Highfield and Brody 2006). We also used  
13 GIS analytical techniques to estimate the type of wetland being altered according to the most  
14 recent National Wetland Inventory (NWI) database. The Texas NWI data was based off of  
15 imagery collected from 1992 – 1993; Florida NWI data was based off of imagery collected from  
16 1972 – 1982. We categorized the following five wetland types: estuarine, lacustrine, marine,  
17 palustrine, and riverine. Because positional accuracy varies in both the NWI and the permit  
18 dataset, permit locations did not always fall directly on an NWI-delineated wetland. In this case  
19 the nearest NWI polygon attributes were transferred to permit locations up to 1 km in distance.  
20 Permits with no NWI wetland within 1 km were dropped from this part of the analysis. Finally,  
21 we used GIS to measure two locational variables. First, we calculated the number and  
22 percentage of permits in urban areas as defined by the U.S. Census to gauge the degree to which  
23 development is occurring close to city centers. Second, we measured the number and percentage



1 of permits within the FEMA-defined 100-year floodplain. Previous studies show that wetland  
2 alteration within floodplains may exacerbate local flooding and associated property loss  
3 (Highfield and Brody 2006). It is important to note that due to lack of digital FEMA data, 100  
4 permits in Texas could not be associated with a particular floodplain.

5

6

## RESULTS

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

15

(Insert Table 1 about here)

16

17

18

19

20

21

22

23

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.

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

6 (Insert Figure 1 about here)

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

16 (Insert Figures 2 and 3 about here)

17 The location of permits issued to alter a naturally occurring wetland is also important  
18 because it indicates the pattern of development and corresponding impact on the natural  
19 environment over time. For example, in Texas, 78% of wetland permits were issued outside of  
20 urban areas, reflecting sprawling growth patterns associated with coastal development (Table 2).  
21 Interestingly, the disparity between permits granted in and out of urban areas increased over the  
22 study period. When considering areas vulnerable to flooding where naturally occurring wetlands  
23 have been shown to be most valuable as flood mitigation devices (Highfield and Brody 2006),

1 results show that 38.5% of permits in coastal Texas were issued within the 100-year floodplain.  
2 This development pattern remained relatively consistent throughout the study period. Florida  
3 tells a different story when examining the location of wetland alteration (Table 3). Over 57% of  
4 permits were issued within urban areas, suggesting a more confined overall spatial pattern of  
5 development compared to Texas. In terms of development in areas most vulnerable to flooding,  
6 almost half (48%) of the permits issued in Florida were located within the 100-year floodplain.

7 (Insert Tables 2 and 3 about here)

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

1 (Insert Tables 4 and 5 about here)

2 DISCUSSION

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

22 It is important to note that while wetland alteration under federal guidelines is almost  
23 always accompanied by mitigation at a ratio of 2:1 or higher, the ecological efficacy for

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

12 Another problem with mitigation efforts is that they are not necessarily aimed at  
13 replacing the functionality of the permitted wetland (i.e., the lost wetland type). When a  
14 particular wetland type is destroyed, mitigation does not always require restoration or creation of  
15 that same wetland type (Cole and Shafer 2002). Kentula pointed out this skewed nature of  
16 mitigation in her breakdown of natural wetland types versus mitigated wetland types in the  
17 northwestern United States in Keddy (2000). This analysis provided strong evidence that  
18 cheaper, easy-to-create wetlands (i.e., depression wetlands) were being created in favor of  
19 geomorphologically complex or rare wetland types (e.g., slope or riverine wetlands; Keddy  
20 2000). Lastly, mitigation is often off-site, away from the location of the permitted wetland, so  
21 any functionality contributed by the mitigated wetland has been exported to another location,  
22 where it may or may not be of similar use or value. For example, in Florida, we found the

1 average distance between wetland mitigation banks and the nearest cluster of wetland alteration  
2 permits was over 30 miles.

