What Impact have Conservation Policies and Beavers had

On Wetlands in Federal, State, and Private Lands?

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Abstract:

Geographic information systems (GIS), were used to analyze the conservation policies of federally and state managed lands compared to privately managed areas within northwestern Pennsylvania. This study was conducted to assess how wetland and beaver protection has impacted the amount of wetlands within the landscape. The study region encompasses the Sugar Lake Division (SLD) of the Erie National Wildlife Refuge (ENWR), Pennsylvania Game Lands #69 (PGL #69), and private lands in close proximity to the previously stated areas. Time series aerial photography were gathered for the region from 1939, 1959, 1993, and 2017. Soil horizon and existing National Wetlands Inventory (NWI) maps were used to help aid in the identification and delineation of wetland boundaries. The results show total area of wetlands (in acres) present per time series. Wetland area decreased from 1939 to 1959, which was primarily attributed to agriculture practices and declining beaver populations. A gain in acres of wetlands is observed from 1959 to both 1993 and 2017 which coincides with wetland conservation policies that began in the 1970s and 1980s.

Introduction:

Wetlands are defined by the United States Fish and Wildlife Service (USFWS), as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominantly undrained hydric soil; (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Batzer, Pennings, & Sharitz., 2014). This definition of a wetland, however, has been politically derived. Ecologist seeking a biologically useful definition of a wetland use a simpler and more straightforward explanation. "A wetland is in an ecosystem that arises when inundation of water produces soils dominated by anaerobic processes and forces biota, particularly rooted plants, to exhibit adaptations to tolerate flooding" (Keddy & Fraser., 2000). This definition of a wetland is more inclusive and useful due to the inability of political definitions to cover all habitats that may function ecologically as wetlands (Batzer et al., 2014).

Wetlands in the United States began disappearing soon after European colonization, with a loss of more than one half of 221 million acres of wetlands. Six states lost more than 85% of wetlands, while another 22 states lost 50% or more of their original acreage (Dahl., 1990; Bishel-Machung et al., 1996). Today, only 103 million acres remain (Dahl & Allord., 1996). This loss of wetlands can be attributed to the common belief among colonial citizens that wetlands were barriers preventing further development of the land, and that they should be eliminated to allow more colonization (Dahl & Allord., 1996). During this time period, the major cause of wetland destruction was agriculture. Wetlands were drained in order

to create productive farmland (Batzer et al., 2014). From the time of colonization up till about the 1970's, it was estimated that almost half of wetlands in the contiguous 48 states had been filled or drained (Tiner., 1984). Roughly 20 years later, in the 1990's, urban and rural development surpassed agriculture as the major threat to wetlands (Dahl., 2011). This trend continued until the 2000's when the loss of wetlands had slowed to the point where no changes could be detected (Batzer et al., 2014). This is most likely attributed to the implementation of state and federal policies to protect and prevent wetland degradation.

In Pennsylvania alone, nearly 1.4% of land, or about 404,000 acres, are wetlands. Among these wetlands, forested wetlands are the most common. The highest densities of wetlands are found in the northwestern and northeastern parts of the state where glaciation has occurred the most throughout history. Nearly one half of the wetlands in Pennsylvania have be degraded over the past 200 years. Between 1966 and 1979 the state had lost about 43,200 acres of wetlands linked to human activities (Majumdar et al., 1989). This loss can be attributed to conversion of the land to cropland, channelization of streams, forestry and mining, urban development, and the construction of pounds and impoundments (Dahl & Allord., 1996).

