# BSU

## Honors Program

Kristina Erickson

# Analysis of “No Net Loss” Wetland Mitigation Policy

Aquatic Biology

May 3rd 2017

Bemidji State University
Honors Program
Department of Biology

Analysis of "No Net Loss" Wetland Mitigation Policy
Kristina Erickson

Richard Koch, Ph.D. Date 1-May-2017
Wetlands Ecology Professor and Advisor

Season Ellison, Ph.D. Date 3 may 2017
Assistant Professor of Interdisciplinary Studies Director of
Honors and Liberal Education Programs

Mark Fulton Ph.D. Date 1-May-2017
Forestry Professor and Advisor

**An Examination of "No Net Loss" Wetland Mitigation Policy**

Kristina Erickson

**Abstract**

Wetlands in the United States have long been destroyed and degraded to make way for anthropogenic development. In recent history, efforts have been made to slow this degradation. The "no net loss" wetland mitigation policy has been in effect since 1991 and seeks to balance the needs of both industry and the environment. However, this policy is flawed. The regulatory process favors the interests of industry and the United States continues to lose wetlands and and their important functions. Therefore, the examination of the current policy is key to prevent future loss of wetland functions.

## Introduction

For a large part of United States history, wetlands have been seen as an obstacle to industry and agriculture (Fretwell et al. 1996). During the early settlement of the country, wetlands made overland travel more difficult by blocking the production of food and fiber (Fretwell et al. 1996). Floodplains also are very fertile for farming and therefore were drained for agricultural reasons (Fretwell et al. 1996).

With the development of technology such as construction machinery, transportation, and farm equipment, the expansion of the United States increased (Fretwell et al. 1996). As expansion increased so did the drainage and damage of wetlands, often with the encouragement of government policy (Fretwell et al. 1996). In 1849, Congress passed the first Swamp and Land acts which allowed for the swamplands of Louisiana to be given to the state for reclamation (Fretwell et al. 1996). The Swamp and Land Acts were made applicable in 12 more states and set the precedent that the United States government encouraged wetland drainage (Fretwell et al.

1996). Further development and expansion projects subsidized by the government would cause continued draining of wetlands (Fretwell et al. 1996).

As of late, education has lead to an understanding of the importance of wetlands and the ecosystem services they provide (Fretwell et al. 1996). However, this only came after the United States had lost over 50% of its native wetlands (Peralta et al. 2010), California lost over 95% of its wetlands, and five other states lost over 85% of their wetlands (Fretwell et al. 1996).

Although, we have begun to protect our wetlands, many regulations tend to favor industry. Furthermore, the recent  proposed budget from President Donald Trump contains billions in cuts to the Environmental Protection Agency (EPA), one of the main bodies overseeing the protection of wetlands (Thrush and Davenport 2017). In conjunction, with the removal of environmental protection regulations the budget cuts make it clear that the administration will favor industry over environmental protection. It seems that, the conservation of wetlands will only be a priority when the public realizes that their loss is detrimental to human needs.

**Benefits of Wetlands**

Wetlands are some of the most diverse and production habitats on the planet. They appear on every continent except Antarctica. Wetlands provide more ecosystem functions than any other habitat per hectare (Peralta et al. 2010). Wetlands provide a multitude of functions that benefit both human populations and the environment.

### *Flood Prevention*

Wetlands prevent flooding by absorbing water overflow and slowing its release into the surrounding landscape. Wetlands are regarded as being the best landscape for preventing seasonal flooding while floodplains are in particular the best at reducing the damage from peak flood events (Watson et al. 2016).

Out of any natural disaster flooding kills the highest number of people every year.(Watson et al. 2016). Furthermore, peak flood events are increasing in frequency, because as climate specialists agree, increased rain events are becoming more and more common (Watson et al.). In addition, the increase in peak events is attributed to the channelization of rivers and the levees constructed on rivers banks (Watson et al. 2016). By channeling and containing rivers we improve flooding conditions in the local area but drastically increase flooding downstream (Watson et al 2016).

