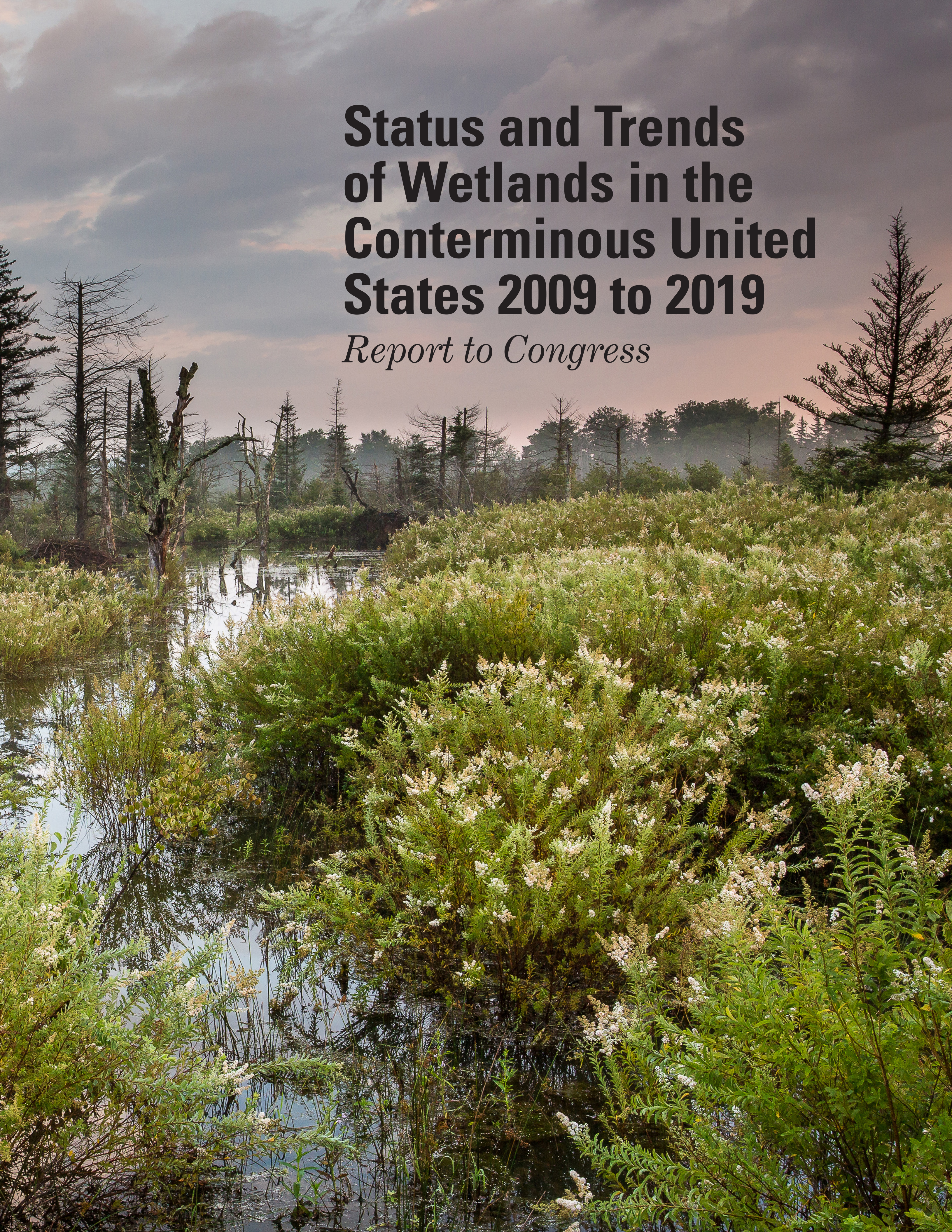
Status and Trends of Wetlands in the Conterminous United States 2009 to 2019

Report to Congress



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On the cover: View of wetlands at Canaan Valley National Wildlife Refuge in West Virginia © Kent Mason.

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Left: View of wetlands at Arapaho National Wildlife Refuge in Colorado. Photo by Tom Koerner, USFWS.

Preface

Members of Congress:

Each of us has a stake in the health of wetlands across our country. Wetlands are highly productive and biologically diverse systems that are a critical driver of economic activity. Wetlands enhance water quality, control erosion, maintain stream flows, sequester carbon, and provide a home to about half of all threatened and endangered species. Decades ago, Congress recognized the importance of wetlands when it wisely mandated this periodic report on the status and trends of wetlands across the Nation. These reports reveal that despite landmark environmental laws like the Clean Water Act, Swampbuster Provision of the Food Security Act, and National Environmental Policy Act; Executive Orders 11990, among others; and policies pledging no net loss of wetlands, we are failing as a Nation to sufficiently protect our wetlands. This report indicates that wetland loss rates have increased by 50 percent over the last decade and continue to disproportionally impact vegetated wetlands such as marshes and swamps. Approximately 670,000 acres of vegetated wetlands, an area greater than the land extent of Rhode Island, disappeared between 2009 and 2019.

The reasons for these losses are complex, but the results are clear – wetland loss leads to the reduced health, safety, and prosperity of all Americans. When wetlands are lost, society loses services such as clean water; slowing of coastal erosion; protection against flooding, drought, and fire; and resilience to climate change and sea level rise. Wetland losses also cause declines in fish, wildlife, and plant populations that many in our communities depend upon to make a living, feed their families, and enjoy the outdoors.

Wetlands status and trends reports are the yardstick used to measure the effectiveness of existing laws and policies aimed at protecting wetlands. This latest report makes it clear that these policies and laws are not sufficient. Over the nearly 70 years covered by the wetlands status and trends reports, the country has achieved the "No Net Loss" goal only once—in the early 2000s. The rate of wetland loss has continued to increase since 2004. In the face of a changing climate and associated increases in storm intensity, flooding, and drought, we cannot afford to lose more wetlands.

The important scientific information in this report is a call to action and provides an opportunity for the country to work together in response. The health of our Nation requires stronger wetlands conservation legislation, Executive action, and partnerships. Federal agencies, Tribes, States, and all landowners must work together now to protect and restore wetlands for the health of our communities, today and into the future. We must commit to raising the bar related to "No Net Loss" to a more explicitly defined standard of "No Net Loss" of vegetated wetlands going forward.

This report delivers the hard truth that we need to act now. I urge you to work with me to accomplish the recommendations in the report. Furthermore, I look forward to working with you to propose and enact stronger laws protecting wetlands, so the next status and trends report tells a positive story.

Deb Haaland
Secretary, Department of the Interior

Right: Southern Appalachian Mountain bogs are a rare wetland habitat, and in turn are home to several rare plants and animals, including the endangered mountain sweet pitcher plant. Photo by Gary Peeples, USFWS.

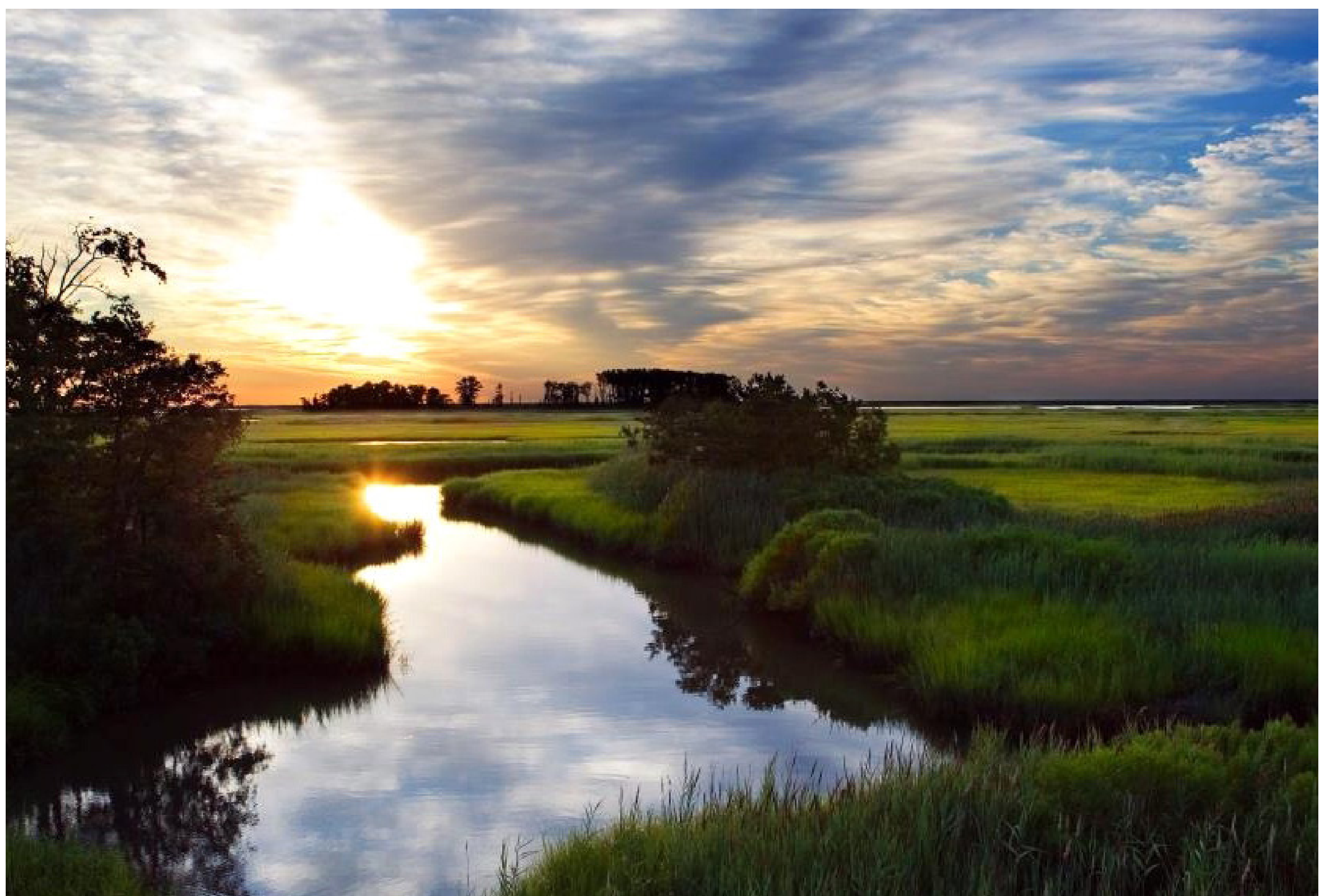
Executive Summary

This is the 6th in a series of Congressionally mandated Wetlands Status and Trends reports spanning nearly 70 years. It provides scientific estimates of wetland area in the conterminous United States as well as change in wetland area between 2009 and 2019. The information in this and past Status and Trends reports is used by natural resource managers and policy makers to make strategic decisions regarding the future of America's wetlands.

There were an estimated 116.4M acres (ac) (47.1M hectares [ha]) of wetlands in the conterminous U.S. in 2019, accounting for <6% of the conterminous U.S by area. The vast majority of wetlands were freshwater (95% or 110.4M ac [44.7M ha]), with saltwater wetlands occupying 6.1M ac (2.5M ha). Most wetlands were vegetated, including 92% (101.5M ac [41.1M ha]) of freshwater and 80% (4.8M ac [1.9M ha]) of saltwater wetlands. Freshwater forested wetlands were the most abundant wetland type overall (52.4M ac [21.2M ha]), with freshwater emergent, scrub-shrub, and ponds occupying 30.0M ac (12.1M ha), 19.1M ac (7.7M ha), and 6.9M ac (2.8M ha), respectively. The most common saltwater wetland type was salt marsh (4M ac [1.6M ha]), followed by non-vegetated areas (e.g., mud flats, beaches, shoals, and sand bars; 1.0M ac [405K ha]) and forested/shrub (800K ac [324K ha]).

Net wetland loss increased substantially (>50%) since the last Wetlands Status and Trends study period (2004–2009), resulting in the loss of 221K ac [89K ha] of wetlands, primarily to uplands, between 2009 and 2019. These losses disproportionately affected vegetated wetlands (forested, scrub-shrub, and/or emergent) resulting in a net loss of 670K ac [271K ha] of these wetlands, more than the land area of Rhode Island. In contrast, there was a net gain in non-vegetated wetlands of 488K ac [197K ha].

Bombay Hook National Wildlife Refuge in Delaware protects one of the largest remaining expanses of tidal salt marsh in the mid-Atlantic region.



Tim Williams/USFWS

Net annual losses of freshwater vegetated wetlands increased by about 50% relative to annual losses in the last study period. The wetlands that were most affected by these losses were freshwater forested wetlands (-426K ac [-172K ha]). Saltwater systems also experienced substantial declines of vegetated wetlands, with total salt marsh area decreasing by 2%. Loss of vegetated wetlands, even if replaced by non-vegetated wetlands, alters wetland function and leads to the reduction of wetland benefits, including mitigation of severe storms and sea level rise, water quality improvement, and provision of food and other natural resources like timber.

In contrast to the rapidly increasing loss of vegetated wetlands, net area of non-vegetated wetlands, like ponds, mud flats, shoals, and sand bars, increased by 488K ac [197K ha]. Non-vegetated wetland gains include an increase in ponds of 455K ac [184K ha] or 7% of total pond habitat and an increase in non-vegetated saltwater wetlands of 33K ac [13K ha] or 3% of that habitat. The loss of vegetation in saltwater wetlands may foreshadow future wetland loss. Studies have shown that the loss of wetland vegetation often precedes the transition from salt marsh to deepwater (e.g., open ocean) due to relative sea level rise and coastal storm impacts.

When net change to all wetlands is considered (-221K ac [-89K ha]), gains in non-vegetated wetlands obscure the magnitude of vegetated wetland losses. Most importantly, the data show an overall increase in the proportion of non-vegetated wetlands at the expense of vegetated wetlands, a trend consistent with previous Wetlands Status and Trends studies.

