Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2009 to 2019

U.S. Department of the Interior
Fish and Wildlife Service

and

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

December 2024

Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2009 to 2019

Megan W. Lang, U.S. Fish and Wildlife Service

Susan-Marie Stedman, National Oceanic and Atmospheric Administration, National Marine Fisheries Service

Jeff C. Ingebritsen, U.S. Fish and Wildlife Service

Rusty K. Griffin, U.S. Fish and Wildlife Service

This report should be cited as: Lang, M.W., Stedman, S., J. C. Ingebritsen, and R. K. Griffin. 2024. Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2009 to 2019. U.S. Department of the Interior, Fish and Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 58 p.

Table of Contents

Acknowledgments

The authors would like to recognize key individuals from their respective agencies who have supported the completion and review of this study. Specifically, from the U.S. Fish and Wildlife Service (U.S. FWS): Jake Li, Assistant Director, Ecological Services; Gina Shultz, Deputy Assistant Director, Ecological Services; Martha Balis-Larsen, Chief, Division of Budget and Technical Support; and Jonathan Phinney, Chief, Branch of Geospatial Mapping and Technical Services. From the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries): Sam Rauch, Deputy Assistant Administrator; Carrie Robinson, Director, Office of Habitat Conservation; and Kara Meckley, Chief, Habitat Protection Division.

Statistical oversight was provided by Emily Silverman, Statistician, U.S. FWS Migratory Birds Program.

Editing, layout, and publication support was provided by Cara C. Schweitzer and Stephanie Smith, NOAA Fisheries.

Editorial, research, and outreach assistance was provided by the following individuals. From the U.S. FWS Ecological Services Program staff: Jane Harner and Lauren Healey. From NOAA Fisheries: Cara C. Schweitzer and Danielle Weissman.

Additional support for field operations and analysis was provided by the following U.S. FWS National Wetlands Inventory Program staff: Mitch Bergeson (currently with the U.S. Geological Survey), Herb Bergquist (retired), Gary Hunt, Amanda Pachomski, John Swords (retired), and Luke Worsham (currently with the Bureau of Land Management).

Mapping and other geospatial services were provided by the following organizations (project leads): Atkins North America Inc. (Matt Cusack), Dewberry Engineers Inc. (Keith Patterson), Ducks Unlimited (Robb Macleod), Saint Mary's University of Minnesota Geospatial Services (Andrew Robertson), SWCA Inc. (Tim O'Neill), and Virginia Tech Conservation Management Institute (Scott Klopfer).

Peer review of the report was provided by the following subject matter experts: Pauline Adams, U.S. Forest Service (U.S. FS); Jay Christensen, U.S. Environmental Protection Agency (U.S. EPA); Chris Darnell, U.S. FWS; Nicholas Enwright, U.S. Geological Survey (USGS); Michelle Lennox, NOAA Fisheries; Kim Penn, NOAA Ocean Service; Amanda Santoni, U.S. EPA; Cara C. Schweitzer, NOAA Fisheries; Bill Wilen, U.S. FWS (retired).

This report is a cooperative effort between the U.S. FWS and NOAA Fisheries to monitor coastal wetland area and change between 2009 and 2019. The report was also supported by the federal Interagency Coastal Wetlands Workgroup – a multi-agency group comprised of members from the U.S. EPA, NOAA, U.S. FS, U.S. FWS, Natural Resources Conservation Service, Federal Highway Administration, USGS, and U.S. Army Corps of Engineers.

Partial funding for this study was provided by the U.S. Environmental Protection Agency.

Executive Summary

This report is the third in a series produced by the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration spanning over twenty years. It provides scientific estimates of wetland area in coastal watersheds of the conterminous United States as well as change in wetland area between 2009 and 2019. The information in this and past reports is used by natural resource managers and policy makers to make strategic decisions regarding the conservation and management of wetlands in U.S. coastal watersheds.

In 2019, the coastal watersheds of the conterminous United States contained an estimated 41.6 million acres of wetlands, accounting for 36% of the wetlands in the entire conterminous United States by area. Coastal watersheds make up only 13% of the conterminous United States and thus contain a disproportionate amount of our nation's wetlands. The majority (85%) of wetlands in coastal watersheds were freshwater. Most wetlands were vegetated (i.e., contained trees, grasses, and other plants), including 96% (34.0 million acres) of freshwater and 79% (5.0 million acres) of saltwater wetlands. Freshwater (palustrine) forested wetlands were the most abundant wetland type overall (21.2 million acres), with freshwater shrub, emergent, and ponds occupying 6.5 million acres, 6.2 million acres, and 1.2 million acres, respectively. The most common saltwater wetland type was salt marsh (estuarine emergent; 4.2 million acres), followed by non-vegetated areas (e.g., mud flats, beaches, shoals, and sand bars; 1.3 million acres) and forested/shrub (871,000 acres). The coastal watershed regions with the most wetland area in 2019 were the Atlantic and Gulf of Mexico with 16.0 million acres and 15.8 million acres, respectively. Coastal watersheds of the Great Lakes had an estimated 8.4 million acres of wetlands. Pacific coastal watersheds had the least amount of wetland area (1.4 million acres).

The rate of net wetland loss in coastal watersheds of the conterminous United States from 2009–2019 (18,190 acres per year) was less than for the two previous Wetlands Status and Trends study periods (1998–2004 and 2004–2009). If this pattern continues, it would indicate progress towards reducing net wetland loss in coastal watersheds. The decreased rate of loss was greatest for freshwater wetlands. In particular, losses to upland urban and lacustrine areas (lakes) declined substantially. The rate of saltwater wetland loss also decreased since the previous study period. However, when compared to loss rates since the 1970s, net saltwater wetland loss from 2009 to 2019 (approximately 3,000 acres per year) was close to the average loss rate for other study periods except 2004–2009, which was unusually high. Overall, the results of this study suggest that from 2009 to 2019 rates of net freshwater wetland loss in coastal watersheds slowed substantially and rates of net saltwater wetland loss were less than from 2004–2009 but similar to other prior periods.

Although net loss in coastal watersheds has decreased since the last Wetlands Status and Trends study period, percent wetland loss was still greater in coastal watersheds than inland areas. Wetlands decreased by 0.5% in coastal watersheds while in the entire conterminous United States (coastal and inland watersheds) wetlands decreased by 0.2%. Net wetland losses in coastal watersheds (13% of the conterminous United States) accounted for 86% of all net losses within the conterminous United States.

Wetland loss was unevenly distributed across coastal regions. North Atlantic and Pacific coastal watersheds experienced a very small net gain in freshwater wetlands. Most net wetland losses were concentrated in the South Atlantic and Gulf of Mexico coastal watersheds, with smaller losses in the Great Lakes area.

Wetland loss was also unevenly distributed among wetland types. This study's findings extend a long-term pattern of vegetated wetland loss and non-vegetated wetland (e.g., ponds and intertidal flats) gain. When comparing the amount of net non-vegetated gain (133,000 acres) to net vegetated wetland loss (314,000 acres) in coastal watersheds, non-vegetated gain equaled over a third of vegetated losses. These non-vegetated wetland gains obscure the pattern of vegetated wetland loss when considering overall wetland change patterns.

Freshwater wetlands were most commonly lost to development, as indicated by the upland urban, upland rural development, and upland other categories. Losses to upland forested plantations were also common. Within the saltwater environment, wetlands were most commonly lost to marine and estuarine deepwater (e.g., open ocean). These saltwater wetland losses are most likely related to factors such as sea level rise, land subsidence, and decreased sediment supply. Some of the reduction in the rate of net wetland loss for 2009 to 2019 as compared to the previous study period (2004 to 2009) is likely related to a decline in construction after the 2008 recession.

The loss and alteration of wetlands documented by this study reduces the prosperity, health, and safety of coastal communities. This occurs through increased susceptibility of people and infrastructure to natural disasters like flooding, drought, and wildfire, as well as decreased food security, less clean water, greater vulnerability to sea level rise and storms, and reduced recreational opportunities. Wetland loss patterns have also affected and are likely to continue to substantially affect plant and animal populations, including commercially, culturally, and recreationally valuable species. When the effects of changes in wetland condition are taken into account, even greater loss of wetland functions and services are indicated.

The pattern of disproportionately high wetland loss and alteration in coastal watersheds is predicted to continue, if not intensify, in many areas, including the southeastern United States. The simultaneous growth of population, infrastructure, sea level rise, and natural disasters in coastal watersheds greatly increases the importance of wetland benefits, such as mitigation of floods, droughts, and severe storms, improved water quality, and opportunities for recreation. This growing demand for wetland benefits highlights the importance of strengthening wetland conservation efforts in this region. The need is especially urgent today because wetlands are being lost more rapidly in coastal watersheds than in other region and they are vital for supporting the health, safety, and economic prosperity of coastal communities.

Introduction

Wetlands are often found at the transition between dry land and water bodies such as lakes, rivers, and oceans, and are a pivotal part of coastal landscapes. They provide habitat for countless species of fish, birds, mammals, and plants, protect shorelines, filter pollutants, and absorb flood waters [1]. Wetlands have long provided food and building materials, as well as places to hunt, fish, kayak, bird watch, and enjoy open spaces.

Coastal watersheds—that is, drainage basins affected by tides or adjacent to the Great Lakes—contain many different types of wetlands. These include saline or brackish wetlands such as salt marshes, seagrass beds, and mangroves, as well as non-saline wetlands such as freshwater marshes and swamps (forested wetlands). Although most people think of wetlands as having vegetation, such as grasses in a marsh or trees in a swamp, wetlands can also be non-vegetated, such as ponds, mudflats, or rocky intertidal shores. Whether directly on the coast providing a home for juvenile fish or further inland absorbing flood waters, wetlands in coastal watersheds are diverse and vital to the health of coastal landscapes. However, wetlands are also some of the most threatened natural systems globally [2] [3].

Wetlands are essential to the economic prosperity of coastal communities [1]. More than half of the U.S. population lives and works in coastal watersheds [4], many in fields that depend on wetlands, such as commercial fishing, tourism, and recreation. Approximately 46 to 95% of U.S. commercial fish landings and 80 to 85% of recreational landings depend on coastal wetlands and estuaries [5]. Commercial fish landings were valued at $4.8 billion in 2020, with Alaska, Hawaii, Oregon, Louisiana, Virginia, and Massachusetts among the states that ranked highest in volume and value of seafood caught [6].

The highest value fishery species—crabs, lobster, scallops, salmon, and shrimp—all use wetlands at some point in their lives and therefore depend on healthy and abundant wetland habitats. The connection between shrimp and wetlands is so strong that scientists have established a direct link between shrimp populations and the amount of wetland edge in the Gulf of Mexico [7]. When wetlands disappear, shrimp populations decline, and the livelihoods of shrimp harvesters are put at risk.

Wetlands support and protect coastal communities in ways that are sometimes not immediately apparent. For example, they can dampen the destructive power of storm waves. Wetlands also absorb flood waters, which often cause the majority of damage from hurricanes and other severe storms. A study on the impact of Hurricane Sandy, which affected 12 coastal states from Maine to North Carolina in 2012, found that wetlands reduced flood heights, preventing more than $625 million in flood damage [8]. Even areas in more inland parts of coastal watersheds, such as Hamilton Township, New Jersey which is about 40 miles from the coast, benefitted from flood reduction provided by wetlands [8].

Coastal wetlands are estimated to save about $39.54 billion (after conversion to 2024 USD) annually in damage to U.S. Atlantic and Gulf of Mexico coastal communities [9]. Conversely, researchers have linked the loss of wetlands in heavily developed areas to increased flooding damage after hurricanes. This was the case in Houston, Texas after Hurricane Harvey in 2017 [10]. When wetlands are replaced with development, stormwater ponds are often constructed to help prevent flooding, a service that was being provided by the original wetland. However, artificial ponds are inadequate substitutes for natural wetlands because they do not provide other important benefits to communities [11].

Wetlands are especially important today because they help to avoid or lessen the impact of many of our most pressing environmental challenges. These challenges include increasing temperatures, sea level rise, hurricanes and other severe storms, droughts and floods, wildfires, and the growing need for readily available clean water [2] [12]. For these reasons and more, the U.S. Fish and Wildlife Service (U.S. FWS) and National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) recognize wetlands as a "trust resource"—a nationally important resource that the government protects for all citizens.

In recognition of the importance of wetlands in coastal watersheds, the U.S. FWS and NOAA Fisheries released a report in 2008 documenting wetland change in the coastal watersheds of the Atlantic, Gulf of Mexico, and Great Lakes [13]. That study estimated a net loss of 361,100 acres of wetlands in coastal watersheds of the eastern United States between 1998 and 2004, which is equivalent to losing about 165 football fields of wetlands each day. Most of that loss occurred in watersheds along the Gulf of Mexico, where an estimated 397,000 acres of freshwater vegetated wetlands were lost due to a number of factors and more than 45,000 acres were lost to deepwater (e.g., open ocean) due to subsidence, sea level rise, and other factors.

In 2013, U.S. FWS and NOAA released a second report documenting wetland change in the coastal watersheds of the Atlantic, Gulf of Mexico, Great Lakes, and Pacific regions of the conterminous United States [14]. Findings from that study indicated that saltwater and freshwater wetland area declined by an estimated 360,720 acres between 2004 and 2009. This is equivalent to a loss of about 220 football fields of wetlands each day. The average annual rate of loss for all wetlands in coastal watersheds was 80,160 acres from 2004 to 2009. Similar to the previous report, most of the wetland loss occurred in watersheds along the Gulf of Mexico. At the same time, saltwater wetlands declined by more than 95,000 acres, almost double the loss reported in the previous report [14].

When these patterns are compared to those for the entire conterminous United States [15], the importance of focusing on wetlands in coastal watersheds is evident. Although coastal watersheds represent only 13% of the conterminous United States by area, they contain all saltwater wetlands and roughly a third of freshwater wetlands (Figure 1). They have also suffered a disproportionate amount of loss compared to non-coastal (inland) wetlands.

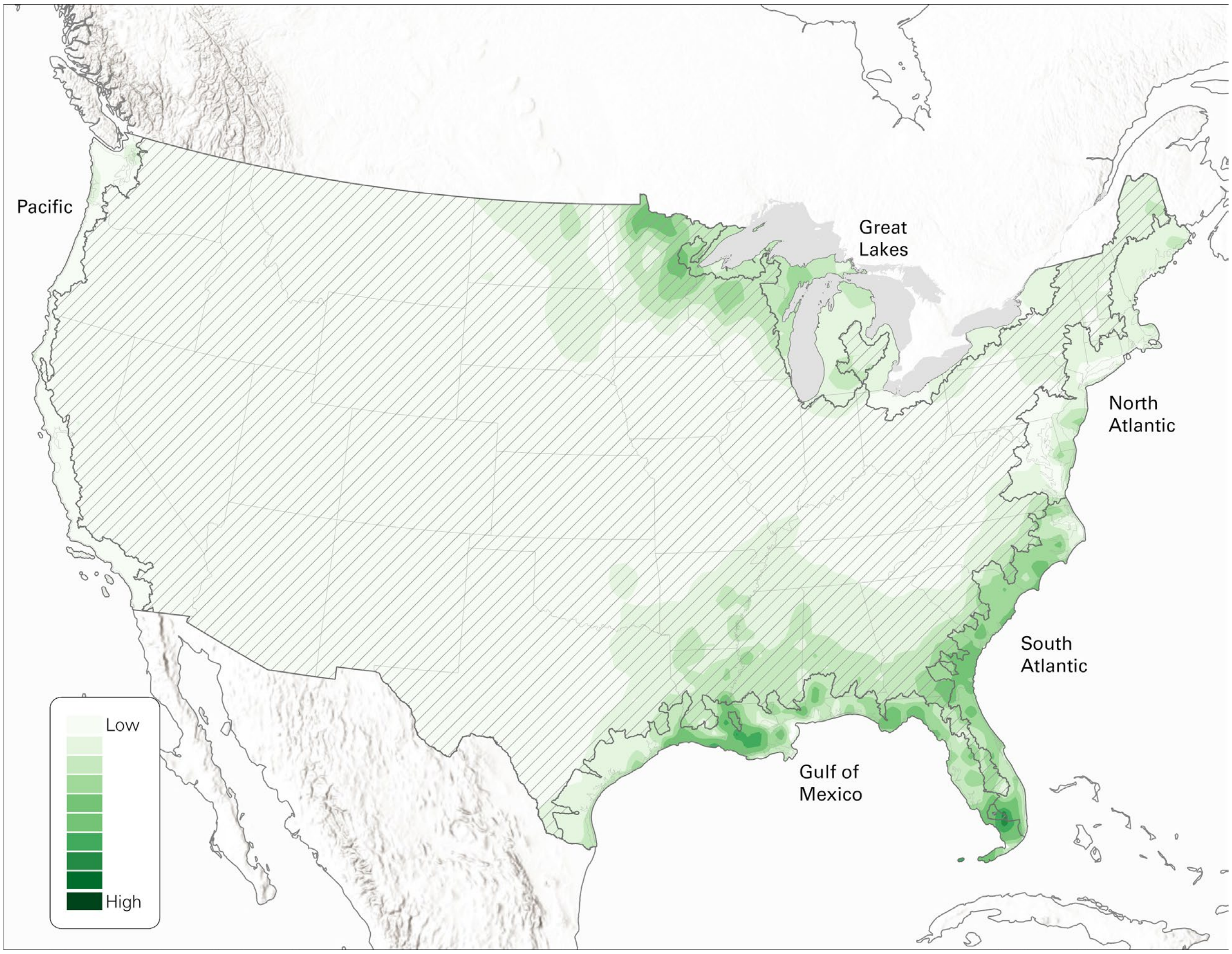

Figure 1. Relative wetland area (i.e., low to high wetland density) for coastal and inland watersheds of the conterminous United States in 2019. Inland watersheds are indicated with a cross-hatch pattern. Coastal watersheds are not cross-hatched and are outlined with a gray border.

Scientific Methods

The goal of this study was to produce statistically valid estimates of wetland and deepwater habitat status (area) and trends (change) between 2009 and 2019 in coastal watersheds of the conterminous United States. Coastal watersheds are defined as U.S. Geological Survey eight-digit hydrologic unit code watersheds that contain tidal waters or drain directly into the Great Lakes. Estimates were produced for coastal watersheds in the Atlantic, Gulf of Mexico, Great Lakes, and Pacific regions, as well as nationally (Table 1).

The study used a survey-based approach carried out within 2,620 plots (four square miles each) randomly distributed within physiographic regions (adapted from Hammond (1970) [16]) with plots allocated to these regions by wetland density (i.e., more plots in wetter areas). A team of highly-trained image interpreters with regional expertise used a combination of fine spatial resolution (≤ 3.3 foot pixel size) airborne and satellite imagery, on-screen digitizing, and field visits to determine land cover (and in some cases land use) types and area in 2009 and 2019. We estimated change over the 10.5 year study period by comparing data from those dates (Figure 2). A group of regional and national experts ensured data quality by repeatedly double-checking for data accuracy in the field as well as digitally, including manual and automated observations. Field verification was completed for 359 sample plots distributed over 23 coastal states. We enhanced measurement accuracy by implementing technological improvements, such as refining 2009 wetland and deepwater boundaries, improving the spatial and temporal resolution of base and ancillary imagery, and collecting field verification data using a global positioning system (GPS) enabled software application.

