Science and Policy of U.S. Wetlands

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I. INTRODUCTION

Wetlands are dynamic areas between land and water that vary in frequency and duration of flooding. Wetlands may be the interface between land and lakes or rivers, or they may be the interface between land and estuaries or sea. Wetlands also occur at areas in the landscape

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where groundwater emerges from the earth. Comprising only 5-8% of the earth's surface, wetlands perform important and unique ecological functions (e.g., finfish and shellfish habitats and nutrient cycling).[1]

The ecological processes that wetlands perform often provide environmental values that are important to help us maintain our quality of life (e.g., sediment sequestering and nutrient recycling that lead to improved water quality, providing space to store water, and abating flooding).[2] Unfortunately, it is only in the last half of the twentieth century that we as a society began to recognize the importance of these wetland systems. Prior to the 1960s, wetlands were considered to be disease-ridden wastelands and were filled and drained at an alarming rate.[3] To date, nearly half of all of the wetlands in the conterminous United States, along with most of their functions and values, have been destroyed.[4]

This Article discusses the importance of wetlands, their ecological functions, the history of wetland losses, and protective legislation in the United States. Despite the existence of wetland protection laws and policies, the cumulative effect of many development activities has degraded and reduced the productivity of these systems, as demonstrated through case study discussions about the Mississippi Delta wetlands and the Everglades. In light of the expense and uncertainty concerning efforts to restore wetlands, this Article concludes with a recommendation for a renewed emphasis on avoiding wetland impacts in the first instance.

II. IMPORTANCE OF WETLANDS

The physical, chemical, and biological processes that occur within a wetland are the *functions* of a wetland. When humans find these functions useful to society, we ascribe a *value* to the function and the benefit it brings, which has become known as an "ecosystem service." Distinction between functions and values (ecosystem services), therefore, becomes blurred because it is humans who make the distinction and also because the benefit may be indirect, thus making it difficult to evaluate. The existence of even limited wetland protection under the Federal Clean Water Act of 1972 is recognition of humankind's valuation of wetland

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1. JAMES S. ABER, FIROOZA PAVRI & SUSAN WARD ABER, WETLAND ENVIRONMENTS: A GLOBAL PERSPECTIVE 4-5 (2012); WILLIAM J. MITSCH & JAMES G. GOSSELINK, WETLANDS 4 (2d ed. 1993).
2. MITSCH & GOSSELINK, *supra* note 1, at 4.
3. RALPH W. TINER, JR., U.S. DEP'T INTERIOR & U.S. FISH & WILDLIFE SERV., WETLANDS OF THE UNITED STATES: CURRENT STATUS AND RECENT TRENDS 1 (1984).
4. *See* Carol A. Johnston, *Cumulative Impacts to Wetlands*, 14 WETLANDS 50 (1994).

functions. Because the systems are rarely sold and do not hold a "market value," many techniques have been adapted to place an economic valuation on ecosystem services.[5] Some societies base their existence on wetland ecosystems,[6] while parts of other societies simply value knowing that such a system exists.[7]

Wetlands contain plants that have adapted to extreme conditions (such as prolonged inundation and lack of oxygen), soils that reflect some degree of flooding, and water presence at or near the surface for some period of time.[8] The stage, frequency, and duration of flooding hold a critical influence on a wetland system's ecology; it is so important that a number of wetland classification systems are based on the flooding regime.[9] Soils assume properties characteristic of the oxygen-poor environment. Some plants are found only in wetlands, and the appearance/absence of specific species can key the keen observer into environmental conditions at times other than during the observation.[10] The interplay between plants, water, and soils (including the microorganisms in the soils) brings about a unique ecosystem. The presence of water creates oxygen-poor conditions, and these anoxic conditions form an environment where certain physical, chemical, and biological processes occur.[11] The processes are so unique, in fact, that wetlands can be considered more than simply transitional areas; they are ecosystems unto themselves with unique biological, chemical, and physical processes beneficial to both nature and humans. The benefits that humankind values from wetland ecosystems can be considered within the broad general categories of water quality (such as sediment

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5. Peter Feather, Daniel Hellerstein & LeRoy Hansen, *Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP*, 1999 U.S. DEP'T AGRIC. ECON. REPORT NO. 778, at 8-19 (1999) (citing Marc O. Ribaudo & Daniel Hellerstein, *Estimating Water Quality Benefits: Theoretical and Methodological Issues*, 1992 U.S. DEP'T AGRIC. TECH. BULL. NO. 1808, at 7); EDWARD B. BARBIER, MIKE ACREMAN & DUNCAN KNOWLER, RAMSAR CONVENTION BUREAU, ECONOMIC VALUATION OF WETLANDS: A GUIDE FOR POLICY MAKERS AND PLANNERS 22-46 (1997) (citing INTERPRETING THE PRECAUTIONARY PRINCIPLE (Timothy O'Riordan & James Cameron eds., 1994); Clem Tisdell, *Economics and the Debate About Preservation of Species, Crop Varieties and Genetic Diversity*, 2 ECOLOGICAL ECONS. 77, 77-90 (1990)); ROBERT COSTANZA, JOHN CUMBERLAND, HERMAN DALY, ROBERT GOODLAND & RICHARD NORGAARD, AN INTRODUCTION TO ECOLOGICAL ECONOMICS 142-43 (1997); ANGUS DEATON & JOHN MUELLBAUER, ECONOMICS AND CONSUMER BEHAVIOR 184 (1980)).

6. *See* KIRSTEN SCHUYT & LUKE BRANDER, WORLD WILDLIFE FUND, THE ECONOMIC VALUES OF THE WORLD'S WETLANDS 9 (2004).

7. *Id.* at 10.

8. MITSCH & GOSSELINK, *supra* note 1, at 22.

9. *Id.* at 24.

10. *Id.* at 23.

11. *Id.* at 17.

and chemical sequestering and recycling), hydrology, and habitat (floral, faunal, and microbial).[12] Following is a discussion of some of the ecological functions that contribute to each of those three values.

A. *Water Quality*

Many researchers have noted improved water quality in watersheds containing wetlands.[13] Much of the water quality benefit is a result of biogeochemical processes that allow wetlands to act as sinks or transformers of nutrients, toxins, metals, and suspended inorganic sediments,[14] whether those substances enter the wetland from the land as runoff or from the stream/river/estuary water as overbank flow or tides. Soils with high clay and organic material constituents (leading to greater cation exchange capacity, CEC) and frequent periods of anoxia are likely the most effective at transforming and holding chemical compounds.[15] The efficiency of processing these substances is also driven by the volume and rate of contaminant application, as well as water permanence and appropriate surfaces for microbial activity.[16] The efficiency declines

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12. *Id.* at 4, 23 (citation omitted).

13. *See* Naomi E. Detenbeck, Carol A. Johnston & Gerald J. Niemi, *Wetland Effects on Lake Water Quality in the Minneapolis/St. Paul Metropolitan Area*, 8 LANDSCAPE ECOLOGY 39, 40-41 (1993); Carol A. Johnston, Naomi E. Detenbeck & Gerald J. Niemi, *The Cumulative Effect of Wetlands on Stream Water Quality and Quantity: A Landscape Approach*, 10 BIOGEOCHEMISTRY 105, 136 (1990); John M. Marton, M. Siobhan Fennessy & Christopher B. Craft, *USDA Conservation Practices Increase Carbon Storage and Water Quality Improvement Functions: An Example from Ohio*, 22 RESTORATION ECOLOGY 117, 123 (2014); Dennis F. Whigham, Carin Chitterling & Brian Palmer, *Impacts of Freshwater Wetlands on Water Quality: A Landscape Perspective*, 12 ENVTL. MGMT. 663, 663 (1988) (citing John R. Kelly & Mark A. Harwell, *Comparisons of the Processing of Elements by Ecosystems, I: Nutrients*, *in* ECOLOGICAL CONSIDERATIONS IN WETLANDS TREATMENT OF MUNICIPAL WASTEWATERS 137, 137-57 (Paul J. Godfrey et al. eds., 1985).

14. PAUL R. ADAMUS ET AL., WETLANDS RESEARCH PROGRAM TECHNICAL REP. WRP-DE-2, 1 WETLAND EVALUATION TECHNIQUE (WET): LITERATURE REVIEW AND EVALUATION RATIONALE 25-30 (Oct. 1991), http://www.dtic.mil/dtic/tr/fulltext/u2/a259108.pdf (citing Parker James Wigington, Jr., C.W. Randall & T.J. Gizzard, *Accumulation of Selected Trace Metals in Soils of Urban Runoff Swale Drains*, 22 WATER RESOURCES BULL. 73, 73-79 (1986)); *see* SCOTT G. LEIBOWITZ, U.S. ENVTL. PROT. AGENCY, A SYNOPTIC APPROACH TO CUMULATIVE IMPACT ASSESSMENT: A PROPOSED METHODOLOGY 78 (Scott G. McCannell & Ann R. Hairston eds., 1992); K. RAMESH REDDY & RONALD D. DELAUNE, BIOGEOCHEMISTRY OF WETLANDS: SCIENCE AND APPLICATIONS 1-2 (2008).

15. REDDY & DELAUNE, *supra* note 14, at 288, 293.

16. *See* J. Fisher & M.C. Acreman, *Wetland Nutrient Removal: A Review of the Evidence*, 8 HYDROLOGY & EARTH SYS. SCIS. 673, 680-81 (2004); C.J. Woltemade, *Ability of Restored Wetlands to Reduce Nitrogen and Phosphorus Concentrations in Agricultural Drainage Water*, 55 J. SOIL & WATER CONSERVATION 303, 306-07 (2000) (citing Mats Jansson et al., *Wetlands and Lakes as Nitrogen Traps*, 23 AMBIO 320, 320-25 (1994); Arnold G. van der Valk & Robert W. Jolly, *Recommendations for Research To Develop Guidelines for the Use of Wetlands To Control Rural Nonpoint Source Pollution*, 1 ECOLOGICAL ENG'G 115, 115-34 (1992)).

with channelization.[17] Two functions that contribute to improved water quality are the ability to capture sediments or other particulates (e.g., detritus) as they move across the landscape and the chemical reactions that take place within a wetland.

1. Particulate Removal/Sediment Deposition

Deposition of sediments or other particulates can be examined as either a hydrological or water quality function. The gentle slope and the presence of vegetation in many wetlands slow water movement and decrease the water's ability to hold sediment after precipitation, overbank flooding, or tidal events.[18] Therefore, sediment and organic debris drop onto the soil surface and prevent, in part, the sediment and debris from entering or returning to the water column.[19] We will treat the deposition—and thus the absence of particulates or sediments in the water—within the water quality function here.

Wetlands adjacent to the upstream reaches of rivers and streams where water in the channel is intermittent (often termed headwater wetlands) are especially important in capturing materials before they reach the water column.[20] More than half of the stream length for a given watershed is usually contributed to by headwater wetlands.[21] Wetlands immediately downslope of areas that contribute nonpoint-source pollution are especially valuable because of their ability to remove particulates, such as those that are found in areas with high agricultural use.[22] However, the width of the wetland buffer may affect the relative ability of these wetlands to filter sediments and particulates.[23] Pesticide and fertilizer (including animal waste) application, as well as road construction, increase the concentration of nutrients, toxins, pollutants,

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17. *See* D.E. Hammer & R.H. Kadlec, *A Model for Wetland Surface Water Dynamics*, 22 WATER RESOURCES RES. 1951, 1952 (1986).

18. ROBERT G. WETZEL, *Wetland Ecosystem Processes*, *in* ECOLOGY OF FRESHWATER & ESTUARINE WETLANDS 285, 285 (Darold P. Batzer & Rebecca R. Sharitz eds., 2006).

19. *Id.* at 286.

20. *See* J.R. Cooper et al., *Riparian Areas as Filters for Agricultural Sediment*, 51 SOIL SCI. SOC'Y AM. J. 416, 419 (1987); Jonathan D. Phillips, *Nonpoint Source Pollution Risk Assessment in a Watershed Context*, 13 ENVTL. MGMT. 493, 499-500 (1989); Whigham, Chitterling & Palmer, *supra* note 13, at 665-66.

21. LUNA B. LEOPOLD, M. GORDON WOLMAN & JOHN P. MILLER, FLUVIAL PROCESSES IN GEOMORPHOLOGY 142 (1964); Mark M. Brinson, *Changes in the Functioning of Wetlands Along Environmental Gradients*, 13 WETLANDS 65, 66-68 (1993).