The substantial loss and alteration of wetlands documented by this study, including the long-term shift towards decreasing vegetated wetlands and increasing non-vegetated wetlands, reduces the prosperity, health, and safety of communities. This occurs through increased susceptibility of people and infrastructure to natural disasters like flood, drought, and wildfire, as well as decreased food security, reduction in clean water, increased harmful algal blooms and related increases in toxins and oxygen depleted "dead zones," 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. This includes rare as well as 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. These impacts can happen rapidly and are often difficult to reverse.

To achieve no net loss of all wetlands, including vegetated wetlands, a strategic update is needed to America's approach to wetland conservation.

Based on a review of wetland policy and management needs, the following strategies are suggested to support this recommendation: Strategy 1) Achieve "No Net Loss" of wetlands and robust coordination with government and non-governmental partners to achieve this goal; Strategy 2) Produce a contemporary NWI Geospatial Dataset and spatially explicit information on wetland function; Strategy 3) Develop and implement enhanced wetland conservation and management approaches based on a holistic review of current and past actions; and Strategy 4) Commit to long-term adaptive conservation, management, and monitoring. These foundational strategies are especially important because most wetlands in the conterminous U.S. have already been lost, wetland loss has recently accelerated, and future declines will likely be magnified by the effects of climate and land use and land cover change. Scientific information, like this report, is foundational to the strategic implementation of all natural resource policy actions and will be critical to the success of this effort.

Introduction

Situated at the transition between dryland and deepwater habitats, wetlands are characterized by unique biological, chemical, and hydrological conditions and, as a result, provide abundant ecosystem services (i.e., benefits that people receive from ecosystems[1]). Wetlands have long provided food and building materials[2,3], as well as recreational opportunities (e.g., hunting, fishing, kayaking, and bird watching) that benefit the health and well-being of tens of millions of Americans each year[1,3,4,5,6,7]. Wetlands are especially valued today because they help to avoid or mitigate many of our most pressing environmental challenges, including increasing temperatures[8,9,7], sea level rise[10,9], hurricanes and other severe storms[3,11,8,12], droughts and floods[8,13,14], wildfires[15], and the growing need for readily available clean water[3,16,7,14]. The ecosystem services provided by wetlands are unmatched by any other habitat except coral reefs. In terms of ecosystem services, wetlands have an economic value over 11 times higher than lakes and rivers, over 36 times higher than forests, and over 33 times higher than grasslands[17]. We estimate that ecosystem services related to commercial fishing, water quality and supply, recreation, and flood control alone provide over $7.7T in benefits annually within the conterminous United States[18].

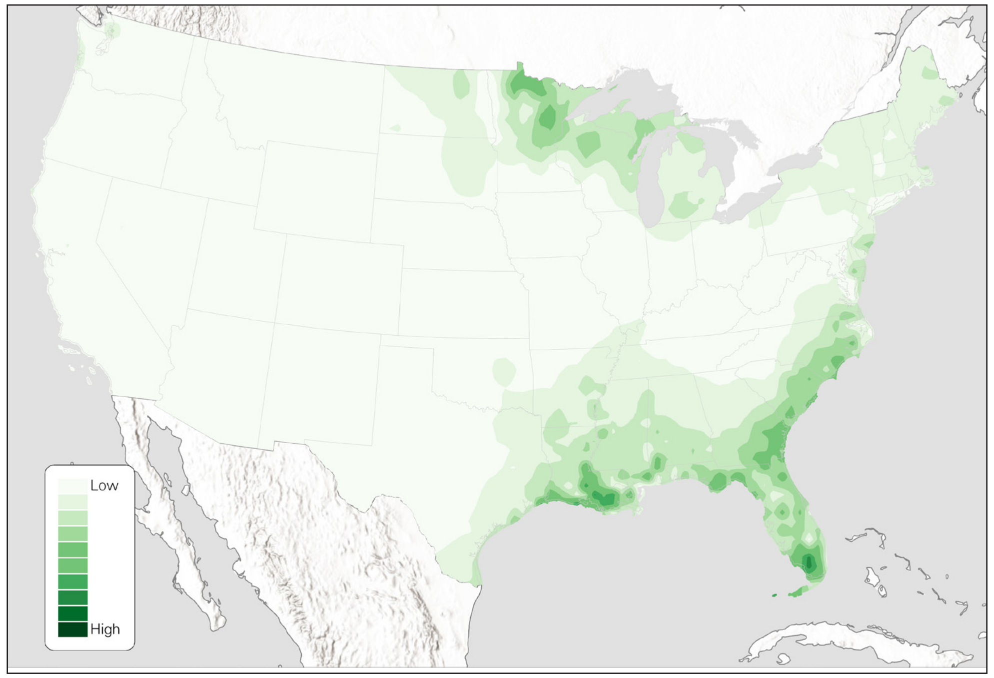


Figure 1. Relative wetland area (i.e., high to low wetland density) for the conterminous United States in 2019.

Wetlands also support a wide range of plant and animal species, many of which are rare or have a commercial or recreational value. Roughly half of the species protected under the U.S. Endangered Species Act (16 U.S.C. 1531-1544) are wetland-dependent[19,20], including the American crocodile, chinook salmon, whooping crane, bog turtle, manatee, and several orchid species. North American populations of wetland-dependent species are declining much more rapidly than other types of plants and animals[1], and half of locally extinct (i.e., no longer living in states where they used to reside) U.S. vascular plants live in wetlands[21]. This means that the importance of America's wetland habitats for vulnerable species will likely increase. Additionally, up to half of North American bird species[22] and ~80% of protected birds[23] depend on wetlands. Approximately 46 to 95% of U.S. commercial fish landings and 80 to 85% of recreational landings were found to depend on coastal wetlands and estuaries[24]. For these reasons and more, the U.S. Fish and Wildlife Service (Service) recognizes wetlands as a "trust resource" — i.e., a nationally important resource that the government protects for all Americans. Many of the pictures in this report highlight Service efforts and lands, including National Wildlife Refuges. These Refuges are 50% wetland by area and strive to conserve and strategically manage wetlands and wetland-dependent species[25].

History and Importance of Wetlands Status and Trends Reports

Recognizing the importance of America's wetlands, Congress enacted the Emergency Wetlands Resources Act (Public Law 99-645) in 1986. Under the provisions of this Act, the Service is required to produce publicly available maps of U.S. wetlands, as well as report to Congress every 10 years on the status and trends of the Nation's wetlands. These mandates are carried out by the Service's National Wetlands Inventory (NWI) Program, which provides foundational scientific information and geospatial data in support of wetland education, science, management, and policy.

Wetlands Status and Trends reports provide impartial scientific estimates of the extent of 17 wetland and deepwater habitats (Table 1) within the conterminous U.S., as well as change in their area over time. Each Status and Trends report builds on the last, providing an invaluable historical perspective and increasing our understanding of landscape patterns and processes. Several regional reports complement the national reports by focusing on areas within the U.S. that are experiencing relatively high rates of wetland loss, including two Coastal Watersheds reports[26,27] and one Prairie Pothole report[28].

Status and Trends reports quantify the cumulative effects of multiple wetland change drivers, including but not limited to climate change, development, agriculture, and federal, Tribal, state, and local government actions. Change drivers are diverse and can lead to wetland gain and loss, as well as change between wetland types. Governmental actions are wide ranging, including the implementation of wetland policies and regulations, compensatory and voluntary restoration, and protection. The information in Status and Trends reports enables natural resource managers and policy makers to make strategic decisions regarding the future of our Nation's wetlands.

Wetlands Status and Trends reports have long catalyzed wetland protection and restoration, and this trend continues today. Status and Trends findings of substantial wetland loss in the mid-1900s[29] catalyzed the creation of highly effective wetland protection and restoration programs and policies, including the Swampbuster

Table 1. Descriptions of wetland, deepwater, and upland categories used in the Wetlands Status and Trends study.

Saltwater	*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	*Common Description*
Palustrine Forested*	Swamps (wetlands with woody plants >6m [6.6 yd] tall)
Palustrine Shrub*	Wetlands with woody plants <6m [6.6 yd] 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 Plantation	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

* *wetland categories*
** *deepwater categories*

Provision of the 1985 Food Security Act (Public Law 99-198), U.S. Farm Bill wetland easement programs (e.g., Agricultural Conservation Easement Program Wetlands Reserve Easements), and the addition of wetland mitigation measures within the Clean Water Act (33 U.S.C.A. 1251 et seq.) permitting process[30]. Although the Wetlands Status and Trends project was not designed to determine the effectiveness of any specific policy, the data have been used to measure progress toward the overarching federal "No Net Loss" wetlands goal[31,32]. The reports continue to support strategic wetland policy and management today by driving collaboration and innovative planning between and amongst federal, Tribal, state, and local partners.

Within the Service and many other federal agencies, Status and Trends reports are used to guide the funding, planning, and implementation of wetland restoration and enhancement, habitat assessments, strategic habitat conservation, and ecosystem management activities. These data have also been used to inform species listing determinations and other actions related to implementation of the Endangered Species Act.

This is the sixth national U.S. Fish and Wildlife Service Wetlands Status and Trends report. Several federal and state agencies, as well as commercial and non-profit organizations, provided data analysis and technical resources that were critical to its completion. The U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration provided financial support.

Bald cypress trees at Great Dismal Swamp National Wildlife Refuge in Virginia. Photo by R. Winn, USFWS.

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 the conterminous United States. This goal was met with a high degree of survey integrity and data quality standards, while improving workflows in response to evolving technologies and maintaining consistency with past Status and Trends studies. Data were collected using a survey-based approach carried out within 5,048 plots (four mi^2 [10.4 km^2] each) randomly distributed within strata across the conterminous U.S. with plots allocated to strata by wetland density (i.e., there were more plots in wetter areas; Figure 1). A cadre of highly-trained image interpreters with regional expertise used a combination of fine spatial resolution (≤ 3.3 ft [1 m] pixel size) remotely sensed imagery, on-screen digitizing techniques, and field visits to determine land cover (and in some cases land use) types and area in 2009 and 2019. Change over the 10.5-year study period was determined by comparing data from those dates (Figure 2). The same plots are sampled during different Status and Trends study periods to support inter-study comparisons. Data quality was ensured by using a multi-step process involving quality control/assurance by a series of regional and national experts, as well as field verification and automated logic checks. Field verification was completed for 1,034 sample plots distributed in 46 states (20% of total plots). Measurement accuracy was enhanced by technological improvements, such as the spatial refinement of many 2009 wetland and deepwater boundaries, improvements in the spatial and temporal resolution of base and ancillary imagery, and digital collection of Global Positioning System-enabled field verification data.


Courtney Celley/USFWS

Horicon National Wildlife Refuge in Wisconsin helps to protect one of the largest freshwater marshes in the United States. This marsh is a critical rest stop for thousands of migrating ducks and Canada geese.

Figure 2. Aerial imagery showing wetland change between 2009 (left) and 2019 (right) for an urbanizing area in the southeastern United States. Note some examples of vegetated wetland loss (A) and pond gain (B).

Wetlands were identified using a biological definition[33], which differs from the federal regulatory definition and does not imply regulatory jurisdiction. The biological definition requires wetland hydrology, and if soil and/or vegetation are present, they must be hydric or hydrophytic, respectively. Freshwater and saltwater wetlands were classified 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]. These three wetland types were further divided into 13 subcategories based primarily on vegetation presence and type, and according to the Federal Geographic Data Committee Wetlands Mapping Standard[33] (Table 1).

In addition to wetland categories, four deepwater and five upland categories were tracked (Table 1). Deepwater habitats have water that is too deep to be considered wetland, including water depth exceeding spring tide in tidal habitats and depth that exceeds 8.2 ft (2.5 m) at low water in non-tidal habitats. "Upland" is used in this report to denote land areas that are too dry to be wetlands. The upland categories were used to help track common drivers of wetland loss and gain and therefore included land use types as well as land cover. Change between wetland, deepwater, and upland categories was only documented when it was clearly indicated in the remotely sensed imagery (e.g., non-ditched inundated area replaced by a ditched non-inundated area) and determined to be long-term and not temporary due to weather or other factors. For more information on procedures used to help ensure the quality of Status and Trends change data please see National Standards and Support Team 2017[34].

The area and area change of wetland and deepwater habitats in the conterminous U.S. (with the exception of the Great Lakes) and associated standard errors were estimated using conventional mathematical and statistical methods. Reported area change values represent net change unless otherwise noted. Net change represents the balance between increases and decreases and is calculated as the difference between all increases and decreases (increases minus decreases) to the area of a particular category. For example, if category A increased by 100 units and decreased by 50 units the net change would be 50 units (100 - 50 = 50 units). In contrast, gross change accounts for all increases and decreases and would be 150 units in this example (100 + 50 = 150 units). We evaluated the magnitude of wetland change relative to measured uncertainty with p-values (2019–2009, paired t-test, df = 5048 plots - 215 strata). Additional information on study methods, including wetland, upland, and deepwater categories, sampling scheme, quality control, and statistical analysis can be found in Dahl 2011[35] and National Standards and Support Team 2017[34].