Table 1. Area of coastal watersheds and coastline included in this study.

Coastal Watershed	Area of Coastal Watersheds (acres)	Coastline (miles)
Atlantic	89,096,000	2,070
Gulf of Mexico	67,562,000	1,630
Great Lakes (U.S. only)	55,869,000	5,180 (including connecting rivers)
Pacific	34,372,000	1,290
Total	246,899,000	10,170

We identified wetlands using a biological definition [17], which differs from the federal regulatory definition and does not imply regulatory jurisdiction. The biological definition requires that hydrology (i.e., inundation and/or soil saturation) meet requirements to be a wetland, and if soil and/or vegetation are present, they must be hydric and hydrophytic, respectively (i.e., soil and vegetation must also indicate wetland status). We classified wetlands into three main types based on salinity: palustrine (salinity < 0.5 ppt), estuarine (salinity between 0.5 and 30 ppt), and marine (salinity ≥ 30 ppt). Considering primarily vegetation presence and type, we then further divided these three wetland types into 13 subcategories that are consistent with the Federal Geographic Data Committee Wetlands Mapping Standard [17] (Table 2).

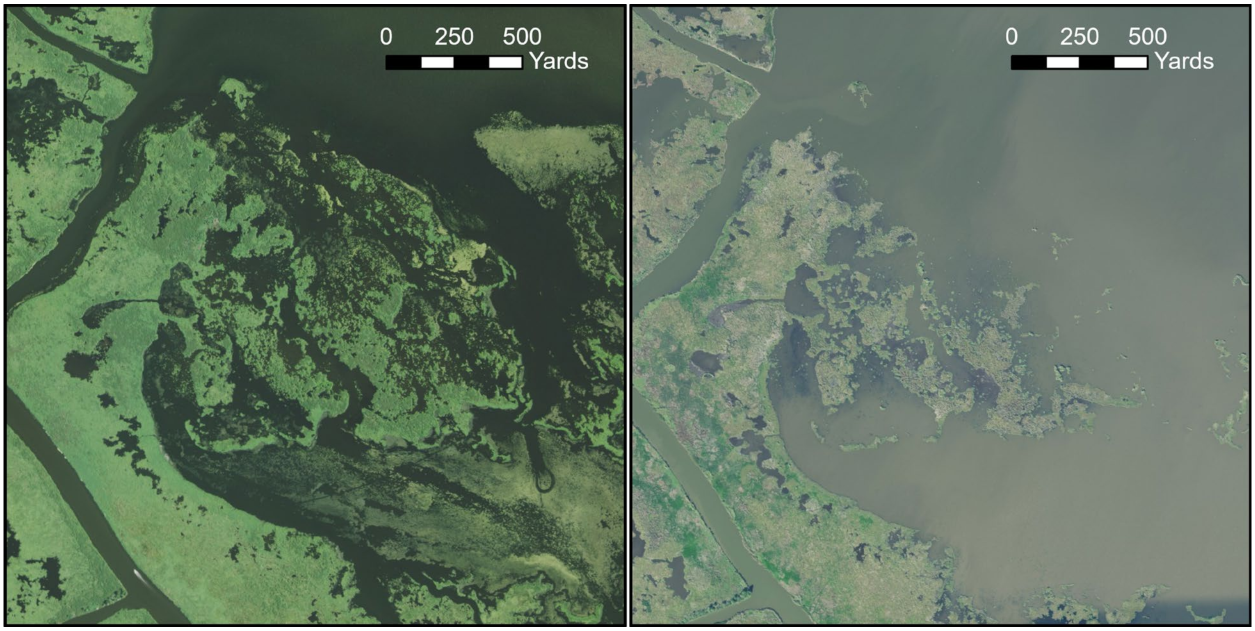

Figure 2. Aerial imagery showing wetland change between 2010 (left) and 2021 (right) for a salt marsh along the Gulf of Mexico coastline. Note areas of substantial wetland loss in the center of the 2021 image.

In addition to wetland categories, we tracked four deepwater and five upland categories (Table 2). Deepwater habitats have water that is too deep to be considered a wetland. This includes tidal habitats (i.e., marine and estuarine) with water depths below spring low tide and non-tidal habitats with depths exceeding 8.2 feet at their lowest levels. We did not include the Great Lakes in our deepwater estimates. We use the term “upland” in this report to denote land areas that are too dry to be wetlands. Upland categories were used to provide more information on what might be driving wetland change. Change between wetland, deepwater, and upland categories was only documented when it was clearly indicated in remotely sensed imagery (e.g., non-ditched water-covered area replaced by a ditched dry area) and determined to be long-term (not temporary due to weather or other factors). For more information on procedures used to help ensure the quality of Wetlands Status and Trends data see National Standards and Support Team (2017) [18].

Area, amount of change, and associated standard errors for wetland and deepwater habitats in the conterminous United States were estimated using conventional mathematical and statistical methods. The change values reported represent net change (as opposed to gross change) unless otherwise noted. Net change represents the balance between increases and decreases for a given category and was calculated as the difference between all increases and decreases (increases minus decreases) to the area of a particular category. We evaluated the magnitude of wetland change relative to measured uncertainty with p-values. Additional information on study methods, including wetland, upland, and deepwater categories, sampling scheme, quality control, and statistical analysis can be found in Dahl (2011) [19] and National Standards and Support Team (2017) [18].

Table 2. Description of wetland, deepwater, and upland categories used in this study.

Saltwater Habitats	Common Description
Marine Subtidal*	Open ocean
Marine Intertidal	Near shore
Estuarine Subtidal*	Open water, bays
Estuarine Intertidal Emergent	Salt marsh
Estuarine Intertidal Forested/Shrub	Mangroves or other estuarine shrubs
Estuarine Intertidal Unconsolidated Shore	Beaches, bars, flats
Freshwater Habitats	**Common Description**
Palustrine Forested	Swamps (wetlands with woody plants >6.6 yards tall)
Palustrine Shrub	Wetlands with woody plants <6.6 yards tall
Palustrine Emergent	Inland marshes/wet meadows
Palustrine Farmed	Farmed wetlands
Palustrine Unconsolidated Bottom (ponds)	Open water ponds, aquatic beds
Pond – Natural characteristics	Small bog lakes, vernal pools, kettles, beaver ponds, alligator holes
Pond – Industrial	Flooded mine or excavation sites (including highway borrow sites), in-ground treatment ponds or lagoons, holding ponds
Pond – Urban use	Aesthetic or recreational ponds, golf course ponds, residential lakes, ornamental ponds, water retention ponds
Pond – Agriculture use	Ponds in proximity to agricultural, farming or silviculture operations such as farm ponds, livestock dug-outs, agricultural waste ponds, irrigation or drainage water retention ponds
Pond – Aquaculture	Ponds singly or in series used for aquaculture including fish rearing
Lacustrine*	Lakes and reservoirs
Riverine* (may be tidal or non-tidal)	Rivers and streams
Uplands	**Common Description**
Agriculture	Cropland, pasture, managed rangeland
Urban	Cities and incorporated developments
Forested Plantations	Planted or otherwise intensively managed forests
Rural Development	Non-urban developed areas and infrastructure
Other Uplands	Rural uplands not in any other category including non-intensively managed forests, grasslands and barren lands

** deepwater categories*

Highlight: The Effect of Restoration on Status and Trends Data

Environmental restoration work involves returning a site to its more natural or historic condition to improve the benefits that it provides. Wetland restoration can be accomplished through many different methods. These include excavating dirt or other fill and re-planting wetland vegetation, removing tidal gates to reconnect marshes to free-flowing water, adding sediment to a marsh surface to rebuild its soil, and eliminating invasive vegetation so native wetland plants can grow (Interagency Workgroup on Wetland Restoration 2003). Wetland restoration is occurring in all 50 U.S. states under a variety of voluntary private and public programs. Numerous large wetland restoration efforts are ongoing in coastal areas such as the Chesapeake Bay (Maryland and Virginia), southern Florida, Louisiana, San Francisco Bay, and Puget Sound. Restoration is also a common form of "compensatory mitigation" – a process in which wetlands lost due to authorized activities, such as fill for development, must be offset according to federal, state, or local laws. Together, these efforts have restored millions of acres of wetlands in the United States (Council on Environmental Quality 2008).

Some of the wetland gain outlined in this report from agriculture and other upland areas as well as deepwater is likely the result of wetland restoration. However, not all restoration conducted in coastal watersheds between 2009 and 2019 would have been counted as a gain in wetland acreage in this study. This is because in many cases restoration is conducted in wetlands that are degraded – often substantially so – but are still considered wetlands. For example, many salt marshes are ditched, which impairs their function. When restored, those marshes usually provide better habitat, more pollution reduction, and enhanced flood protection, but the area of wetlands on the landscape does not change post-restoration. The restoration of a degraded wetland does not result in a gain in wetland area, and is therefore not captured as a wetland gain in this report. Only the restoration of an area that is no longer a wetland, such as a marsh that has been filled in with dirt and no longer has wetland characteristics, results in a gain of wetland area and is captured by Status and Trends data.

Restoration of all kinds is an important part of wetland conservation. Increasing both the function and acres of wetlands on the landscape will be necessary to ensure that wetlands continue to provide the ecosystem services so vital to coastal watersheds and populations.

Citations

Interagency Workgroup on Wetland Restoration. 2003. *An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement*. National Oceanic and Atmospheric Administration, Washington D.C., 92 p.

Council on Environmental Quality. 2008. *Conserving America's Wetlands: Four Years of Progress Implementing the President's Goal.* Washington, D.C., 32 p.

Study Results

Area of Wetlands in Coastal Watersheds

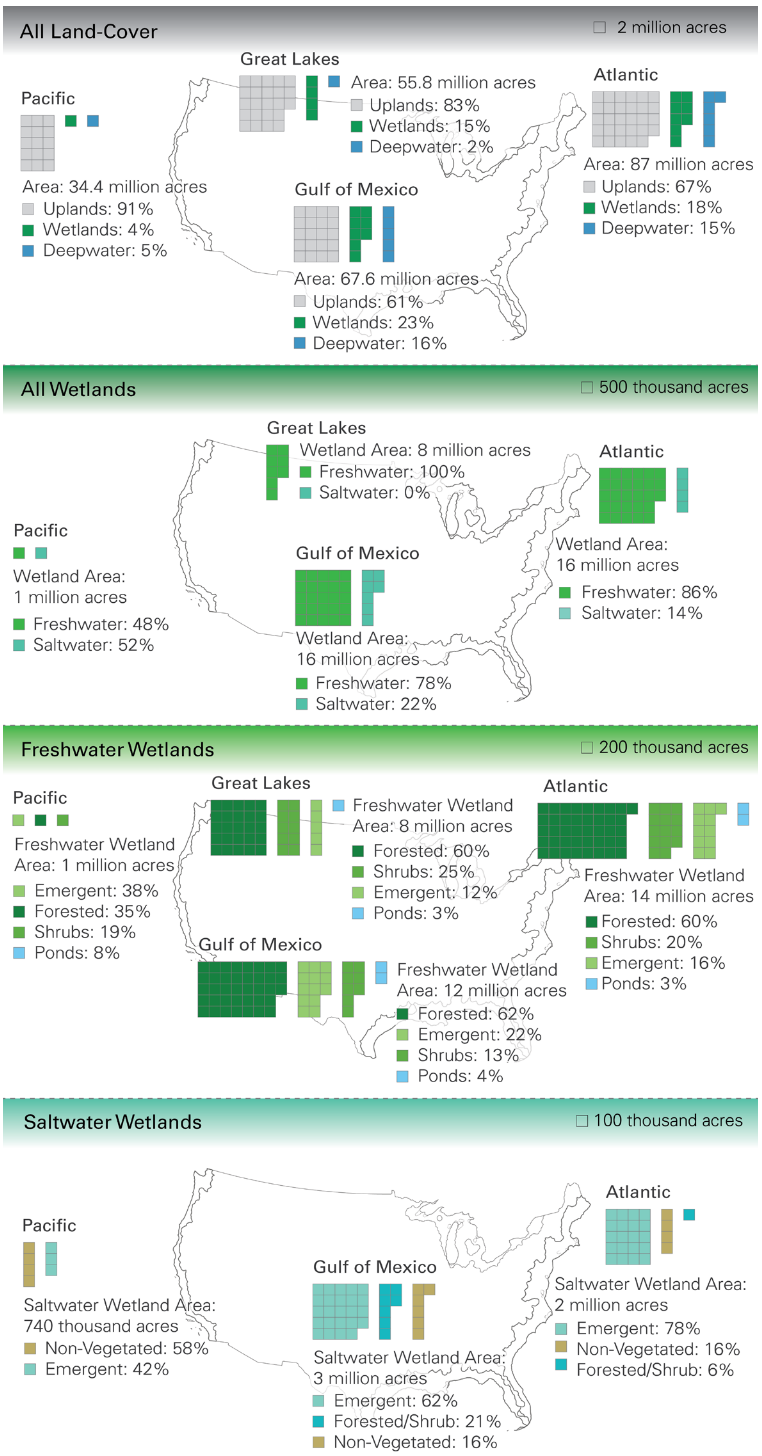

Figure 3. Area of upland, deepwater, and wetlands within coastal regions of the conterminous United States in 2019.

Coastal watersheds of the conterminous United States contained an estimated 41.6 million acres of wetlands in 2019 (Table 3). Coastal watersheds made up 13% of the conterminous United States by area and contained 36% of its wetlands (Table 4). All saltwater and 32% of freshwater (i.e., palustrine) wetlands were found in coastal watersheds. Wetlands occupied a much larger proportion of land area in coastal watersheds (17%) relative to inland watersheds (<6%). Woody freshwater wetlands, especially forested wetlands, were more common in coastal watersheds compared to inland areas (40% of forested wetlands are found in coastal watersheds).

The vast majority of wetlands in coastal watersheds were freshwater (85% or 35.3 million acres; Figure 3), with saltwater (estuarine and marine) wetlands occupying 6.4 million acres (15%; Table 3). Most coastal wetlands were vegetated, including 96% (34.0 million acres) of freshwater and 79% (5.0 million acres) of saltwater wetlands. Freshwater forested wetlands were the most abundant type overall (21.2 million acres), with freshwater shrub, emergent, and ponds occupying 6.5 million acres, 6.2 million acres, and 1.2 million acres, respectively.

Table 3. Summary of 2019 area and 2009–2019 area change for select wetland and deepwater categories in coastal watersheds of the conterminous United States.

	Area, In Thousands of Acres				
Wetland/Deepwater Category	*Estimated Area, 2009*	*Estimated Area, 2019*	*Change, 2009-2019*	*Change (%)*	*Change P-Value*
Saltwater Non-Vegetated	1,306 (6.9)	1,343 (6.8)	37 (24.9)	2.8%	<.001
Saltwater Vegetated	5,109 (3.4)	5,041 (3.4)	-68 (17.8)	-1.3%	<.001
Estuarine Intertidal Emergent	4,244 (5.4)	4,170 (5.4)	-74 (25.6)	-1.8%	<.001
Estuarine Intertidal Forested/Shrub	864 (12.2)	871 (12.1)	6 (123.0)	0.7%	0.416
All Saltwater Wetlands	6,415 (2.1)	6,384 (2.1)	-31 (26.7)	-0.5%	<.001
Palustrine Ponds	1,111 (1.7)	1,206 (1.6)	96 (4.7)	8.6%	<.001
Palustrine Farmed	83 (11.6)	73 (15.7)	-10 (37.5)	-11.7%	0.008
Freshwater Vegetated	34,230 (1.5)	33,985 (1.5)	-246 (9.1)	-0.7%	<.001
Palustrine Emergent	6,215 (6.0)	6,231 (5.9)	17 (355.0)	0.3%	0.778
Palustrine Shrub	6,718 (5.6)	6,540 (5.7)	-178 (52.0)	-2.7%	0.055
Palustrine Forested	21,298 (3.2)	21,214 (3.2)	-84 (113.4)	-0.4%	0.378
Palustrine Shrub and Forested	28,016 (2.1)	27,753 (2.1)	-262 (14.6)	-0.9%	<.001
All Freshwater Wetlands	35,424 (0.8)	35,264 (0.8)	-160 (7.3)	-0.5%	<.001
All Non-Vegetated Wetlands	2,417 (1.9)	2,549 (1.8)	133 (3.9)	5.5%	<.001
All Vegetated Wetlands	39,339 (1.0)	39,025 (1.0)	-314 (5.5)	-0.8%	<.001
All Wetlands	41,838 (0.6)	41,647 (0.6)	-191 (4.7)	-0.5%	<.001
Lacustrine	3,453 (11.5)	3,495 (11.4)	42 (34.5)	1.2%	0.004
Riverine	1,352 (13.0)	1,343 (13.1)	-9 (69.1)	-0.6%	0.148
Estuarine Subtidal	21,777 (2.8)	21,830 (2.8)	53 (46.7)	0.2%	0.032
All Deepwater Habitats	26,581 (1.5)	26,668 (1.5)	87 (21.3)	0.3%	<.001

*Coefficient of variation (CV; [standard error/mean] * 100) for each entry expressed as percent is given in parentheses below area and change values. P-value is provided for change. The lacustrine category does not include the open water areas of the Great Lakes. Farmed wetlands are neither vegetated nor non-vegetated by definition and therefore were not included in either group. The saltwater non-vegetated category includes estuarine and marine habitats. Any apparent discrepancy between the area estimates and their reported difference is due to rounding.*

Saltwater wetlands were limited to Atlantic, Gulf of Mexico, and Pacific watersheds and occupied only 0.3% of the conterminous United States. The most common saltwater wetland type was estuarine emergent marsh (i.e., salt marsh; 4.2 million acres), followed by estuarine and marine non-vegetated areas (e.g., beaches, mud flats, shoals, and sand bars; 1.3 million acres) and estuarine forested/shrub (871,000 acres). Deepwater habitats occupied a total of 26.7 million acres within coastal watersheds, including 21.8 million acres of estuarine subtidal, 3.5 million acres of lacustrine (lakes not including the Great Lakes), and 1.3 million acres of riverine (i.e., river and stream) habitat.

Although wetlands occurred along all coasts, wetland area was distributed unevenly among coastal regions in 2019 (Table 5; Figure 3). The coastal watersheds of the Atlantic and Gulf of Mexico had very similar amounts of wetland area (16.0 million acres and 15.8 million acres, respectively) with the South Atlantic having three times as many wetlands as the North Atlantic. Coastal watersheds of the Great Lakes had about half that wetland area (8.4 million acres) and Pacific coastal watersheds had the least amount of wetland area with an estimated 1.4 million acres. Most freshwater wetlands were found in coastal watersheds of the Atlantic (13.7 million acres), followed by the Gulf of Mexico (12.4 million acres), Great Lakes (8.4 million acres), and Pacific (0.7 million acres). Most saltwater wetlands were found in coastal watersheds of the Gulf of Mexico (3.4 million acres), followed by the Atlantic (2.2 million acres), and Pacific (0.7 million acres).

Table 4. Estimated freshwater (palustrine) wetland area in the coastal watersheds of the Atlantic, Gulf of Mexico, Great Lakes, and Pacific as compared to the conterminous United States, 2019.