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

15         Third, our results show that a large percentage of wetland alteration permits in both states  
16 were issued within the 100-year floodplain (Florida has a higher percentage due to more  
17 floodplain area and more people living in the floodplain). This finding has significant policy  
18 implications because wetland alteration within floodplains increases impervious surface area and  
19 reduces or eliminates a wetland's ability to capture, hold, and store water runoff. For example,  
20 Highfield and Brody (2006) found that wetland alteration permits within the FEMA designated  
21 100-year floodplain significantly increased reported flood damage in Florida, even when  
22 controlling for biophysical and socioeconomic factors. Disrupting the natural hydrological  
23 system can exacerbate flooding or create flood problems in areas not originally considered

1 vulnerable to this hazard. Thus, developments initially considered safe from flood threats  
2 become an unexpected target of expensive flood damage over time. Assuming some  
3 development will occur within the floodplain, it should not be allowed to adversely impact or  
4 eliminate wetlands of high hydrological value. The planning goal in this case is to allow  
5 development to proceed without compromising the hydrological function and value wetland  
6 systems. Planning to mitigate floods clearly has benefits when consider property damage and  
7 human casualties. Despite having more floodplain area, people living in the floodplain, wetland  
8 alteration permits, impervious surfaces, annual precipitation, and valuable structures vulnerable  
9 to flooding, Florida has a lower number of flood events and flood casualties than coastal Texas  
10 (see Brody et al. 2007). A major difference between the two states is that Florida is twice as  
11 prepared to mitigate the adverse impacts from floods as measured through its mandated  
12 comprehensive plans and FEMA Community Rating System scores.

13         This study should be considered only a starting point towards a more comprehensive  
14 research agenda focused on several fronts. First, we do not consider compensatory wetland  
15 mitigation, which may be an important aspect of maintaining the values of wetland systems.  
16 Future work on this topic should systematically review the type, location, and extent of  
17 mitigation for each permit issued. Second, our study does not investigate the factors driving  
18 permit issuance. Additional research should seek to explain which socioeconomic, demographic,  
19 and political variables are most important in influencing the pattern of wetland alteration over  
20 time. Third, we only examine a thirteen-year period of wetland alteration across two states.  
21 Future work should track wetland impacts over longer time periods and larger regions to form a  
22 more complete picture of how wetland systems are being affected. Fourth, as is the case with  
23 any secondary data, the accuracy of both permit locations and NWI data is not ideal. The permit

1 locations utilized in this analysis were those provided by the permit record itself; they were not  
2 accompanied by any statements of positional accuracy. In addition, NWI data is a remotely-  
3 sensed spatial product and may be subject to errors despite attempts to reduce or eliminate them.  
4 Although no alternative to either of these datasets currently exist at this scale of analysis, future  
5 research conducted at smaller scales could more comprehensively rectify potential differences  
6 between these two datasets. Finally, more work needs to be done on the area and type of wetland  
7 being altered and how this may affect flooding, water quality, critical habitats, and other  
8 ecosystem services provided by naturally occurring wetlands.

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

15

16

#### ACKNOWLEDGEMENTS

17

18

19

20

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

- 1  
2 Brady, S. J. and C. H. Flather. 1994. Changes in wetlands on nonfederal rural land of the  
3 conterminous United States from 1982 to 1987. *Environmental Management* 18(5):693-705.  
4
- 5 Brody, S. D. and W. E. Highfield. 2005. Does Planning Work? Testing the Implementation of  
6 Local Environment Planning in Florida. *Journal of the American Planning Association*  
7 71(2):159-176.  
8
- 9 Brody, S. D., W. E. Highfield, H. C. Ryu, and L. Spanel-Weber. 2007. Examining the  
10 Relationship between Wetland Alteration and Watershed Flooding in Texas and Florida.  
11 *Natural Hazards* 40(2):413-428.  
12
- 13 Brusati, E. D., P. J. DuBowy, and T.E. Lacher, Jr. 2001. Comparing Ecological Functions of Natural  
14 and Created Wetlands for Shorebirds in Texas. *Waterbirds* 24(3):371-380.  
15
- 16 Campbell, D. A., C. A. Cole, and R. P. Brooks. 2002. A comparison of created and natural wetlands in  
17 Pennsylvania, USA. *Wetlands Ecology and Management* 10:41-49.  
18
- 19 Cole, C. A. and D. Shafer. 2002. Section 404 wetland mitigation and permit success criteria in  
20 Pennsylvania, USA, 1986-1999. *Environmental Management* 30(4):508-515.  
21
- 22 Cole, C. A. and R. P. Brooks. 2000. A comparison of the hydrologic characteristics of natural and  
23 created mainstem floodplain wetlands in Pennsylvania. *Ecological Engineering* 14:221-231.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22