### *Water Purification*

Similar to how wetlands prevent flooding, they also help to purify water. Wetlands slow the flow of water which allows for heavy metals and other impurities to sink out the water supply (Robertson 2004). By eliminating wetlands more pollution enters the nation's rivers and pollution levels downstream increase (Peralta et al. 2010).

### *Carbon Sequestration*

Wetlands aid in the storage of carbon in several ways. First, wetland soils are often saturated with water (Adhikari et al. 2009). Therefore, they support anaerobic soil conditions that often trap the carbon in the soil (Adhikari et al. 2009). By lowering the water level in these wetlands it can oxidize and release the stored carbon into the atmosphere.

Peatland wetlands have been recognized mainly for their ability to store carbon (Adhikari et al. 2009). They remove CO2 from the atmosphere via photosynthesis and then store some of this carbon in the accumulating peat (Frolking and Fuglestvedt 2006). Although wetlands only cover 6% of the earth's surface they account for 12% of the earth's carbon sequestration (Erwin 2008).

*Wildlife Habitat*

Wetlands play a large role in regional biodiversity of the ecosystem. They provide habitat for many wetland dependent plant and animal species such as frogs, ducks, turtles, and many diverse plant species. Boylan and Maclean (1997) estimate that 46% of the endangered species in the United States are wetland dependent.

Wetlands provide feeding and breeding grounds for many species (Kalen 1993). These species include those that are endangered and threatened (Kalen 1993). Included in these species are waterfowl which are sought after for sport. Seasonal wetlands also provide habitat for migratory waterfowl (Whigham 1999)

**History of Wetland Legislation**

The Swamp and Land Acts of 1849, 1850, and 1860 encouraged the draining and filling of wetlands for the sake of expansion (Kalen 1993). Later, it was realized that these waterlogged landscapes performed important roles within the landscape.

The River and Harbors Act of 1899, is known as the oldest environmental protection legislation (Kalen 1993). This Act made it a misdemeanor to discharge any refuse into what was considered navigable waters of the United States (Kalen 1993). The act was enacted after the creation of The National Rivers and Harbors Congress and the Inland Waterways Commission (Kalen 1993).

Section 9 of The Rivers and Harbors Act, requires congressional approval to create any kind of dam, dike, or causeway that affects a navigable water (Kalen 1993). Section 10, requires the same approval for any obstruction of navigable waters (Kalen 1993). Although the Act was the first attempt at conservation of the nation's water the focus was mainly for ease of movement for commerce and military reasons (Kalen 1993).

In the 1960s, two Supreme Court cases helped this change to focus on ease of commerce to that of protection against pollution (Kalen 1993). One of these cases stopped the Republic Steel Corporation from dumping industrial waste into the Mississippi River (Kalen 1993).

In 1972, The Water Pollution Control Act was enacted (Robertson 2004). The Water Pollution and Control Act gave the United States Government the ability to regulate land use (Robertson 2004). Later, in 1977, the Water Pollution and Control Act later became the Clean Water Act (Robertson 2004).The Clean Water Act has two major parts. The first deals with the federal financing of sewage treatment plants, and the second pertains to industrial and municipal discharges (Copeland 2006). Before, 1987 the main focus was on point source pollution (Copeland 2006). However, after 1987, the focus went to nonpoint source pollution, which accounts for roughly 50% of the pollution to our nation's waterways (Copeland 2006).

This section of the Clean Water Act influences wetland protection as it pertains to the filling and draining of water of the United States, including some wetlands (Bendor 2009).

Section 404 of the Clean water act gives the Army Corps of Engineers (ACOE) and the EPA the responsibility for overseeing the draining and filling of wetlands (Bendor 2009).

These regulations may be a direct result of the Ramsar Convention, which was held in February of 1971 (Matthews 1993). This convention contained 18 countries whose representatives came together to discuss the importance of wetland conservation (Matthews 1993).

“No Net Loss” is a wetland policy championed by President George H.W. Bush and late 1980s and echoed by President Bill Clinton (Salzman 2005). The policy is su the idea that any degradation of wetlands can be compensated for by restoring or creating another wetland (Salzman 2005). The policy was politically popular because it addressed environmental concerns while simultaneously supporting development and economic progress.