Wetland Category	*Area in Acres, 2019*		
	Wetlands in Coastal Watersheds	*Wetlands in Conterminous United States*	*% Wetland Area in Coastal Watersheds*
Freshwater Non-Vegetated (Ponds)	1,206,064 (1.6)	6,876,057 (1.3)	17.5%
Palustrine Farmed	72,888 (15.7)	1,972,899 (24.0)	3.7%
Freshwater Vegetated	33,984,732 (1.5)	101,527,286 (1.7)	33.5%
-Palustrine Emergent	6,231,377 (5.9)	30,008,202 (7.8)	20.8%
-Palustrine Shrub	6,539,677 (5.7)	19,090,867 (5.0)	34.3%
-Palustrine Forested	21,213,677 (3.2)	52,428,216 (2.7)	40.5%
All Freshwater Wetlands	35,263,684 (0.8)	110,376,242 (0.8)	31.9%
All Freshwater Wetlands (no Pf)	35,190,796 (0.9)	108,403,343 (0.9)	32.5%

Coefficient of variation expressed as a percentage is given in parentheses.

Change in All Wetland Types

Wetland losses within coastal watersheds of the conterminous United States exceeded gains, resulting in a net loss of 191,000 acres between 2009 and 2019 (Table 3). Net loss was disproportionately high in coastal watersheds relative to the entire conterminous United States, which lost 221,000 acres during the same period. Wetland loss within coastal watersheds was unevenly distributed across regions (Table 5). Coastal watersheds adjacent to the Gulf of Mexico sustained the largest wetland losses (114,000 acres), followed by the South Atlantic (77,500 acres), and Great Lakes (32,600 acres). Those along the North Atlantic and Pacific gained wetland area (19,900 acres and 12,700 acres, respectively).

Net loss within coastal watersheds was driven by the conversion of wetlands to either upland or deepwater land cover types (Figure 4). Conversion to upland was the dominant driver of wetland loss resulting in a total wetland reduction of 136,000 acres. Conversion to deepwater areas accounted for a loss of 55,000 acres. This continued wetland loss to both deepwater and uplands extends a long-term pattern (Figure 5) that has already resulted in the conterminous United States, including coastal and inland watersheds, losing over half of its wetland area since the 1780s [20]. However, the rate of wetland loss within coastal watersheds (18,000 acres/year) was lower in this study period than in the previous period (2004–2009; 80,000 acres/year).

In addition to net wetland loss, Wetlands Status and Trends data for 2009–2019 indicate a fundamental alteration of wetland type within coastal watersheds. The decrease in vegetated wetlands was 314,000 acres (Table 3). In contrast, non-vegetated wetlands and deepwater categories increased in area (133, 000 and 87,000 acres, respectively). When change to all

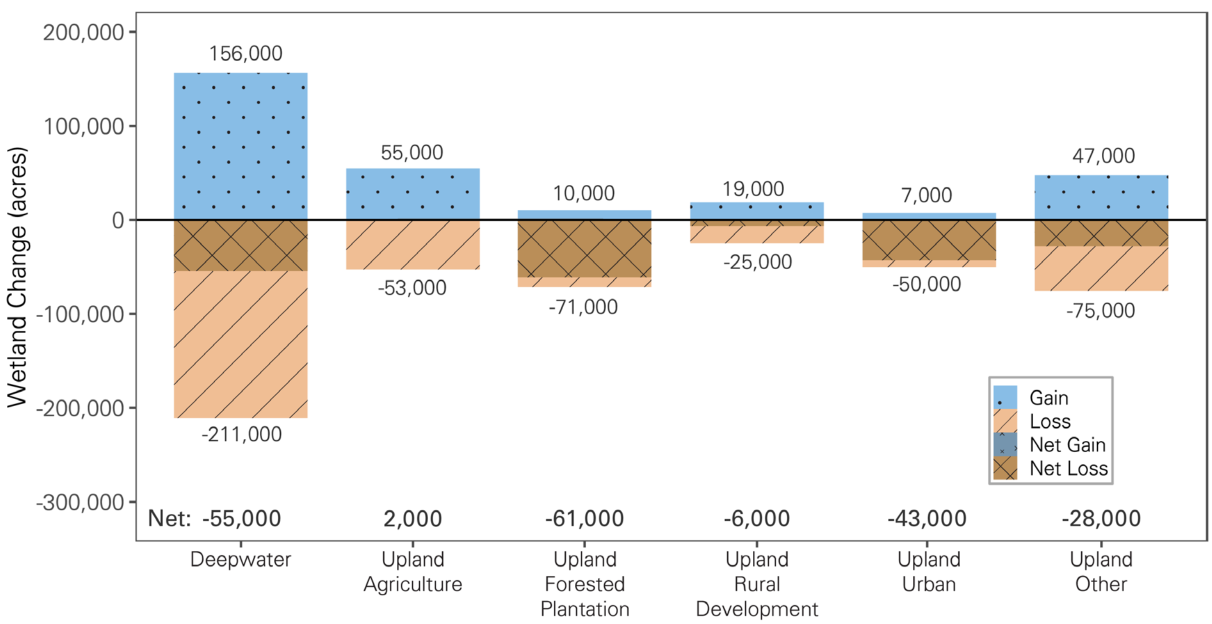

Figure 4. Wetland gain and loss between 2009 and 2019 in coastal watersheds of the conterminous United States attributed to different change drivers, including gross and net values. Numbers have been rounded to the nearest thousand.

wetland types is considered (a loss of 191,000 acres), the gains in non-vegetated wetlands (e.g., stormwater ponds and intertidal flats) obscure the magnitude of vegetated wetland (e.g., marshes and swamps) losses. Most importantly, data from this (Figure 5) and previous Wetlands Status and Trends reports [15] indicate a long-term sustained increase in non-vegetated wetland area and decrease in vegetated wetland area within coastal watersheds.

Table 5. Changes in wetland area by region for coastal watersheds of the conterminous United States.

	Area in Acres				
Coastal Region	*Wetland Area 2009*	*Wetland Area 2019*	*Change, 2009-2019*	*Change (%)*	*Change P-Value*
North Atlantic	3,984,275	4,004,158	19,883	0.5%	<.001
South Atlantic	12,039,770	11,962,224	-77,546	-0.6%	<.001
Gulf of Mexico	15,932,405	15,818,848	-113,557	-0.7%	<.001
Great Lakes	8,469,407	8,436,854	-32,552	-0.4%	<.001
Pacific	1,412,528	1,425,250	12,722	0.9%	<.001
Total	**41,838,385**	**41,647,334**	**-191,051**	**-0.5%**	**<.001**

Saltwater Wetland Changes

Saltwater wetlands within coastal watersheds of the conterminous United States experienced a net decrease of 31,000 acres between 2009 and 2019 (Table 3). Saltwater vegetated wetlands decreased across all regions leading to a total decrease of 1.3% (68,000 acres), while non-vegetated wetlands increased across all regions leading to an increase of 2.8% (37,000 acres; Table 6). Estuarine emergent marsh (i.e., salt marsh), the largest saltwater wetland category by area, decreased by 1.8% or 74,000 acres. There were small increases in salt marsh in areas formerly occupied by freshwater wetlands (21,000 acres) and uplands (2,000 acres; Figure 6). The pattern of decreasing salt marsh and increasing non-vegetated saltwater wetlands (i.e., estuarine intertidal unconsolidated shore and marine intertidal) has been consistent for the past 70 years with the exception of a small amount of non-vegetated wetland loss between 1986 and 1997 [15].

Net decrease in salt marsh was primarily associated with change of marsh to non-vegetated habitats (Figure 6). In most cases, salt marsh was converted to marine and estuarine subtidal (deepwater; 65,000 acres), but change to intertidal non-vegetated wetlands (e.g., mud flats, shoals, and sand bars) also occurred (23,000 acres). The net loss of salt marsh to these other categories is a highly statistically significant ($p < .001$) pattern that has been ongoing for about 70 years.

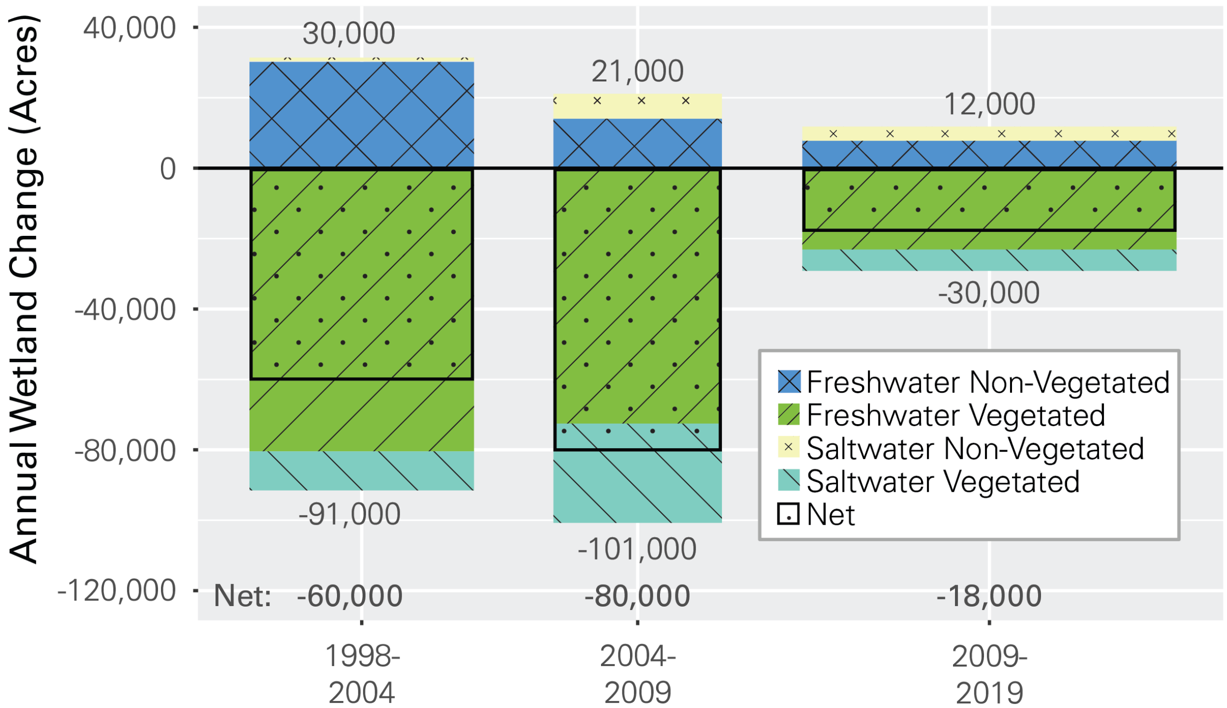

Figure 5. Annual net vegetated and non-vegetated change in fresh and saltwater environments, as well as overall wetland change, across study periods in coastal watersheds of the conterminous United States.

Freshwater Wetland Changes

Coastal watersheds are losing large amounts of vegetated freshwater wetlands to upland and deepwater (Table 3). The net decrease of all freshwater wetlands within coastal watersheds was 160,000 acres. The largest loss of freshwater wetlands was to development as indicated by losses to upland urban (42,000 acres), upland other (often a precursor to development; 32,000 acres), and upland rural development (6,000 acres). Together these categories (Figure 7) accounted for 80,000 acres of loss. Loss to upland forested plantations (61,000 acres) was also substantial, followed by loss to deepwater lakes (i.e., lacustrine; 9,000 acres). A gain of freshwater wetlands from upland agriculture (2,000 acres) and rivers (riverine; 14,000 acres) also occurred. When only vegetated freshwater wetlands are considered (Figure 7), net decrease in area was substantially greater (222,000 acres), including conversion to ponds (30,000 acres) and loss to upland agriculture (28,000 acres). Freshwater vegetated wetland loss was greatest along the Gulf of Mexico (129,000 acres), followed by the Atlantic (88,000 acres; losses primarily in the South Atlantic) and Great Lakes (41,000 acres; Table 7). Freshwater vegetated wetlands increased along the Pacific coast (12,000 acres).

Table 6. Summary of 2009 and 2019 area and 2009 through 2019 area change for saltwater wetlands in coastal watersheds of the conterminous United States by region.

A1. Estimated Changes to Saltwater Wetlands of the North Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Saltwater Non-Vegetated	231,491 (13.3)	241,657 (12.9)	10,165 (42.8)	4.4%	0.020
Estuarine Intertidal Vegetated	720,512 (9.2)	715,147 (9.2)	-5,365 (43.0)	-0.7%	0.020
All Saltwater Wetlands	952,003 (5.3)	956,804 (5.3)	4,800 (59.4)	0.5%	0.093

A2. Estimated Changes to Saltwater Wetlands of the South Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Saltwater Non-Vegetated	106,078 (9.5)	109,576 (9.4)	3,498 (42.0)	3.3%	0.017
Estuarine Intertidal Vegetated	1,129,036 (4.7)	1,131,084 (4.7)	2,048 (254.1)	0.2%	0.694
All Saltwater Wetlands	1,235,114 (2.9)	1,240,660 (2.9)	5,546 (64.3)	0.4%	0.120

A. Estimated Changes to Saltwater Wetlands of the Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Saltwater Non-Vegetated	337,570 (9.6)	351,233 (9.4)	13,663 (33.6)	4.0%	0.003
Estuarine Intertidal Vegetated	1,849,548 (4.6)	1,846,230 (4.6)	-3,317 (171.6)	-0.2%	0.560
All Saltwater Wetlands	2,187,117 (2.8)	2,197,463 (2.8)	10,346 (44.1)	0.5%	0.024

Table 6 (continued). Summary of 2009 and 2019 area and 2009 through 2019 area change for saltwater wetlands in coastal watersheds of the conterminous United States by region.

B. Estimated Changes to Saltwater Wetlands of the Gulf of Mexico Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Saltwater Non-Vegetated	546,252 (8.2)	564,751 (8.0)	18,500 (39.4)	3.4%	0.011
Estuarine Intertidal Vegetated	2,941,302 (3.9)	2,881,925 (4.0)	-59,377 (17.2)	-2.0%	<.001
All Saltwater Wetlands	3,487,554 (2.3)	3,446,677 (2.3)	-40,877 (17.0)	-1.2%	<.001

C. Estimated Changes to Saltwater Wetlands of the Pacific Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Saltwater Non-Vegetated	422,332 (17.0)	427,124 (16.8)	4,792 (67.2)	1.1%	0.138
Estuarine Intertidal Vegetated	317,820 (31.6)	312,386 (31.3)	-5,434 (60.3)	-1.7%	0.098
All Saltwater Wetlands	740,153 (12.5)	739,511 (12.5)	-642 (61.0)	-0.1%	0.101

Freshwater woody wetland area (i.e., shrub and forested) decreased by a net of 262,000 acres, including a decrease of 178,000 acres of freshwater shrub wetlands, the largest single category decrease during the study period (Table 3). The majority of this decrease was driven by loss to upland (170,000 acres), including losses to upland forested plantation (64,000 acres), upland other (45,000 acres), upland urban (27,000 acres), upland rural development (18,000 acres), and upland agriculture (16,000 acres; Figure 8).

Decrease in woody wetland area was also driven by conversion to other wetland types, including freshwater emergent (58,000 acres), ponds (19,000 acres), and salt marsh (15,000 acres; Figure 8). The magnitude of gross change (i.e., all increases and decreases) between woody and freshwater emergent wetlands (757,000 acres) was nearly four times larger than gross losses/gains to upland (197,000 acres). Change between these wetland categories was likely driven primarily by timber harvest and subsequent regrowth of non-woody plants [120].

Table 7. Summary of 2009 and 2019 area and 2009 through 2019 area change for freshwater (palustrine) wetlands in coastal watersheds of the conterminous United States by region.

A1. Estimated Changes to Freshwater Wetlands of the North Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	183,672	185,432	1,760	1.0%	0.128
	(4.7)	(4.4)	(65.7)		
Freshwater Vegetated	2,839,296	2,852,637	13,342	0.5%	0.211
	(4.1)	(4.1)	(79.8)		
All Freshwater Wetlands	3,022,968	3,038,069	15,101	0.5%	0.013
	(2.3)	(2.3)	(40.2)		

A2. Estimated Changes to Freshwater Wetlands of the South Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	261,350	281,815	20,466	7.8%	<.001
	(3.2)	(3.0)	(7.2)		
Freshwater Vegetated	10,528,747	10,427,756	-100,990	-1.0%	<.001
	(2.2)	(2.2)	(10.3)		
All Freshwater Wetlands	10,790,096	10,709,572	-80,525	-0.7%	<.001
	(1.2)	(1.2)	(7.4)		

A. Estimated Changes to Freshwater Wetlands of the Atlantic Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	445,022	467,247	22,225	5.0%	<.001
	(2.7)	(2.5)	(8.4)		
Freshwater Vegetated	13,368,042	13,280,393	-87,649	-0.7%	<.001
	(1.9)	(1.9)	(17.0)		
All Freshwater Wetlands	13,813,064	13,747,641	-65,424	-0.5%	<.001
	(1.0)	(1.1)	(13.0)		

Table 7 (continued). Summary of 2009 and 2019 area and 2009 through 2019 area change for freshwater (palustrine) wetlands in coastal watersheds of the conterminous United States by region.

B. Estimated Changes to Freshwater Wetlands of the Great Lakes Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	223,154 (4.1)	232,800 (4.0)	9,646 (11.6)	4.3%	<.001
Freshwater Vegetated	8,217,934 (4.4)	8,177,162 (4.4)	-40,773 (19.3)	-0.5%	<.001
All Freshwater Wetlands	8,441,088 (2.6)	8,409,961 (2.6)	-31,127 (15.1)	-0.4%	<.001

C. Estimated Changes to Freshwater Wetlands of the Gulf of Mexico Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	386,053 (2.7)	448,295 (2.6)	62,243 (6.1)	16.1%	<.001
Freshwater Vegetated	12,030,967 (2.3)	11,901,975 (2.3)	-128,993 (11.1)	-1.1%	<.001
All Freshwater Wetlands	12,417,020 (1.2)	12,350,270 (1.2)	-66,750 (11.6)	-0.5%	<.001

D. Estimated Changes to Freshwater Wetlands of the Pacific Coast

Wetland Category	*Area in Acres*			*Change (%)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009-2019*		
Freshwater Non-Vegetated (Ponds)	56,289 (6.2)	57,722 (6.0)	1,433 (41.6)	2.5%	0.017
Freshwater Vegetated	613,544 (8.4)	625,202 (8.3)	11,658 (19.6)	1.9%	<.001
All Freshwater Wetlands	669,833 (4.5)	682,924 (4.5)	13,091 (9.9)	2.0%	<.001

The net decrease of freshwater vegetated wetlands co-occurred with a substantial net increase in ponds of 96,000 acres (Table 3). Pond area increased by 8.6% during the study period. These increases were greatest along the Gulf of Mexico (16.1%), followed by the Atlantic (5.0%), Great Lakes (4.3%), and Pacific (2.5%; Table 7). Increases were primarily gains of urban

(35,000 acres) and agricultural (33,000 acres) but also included natural and industrial ponds (16,000 and 12,000 acres, respectively). Increases in urban and industrial ponds were likely primarily driven by development (e.g., stormwater management ponds). The increase in agricultural ponds was likely associated with a combination of excavation and diking to support farming practices (e.g., irrigation/water supply). Most ponds were gained from upland agriculture (37,000 acres), followed by upland other (16,000 acres), upland forested plantation (8,000 acres), and upland urban (4,000 acres; Figure 9). Vegetated wetlands were also changed to ponds, resulting in a net pond increase of 30,000 acres and a commensurate decrease in vegetated wetland area. These changes continue a long-term pattern of freshwater vegetated wetland decrease and pond increase that has persisted for about 70 years [15].