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.

- 1 Day, J. W. Jr., J. Ko, J. Rybczyk, D. Sabins, R. Bean, G. Berthelot, C. Brantley, L. Cardoch, W.  
2 Conner, J. N. Day, A. J. Englande, S. Feagley, E. Hyfield, R. lane, J. Lindsey, J. Mistch, E.  
3 Reyes, and R. Twilley. 2004. The use of wetlands in the Mississippi Delta for wastewater  
4 assimilation: a review. *Ocean & Coastal Management* 47:671-691.
- 5
- 6 Downing, D. M., C. Winer, and L. D. Wood. 2003. Navigating Through Clean Water Act  
7 Jurisdiction: A Legal Review. *Wetlands* 23(3):475 – 493.
- 8
- 9 Erwin, K.L. 1991. An evaluation of wetland mitigation in the South Florida Water Management  
10 District, vol. I. Final Report to the South Florida Water Management District, West Palm  
11 Beach, FL. 124 pp.
- 12
- 13 Fenner, T. 1991. Cumulative impacts to San Diego County wetlands under federal and state  
14 regulatory programs 1985–1989. MA thesis. San Diego State University.
- 15
- 16 Frayer, W. E., T. J. Monahan, D. C. Bowden, and F. A. Graybill. 1983. Status and trends of  
17 wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's.  
18 Colorado State University, Ft. Collins, CO. 31 p.
- 19
- 20 Gallihugh, J. L. and J. D. Rogner. 1998. Wetland mitigation and 404 permit compliance study,  
21 Volume 2. U. S. Fish and Wildlife Service, Barrington, IL.
- 22

- 1 Gorham, E. 1991. Northern peatlands: role in the carbon cycle and probable responses to  
2 climatic warming. *Ecological Applications* 1:182-195.  
3
- 4 Highfield, W. E. and S. D. Brody. 2006. The Price of Permits: Measuring the Economic  
5 Impacts of Wetland Development on Flood Damages in Florida. *Natural Hazards Review*  
6 7(3):23-30.  
7
- 8 Holland, C. C. and M. E. Kentula. 1992. Impacts of section 404 permits requiring  
9 compensatory mitigation on wetlands in California (USA). *Wetlands Ecology and*  
10 *Management* 2(3):157-169.  
11
- 12 Holland, C. C., J. Honea, S. E. Gwin, and M. E. Kentula. 1995. Wetland degradation and loss in  
13 the rapidly urbanizing area of Portland, Oregon. *Wetlands* 15(4):336-345.  
14
- 15 “Issuance of Nationwide Permits; Notice.” 2005. *Federal Register*, 67(10):2019-2095.  
16
- 17 Josselyn, M., J. Zedler, and T. Griswold. 1989. Wetland mitigation along the Pacific Coast of  
18 the United States. p. 1-35. *In* J. Kusler and M.E. Kentula, (eds.) *Wetland creation and*  
19 *restoration: The status of the science*. Environmental Research Laboratory. Corvallis,  
20 Oregon.  
21
- 22 Kadlec, R. H. and R. L. Knight. 1996. *Treatment Wetlands*. CRC Press/Lewis Publishers, Boca  
23 Raton, FL. 893 pp.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21

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.