22. Cooper et al., *supra* note 20, at 420; *see* R. Richard Lowrance, Robert L. Todd & Loris E. Asmussen, *Waterborne Nutrient Budgets for the Riparian Zone of an Agricultural Watershed*, 10 AGRIC., ECOSYSTEMS & ENV'T 371, 377 (1983); Phillips, *supra* note 20.

23. Jonathan D. Phillips, *Nonpoint Source Pollution Control Effectiveness of Riparian Forests Along a Coastal Plain River*, 110 J. HYDROLOGY 221, 230-36 (1989).

and bacteria in surface and groundwater runoff.[24] Land development and urbanization also can increase the amount of sedimentation and nutrient loading into the adjacent wetlands.[25] Wetlands adjacent to large stream systems also capture sediments and transform nutrients and pollutants.[26] These wetlands, however, are positioned to remove nutrients or pollutants from the water overflowing the banks onto the wetlands rather than overland flow.[27] Coastal wetlands may have the added function of filtering waters from the tidal waters of estuaries and seas.[28] Research demonstrates that in areas with sediment, particulate, or pollution inputs, watersheds with high wetland land cover have better water quality than in places with low wetland land cover.[29]

Human activity—such as agricultural clearing and irrigation, logging, or urban development—sends pulses of sediment through a watershed; wetlands capture and accumulate much of the particulate material before arrival in the waterway and resulting water quality degradation.[30] This trapping and accumulation of particulates improves the quality of adjacent waters. Also, the vertical elevation determined by such deposition controls the microtopography, which can determine which plants are suitable to live in that environment.[31] Sediment deposition occurs in wetlands across all areas of the landscape; it is in the coastal area, however, where deposition is of critical importance to

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24. L.W. Canter, *Nitrates and Pesticides in Ground Water: An Analysis of a Computer-Based Literature Search*, *in* GROUND WATER QUALITY AND AGRICULTURAL PRACTICES 153, 157 (Deborah M. Fairchild ed., 1987); T.C. Daniel et al., *Nonpoint Source Loading Rates from Selected Land Uses*, 18 WATER RESOURCES BULL. 117, 117 (1982).

25. *See* Canter, *supra* note 24, at 157.

26. Brinson, *supra* note 21, at 65-68.

27. *Id.* at 70-71.

28. *See generally* Kenneth A. Krieger, *Effectiveness of a Coastal Wetland in Reducing Pollution of a Laurentian Great Lake: Hydrology, Sediment, and Nutrients*, 23 WETLANDS 778 (2003).

29. Johnston, *supra* note 4, at 52-53 (discussing several studies on the relationship between loss of wetlands and watershed floodflow); TIFFANY WRIGHT ET AL., U.S. ENVTL. PROT. AGENCY, DIRECT AND INDIRECT IMPACTS OF URBANIZATION ON WETLAND QUALITY: WETLANDS & WATERSHEDS ART NO. 1, at i (2006).

30. *See generally* Michael G. Dosskey et al., *The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams*, 46 J. AM. WATER RESOURCES ASS'N 261 (2010).

31. Charles A. Simenstad & Ronald M. Thom, *Functional Equivalency Trajectories of the Restored Gog-Le-Hi-Te Estuarine Wetland*, 6 ECOLOGICAL APPLICATIONS 38, 53 (1996) (citing C.B. Craft, S.W. Broome & E.D. Seneca, *Nitrogen, Phosphorus and Organic Carbon Pools in Natural and Transplanted Marsh Soils*, 11 ESTUARIES 272 (1988); René Langis, Malgorzata Zalejko & Joy B. Zedler, *Nitrogen Assessments in a Constructed and a Natural Salt Marsh of San Diego Bay*, 1 ECOLOGICAL APPLICATIONS 40 (1991)); C. W. Lindau & L.R. Hossner, *Substrate Characterization of an Experimental Marsh and Three Natural Marshes*, 45 SOIL SCI. SOC'Y AM. J. 1171 (1981)).

maintain wetland areas.[32] Deposition allows tidal marshes to maintain their elevation as sea level rises; in times of falling sea level, the water would no longer bring sediment to the wetland surface, and deposition would cease.[33] Recent modeling results suggest that sedimentation rates were at their highest during times of mass deforestation following European settlement of New England.[34] The high sediment influx during that period facilitated the formation of large expanses of tidal marshes that could not initially form under rates found today, although maintenance is supported by current sedimentation rates.[35] In tidal marshes, both mineral sedimentation and organic matter accumulation from slowly decaying plants are important in keeping vertical balance with rising seas.[36] Tidal freshwater marshes contain higher mineral content than salt marshes; however, the organic matter in the freshwater marshes is responsible for a relatively greater proportion of the vertical accumulation because of its high porosity.[37]

2. Nutrient Cycling and Detrital Processes

The fluctuation between oxygen-rich (oxic) and anoxic conditions in wetlands facilitates many microbially mediated chemical reactions.[38] The presence of water in a wetland delays decomposition; in addition to high surface area afforded by multiple vertical strata of vegetation in these moist environments, microbiological activity (including that of algae (periphyton)) is enhanced.[39] Because they have the widest range of chemical reactions dependent upon the amount of oxygen present, wetlands play a critical role in the form of nitrogen (N) available at a broad scale.[40] Microbially mediated conversion of N in its many forms

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32. *See id.*

33. James T. Morris et al., *Responses of Coastal Wetlands to Rising Sea Level*, 83 ECOLOGY 2869, 2869 (2002).

34. Matthew L. Kirwan et al., *Rapid Wetland Expansion During European Settlement and Its Implication for Marsh Survival Under Modern Sediment Delivery Rates*, 39 GEOLOGY 507, 507 (2011) (citing Stanley W. Trimble, *The Fallacy of Stream Equilibrium in Contemporary Denudation Studies*, 277 AM. J. SCI. 876 (1977).

35. *Id.* at 509-10.

36. S. Bricker-Urso et al., *Accretion Rates and Sediment Accumulation in Rhode Island Salt Marshes*, 12 ESTUARIES 300, 315 (1989); Carl T. Friedrichs & James E. Perry, *Tidal Salt Marsh Morphodynamics: A Synthesis*, 27 J. COASTAL RES. (SPECIAL ISSUE) 7, 7 (2001); Morris et al., *supra* note 33, at 2872.

37. *See* Scott C. Neubauer, *Contributions of Mineral and Organic Components to Tidal Freshwater Marsh Accretion*, 78 ESTUARINE, COASTAL & SHELF SCI. 78, 82-83 (2008).

38. *See* WETZEL, *supra* note 18, at 286-302.

39. *See id.*

40. Stephen P. Faulkner & Curtis J. Richardson, *Physical and Chemical Characteristics of Freshwater Wetland Soils*, *in* CONSTRUCTED WETLANDS FOR WASTEWATER TREATMENT 41, 51-55

occurs because of the fluctuations between aerobic and anaerobic conditions.[41] In the absence of oxygen, ammonium (the form of N present in anoxic conditions) can be captured by vegetation and prevented from moving into the adjacent water column, where excess N may contribute to eutrophication.[42] Wetlands also play a role in phosphorus cycling. Freshwater wetland soils in the presence of certain elements (especially iron) bind phosphorus (P), preventing P pollution from entering adjacent water bodies.[43] Wetlands are so effective at binding nutrients that they have become a successful means of wastewater treatment.[44]

Wetland vegetation also is affected by the hydrology; the influx of new nutrients and the removal of waste products stimulate high productivity. The vegetation then affects the hydrology—through sediment trapping and removal of pore water through transpiration—which can lead to fluctuations on varying temporal and spatial scales.[45] Decomposing vegetation provides organic material, or energy, to fuel microbial activity.[46] In turn, the microbes break down the material making it available for further plant uptake.[47] This energy is in the form of carbon (C), and the collective activity of all these reactions can alter the form of C present—converting gaseous carbon dioxide (CO_2) to plant sugars and back to CO_2 or methane; thus, wetland ecosystems may play a disproportionate role in regulating the storage of global carbon.[48]

B. Hydrology

The importance of the source, duration, depth, and frequency of flooding, or wetland hydrology, cannot be overstated; hydrology is the driving force of a wetland. Wetlands are flooded by water from multiple sources, including precipitation (directly or indirectly), surface, and

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(Donald A. Hammer ed., 1989); *see* PAUL A. KEDDY, WETLAND ECOLOGY: PRINCIPLES AND CONSERVATION 35, 71 (2d ed. 2010).

41. REDDY & DELAUNE, *supra* note 14, at 262.

42. *See id.* at 257, 260-62, 264.

43. Randolph M. Chambers & William E. Odum, *Porewater Oxidation, Dissolved Phosphate and the Iron Curtain: Iron-Phosphorus Relations in Tidal Freshwater Marshes*, 10 BIOGEOCHEMISTRY 37, 38-39 (1990).

44. *See* ROBERT H. KADLEC & SCOTT WALLACE, TREATMENT WETLANDS (2d ed. 2009) (discussing design, construction, and operation of wetland treatment systems).

45. WETZEL, *supra* note 38, at 285.

46. *Id.* at 286-87, 289.

47. *See id.* at 296.

48. WILLIAM H. SCHLESINGER & EMILY S. BERNHARDT, BIOGEOCHEMISTRY: AN ANALYSIS OF GLOBAL CHANGE 235 (3d ed. 2013) (citing Eville Gurham, *Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming*, 1 ECOLOGICAL APPLICATIONS 182, 182 (1991)).

groundwater flow. Wetland hydrology plays a large role in which plants survive in the environment; the plants, in turn, play a large role in how much water remains in the particular wetland through sedimentation, as discussed previously, as well as evapo-transpiration (ET). Tidal freshwater wetlands, for example, transport more water to the atmosphere than saltwater marshes through ET; researchers found higher leaf area index (and thus shading that cools the soil) to be a good predictor of an increase in ET.[49] Functions that support a wetland's ability to moderate flooding of developed areas are flood abatement and erosion control.

1. Flood Abatement

Because of their position in the landscape, wetlands have great capacity to hold water that arrives via precipitation, or river or coastal flooding; those that are not normally filled to capacity with surface water are effective as water storage systems during or following flood events. The capacity of a wetland to alter flood flows is related to its storage capacity and landscape position.[50] Wetlands upstream or high in a watershed—both depressional and associated with a stream—receive their water primarily from precipitation and surface flow, while downstream wetlands may be dominated by overbank flow.[51] Headwater streams play a critical flood protection role, although not always obvious, especially during periods of low flow.[52] The position and abundance of headwater wetlands create large water storage capacity and delay peak flows from their destination in the downslope flow.[53] Water storage in the wetland may result in desynchronization of the water's flow downstream and, therefore, a decrease of downstream peak flows and, thus, flooding.[54]

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49. BETH H. HUSSEY & WILLIAM E. ODUM, *Evapotranspiration in Tidal Marshes*, 15 ESTUARIES 59, 67 (1992).

50. ADAMUS ET AL., *supra* note 14, at 15-18 (citing D.M. THOMAS & M.A. BENSON, U.S. DEP'T INTERIOR, GENERALIZATION OF STREAMFLOW CHARACTERISTICS FROM DRAINAGE-BASIN CHARACTERISTICS (1975)).

51. Mark M. Brinson, *Strategies for Assessing the Cumulative Effects of Wetland Alteration on Water Quality*, 12 ENVTL. MGMT. 655, 656 (1988).

52. *Id.* at 656.

53. ADAMUS ET AL., *supra* note 14, at 15-16 (citing D.M. THOMAS & M.A. BENSON, U.S. DEP'T INTERIOR, GENERALIZATION OF STREAMFLOW CHARACTERISTICS FROM DRAINAGE BASIN CHARACTERISTICS (1975)).

54. MITSCH & GOSSELINK, *supra* note 1, at 519; R.P. Novitski, *The Hydrologic Characteristics of Wisconsin Wetlands and Their Influence on Floods, Streamflow, and Sediment*, *in* WETLAND FUNCTIONS AND VALUES: THE STATE OF OUR UNDERSTANDING 377, 385 (Phillip E. Greeson et al. eds., 1979); *see* John M. Kittelson, *Analysis of Flood Peak Moderation by Depressional Wetland Sites*, *in* THE ECOLOGY AND MANAGEMENT OF WETLANDS: 1 ECOLOGY OF WETLANDS 98, 104 (Donald D. Hook et al. eds., 1988).