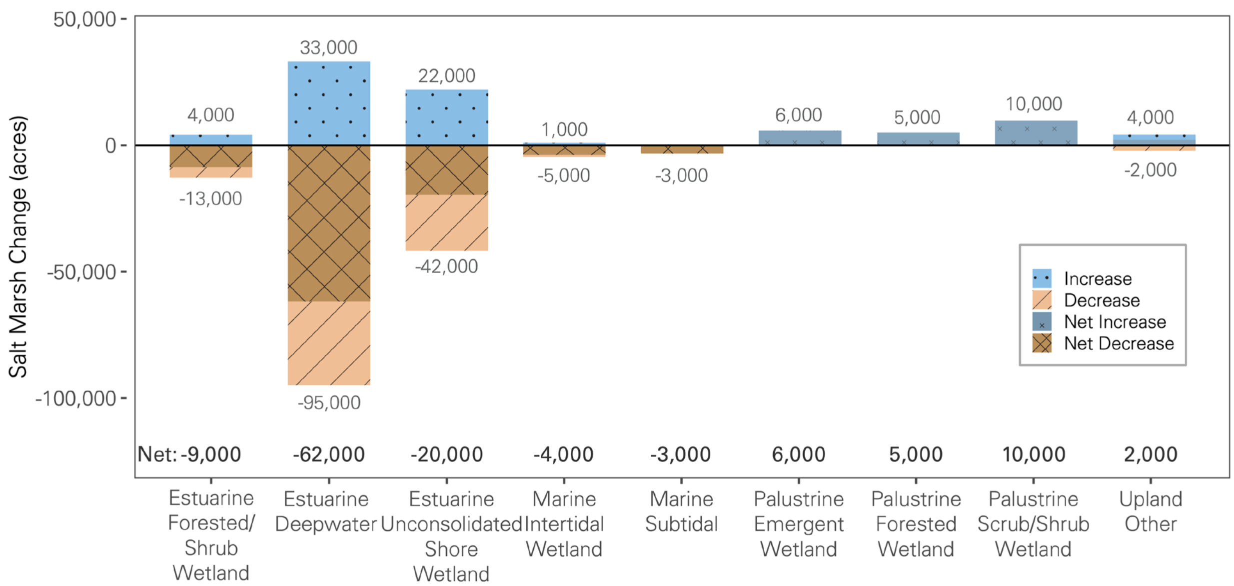

Figure 6. Salt marsh (estuarine intertidal emergent) area change between 2009 and 2019 in coastal watersheds of the conterminous United States attributed to different drivers, including both gross and net change. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

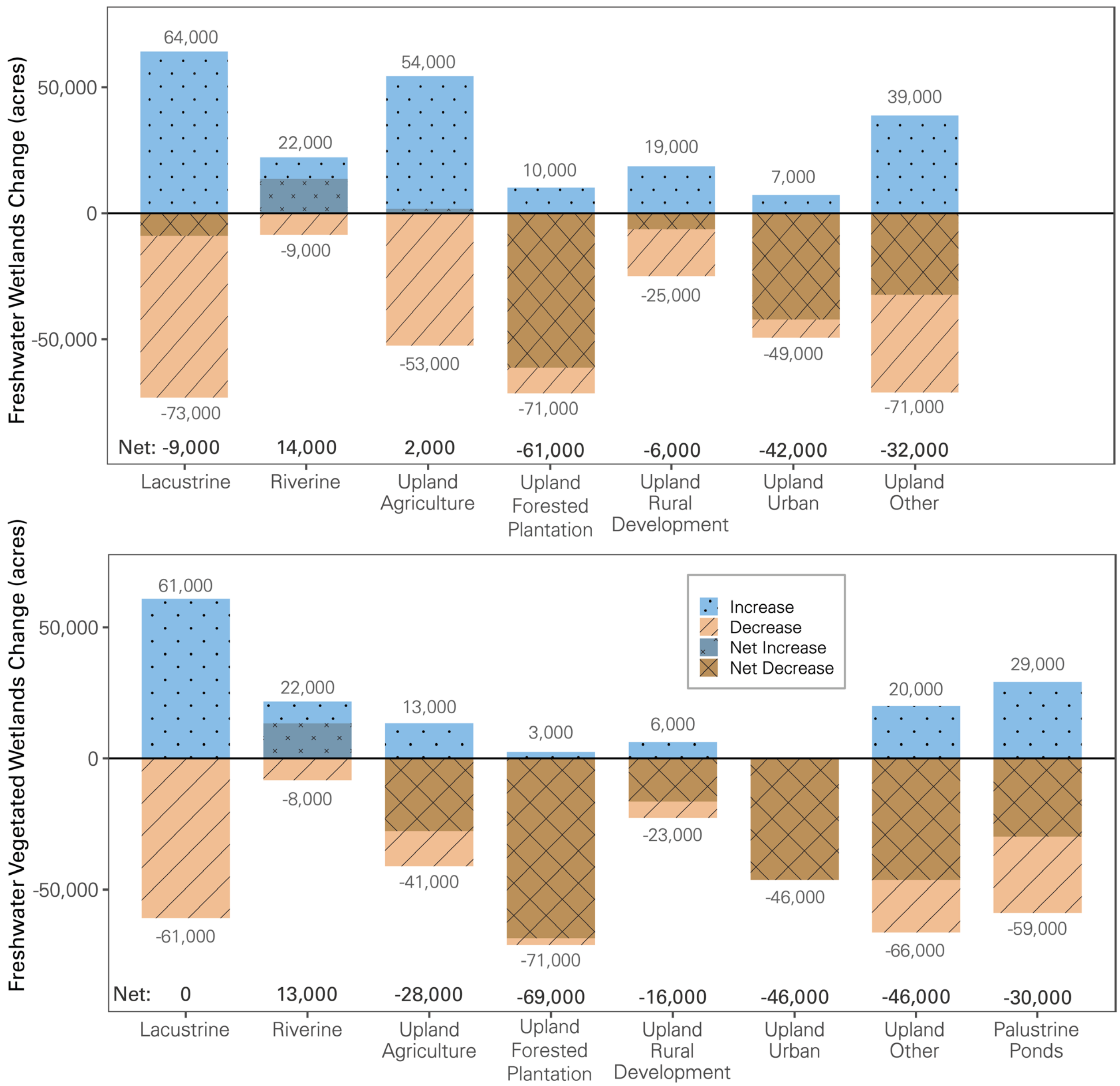

Figure 7. Freshwater (palustrine) all wetland (top) and vegetated wetland (bottom) change between 2009 and 2019 in coastal watersheds of the conterminous United States attributed to different drivers, including gross and net change. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

Highlight: Using Wetlands Status and Trends Reports to Support Great Lakes Conservation Initiatives

Wetlands Status and Trends reports support strategic planning and the implementation of wetland conservation projects by providing valuable scientific information on U.S. wetlands, including how they are changing. This information helps policymakers and managers determine what conservation actions are needed to better support people and the plants and animals they depend on. Strategic conservation of coastal wetlands benefits communities now and in the future by helping to reduce the impact of natural disasters, improve water quality, bolster water supply, support biodiversity, and provide opportunities for recreation, including hunting, fishing, and birdwatching.

The U.S. Fish and Wildlife Service (U.S. FWS) works with private landowners, Tribes, states, conservation groups, corporations, and others to protect and restore wetlands, in part by administering competitive grant programs in coastal watersheds. The grant programs rely on Wetlands Status and Trends reports to help identify grant proposals that benefit wetland types most in need of conservation. Based on the findings in this and other reports, vegetated wetlands such as swamps and marshes are among the wetland types in greatest need.

One important wetland grant program is the U.S. FWS North American Wetlands Conservation Act (NAWCA) Program. It provides grants to protect, restore, and enhance wetlands throughout North America, primarily for the benefit of migratory birds. A recently completed project in the Great Lakes area conserved nearly 2,000 acres of the Pleasantview Swamp, one of the largest intact wetlands in the northern part of Lower Michigan.

In addition to improving water quality in a renowned trout stream and two Great Lakes, the project provides rare and much desired shoreline protection. This benefits resident and migratory birds, including the federally endangered piping plover, as well as other species like beavers and otters. The public can enjoy these conserved lands through local birding and water trails, as well as the state-designated historic M-119 Tunnel of Trees. This 20-mile scenic drive features a continuous tree canopy that creates the feeling of traveling through a tunnel. It is one of the most popular natural attractions in Michigan. This project was very cost-effective, leveraging resources worth more than three times the amount of the NAWCA grant to provide a wide range of benefits to people, fish, and wildlife.

National Coastal Wetlands Conservation (NCWC) Grants are another source of funding for wetland conservation. They are provided to coastal and Great Lakes states, as well as U.S. territories, to protect, restore, and enhance coastal wetland ecosystems. A NCWC grant recently helped the state of Michigan conserve a critical parcel of land connecting the northern and southern portions of Negwegon State Park. The project helps to protect eight miles of continuous shoreline along Thunder Bay and almost 500 acres of nationally declining vegetated wetlands. Its high-quality marsh —which includes sedge, rush, and bulrush—provides important habitat for migratory and resident birds, such as the state threatened Caspian tern and common loon, as well as the federally endangered Hine’s emerald dragonfly. Forested wetlands provide habitat for additional species, such as bald eagles, osprey, wood ducks, and flying squirrels. More than 40 fish species, including juvenile lake whitefish, an important recreational species, will also benefit from the protection of these wetlands. This project will prevent fragmentation of important wetlands and provide public access to the shoreline for fishing, bird watching, and kayaking. It also features a view of the National Oceanic and Atmospheric Administration's Thunder Bay Marine Sanctuary and is part of the Great Lakes Maritime Heritage Trail. Finally, the newly conserved land will serve as an outdoor classroom for local schools and community groups.

Federal efforts that conserve coastal wetlands, such as NCWC and NAWCA grants, are especially important because they protect communities from floods, filter our water, provide recreation, and support local economies. Because roughly half of threatened and endangered species are wetland dependent, conserving vulnerable coastal wetlands helps to recover these species, and keep others from being listed.

Discussion

Summary of Results

The rate of wetland loss in coastal watersheds of the conterminous United States from 2009–2019 was less than for the two previous Wetlands Status and Trends study periods (1998-2004 and 2004–2009; Figure 5). If this pattern continues, it would indicate progress towards reducing wetland loss in coastal watersheds. The decreased rate of loss was greatest for freshwater wetlands. In particular, losses to upland urban and lacustrine areas (lakes) declined substantially. The rate of saltwater wetland loss also decreased since the previous study period (2004–2009). However, when compared to loss rates since the 1970s [15], saltwater wetland loss from 2009 to 2019 was close to the average loss rate for other study periods except 2004–2009, which was unusually high. Overall, the results of this study suggest that from 2009 to 2019 rates of freshwater wetland loss in coastal watersheds slowed substantially and rates of saltwater wetland loss were less than from 2004–2009 but similar to other prior periods.

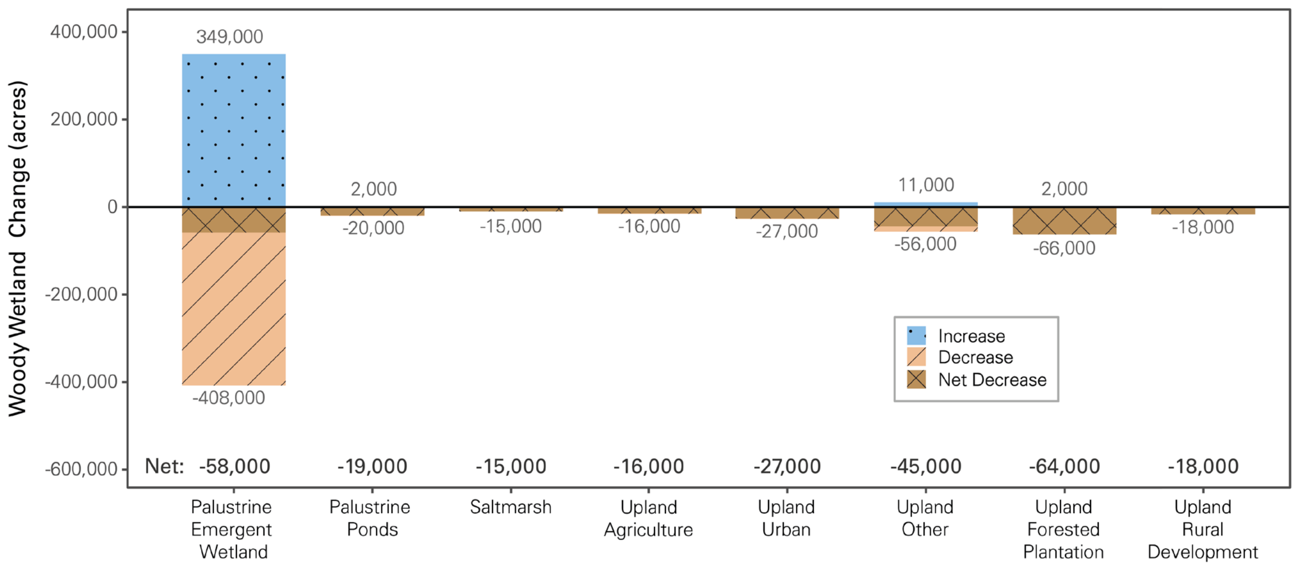

Figure 8. Woody freshwater (palustrine forested and shrub) wetland area change between 2009 and 2019 in coastal watersheds of the conterminous United States attributed to different drivers, including both gross and net change. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

Although net loss in coastal watersheds has decreased since the last Wetlands Status and Trends study period, percent wetland loss was still higher in coastal watersheds than inland areas. All wetland types combined decreased by 0.5% and vegetated wetlands decreased by 0.8% in coastal watersheds (Table 3). Salt marsh decreased by the greatest amount of all wetland types (1.8%). In comparison, in the entire conterminous United States (coastal and inland watersheds), all wetland types decreased by (0.2%) and vegetated wetlands decreased by (0.6%) [15]. Wetland losses in coastal watersheds (13% of the conterminous United States) accounted for 86% of all wetland losses and 47% of vegetated wetland losses within the conterminous United States. The disproportionate amount of wetland loss in coastal watersheds underscores the need to continue to monitor these areas.

Wetland loss was unevenly distributed across coastal regions (Tables 6 and 7). The North Atlantic and Pacific coastal watersheds experienced a very small gain in freshwater wetlands. Most wetland losses were concentrated in the South Atlantic and Gulf of Mexico coastal watersheds, with smaller losses in the Great Lakes area (Figure 10).

Wetland loss was also unevenly distributed among wetland types. This study's findings extend a long-term pattern of vegetated wetland loss and non-vegetated wetland (e.g., ponds and intertidal flats) gain [15]. Net freshwater wetland loss to upland (i.e., land areas that are too dry to be wetlands) or deepwater (i.e., water bodies deeper than 8.2 ft at low water or, if tidal, below mean low spring tide) disproportionately affected vegetated wetlands, relative to non-vegetated wetlands, resulting in a net loss of 246,000 acres of freshwater vegetated wetlands (Table 3). In contrast, the area of non-vegetated wetlands increased. Net pond area was gained from all upland and freshwater wetland classes, making it a particularly ubiquitous pattern (Figure 9). Pond gains represent the largest percent habitat change (8.6% increase; gain of 96,000 acres) of any wetland or deepwater category. Similarly, non-vegetated saltwater wetland area expanded by 2.8% (37,000 acres) while vegetated saltwater wetland area decreased in all regions with saltwater habitats (1.3% overall; 68,000 acres; Table 6). When comparing the amount of non-vegetated gain (133,000 acres) to vegetated wetland loss (314,000 acres) in coastal watersheds, non-vegetated gain equaled over a third of vegetated losses. These non-vegetated wetland gains obscure the pattern of vegetated wetland loss when considering overall wetland change patterns.