Wetlands account for about 6% of the earth's land surface, but they are disproportionately important from an ecological standpoint. The majority of amphibians rely on wetland ecosystems for survival, and more importantly for reproduction. They are crucial habitats for many species of birds such as waterfowl. Wetlands have the ability to support both terrestrial and aquatic biota. Wetlands also provide ecosystem services which are "components of nature, directly enjoyed, consumed, or used to yield human well-being" (Boyd and Banzhaf., 2006). For humans, wetlands provide nutrient cycling, water supplies, flood regulation, wastewater treatment, water filtration, pollination, and decomposition of organic waste (Batzer et al., 2014; Costanza et al., 2000; Ingraham & Foster., 2008). Food production, recreation, and cultural values are associated with wetlands as well (Batzer et al., 2014; Costanza et al., 2000). A Canadian assessment placed the value of $10,000,000,000 (1985 Canadian dollars), on the countries wetlands. This economic value was almost half attributed to recreational activities such as nature appreciation activities, hunting, and fishing (Batzer et al., 2014).

The National Wildlife Refuge System, operated by the USFWS consists of 545 Refuges, 37 Wetland Management Districts, and 50 Coordination Areas, each of which are managed by states. The Refuge System is the largest network of public lands encompassing over 95 million acres in the U.S. (Ingraham & Foster, 2008; Meretsky et al, 2006). Its policies suggests that the refuge system is best for purposes like the conservation of biodiversity and maintenance of ecological integrity (Fischman, 2003; Ingraham & Foster, 2008). The designation of land by the refuge system protects lands from intensive economic production and recreational activity (Ingraham & Foster, 2008). This can be attributed to the abundant acreage of wetlands in the Erie National Wildlife Refuge (ENWR), (USFWS, 2018). The

ENWR was established in 1959 and funded through the purchases of Federal Duck Stamps. The objective of the ENWR was to provide habitats for nesting, feeding, brooding, and resting for waterfowl and other migratory birds. The ENWR supports the diversity of wildlife species and an opportunity for the public to recreate and be educated about the environment. The ENWR encompasses over 2500 acres of wetlands including beaver flooding's, ponds, marshes, swamps, man-made impoundments, creeks, and wet meadows, all of which provide sought after waterfowl habitat (USFWS, 2018).

Wetland habitats are dynamic features and are constantly being created, altered, and destroyed. Natural wetland loss can occur over short periods of time for many reasons (Batzer et al., 2014). Shifts in Castor Canadensis, commonly known as the North American Beaver, activity can cause the natural creations and losses of wetlands over a fairly short time period (Johnston, 2012). The beaver is a large rodent that has a large impact on wetland ecology. This animal is known to be an ecosystem engineer, due to the beaver's ability to greatly modify its environment. Beavers are the only animals capable of creating wetlands. This is a result from their dam-building practices (Batzer et al., 2014). Beavers jam mud, logs, and other debris to form a wall across a stream. This allows the water level to rise over the banks of the stream channel, thus creating a pond. The upland plants and trees die as the soils become anoxic. The canopy above the pond opens and the water is then introduced to aquatic plants. This creates a natural wetland that will persist until the beaver colony perishes or moves out (Naiman, Johnston, & Kelley, 1988). Beaver dams change the drainage pattern and add to the overall storage capacity of precipitation. By changing the flow of water in the landscape, beaver impoundments convert terrestrial ecosystems to aquatic ecosystems, alter plant communities, and effect pathways and rates of nutrient cycling. This also elevates the subsurface water table, allocating for moist soils to appear (Batzer et al., 2014).

This raises the question of, how has the protection of wetlands as well as beavers and their habitats impacted wetlands around northwestern Pennsylvania? This study's goal was to correlate the differing policies that are aimed at protecting wetlands by the federal government (USFWS) in the ENWR, state managed lands by the Pennsylvania Game Commission (PGC) in the Pennsylvania State Game lands number #69 (PGL #69), and private areas of land. GIS and time series aerial photographs were used from 1939 to 2017 to identify and delineate wetland habitats. If a positive correlation can be found between conservation policies and wetland increases, the results can be used to perform similar land use/ land cover analysis on other studies. Also, the results can help better understand wetland gains and losses in other regions.