Results

Area of U.S. Wetlands

There were an estimated 116.4M ac (47.1M ha) of wetlands in the conterminous U.S. in 2019, accounting for <6% of the total area of the conterminous U.S. (Table 2; Figure 3). The vast majority of wetlands were freshwater (palustrine; 95% or 110.4M ac [44.7M ha]), with saltwater (estuarine and marine) wetlands occupying 6.1M ac (2.5M ha; 5%). Most wetlands were vegetated, including 92% (101.5M ac [41.1M ha]) of freshwater and 80% (4.8M ac [1.9M ha]) of saltwater wetlands. Freshwater (i.e., palustrine) forested wetlands were the most abundant type overall (52.4M ac [21.2M ha]), with freshwater emergent, scrub-shrub, and ponds occupying 30.0M ac (12.1M ha), 19.1M ac (7.7M ha), and 6.9M ac (2.8M ha), respectively. The most common saltwater wetland type was estuarine emergent marsh (i.e., salt marsh; 4M ac [1.6M ha]), followed by estuarine and marine non-vegetated areas (e.g., beaches, mud flats, shoals, and sand bars; 1.0M ac [405K ha]) and estuarine forested/shrub (800K ac [324K ha]). In 2019 deepwater habitats occupied a total of 44.7M ac (18.1M), including 20.0M ac (8.1M ha) of estuarine subtidal, 17.2M ac (7.0M ha) of lacustrine (not including the Great Lakes), and 7.4M ac (3.0M ha) of riverine habitat. A summary of data for the 2009–2019 study period, including p-values from paired t-tests, can be found in Table 2.

Change In All Wetland Types

Wetland losses within the conterminous U.S. exceeded gains, resulting in a net wetland loss of 221K ac [89K ha] during the study period (Table 2). This net loss

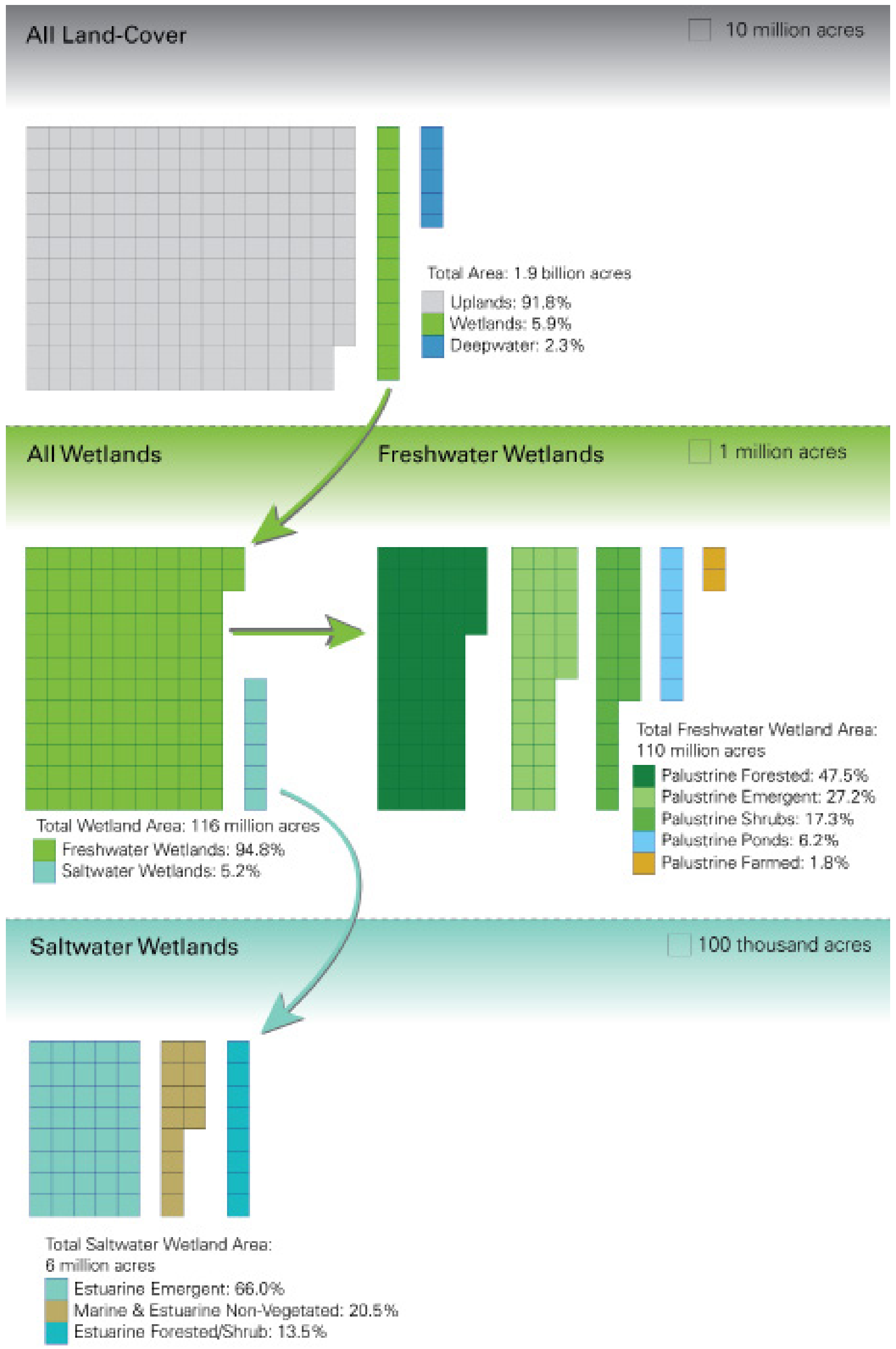


Figure 3. Area of upland, deepwater, and wetlands within the conterminous United States in 2019.

Table 2. Summary of 2019 area and 2009–2019 area change for select wetland and deepwater categories.

Wetland/Deepwater Category	*Area, In Thousands of Acres (%CV)*			*Change (In Percent)*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change, 2009–2019*		
Marine Intertidal	206 (13.7)	209 (13.5)	3 (75.7)	1.3%	0.187
Estuarine Intertidal Unconsolidated Shore	1,005 (11.7)	1,035 (11.3)	30 (41.4)	3.0%	0.016
Estuarine Intertidal Vegetated	4,880 (3.5)	4,817 (3.5)	-63 (17.8)	-1.3%	<.001
All Intertidal Wetlands	6,091 (2.1)	6,061 (2.2)	-30 (24.4)	-0.5%	<.001
Palustrine Ponds	6,421 (1.3)	6,876 (1.3)	455 (4.3)	7.1%	<.001
Palustrine Farmed	2,012 (23.4)	1,973 (24.0)	-40 (63.6)	2.0%	0.116
Freshwater Vegetated	102,134 (1.7)	101,527 (1.7)	-607 (11.0)	-0.6%	<.001
Palustrine Emergent	30,092 (7.8)	30,008 (7.8)	-84 (160.2)	-0.3%	0.533
Palustrine Shrub	19,187 (4.9)	19,091 (5.0)	-97 (206.8)	-0.5%	0.629
Palustrine Forested	52,854 (2.7)	52,428 (2.7)	-426 (42.1)	-0.8%	0.018
All Freshwater Wetlands	110,567 (0.9)	110,376 (0.9)	-191 (18.7)	-0.2%	<.001
All Non-Vegetated Wetlands	7,632 (1.1)	8,120 (1.0)	488 (3.4)	6.4%	<.001
All Vegetated Wetlands	107,014 (1.2)	106,344 (1.2)	-670 (7.6)	-0.6%	<.001
All Wetlands	116,658 (0.7)	116,437 (0.7)	-221 (34.3)	-0.2%	<.001
Lacustrine	17,068 (10.3)	17,227 (10.1)	159 (63.2)	0.9%	0.094
Riverine	7,435 (8.4)	7,402 (8.4)	-33 (155.1)	-0.4%	0.653
Estuarine Subtidal	19,987 (2.2)	20,043 (2.2)	56 (28.3)	0.3%	<.001
All Deepwater Habitats	44,490 (2.3)	44,672 (2.3)	182 (34.7)	0.4%	0.002

*Note that only non-vegetated wetland categories increased in area, whereas all area decreases were associated with vegetated wetlands. 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 estuarine intertidal vegetated category includes estuarine intertidal emergent and forested/shrub. 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. Any apparent discrepancy between the area estimates and their reported difference is due to rounding.*

was driven by the conversion of wetlands to upland and deepwater land cover types (Figure 4). Conversion to upland was the dominant driver of net wetland loss resulting in a total wetland reduction of 194K ac (79K ha). Conversion to deepwater areas accounted for a loss of 27K ac [11K ha].

The rate of net wetland loss (-21K ac/yr [-8.5K ha/yr]) accelerated by over 50% between this study period (2009–2019) and the previous period (2004–2009). This finding extends a long-term pattern of net wetland loss (Figure 5) that likely began hundreds of years ago with European colonization. This trend has already resulted in the conterminous U.S. losing over half of its wetland area[36].

In addition to net wetland loss, Status and Trends data for 2009–2019 indicate a fundamental alteration of wetland type at a national scale. While the area of all vegetated wetland categories decreased, all non-vegetated

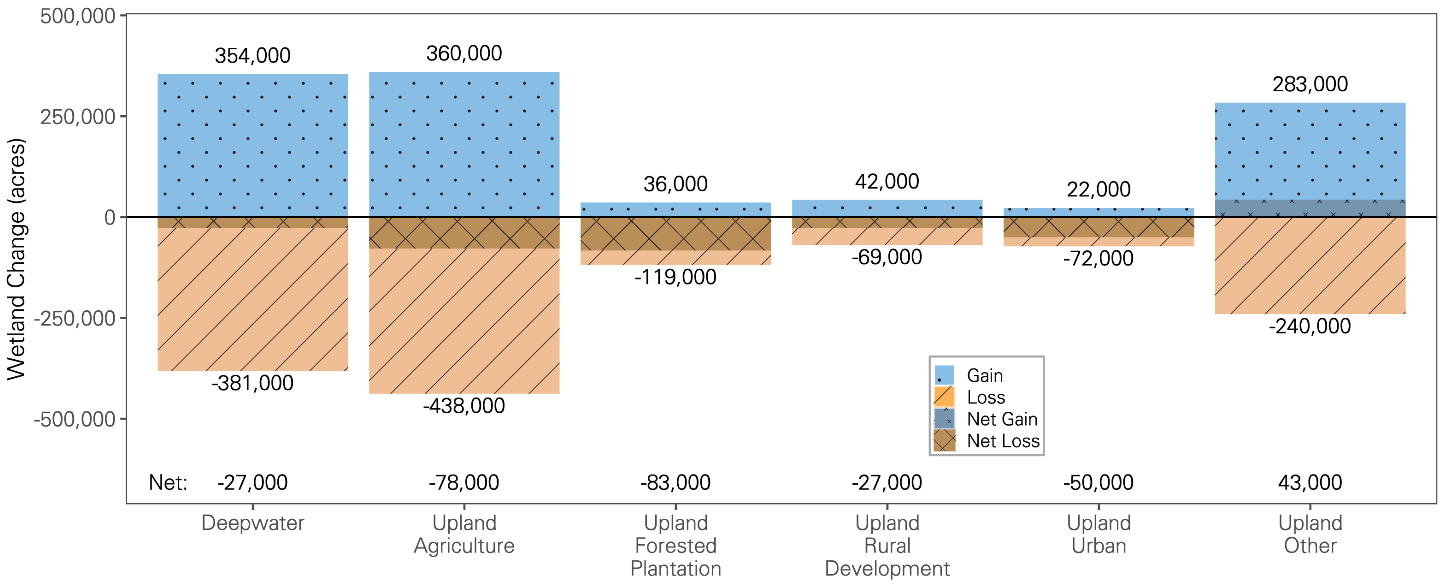


Figure 4. Wetland gain and loss between 2009 and 2019 in the conterminous United States attributed to different change drivers. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

wetland categories increased in area (Table 2). The net decrease in vegetated wetlands was 670K ac. In contrast, non-vegetated wetlands and deepwater categories gained net area (488K and 182K ac [197K and 74K ha], respectively). When net change to all wetlands is considered (-221K ac [-89K ha]), the gains in non-vegetated wetlands obscure the magnitude of the vegetated wetland losses. Most importantly, the data show an overall increase in the proportion of non-vegetated wetlands at the expense of vegetated wetlands, a trend consistent with previous Status and Trends studies.

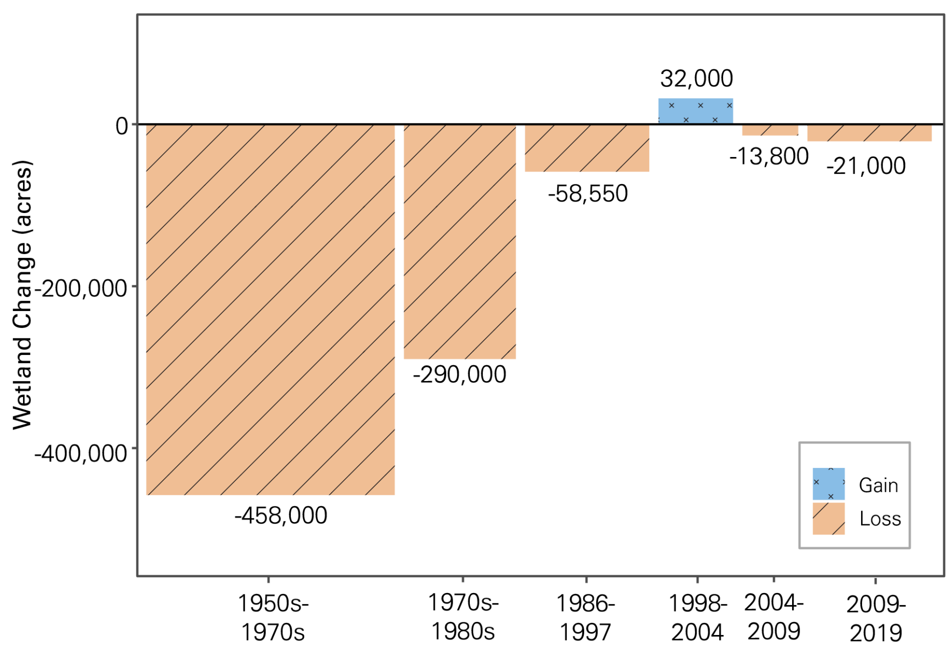


Figure 5. Average annual net wetland gain or loss across Wetlands Status and Trends study periods. Width of bars represents length of study period.