- 1 Liu, P. L., P. Lynett, H. Fernando, B. E. Jaffe, H. Fritz, B. Higman, R. Morton, J. Goff, and C.  
2 Synolakis. 2005. Observations by the International tsunami survey team in Sri Lanka.  
3 Science 308:1595.  
4
- 5 Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert. 2003. Crop Freezes and land-use change in  
6 Florida. Nature 426:29-30.  
7
- 8 Middleton, B. A. and K. L. McKee. 2001. Degradation of mangrove tissues and implications for peat  
9 formation in Belizean island forests. Journal of Ecology 89:818-828.  
10
- 11 Minello, T. J., K. W. Able, M. P. Weinstein, and C. G. Hays. 2003. Salt Marshes as nurseries for nekton:  
12 testing hypotheses on density, growth, and survival through meta-analysis. Marine Ecology Progress  
13 Series 246:39-59.  
14
- 15 Mitsch, W. J. and J. G. Gosselink. 2000. Wetlands: 3<sup>rd</sup> Edition. Wiley & Sons, New York. 920 pp.  
16
- 17 Mitsch, W. J., J. W. Day, J. W. Gillian, P. M. Groffman, D. L. Hey, G. W. Randall, and N. Wang. 2001.  
18 Reducing Nitrogen Loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to  
19 Counter a Persistent Ecological Problem. Bioscience 51(5):373-388.  
20
- 21 Ogden, J. C. 1994. A comparison of wading bird nesting colony dynamics (1931-1946 and 1974-1989)  
22 as an indication of ecosystem conditions in the southern Everglades, p. 533-570. In S. Davis and J.  
23 Ogden (eds.) Everglades: the Ecosystem and its Restoration. Delray Beach, Florida, St. Lucie Press.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21

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.

- 1 Stein, E. D. and R.E. Ambrose. 1998. Cumulative impacts of Section 404 Clean Water Act  
2 permitting on the riparian habitat of the Santa Margarita, California watershed. *Wetlands*  
3 18(3):393-408.  
4
- 5 Steiner, F., S. Pieart, E. Cook, J. Rich, and V. Coltman. 1994. State Wetlands and Riparian  
6 Area Protection Programs. *Environmental Management* 18(2):183-201.  
7
- 8 Turner, R. E. 1997. Wetland loss in the northern Gulf of Mexico: multiple working hypotheses.  
9 *Estuaries*. 20:1-13.  
10
- 11 United States Army Corps of Engineers (USACE). 2005. U.S. Army Corps of Engineers—  
12 Jacksonville District regional general permits,  
13 (<http://www.saj.usace.army.mil/permit/permitting/general-permits.htm>).  
14
- 15 United States Geological Survey. 1996. National Water Summary on Wetland Resources. USGS  
16 Water-Supply Paper 2425. Washington, D.C.  
17
- 18 Zedler, J. B. 1991. The Challenge of Protecting Endangered Species Habitat Along the Southern  
19 California Coast. *Coastal Management* 19:35-53.  
20
- 21 Zedler, J. B. and J. C. Callaway. 1999. Tracking wetland restoration: do mitigation sites follow desired  
22 trajectories. *Restoration Ecology* 7(1):69-73.  
23



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

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

State	Permit Type							
	General		Individual		Letter of Permission		Nationwide	
	<i>n</i>	% of Total	<i>n</i>	% of Total	<i>n</i>	% of Total	<i>n</i>	% 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%

1 Table 2. Breakdown showing number and percentage of Section 404  
 2 permits issued within urban areas and floodplains in Texas: 1991-  
 3 2003. 100 permit locations in Texas did not have FEMA data and  
 4 were not included.