Methods:

This project examined the southern part of the ENWR, known as the Sugar lake Division (SLD), along with the SGL #69, and a multitude of combined, privately-owned and managed areas of land. The three areas examined are located in Crawford County, Pennsylvania and east of Interstate 79. The areas are shown in Figure 1: Location of study region extent. The ENWR is comprised of two divisions. The Seneca Division to the north, and the SLD in the south. The SLD of the ENWR is the southernmost division and is located about 15 miles east of the city of Meadville, Pennsylvania. The SGL #69 is located about 5 miles east of the SLD. The privately-owned land parcels examined are located between and to the north the federal and state lands.

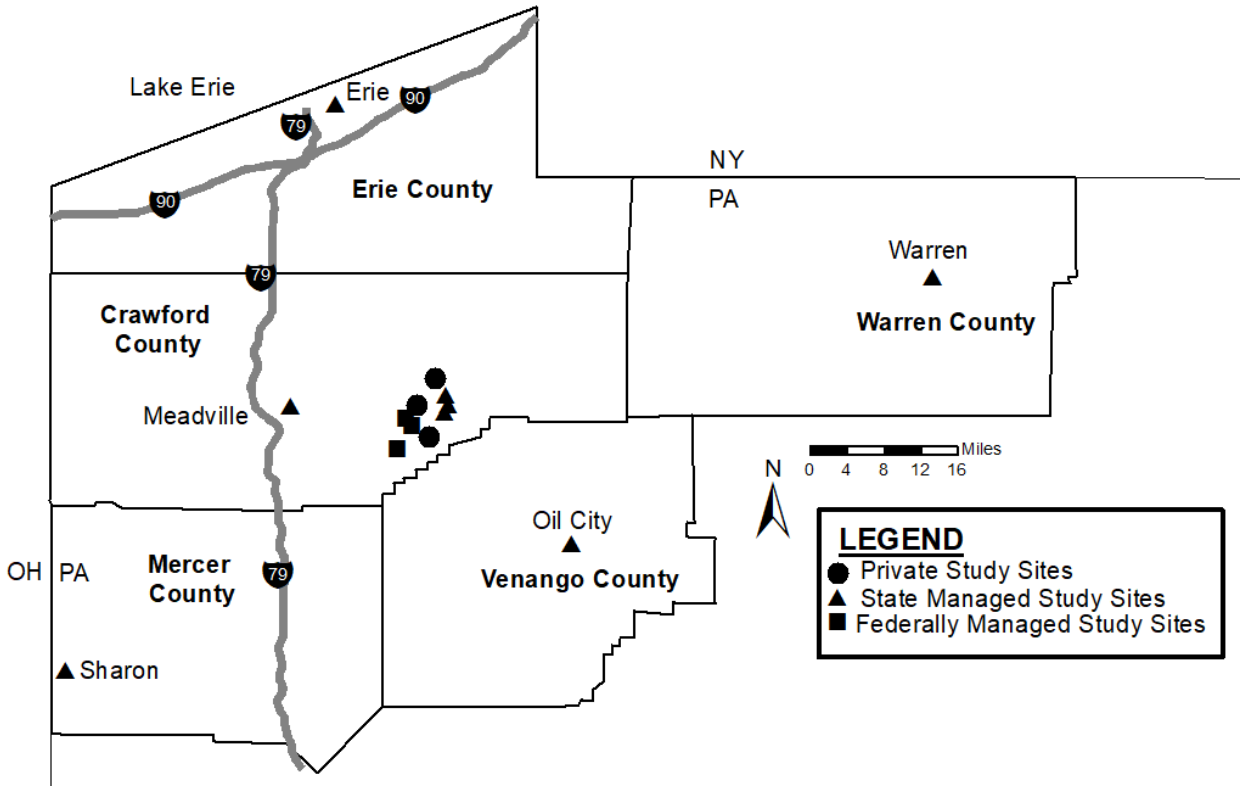


Figure 1: Location of study region extent

There are a total of nine study sites, with three being representative of each different type of managed land. There are three study sites within each, the federal and state lands. As for the privately owned lands, there are two sites located in between the boundaries of the federal and state lands. The third site is adjacent to, but oriented north of the SGL #69. Physically, the study region sits in a valley with the SLD to the west and the SGL #69 to the east. The elevation is all relatively similar, ranging from about 1,350 to 1,600 feet above sea level. Much of the soil types within the area have poor draining abilities and therefore are labeled hydric. A hydric soil is described as "soils that form under anaerobic