Saltwater Wetland Trends

Saltwater wetlands within the conterminous U.S. experienced a net decrease of 30K ac (12K ha) between 2009 and 2019 (Table 3). Estuarine emergent marsh (i.e., salt marsh) experienced the largest net percent reduction of any wetland category (2% or -70K ac [-28K ha]), while non-vegetated saltwater wetland area increased by 3% (33K ac [13K ha]). There were small net increases in estuarine marsh in areas formerly occupied by freshwater wetlands (22K ac [9K ha]) and uplands (2K ac [800 ha]; Figures 6). The pattern of decreasing estuarine marsh and increasing non-vegetated saltwater wetlands (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 (Figure 7).

Net decrease in estuarine emergent marsh (i.e., salt marsh) was primarily associated with change of marsh to non-vegetated habitats (Figure 6). In most cases, estuarine marsh was converted to marine and estuarine subtidal (deepwater; 61K ac [25K ha]), but change to intertidal non-vegetated wetlands (e.g., beaches, mud flats, shoals, and sand bars) also occurred (24K ac [10K ha]). Dynamic exchange between land cover categories is common within the saltwater environment. However, it is

Table 3. Summary of 2019 area and 2009–2019 area change for saltwater wetlands.

Wetland Category	*Area, In Thousands of Acres (%CV)* Estimated Area, 2009	Estimated Area, 2019	Change, 2009–2019	*Change (In Percent)*	*% of Saltwater Wetlands*	*Change P-Value*
Marine Intertidal	206 (13.7)	209 (13.5)	2.7 (75.7)	1.3%	3.4%	0.187
Estuarine Intertidal Unconsolidated Shore	1,005 (11.7)	1,035 (11.3)	30.1 (30.1)	2.9%	17.1%	0.016
Marine and Estuarine Intertidal Non-Vegetated	1,211 (6.9)	1,244 (6.7)	32.8 (25.7)	2.6%	20.5%	<.001
Estuarine Emergent	4,070 (5.5)	4,000 (5.5)	-69.5 (25.5)	-1.7%	66.0%	<.001
Estuarine Forested/Shrub	810 (12.1)	816 (12.0)	6.7 (114.2)	0.8%	13.5%	0.381
Estuarine Intertidal Vegetated	4,880 (3.5)	4,817 (3.5)	-62.8 (17.8)	-1.3%	79.5%	<.001
All Estuarine and Marine Intertidal	6,091 (2.1)	6,061 (2.2)	-30.1 (24.4)	-0.5%		<.001

*Marine and estuarine intertidal non-vegetated category includes estuarine intertidal unconsolidated shore and marine intertidal. Estuarine intertidal vegetated includes estuarine emergent and estuarine forested/shrub. Coefficient of variation (CV; [standard error/mean] * 100) for each entry expressed as percent is listed in parentheses below area and change values. Any apparent discrepancy between the area estimates and their reported difference is due to rounding.*

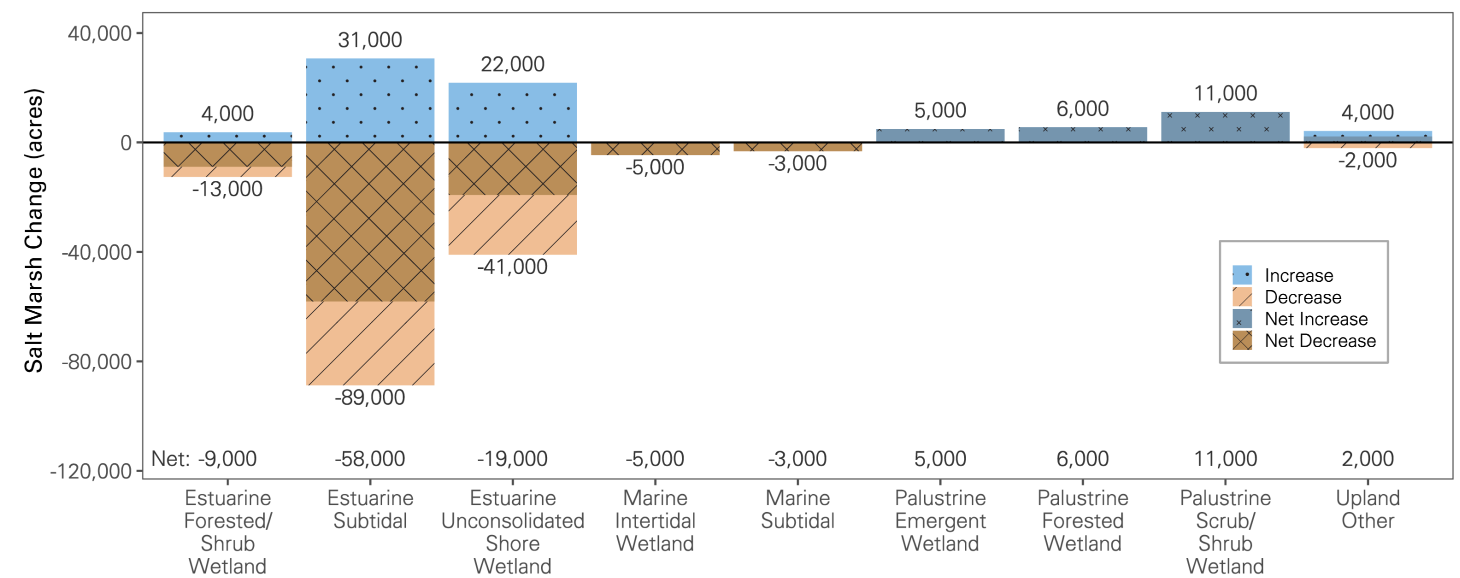


Figure 6. Salt marsh (estuarine intertidal emergent) area change between 2009 and 2019 in the conterminous United States attributed to different drivers. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

important to note that the net loss of estuarine marsh exhibits a highly significant (p <.001), long-term, and disproportionately one-way pattern.

Freshwater Wetland Trends

The conterminous U.S. is still losing large amounts of vegetated freshwater wetlands to deepwater and upland (Table 4). The net area decrease of all freshwater vegetated wetlands was -607K ac [-246K ha]). Freshwater forested wetlands experienced a larger net decrease in area (-426K ac [-172K ha]) than any other category during this study period. Approximately 288K ac [117K ha] of this decrease was due to loss of forested wetlands to uplands, and almost twice as much (559K ac [226K ha]) forested wetland was changed to freshwater emergent wetland. Gross change (i.e., all increases and decreases) between forested and emergent or scrub-shrub wetland types (3.7M [1.5M ha]) was likely driven in large part by timber harvest. This wetland type change eclipsed gross gains and losses related to uplands (307K ac [124K ha]).

The net decrease of vegetated wetlands co-occurred with a substantial net increase in open-water ponds of 455K ac [184K ha].

Table 4. Summary of 2019 area and 2009–2019 area change for freshwater wetlands.

Wetland Category	*Area, In Thousands of Acres (%CV)*			*Change (In Percent)*	*% of Freshwater Wetlands*	*Change P-Value*
	Estimated Area, 2009	*Estimated Area, 2019*	*Change 2009-2019*			
Palustrine Emergent	30,092.4 (7.8)	30,008.2 (7.8)	-84.2 (160.2)	-0.3%	27.2%	0.9225
Palustrine Shrub	19,187.4 (4.9)	19,090.9 (5.0)	-96.5 (206.8)	-0.5%	17.3%	0.6180
Palustrine Forested	52,854.2 (2.7)	52,428.2 (2.7)	-426.0 (42.1)	-0.8%	47.5%	0.0176
Freshwater Vegetated Wetlands	102,134.1 (1.7)	101,527.3 (1.7)	-606.8 (11.0)	-0.3%	92.0%	<.001
Aquaculture Ponds	159.0 (30.8)	153.8 (30.7)	-5.0 (166.8)	-3.1%	0.1%	0.5489
Agriculture Ponds	3,057.0 (3.9)	3,310.2 (3.9)	253.0 (12.9)	8.3%	3.0%	<.001
Industrial Ponds	367.6 (11.8)	435.1 (10.8)	68.0 (24.6)	18.5%	0.4%	<.001
Natural Ponds	1,838.7 (6.3)	1,887.6 (6.3)	49.0 (49.1)	2.7%	1.7%	0.0416
Urban Ponds	998.6 (6.8)	1,089.3 (6.5)	91.0 (13.5)	9.1%	1.0%	<.001
Palustrine Ponds	6,420.9 (1.3)	6,876.1 (1.3)	455.2 (4.3)	7.1%	6.2%	<.001
Palustrine Farmed	2,012 (23.4)	1,973 (24.0)	-39.6 (63.6)	-2.0%	1.8%	0.1160
All Freshwater Wetlands*	110,567.4 (0.9)	110,376.2 (0.9)	-191.2 (18.7)	-0.2%		0.0737

*Freshwater vegetated wetlands include the palustrine emergent, shrub, and forested categories. Coefficient of variation (CV; [standard error/mean] * 100) for each entry expressed as percent is listed in parentheses below area and change values. Any apparent discrepancy between the area estimates and their reported difference is due to rounding.*

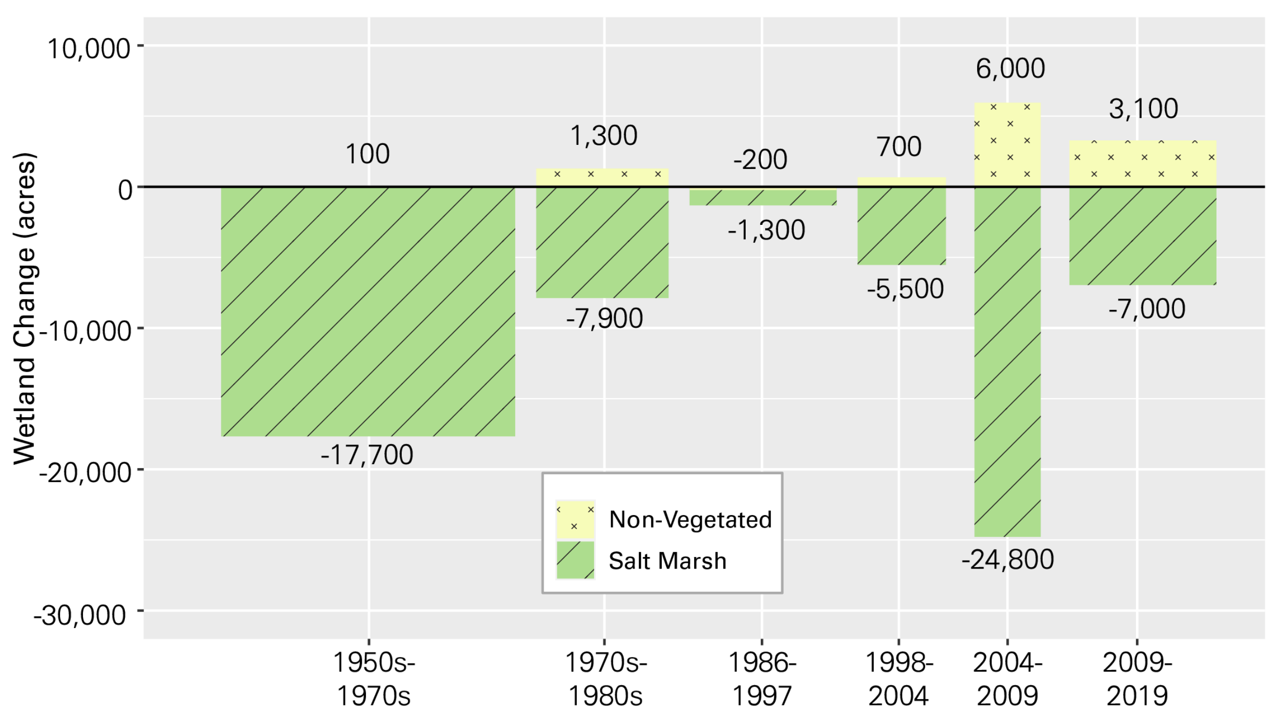


Figure 7. Net annual change in salt marsh and non-vegetated saltwater wetlands within the conterminous United States between the mid-1900s and 2019. Width of bars represents length of study period.