Year	Urban		Floodplain	
	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%
<hr/> Total	2446	8689	4298	6801
	22.0%	78.0%	38.7%	61.3%

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

Year	Urban		Floodplain	
	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%
<b>Total</b>	<b>15753</b>	<b>11701</b>	<b>13293</b>	<b>14161</b>
	57.4%	42.6%	48.4%	51.6%

- 1 Table 4. Texas Section 404 permits by nearest wetland system type: 1991-2003. 3,209 permits  
 2 were within the area but lacked digital NWI data. 130 permits fell outside of 1 km boundary and  
 3 were not included. The average distance from permit to NWI wetland = 78.9 m and median  
 4 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%
	<i>23.2%</i>	<i>19.1%</i>	<i>18.6%</i>	<i>39.2%</i>		
Lacustrine	132	46	12	149	339	4.3%
	<i>38.9%</i>	<i>13.6%</i>	<i>3.5%</i>	<i>44.0%</i>		
Marine	3	16	5	28	52	0.7%
	<i>5.8%</i>	<i>30.8%</i>	<i>9.6%</i>	<i>53.8%</i>		
Upland	2	12	0	3	17	0.2%
	<i>11.8%</i>	<i>70.6%</i>	<i>0.0%</i>	<i>17.6%</i>		
Palustrine	335	323	119	2014	2791	35.7%
	<i>12.0%</i>	<i>11.6%</i>	<i>4.3%</i>	<i>72.2%</i>		
Riverine	356	51	107	366	880	11.3%
	<i>40.5%</i>	<i>5.8%</i>	<i>12.2%</i>	<i>41.6%</i>		

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

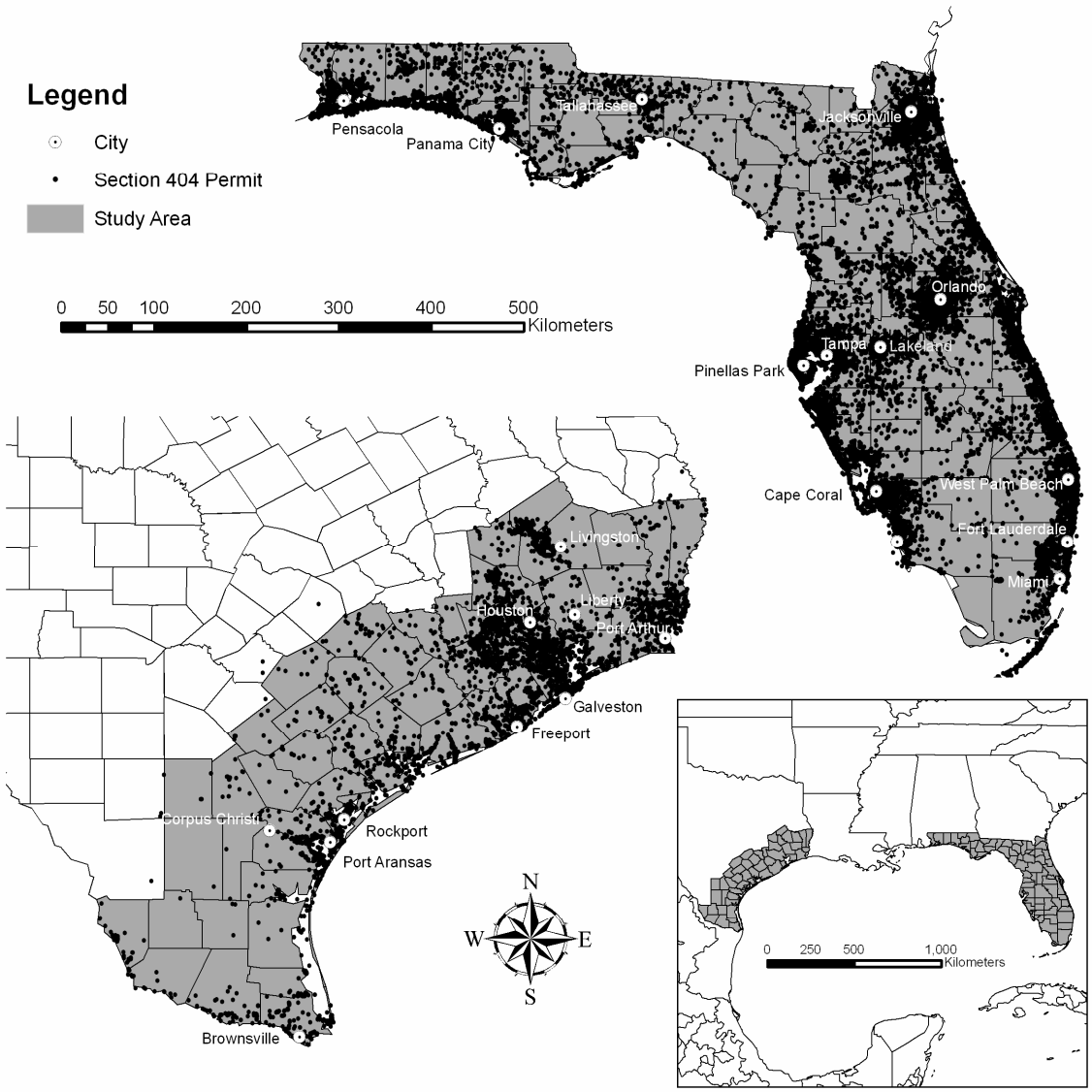
Wetland Type	Permit Type				Total	% of All Permits
	General	Individual	Letter	Nationwide		
Estuarine	2773	1303	1280	4164	9520	34.8%
	<i>29.1%</i>	<i>13.7%</i>	<i>13.4%</i>	<i>43.7%</i>		
Lacustrine	315	90	36	666	1107	4.0%
	<i>28.5%</i>	<i>8.1%</i>	<i>3.3%</i>	<i>60.2%</i>		
Marine	73	153	112	305	643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