In coastal areas, the desynchronization also provides a habitat function by preventing freshwater dilution of brackish water in estuaries, which can negatively impact fish reproduction and productivity.[55]

2. Erosion Control

Moving water can erode sediment or shorelines and deliver sediment to the water column. The processes of deposition described previously and erosion (or organic matter oxidation in the periodic absence of saturated conditions) create a dynamic system where wetlands either (1) silt up, (2) maintain equilibrium, or (3) convert to open water.[56] Vegetative roots adjacent to shorelines serve to stabilize the shoreline and prevent local erosion.[57] By providing frictional resistance and space to slow and hold water, coastal wetlands reduce the energy in waves and currents that are responsible for erosion—both immediately adjacent to the shoreline and elsewhere in the watershed.[58] The higher the velocity of flowing water, the greater is its erosive potential.[59]

C. Habitat

As with other functions, the ability of wetlands to provide habitat for a range of plants and animals is dependent upon the presence of water at annual and seasonal cycles as well as longer cycles.[60] The permanence of water in any wetland affects the number of species reliant upon it.[61] Animal diversity and productivity in wetlands are similar to that in terrestrial and aquatic/marine habitats, with the exception of amphibians and reptiles whose diversity and productivity exceed other systems and

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55. M.W. Street & J.D. McClees, *North Carolina's Coastal Fishing Industry and the Influence of Coastal Alterations*, *in* POCOSIN WETLANDS: AN INTEGRATED ANALYSIS OF COASTAL PLAIN FRESHWATER BOGS IN NORTH CAROLINA 238, 247 (Curtis J. Richardson et al. eds., 1981).

56. *See* KEDDY, *supra* note 41, at 113-14.

57. NAT'L RESEARCH COUNCIL, COMPENSATING FOR WETLAND LOSSES UNDER THE CLEAN WATER ACT 12 (2001).

58. TY V. WAMSLEY ET AL., U.S. ARMY CORPS ENG'RS, INFLUENCE OF MARSH RESTORATION AND DEGRADATION ON STORM SURGE AND WAVES 7 (2009).

59. THOMAS DUNNE & LUNA B. LEOPOLD, WATER IN ENVIRONMENTAL PLANNING 513 (1978).

60. *See* KEDDY, *supra* note 40, at 124-73, 184 (citing E.J. Chaneton & J.M. Facelli, *Disturbance Effects on Plant Community Diversity: Spatial Scales and Dominance Hierarchies*, 93 VEGETATIO 143, 143-55 (1991); Pamela J. Latham, Leonard G. Pearlstine & Wiley M. Kitchens, *Species Association Changes Across a Gradient of Freshwater, Oligonaline, and Mesohaline Tidal Marshes Along the Lower Savannah River*, 14 WETLANDS 174, 174-83 (1994)).

61. Scott A. Wissinger, *Ecology of Wetland Invertebrates: Synthesis and Applications for Conservation and Management*, *in* INVERTEBRATES IN FRESHWATER WETLANDS OF NORTH AMERICA: ECOLOGY AND MANAGEMENT 1043, 1043 (Darold P. Batzer, Russell B. Rader & Scott A. Wissinger eds., 1999).

whose reproduction may depend on wetlands.[62] The abundant plants (including aquatic vegetation and seeds and roots of emergent plants) support herbivorous animals, but few truly aquatic animal species feed on these macrophytes, leading wetlands to function for animals more like terrestrial systems than aquatic systems.[63] Macrophytes eventually become detritus and support food webs from this perspective, although the magnitude of this contribution into animal biomass is uncertain.[64] Wetlands are best known for their role in supporting finfish and shellfish; hence, we will emphasize the function supporting those taxa in the following discussion.

Fish that populate wetlands—be they inland or coastal, fresh or salt water—are typically small animals except in the larger adjacent channels; larger fish can be important to the overall ecology, especially by perturbing the bottom and affecting water quality and benthic ecology.[65] Tidal marshes, including both salt and tidal freshwater marsh systems, are recognized as important habitat, especially in their capacity as refugia for small fish,[66] nursery areas,[67] and spawning grounds for anadromous fishes.[68]

Salt and freshwater wetlands under tidal influence support estuarine food webs through C and nutrient additions;[69] however, the temporal and

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62. Darold P. Batzer, Robert Cooper & Scott A. Wissinger, *Wetland Animal Ecology*, *in* ECOLOGY OF FRESHWATER AND ESTUARINE WETLANDS 242, 242-43 (Darold P. Batzer & Rebecca R. Sharitz eds., 2006).

63. *Id.* at 246 (citing William E. Odum & Eric J. Heald, *The Detritus-Based Food Web of an Estuarine Mangrove Community*, *in* 1 ESTUARINE RESEARCH 265, 265-83 (L. Eugene Cronin ed., 1975); Mark M. Brinson, Ariel E. Lugo & Sandra Brown, *Primary Productivity, Decomposition, and Consumer Activity in Freshwater Wetlands*, 12 ANNUAL REV. ECOLOGY & SYSTEMATICS 123, 123-61 (1981); Ola Marklund et al., *Effects of Waterfowl and Fish on Submerged Vegetation and Macroinvertebrates*, 47 FRESHWATER BIOLOGY 2049, 2049-59 (2002)).

64. *Id.*

65. *Id.* at 278.

66. David L. Castellanos & Lawrence P. Rozas, *Nekton Use of Submerged Aquatic Vegetation, Marsh, and Shallow Unvegetated Bottom in the Atchafalaya River Delta, a Louisiana Tidal Freshwater Ecosystem*, 24 ESTUARIES 184, 194 (2001) (citing Lawrence P. Rozas & William E. Odum, *Occupation of Submerged Aquatic Vegetation by Fishes: Testing the Roles of Food and Refuge*, 77 OECOLOGIA 101, 102 (1988); Lawrence P. Rozas & William E. Odum, *Use of Tidal Freshwater Marshes by Fishes and Macrofaunal Crustaceans Along a Marsh Stream-Order Gradient*, 10 ESTUARIES 36, 40 (1987) [hereinafter Rozas & Odum, *Use of Tidal Freshwater Marshes*]).

67. LEAH GRAFF & JULIE MIDDLETON, NAT'L OCEANIC & ATMOSPHERIC ADMIN., WETLANDS AND FISH: CATCH THE LINK 10 (2001); Rozas & Odum, *Use of Tidal Freshwater Marshes*, *supra* note 66, at 40.

68. GRAFF & MIDDLETON, *supra* note 67, at 4.

69. C.A. Currin et al., *Determination of Food Web Support and Trophic Position of the Mummichog,* Fundulus heteroclitus*, in New Jersey Smooth Cordgrass (*Spartina alterniflora*), Common Reed (*Phragmites australis*), and Restored Salt Marshes*, 26 ESTUARIES 495, 508 (2003); Thomas J. Kwak & Joy B. Zedler, *Food Web Analysis of Southern California Coastal*

spatial variation of this pulse into the estuary varies by marsh system. The net fate of C from tidal systems is variable, because free-moving forms of C are episodically pulsed into adjacent water bodies in summer and fall, whereas more refractory C is released only in the spring in salt marshes.[70] Some estuarine and marine food webs rely upon these episodic pulses of C; if the marsh systems change dynamics with sea-level rise,[71] as predicted, there may be an economic impact on economically important fishes such as striped bass (*Morone saxatilis*), which are known to use tidal marshes widely.[72]

Managers have listed thirty-nine finfish and shellfish that use salt marshes and thirty-three that use tidal freshwater marshes.[73] Nine of those utilize both marsh systems.[74] Those using salt marshes include the eastern oyster (*Crassostria virginica*) and bluefish (*Pomatomus saltatrix*).[75] Historically, both marsh systems provided spawning and nursery habitat for finfish and shellfish, including the recently listed federally threatened sturgeon (*Acipenser oxyrhinchus*).[76] Fishes utilizing tidal freshwater marshes include species of freshwater, estuarine, anadromous and catadromous, and some estuarine-marine groups.[77]

III. HISTORY OF WETLAND LOSSES

In our current day and age, we recognize the natural and socioeconomic importance of our national wetlands. As mentioned previously, they provide ecological and societal services, such as habitat for fish and fowl, flood abatement, water quality improvement through sediment trapping and nutrient processing, as well as other important services.[78]

Wetlands Using Multiple Stable Isotopes, 110 OECOLOGIA 262, 274 (1997); Judith M. Stribling & Jeffrey C. Cornwell, *Identification of Important Primary Producers in a Chesapeake Bay Tidal Creek System Using Stable Isotopes of Carbon and Sulfur*, 20 ESTUARIES 77, 84 (1997).

70. *See* WILLIAM E. ODUM ET AL., U.S. FISH & WILDLIFE SERV., THE ECOLOGY OF TIDAL FRESHWATER MARSHES OF THE UNITED STATES EAST COAST: A COMMUNITY PROFILE 37 (1984) (citing John M. Teal, *Energy Flow in the Salt Marsh Ecosystem of Georgia*, 43 ECOLOGY 614, 614-24 (1962)).

71. *See* Morris et al., *supra* note 33, at 2869.

72. GRAFF & MIDDLETON, *supra* note 67, at 11; ODUM ET AL., *supra* note 70, at 49.

73. GRAFF & MIDDLETON, *supra* note 67, at 39-40, 42-44.

74. *Id.*

75. *Id.* at 39-40.

76. *Id.* at 23, 44.

77. *See* MITSCH & GOSSELINK, *supra* note 1, at 351-52 (citation omitted).

78. NAT'L RESEARCH COUNCIL, WETLANDS: CHARACTERISTICS AND BOUNDARIES 36-38 (1995) (citing MARK M. BRINSON ET AL., U.S. FISH & WILDLIFE SERV. & U.S. DEP'T INTERIOR, RIPARIAN ECOSYSTEMS: THEIR ECOLOGY AND STATUS 74 (1981); RALPH W. TINER, JR. U.S. DEP'T INTERIOR & U.S. FISH & WILDLIFE SERV., *supra* note 3, at 19.).

However, our recognition of wetlands' values was not always the case. Archaeological work has documented that, as early as 750 A.D., the prehistoric inhabitants of Marco Island, Florida, altered the wetland habitat of the island by constructing a system of lagoons, canals, and shell seawalls.[79] Evidence also exists that purposeful change of wetlands to agricultural ecosystems began in earnest in the tenth century.[80] The purposes of the modifications were perhaps to provide solid, dry ground to live on, or to provide protection from storm tides, or to provide for more rapid access to fin- and/or shell-fishing grounds. In the Nordic region of Europe, building dikes and filling wetlands to keep out the sea and develop human-habitable land has been common since the fourteenth century.[81]

When European settlers first arrived in this country, they used the rivers as a source of travel and distribution of goods (commerce).[82] In general, they saw wetlands as a waste area, a source of disease, and an obstacle to commerce.[83] The presence of corduroy roads (or "trackways") are visible in many of the tidal marshes of the lower Chesapeake Bay, Virginia.[84] These trackways were constructed from local timber laid side by side and covered with soil or other fillers.[85] River transport was particularly necessary in the seventeenth and eighteenth centuries because road travel was tenuous and dangerous. Therefore, the construction of these roads across the marshes allowed the progression of commerce via the tidal marshes from the new world to the old.[86] However, due to the problem of an unstable soil (characteristic of tidal wetlands), the tidal marshes were seen not as access to the navigable water, but as a problem to be overcome.[87]

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79. Byrony Coles, *Wetland Archaeology: A Wealth of Evidence*, *in* WETLANDS: A THREATENED LANDSCAPE 145, 165 (Michael Williams ed., 1990).

80. Michael Williams, *Agricultural Impacts in Temperate Wetlands*, *in* WETLANDS: A THREATENED LANDSCAPE, *supra* note 79, at 181, 182.

81. *Id.* at 184.

82. *America Runs on the Mississippi River*, AMERICAN RIVERS, http://www.americanrivers.org/rivers/fun/america-runs-on-the-mississippi-river/ (last visited Nov. 13, 2015).

83. MITSCH & GOSSELINK, *supra* note 1, at 9, 12.

84. John Gresham, *A Day in the Life of York River State Park: Our Slice of the River*, EXPLORE VA. OUTDOORS (Dec. 15, 2014), http://www.virginiaoutdoors.com/article/more/5329.