Pond area increased by over 7% during the study period (Table 4). These increases were primarily gains of agricultural ponds (253K ac [102K ha]) but also included urban (91K ac [37K ha]), industrial (68K ac [28K ha]), and natural (49K ac [20K ha]) 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 and conservation practices) as well as changes in weather and climate. In contrast, increases in urban and industrial ponds were primarily driven by development (e.g., stormwater management ponds). All upland categories experienced some conversion to ponds, but most ponds were gained from upland agriculture and upland other, resulting in net gains of 184K and 126K ac (74K and 51K ha), respectively (Figure 8). Vegetated wetlands were also changed to ponds, resulting in a net pond area increase of 106K ac (43K ha) and a commensurate decrease in

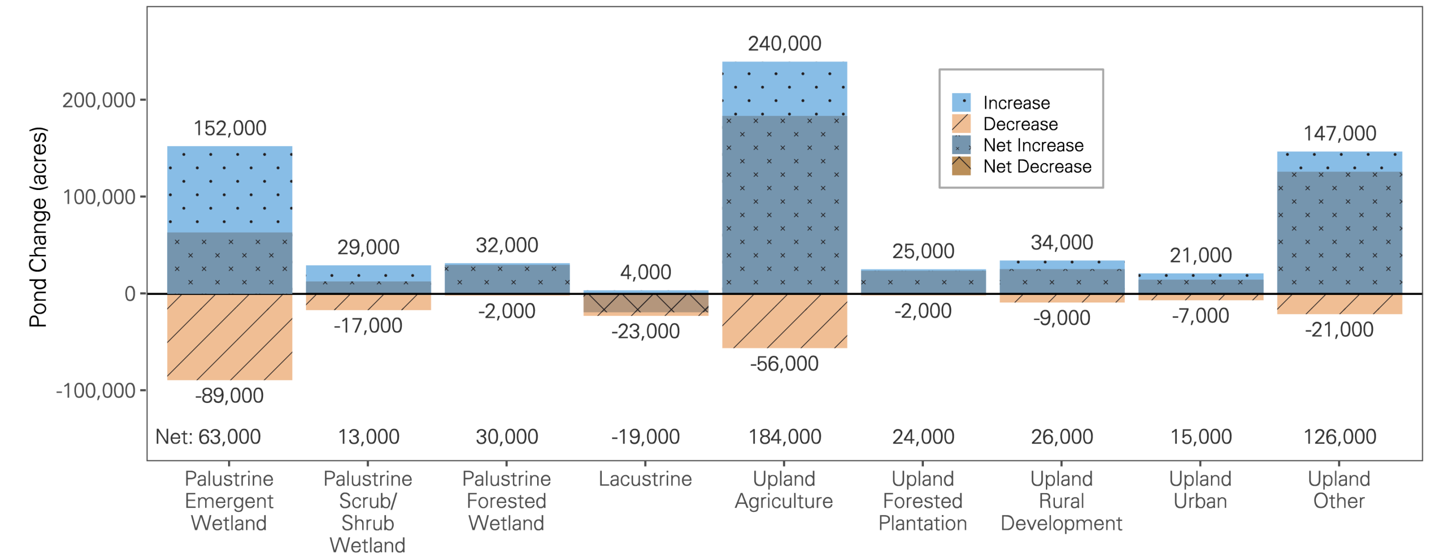


Figure 8. Pond area change between 2009 and 2019 in the conterminous United States attributed to different drivers. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

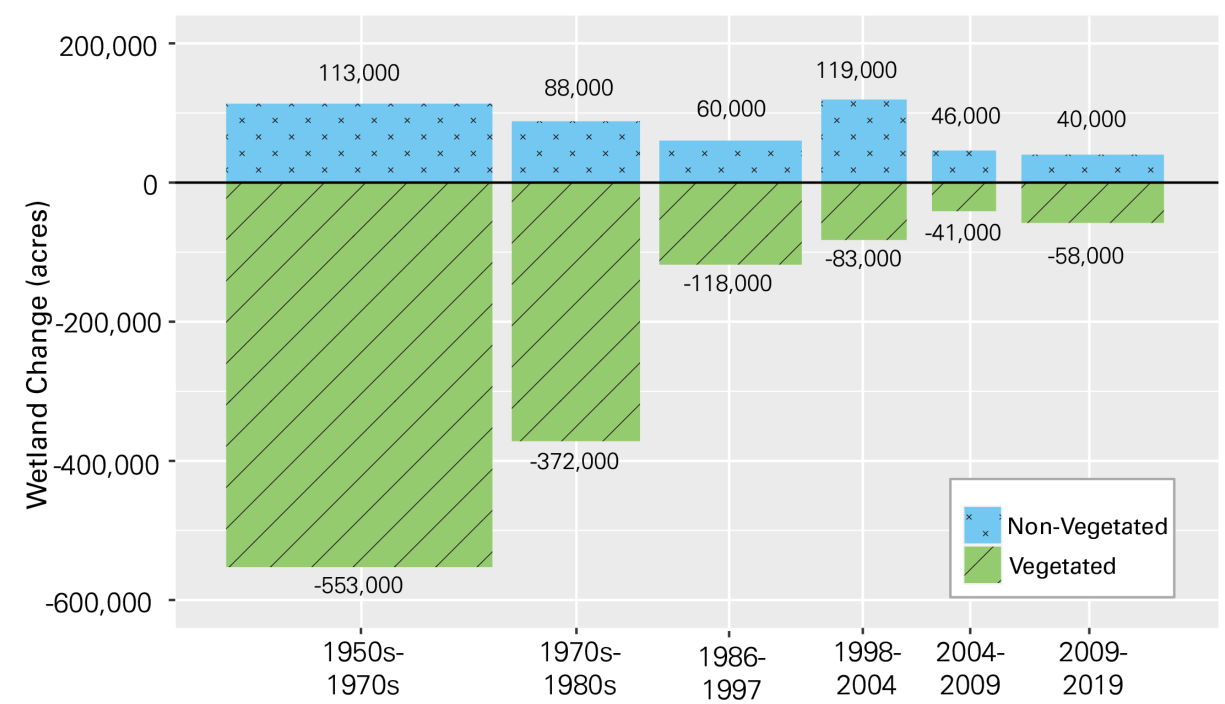


Figure 9. Net annual non-vegetated and vegetated freshwater wetland change within the conterminous United States between the mid-1900s and 2019. Width of bars represents length of study period.

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 (Figure 9). This pattern has obscured vegetated wetland losses.

The magnitude and dominant drivers of change varied depending on wetland type (e.g., vegetated versus non-vegetated). The largest driver of all freshwater wetland net loss (-191K ac [-77K ha]) was an increase in upland forested plantations (83K ac [34K ha]), followed by increases in upland agriculture (78K ac [32K ha]), upland urban (49K ac [20K ha]), upland rural development (27K ac [11K ha]), and lacustrine area (25K ac [10K ha]). There was also a net gain of 39K ac (16K ha) in freshwater wetlands from upland other (Figure 10). When only vegetated freshwater wetlands are considered, net loss to upland was substantially higher (-607K ac [-246K ha]), including net losses to upland agriculture (-211K ac [-85K ha]), upland forested plantation (-107K ac [-43K ha]), upland other (-86K ac [-35K ha]), upland urban (-64K ac [-26K ha]), and upland rural development (-51K ac [-21K ha]; Figure 10).

Right: Ghost forest at St. Marks National Wildlife Refuge along the Gulf coast of Florida. Ghost forests form when salt water kills trees, often due to sea level rise. Photo by Megan Lang, USFWS.

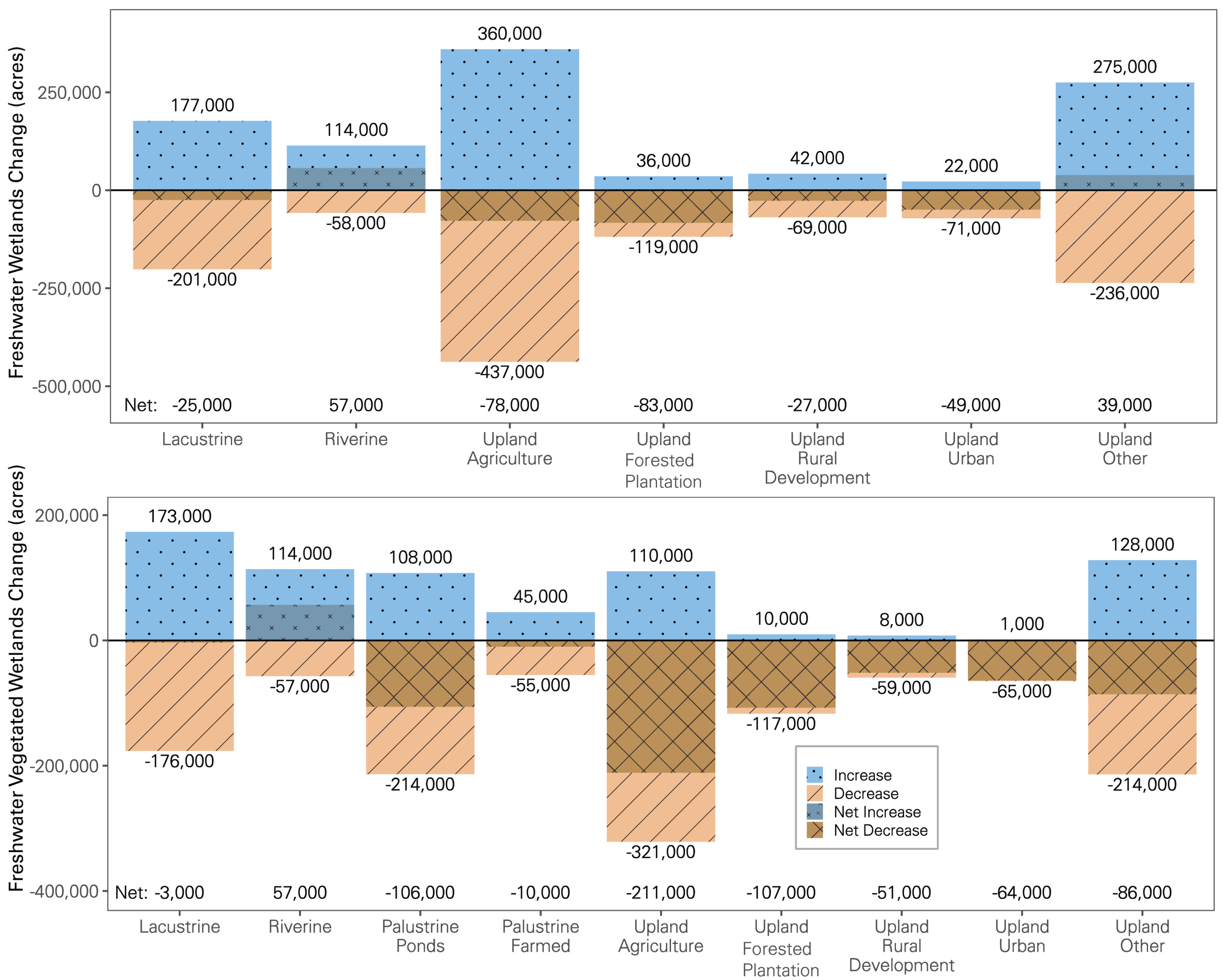


Figure 10. Freshwater all wetland (top) and vegetated wetland (bottom) change between 2009 and 2019 in the conterminous United States attributed to different drivers. Note: Only categories associated with amounts of change that were large enough to be clearly visible were included in the graph.

Discussion

Drivers of Change

The losses documented by this study extend a long-term pattern of net wetland loss[36] within the conterminous U.S., the primary causes of which have shifted through time. During the mid-1900s (i.e., twentieth century), net loss was dominated by drainage and fill, primarily associated with agriculture[29]. By the late 1900s (i.e., 1986–1997), urban and rural development was associated with over half (53%) of net wetland loss, followed by agriculture (26%) and silviculture (i.e., upland forested plantations; 23%)[37]. While we estimate that conversion of wetlands to upland through drainage and fill is still the main driver of loss (Figure 4), other less direct mechanisms are also important, including those associated with the effects of climate change (e.g., increased temperature and therefore evaporation and changes in precipitation patterns)[38,39,40]. These varying drivers often interact, accelerating loss[41,42,39]. The result has been the loss of more than half of wetlands in the conterminous U.S. since European colonization[36].

Loss accelerated during this study period, resulting in substantial net reduction of all wetlands (-221K ac [-89K ha]) and an even greater reduction in vegetated wetlands. Vegetated wetland decreases (-670K ac [271K ha]) exceeded the land area of Rhode Island, while non-vegetated wetland increase (488K [197K ha]) was equivalent to ~75% of that state's area. Estuarine emergent marsh (i.e., salt marsh) demonstrated the largest net percent reduction of any wetland category (2% or -70K ac [-28K ha]), while non-vegetated saltwater wetland area increased by 3%

Dan Severson/USFWS

Federally endangered whooping cranes at Quivira National Wildlife Refuge in Kansas.

(33K ac [13K ha]). Net freshwater vegetated wetland area decreased by 607K ac [246K ha] during the study period. The majority of that decrease is attributable to declines in freshwater forested wetlands (-426K ac [-172K ha]). In contrast, pond area increase (455K ac [184K ha] exceeded forested wetland decrease, resulting in a 7% gain of pond habitat.

Significance of Wetland Loss

The substantial loss of wetlands documented by this study (Table 2) reduces the prosperity, health, and safety of communities through increased susceptibility of people and infrastructure to natural disasters like flood, drought, and wildfire[43,44,11,8,45,12,46,13], decreased food security[3], reduction in clean water[3,45,16,46], increased harmful algal blooms and related increases in toxins and oxygen depleted "dead zones"[1,47,48], greater vulnerability to sea level rise and storms[3,11,8,41,12,9], and reduced recreational opportunities[3,7]. The impacts of natural disasters, heightened by wetland loss, have been especially substantial[44,12,13]. Since 1980, 355 U.S. weather and climate related disasters with damages over $1B have occurred at a total cost of $2.54T and 15,955 related deaths[49]. Hurricane Sandy is estimated to have cost $4.4B in lost ecosystem services through damage to New Jersey's wetlands alone[41].

Wetland loss also leads to declines in fish, wildlife, and plant populations, including rare, commercially important, and culturally valuable species[50,51,52,53,54,55,23,3,16,56,57]. For example, a five-county area in Minnesota that historically supported about 300,000 dabbling-duck breeding pairs could support less than 59,000 pairs after about half of its historical wetland area was lost[58]. Similar declines in wetland area and wetland-dependent species are occurring globally, including an 83% decline in freshwater wildlife species populations between 1970 and 2018, more than for any other wildlife type[59]. The impact of wetland loss on biodiversity and other ecosystem services may not be fully evident for several decades[60,47].

Human and environmental impacts stem from not only the loss of wetlands but their replacement with other land covers. For example, replacement of wetlands with development and agriculture reduces wetland pollutant removal services, and increases pollutant inputs in the form of fertilizer, waste, sediment, and toxins. Replacement of wetlands with development also increases the amount of impervious surfaces in a watershed, which has been linked to degraded watershed health[61]. Additionally, replacement of wetlands with development often places people and infrastructure in locations that are more vulnerable to natural disasters, such as storm surge along the coasts and flooding near streams.