4



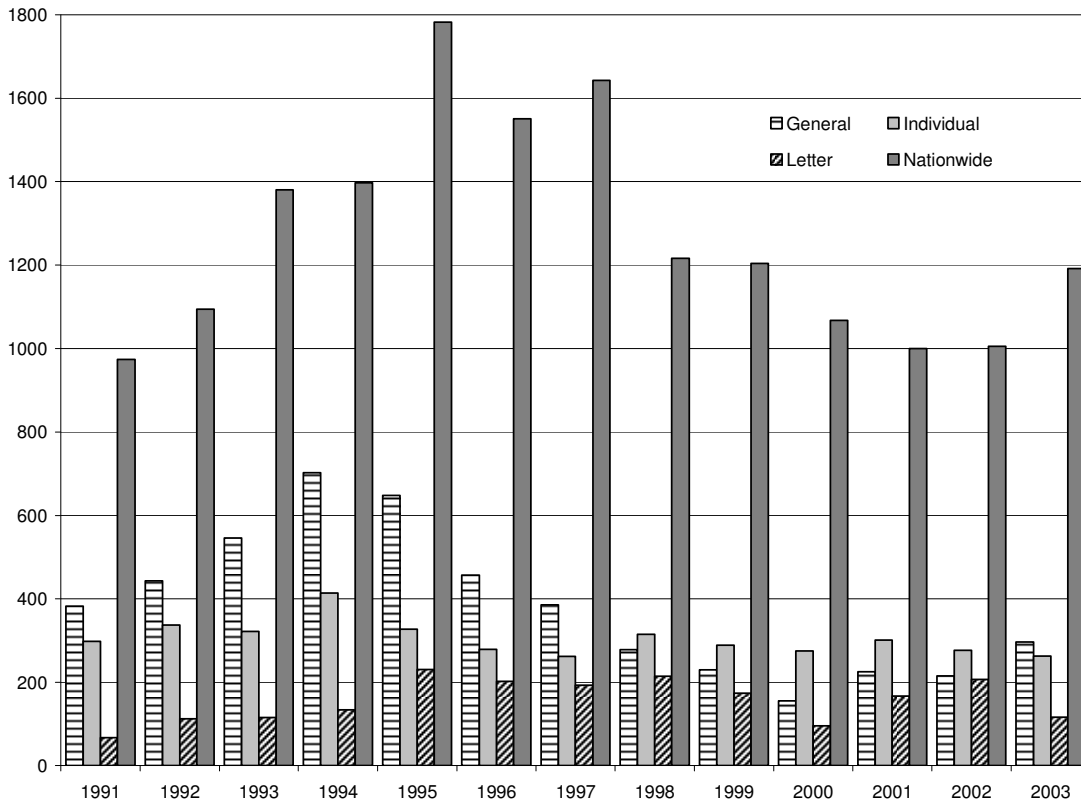
- 1 List of Figures
- 2 Figure 1. Map of greater Gulf of Mexico region with study areas of Texas and Florida
- 3 highlighted. Expanded maps show major metropolitan areas of Florida and coastal Texas and
- 4 Section 404 permit locations from 1991 to 2003.
- 5
- 6 Figure 2. Histogram plot of Section 404 Permits issued in Florida by type and year: 1991 –
- 7 2003.
- 8
- 9 Figure 3. Histogram plot of Section 404 Permits issued in Texas by type and year: 1991 – 2003.