In 1987, the EPA held the National Wetland Policy Forum. The forum contained a wide degree of stakeholders that met to address policies concerning how the country should handle its wetland policy (Bendor 2005). The conference ended with the recommendation of “No Net Loss”. In 1990, both the ACOE and EPA endorsed the “No Net Loss” policy.

**Permitting Process for "No Net Loss"**

The definition of a wetland used by the EPA and ACOE is as follows:

"Wetlands are areas that inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas"

-Definition of a wetland used by the ACOE and EPA for regulatory purposes since 1970.

This definition is used to define "Jurisdictional wetlands" or wetlands that fall under the permitting control of the ACOE and the EPA in accordance with Section 404 of the Clean Water Act (Section 404).

According to Section 404 of the Clean water act no filling or discharge is allowed into a Jurisdictional Wetland without a permit from the ACOE. The ACOE can grant two types of permits. The first, being a general permit, issued for projects that will have a minimal impact and can be issued nationwide or regionally (Sunding and Zilberman 2002). For example, these permits can be issued for minor road crossings or utility line backfills (Sunding and Zilberman 2002). Individual permits are granted for developers looking to take on larger projects (Sunding and Zilberman 2002).

The ACOE receives applications for individual permits and then can take one of three actions 1). Deny the permit 2) Accept the permit 3) Accept the permit with the contingency of compensation (Robertson 2004). The outline for the permit review process can be found in The Corps Regulatory Program Regulations (Brinson and Rheinhardt 1996). Before a permit is accepted it must be shown that there are no practical alternatives exist, and that all steps to minimize damage have been taken (Section 404).

There are three ways that a company can provide wetland compensation. The first is creation, or taking a upland habitat and turning into a wetland habitat (Brinson and Rheinhardt 1996). Second, restoration, or taking a degraded wetland and restoring its function (Brinson and Rheinhardt 1996). Last, the company can provide in Lieu Fee Mitigation, or donate funds to organization that purchases land for the sake of restoration or creation of a wetland (Brinson and Rheinhardt 1996). Compensation can be done on-site, which is preferred, or off site (Brinson and Rheinhardt 1996).

**Wetland Mitigation Banking**

In 1993, President Bill Clinton released his plan for the protection of the nation's wetlands (Silverstein 1994). This plan sited wetland mitigation banking as a way to both save our nation's wetlands as well as protect commercial interests (Silverstein 1994).

Wetland Mitigation Banking, is the process of third parties performing creation or restoration of wetlands to gain credits (Robertson 2004). These credits can then be sold to developers looking to degrade a wetland (Robertson 2004). This free market approach has been advocated for by both President Clinton and President George W. Bush (Silverstein 1994). The approach was proposed because, many wetland mitigation sites were not successful (Robertson

2004). In the 1980s mitigation was common but many of the sites were not successful or were of poor ecological quality (Robertson 2004). Furthermore, industrial interests felt the permitting process was too difficult and discouraged development (Robertson 2004). Mitigation Banking was meant to solve these problems by: restoring wetlands and establishing their success before the destruction of a wetland, allow restoration to be completed on less expensive land, and speed up the permitting process for developers (Robertson 2004).

In 1991, one year after the EPA and ACOE endorsed "no net loss" they endorsed Mitigation Banking (Race and Fonseca 1996).Although, Mitigation Banking was meant to solve many of the problems associated with wetland mitigation it also has its downsides (Robertson 2004). Off-site mitigation causes a direct loss of wetlands to a particular area (Robertson 2004). Also, it makes in-kind mitigation less likely (Robertson 2004). Last, created wetlands do not perform the same level of function as natural wetlands and Mitigation Banking encourages the degradation of wetland by easing the process. Limitations of Mitigation Banking will be discussed as cons of wetland mitigation.