Vegetated vs. Non-Vegetated Wetlands

Status and Trends reports indicate a consistent and fundamental shift towards more non-vegetated wetlands and fewer vegetated wetlands for at least the past 70 years. During the 2009–2019 study period, this pattern within freshwater systems was primarily driven by increases in agricultural, urban, and industrial ponds paired with vegetated wetland losses to upland (agriculture, development, and forested plantations) and lakes. Change of wetlands to ponds also played a role (Figure 10). This is particularly notable because ponds do not naturally occur in many parts of the U.S.

Within saltwater systems, the pattern of increasing non-vegetated wetlands and decreasing vegetated wetlands was driven primarily by the replacement of estuarine emergent marsh (i.e., salt marsh) by non-vegetated wetlands, accompanied by the loss of marsh to deepwater (Figures 6 and 11). The loss of emergent vegetation in saltwater wetlands may foreshadow future wetland loss. In saltwater wetlands, vegetation loss often precedes the transition from

Figure 11. Aerial imagery showing salt marsh (estuarine emergent marsh) loss between 2009 (left) and 2019 (right) in Louisiana.

estuarine marsh to deepwater due to relative sea level rise and coastal storm impacts[38,41]. Although coastal habitats are dynamic by nature due to waves, currents, and other natural forces, this highly significant ($p < .001$), long-term pattern of net estuarine marsh decrease and non-vegetated wetland and deepwater gain is consistent with the documented effects of human modification[62] and climate change[10,41,63]. Similarly, findings of freshwater wetland and upland change to saltwater wetland is most likely the result of landward migration of saltwater wetlands with relative sea level rise[9,56,63,64].

Vegetated wetland decreases primarily occurred in the Southeast and Great Lakes regions. Decreases were particularly prevalent within the Southeast, including the coastal watersheds of Texas, Louisiana, Florida, the Carolinas, and the Delmarva Peninsula, as well as near the Mississippi and Mobile River alluvial plains (Figure 12). In addition to other drivers of wetland change, the Southeast experienced multiple hurricanes during the study period including Irma [2017], Harvey [2017], Michael [2018], Florence [2018], and Dorian [2019]. Wetland losses are predicted to continue in these areas due to the dual pressures of land use and climate change[65].

Loss of wetland vegetation is an important driver of ecologic deterioration, partially because non-vegetated wetlands function differently than vegetated wetlands and often provide fewer ecosystem services[66,67,64,68]. For example, in the Peconic Estuary, New York the annual economic value of estuarine marsh was found to be five times that of intertidal mud flats[69]. Plants dissipate wave energy and trap sediment while their roots stabilize shorelines, building resilience to storms and sea level rise[3,11,41]. This benefit is substantial, saving infrastructure and lives. Salt marsh (i.e., estuarine emergent marsh) can reduce wave heights by 72%[70].

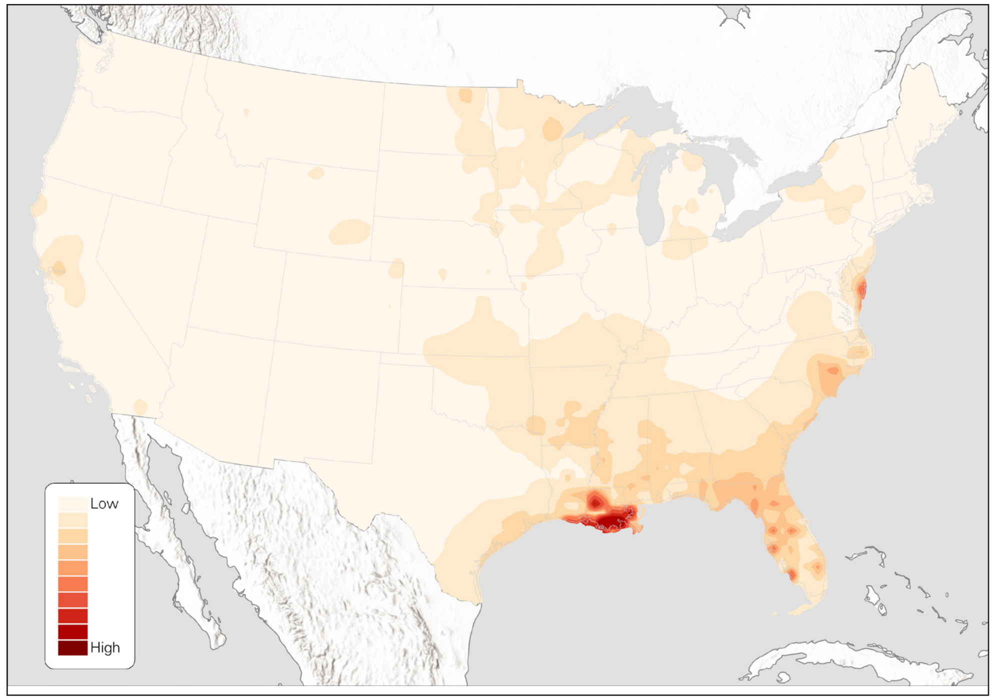


Figure 12. Map showing relative density of net vegetated wetland decrease (loss to upland and deepwater and change to non-vegetated wetlands) in the conterminous United States between 2009 and 2019.

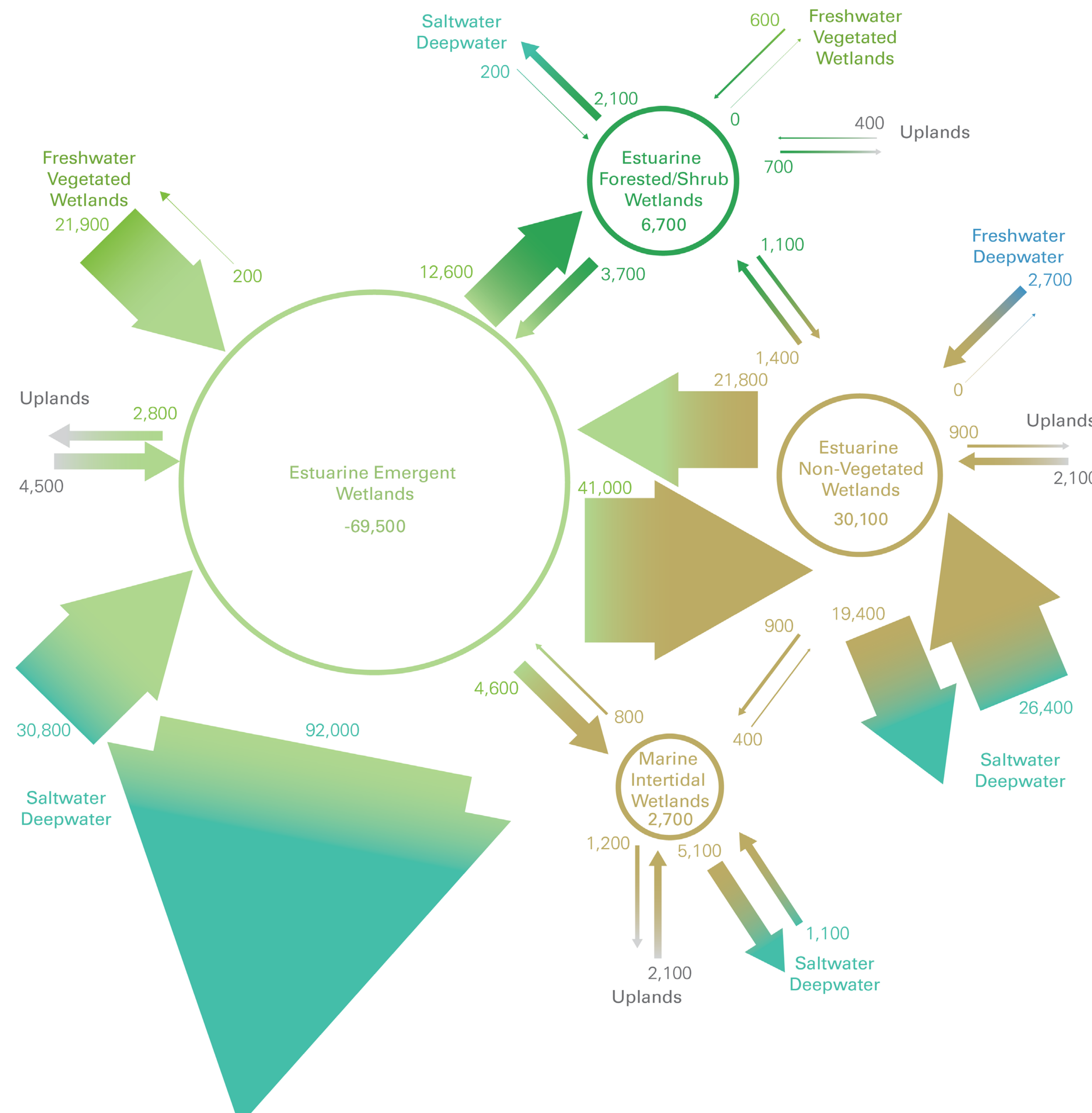
Every year coastal wetlands are estimated to provide over $23B in storm protection[71]. Wetland plants are often used for construction and energy production[2,40], including through the harvest of timber and thatch. Vegetation also enhances water quality by trapping sediment, oxygenating the water column, and reducing the concentration of excess nutrients and other pollutants[3,68].

Vegetated wetlands help to regulate the climate by capturing carbon dioxide from the atmosphere and storing it in plant material and sediment[8,9,68]. The rate at which estuarine and marine vegetated wetlands sequester this “blue carbon” is estimated to be more than ten times greater than the rate at which tropical forests sequester carbon[72]. Estuarine and marine vegetated wetlands have been found to store at least three to five times more carbon than tropical forests[8]. When wetland plants are lost, carbon is often released to the atmosphere, increasing carbon dioxide, a major greenhouse gas[9]. Pendelton et al. (2012)[73] estimated that the current global cost of carbon dioxide emissions associated with mangrove, salt marsh, and seagrass loss is between $6.1 and $42B annually.

Wetland plants provide vital food and habitat for imperiled species (e.g., saltmarsh sparrow and black rail) as well as commercially valuable species, including shrimp, crab, oyster, and salmon[56,68]. Vegetated wetlands make excellent nurseries because plants prevent large predators from reaching young fish and shellfish[74]. The connection between fisheries and vegetated wetlands is so strong that scientists have directly linked fishery yields to vegetated wetland area and yield declines to vegetated wetland area decreases (e.g., shrimp and estuarine marsh)[75,76]. In summary, the presence of vegetation enables a much wider range of important ecosystem functions relative to non-vegetated wetlands.

Although non-vegetated wetlands do not provide the same type and number of functions as vegetated wetlands, many provide important benefits. For example, ponds can improve water quality and reduce flooding[77,65,67]. However, artificial water bodies, including many ponds, often differ from natural features in ways that extend beyond the lack of vegetation. For example, artificial water bodies often differ from natural water bodies in size, shape, distribution, depth, inundation pattern, and other factors[78,79]. Some artificial water bodies have compacted soil, which deters groundwater exchange and reduces water quality benefits. In total, these differences lead to variations in function at the

Figure 13. Net change in saltwater wetland, deepwater, and upland categories between 2009 and 2019 and fluxes between categories. 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 to deepwater and non-vegetated wetlands.



individual and landscape scale that can reduce ecosystem services[64,79] such as water quality benefits[80,78] and habitat for waterbirds and other species[81,78,82].

Because of the relationship between wetland type and ecosystem services, it is critical that change between wetland types be considered along with wetland loss and gain when developing wetland policies and management approaches. Ideally, the loss of one type of wetland would be mitigated with a replacement of the same type of wetland; otherwise, substantial losses of ecosystem services may result even if total wetland area does not decrease. This is especially important when long-term, highly significant shifts between fundamentally different wetland types are evident (e.g., Figures 7 and 9). Conservation and management approaches that are geared only to overall wetland loss will not provide long-term support for the full range of wetland functions and services.

Impacts to Animals and Plants

Substantial long-term net wetland loss paired with a fundamental shift from vegetated to non-vegetated wetlands has affected and is likely to continue to substantially affect plant and animal populations. This was highlighted by a recent State of the Birds report by the North American Bird Conservation Initiative[83], 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). In addition to these rail species, 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 illustrate the strong link between animals and their habitats and emphasize the importance of monitoring change among different wetland types[1].

In addition to birds, species of amphibians, fish, mollusks, crustaceans, and turtles have and will likely continue to experience substantial declines partly due to wetland loss and degradation. For example, 43% of amphibian species populations are declining and nearly a third of the world's amphibian species are threatened with extinction[1]. Within the U.S., 61% of amphibian species are declining[84]. Additionally, half of crayfish and two thirds of freshwater mollusks in the U.S. are at risk of extinction. About 10% of U.S. freshwater mollusks are likely to already be extinct[1].

Wetland loss affects species through various mechanisms, including overall reduction of suitable habitat and habitat fragmentation. When fragmented, habitat can be too small, isolated, or disconnected to maintain plant and animal populations. Habitat fragmentation affects a wide array of organisms, including some migratory species (e.g., anadromous fish) and species with limited dispersal abilities (e.g., plants, aquatic insects, amphibians, and small mammals)[85,51]. The reduction of small prey species can negatively affect wider-ranging species, like raptors[86]. Migratory birds can also be affected when reductions in wetland habitat force individuals into smaller areas, reducing the availability of food and nesting sites and sometimes leading to disease and death[57]. Wetland losses in the Prairie Pothole Region (i.e., a grassland ecoregion that extends across the central United States and Canada) are thought to have reduced populations of wetland-dependent species by half and caused the complete removal of many species from that landscape[47].