1 Figure 1.



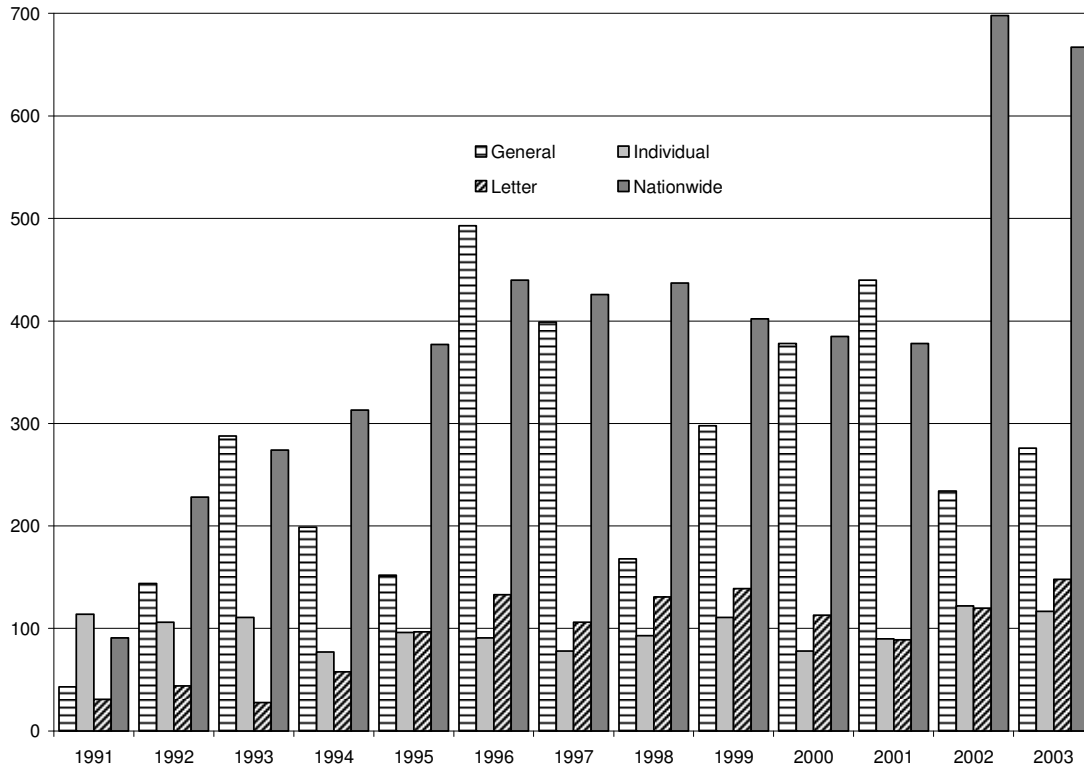
2

1 Figure 2.



2

1 Figure 3.



2