## Cons of Wetland Mitigation

### *Wetland Type Discrepancy*

The Department of Natural Resources (DNR) sites two separate methods for classifying wetlands (Types). The first was Circular 39, established by Shaw and Fredine in 1956 (Types). According to this system there are 20 different types of wetlands, and eight of these are found in

Minnesota (Types). The Cowardin system of classification takes into account different modifiers for wetland classification (Types). Both these methods establish that there are many different types of wetlands with a complex array of functions. Therefore, mitigation often does not account for the replacement of different wetland types.

Furthermore, some types of wetlands are more difficult if not impossible to replace. River floodplains cannot be replaced without creating a river for water transport or the expansion of an existing floodplain (Brinson and Rheinhardt 199). Creating a river is problematic and expanding a floodplain jeopardizes surrounding upland habitat (Brinson and Rheinhardt 1996). Peatland wetlands cannot be recreated without taking peat from an existing wetland or waiting the decades to centuries it takes for peat to form naturally (Brinson and Rheinhardt 1996).

Open water wetlands are often favored for mitigation. Several studies have determined that mitigation has caused a lower diversity in the types of wetland present (Robertson 2004).

*Wetlands Not Covered Under the Clean Water Act*

Dry-end wetlands are wetlands that are intermittently flooded and may only be saturated for a short period of time (Whigham 1999). Some of these wetlands are isolated, maintained by fluctuating ground water, and are not connected to any open water system (Whigham 1999). Often they are depressional wetlands such as vernal pools and playas (Whigham 1999). These wetlands often fall under umbrella nationwide permits that provide an easy means for development. Also, these types of wetlands may not be considered Jurisdictional Wetlands and not protected under the Clean Water Act at (Whigham 1999).

The argument for not protecting these dry-end wetlands is mainly based on the idea that they do not provide a significant level of benefit (Whigham 1999). However, seasonally flooded wetlands offer important habitat for migrating waterfowl (Whigham 1999). They also tend to be some of the first wetlands that receive runoff from agricultural fields and help to reduce pollution from entering the main water sources (Whigham 1999).

*Temporal Loss of Wetland Function*

Wetlands do not appear overnight. They are complex systems that are influenced by succession (Ruiz-Jean and Aide 2005). The soil nutrients, organisms, and plant communities all take decades to appear (Ruiz-Jean and Aide 2005). In 1991, Frenkel and Morlan did a study that estimated it would take 50 years to restore a dike salt marsh in Oregon to its former status. Even wetlands are often mitigated ahead of a proposed project there is still a loss of wetland functions for a large amount of time.

Another study done by Hitzhusen et al. (2004), estimated that it could take between 13-33 years for a particular wetland to reach maturity. It was also found that this estimated lag time could cost between $16,640 and $27,392.

*Spatial Loss of Wetland Functions*

On-site and In-kind mitigation are the preferred methods for compensation. These types of mitigation most closely replace the functions of the wetland degraded (Bendor 2009).

However, this is not always possible and the institution of Mitigation Banking makes this like compensation less likely (Bendor 2009). Therefore, the local ecosystem and community loses the wetland functions provided as they are created somewhere else.

*Risk of Compensation Site Failure*

As previously discussed wetlands are some of the most complex ecosystems on the planet. One of the most important and difficult aspects to replace is Hydrology. A wetland needs a water source whether it be groundwater, surface water, precipitation, or runoff (Bedford 1996). Moreover, wetlands need landscapes that promote water retention such as surface relief, and a thick semi or non-permeable soil layer (Bedford 1996). Also, low elevations are more likely to support wetland hydrology than higher elevations (Peralta et al. 2010). Because, of the complexity of wetland systems there is a chance of site failure (Bedford 1996). In one study it was found that 60% of mitigation credits had not met goals of restoration in one Chicago district (Bendor 2009).

To adjust for the possibility of failure it is often required for the developer to restore or create a larger area of wetland than the area being degraded (Bendor 2009). This is called the mitigation ratio, and increases with the suspected degree of failure (Bendor 2009).

*Lack of Knowledge and Limited Study Length*

The ideal goal for any restoration project is to create an ecosystem that can sustain itself without any further assistance (Ruiz-Jean and Aide 2005). The Society of Ecological Restoration International produced a primer that lists nine criteria for successful regulation, however, three main criteria are relied on for restoration. 1) diversity 2) vegetation 3) Ecological processes (Ruiz-Jean and Aide 2005).