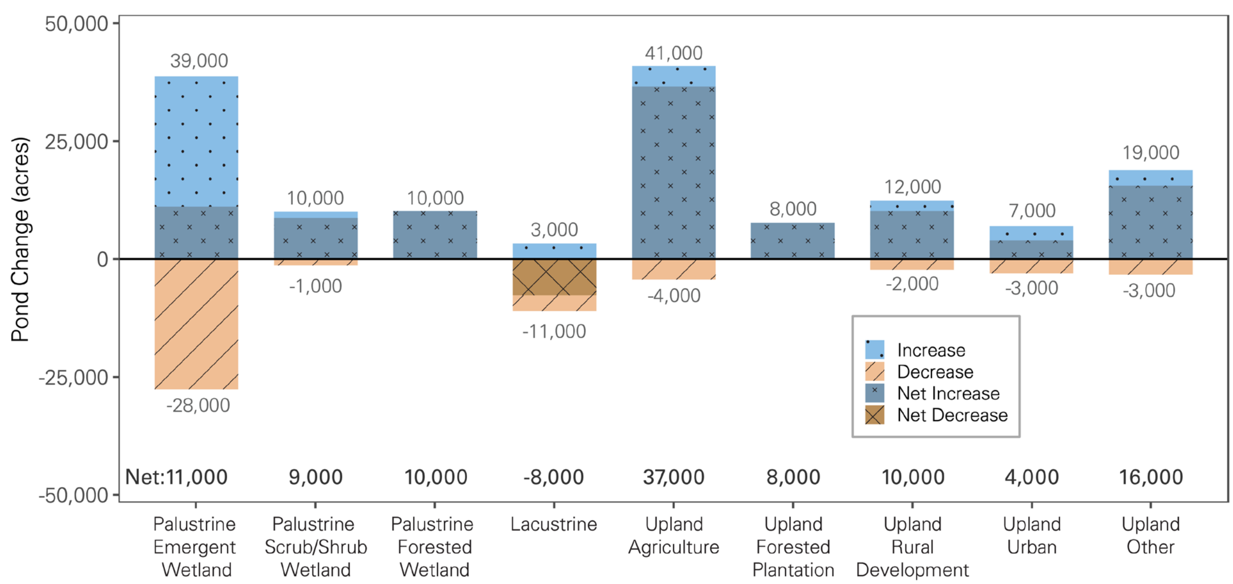

Figure 9. Pond area change between 2009 and 2019 in coastal watersheds of the conterminous United States attributed to different drivers, including both gross and net change. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

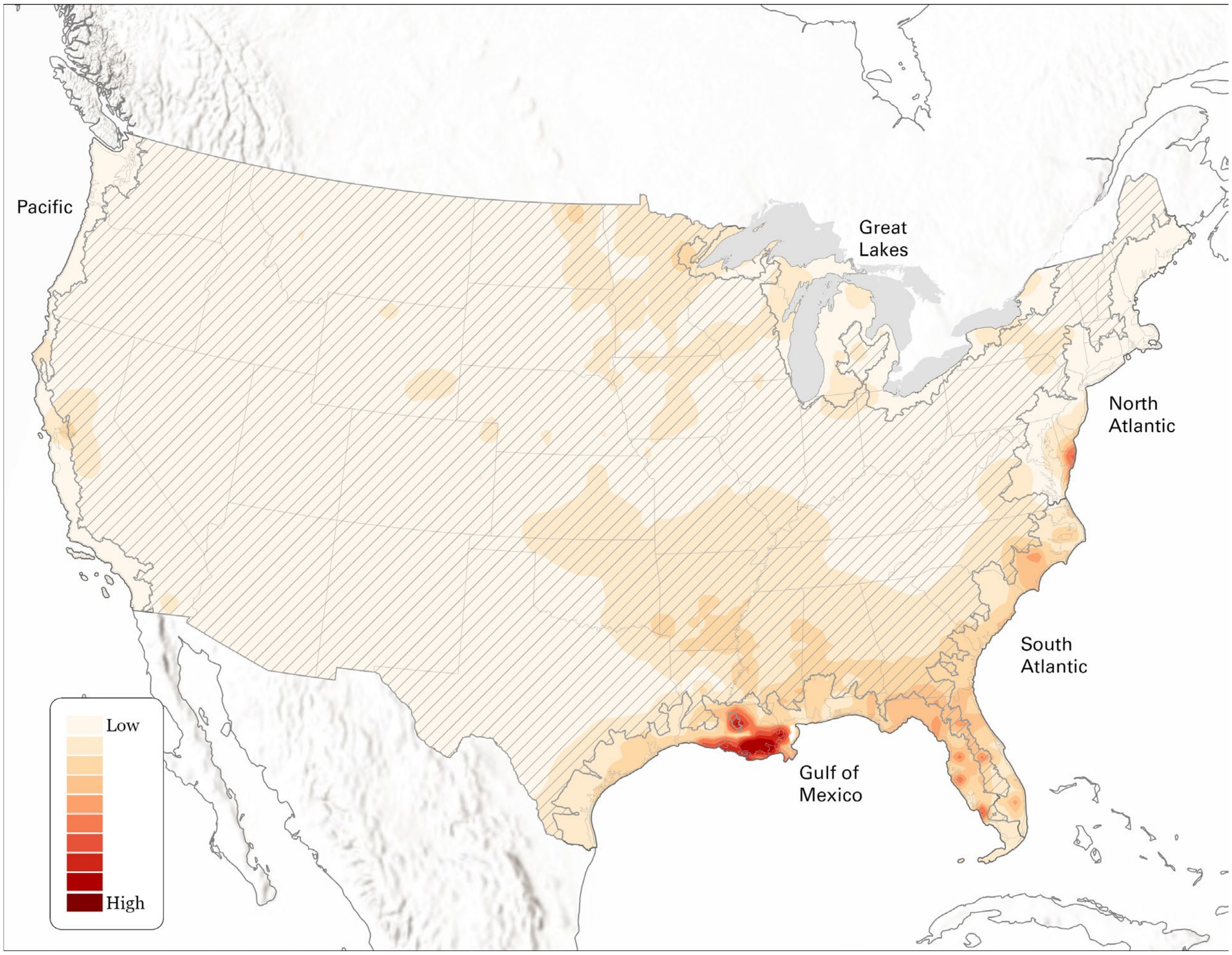

Figure 10. Map showing relative density of net vegetated wetland decrease (loss to upland and deepwater and change to non-vegetated wetlands) in the conterminous United States between 2009 and 2019. Inland areas are indicated with a cross-hatch pattern. Coastal Watersheds are not cross-hatched and are outlined with a gray border.

Why is Wetland Loss Occurring?

One of the main reasons wetland loss occurs in coastal watersheds is likely the high concentration of wetlands and people in coastal areas (Figure 1). Coastal areas have long been known to contain a higher proportion of people, roads, and buildings than inland areas. Over half of the U.S. population lives in coastal watershed counties, making the population density in these counties six times greater than inland counties [4]. Between 1950 and 2000, developed land increased by 220% and structures by 446% along the coastline [21]. As a result, the coastal United States is twice as developed as the rest of the country—8.8% versus 4.1%, respectively [22]. Population growth continues to be concentrated in coastal areas [23]. From 2000 to 2016, 79.3% of national population growth occurred in coastal states [24]. These facts help to explain why drainage and fill for development, as indicated by wetland loss to upland urban, upland rural development, and upland other, was likely the main cause of wetland loss within coastal watersheds from 2009 to 2019.

Wetland loss to development was concentrated in coastal watersheds, with over 85% of net loss to upland urban development between 2009 and 2019 occurring in this region. The U.S. federal Interagency Coastal Wetlands Workgroup (2022) [25] found that in four coastal watersheds (i.e., Cape Fear, North Carolina; San Francisco Bay, California; Galveston Bay, Texas; and Tampa Bay, Florida) development accounted for between 39 to 98% (average of 70%) of total net wetland loss between 1996 and 2010.

Wetland loss was distributed unevenly between coastal regions. Loss was especially high in areas with a relatively high density of wetlands, like the South Atlantic and Gulf of Mexico coastal watersheds (Figure 1). Loss was lower in areas that have a low density of wetlands due to either a lack of low-lying areas (e.g., Pacific coastal watersheds) or historical losses that have left few wetlands remaining on the landscape. Increases in human population often increases the demand for new development. Differences in state and local policies play a role in the distribution of new development, which can contribute to wetland loss or promote wetland conservation [25] [26]. Wetland loss to development has been found to be highest in the rapidly developing areas surrounding cities and associated suburbs [27] [26]. This type of development is growing more rapidly than any other type of land use in the United States [28] and is commonly associated with coastal areas and wetlands [29].

Data on the construction of new housing suggest that decline in the rate of wetland loss seen in this study may be partly related to reduced activity in the construction industry before and during the 2008 economic downturn [4]. Housing starts (the number of new houses where construction has begun) peaked at more than 2 million in January 2006 but dropped to approximately 500,000 in January 2009 [30]. Although the U.S. economy began to recover in 2009, the total number of housing starts for 2009–2019 was only 56% of the previous decade.

Looking forward, housing starts are expected to rise over the next decade [30]. The U.S. population is expected to increase by more than 20 million between 2020 and 2030 [31]. A study by Zou et al. (2024) [26] projected that future wetland loss to impervious surface in U.S. metropolitan areas will be concentrated in coastal watersheds. Consequently, development pressure on coastal areas, particularly in the southeast United States, is predicted to remain high [32]. Net loss of wetlands to development is likely to continue, particularly in the southeast, unless the way wetlands are managed and conserved changes.

The loss of vegetated wetlands, like swamps and marshes, to development is often associated with smaller gains of open water ponds. This is particularly common in the Coastal Plain of the southeast United States, where developers often seek to replace the water storage provided by naturally occurring wetlands by creating ponds. For example, scientists estimated that over 76,000 stormwater ponds were constructed in Florida in 2012 or earlier [33], and 21,594 ponds were recorded in South Carolina's coastal counties in 2013 with almost half being created to store and manage stormwater in developed areas [34]. Although these ponds serve an important purpose (flood reduction) their lack of vegetation and other differences (e.g., steep sides, compacted soil, and differences in depth, size, shape, and location [11] [35]) mean that ponds typically provide fewer ecosystem services (i.e., direct and indirect benefits that ecosystems provide humans) than vegetated wetlands. The rapid increase in ponds, especially in areas like the southeast United States where ponds are not commonly part of the natural landscape [32], is quickly changing the character and functioning of our wetland resources.

Upland forested plantations were the second largest driver of wetland loss in coastal watersheds from 2009 to 2019 (Figure 4). Forested wetlands are the most common wetland type within the conterminous United States. They are concentrated in coastal areas in that 40% of freshwater forested wetlands are in coastal watersheds (Table 4). Over a third of freshwater shrub wetlands are also found in coastal watersheds. Although these wetlands include pocosins (low nutrient peatlands commonly found in the southeastern United States) and other ecosystems with naturally-occurring shrub vegetation, the vast majority of freshwater shrub wetlands would be forested if not for disturbance (e.g., timber harvest). During this study period, woody freshwater wetland area decreased by 0.9% (262,000 acres; Table 3). Some of this decrease was from areas changing to freshwater emergent wetland (58,000 acres) which was likely mostly the result of timber harvest, but net loss to upland was even greater (169,000 acres), including a loss of 64,000 acres to upland forested plantation (Figure 8). Recent field-based research suggests that ditching combined with changes in soil properties over the harvest cycle might be associated with the loss of wetlands to upland forested plantations [36]. Improved understanding of the cause of wetland loss to upland forested plantations would support more effective wetland conservation.

Saltwater wetlands were most often lost to deepwater, including estuarine and marine habitats (Figure 11). The major environmental processes likely responsible for this loss include subsidence (i.e., natural or human caused sinking of land), erosion, and sea level rise. The greatest amount of saltwater wetland loss (almost 50,000 acres) occurred in the Gulf of Mexico coastal area (Table 6). Rates of subsidence in this area are very high with cities along the northern Gulf of Mexico coast, like Houston, Texas, experiencing the highest rates in the United States (up to 3.5 inches per year [37]).

The Gulf of Mexico coastal area also experiences some of the highest rates of shoreline erosion—up to 30 feet per year in Louisiana and nine feet per year in Mississippi [38]. Shoreline loss is not isolated to the Gulf of Mexico; Virginia's Eastern Shore is experiencing substantial shoreline loss of more than nine feet per year [38], which is likely one reason the Delmarva Peninsula (Delaware, Maryland, and Virginia) is a hotspot of saltwater wetland loss in the mid-Atlantic region (Figure 10).

Sea level rise is a global phenomenon with a current rate of about 0.18 inches per year [39]. However, local or regional subsidence can amplify sea level rise, resulting in rates that are much higher. For example, the current rate of relative sea level rise in the Gulf of Mexico is 0.39 inches per year [40], while in the Mid-Atlantic the local rate is as much as three to four times the global average [41] [42]. Sea level rise is predicted to accelerate globally over the rest of this century, continuing to affect wetlands and other coastal ecosystems [43].

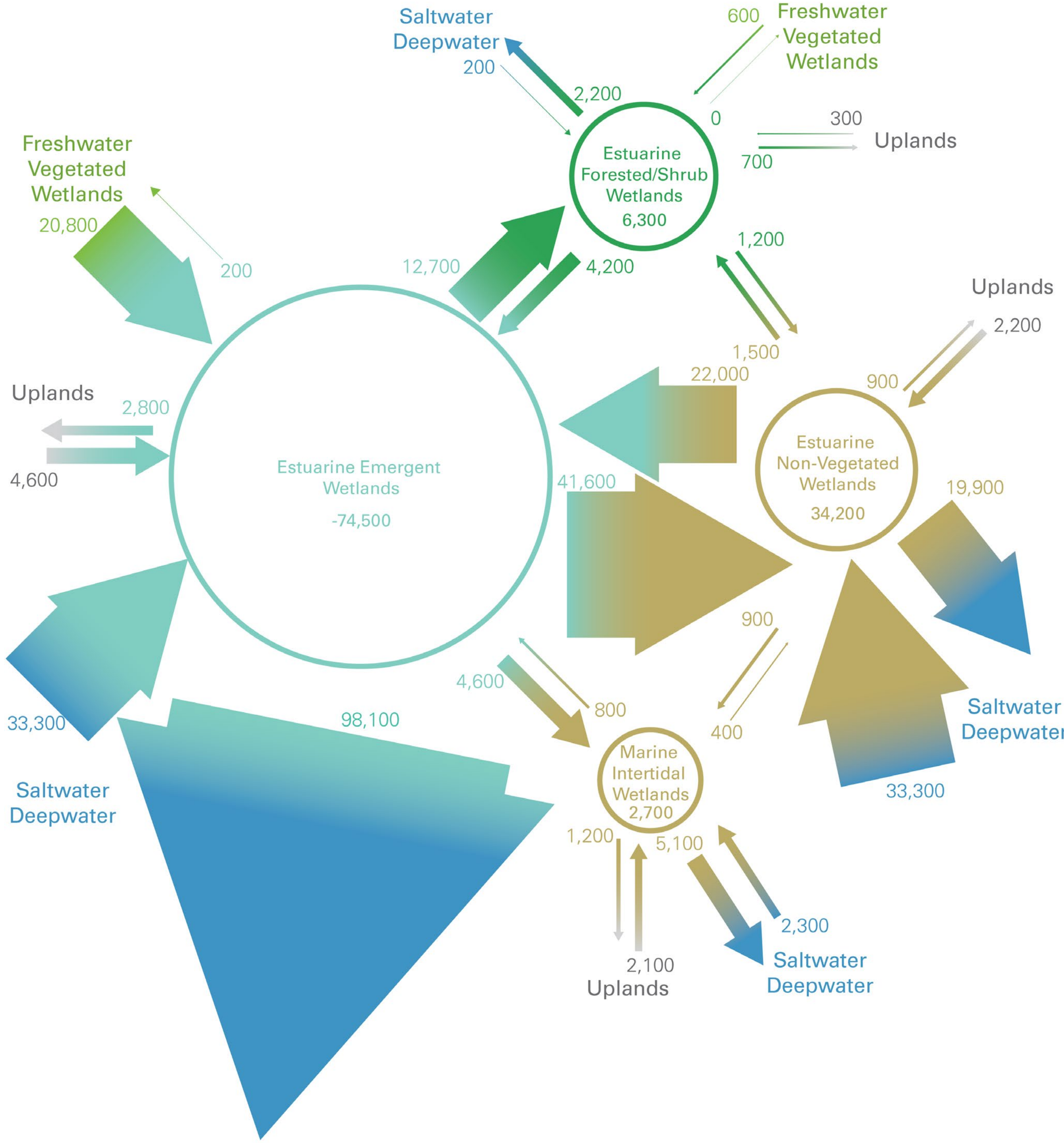

Figure 11. Net change in saltwater wetland, deepwater, and upland categories between 2009 and 2019 and fluxes between categories in coastal watersheds of the contiguous United States. The relative size of each category is indicated by the size of the circle. Net acreage change for each category is included within the circles and changes between categories are indicated by the size of the arrows and the nearby numbers. Values are acres rounded to the nearest hundreds. Note that the largest fluxes are from salt marsh (estuarine emergent wetland) to deepwater and non-vegetated wetlands.

Wetland loss due to sea level rise, land subsidence, and other similar factors can be accelerated by natural disasters, like hurricanes. We hypothesize that hurricane impacts to wetland-dense areas, like the Mississippi Delta, may be responsible for an unusually high loss of saltwater vegetated wetlands during the 2004 to 2009 Wetlands Status and Trends study period. Couvillion et al. (2017) [44] found that the rate of wetland loss along the coast of Louisiana has varied over time and postulated that this may be caused by episodic events, such as hurricanes. Hurricanes Katrina and Rita, which made landfall in the wetland-rich Mississippi Delta in 2005, were found to accelerate wetland loss in this region [45]. Katrina was followed by Humberto in 2007 and Gustav and Ike in 2008, with each hurricane causing more wetland loss. Therefore, the decrease in the amount of saltwater wetland loss from 2009 to 2019 relative to 2004 to 2009 is most likely because the loss from 2004 to 2009 was amplified by hurricane activity. This exacerbated loss may become more common as climate change continues to intensify hurricane activity [46].

In addition to regional and global factors, local influences likely also played a role in the net loss of saltwater wetlands during the study period. Impacts at the local scale that can directly degrade or destroy salt marsh include dredging, dumping of sediment (spoils), grid ditching, canal cutting, leveeing, and salt hay farming. Indirect impacts, which can affect even larger areas, include those that interfere with normal tidal flooding, alter wetland drainage, and/or reduce sediment inputs. Reduced amounts of sediment in rivers and streams due to dams, dikes, tide gates, and other modifications commonly result in “sediment starved” wetlands that are less able to persist as sea level rises. This situation is most noticeable in the Mississippi Delta region, where over a million acres of land has been lost since the 1930s [47], but is also evident in other areas, including Pacific coastal watersheds [48]. Interrupted longshore (coastal) sediment transport due to shoreline hardening (addition of artificial structures made of hard materials like concrete, steel, and riprap), jetties, and groins is also responsible for the loss of saltwater wetlands throughout coastal areas. The interactions between local, regional, and global drivers of wetland change has been found to accelerate wetland loss [49] [50] [51].

Wetlands Status and Trends studies indicate that saltwater wetlands have been undergoing substantial long-term changes in both wetland type and abundance. A gain of non-vegetated saltwater wetlands (e.g., mud flats, bars, and shoals) and a much larger loss of vegetated wetlands (e.g., salt marsh) was observed in all regions along the marine coast between 2009 and 2019, a pattern that began nearly 70 years ago [15]. Studies conducted using different approaches have found similar patterns, including one which reported a loss of 68,000 acres of saltwater vegetated wetlands, mainly to open water, in the conterminous United States between 1996 and 2016 [52]. Coastal areas commonly experience shifts in the distribution and abundance of saltwater wetlands with tides, currents, waves, and other forces, but these changes have not historically resulted in long-term net loss at the regional or national scale (Hopkinson 2019). The net loss of vegetated saltwater wetlands documented by this and past Wetlands Status and Trends reports is widespread and has been occurring for several decades [15]. This type of change is consistent with the documented effects of climate change, including sea level rise [53] [49] [54], as well as human modification [55].

Loss of saltmarsh vegetation and the resulting conversion of saltmarsh to non-vegetated wetlands is often an indicator of overall ecologic deterioration, which results in the loss of ecosystem services such as water filtration and support for fisheries. Furthermore, loss of vegetation may foreshadow additional wetland loss since vegetation loss often precedes the transition from salt marsh to deepwater (e.g., open ocean) [56] [49]. Therefore, the decrease in saltmarsh and increase in non-vegetated wetlands documented in this and previous Wetlands Status and Trends reports may be indicative of more severe impacts on coastal ecosystems than are immediately apparent.

Gains in salt marsh from freshwater wetland and upland were also observed in this study (Figure 6), likely the result of salt marsh moving landward with relative sea level rise [57] [58] [54]. This migration of saltwater wetlands into freshwater or upland environments with sea level rise is called "transgression." Upslope migration can occur in areas that are free of topographic barriers (e.g., low slope areas) and areas without anthropogenic barriers, such as seawalls or levees. Unfortunately, some of the factors leading to wetland loss (e.g., development and sediment reduction) may make it difficult for salt marshes to migrate upslope (inland) in some areas, eventually leading to even greater wetland loss.

Even where there is room for salt marshes to move inland, these wetlands accrete sediment (grow vertically) more slowly than freshwater wetlands [54] so they are less able to keep up with sea level as it rises than the freshwater wetlands they are replacing. Therefore, the conversion of freshwater wetlands to saltwater could mean additional loss of wetlands to deepwater habitats in the future [59]. Average global sea level rise is expected to accelerate through time, increasing by between 1.4 and 2.8 feet by 2100 (relative to the average sea level between 1986 and 2005) and increasing even more for hundreds of years into the future [43]. These rising sea levels are likely to continue to drive the transgression of saltwater wetlands and wetland loss, despite small gains in salt marshes in some areas.