85. Megan Kate Nelson, *Environment*, *in* CIVIL WAR IN AMERICA: A SOCIAL AND CULTURAL HISTORY 64, 72 (Maggi M. Morehouse & Zoe Trodd eds., 2013); John J. Riser, *The Building of Braddock's Road*, 2011 GOLD STAR J. 32, 32, 37.

86. *See* Nelson, *supra* note 85, at 64.

87. *See* JOHN LUTHER RINGWALT, DEVELOPMENT OF TRANSPORTATION SYSTEMS IN THE UNITED STATES 26 (1888).

A. *Wetlands as a Disease Vector*

Much of the European settlers' disdain for wetlands came from the old country itself, because wetlands in the old country were perceived as the source of diseases that affected humans.[88] In some cases, the fear was real.[89] Malarial outbreaks in southwest Spain during the nineteenth century were "more severe in certain endemic regions that were primarily related to different types of inland aquatic ecosystems."[90] In fact, the Spanish word for malaria, *paludismo*, is derived from the Latin *palus* ("swamp, pool").[91] It was not until after World War II that malaria was eradicated from Spain (other European countries had eradicated all forms of malaria prior to WWII) through both the "drying up of wetlands" and improvement of sanitation.[92] Therefore, it is not difficult to understand why many of the settlers arriving in the New World viewed wetlands as dangerous, dismal, and malicious components of the landscape.

Even as late as the mid-twentieth century, many countries, including the United States, were attempting to drain and/or fill wetlands, with the goal of improving human health.[93] Even today, it is important to recognize that wetlands did, and still can, play an important role in the spread of water- and vector-borne diseases.[94] However, the World Health Organization has instituted recommendations to control waterborne diseases that do not include destruction of wetlands.[95] In fact, studies have shown that the natural ability of wetlands to recycle N,[96] act as

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88. *See* Arturo Sousa et al., *Historical Importance of Wetlands in Malaria Transmission in Southwest of Spain*, 28 LIMNETICA 283, 283-300 (2009).

89. *See id.*

90. *Id.* at 287.

91. *Id.* at 284 (citation omitted).

92. *Id.* at 287.

93. *See* MITSCH & GOSSELINK, *supra* note 1, at 15.

94. Sousa et al., *supra* note 88, at 284-85.

95. For a review of approaches to waterborne-disease control, see Stuart Batterman et al., *Sustainable Control of Water-Related Infectious Diseases: A Review and Proposal for Interdisciplinary Health-Based Systems Research*, 117 ENVTL. HEALTH PERSPECTIVES 1023 (2009). The World Health Organization supports "Integrated Vector Management." *See* World Health Org., *Better Environmental Management for Control of Dengue*, HEALTH & ENV'T LINKAGES INITIATIVE (HELI), http://www.who.int/heli/risks/vectors/denguecontrol/en/ (last visited Oct. 6, 2015); World Health Org., *Malaria Control: The Power of Integrated Action*, HEALTH & ENV'T LINKAGES INITIATIVE (HELI), http://www.who.int/heli/risks/vectors/malariacontrol/en/ (last visited Oct. 6, 2015).

96. Stephen J. Jordan, Jonathan Stoffer & Janet A. Nestlerode, *Wetlands as Sinks for Reactive Nitrogen at Continental and Global Scales: A Meta-Analysis*, 14 ECOSYSTEMS 144, 151-53 (2011).

nursery habitats for fish,[97] and provide flood buffering[98]—all of these ecosystem services—can far outweigh the potential of a wetland ecosystem to serve as a disease vector. Others have suggested wetland management techniques to alleviate vector problems.[99]

B. Agriculture and Wetlands

Not all early wetland losses in the United States were related to disease control. In fact, the majority of losses came about through the New World settlers' reliance on the development of agriculture.[100] Ralph E. Heimlich and colleagues reported that twenty-eight million acres of wetlands were converted for agricultural use in nine Midwestern states.[101] One online encyclopedia has quantified the drainage of wetlands for the creation of agricultural land to have "doubled between 1905 and 1910 and again between 1910 and 1920.[102] By 1920 state drainage districts in the United States encompassed an area larger than Missouri."[103]

C. Other Cause of Wetland Loss

Not all wetland loss is intentionally caused by humans. Sea-level rise,[104] whether naturally occurring or human-enhanced, can drown tidal wetlands through submergence.[105] At the same time, changes in global precipitation patterns due to climate change may alter the hydrology of

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97. LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, THE 2009 EVALUATION REPORT TO THE U.S. CONGRESS ON THE EFFECTIVENESS OF COASTAL WETLANDS PLANNING, PROTECTION AND RESTORATION ACT PROJECTS 2-3 (2010).

98. *See* Phillips, *supra* note 23, at 221-22.

99. *See* Richard C. Russell, *Constructed Wetlands and Mosquitoes: Health Hazards and Management Options—An Australian Perspective*, 12 ECOLOGICAL ENGINEERING 107, 120-21 (1999).

100. RALPH E. HEIMLICH ET AL., ECON. RESEARCH SERV., U.S. DEP'T AGRIC., AGRIC. ECON. REP. NO. 765, WETLANDS AND AGRICULTURE: PRIVATE INTERESTS AND PUBLIC BENEFITS 18 (Sept. 1998) http://www.ers.usda.gov/media/929243/aer765_002.pdf.

101. *Id.* (citation omitted).

102. *Wetlands—History of Wetlands Use*, LIBR. INDEX, http://www.libraryindex.com/pages/2629/Wetlands-HISTORY-WETLANDS-USE.html (last visited Oct. 6, 2015).

103. *Id.*

104. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 387 (Susan Solomon et al. eds., 2007) (summarizing scientific findings of rising seas).

105. J. Court Stevenson & Michael S. Kearney, *Impacts of Global Climate Change and Sea Level Rise on Tidal Wetlands*, *in* HUMAN IMPACTS ON SALT MARSHES: A GLOBAL PERSPECTIVE 171, 176 (Brian R. Silliman et al. eds., 2009); Scott C. Neubauer & Christopher B. Craft, *Global Change and Tidal Freshwater Wetlands: Scenarios and Impacts*, *in* TIDAL FRESHWATER WETLANDS 253, 257 (Aat Barendregt et al. eds., 2009) (citing Kevin K. Moorhead & Mark M. Brinson, *Response of Wetlands to Rising Sea Levels in the Lower Coastal Plains of North Carolina*, 5 ECOLOGICAL APPLICATIONS 261, 261-71 (1995)).

some freshwater wetlands.[106] Brett A. Werner and colleagues found that a shift northward of predicted precipitation in the Midwestern United States[107] would decrease precipitation input to numerous western prairie potholes, which are important for wildlife and agricultural irrigation.[108]

D. Current Trends

Thomas E. Dahl and Susan-Marie Stedman report a decline of 62,300 acres (25,200 hectares) of wetlands in the coterminous United States from 2004 to 2009.[109] The loss, while not statistically significant, was evident in a 1.4% decline (84,100 acres; 34,050 hectares) in estuarine wetlands.[110] However, this most recent accounting of trends in wetland loss is widely regarded as inaccurate because some types of freshwater wetlands, such as farm ponds, increased in acreage, while acreage of forested wetlands declined.[111] Overall, Ralph W. Tiner, Jr., has estimated that more than 50% of the wetlands present in the conterminous United States during the seventeenth century have been lost, mostly due to human activity.[112]

IV. HISTORY OF PROTECTIVE LEGISLATION

At the federal level, the Clean Water Act (CWA)[113] is the principal law that protects wetlands, via a permit program.[114] If a company wants to fill in a wetland to construct, for example, a shopping mall or residential subdivision, it generally must seek permission from the United States Army Corps of Engineers (Corps).[115] The Corps will then decide whether to issue a section 404 permit to allow the project to

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106. Brett A. Werner, W. Carter Johnson & Glenn R. Guntenspergen, *Evidence for 20th Century Climate Warming and Wetland Drying in the North American Prairie Pothole Region*, 3 ECOLOGY & EVOLUTION 3471, 3476 (2013).

107. U.S. GLOBAL CHANGE RESEARCH PROGRAM, GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 31 (Thomas R. Karl, Jerry M. Melillo & Thomas C. Peterson eds., 2009).

108. Werner, Johnson & Guntenspergen, *supra* note 106, at 3478.

109. T.E. DAHL, U.S. FISH & WILDLIFE SERV., STATUS AND TRENDS OF WETLANDS IN THE COTERMINOUS UNITED STATES 2004 TO 2009, at 16 (2011).

110. *Id.*

111. *See id.*

112. *See* TINER, *supra* note 3, at 29-30 (citing W.E. FRAYER ET AL., U.S. FISH & WILDLIFE SERV., STATUS AND TRENDS OF WETLANDS AND DEEPWATER HABITATS IN THE CONTERMINOUS UNITED STATES, 1950'S TO 1970'S (1983)).

113. *See* Clean Water Act, 33 U.S.C. §§ 1251-1387 (2012).

114. *Id.* § 1344.

115. 33 C.F.R. § 320.2 (2014).

proceed and, if so, under what conditions.[116] The goal of the CWA section 404 program is "no net loss" of wetland functions and values.[117]

To attempt to accomplish this laudable goal, the United States Congress established a complicated relationship between the Corps and the United States Environmental Protection Agency (EPA).[118] Although the Corps makes the section 404 permit decision, it must apply EPA regulations—the so-called section 404(b)(1) guidelines—in doing so.[119] If the EPA disagrees with the Corps' decision, it can issue a veto, although it rarely does.[120] Both agencies also have enforcement authority.[121]

To view the CWA as a wetland-protection law is a bit of an overstatement. The CWA applies to "the waters of the Unites States," a term that has prompted a trilogy of U.S. Supreme Court cases.[122] These cases have resulted in the agencies asserting regulatory jurisdiction over a subset of wetlands; only wetlands that are navigable or have some significant nexus to a traditional navigable body of water are covered.[123] Moreover, only certain activities trigger the need for a section 404 permit, specifically the discharge of dredged or fill material.[124] The mere act of draining a wetland or removal of wetland vegetation is not regulated by the CWA.[125] Moreover, even if a proposed project requires a section 404 permit, most CWA permit requests are granted.[126] Although the Corps has the authority to deny permits that do not satisfy the section 404(b)(1) guidelines, it denies relatively few permits.[127]

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116. *Id.* §§ 320.2, .4(4)-(5).

117. ROYAL C. GARDNER, LAWYERS, SWAMPS, AND MONEY: U.S. WETLAND LAW, POLICY, AND POLITICS 93-94 (2011); *see* Palmer Hough & Morgan Robertson, *Mitigation Under Section 404 of the Clean Water Act: Where It Comes From, What It Means*, 17 WETLANDS ECOLOGY & MGMT. 15, 26 (2009).

118. GARDNER, *supra* note 117, at 73-75, 77.

119. 40 C.F.R. § 230 (2014).

120. *See* 33 U.S.C. § 1344(c) (2012) (discussing the EPA's veto authority); *see generally Chronology of 404(c) Actions*, U.S. ENVTL. PROT. AGENCY, http://water.epa.gov/lawsregs/guidance/wetlands/404c.cfm (last visited Oct. 6, 2015) (showing that the EPA has issued vetoes only thirteen times in the last thirty-one years).

121. GARDNER, *supra* note 117, at 159-61.

122. *See* Rapanos v. United States, 547 U.S. 715 (2006); Solid Waste Agency of N. Cook Cnty. v. U.S. Army Corps of Eng'rs, 531 U.S. 159 (2001); United States v. Riverside Bayview Homes, Inc., 474 U.S. 121 (1985).

123. 40 C.F.R. §§ 230.1(a), .2(b).

124. 33 U.S.C. § 1344; 33 C.F.R. § 320.1(b) (2014).

125. GARDNER, *supra* note 117, at 57.

126. *Id.* at 101-02.

127. CRAIG PITTMAN & MATTHEW WAITE, PAVING PARADISE: FLORIDA'S VANISHING WETLANDS AND THE FAILURE OF NO NET LOSS 75 (2009) (stating that from 1999-2003, the Jacksonville District approved about 12,000 permits while denying only one).