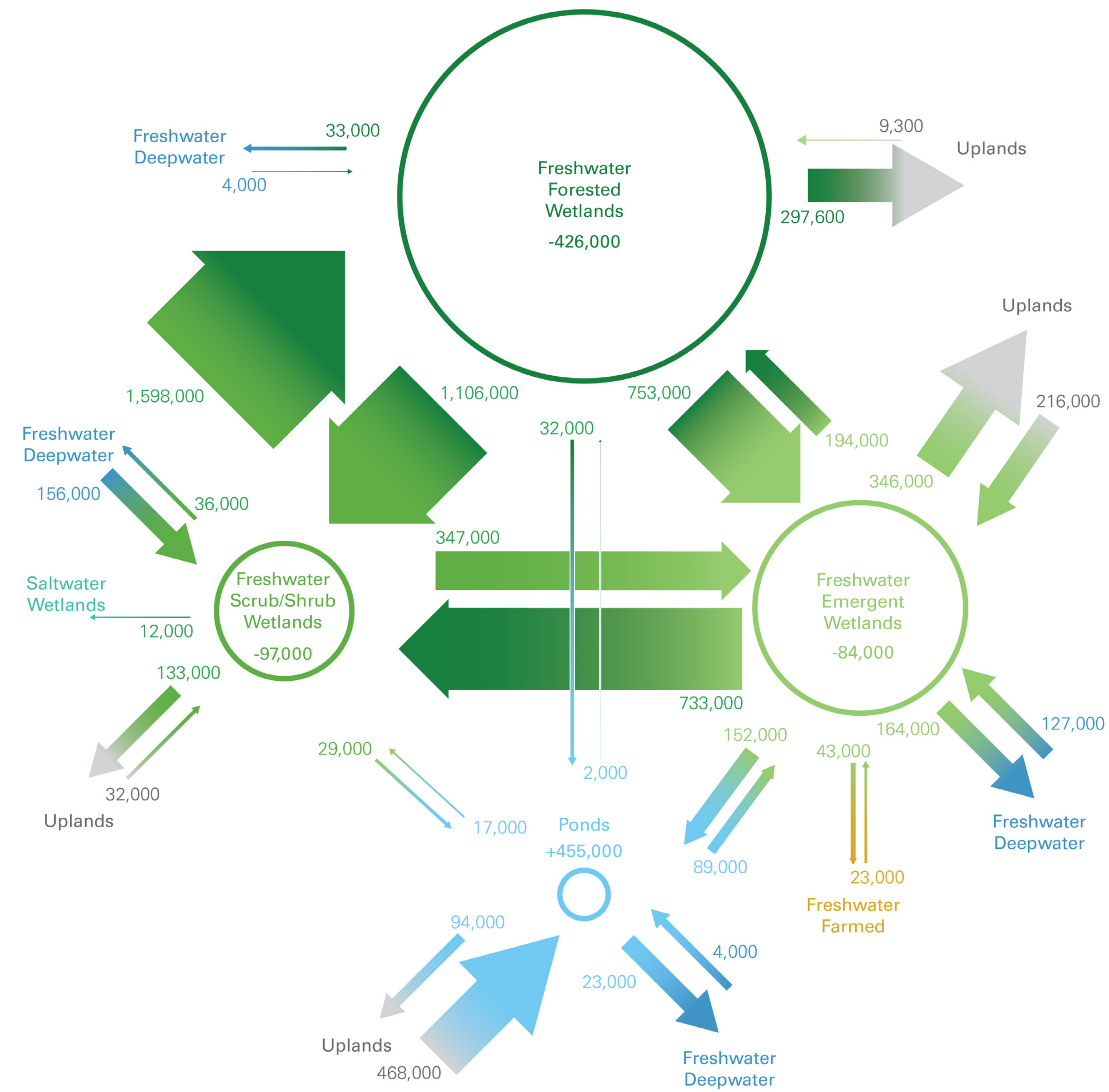
Impacts of the wetland loss and change patterns highlighted by this study will likely be magnified by future climate change[53,47,10,57]. The combined effect could lead to extinction of additional wetland-dependent species, especially those that cannot move through remaining wetland fragments to reach suitable habitat. Climate change impacts are predicted to increase along the coast[39,40], as well as in inland areas like the Prairie Pothole Region where wetlands support 50–80% of North America's duck population[87]. Long-term and often rapid reduction of wetland habitat and a shift towards more non-vegetated wetlands has already resulted in the decline of many wetland-dependent species and is predicted to continue to do so.

Effects of Disturbance

Status and Trends results indicate that the combined effects of wetland loss and disturbance on some ecosystem functions may be much larger than predicted based on wetland loss alone. Even wetlands that remain on the landscape can be substantially altered by disturbance, including harvesting or planting of commodity crops. Wetlands near urban, suburban, and even rural development are often affected by pollutants, changes in water regime, alteration of hydrologic connectivity, changing salinity, and the introduction of invasive species. These factors can lead to declines in important ecosystem services, such as filtering water, protecting people and infrastructure from natural disasters, and maintaining biodiversity[1,32,55,78,9,88].

The magnitude of this disturbance can begin to be approximated by considering gross (instead of net) wetland change and by considering change to other wetland categories instead of solely net loss/gain to upland or deepwater (Figures 13 and 14). For example, almost twice as much freshwater (i.e., palustrine) forested wetland was replaced by freshwater emergent wetland than was lost to upland (559K versus 288K ac [226K versus 117K ha]). Furthermore, total gross wetland changes (e.g., increases and decreases to area caused by loss or gain to upland or deepwater and change to or from other wetland classes) affected 22% of the freshwater scrub/shrub category even though net estimates of change for this category were extremely low (i.e., <1%). These findings likely demonstrate that the magnitude of disturbance due to timber harvest is much higher than might be predicted solely based on

Figure 14. Net change in freshwater wetland, deepwater, and upland categories between 2009 and 2019 and fluxes between categories. Relative size of each category is indicated by the size of the circle. Net acreage change for each category is included within circles and changes between categories are indicated by the size of the arrows and the nearby numbers. Values are acres rounded to the nearest thousands. Note that the largest fluxes are between vegetated wetland categories and that there is net loss of these wetlands to upland.



net wetland loss to upland forested plantation (Figures 14 and 15). Similar conclusions can be drawn when considering the impacts of development and agriculture disturbance.

In addition to direct disturbance (i.e., impacts to the wetland itself), wetland persistence and function over time can be affected by impacts to adjacent areas. These include the hardening of shorelines[89,56], reduction in the quality of incoming water[88,40], change in water levels due to levees, dams, dikes, and water control structures[62,41], groundwater and hydrocarbon withdrawal[10], and reduction of sediment transported by rivers and other waterways[11,10,90].

This mix of direct and indirect disturbance is likely to have cumulative and/or synergistic effects resulting in even greater wetland loss and degradation[53,1]. Status and Trends reports can begin to approximate the effects of disturbance on wetland condition but were not intended specifically for this purpose. The U.S. Environmental Protection Agency documents the effects of human disturbance on wetlands, and recently reported that 80% of wetlands in the conterminous U.S. 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[91].

Accumulation of Impacts over Time

The impacts of wetland loss, gain, and change on the functions and services provided by wetlands are cumulative over space and time and may be difficult to reverse. Recent studies indicate that declines in wetland function associated with loss may be punctuated by tipping points that lead to rapid, potentially difficult to reverse, declines in ecosystem services and the viability of wetland-dependent species[92,1,44,47,57]. Other studies have concluded that the full impact of wetland loss on ecosystem function may not be evident right away. It can take decades, centuries, or longer before restored wetlands function like natural wetlands[93,94,47,95,78,96,97]. In many cases, this equivalency may never be achieved. All these findings indicate that once wetland services are lost, they may never be completely regained.

Figure 15. Aerial imagery of a forested plantation in 2009 (left) and 2019 (right). Examples of tree harvest in wetlands (A) and tree regrowth in uplands (B) are provided. Tree harvest without change in wetland hydrology would alter wetland type. It would not indicate wetland loss.

Mallards take flight at Rainwater Basin Wetland Management District in Nebraska.

The long-term cumulative effect of wetland impacts can be seen in studies concluding that certain types of wetlands may disappear from some regions within the next several decades. For example, under high sea level rise scenarios, all salt marsh is predicted to be lost in California and Oregon by 2100[56]. Globally, between 20–90% of coastal wetlands are predicted to be lost before 2100[39].

Importance of Long-Term Wetland Monitoring

The monitoring of land use and land cover change is an essential[1,98,99] but often under-resourced part of effective natural resource conservation and management[42,100,101]. The type and size of a wetland largely determines its potential to provide human and wildlife benefits, but these benefits and their connection to wetlands may only become apparent at the landscape scale[79]. Thus, by tracking wetland and deepwater area (status) and change (trends) at the landscape scale, Wetlands Status and Trends reports provide metrics by which the effectiveness of environmental policy and management actions can be evaluated. This information allows all Americans to plan for the ecosystem service needs of current and future generations, including needs related to changes in climate, land cover, and population.

To be most effective, monitoring must occur at spatial and temporal scales relevant to policy development and should include the land cover and/or land use categories necessary to understand drivers and implications of change[102]. Wetland change most commonly occurs through small, incremental steps over an extended time[103]. Change often affects small wetlands, which play a disproportionally large role in the delivery of ecosystem services[85,104,105, 67], as well as small portions of larger wetlands[79]. Wetland management (e.g., restoration, cultivation, and drainage) often occurs at the parcel or individual wetland scale[46,64]. Therefore, implementing effective wetland policies requires a long-term monitoring approach (e.g., decades[1]; Figure 5) that is well suited for measuring small changes to specific wetland types. The Service's decadal Wetlands Status and Trends studies meet these requirements by measuring change to 17 different wetland and deepwater classes over a 70-year period using 1 m (1.1 yd) imagery to detect very small changes (e.g., 0.1 ac [0.04 ha]) that could not be reliably detected using Landsat or similar moderate resolution (e.g., 30 m [32.8 yd]) satellite sensors.

Conclusions

Net wetland loss increased substantially (>50%) since the last Wetlands Status and Trends study period (2004–2009), thereby extending a long-term pattern of wetland loss in the conterminous U.S. This loss was coupled with a shift towards fewer vegetated wetlands and decreased woody biomass within remaining vegetated wetlands (e.g., remaining wetlands more likely to be emergent instead of forested). These longstanding patterns have and will continue to result in reductions in ecosystem functions and services. The reduction of these benefits has negatively affected human health, safety, and prosperity, and, if this trend endures, will continue to do so. Populations of fish, wildlife, and plants will also continue to be negatively affected. Because Wetlands Status and Trends reports do not directly assess changes in wetland condition, the patterns of wetland loss, gain, and change documented in these reports are a conservative estimate of the effects of human, climate, and other change drivers on ecosystem services[106]. When the effects of changes in wetland condition are taken into account, even greater losses of wetland functions and services are indicated. These negative impacts will likely be magnified by the effects of future climate change and increasing changes in land use and land cover[38,42,65,39,107].

Net wetland losses decreased substantially after the implementation of a series of broad U.S. wetland policies in the 1970s and ‘80s (Figure 5). However, the U.S. has not achieved the bipartisan “No Net Loss” wetlands goal originally recommended in 1987[31] and adopted by multiple federal administrations, as well as many states. This goal accounts for the inevitability of some wetland loss by focusing on net change (i.e., the balance of losses and gains) in both wetland area and function[108]. Failure to achieve this goal is documented by this Status and Trends report, as well as a wide assemblage of other studies[109,53,110,111,100,64,112]. Although the “No Net Loss” goal was established over 35 years ago, the need to reverse wetland loss trends is even more critical today as society faces a growing number and/or intensity of natural disasters, sea level rise, and the increasing need for clean, abundant fresh water[9,7,64,113].

Measuring the effectiveness of wetland policy and management actions requires the consideration of changes in wetland area and type as well as broader trends in the environment and the needs of people[25,13]. These broader trends include increasing human populations, especially in wetland-dense and natural disaster-vulnerable locations like coastal watersheds, as well as the effects of climate and land use and land cover change[47,114]. The growing demand for wetland benefits paired with the decreased capacity of wetlands to provide them highlights the need for additional proactive solutions to reverse the persistent and accelerating national trend of wetland loss.

Shiras moose bull at Seedskadee National Wildlife Refuge in Wyoming. Photo by Tom Koerner, USFWS.

Recommendation

To achieve no net loss of all wetlands, including vegetated wetlands, a strategic update is needed to America’s approach to wetland conservation. This update should address foundational wetland policy and management gaps that have been identified by numerous researchers and organizations[25,115,116,117,118,13,101,64,113], including the need for: 1) more effective coordination and leveraging within and across governance levels and 2) enhanced scientific information that meets policy and management requirements. These gaps can be addressed by implementing the strategies described below. Implementing these strategies would support Executive Order 11990 (Protection of Wetlands) and enable the evidenced-based policy analysis and strategic implementation necessary to conserve America’s remaining wetlands.

Strategy 1: Achieve “No Net Loss” of wetlands and robust coordination with government and non-governmental partners to achieve this goal.

Wetland conservation depends on an inter-related array of federal, Tribal, state, and local policies and management actions that are implemented across public and private lands. Although past federal policies (e.g., Executive Order 11990) mandated that individual agencies take action to minimize wetland loss and degradation, and ad hoc groups, like the Interagency Coastal Wetlands Workgroup[119], endeavor to reduce wetland losses in some geographies, holistic national coordination towards achieving no net loss is not currently mandated nor is it occurring. An important first step towards enhanced coordination would be to establish the requirement to work effectively across and within government levels to achieve no net loss of wetlands, with an emphasis on vegetated wetlands. Establishing this requirement would facilitate the creation of related governance structures and dedication of requisite staff time, the lack of which has hampered wetland conservation efforts in the past. However, meaningful progress will also depend on sufficient resources and mechanisms to share or pool resources once collaborative actions are identified. Endter-Wada et al. (2020)[13] suggest that creating a governance structure like a national wetland commission with the requisite autonomy, authority, incentives, resources, and connections to existing stakeholder groups would facilitate more effective wetland conservation. Enhanced coordination is needed not only across multiple agencies/levels of government, but also with the private sector and individuals.