Often these criteria are not met by restoration projects. One of the main reasons for this failure is the short study length of most mitigation projects (Ruiz-Jean and Aide 2005). Most mitigation studies take place for 4 years whereas longer studies ranging from 5- 10 years (Ruiz-Jean and Aide 2005). The problem is that wetlands mature much slower than this.

West et. al. did a study in 2000 to address the importance of study length in assessing a wetland (Ruiz-Jean and Aide 2005). They studied a marsh and found that if the study would have ended at the 4 year mark the species pool would have been underestimated by 20% (Ruiz-Jean and Aide 2005).

Studies on wetland mitigation often only take place for the duration the mitigation is needed for permitting reasons. Many sites are susceptible to flushing during storm events because they were not originally meant to contain wetland hydrology (Ruiz-Jean and Aide 2005). After the study duration it is often possible for the restoration site to return to its uppland state.

Wetland creation and restoration are relatively new prospects. With our knowledge base still in its infancy it is often difficult to assess if restoration has been or will be successful. The main reason for the lack of research and study duration is the lack of funding available for long term research projects (Ruiz-Jean and Aide 2005).

*Degraded Wetland Sites May No Longer Support Wetland Hydrology and Vegetation*

Many wetlands were reclaimed as farmland. Although the land once supported a wetland farming greatly changes the soil composition and the hydrology of the land (Ruiz-Jean and Aide 2005). In a study done on the 342 hectare Morris Wetland Bank it was found that bacterial communities were significantly different than that of nearby reference wetlands (Ruiz-Jean and Aide 2005). The soil moisture, organic carbon, total nitrogen, and nutrient composition also did not match that of reference wetlands (Ruiz-Jean and Aide 2005).

Another study done in Barra Farms Regional Wetland Mitigation Bank, found that turning the land into farmland had required the building of drainage ditches (Bruland et al. 2003). The drainage caused the water table to be lowered directly resulting in the oxidation of previously reduced soils (Bruland et al. 2003). Hence permanently changing the chemical makeup of the soil (Bruland et al. 2003).

*Created and Restored Wetlands do not Meet the Same Functions as Naturally Occurring Wetlands*

Vegetation plays a large role in both the function and the identification of wetlands (Balcombe et al. 2005). Therefore, vegetation communities can be used as a criteria for successful mitigations. In a study done in West Virginia 11 mitigated wetlands were compared to reference wetlands (Balcombe et al. 2005). It was found that the plant species differed between mitigated wetlands and natural wetlands (Balcombe et at. 2005). This was felt to be a direct result of the maturity of the wetland with some hydrophytic species being more quick to establish themselves (Balcombe et al. 2005). The study also found that mitigated wetlands had higher rates of invasive species than natural wetlands did (Balcombe et al. 2005). This may be due to the ability of these invasive species to take over and outcompete unestablished native species. Last, it was found that mitigated wetlands had lower numbers of submerged wetland vegetation (Balcombe et al. 2005). Submerged vegetation is largely correlated with increased water quality (Balcombe et al. 2005).

Hydrology is the most defining characteristic of a wetland. How water flows into and out of system determines the vegetation diversity, nutrients available, and its ability to perform important wetland functions such as flood control. Balcombe et al 2005, found that when studying four mitigated sites compared to natural wetlands that the hydrology varied greatly. The wetlands studied were part of a floodplain system (Cole and Brooks 2000). It was found that water remained in the root zone much longer than in the natural wetlands and that created wetlands were much “wetter” than the natural wetlands in the area (Cole and Brooks 2000). The permitting process often requires mitigated wetlands to have a noticeable hydrological component; therefore, explaining why mitigated wetlands often had standing water when the reference wetlands did not (Cole and Brooks 2000).

Wetlands often need relief in the earth's surface to retain water. Natural depressional wetlands often have multiple micro-reliefs in their structure. This is due to changing water flows, animal burrowing, or differences in rock and soil compensation. Created depressional wetlands are often created using machinery, this scrapes the terrain and does not provide micro-relief (Stolt et al. 2000). Micro-relief allows alternating low and high areas to encourage animal and plant diversity by providing different habitats (Stolt et al.). The absence of micro-relief negatively affects the diversity of the wetland.