Consequences of Wetland Loss for Coastal Communities

The loss of wetlands documented by this study (Table 3) reduces the prosperity, health, and safety of coastal communities. Wetland loss results in increased susceptibility of people, roads, and buildings to natural disasters like flood, drought, and wildfire [60] [61] [62] [63]. When energy infrastructure is present, wetland loss can increase its vulnerability and make oil spills and associated environmental and economic impacts more likely [64]. Wetland loss also reduces the availability of clean water [2] [12], leading to harmful algal blooms and oxygen-depleted "dead zones" where aquatic life cannot survive [65] [66]. Finally, fish and wildlife populations decline when wetland habitat is lost, leading to reduced opportunities for fishing, hunting, birdwatching, and other recreational activities [2] [67]. Commercial fishing can also suffer when the abundance of species such as shrimp and blue crabs decline with wetland loss [68]. The benefits provided by wetlands are so important to our communities that their loss is considered to be a primary threat to the sustainable development of cities [67].

Wetland loss also heightens the impacts of natural disasters, leading to substantial losses of property and lives. Since 1980, 400 U.S. weather and climate related disasters with damages over a billion dollars have occurred at a total cost of $2.79 trillion and 16,768 related deaths [69]. The loss of 2.5 acres of coastal wetland was found to increase hurricane damage by an average of $56,182 (after conversion to 2024 USD) [9]. The same study estimated that storm protective services were decreased by $48.24 billion (after conversion to 2024 USD) due to historical wetland loss in the Hurricane Katrina affected area and $2.83 billion (after conversion to 2024 USD) due to wetland loss during the Hurricane itself. Without wetlands, it is estimated that damage from Hurricane Ike would have been $934 million higher and that flooding, including an extreme storm surge of greater than 13 feet, would have affected 18,471 additional people [10].

The impacts of hurricanes and other natural disasters on wetlands reverberate through time, causing long-term loss of ecosystem services. Hurricane Sandy is estimated to have cost $4.4 billion in lost ecosystem services through damage to New Jersey's wetlands alone [49]. Without additional wetland protection and restoration, flood damage related to extreme sea level events is expected to increase by two to three magnitudes by 2100 [43]. A large part of this increased flood damage is associated with predicted increases in development along the coast [21] [10].

Effects on humans and the environment stem from not only the loss of wetlands but their replacement with other land covers. For example, when wetlands are replaced with development and agriculture, not only is the water filtration provided by the wetlands lost, but the new development or farmland often increases the amount of waste, sediment, and toxins released into the environment, decreasing water quality. When wetlands with organic rich soils are drained and farmed, substantial amounts of carbon are often released to the atmosphere, causing the land surface to decrease in elevation (e.g., 0.35 to 0.79 inches/year [70]), and worsening climate change. When wetlands are filled or drained for development, the result is people living in locations that are more vulnerable to natural disasters, such as storm surge along the coasts and flooding near streams. The addition of impervious surfaces, in the form of roads, parking lots, and buildings within those developed areas further increases the likelihood of destructive floods [60].

Increases in development were found to be particularly prevalent in hurricane prone areas, like the southeast United States [21]. By 2100, an estimated 2.5 million U.S. coastal properties worth $1.07 trillion will be at risk of regular flooding, and even more properties will be at risk during episodic events like hurricanes [71]. Conversely, damage from storm surge, high winds, and flooding is greatly reduced when wetlands occupy areas that are prone to natural disasters, such as coastlines and other floodplains. Monitoring not only wetland loss but the types of land covers that replace wetlands provides a better understanding of how these changes affect people. In turn, this helps determine what can be done to better ensure the health and prosperity of coastal communities in the future.

Highlight: Working Together to Restore Salt Marsh in the Delmarva Peninsula

Coastal communities have long benefitted from salt marshes. These tidal wetlands provide clean water for swimming and boating, protect people and infrastructure from severe storms, and help fill our plates with bountiful seafood. Salt marshes are also popular places for recreational activities such as fishing, kayaking, and bird watching. They are home to vulnerable species, like the saltmarsh sparrow, black rail, and diamondback terrapin.

Unfortunately, these important ecosystems have endured centuries of historical management that have led to their degradation and disappearance. By the 1930s roughly 90% of salt marsh along the North Atlantic Coast (from Virginia to Maine) was ditched to produce hay, graze cattle, and reduce mosquito populations, among other reasons (Bourn and Cottam 1951). These ditches, often created a century ago or more, are now associated with large areas of plant dieback. If not addressed, legacy ditches will likely continue to lead to wetland loss.

In many areas, salt marshes are converting to areas of open water as an unintended consequence of ditch creation. Long mounds of excavated soil, made taller by natural processes, typically border the ditches. These higher elevation areas limit the exchange of tidal water, setting off a cascade of environmental changes that can ultimately lead to the die-off of surrounding plants. Without grassy, deep rooted marsh vegetation to build and hold onto the soil, it slowly (or sometimes quickly) washes away, leaving pools of open water.

Relative sea level rise, which is especially severe along the Delmarva Peninsula (Delaware, Maryland, Virginia), often accelerates salt marsh loss and creation of open water pools. These unnaturally large open water pools do not provide the same benefits as natural pools. On the Delmarva Peninsula, the degradation has caused a hotspot of vegetated wetland loss (Figure 10: Map of Vegetated Wetland Loss).

Scientists and land managers are working to restore these degraded areas and make them more resilient to sea level rise. The U.S. Fish and Wildlife Service (U.S. FWS) is partnering with other federal agencies, states, non-profit organizations, and private landowners to restore salt marsh along the Delmarva Peninsula. This work is being supported, in part, by the National Oceanic and Atmospheric Administration and National Fish and Wildlife Foundation through the National Coastal Resilience Fund. The Maryland Coastal Bays Program is another major partner in this effort. It is one of 28 National Estuary Programs, which are funded by the U.S. Environmental Protection Agency to restore and protect estuaries of national significance. The team is using innovative, low-tech solutions that include creating runnels (small, shallow channels that help to circulate water), filling ditches, planting marsh vegetation, and strategically cleaning ditches.

These simpler approaches are being augmented with those that are more resource intensive but longer lasting. For example, practitioners are adding thin layers of sediment to the marsh surface, building up its elevation and encouraging the growth of vegetation. Stimulating the natural recovery of salt marsh makes it more resilient to sea level rise and other causes of wetland loss.

In addition to restoring these areas, partners are monitoring marsh recovery so that restoration practices can be even more successful in the future.

Ultimately, the ability of salt marshes to persist along the Delmarva Peninsula will depend on their ability to move further inland as sea levels rise. In addition to restoring degraded salt marsh, the U.S. FWS is working with partners to protect marsh migration pathways. The efforts will allow coastal communities to continue to benefit from these important wetlands for centuries to come.

Citation

Bourn, W.S. and C. Cottam. 1951. *Some biological effects of ditching tidewater marshes.* U.S. Fish and Wildlife Service.

Impacts to Animals and Plants

The long-term loss of wetlands in coastal watersheds documented by this and previous Wetlands Status and Trends reports leads to declines in fish, wildlife, and plant populations, including rare and recreationally, commercially, and culturally valuable species [72] [73] [74] [75]. This is largely because these species have evolved to depend on the unique physical, chemical, and/or biological conditions that exist in or because of coastal wetlands. When these wetlands are lost, it can be challenging for populations of these species to persist over time. Wetland loss and degradation are at least partially responsible for widespread, rapid declines in wetland dependent species [65].

The decline of water birds that depend on coastal wetlands is of particular concern globally. The loss of coastal habitats, including wetlands, is considered a primary threat to many bird populations. These include several that rely on marsh habitat, such as the marsh wren, mottled duck, boat-tailed grackle, seaside sparrow, clapper rail, saltmarsh sparrow, Belding's savannah sparrow, and many other species [58] [76] [77].

Wetland loss affects fish in multiple ways including loss of habitat, increased water pollution, and reduced availability of food [73] [78]. The loss and alteration of coastal wetlands such as salt marsh, mangroves, and sea grass is also likely to negatively affect populations of dolphins, rays, otters, sea turtles, manatees, and other large marine species due to reduced opportunities to forage, hunt, and breed [79].

Other groups of species that are largely wetland dependent and live in coastal watersheds—including amphibians, crayfish, and mussels—are also declining. Within the United States, 61% of amphibian species are declining [80]. Additionally, half of crayfish and two thirds of freshwater mollusks in the United States are at risk of extinction. About 10% of U.S. freshwater mollusks, many of which live in Coastal Plain streams and wetlands [81], are likely to already be extinct [65]. These species are an important link in the food web, supporting populations of fish, birds, and other wildlife. Some are also valuable to recreational and commercial fisheries.

Wetland loss affects species not only through direct habitat loss but also through habitat fragmentation. When habitat is fragmented, it can become too small, isolated, or disconnected to sustain plant and animal populations. Habitat fragmentation affects numerous species, including migratory birds and fish, and species that cannot move long distances (e.g., plants, aquatic insects, amphibians, and small mammals) [82] [83]. A decline in the number of prey species, such as small mammals, can negatively affect wider-ranging species, like raptors [84]. Studies have also shown that reductions in wetland habitat force migratory birds to crowd together, sometimes leading to disease and death [85]. Given the multiple ways wetland loss affects species, the full impact of that loss on biodiversity and other ecosystem services may not be evident for several decades [29] [66].

The effects of wetland loss and alteration on plants include not only the direct loss of wetland plants but also related changes in environmental conditions. For example, wetland loss can make areas too wet or too dry for some wetland plants to survive or reproduce. Because many invasive non-native species thrive in disturbed areas, wetland alteration can result in an increase in these species, such as common reed and purple loosestrife. These plants typically out-compete native species, creating habitats that do not function as well as habitats with native species [86]. Wetland loss can also affects plants through reduced water filtration capacity that can result in an increase in pollutants like nutrients. In aquatic environments, increased nutrient pollution often leads to excessive algal growth. When the algae dies, it is decomposed by bacteria, a process that uses large amounts of oxygen. In areas of depleted oxygen, many plants, animals, and fish cannot survive. This is how "dead zones" the size of Connecticut occur each year in the Gulf of Mexico, affecting fisheries throughout the southern coastal United States [87].

The impacts of historical wetland loss and alteration on wetland-dependent species will likely be magnified by future climate change [74] [85], especially along the coast [51] [88]. Climate change-driven habitat transformation along the coastline includes the loss of wetlands and change between wetland types, including the expansion of mangroves into former salt marsh [53]. The combined effects of habitat loss, alteration, and climate change could lead to rapid declines in wetland-dependent species populations as tipping points are reached [66] [85] and, ultimately, to the extinction of some species. This is especially the case for species that cannot move through remaining wetland fragments to reach suitable habitat. Loss of biodiversity decreases ecosystem resilience to climate and other types of change and the ability of these ecosystems to support coastal communities into the future [65].

Effects of Vegetated Wetland Decline

Loss of wetland vegetation and the shift towards non-vegetated wetlands (e.g., ponds and intertidal flats) generally leads to ecologic deterioration. When wetlands lose vegetation, they also lose their ability to provide a wide array of ecosystem services [89] [90] [91]. Plants dissipate wave energy and trap sediment while their roots stabilize shorelines, building resilience to storms and sea level rise [2] [61] [49]. Salt marshes can reduce wave heights by 72% [92] and alleviate flooding in nearby communities by reducing the height and duration of storm surge [2] [61]. This benefit is substantial, saving infrastructure and lives. Every year coastal wetlands are estimated to provide over $39.54 billion (after conversion to 2024 USD) in storm protection [9]. When vegetation is lost, soil erosion often increases [93] [94], ultimately decreasing wetland area and reducing the benefits those wetlands provide to coastal communities.

Wetland plants are often used for construction and energy production [95] [88], as well as to support rich cultural traditions. This includes the harvest of timber for energy production and construction as well as the creation of cultural touchstones, like Gullah sweetgrass baskets in the coastal areas of the southeast United States. Wild rice, a wetland plant, holds great economic, cultural, and spiritual importance to many native American Tribes, including the Ojibwe who currently live near the Great Lakes [96]. Vegetation also enhances water quality by trapping sediment, oxygenating the water column, and reducing the concentration of excess nutrients and other pollutants [2] [91]. All of these benefits decline or are lost entirely when vegetated wetlands become unvegetated.

Vegetated wetlands also help to regulate the climate by capturing carbon dioxide, a major greenhouse gas, from the atmosphere and storing it in plant material and sediment [97] [57] [91]. The rate at which saltwater vegetated wetlands sequester this “blue carbon” is estimated to be more than ten times greater than tropical forests [98]. Saltwater vegetated wetlands have been found to store at least three to five times more carbon than tropical forests [97]. These wetlands represent 0.2% of the ocean surface but support carbon stocks equivalent to half of what is buried in all ocean sediments [99]. When wetland plants are lost, carbon is often released to the atmosphere, increasing carbon dioxide [57]. Pendelton et al. (2012) [97] estimated that the global economic damage of carbon dioxide emissions associated with the loss and degradation of mangrove, salt marsh, and seagrass was between $6 and $42 billion annually.

Decreases in vegetated wetlands affect a broad array of fish and wildlife, from rare and culturally valuable species to species that support the economies of our nation’s coastal communities. For example, a meta-analysis of 160 peer-reviewed scientific studies concluded that habitats like underwater grasses, mangroves, and salt marsh significantly increased the abundance of juvenile fish and invertebrates (e.g., shrimp) relative to unstructured habitats, like sand and mud [78]. This is partially because young fish and shellfish depend on wetland vegetation to hide from predators [100]. Scientists have estimated that salt marsh accounts for 25% of blue crab and 66% of shrimp production in the Gulf of Mexico [101]. An acre of salt marsh was estimated to support $6,471 of recreational fisheries on the east coast of Florida alone in 1984 (equivalent to $19,991 in 2024). Examples of freshwater fish in coastal watersheds that depend on wetland vegetation, particularly for spawning and feeding, include northern pike, bluegill, and large and small mouth bass. Many amphibians, including frogs and salamanders also depend on vegetated wetlands [102]. For example, most amphibians lay gelatinous egg masses in water and often secure them to or hide them amongst vegetation. Once young emerge, they depend on vegetation for shelter and food. Many larger species, including wading birds, are drawn to vegetated wetlands because they feed on smaller species, including young fish, shellfish, and amphibians. Bird species that depend on vegetation for nesting, rearing young, and shelter include the saltmarsh sparrow, marsh wren, sora, black rail, king rail, and wood ducks. It would be very challenging for populations of these species to persist outside of vegetated wetlands.

The strong link between animals and vegetated wetlands was highlighted by a recent State of the Birds report by the North American Bird Conservation Initiative [103], which documented trends in bird populations that are likely related to wetland and deepwater patterns described in this report (i.e., loss of vegetated wetlands and gain of ponds and lakes). For example, about a third of waterbirds are experiencing population declines, including several rail species (e.g., black rail and king rail) that rely almost exclusively on vegetated wetlands (e.g., marshes). Other “Tipping Point” species (i.e., cumulative population loss exceeded 70% since 1980) include the seaside and saltmarsh sparrow, which also rely heavily on vegetated wetlands, and one third of shorebirds. However, most species of diving and dabbling ducks that use both vegetated wetlands and open water habitats (e.g., ponds and lakes) have been generally stable or increasing. These recent findings are reinforced by other studies [104] [58] [76] and highlight the importance of monitoring change between different wetland types.

Effects of Disturbance

Results from Wetlands Status and Trends reports indicate that the effects of human alteration on wetland functions may be much larger than predicted based on net wetland loss alone. Even wetlands that remain on the landscape can be substantially altered by disturbance. Wetlands near urban, suburban, and even rural development are often affected by pollutants [105] [88], which can significantly degrade wetlands. Other types of disturbance include changes in water levels due to levees, dams, dikes, groundwater and hydrocarbon extraction, and water control structures [53] [55] [49], alteration of hydrologic connectivity, changes in salinity, reduction of sediment transported by rivers and other waterways [61] [53], and the introduction of invasive species [86]. These impacts can lead to declines in important ecosystem services, such as water filtration, protection of people and infrastructure from natural disasters, and maintenance of biodiversity [65] [106] [104] [105]. A combination of different types of disturbance is likely to amplify these effects and can lead to wetland loss [74] [65] [49].

The magnitude of this disturbance in coastal watersheds can begin to be approximated by considering change to other wetland categories instead of solely net loss/gain to upland or deepwater. Generally, the natural process of plant competition and growth (i.e., plant succession) does not result in a decrease in forested area. When this does occur, disturbance is typically indicated. Timber harvest for wood production is a very common type of forest disturbance. The area of freshwater forested wetland that was replaced by freshwater emergent wetland was over four times greater than the area that was lost to upland forested plantations (228,000 versus 46,000 acres). This finding suggests that the overall impact of silvicultural practices on wetlands is likely greater than solely the net loss of wetlands to upland forested plantations.

Wetlands can also be affected by disturbance in adjacent areas, including the "hardening"–placing seawalls, bulkheads, or similar structures on the shore to reduce erosion–of shorelines [107] [58] [43]. A study by Gittman et al. (2015) [108] indicated that 14,300 miles or 14% of shoreline along the Pacific, Gulf of Mexico, and Atlantic is already armored by seawalls, bulkheads, or other structures with this alteration expected to continue at a rate of 124 miles per year. The study predicts that the percent of hardened shoreline will double by 2100, resulting in about a third of the shoreline in the conterminous United States being affected. This type of shoreline alteration prevents saltwater wetlands from transgressing inland with sea level rise and leads to additional wetland loss.

Wetlands Status and Trends reports can begin to approximate the effects of human disturbance on wetland condition (i.e., chemical, physical, and biological integrity) but were not intended specifically for this purpose. The U.S. Environmental Protection Agency documents the effects of disturbance, and recently reported that over half of estuarine wetlands in the conterminous United States were in fair or poor condition due to human-driven physical alteration, like vegetation removal or replacement, obstruction of water flow, soil compaction, and ditching [109]. In 2016, estuarine wetland condition was best in the Atlantic, lower in the Gulf of Mexico and Florida, and least in the Pacific regions (50%, 43%, and 0% in good condition, respectively).

Accumulation of Impacts Over Time

The effects of wetland loss, gain, and alteration accumulate through time and may be difficult to reverse. Additional losses further exacerbate historical declines in ecosystem functions within coastal watersheds. Recent studies indicate that declines in wetland function associated with loss may be punctuated by tipping points that lead to rapid declines in ecosystem services and the viability of wetland-dependent species [65] [66] [85] [43]. Other studies have concluded that the full impact of wetland loss may not be evident right away, in part because it can take several generations before the full impact of habitat loss and alteration on species populations is evident [110] [111] [66]. Scientists have named this situation "extinction debt" [112].