Permit applicants are required to follow an "avoid-minimize-compensate" sequence.[128] They are to avoid wetland impacts if practicable (depending on the scope and type of project), minimize unavoidable impacts (perhaps by reconfiguring a project or altering its timing), and then compensate for any remaining impacts (through the restoration, creation, enhancement and/or preservation of other wetlands in the watershed).[129] The use of compensation (also known as compensatory mitigation) to offset wetlands impacts is key to achieving the goal of no net loss.[130] Many studies, however, have found that compensatory mitigation projects have failed to replace lost area and functions (and thus ecosystem services) at an alarming rate.[131]

Compensatory mitigation has been especially challenging when the responsibility for the effectiveness of the mitigation site lies with a permittee (e.g., the developer). The National Research Council reviewed a series of studies that indicated that permittee-responsible mitigation did not fare well because it was sometimes never started. If commenced, the resulting wetland did not provide the expected functions; the agencies rarely exercised enforcement oversight; and even if a mitigation project resulted in a functioning wetland, often there was no long-term stewardship strategy in place.[132] Accordingly, this failure of permittee-responsible mitigation caused the Corps and the EPA (and Congress) to adopt a preference for an alternative approach to providing wetland mitigation and compensating for lost functions: wetland mitigation banking.[133]

Under this approach, an environmental restoration company might restore a previously drained wetland, and the environmental "lift"—the delta between the baseline conditions and the conditions of the rehabilitated site—is quantified as environmental credits.[134] With the Corps' approval, these credits can then be sold to developers and other

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128. *See* 33 C.F.R. § 332.1(c) (2014); 40 C.F.R. § 230.91(c) (2014).

129. 33 C.F.R. § 332.1(c); 40 C.F.R. § 230.91(c).

130. *See* 33 C.F.R. § 332.1(c); 40 C.F.R. § 230.91(c).

131. *See, e.g.*, NAT'L RESEARCH COUNCIL, *supra* note 57, at 113-21; Rebecca L. Kihslinger, *Success of Wetland Mitigation Projects*, 30 NAT'L WETLANDS NEWSL. (Envtl. Law Inst., Wash., D.C.), Mar.-Apr. 2008, at 14; R. Eugene Turner, Ann M. Redmond & Joy B. Zedler, *Count It by Acre or Function—Mitigation Adds Up to Net Loss of Wetlands*, 23 NAT'L WETLANDS NEWSL. (Envtl. Law Inst., Wash., D.C.), Nov.-Dec., 2001, at 5.

132. NAT'L RESEARCH COUNCIL, *supra* note 57, at 138.

133. 33 C.F.R. § 332; 40 C.F.R. § 230.92. The agencies' regulations establish a preference hierarchy for compensatory mitigation: offsets are generally preferred to be provided through mitigation bank credits, followed by in-lieu fee program credits and then permittee-responsible mitigation. 33 C.F.R. § 332.3(b).

134. 33 C.F.R. § 332; 40 C.F.R. § 230.92.

section 404 permittees who need to provide compensatory mitigation.[135] While on one level it may appear that the permittee is purchasing an environmental credit, what it is really buying is a release of liability.[136] For when the Corps approves the use of wetland mitigation bank credits to satisfy a permittee's compensatory mitigation obligations, the responsibility to provide the mitigation shifts to the mitigation banker.[137]

The number of wetland mitigation banks in the United States has increased dramatically.[138] Although the use of mitigation banks is an administrative improvement over permittee-responsible mitigation,[139] more studies are needed to assess their contribution toward replacing lost functions and ecosystem services.[140]

Outside of the CWA regulatory program, incentive-based approaches have also been used to encourage private landowners to restore and protect wetlands, especially in the agricultural context.[141] Sometimes the incentive is a carrot, and sometimes it is a stick.

On the carrot side, the federal government has several programs, such as the Wetlands Reserve Program[142] and the Conservation Reserve Program,[143] that pay landowners to restore previously drained wetlands. The amount of cost-sharing and funding typically depends on how long the property owner agrees to protect the site.[144] For example, the level of payment will be greater if the owner agrees to place a permanent conservation easement on the site as opposed to a ten- or thirty-year easement.[145]

On the stick side, the "Swampbuster" program has proved to be the most effective means of reducing wetland losses due to agricultural

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135. 33 C.F.R. § 332; 40 C.F.R. § 230.92.

136. GARDNER, *supra* note 117, at 173.

137. *Id.*

138. *Id.* at 120 (stating that in 2010 "it was reported that there were now nearly a thousand approved mitigation banks, with another 500 banks in some stage of development") (citing JESSICA WILKINSON & JARED THOMPSON, ENVTL. LAW INST., 2005 STATUS REPORT ON COMPENSATORY MITIGATION IN THE UNITED STATES 8 (2006); ENVTL. LAW INST., BANKS AND FEES: THE STATUS OF OFF-SITE WETLAND MITIGATION IN THE UNITED STATES 35, 37-39 (2002)).

139. Craig Denisoff & David Urban, *Evaluating the Success of Wetland Mitigation Banks*, 34 NAT'L WETLANDS NEWSL. (Envtl. Law Inst., Wash. D.C.), July-Aug. 2012, at 8.

140. *See* Rebecca L. Kihslinger & Virginia Baker, *Evaluating Wetland Mitigation Performance Across Mitigation Mechanisms*, 34 NAT'L WETLANDS NEWSL. (Envtl. Law Inst., Wash. D.C.), July-Aug. 2012, at 7 (discussing upcoming ELI study).

141. Royal C. Gardner, *Rehabilitating Nature: A Comparative Review of Legal Mechanisms That Encourage Wetland Restoration Efforts*, 52 CATH. U. L. REV. 573, 587-92 (2003).

142. 16 U.S.C. § 3837 (2012).

143. *Id.* § 3831.

144. *See id.* § 3837(f).

145. Gardner, *supra* note 141, at 594-95 (citing 7 C.F.R. §§ 1467.9, .9(a)(2) (2002)).

conversion.[146] Under this program, if a farmer drains or alters a wetland in order to produce an agricultural commodity, the farmer is then at risk of becoming ineligible to receive federal loans, federally subsidized insurance, and other benefits.[147] Since the enactment of Swampbuster in 1985, wetland losses due to agricultural conversion have significantly declined.[148]

Note that these regulatory and nonregulatory programs are largely focused on direct impacts to wetlands. They do not address many other causes of wetland loss and degradation.

V. CASE STUDIES

There are many examples in the United States where human activities have modified wetland functions and the resulting ecological services. We will use the Mississippi Delta and the Everglades as broad scale case studies that elucidate both the impacts humans have made to wetlands and the difficulty that exists in returning wetlands to their original ecological state.

A. *Loss of Mississippi Delta*

The coastal salt marshes of the Mississippi Delta have formed over the past 7,000 to 8,000 years on the alluvial deposits of the sediment-rich Mississippi River.[149] They currently comprise more than 40% of the coastal wetlands of the continental United States.[150] Prior to arrival of the colonists in Louisiana, the Delta consisted of more than 6,554ha of marshes, swamps, and shallow coastal lakes; this declined to 3,555ha by the mid-1980s for a loss of nearly 50% of the original amount.[151] Dunbar and his associates estimated that between 1958 and 1974 there was an

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146. The "swampbuster" program is codified at 16 U.S.C. § 3821 (2012).

147. Gardner, *supra* note 141, at 597 (citing 16 U.S.C. § 3822(f)(1)-(2) (2002)).

148. *See* NAT'L RESEARCH COUNCIL, *supra* note 57, at 17 (citing THOMAS E. DAHL, U.S. DEP'T INTERIOR & U.S. FISH & WILDLIFE SERV., STATUS AND TRENDS OF WETLANDS IN THE CONTERMINOUS UNITED STATES 1986 TO 1987, at 11 (2000); Thomas E. Dahl & Craig Johnson, U.S. Dep't Interior & U.S. Fish & Wildlife Serv., WETLANDS: STATUS AND TRENDS IN THE CONTERMINOUS UNITED STATES MID-1970'S TO MID-1980'S, at 2 (1991)).

149. Harry H. Roberts, *Dynamic Changes of the Holocene Mississippi River Delta Plain: The Delta Cycle*, 13 J. COASTAL RES. 605, 625 (1997).

150. *Mississippi River Delta*, NAT'L WILDLIFE FED'N, http://www.nwf.org/Wildlife/Wild-Places/Mississippi-River-Delta.aspx (last visited Oct. 7, 2015).

151. MITSCH & GOSSELINK, *supra* note 1, at 46 (citing THOMAS E. DAHL, U.S. DEP'T INTERIOR & U.S. FISH & WILDLIFE SERV., WETLANDS: LOSSES IN THE UNITED STATES 1780'S TO 1980'S, at 6 (1990)).

average loss of 11,800ha/yr of Delta marshes.[152] This declined to 6,550ha/yr in the period 1983 through 1990.[153]

The land-water interface has been identified as an important feature of wetland habitat related to biological productivity.[154] Louisiana salt marshes are considered some of the most productive wetlands in the United States[155] and provide important ecological services to the people and industries of Louisiana. They act as a natural buffer for many coastal areas during storm events and as fish and finfish habitat (feeding and nursery).[156] A 1997 report to the U.S. Congress found that "[w]ith greater than 1.1 billion pounds of fish and shellfish harvested annually, domestic and commercial landing statistics indicate that Louisiana provides more fishery landings than any other state in the conterminous United States."[157] They found that at that time "as much as 16% of the nation's fisheries harvest, including shrimp, crabs, crayfish, oysters and many finfish, comes from Louisiana's coast."[158] In 2007, the Izaak Walton League reported that "Louisiana's coastal fisheries produced more than $289 million in dockside landings . . .—26 percent of the seafood in the lower 48 states."[159]

Douglas Helmers found that the state provided habitat for approximately five million wintering waterfowl.[160] The U.S. Fish and Wildlife Service reported that hunters spent $525 million in Louisiana in 2006, and anglers spent more than $1 billion.[161] Federally listed threatened and endangered species found in Louisiana's coastal wetlands

152. *See* J.B. DUNBAR, L.D. BRITSCH & E.B. KEMP III, U.S. ARMY CORPS ENG'RS, TECHNICAL REP. GL-90-2, LAND LOSS RATES, REPORT 3, LOUISIANA COASTAL PLAIN: TECHNICAL REPORT 22 (Mar. 1992), http://www.atic.mil/tr/fulltext/u2/a256591.pdf.

153. *See id.*

154. LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, THE 1997 EVALUATION REPORT TO THE U.S. CONGRESS ON THE EFFECTIVENESS OF LOUISIANA COASTAL WETLAND RESTORATION PROJECTS 4 (1997) (citing R. DANIEL SMITH, U.S. ARMY CORPS ENG'RS, WETLANDS RESEARCH PROGRAM TECHNICAL REP. WRP-DE-3, A CONCEPTUAL FRAMEWORK FOR ASSESSING THE FUNCTIONS OF WETLANDS 5 (Aug. 1993), http://www.dtic.mil/dtic/tr/fulltext/u2/a270304.pdf).

155. MITSCH & GOSSELINK, *supra* note 1, at 62.

156. *Id.* at 514, 522.

157. LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, *supra* note 154, at 2 (citation omitted).

158. *Id.*

159. Dawn Merritt, Izaak Walton League Am., *Damaged Delta*, 2011 OUTDOOR AM. 30, 31.

160. LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, *supra* note 154, at 5 (citing DOUGLAS L. HELMERS, SHOREBIRD MANAGEMENT MANUAL 42 (1992)).

161. Merritt, *supra* note 159, at 31.

include brown pelicans, bald eagles,[162] Louisiana black bears, piping plovers, and green sea turtles.[163] The Louisiana black bear population has declined over the past decades reportedly due to loss of wetland habitat.[164] Approximately 6% of the 183 fish species found in the delta are found on the endangered, threatened, or special concern lists of the U.S. Fish and Wildlife Service.[165]

The wetlands of the Mississippi Delta have been, and continue to be, assaulted on multiple fronts.[166] Since the settlement of the Mississippi River basin by European colonists, Louisiana wetlands have been vulnerable to conversion into upland or open water.[167] Experts believe that within the last several centuries, "the impact of human activities in the region has been pervasive and comparable to, if not greater than, natural processes in the magnitude of their cumulative effects on wetland loss."[168] In the eighteenth century, industrial uses of the Delta were limited to fishing and fur trapping (muskrat).[169] The initial creation of levees to allow for the development of agriculture (including rice, corn, cotton, and tobacco) also began early in that century.[170] As agriculture in the area increased in importance, ditches and canals were dug to ease transportation access of agricultural goods to distant markets.[171] The levees also proved to be a source of major downstream flooding and, therefore, significantly altered the hydrology and energy of the

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162. LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, *supra* note 154, at 5 (citing LA. COASTAL WETLANDS CONSERVATION & RESTORATION TASK FORCE, LOUISIANA COASTAL RESTORATION PLAN 5 (NOV. 1993), http://lacoast.gov/reports/cwcrp/1993/19931cwrp-1executive_summary.pdf).