Coordination is often hampered not only by the challenge of working between and within levels of government but also by the complex suite of authorities and regulations that influence wetland conservation[101,113]. Many authorities provide a mechanism through which wetlands and their benefits can be conserved, but these authorities are often focused on different outcomes (e.g., water quality, water supply, and habitat) and geographies (e.g., federal properties, states, or regions like the Chesapeake Bay or Great Lakes Watersheds). The importance of fully understanding these disparate mechanisms (see Strategy 3 below) as well as enhanced coordination will become even more critical as the drivers of wetland loss become increasingly more complex[38].

Strategy 2: Produce a contemporary NWI Geospatial Dataset and spatially explicit information on wetland function.

Strategic planning and coordination are required to reverse longstanding wetland loss trends within the conterminous U.S. A prerequisite for this planning is a contemporary wetlands geospatial dataset[120,113]. The strategic conservation decision-making that will be required to achieve no net loss of wetlands is dependent on knowing the location, abundance, and type of America’s wetlands. This information is the foundation of national analyses and decision-support tools. The geospatial dataset should be interoperable with other components of the U.S. National Spatial Data Infrastructure (e.g., 3D Hydrography Program datasets) to enable effective modeling of wetland functions and services within the context of the broader landscape and the needs of people. Information must be provided at a spatial resolution that is relevant to national planning and funding efforts as well as to parcel scale implementation[46,64,113].

The necessary information is provided by the Service’s NWI Geospatial Dataset, but to fully meet this need it should be updated in some geographies[121]. In addition to its operational spatial scale, the NWI dataset provides highly detailed information on wetland type, which is critical for assessing wetland functions and ecosystem services[32,102,41,113]. Information on wetland functions and services is increasingly being sought by government and non-governmental organizations[113] and the NWI Geospatial Dataset is routinely used to help provide this information[122]. However, national landscape scale functional assessment standards and the resources to enhance and host wetland functional data are needed before the information can be most effectively used. Standards provide consistent workflows and specifications which help to ensure that data meet the needs of a larger community and are FAIR – findable, accessible, interoperable, and reusable – in accordance with the Geospatial Data Act of 2018.

Strategy 3: Develop and implement enhanced wetland conservation and management approaches based on a holistic review of current and past actions.

A key task for the coordination group described in Strategy 1 (above) will be to develop and implement more effective conservation and management approaches to meet the goal of no net loss of wetlands. Doing this will necessitate an understanding of the effectiveness of current and past authorities, regulations, programs, and other actions relative to the "No Net Loss" goal as well as future requirements. Building understanding will require an unsparing evaluation of wetland conservation approaches, their outcomes, and why those outcomes occurred. This could be accomplished by bringing together experts from a wide range of disciplines and focus areas in a process similar to the way reviews are conducted by the National Academy of Science. In addition to driving strategic development of enhanced approaches, the information would serve to more fully leverage the contemporary geospatial inventory of wetlands referenced in Strategy 2 (above) within an adaptive management framework and more fully enable the development of landscape scale

Tom Koerner /USFWS

The Sand Lake Wetlands Management District in South Dakota. This area includes the Sand Lake National Willdife Refuge and supports some of the highest concentrations of nesting waterfowl in North America.

decision-support tools. Only by understanding why the "No Net Loss" goal has not been met can new conservation approaches be developed that will achieve the goal.

Strategy 4: Commit to long-term adaptive conservation, management, and monitoring.

Addressing America's wetland conservation needs requires a long-term commitment to adaptive conservation, management, and monitoring. The U.S. has been working to address net wetland loss for over half a century and yet the consequences of continuing wetland losses are increasingly affecting our communities through increased susceptibility to natural disasters, poor water quality, and failing infrastructure. Current conservation policies have not met their goals, including no net loss, and predicted environmental change will make this even more difficult. These challenges highlight the need for not only long-term resolve but also commitment to improving our approaches over time through the adaptive management process[25]. Data provided by the Wetlands Status and Trends study are foundational to this process because they measure progress towards achieving conservation goals. It is recommended that the coordination group described in Strategy 1 (above) use future Wetlands Status and Trends studies along with other scientific findings to evaluate and reconsider policies and management approaches in light of current trends.

Looking Forward

New approaches are needed to conserve and restore our Nation's wetlands. Foundational strategies to develop these approaches are outlined in the preceding Recommendation Section. The need is especially urgent today because most wetlands in the conterminous U.S. have already been lost, wetland loss has recently accelerated, and future declines will likely be magnified by the effects of climate change as well as land use and land cover change. Scientific information, like this report, is foundational to the strategic implementation of all natural resource policy actions and will be critical to success. The Service will continue to work with all partners to conserve and restore wetlands, in part by producing Wetlands Status and Trends reports to Congress as mandated by the Emergency Wetlands Resources Act (Public Law 99-645). Achieving no net loss of all wetlands, especially vegetated wetlands, will require a collaborative approach that includes Tribal, state, local, and private partners to ensure the lasting health of America's people, environment, and economy.

View of Beaver Pond at Aroostook National Wildlife Refuge in Maine.

Keith Ramos/USFWS

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Appendix A: Data Matrix

Rows identify the 2019 classification. Columns identify the 2009 classification. Percent coefficients of variation for estimates appear below the acreage entry. An example of how to interpret this matrix is as follows: 88,757 acres of estuarine emergent wetland in 2009 are estimated to have changed to estuarine subtidal wetland in 2019.

2019 Classification, Estimated Acreage, and Percent Coefficient of Variation		2009 Classification, Estimated Acreage, and Percent Coeficient of Variation																							
		Saltwater Wetland Habitats						Freshwater Wetland Habitats									Deepwater Habitats		Uplands						
		Marine Intertidal	Marine Subtidal	Estuarine Subtidal	Estuarine Emergent	Estuarine Forested Shrub	Estuarine Unconsolidated Shore	Palustrine Farmed	Palustrine Forested	Palustrine Shrub	Palustrine Emergent	Aquaculture Ponds	Agriculture Ponds	Industrial Ponds	Natural Ponds	Urban Ponds	Lacustrine	Riverine	Agriculture	Urban	Other	Forested Plantation	Rural Development	Acreage Totals, 2019	
Saltwater Wetland Habitats	Marine Intertidal	198,925 14	1,304 49	965 41	4,591 39	35 59	928 52	0 -	0 -	144 95	32 77	0 -	0 -	6 95	6 95	0 -	0 -	86 99	0 1	4 96	2,061 25	0 -	6 95	209,092 14	Marine Intertidal
	Marine Subtidal	4,952 36	2,364,418 12	6,370 47	3,197 46	238 71	3,354 47	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	2,043 -	0 -	0 -	2,384,572 12	Marine Subtidal
	Estuarine Subtidal	99 95	0 -	19,920,823 2	88,757 9	1,886 35	15,996 16	25 98	361 69	990 56	2,028 50	0 -	10 71	73 89	208 60	16 70	0 -	422 95	2,117 92	739 72	8,012 38	1 96	127 30	20,042,689 2	Estuarine Subtidal
	Estuarine Emergent	775 70	139 95	30,689 17	3,916,862 6	3,719 23	21,821 19	0 -	5,554 67	11,166 67	4,956 57	0 -	0 -	97 95	46 65	0 -	0 -	0 -	108 73	41 55	4,196 50	179 79	5 70	4,000,354 6	Estuarine Emergent
	Estuarine Forested Shrub	0 -	0 -	163 57	12,560 59	801,535 12	1,144 38	11 98	273 64	257 72	37 98	0 -	0 -	0 -	0 -	0 -	0 -	0 -	8 98	2 95	259 48	76 99	0 -	816,325 12	Estuarine Forested Shrub
	Estuarine Unconsolidated Shore	356 57	680 95	25,722 37	40,993 15	1,437 72	960,643 12	0 -	66 65	225 50	146 51	0 -	0 -	0 -	6 96	6 93	34 99	2,619 99	48 45	37 95	1,971 18	0 -	29 62	1,035,018 11	Estuarine Unconsolidated Shore
Freshwater Wetland Habitats	Palustrine Farmed	0 -	0 -	0 -	0 -	0 -	0 -	1,901,388 25	5,858 46	5,869 39	43,310 46	1,910 99	1,027 58	0 -	3,152 77	0 -	0 -	0 -	9,771 25	0 -	0 -	616 100	0 -	1,972,899 24	Palustrine Farmed
	Palustrine Forested	0 -	0 -	0 -	34 59	31 72	84 93	219 95	50,620,791 3	1,597,662 9	194,084 13	0 -	182 54	0 -	1,564 38	0 -	85 76	4,201 36	1,099 58	0 -	5,918 35	2,263 49	0 -	52,428,216 3	Palustrine Forested
	Palustrine Shrub	0 -	0 -	0 -	19 95	0 -	98 99	22,007 37	1,106,145 10	17,025,715 5	732,905 9	791 88	3,262 26	959 77	11,191 47	522 63	74,114 87	81,554 60	10,285 44	6 98	18,894 41	1,411 48	989 71	19,090,867 5	Palustrine Shrub
	Palustrine Emergent	46 99	0 -	806 78	92 62	0 -	0 -	22,859 22	752,924 9	346,965 16	28,452,497 8	739 60	28,867 14	5,967 46	50,807 15	2,728 25	99,032 26	27,877 36	98,831 31	1,218 50	103,210 32	5,950 39	6,787 70	30,008,202 8	Palustrine Emergent
	Aquaculture Ponds	0 -	0 -	0 -	0 -	0 -	0 -	0 -	10 98	521 99	1,152 49	141,925 31	0 -	0 -	0 -	0 -	0 -	0 -	4,380 77	0 -	5,860 100	0 -	0 -	153,848 31	Aquaculture Ponds
	Agriculture Ponds	0 -	0 -	0 -	0 -	19 98	0 -	903 62	15,111 26	6,305 24	53,999 24	0 -	2,976,442 4	37 98	419 57	0 -	171 95	0 -	169,416 15	384 60	68,208 13	14,604 20	4,149 32	3,310,166 4	Agriculture Ponds
	Industrial Ponds	0 -	0 -	0 -	5 95	0 -	0 -	0 -	811 31	3,412 48	4,186 29	0 -	212 56	339,463 12	2,020 95	0 -	993 98	0 -	35,213 28	4,061 57	25,212 30	2,392 30	17,169 35	435,149 11	Industrial Ponds
	Natural Ponds	0 -	0 -	21 69	0 -	0 -	0 -	114 72	10,624 19	17,320 17	84,979 20	0 -	232 76	0 -	1,742,364 7	30 98	2,481 38	529 85	7,356 53	2,674 98	16,465 38	1,501 35	952 79	1,887,643 6	Natural Ponds
	Urban Ponds	0 -	0 -	0 -	0 -	4 97	0 -	0 -	5,076 35	1,883 24	8,117 24	23 98	271 91	1,709 98	301 64	984,114 7	13 98	0 -	23,440 16	14,003 15	31,239 28	6,918 33	12,141 18	1,089,251 6	Urban Ponds
Deepwater Habitats	Lacustrine	0 -	0 -	0 -	0 -	0 -	0 -	2,438 92	20,663 33	10,867 36	144,875 29	0 -	759 55	4,740 47	14,975 31	2,134 84	16,879,673 10	31 84	50,156 40	3,585 97	74,535 63	4,880 92	12,609 77	17,226,919 10	Lacustrine
	Riverine	57 99	0 -	0 -	19 98	0 -	28 99	0 -	12,382 25	25,521 73	19,002 54	0 -	10 98	0 -	217 80	456 98	1,535 63	7,305,361 9	23,970 50	760 92	12,848 35	128 108	195 74	7,402,490 9	Riverine
Uplands	Agriculture	0 -	0 -	0 -	92 96	211 98	0 -	59,968 17	54,209 20	36,643 18	230,577 14	13,254 52	36,210 16	1,312 78	1,724 36	3,552 51	3,965 66	611 100						560,419,993 3	Agriculture
	Urban	78 95	0 -	185 54	539 71	33 57	256 65	0 -	25,595 31	11,943 36	27,410 44	259 98	1,897 49	2,132 50	375 83	1,868 36	346 69	41 99						51,402,787 7	Urban
	Other	1,118 46	27 95	830 34	2,050 31	454 38	575 40	1,574 83	109,089 15	40,070 26	64,640 18	0 -	5,720 31	5,626 64	8,595 53	925 31	5,955 61	11,896 89						1,056,911,706 2	Other
	Forested Plantation	0 -	0 -	0 -	0 -	0 -	0 -	237 98	66,964 21	36,551 36	13,336 28	0 -	1,005 71	0 -	269 42	276 89	0 -	0 -						80,910,601 6	Forested Plantation
	Rural Development	0 -	0 -	4 60	71 59	14 79	10 69	728 57	41,718 32	7,388 21	10,152 23	35 98	879 33	5,517 45	438 61	2,017 31	9 95	29 95						33,114,591 8	Rural Development
	Acreage Totals, 2009	206,407 14	2,366,568 12	19,986,578 2	4,069,881 6	809,615 12	1,004,937 12	2,012,471 23	52,854,225 3	19,187,416 5	30,092,420 8	158,935 31	3,056,985 4	367,638 12	1,838,677 6	998,644 7	17,068,407 10	7,435,258 8	562,228,618 3	50,759,989 7	1,058,447,653 2	79,136,799 6	32,165,258 8		

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