The long-term cumulative effects of wetland impacts can be seen in studies concluding that certain types of coastal wetlands have experienced substantial losses over time and may disappear from some regions within the next several decades. For example, over half of original salt marsh area has already been lost in the United States [113]. Louisiana alone has lost between about 10 and 32 square miles (6.4 and 20,500 acres) of coastal wetlands per year since 1932 [44]. This is the equivalent of losing an area of coastal wetlands the size of a football field every 34 to 100 minutes. Under high sea level rise scenarios, all salt marsh is predicted to be lost in California and Oregon by 2100 [58]. In this century, drowning (i.e., submergence that results in death of marsh plants and conversion to open water) of even somewhat resilient marshes is expected to spread from the Gulf of Mexico and Mid-Atlantic, where it is already occurring, to the South Atlantic and then Pacific [3]. The growing impact of hurricanes and sea level rise along our coasts combined with an increasing coastal population will require a sustained effort to preserve remaining wetlands for the future.

A combination of wetland restoration and protection will be vital for conserving the ecosystem services that our coastal communities rely on. This is partially because it can take decades, centuries, or longer before restored wetlands function as well as high-quality natural wetlands [114] [115] [116] [11] [117]. In some cases, this equivalency may never be achieved [106]. Efforts to increase both the area and function of wetlands through restoration will be necessary to ensure that wetlands continue to provide their multitude of benefits throughout coastal watersheds.

Highlight: Protecting Scarce and Vulnerable Wetlands on the Pacific Coast

Wetlands in the coastal watersheds of California, Oregon, and Washington are much rarer than their counterparts on the Atlantic coast. This is partly due to the steep topography of the Pacific coast, but it is also due to the historical loss of wetlands in that area. California alone lost over 90% of its wetlands over the past two centuries (Dahl, 1990), with millions of acres diked and drained for development, agriculture, and other uses. The remaining wetlands of the Pacific coast are highly susceptible to becoming submerged over the coming century due to the combined effects of sea-level rise, low sediment supply, and a lack of undeveloped space for wetlands to move inland (Thorne et al., 2018).

Wetlands along the Pacific coast form a critical network of stopover sites for millions of migratory birds that use these habitats to breed, rest, refuel, and overwinter. When these habitats are lost or degraded, migratory birds lose vital parts of this network and have fewer safe places to land. Coastal wetlands along the Pacific coast are also important to fish populations, providing young salmon with transition zones where they can rest and feed as they move from fresh water to salt water. Without these transition zones, fewer salmon survive the arduous trip from streams, where they hatch, to the open ocean, where they spend most of their adult lives.

Partnerships have been an effective means of protecting wetlands along the Pacific coast. Over 24,000 acres of wetlands and associated habitats in Washington, Oregon, and California have been protected as part of the National Estuarine Research Reserve System, a partnership between the National Oceanic and Atmospheric Administration and coastal states to protect and study estuarine systems in collaboration with surrounding communities. Seventy-five miles north of Seattle, Washington, the Padilla Bay National Estuarine Research Reserve protects thousands of acres of wetlands and other habitats vital to salmon, herring, Dungeness crab, eagles, shorebirds, harbor seals, and river otters. Once spanning 7,000 acres, the tidal marsh and tidal swamp surrounding Padilla Bay have shrunk dramatically, with less than 200 acres remaining. With funding from the Bipartisan Infrastructure Law, in 2023 the Washington State Department of Ecology acquired an additional 74.5 acres of tidal marsh and farmland that will be restored to wetlands to provide additional habitat and reduce flooding along the main road and utilities that the local community depends on. The project's proximity to a revered former Samish Indian Nation village restores cultural ties and publicly acknowledges ongoing tribal stewardship.

Citations

Dahl, T. E. 1990. *Wetlands Losses in the United States 1780's to 1980's*. U.S. Department of the Interior; Fish and Wildlife Service. Washington, D.C. 13 pp.

Thorne, K., MacDonald, G., Guntenspergen, G., Ambrose, R., Buffington, K., Dugger, B., Freeman, C., Janousek, C., Brown, L., J. Rosencranz, and J. Holmquist. 2018. U.S. Pacific coastal wetland resilience and vulnerability to sea-level rise. *Science Advances* 4.

Conclusions

Net wetland loss has continued in coastal watersheds since the last Wetlands Status and Trends study period (2004–2009). While the rate of loss was less than that of the previous study period, there was proportionally more loss in coastal watersheds than in inland portions of the conterminous United States. Wetland losses in coastal watersheds (13% of the conterminous United States) accounted for 86% of all wetland loss and 47% of all vegetated wetland loss within the conterminous United States.

The findings of this report should be viewed in the context of wetland change occurring throughout the conterminous United States. During 2009 – 2019, wetland loss and alteration also occurred in inland watersheds [15] that ultimately drain to the coast. This highlights the cumulative effects of wetland loss and alteration in inland and coastal watersheds on human and environmental health, as well as the importance of coastal wetlands as a final opportunity to filter pollutants and absorb floodwaters before they affect coastal communities.

The fundamental nature of wetlands in coastal watersheds is also being altered as these areas preferentially lose vegetated wetlands (e.g., salt marsh and swamps) and gain non-vegetated wetlands (e.g., intertidal flats and ponds). Between 2009 and 2019, vegetated wetlands decreased by 314,000 net acres and non-vegetated wetlands increased by 133,000. The majority of new non-vegetated wetlands were ponds, with the most common type being stormwater ponds associated with urban development. These most recent findings extend a long-term pattern of wetland loss and alteration in coastal watersheds that goes back hundreds of years [118] [20] [15].

Wetlands in coastal watersheds are particularly vulnerable to loss, alteration, and degradation because of the wide variety of forces affecting coastal areas. From the intense effects of hurricanes to the expanding effects of urbanization, these forces have led to substantial wetland alteration and loss. Compounding the problem is that wetlands in coastal watersheds experience adverse effects in both the fresh and saltwater environments leading to loss on two, often interacting, fronts. While development and other human actions convert wetlands to uplands throughout coastal watersheds, relative sea level rise and storm surge often lead to the loss of wetlands to open ocean along the coastline. These different but interacting forces have historically and continue to lead to a greater percent loss of wetlands and their benefits in coastal watersheds than occurs in inland settings.

Wetland loss and alteration reduces the health, safety, and prosperity of coastal communities. People and buildings become more vulnerable to severe storms and flooding while populations of fish, wildlife, and plants that coastal communities depend on for food, recreation, and livelihoods decline. Since all watersheds, including those along the coast, are connected through the flow of water, wetland changes in one part of the watershed affect the environment and people in other parts of the watershed. These effects include the reduction of water quality in lakes, estuaries, and bays and associated impacts on drinking water, tourism, and recreation, including fishing, boating, and bird watching. Because Wetlands Status and Trends reports assess changes in wetland area but not condition (i.e., chemical, physical, and biological integrity), the patterns of loss and alteration documented in these reports are likely an underestimate of the effects of human, climate, and other influences on wetlands and their benefits.

This pattern of disproportionately high wetland loss and alteration in coastal watersheds is predicted to continue, if not intensify, in many areas, including the southeastern United States. Rates of relative sea level rise and the intensity of severe storms has and is expected to continue to increase along our coasts. This can lead to the loss of wetlands that lack the capacity to move landward or adapt through other means. At the same time, coastal populations and related infrastructure, like roads, bridges, and buildings, are predicted to increase, potentially further contributing to wetland loss at and away from the coastline. The simultaneous increase of population, infrastructure, sea level rise, and natural disasters has and is projected to continue to greatly increase the likelihood of property damage and loss of life in coastal watersheds, especially as wetlands continue to be lost. The growing demand for wetland benefits, such as flood protection, due to increasing population densities and likelihood of natural disasters highlights the importance of strengthening wetland conservation efforts in this region.

Recently published reports provided recommendations for enhancing the conservation of wetlands, including those in coastal watersheds. Strategies in the National Wetlands Status and Trends report [15] highlight the importance of stronger coordination within and between governmental and non-governmental organizations as well as the need to support the collection and sharing of enhanced scientific data. These data, including information on the effectiveness of past approaches and landscape scale geospatial data, are needed to support the formulation and implementation of strategic conservation. Finally, the report emphasizes the need for a long-term commitment to improving wetland conservation approaches over time.

Recommendations more specific to coastal watersheds can be found in the Interagency Coastal Wetlands Workgroup's "Recommendations for Reducing Wetland Loss in Coastal Watersheds of the United States" [25]. The recommendations include actions related to increasing the area of wetlands restored in coastal watersheds; reducing loss of coastal wetlands to development; reducing loss of coastal wetlands associated with silviculture in the Southeast; supporting the collection, enhancement, and dissemination of landscape-scale wetland monitoring data; and conducting targeted outreach. The intent of the recommendations in both documents is to help forge cooperation and build capacity to reduce wetland losses nationwide.

Increasingly, scientists and decision-makers around the world are concluding that coastal wetlands are critical landscape features that help drive and sustain economic prosperity [119]. The findings of this report demonstrate that it is possible to reduce wetland losses in our nation's coastal watersheds, but new approaches are needed to continue to reduce this loss. The need is especially urgent today because wetlands are being lost more rapidly in coastal watersheds than in other regions and they are vital for supporting the health, safety, and economic prosperity of coastal communities.

The U.S. FWS and NOAA will continue to work with all partners to conserve and restore coastal wetlands, in part by producing Wetlands Status and Trends reports for coastal watersheds. Scientific information, like this report, is foundational to the strategic implementation of all natural resource policy actions and will be critical to improving the conservation of wetlands in coastal watersheds. Continuing to reduce the loss of coastal wetlands, especially vegetated wetlands, will require a collaborative approach that includes Tribal, state, local, and private partners to ensure the lasting health of the nation's people, environment, and economy.

Highlight: Conserving Rare Coastal Prairie and Marshland in Texas

Coastal prairies are a type of grassland found along the coast of Texas and Louisiana. Within these prairies are natural depressions often called “pothole wetlands.” Although these wetlands may appear to be isolated from one another, research has shown that they are connected to surrounding waters through drainage paths that are seasonally wet (Wilcox et al. 2011). Fresh water flows through the coastal prairie towards the Gulf of Mexico where the coastal prairie transitions to freshwater and saltwater marsh.

This coastal prairie-marsh system supports high levels of plant and animal diversity including migratory and year-round populations of waterfowl, raptors, shorebirds, and wading birds, like brown pelicans, peregrine falcons, white-tailed hawks, and seaside sparrows. Coastal wetlands in Texas also provide crucial spawning and nursery habitat for several species of fish and shellfish including black drum, southern flounder, red snapper, shrimp, blue crab, and eastern oyster. These species support a substantial commercial fishery on the Texas coast.

The sponge-like qualities of the Texas coastal prairie help filter pollution from fresh water that flows into Galveston Bay and the Gulf of Mexico. Prairies and marshlands act as natural buffers against storms and hurricanes, absorbing and dispersing water from storm surges and floods. Currently, it is estimated that natural coastal habitat protects about $2.4 billion dollars of property in Texas (Fern et al. 2023).

The original extent of coastal prairies once spanned over 9 million acres. By 1937, 93% of the coastal prairie in Texas had been lost (Lehmann 1941). Today, less than 1% of the original coastal prairie system remains in its native state. This loss has caused large declines in many wildlife populations and contributed to the increasing occurrence of severe flooding in the Houston-Galveston area (Kahn 2005).

With only 10% of the remaining coastal prairie in public ownership, partnerships with private landowners are very important for conservation efforts. The Texas Prairie Wetlands Project is a cooperative program between the U.S. Fish and Wildlife Service, U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), Ducks Unlimited, Inc., Texas Parks and Wildlife Department, and private landowners to maintain wetlands on private lands for the benefit of wildlife. Another effort, the Texas Coastal Prairie Initiative, is using funding from NRCS to permanently protect coastal prairie through conservation easements. The protection and restoration of the remaining wetlands in coastal Texas is crucial for ensuring continuing support of the fish, wildlife, and human uses.

Citations

Fern, R.R., Baron, M. D., England, A. E., Giese, J. C., Kraai, K. J., Lancaster, J. D., Oldenburger, S. L., Shipes, J. C., B. C. Wilson, and S. R. Wyckoff. 2023. The state of Texas wetlands: A review of current and future challenges. *Texas Water Journal* 14(1):136-174.

Khan, S.D. 2005. Urban development and flooding in Houston Texas, inferences from remote sensing data using neural network technique. *Environmental Geology* 47: 1120–1127.

Lehmann, V.M. 1941. 2011. Attwater's prairie chicken, its life history and management. U.S. Fish and Wildlife Service, *North American Fauna* No. 57. 65 p.

Wilcox, B.P., Dean, D.D., Jacob, J.S. et al. Evidence of surface connectivity for Texas gulf coast depressional wetlands. *Wetlands* 31: 451–458.

Literature Cited

1. Hopkinson, C. S., Wolanski, E., Brinson, M., D. Cahoon, and G. Perillo. 2009. Coastal Wetlands: A Synthesis. In *Coastal Wetlands*. Elsevier. p. 1-75.

2. Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E.W., A .C. Stier and B. R. Silliman. 2011. The value of estuarine and coastal ecosystem services. *Ecological Monographs* 81(2):169-193.

3. Osland, M. J., Bogdan C., Grace, J. B., Enwright, N. M., Guntenspergen, G. R., Buffington, K. J., Thorne, K. M., Carr, J. A., W.V. Sweet, and B. R. Couvillion. 2024. Rising seas could cross thresholds for initiating coastal wetland drowning within decades across much of the United States. *Communications Earth & Environment* 5(1):372.

4. National Oceanic and Atmospheric Administration and U.S. Census Bureau. 2013. *National Coastal Population Report Population Trends from 1970 to 2020*. 23 p.

5. Lellis-Dibble, K.A., K.E. McGlynn, and T.E. Bigford. 2008. *Estuarine Fish and Shellfish Species in U.S. Commercial and Recreational Fisheries: Economic Value as an Incentive to Protect and Restore Estuarine Habitat.* U.S. Department of Commerce. Washington, D.C. 94 p.

6. National Marine Fisheries Service. 2022. *Fisheries of the United States, 2020.* 28 p.

7. Jerabek, A., Darnell, K. M., C. Pellerin, and T. J. Carruthers. 2017. Use of marsh edge and submerged aquatic vegetation as habitat by fish and crustaceans in degrading southern Louisiana coastal marshes. *Southeastern Geographer* 57(3):212-230.

8. Narayan, S., Beck, M. W., Wilson, P., Thomas, C. J., Guerrero, A., Shepard, C. C., Reguero, B. G., Franco, G., J. C. Ingram, and D. Trespalacios. 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. *Scientific Reports* 7(1):1-12.

9. Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., S. J. Anderson, and K. Mulder. 2008. The value of coastal wetlands for hurricane protection. *AMBIO: A Journal of the Human Environment* 37:241–248.

10. Al-Attabi, Z., Xu, Y., G. Tso, and S. Narayan. 2023. The impacts of tidal wetland loss and coastal development on storm surge damages to people and property: A Hurricane Ike case-study. *Scientific Reports* 13(1):4620.

11. Rooney, R. C., Foote, L., Krogman, N., Pattison, J.K., M. J. Wilson, and S. E. Bayley. 2015. Replacing natural wetlands with stormwater management facilities: Biophysical and perceived social values. *Water Research* 73:17-28.

12. Tomscha, S., Deslippe, J., de Róiste, M., S. Hartley, and B. Jackson. 2019. Uncovering the ecosystem service legacies of wetland loss using high-resolution models. *Ecosphere* 10(10).

13. Stedman, S. and T.E. Dahl. 2008. *Status and Trends of Wetlands in the Coastal Watersheds of the Eastern United States 1998 to 2004*. National Oceanic and Atmospheric Administration National Marine Fisheries Service and U.S. Department of the Interior Fish and Wildlife Service. Washington, D.C. 32 p.

14. Dahl, T.E. and S. Stedman. 2013. *Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2004 to 2009*. U.S. Department of the Interior Fish and Wildlife Service and National Oceanic and Atmospheric Administration National Marine Fisheries Service. Washington, D.C. 46 p.

15. Lang, M.W., J.C. Ingebritsen, and R.K. Griffin. 2024. *Status and Trends of Wetlands in the Conterminous United States 2009 to 2019.* U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C. 43 p.

16. Hammond, E.H. 1970. Physical subdivisions of the United States of America. In *National Atlas of the United States of America*. Department of the Interior, U.S. Geological Survey. Washington, D.C. 61 p.

17. Federal Geographic Data Committee. 2013. *Classification of Wetlands and Deepwater Habitats of the United States.* Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service. Washington, D.C.

18. National Standards and Support Team. 2017. *Technical Procedures for Conducting Status and Trends of the Nation's Wetlands (version 2).* U.S. Fish and Wildlife Service Division of Budget and Technical Support. Washington, D.C. 76 p.

19. Dahl, T.E. 2009. *Status and Trends of Wetlands in the Conterminous United States 2004 to 2009.* U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C. 108 p.

20. Dahl, T.E. 1990. *Wetlands Losses in the United States 1780's to 1980's*. U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C. 13 p.

21. Braswell, A. E., Leyk, S., D. S. Connor, and J. H. Uhl. 2022. Creeping disaster along the US coastline: Understanding exposure to sea level rise and hurricanes through historical development. *PLOS ONE* 17(8).

22. National Oceanic and Atmospheric Administration. 2024. Land Cover Change. Available from: https://coast.noaa.gov/states/fast-facts/land-cover-change.html.

23. Hauer, M.E., R.K. Saunders, and D. Shtob. 2022. Research note: Demographic change on the United States coast, 2020–2100. *Demography* 59(4):1221-1232.

24. National Ocean Economics Program. Coastal Economy, Population, and Housing. 2024. Available from: https://www.oceaneconomics.org/cstecon_pop_housing/cecon_pop_housing.html.

25. Interagency Coastal Wetlands Workgroup. 2022. *Recommendations for Reducing Wetland Loss in Coastal Watersheds of the United States*. Washington, D.C. 41 p.

26. Zou, Z., Huang, C., Lang, M.W., Du, L., McCarty, G., Ingebritsen, J. C., Harner, J., Griffin, R., W. Gong, and J. Lu. 2024. Hotspots of wetland loss to impervious surfaces in the conterminous United States. *Science of The Total Environment* 948:174787.

27. Urban, M. C. and R. Roehm. 2018. The road to higher permanence and biodiversity in exurban wetlands. *Oecologia* 186(1):291-302.

28. Brown, D. G., Johnson, K.M., T. R. Loveland, and D.M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950–2000. *Ecological Applications* 15(6):1851-1863.

29. Hansen, A.J., Knight, R.L., Marzluff, J.M., Powell, S., Brown, K., P. H. Gude, and Jones, K. 2005. Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. *Ecological Applications* 15(6):1893-1905.

30. Congressional Budget Office. 2024. *The Outlook for Housing Starts*. Washington, D.C. 38 p.

31. Johnson, S. 2020. *A Changing Nation: Population Projections Under Alternative Immigration Scenarios.* U.S. Census Bureau. Washington, DC. 21 p.

32. Beckingham, B., T. Callahan, and V. Vulava. 2019. Stormwater ponds in the southeastern U.S. coastal plain: Hydrogeology, contaminant fate, and the need for a social-ecological framework. *Frontiers in Environmental Science* 7:117.

33. Sinclair, J.S., Reisinger, A.J., Bean, E., Adams, C.R., L. S. Reisinger, and B. V. Iannone III. 2020. Stormwater ponds: An overlooked but plentiful urban designer ecosystem provides invasive plant habitat in a subtropical region (Florida, USA). *Science of the Total Environment* 711:135133.