163. *Mississippi River Delta*, *supra* note 150.

164. *See id.*; Jared S. Laufenberg & Joseph D. Clark, *Louisiana Black Bear Management and Research*, LA. DEP'T WILDLIFE & FISHERIES, http://www.wlf.louisiana.gov/Louisiana-black-bear-management-and-research (last visited Sept. 18, 2015); *Bears Den in Wetland Reserve Program Lands*, U.S. FISH & WILDLIFE SERV., http://www.fws.gov/southeast/es/BearsDenWetlandReserveProgramLands.html (last visited Oct. 8, 2015).

165. *Draft Heritage Study and Environmental Assessment, Vol. 2*, NAT'L PARK SERV., http://www.nps.gov/nhl.learn/delta/volume2/natural.htm#fisheries (last visited Oct. 8, 2015) (citing U.S. DEP'T INTERIOR, OUR LIVING RESOURCES: A REPORT TO THE NATION ON THE DISTRIBUTION, ABUNDANCE, AND HEALTH OF U.S. PLANTS, ANIMALS, AND ECOSYSTEMS 142 (Edward T. LaRoe et al. eds., 1995)).

166. Robert A. Morton, Ginger Tiling & Nicholas F. Ferina, *Causes of Hot-Spot Wetland Loss in the Mississippi Delta Plain*, 10 ENVTL. GEOSCIENCES 71, 72 (2003).

167. JAMES G. GOSSELINK, U.S. FISH & WILDLIFE SERV. & U.S. ARMY CORPS ENG'RS, FWS/0BS-84109, THE ECOLOGY OF DELTA MARSHES OF COASTAL LOUISIANA: A COMMUNITY PROFILE 2-3 (May 1984).

168. Donald F. Boesch et al., *Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana*, 20 J. COASTAL RES. (SPECIAL ISSUE) 1, 37 (1994).

169. *See* GOSSELINK, *supra* note 167, at 3.

170. *Id.* at 2.

171. *See id.* at 3.

downstream salt marshes.[172] In more recent history, Louisiana wetlands have been lost to agricultural and urban expansion, canal and spoil bank construction, and the creation of dry uplands by draining of forested wetlands.[173] The man-made levees extend all the way from Illinois to the mouth of the river and, therefore, prevented silt from being deposited on the floodplains.[174] Upstream dams will continue to trap sediment that would have originally provided natural material for accumulation and, therefore, increases in elevation for the downstream marshes.[175] The increase in elevation becomes critical in light of relative sea-level rise; without sediment, the downstream wetlands may become inundated and drown.[176]

In the mid-twentieth century, the gas and oil industry came to the Mississippi Delta.[177] Development of the industry required rapid transport of the raw product to inland processing facilities. Therefore, there was large-scale dredging of "thousands of miles of canals through the coastal wetlands" to provide for large barge and tanker movement.[178] Canals have caused saltwater intrusion into freshwater wetlands resulting in dieback of wetland vegetation.[179] With no vegetation to hold the mucky soils, these wetland areas are easily eroded away by water currents and converted into open water. Unfortunately, once wetland deterioration proceeds to the point where the length of the land-water interface begins to decline, there may be a long-term decline in fishery productivity.[180] Geologists have also hypothesized that the extraction of resources (such as oil and natural gas) from beneath the land's surface has accelerated the sinking of the land in conjunction with the loss of

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172. G. TYLER MILLER, JR. & SCOTT SPOOLMAN, ENVIRONMENTAL SCIENCE: PROBLEMS, CONCEPTS, AND SOLUTIONS 24-25 (12th ed. 2008); GOSSELINK, *supra* note 167, at 52.

173. Boesch et al., *supra* note 168, at 17.

174. Katherine Kemp, *The Louisiana Environment: The Mississippi Levee System and the Old River Control Structure*, TUL. U., http://www.tulane.edu/~bFlerty/envirobio/enviroweb/FloodControl.htm (last updated Jan. 6, 2000).

175. John Tibbetts, *Louisiana's Wetlands: A Lesson in Nature Appreciation*, 114 ENVTL. HEALTH PERSPECTIVES A40, A42 (2006).

176. Morton, Tiling & Ferina, *supra* note 166, at 72; Denise J. Reed, *Patterns of Sediment Deposition in Subsiding Coastal Salt Marshes, Terrebonne Bay, Louisiana: The Role of Winter Storms*, 12 ESTUARIES 222, 222 (1989) (citing U.S. FISH & WILDLIFE SERV., FWS/OBS-82/59, PROCEEDINGS OF THE CONFERENCE ON COASTAL EROSION AND WETLAND MODIFICATION IN LOUISIANA: CAUSES, CONSEQUENCES, AND OPTIONS (Donald F. Boesch ed., Oct. 1982); H. Jesse Walker et al., *Wetland Loss in Louisiana*, 69A GEOGRAFISKA ANNALER 189 (1987)).

177. GOSSELINK, *supra* note 167, at 3.

178. *Id.*

179. *See* GAY M. GOMEZ, THE LOUISIANA COAST: GUIDE TO AN AMERICAN WETLAND 123 (2008).

180. *See* COASTAL PROT. & RESTORATION AUTH. OF LA., LOUISIANA'S COMPREHENSIVE MASTER PLAN FOR A SUSTAINABLE COAST 21 (2012).

alluvium, further contributing to the fall of wetland surfaces below sea level.[181]

However, human activities are not responsible for all of the losses. Sea-level rise due to thermal expansion of the warming ocean waters and glacial melt, whether natural or human-induced, also has accelerated coastal wetland loss by increasing inundation of the wetland surface.[182] Coupled with the loss of sediments to coastal wetlands (see above), the drowning of the wetlands may be exacerbated.[183] Hurricanes can also cause losses through erosion of wetland areas, as seen when both Katrina and Rita hit the Delta in 2005.[184]

Because the natural processes that created the Mississippi Delta were at work over thousands of years, they are difficult to restore. In 2007, the Louisiana State Legislature created Louisiana's Comprehensive Master Plan for a Sustainable Coast (Master Plan).[185] The Master Plan includes freshwater and sediment diversion, use of dredged material from canal projects to create new wetlands, projects to prevent shoreline erosion, restoration of wetland hydrology, and vegetation planting.[186] These efforts are predicted to save about 465 square kilometers of wetlands; however, that still leaves a dire prediction of approximately 1,619 square kilometers vulnerable to loss in the future.[187]

Solutions to prevent Louisiana wetlands loss must include the avoidance of freshwater diversion, a focus on maintaining soil strength by avoiding excess nutrient loading, and methods to prevent inundation. However, there are many stakeholders involved in the decision-making process. Numerous "solutions" have been proposed, including breaching levees to allow water to enter wetlands, slowing velocity, depositing sediment in the wetlands, and using restored riparian wetlands to trap sediment and nutrients to reduce loadings to the Gulf.[188] While these

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181. Tibbetts, *supra* note 175, at A42 (quoting NAT'L RESEARCH COUNCIL, DRAWING LOUISIANA'S NEW MAP: ADDRESSING LAND LOSS IN COASTAL LOUISIANA 16 (2006)).

182. U.S. GEOLOGICAL SURVEY, USGS FS-089-97, COASTAL WETLANDS AND GLOBAL CHANGE: OVERVIEW (June 1997).

183. *See* Boesch et al., *supra* note 168, at 24.

184. Robert A. Morton & John A. Barras, *Hurricane Impacts on Coastal Wetlands: A Half-Century Record of Storm-Generated Features from Southern Louisiana*, 27 J. COASTAL RESEARCH 27, 38 (2011) (citing John A. Barras, *Satellite Images and Aerial Photographs of the Effects of Hurricane Katrina and Rita on Coastal Louisiana*, U.S. GEOLOGICAL SURVEY DATA SERIES (2007), http://pubs.usgs.gov/ds/2007/281/ (last visited Oct. 9, 2015)).

185. COASTAL PROT. & RESTORATION AUTH. OF LA., *supra* note 180, at 24.

186. *Id.* at 68-73.

187. Biao Zhong & Y. Jun Xu, *Risk of Inundation to Coastal Wetlands and Soil Organic Carbon and Organic Nitrogen Accounting in Louisiana, USA*, 45 ENVTL. SCI. & TECH. 8241, 8245 (2011).

188. COASTAL PROT. & RESTORATION AUTH. OF LA., *supra* note 180, at 68-73.

ideas please some, such as shrimpers who point out the direct relationship of healthy shrimp population to healthy Delta wetlands,[189] others, such as oyster farmers, point out the harm that added fresh water would do to their crop.[190] It is the conflict between the stakeholders that makes the management and restoration of the Delta wetlands difficult from a social and political point of view. Finding a consensus will be difficult, but until one is found, the wetland losses in the Mississippi River Delta will continue.

B. The Everglades

Wetland losses also occur as a side effect of other federal mandates. Nowhere is this more clear than in the Florida Everglades, where the Corps' water resource development authorizations have resulted in extensive loss of wetland functions and values.

"The Everglades is the largest subtropical wetland in the United States."[191] It was formed thousands of years ago when conditions allowed the formation of highly organic soils (peat) in the shallow embayment of southern Florida.[192] This unique ecosystem is the largest remaining wilderness east of the Mississippi.[193] The portion of the historic Everglades that is now the Everglades National Park (ENP) has been designated by the United Nations as a World Heritage Site and a World Biosphere Reserve.[194] It also is recognized as a Wetland of International Importance under the Ramsar Convention.[195]

The plight of the Everglades was brought to the forefront of American consciousness with Marjory Stoneman Douglas's book, *The Everglades: River of Grass*.[196] In fact, the Everglades is not a river

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189. *See* David P. Muth, *The Once and Future Delta*, *in* PERSPECTIVES ON THE RESTORATION OF THE MISSISSIPPI DELTA: THE ONCE AND FUTURE DELTA 9, 19 (John Day et al. eds., 2014).

190. *Id.*

191. Curtis J. Richardson, *The Everglades: North America's Subtropical Wetland*, 18 WETLANDS ECOLOGY & MGMT. 517, 517 (2010).

192. Christopher B. Craft & Curtis J. Richardson, *Soil Characteristics of the Everglades Peatland*, *in* THE EVERGLADES EXPERIMENTS: LESSONS FOR ECOSYSTEM RESTORATION 59, 59 (Curtis J. Richardson ed., 2008) (citing Patrick J. Gleason & Peter Stone, *Age, Origin, and Landscape Evolution of the Everglades Peatland*, *in* EVERGLADES: THE ECOSYSTEM AND ITS RESTORATION 149 (Steven M. Davis & John C. Ogden eds., 1994)).

193. Terence "Rock" Salt, Stuart Langton & Mary Doyle, *The Challenges of Restoring the Everglades Ecosystem*, *in* LARGE-SCALE ECOSYSTEM RESTORATION: FIVE CASE STUDIES FROM THE UNITED STATES 5, 6 (Mary Doyle & Cynthia A. Drew eds., 2008).

194. *Id.* at 5.

195. Richardson, *supra* note 191, at 518.

196. *See* MARJORY STONEMAN DOUGLAS, THE EVERGLADES: RIVER OF GRASS (2d ed. 1947).

consisting merely of grass. Technically not even a marsh, but a fen, the Everglades hosts a mosaic of hydrologically interconnected habitats of sawgrass ridges, tree islands, wet prairies, sloughs, and alligator holes.[197] Stoneman Douglas's imagery may not reflect the full diversity that exists in the Everglades. It is a diverse and challenged ecosystem containing a rich canvas of species: 2,000 plants, 45 mammals, 50 reptiles, 20 amphibians, hundreds of fish and 350 birds.[198] The headwaters can be found in the Kissimmee River Valley that feeds into Lake Okeechobee (along with Nubbin Slough, Taylor Creek, and Fisheating Creek). Historically, Lake Okeechobee retained most of the surface waters except in high-water periods, including storms, and connected with the Everglades via sheet flow at the southeastern edge and groundwater.[199] The Everglades' primary water source is precipitation (40-60 inches per year—75% of which falls between May and October), which moved via sheet flow in its unaltered state from Lake Okeechobee to Florida Bay.[200] Half of the "river of grass" has been lost, and what remains is fragmented. Only half of the original water flow makes it to the Everglades today.[201]

Substantial human alteration of the Everglades system began with agriculture and continued into the 1880s, when canals were installed to increase drainage and make southern Florida more suitable for development.[202] Canal building persisted through the early 1900s until it was noted that the system was ineffective in moving water off of developed agricultural lands and increased soil loss through oxidation and fire.[203] In 1948, the Central and Southern Florida Project was initiated with the intention of delivering water for flood protection, water and soil management, salinity intrusion reduction (also brought about by the canals), and other environmental benefits. The Tamiami Trail, a road

197. Richardson, *supra* note 191, at 518, 523, 531-32 (citing HAKAN RYDIN & JOHN K. JEGLUM, THE BIOLOGY OF PEATLANDS 2 (2006)).