Soil composition is another large component of the function of a wetland. In a study completed in Virginia found that the particle size of soil in natural wetlands varied more than the particle size of soil in created wetlands (Stolt et al. 2000). The variability in natural wetlands was between 7% and 86% and in created wetlands it was between 33%-53% (Stolt et al. 2000). The variation in soil is attributed to the alluvial patterns of natural wetlands (Stolt et al. 2000). Natural wetland soil develops by flooding and deposition which creates stratified layers (Stolt et al. 2000). Constructed wetlands tend to have simple A-C layer system and plant roots tend to be contained to the first 50cm of soil (Stolt et al. 2000).

Created wetlands are used to replace natural wetlands in an effort to maintain wetlands functions. However, these wetlands are not the same as natural wetlands and often do not meet the level of function of a natural wetland.

**Conclusion**

"No Net Loss" wetland policy has been supported by several United States Presidents, The EPA, and the ACOE. The policy attempts to bridge the gap between the need for development and the preservation of our natural resources. It provides politicians with a positive public image by making it appear that are supporting both industry and the environment.

The efforts to reduce the loss of wetlands in this country have had a positive effect. Between 1986 and 1997 the rate of wetland destruction was estimated to be 23% of what it had been the previous decade (Compensating). Also, increased regulation of pollution has helped to decrease the degradation of wetlands in the United States (Compensating).

However, the policy is not without its flaws. The permitting process uses the compensation of wetlands as an effort to allow for development. This approach however, does not take into account that faults with wetland creation.

Wetlands are complex systems that form after decades to centuries of succession. Attempting to recreate this natural system in a short time period has lead to the loss of wetland functions in this country. Furthermore, not every wetland can be recreated causing us to lose many important functions.

Furthermore, studies are usually only completed for the length of time needed to obtain the permitting credit. Therefore, we do not have the level of knowledge necessary to provide successful mitigation in the future. Often the problem is funding. Funding a study for a project that had already been completed is not an appealing venture.

Because, of this lack of knowledge, created wetlands do not meet the same standards as those who are natural. They do not support the same level of function that natural wetlands do. In some instances the wetland may be almost impossible to recreate.

Although, there have been many changes to wetland conservation policy, and those changes have been positive there is a long way to come. Currently the EPA is facing budget cuts of 5.7 billion dollars (Eileen and Mooney 2017). Coupled with the removing of environmental protection regulations the current administration makes it clear that it values industry over the environment (Eileen and Mooney 2017). We must be vigilant to make sure we do not go backwards when it comes to protecting our resources.

Currently we do not posses the means to compensate for the functions of natural wetlands completely. Therefore, until the time comes that we can compensate for all of these functions we must conserve the natural wetlands. Also, we will need to continue to fund research that adds to our knowledge base and leads towards more successful compensation.

**References**

Adhikari, S., R. M. Bajracharaya, and B. K. Sitaula. 2009. A Review of Carbon Dynamics and Sequestration in Wetlands. Journal of Wetlands Ecology 2.

Balcombe, C. K., J. T. Anderson, R. H. Fortney, J. S. Rentch, W. N. Grafton, and W. S. Kordek. 2005. A comparison of plant communities in mitigation and reference wetlands in the mid-appalachians. Wetlands 25:130–142.

Bedford, B. L. 1996. The Need to Define Hydrologic Equivalence at the Landscape Scale for Freshwater Wetland Mitigation. Ecological Applications 6:57–68.

Bendor, T. 2009. A dynamic analysis of the wetland mitigation process and its effects on no net loss policy. Landscape and Urban Planning 89:17–27.

Boylan K. D and D. R. Maclean (1997). Linking species loss with wetland loss. Nat. Wetlands in south-central Wisconsin. *Wetlands* 17: 518-572.

Brinson, M. M., and R. Rheinhardt. 1996. The Role of Reference Wetlands in Functional Assessment and Mitigation. Ecological Applications 6:69–76.