34. Smith, E. M., Sanger, D. M., A. Tweel, and E. Koch. 2019. A Pond Inventory for the Eight Coastal Counties of South Carolina. In *Stormwater Ponds in Coastal South Carolina. South Carolina Sea Grant Consortium*. Charleston, S.C. p. 3-14.

35. Rains, M., Schmidt, K., Landry, S., W. Kleindl, and K. Rains. 2023. Reorganizing the waterscape: Asymetric loss of wetlands and gain of artificial water features in a mixed-use watershed. *Wetlands* 43(7):91.

36. Skaggs, R. W., D. M. Amatya, and G. M. Chescheir. 2020. Effects of drainage for silviculture on wetland hydrology. *Wetlands* 40(1):47–64.

37. Khan, S. D., Gadea, O. C., A. Tello Alvarado, and O. A. Tirmizi. 2022. Surface deformation analysis of the Houston area using time series interferometry and emerging hot spot analysis. *Remote Sensing* 14(15):3831.

38. Hapke, C.J., and D. Reid. 2011. *National assessment of shoreline change: Historical shoreline change along the New England and Mid-Atlantic coasts*. U.S. Geological Survey. 57 p.

39. Hamlington, B. D., Bellas-Manley, A., Willis, J. K., Fournier, S., Vinogradova, N., Nerem, R. S., Piecuch, C. G., P. R. Thompson, and R. Kopp. 2024. The rate of global sea level rise doubled during the past three decades. *Communications Earth & Environment* 5(1):601.

40. Dangendorf, S., Hendricks, N., Sun, Q., Klinck, J., Ezer, T., Frederikse, T., Calafat, F. M., T. Wahl, and T. E. Törnqvist. 2023. Acceleration of U.S. Southeast and Gulf coast sea-level rise amplified by internal climate variability. *Nature Communications* 14(1):1-11.

41. Sallenger Jr, A. H., K. S. Doran, and P. A. Howd. 2012. Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature Climate Change* 2(12):884-888.

42. Kirwan, M. L. and K. B. Gedan. 2019. Sea-level driven land conversion and the formation of ghost forests. *Nature Climate Change* 9:450–457.

43. Oppenheimer, M. and J. Hinkel. 2019. Sea level rise and implications for low-lying islands, coasts and communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.* Cambridge University Press. New York, NY. p. 321–445.

44. Couvillion, B.R., Barras, J.A., Steyer, G.D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., B. Griffin, and D. Heckman, D. 2017. *Land Area Change in Coastal Louisiana 1932 to 2016.* U.S. Geological Survey. 16 p.

45. Barras, J.A., J.C. Bernier, and R.A. Morton. 2008. *Land area change in coastal Louisiana--A multidecadal perspective (from 1956 to 2006)*. Scientific Investigations Map 3019. U.S. Geological Survey.

46. Balaguru, K., Xu, W., Chang, C. C., Leung, L. R., Judi, D. R., Hagos, S. M., Wehner, M. F., J. P. Kossin, and M. Ting. 2023. Increased U.S. coastal hurricane risk under climate change. *Science Advances* 9(14).

47. Blum, M., Rahn, D., B. Frederick, and S. Polanco. 2023. Land loss in the Mississippi River Delta: Role of subsidence, global sea-level rise, and coupled atmospheric and oceanographic processes. *Global and Planetary Change* 222:104048.

48. Ensign, S.H., J.N. Halls, and E.K. Peck. 2023. Watershed sediment cannot offset sea level rise in most US tidal wetlands. *Science Advances* 382(6675):1191-1195.

49. Hauser, S., M.S. Meixler, and M. Laba. 2015. Quantification of impacts and ecosystem services loss in New Jersey coastal wetlands due to Hurricane Sandy storm surge. *Wetlands* 35(6):1137-1148.

50. Finlayson, C. M., Capon, S. J., Rissik, D., Pittock, J., Fisk, G., Davidson, N. C., Bodmin, K. A., Papas, P., Robertson, H. A., M. Schallenberg, and N. Saintilan. 2017. Policy considerations for managing wetlands under a changing climate. *Marine and Freshwater Research* 68(10):1803-1815.

51. Intergovernmental Panel on Climate Change. 2019. Summary for Policymakers. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge University Press. New York, NY, USA. p. 3-35.

52. Enwright, N. M., Osland, M. J., Thorne, K. M., Guntenspergen, G. R., Grace, J. B., Steyer, G. D., Herold, N., B. Chivoiu, and M. Han. 2024. Observing coastal wetland transitions using national land cover products. *Progress in Physical Geography: Earth and Environment* 48(1):113-135.

53. Comeaux, R.S., M.A. Allison, and T.S. Bianchi. 2012. Mangrove expansion in the Gulf of Mexico with climate change: Implications for wetland health and resistance to rising sea levels. *Estuarine Coastal and Shelf Science* 96:81-95.

54. Halls, J.N. and J.L. Magolan. 2019. A methodology to assess land use development, flooding, and wetland change as indicators of coastal vulnerability. *Remote Sensing* 11(19):23.

55. Kennish, M.J. 2001. Coastal salt marsh systems in the US: A review of anthropogenic impacts. *Journal of Coastal Research* 17(3):731-748.

56. Kirwan, M.L. and J.P. Megonigal. 2013. Tidal wetland stability in the face of human impacts and sea-level rise. *Nature* 504:53-60.

57. Moomaw, W. R., Chmura, G. L., Davies, G. T., Finlayson, C. M., Middleton, B. A., Natali, S. M., Perry, J. E., N. Roulet, and A. Sutton-Grier. 2018. Wetlands in a changing climate: Science, policy and management. *Wetlands* 38(2):183-205.

58. Thorne, K., MacDonald, G., Guntenspergen, G., Ambrose, R., Buffington, K., Dugger, B., Freeman, C., Janousek, C., Brown, L., J. Rosencranz, and J. Holmquist. 2018. US Pacific coastal wetland resilience and vulnerability to sea-level rise. *Science Advances* 4(2).

59. Osland, M. J., Hughes, A. R., Armitage, A. R., Scyphers, S. B., Cebrian, J., Swinea, S. H., Shepard, C. C., Allen, M. S., Feher, L. C., J. A. Nelson, and C. L. O'Brien. 2022. The impacts of mangrove range expansion on wetland ecosystem services in the southeastern United States: Current understanding, knowledge gaps, and emerging research needs. *Global Change Biology* 28(10):3163-3187.

60. Brody, S. D., Highfield, W. E., 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.

61. Shepard, C.C., C.M. Crain, and M.W. Beck. 2011. The protective role of coastal marshes: A systematic review and meta-analysis. *PLOS One* **6**(11).

62. Jacob, J., Pandian, K., R. Lopez, and H. Biggs. 2014. *Houston-Area Freshwater Wetland Loss, 1992-2010.* Texas A&M University. 43 p.

63. Endter-Wada, J., K. M. Kettenring, and A. Sutton-Grier. 2020. Protecting wetlands for people: Strategic policy action can help wetlands mitigate risks and enhance resilience. *Environmental Science & Policy* 108:37-44.

64. Barnes, S., Bond, C., Burger, N., Anania, K., Strong, A., S. Weilant, and S. Virgets. 2015 Economic valuation of coastal land loss in Louisiana*. Journal of Ocean and Coastal Economics* 4(1).

65. Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Wetlands and Water Synthesis*. World Resources Institute. Washington, D.C. 80 p.

66. Blann, K. L., Anderson, J. L., G. R. Sands, and B. Vondracek. 2009. Effects of agricultural drainage on aquatic ecosystems: a review. *Critical Reviews in Environmental Science and Technology* 39(11):909-1001.

67. Alikhani, S., P. Nummi, and A. Ojala. 2021. Urban Wetlands: A Review on Ecological and Cultural Values. *Water* 13(22).

68. Rozas, L. P., Minello, T. J., R. J. Zimmerman, and P. Caldwell. 2007. Nekton populations, long-term wetland loss, and the effect of recent habitat restoration in Galveston Bay, Texas, USA. *Marine Ecology Progress Series* 344:119-130.

69. NOAA National Centers for Environmental Information. 2024. U.S. Billion-Dollar Weather and Climate Disasters. Available from: https://www.ncei.noaa.gov/access/billions/

70. Moorman, M. C., Ladin, Z. S., Tsai, E., Smith, A., Bessler, A., Richter, J., Harrison, R., Van Druten, B., Stanton, W., C. Hayes, and B. W. Harris. 2024. Will they stay or will they go–understanding South Atlantic coastal wetland transformation in response to sea-level rise. *Estuaries and Coasts* 47(7) 2011-2026.

71. Union of Concerned Scientists. 2018. *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate.* Cambridge, Massachusetts.

72. Conway, C. J., W. R. Eddleman, and S. H. Anderson. 1994. Nesting success and survival of Virginia rails and soras. *Wilson Bulletin* 106(3):466-473.

73. Graff, L. and J. Middleton. 2001. *Wetlands and Fish: Catch the Link*. Department of Commerce. National Oceanic and Atmospheric Administration. Washington, D.C.

74. Brinson, M. M. and A. I. Malvarez. 2002. Temperate freshwater wetlands: Types, status, and threats. *Environmental Conservation* 29(2):115-133.

75. Kusler, J. 2006. *Common Questions: Wetland Conservation and the Protection of Migratory Birds*. Association of State Wetland Managers, Inc. and The International Institute for Wetland Science and Public Policy.

76. Remsen Jr, J. V., Wallace, B. P., Seymour, M. A., D. A. O'malley, and E. I. Johnson. 2019. The regional, national, and international importance of Louisiana's coastal avifauna. *The Wilson Journal of Ornithology* 131(2):221-434.

77. McKown, J. G., Burdick, D. M., Moore, G. E., Peter, C. R., A. R. Payne, and J. L. Gibson. 2023. Runnels reverse mega-pool expansion and improve marsh resiliency in the Great Marsh, Massachusetts (USA). *Wetlands* 43(4):35.

78. Lefcheck, J. S., Hughes, B. B., Johnson, A. J., Pfirrmann, B. W., Rasher, D. B., Smyth, A. R., Williams, B. L., M. W. Beck, and R. J. Orth. 2019. Are coastal habitats important nurseries? A meta-analysis. *Conservation Letters* 12(4).

79. Sievers, M., Brown, C. J., Tulloch, V. J., Pearson, R. M., Haig, J. A., M. P. Turschwell, and R. M. Connolly. 2019. The role of vegetated coastal wetlands for marine megafauna conservation. *Trends in Ecology & Evolution* 34(9):807-817.

80. Muths, E., Scherer, R. D., S. M. Amburgey, and P. S. Corn. 2012. *The State of Amphibians in the United States*. Department of the Interior, U.S. Geological Survey.

81. Sepkoski, J. J. and M. A. Rex. 1974. Distribution of freshwater mussels: Coastal rivers as biogeographic islands. *Systematic Biology* 23(2):165–188.

82. Semlitsch, R. D. and J. R. Bodie. 1998. Are small, isolated wetlands expendable? *Conservation Biology* 12(5):1129-1133.

83. Lehtinen, R. M., S. M. Galatowitsch, and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands* 19:1-12.

84. Murphy, R.K. 1997. Importance of prairie wetlands and avian prey to breeding Great Horned Owls (*Bubo virginianus*) in northwestern North Dakota. In *Biology and Conservation of Owls of the Northern Hemisphere*. J.R. Duncan, D.H. Johnson, and H. Nicholls, editors. 286–298.

85. Donnelly, J. P., Moore, J. N., M. L. Casazza, and S. P. Coons. 2022. Functional wetland loss drives emerging risks to waterbird migration networks. *Frontiers in Ecology and Evolution* 10:18.

86. Zedler, J. B. and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: opportunities, opportunists, and outcomes. *Critical Reviews in Plant Sciences* 23:431-452.

87. Rabalais, N. and R. Turner. 2003. Gulf of Mexico hypoxia, A.K.A. “the dead zone”. *Annual Review of Ecology and Systematics* 33:235-263.

88. Jordan, P. and P. Frohle. 2022. Bridging the gap between coastal engineering and nature conservation? A review of coastal ecosystems as nature-based solutions for coastal protection. *Journal of Coastal Conservation* 26(2).

89. Gopal, B. 2016. Should 'wetlands' cover all aquatic ecosystems and do macrophytes make a difference to their ecosystem services? *Folia Geobotanica* 51(3):209-226.

90. Birch, W. S., Drescher, M., J. Pittman, and R. C. Rooney. 2022. Trends and predictors of wetland conversion in urbanizing environments. *Journal of Environmental Management* 310:10.

91. Gaglio, M., Bresciani, M., Ghirardi, N., Muresan, A. N., Lanzoni, M., Vincenzi, F., G. Castaldelli, and E. A. Fano. 2022. Aquatic vegetation loss and its implication on climate regulation in a protected freshwater wetland of Po River Delta Park (Italy). *Water* 14(1).

92. Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., Van Wesenbeeck, B., Pontee, N., Sanchirico, J. N., Ingram, J. C., G. M. Lange, and K. A. Burks-Copes. 2016. The effectiveness, costs and coastal protection benefits of natural and nature-based defences. *PLOS ONE* 11(5).

93. Stammermann, R. and M. Piasecki. 2012. Influence of sediment availability, vegetation, and sea level rise on the development of tidal marshes in the Delaware Bay: A review. *Journal of Coastal Research* 28(6):1536-1549.

94. Silliman, B. R., He, Q., Angelini, C., Smith, C. S., Kirwan, M. L., Daleo, P., Renzi, J. J., Butler, J., Osborne, T. Z., J. C. Nifong, and J. van de Koppel. 2019. Field experiments and meta-analysis reveal wetland vegetation as a crucial element in the coastal protection paradigm. *Current Biology* 29(11):1800-1806.

95. Hickman, C.A. 1990. Forested wetland trends in the United States - an economic perspective. *Forest Ecology and Management* 33-4(1-4):227-238.

96. Bouayad, A. 2020. Wild rice protectors: An Ojibwe odyssey. *Environmental Law Review* 22(1):25-42.

97. Pendleton, L., Donato, D. C., Murray, B. C., Crooks, S., Jenkins, W. A., Sifleet, S., Craft, C., Fourqurean, J. W., Kauffman, J. B., N. Marbà, and P. Megonigal. 2012. Estimating global “blue carbon” emissions from conversion and degradation of vegetated coastal ecosystems. *PLOS ONE* 7(9).

98. Mcleod, E., Chmura, G. L., Bouillon, S., Salm, R., Björk, M., Duarte, C. M., Lovelock, C. E., W. H. Schlesinger, and B.R. Silliman. 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9(10):552-560.

99. Duarte, C. M., Losada, I. J., Hendriks, I. E., I. Mazarrasa, and N. Marbà. 2013. The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change* 3(11):961-968.

100. Boesch, D. F. and R. E. Turner. 1984. Dependency of fishery species on salt marshes: the role of food and refuge. *Estuaries and Coasts* 7:460–468.

101. Zimmerman, R. J., T. J. Minello, and L. P. Rozas. 2000. Salt marsh linkages to productivity of penaeid shrimps and blue crabs in the northern Gulf of Mexico *in* Concepts and Controversies. In *Tidal Marsh Ecology*, M.P. Weinstein and D.A. Kreeger, editors. Springer Netherlands. p. 293-314.

102. Burrow, A. and J. Maerz. 2022. How plants affect amphibian populations. *Biological Reviews* 97(5):1749-1767.

103. North American Bird Conservation Initiative. 2022. *The State of the Birds*. United States of America.

104. Ward, M. P., B. Semel, and J. R. Herkert. 2010. Identifying the ecological causes of long-term declines of wetland-dependent birds in an urbanizing landscape. *Biodiversity and Conservation* 19(11):3287-3300.

105. Hess, K. M., Sinclair, J. S., Reisinger, A. J., E. Z. Bean, and B. V. Iannone. 2022. Are stormwater detention ponds protecting urban aquatic ecosystems? A case study using depressional wetlands. *Urban Ecosystems* 25(4):1155-1168.

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

107. Douglas, S. H., J. C. Bernier, and K. E. L. Smith. 2018. Analysis of multi-decadal wetland changes, and cumulative impact of multiple storms 1984 to 2017. *Wetlands Ecology and Management* 26(6):1121-1142.

108. Gittman, R. K., Fodrie, F. J., Popowich, A. M., Keller, D. A., Bruno, J. F., Currin, C. A., C. H. Peterson, and M. F. Piehler. 2015. Engineering away our natural defenses: An analysis of shoreline hardening in the US. *Frontiers in Ecology and the Environment* 13(6):301-307.

109. U.S. Environmental Protection Agency. 2024. *National Wetland Condition Assessment: The third collaborative survey of wetlands in the United States.* EPA 843-R-24-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development.

110. Jenkins, D. G., S. Grissom, and K. Miller. 2003. Consequences of prairie wetland drainage for crustacean biodiversity and metapopulations. *Conservation Biology* 17(1):158-167.

111. Poole, K.E. and J.A. Downing. 2004. Relationship of declining mussel biodiversity to stream-reach and watershed characteristics in an agricultural landscape. *Journal of the North American Benthological Society* 23(1):114-125.

112. Hanski, I. and O. Ovaskainen. 2002. Extinction debt at extinction threshold. *Conservation Biology* 16(3):666-673.

113. Watzin, M.C. and J.G. Gosselink. 1992. *The Fragile Fringe: Coastal Wetlands of the Continental United States.* Louisiana Sea Grant College Program: Baton Rouge, Louisiana.

114. Malakoff, D. 1998. Ecology - Restored wetlands flunk real-world test. *Science* 280(5362):371-372.

115. Brooks, R. P., Wardrop, D. H., C. A. Cole, and D. A. Campbell. 2005. Are we purveyors of wetland homogeneity? A model of degradation and restoration to improve wetland mitigation performance. *Ecological Engineering* 24(4):331-340.

116. Moreno-Mateos, D., Power, M. E., F. A. Comín, and R.Yockteng. 2012. Structural and functional loss in restored wetland ecosystems. *PLOS Biology* 10(1).

117. Tillman, S. C., Spyreas, G., A. Olnas, and J. W. Matthews. 2022. Plant communities in wetland mitigation banks surpass the quality of those in the most degraded, naturally occurring wetlands, but fall short of high-quality wetlands. *Ecological Engineering* 176: 13.

118. Bourn, W.S. and C. Cottam. 1951. *Some biological effects of ditching tidewater marshes*. U.S. Fish and Wildlife Service.

119. Kingsford, R. T., Bino, G., Finlayson, C. M., Falster, D., Fitzsimons, J. A., Gawlik, D. E., Murray, N. J., Grillas, P., Gardner, R. C., T. J. Regan, and D. J. Roux. 2021. Ramsar wetlands of international importance–improving conservation outcomes. *Frontiers in Environmental Science* 9:643367.

120. Aust, W.M., C. Bolding, and S. Barrette. 2020. Silviculture in forested wetlands: Summary of current forest operations, potential effects, and long-term experiments. *Wetlands* 40:21-36.

U.S. Department of the Interior
Fish and Wildlife Service
www.fws.gov

and

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
www.fisheries.noaa.gov

December 2024