198. *See* Salt, Langton & Doyle, *supra* note 193, at 5.

199. Thomas L. Crisman, *Everglades Ecology: The Impacts of Altered Hydrology*, *in* LARGE-SCALE ECOSYSTEM RESTORATION: FIVE CASE STUDIES FROM THE UNITED STATES, *supra* note 193, at 34, 34-35.

200. Salt, Langton & Doyle, *supra* note 193; Stephen Polasky, *Rivers of Plans for the Coastal River of Grass; The Political Economy of Everglades Restoration*, *in* LARGE-SCALE ECOSYSTEM RESTORATION: FIVE CASE STUDIES FROM THE UNITED STATES, *supra* note 193, at 44, 44; Richardson, *supra* note 191, at 522-23.

201. U.S. ARMY CORPS ENG'RS, COMPREHENSIVE EVERGLADES RESTORATION PLAN 1-1 to -2, 5-4 (Apr. 1999); Richardson, *supra* note 191, at 537.

202. *See* Fred Sklar et al., *The Effects of Altered Hydrology on the Ecology of the Everglades*, *in* THE EVERGLADES, FLORIDA BAY, AND CORAL REEFS OF THE FLORIDA KEYS: AN ECOSYSTEM SOURCEBOOK 40, 40 (James W. Porter & Karen G. Porter eds., 2002).

203. *Id.* at 45.

connecting Florida's east and west coasts, bisected the Everglades and disconnected water flow between the northern and southern Everglades.[204] In the 1960s, the Kissimmee River was straightened into a fifty-six-mile-long canal with six water-control structures.[205] Lake Okeechobee was encircled by an earthen levee called the Herbert Hoover Dike, preventing overflow in high-water events.[206] Water Conservation Areas were planned to store water and prevent its flow southward.[207] These events changed the Everglades' hydrology from sheet water flows to a system of more than 1,600 miles of canals and levees, more than 500 water-control structures, more than 700 culverts, and 60 pumping stations.[208] Alterations to historical hydrology have reduced flows by 70%.[209] The engineered system now delivers 1.7 billion gallons of fresh water into the Atlantic each day via pumps.[210]

Water previously allowed to seep into the limestone beneath the soil surface is now funneled through an intensely managed canal system so it no longer permeates the soil and recharges the aquifer. Anthropogenic drainage has exposed the formerly anaerobic peat to oxygen, which promotes its loss, thereby increasing subsidence.[211] The absence of water in organic peats causes dewatering and subsequent subsidence.[212] This leads to at least two changes: (1) the slope and flow of surface water not yet in the canals and (2) moderated vertical elevation differences between ridge and sloughs. The managed water depths also affect which plants exist in particular areas: in its preimpact state, nutrient inputs were low

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204. *Id.* at 42.

205. Salt, Langton & Doyle, *supra* note 193, at 7 (citing S. FLA. WATER MGMT. DIST., KISSIMMEE RIVER RESTORATION STUDIES TECHNICAL PUB. ERA 432, 1 ESTABLISHING A BASELINE PRE-RESTORATION STUDIES OF THE CHANNELIZED KISSIMMEE RIVER 1-5 (Stephen G. Bousquin et al., Nov. 2005), http://www.sfwma.gov/portal/page/portal/pg-grp-tech-pubs/portlet_tech_pubs/era-432.pdf).

206. Crisman, *supra* note 199, at 36 (citing MICHAEL GRUNWALD, THE SWAMP: THE EVERGLADES, FLORIDA, AND THE POLITICS OF PARADISE 199 (2006)); Alan D. Steinman et al., *The Past, Present, and Future Hydrology and Ecology of Lake Okeechobee and Its Watersheds*, *in* THE EVERGLADES, FLORIDA BAY, AND CORAL REEFS OF THE FLORIDA KEYS: AN ECOSYSTEM SOURCEBOOK, *supra* note 202, at 19, 28.

207. *See* Salt, Langton & Doyle, *supra* note 193, at 7.

208. E-mail from Julie Lyons, S. Fla. Water Mgmt. Dist., to Lori Sutter (Mar. 14, 2012, 10:00 AM EST) (on file with author).

209. Richardson, *supra* note 191, at 537.

210. Salt, Langton & Doyle, *supra* note 193, at 8. See Appendix A for a representation of each of these areas.

211. Sklar et al., *supra* note 202, at 44 (citing B.S. Clayton, J.R. Neller & R.J. Allison, *Water Control in the Peat and Muck Soils of the Florida Everglades*, 378 BULL.-U. FLA. AGRIC. EXPERIMENT STATION 15 (1942)).

212. *Id.* at 45.

and water depth controlled the distribution of vegetation.[213] Continual high water is known to impact plant reproduction, especially limiting genetic diversity as a result of lowered nonvegetative reproduction success.[214] Cattail (*Typha domingensis* Pers.) has replaced the native dominant, sawgrass (*Cladium jamaicense* Crantz). Extensive research has linked this phenomenon to prolonged wetting as well as nutrient enrichment.[215]

Nutrients historically arrived in the Everglades via atmospheric deposition (both rainfall and dry fallout), which is typically low in phosphorus (P),[216] the limiting nutrient in most freshwater wetlands. Slough vegetation appears to be most sensitive to P-enrichment.[217] The high density of agricultural lands feeding the canal system leads to increased runoff high in fertilizers—particularly P from sugar cane.[218] Short-term P-enrichment results in increased growth, which may increase accumulation of highly organic detritus; extended enrichment shifts the composition of vegetation, such as previously described with cattail and sawgrass. In some areas, the now-abundant P has shifted the limiting nutrient toward N, which can lead to loss of species adapted to life in low-P environments with a concomitant gain of species able to grow more quickly in the presence of higher P. This shift occurs not only with macrophytes, but also periphyton (algae, bacteria and other microorganisms), which can, in turn, reduce levels of dissolved oxygen in the water column.[219] Impacts are carried up through the food web; more species of invertebrates and small fish tend to appear in enriched areas relative to unenriched areas.[220]

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213. *See id.* at 44.

214. Kimberli J. Ponzio, Steven J. Miller & Mary Ann Lee, *Germination of Sawgrass,* Cladium Jamaicense Crantz*, Under Varying Hydrologic Conditions*, 51 AQUATIC BOTANY 115, 117 (1995).

215. *Id.* (citing J.W. BRADBEER, SEED DORMANCY AND GERMINATION (1988)).

216. Paul V. McCormick et al., *Effects of Anthropogenic Phosphorus Inputs on the Everglades*, *in* THE EVERGLADES, FLORIDA BAY, AND CORAL REEFS OF THE FLORIDA KEYS: AN ECOSYSTEM SOURCEBOOK, *supra* note 202, at 83, 85.

217. *See* J.P. Sah et al., *Trajectories of Vegetation Response to Water Management in Taylor Slough, Everglades National Park, Florida*, 34 WETLANDS 65, 77 (2014).

218. WILLIAM R. LOWRY, REPAIRING PARADISE: THE RESTORATION OF NATURE IN AMERICA'S PARKS 112 (2009); McCormick et al., *supra* note 216, at 83, 97; Salt, Langton & Doyle, *supra* note 193, at 12.

219. McCormick et al., *supra* note 216, at 83, 90 (citing JOAN A. BROWDER ET AL., NAT'L MARINE FISHERIES SERV. & NAT'L PARK SERV., REP. T-662, BIOMASS AND PRIMARY PRODUCTION OF MICROPHYTES IN PERIPHYTON HABITATS OF THE EVERGLADES (May 1982); Russell B. Rader & Curtis J. Richardson, *Response of Macroinvertebrates and Small Fish to Nutrient Enrichment in the Northern Everglades*, 14 WETLANDS 134 (1994)).

220. *See* Rader & Richardson, *supra* note 219, at 138.

The system of canals impacts not only the delivery of nutrients from urban and agricultural runoff, but also the flow of pesticides, herbicides, and heavy metals.[221] Hydrologic manipulation leads to altered states of fire, an important component of Everglades ecology.[222] The engineered hydrology that changes fire frequency from its natural nine-year cycle may change the dominant vegetation or lead to long-lasting, underground peat fires that can be especially devastating.[223] High fire frequency limits the success of the native grass, sawgrass, but the invasive Brazilian pepper (*Schimus terebinthifolius*) is successful in drained habitats, regardless of fire.[224]

Canals fragment the landscape and break up the seamless transition of habitats along the natural gradient. They also can serve as biotic conduits—pathways for exotic plants and animals to disperse.[225] According to the Florida Department of Environmental Protection, 1.5 million acres of land presently host invasive species.[226] Southern Florida has experienced a population decline in wading birds[227] with some populations declining "by 90% since the 1930s."[228] Some sixty-eight species are considered threatened or endangered.[229]

Although designated as a national park in 1947, it was not until 1970 that Congress recognized the adverse impact draining was having

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221. Robert A. Miller & Harold C. Mattraw, Jr., *Storm Water Runoff Quality from Three Land-Use Areas in South Florida*, 18 WATER RESOURCES BULL. 513, 517 (1982).

222. *See* Sklar et al., *supra* note 202, at 40, 58 (citing DALE WADE, JOHN EWEL & RONALD HOFSTETTER, U.S. DEP'T AGRIC., FOREST SERV. GEN. TECHNICAL REP. SE-17, FIRE IN SOUTH FLORIDA ECOSYSTEMS (Mar. 1980)).

223. *Id.* at 56-58 (citing Yegang Wu et al., *Fire Simulations in the Everglades Landscape Using Parallel Programming*, 93 ECOLOGICAL MODELLING 113 (1996)).

224. Crisman, *supra* note 199, at 37 (citing Robert F. Doren, Louis D. Whiteaker & Anne Marie LaRosa, *Evaluation of Fire as a Management Tool for Controlling* Schinus terebinthifolius *as Secondary Successional Growth on Abandoned Agricultural Land*, 15 ENVTL. MGMT. 121 (1991); Alan Herndon, Lance Gunderson & John Stenberg, *Sawgrass (*Cladium Jamaicense*) Survival in a Regime of Fire and Flooding*, 11 WETLANDS 17 (1991)).

225. *See* Sklar et al., *supra* note 202, at 40-56 (discussing the geographic extent of canals through the Everglades).

226. Salt, Langton & Doyle, *supra* note 193, at 9 (citing FLA. DEP'T ENVTL. PROT., DEPARTMENT OF ENVIRONMENTAL PROTECTION FINAL LONG-RANGE PROGRAM PLAN FOR FY 2006-07 THROUGH FY 2010-11, at 36 (2006)).

227. Dale E. Gawlik & Fred Sklar, *Critical Ecosystems Studies Initiative Task 3: Effects of Hydrology on Wading Bird Foraging Parameters Report*, U.S. GEOLOGICAL SURVEY (Feb. 18, 2000), http://sofia.usgs.gov/publications/reports/wading_bird/index.html (citing Carl Walters, Lance Gunderson & C.S. Holling, *Experimental Policies for Water Management in the Everglades*, 2 ECOLOGICAL APPLICATIONS 189, 195 (1992)).

228. William F. Loftus & Dale E. Gawlik, *How Will Research on Fishes and Wading Birds Guide and Evaluate Everglades Restoration?*, U.S. GEOLOGICAL SURVEY, http://sofia.usgs.gov/sfrsf/rooms/wild_wet_eco/fish_bird/program.html (last updated Jan. 15, 2013, 12:44 PM).