Bruland , G. L., M. F. Hanchey, and C. J. Richardson. 2003. Effects of Agriculture and Wetland Restoration on Hydrology, soils, and Water Quality of a Carolina Bay Complex. Wetlands Ecology and Management 11:141–156.

Compensating for wetland losses under the Clean Water Act. 2001. . National Academy Press Washington, D.C.

Copeland , C. 2010. Clean Water Act: A Summary of the Law . Congressional Research Service .

Eilperin, J., S. Mufson, and C. Mooney. 2017, April 2. New EPA Documents Reveal Even Deeper Cuts. The Washington Post.

Erwin, K. L. 2008. Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecology and Management 17:71–84.

Fretwell, J. D., J. S. Williams, P. J. Redman, T. H. Votteler, and T. A. Muir. 1996. National water summary on wetland resources. United States Government Printing Office Washington, DC.

Frolking, S., N. Roulet, and J. Fuglestvedt. 2006. How northern peatlands influence the Earth's radiative budget: Sustained methane emission versus sustained carbon sequestration. Journal of Geophysical Research 111.

Gutrich, J., D. Donovan, M. Finucane, W. Focht, F. Hitzhusen, S. Manopimoke, D. Mccauley, B. Norton, P. Sabatier, J. Salzman, and V. Sasmita Widjaja. 2005. Science in the public process of ecosystem management: lessons from Hawaii, Southeast Asia, Africa and the US Mainland. Journal of Environmental Management 76:197–209.

Kalen , S. 1993. Commerce to Conservation: The Call for a National Water Policy and the Evolution of Federal Jurisdiction over Wetlands. North Dakota Law REview 69:873–914.

Matthews, G. V. T. 1993. The Ramsar Convention on Wetlands: its history and development. Ramsar Convention Bureau Gland, Switzerland.

Peralta, A. L., J. W. Matthews, and A. D. Kent. 2010. Microbial Community Structure and Denitrification in a Wetland Mitigation Bank. Applied and Environmental Microbiology 76:4207–4215.

Race, M. S., and M. S. Fonseca. 1996. Fixing Compensatory Mitigation: What Will it Take? Ecological Applications 6:94–101.

Ruiz-Jaen, M. C., and T. M. Aide. 2005. Restoration Success: How Is It Being Measured? Restoration Ecology 13:569–577.

Robertson, M. M. 2004. The neoliberalization of ecosystem services: wetland mitigation banking and problems in environmental governance. Geoforum 35:361–373.

Salzman, J. 2005. "No Net-Loss" – Instrument Choice in Wetlands Protection . Duke Law School Science, Technology and Innovation Research Paper Series .

Section 404 of the Clean Water Act: How Wetlands are Defined and Identified. 2016, September 26. . Environmental Protection Agency.

Silverstein, J. 1994. Taking Wetlands to the Bank: The Role of Wetland Mitigation Banking in a Comprehensive Approach to Wetlands Protection. Boston College Environmental Affairs Law Review 22.

Stolt, M. H., M. H. Genthner, W. L. Daniels, V. A. Groover, S. Nagle, and K. C. Haering. 2000. Comparison of soil and other environmental conditions in constructed and adjacent palustrine reference wetlands. Wetlands 20:671–683.

Sunding, D., and D. Zilberman. 2002. The Economics of Environmental Regulation by Licensing: An Assessment of Recent Changes to the Wetland Permitting Process. Natural Resources Journal 42.

Thrush, G., and C. Davenport. 2017, March 15. Donald Trump Budget Slashes Funds for E.P.A. and State Department. New York Times.

Types of wetlands. (n.d.). . Minnesota Department of Natural Resources . http://www.dnr.state.mn.us/wetlands/types.html.

Watson, K. B., T. Ricketts, G. Galford, S. Polasky, and J. O'neil-Dunne. 2016. Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT. Ecological Economics 130:16–24.

Whigham, D. F. 1999. Ecological Issues Related to Wetland Preservation, Restoration, and Creation . The Science of the Total Environment 240:31–40.