229. Phyllis McIntosh, *Reviving the Everglades*, NAT'L PARKS, Jan./Feb. 2002, at 30, 30.

on the area and required that a minimum water flow be diverted into the park.[230] In 1989, the ENP expanded in size, and the Corps was directed to modify its drainage network, increasing flows to the park and making progress toward the restoration of natural hydrology.[231] The state of Florida also recognized the need for restoration with legislation, such as the Save Our Everglades Act in 1983 and the Surface Water Improvement and Management Act (SWIM) of 1987.[232] Implementation of SWIM in Lake Okeechobee and Biscayne Bay were completed, but the Everglades SWIM plan was the subject of litigation.[233] The revised postlitigation plan called for 40,000 acres of treatment wetland to be created/restored within the Everglades Agricultural Area (EAA) immediately below Lake Okeechobee to remove P coming off the sugar fields and into the ENP.[234] In 1992, a consent decree was established calling for storm water treatment areas to meet certain P-limits entering ENP (as well as nearby Loxahatchee National Wildlife Refuge).[235] The Everglades Forever Act (EFA)[236] established both a tax on farmers within the EAA and imposed best management practices to reduce P-inputs and limit the incursion of invasive species. It is the EFA with the federal Water Resources Development Acts (WRDA)[237] that "form much of the legal basis for current Everglades restoration."[238] The lead planning and implementation agency is the Corps, but many state and federal agencies are also involved.[239] The 1996 WRDA directed the Corps to review what is needed for ecosystem restoration.[240]

The Everglades' beauty and function may warrant protection, but because Florida is one of the country's fastest growing states in terms of number of inhabitants, it is the Everglades' status as the coastline population's primary source of freshwater that drives its protection. The Corps' review of water management led to development of the Comprehensive Everglades Restoration Plan (CERP), which was

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230. Salt, Langston & Doyle, *supra* note 193, at 11.
231. *Id.*
232. *Id.*
233. *Id.*
234. *Id.* at 12.
235. *Id.* (citing United States v. S. Fla. Water Mgmt. Dist., 847 F. Supp. 1567 (S.D. Fla. 1992)).
236. Everglades Forever Act, Fla. Stat. § 373.4592 (2010).
237. Water Resources Development Act (1992), Pub. L. No. 102-580, tit. II, § 205, 106 Stat. 482 (1992); Water Resources Development Act (1996), Pub. L. No. 104-303, tit. II, § 212, 110 Stat. 3684 (1996); Water Resources Development Act (2000), Pub. L. No. 106-541, tit. III, § 309, 114 Stat. 2572 (2000).
238. Salt, Langton & Doyle, *supra* note 193, at 12.
239. *See id.* at 13-17.
240. *Id.* at 13.

authorized by WRDA 2000 and remains as the framework for Everglades restoration to this day.[241]

CERP authorized restoration at the cost of $7.8 billion with the goal of "getting the water right."[242] The total cost of South Florida restoration, including both water flows and habitat protection is estimated to be $14.8 billion,[243] a figure that was later updated to $19.7 billion.[244] Reconnecting the hydrology and landscape of southern Florida is the largest effort of its kind, including some 200 individual restoration projects, 68 of which are specifically outlined within CERP.[245] The progress is slow. Federal funding has been delayed, leading state officials to undertake some projects on their own.[246]

Thomas Crisman[247] suggests that restoration is too lofty; rather, he submits that rehabilitation may be in order—recognizing that the structure and function of Everglades may never return to the state it was in prior to human impact.[248] Whether we restore or rehabilitate, this effort is considered a test to modern society's resolve to maintain the ecosystem in the face of many pressures and management regimes.[249]

VI. CONCLUSION

Wetlands are complex ecosystems. A particular wetland's functions—its physical, chemical, and biological processes—can provide a range of important ecosystem services to people. Many wetland systems in the United States, however, such as those in the Mississippi

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241. *Id.* CERP components are (1) Surface Water Storage Reservoirs, (2) Water Preserve Areas, (3) Management of Lake Okeechobee as an Ecological Resource, (4) Improved Water Deliveries to the Estuaries, (5) Underground Water Storage, (7) Treatment Wetlands, (8) Improved Water Deliveries to the Everglades, (9) Removal of Barriers to Sheetflow, (10) Storage of Water in Existing Quarries, (11) Reuse of Wastewater, (12) Pilot Projects, (13) Improved Water Conservation, (14) Additional Feasibility Studies. *Comprehensive Everglades Restoration Plan: The Plan in Depth—Part 1*, EVERGLADESRESTORATION.GOV, http://141.232.10.32/about/rest_plan_pt_01.aspx (last visited Oct. 10, 2015).

242. U.S. ARMY CORPS ENG'RS, *supra* note 201, at 1-3, 8-12.

243. Salt, Langton & Doyle, *supra* note 193, at 14.

244. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-07-520, REPORT TO COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE, HOUSE OF REPRESENTATIVES: SOUTH FLORIDA ECOSYSTEM: RESTORATION IS MOVING FORWARD BUT IS FACING SIGNIFICANT DELAYS, IMPLEMENTATION CHALLENGES, AND RISING COSTS 35 (2007).

245. *Id.* at 3 & n.2.

246. *Id.* at 23.

247. Crisman, *supra* note 199, at 40.

248. *Id.* at 40-41.

249. Richardson, *supra* note 191, at 518 (citing Curtis J. Richardson, *An Ecological Approach for Restoration of the Everglades Fen*, *in* THE EVERGLADES EXPERIMENTS: LESSONS FOR ECOSYSTEM RESTORATION, *supra* note 192, at 640-41).

Delta and the Everglades, have been significantly and adversely altered through numerous human activities.

These wetland losses have occurred despite the existence of the CWA and similar laws that require government approval before a proposed project harms a wetland. Most permit applications are granted, albeit often with the condition that the functional loss be offset through compensatory mitigation. These individual compensatory mitigation projects (whether performed by the permittee or a mitigation bank or otherwise) do not necessarily replace the lost functions and services. The massive wetland restoration projects that the government is undertaking along the Gulf and in the Everglades serve to underscore the technical challenges and economic costs of attempting to restore wetland functions and services once they are lost. It would be better to avoid wetland impacts in the first instance.

CWA regulations (the section 404(b)(1) guidelines) do state that wetland impacts are to be avoided if practicable.[250] But as noted by Wilkinson and his coauthors, while much of the Corps and EPA's focus has been on "improving the third step in the mitigation process—compensatory mitigation," the agencies have paid little attention to developing "tools, guidance and/or regulations to ensure the rigorous application of [the] avoidance" requirement.[251] Avoidance especially ought to be invoked with respect to wetlands that are difficult to restore.[252]

Moreover, CWA regulations provide an additional ground for permit denial: "No discharge of dredged or fill material shall be permitted if it . . . [c]auses or contributes to violations of any applicable State water quality standard."[253] Thus, even if the permit applicant can demonstrate that avoidance is not "practicable," the Corps can deny the permit on the basis of the proposed project's contribution to the cumulative impacts in a watershed.[254]

The counterargument is that permit denials will unduly infringe on private property rights and open the government to just compensation

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250. 40 C.F.R. § 230 (2014).

251. JESSICA B. WILKINSON ET AL., THE NEXT GENERATION OF MITIGATION: LINKING CURRENT AND FUTURE MITIGATION PROGRAMS WITH STATE WILDLIFE ACTION PLANS AND OTHER STATE AND REGIONAL PLANS 35 (2009) (citing James Murphy, Jan Goldman-Carter, & Julie Sibbing, *Avoidance Avoided: How the New Rule Fails To Adequately Promote Avoidance and Places Difficult-To-Replace Systems at Risk*, 31 NAT'L WETLANDS NEWSL. (Envtl. Law Inst., Wash., D.C.), Mar.-Apr., 2009, at 14).

252. NAT'L RESEARCH COUNCIL, *supra* note 57, at 4.

253. 40 C.F.R. § 230.10(b)(1).

254. *Id.* § 230.10(a).

payments. While the specter of regulatory takings does appear to influence the Corps' willingness to grant permits,[255] it is generally difficult for a disappointed permit applicant to bring a successful case.[256] However, the U.S. Supreme Court's most recent pronouncement on this point in *Koontz v. St. Johns River Water Management District*[257] may well encourage additional challenges or lead agencies to not require sufficient compensatory mitigation.[258]

To be sure, if more permits are denied, we as a society may have to pay more regulatory takings claims. But if more permits are not denied, we as a society will still pay—through either large-scale restoration efforts and/or lost ecosystem services.

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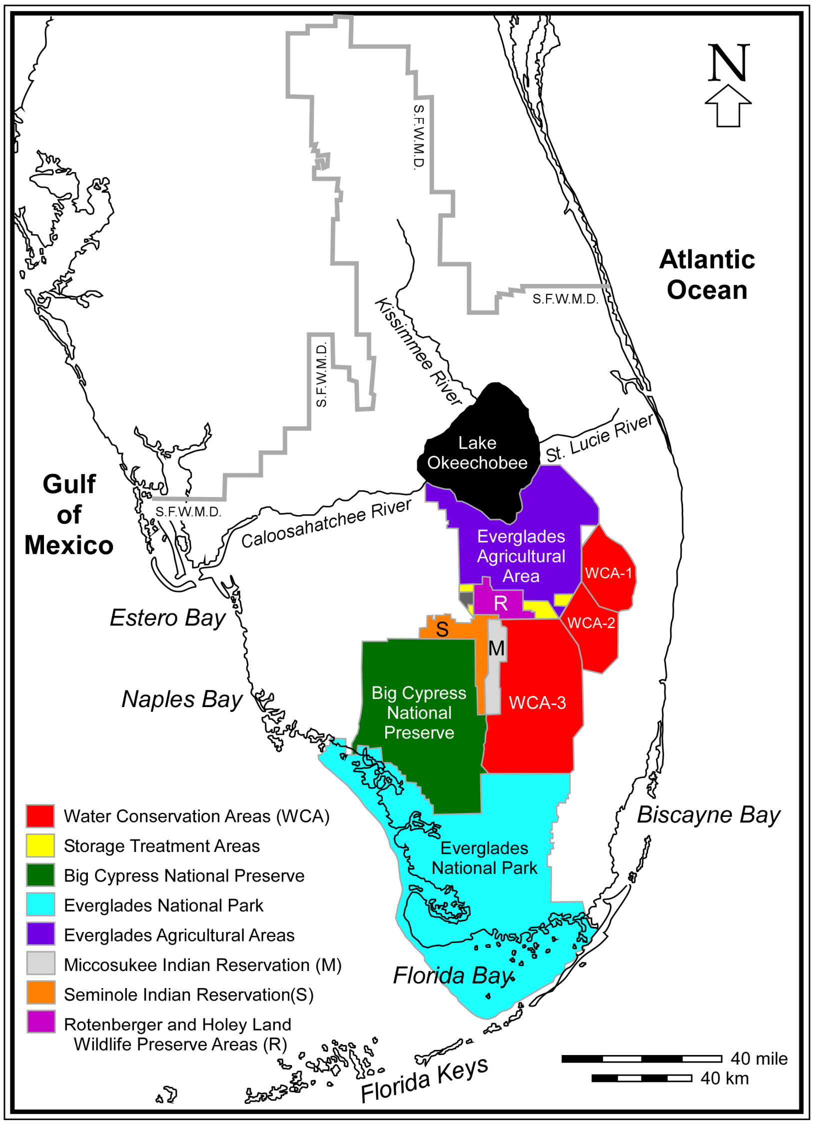
255. *E.g.*, Sierra Club v. Van Antwerp, 709 F. Supp. 2d 1254, 1269 (S.D. Fla. 2009), *aff'd*, 362 F. App'x 100 (11th Cir. 2010) (observing that "the Corps' decision to issue the permits was at least in part based on the Corps' belief that financial costs to the United States, i.e., from inverse condemnation actions by the miners (which may or may not succeed), might result from any prohibitions or limits on the proposed limestone mining").

256. *See* GARDNER, *supra* note 117, at 177-90 (discussing wetland regulatory takings cases).

257. 133 S. Ct. 2586, 2603 (2013) (holding that a permit condition requiring off-site mitigation could be an unconstitutional exaction).

258. Royal C. Gardner, *Lawyers, Swamps, and Money: Koontz and Off-Site Mitigation*, ISLAND PRESS (July 29, 2013), http://www.islandpress.org/node/579.

Appendix A
Boundaries in the Florida Everglades.



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