conditions that develop while the soils are inundated or saturated near their surface. These soils can form under a variety of hydrologic regimes that include nearly continuous saturation (swamps and marshes), short duration flooding (riparian systems), and periodic saturation" (Vepraska and Faulkner, 2001). Also, the study region has a network of streams running throughout it, creating areas that may present natural wetlands.

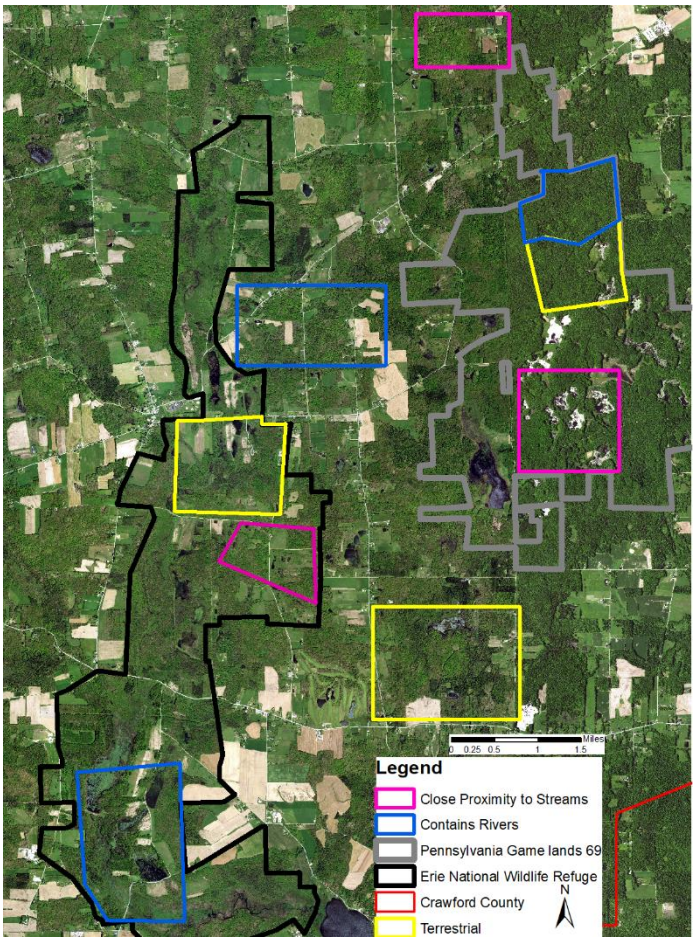


Figure 2: Location of selected study sites.

Study Site Selection

To ensure that the selection of the study sites were unbiased, a list of physical characteristics was constructed and the nine total sites were to meet all of the criteria. There are three sites within each category of land management. The study sites were determined whether the areas have hydric soil types. The soils were gathered from the US Department of Agriculture's Web Soil Survey. The soil zones in the analysis had drainage characteristics of either "Very Poorly Drained" or "Poorly Drained." Areas were selected from this based upon the presence of larger areas of contiguous hydric soil zones to give a greater chance of locating wetlands. It was assumed during the selection process that the soils would not vary

greatly in hydric soil zones, meaning that even areas adjacent to those hydric soils, could also be classified as "Somewhat Poorly Drained," a slightly better drained soil zone. Study sites would be too restrictive if they were limited to only containing hydric soils. Therefore, only most of the site needed to be flat or have hydric soil types. The areas were then analyzed using a topographic map from the U.S. Geological Survey (USGS) depicting elevation and slope. To be considered for further analysis, the areas needed to contain relatively flat, depressions, or very little slope. This attribute prevented a site on a hillside, where wetlands would be unlikely to occur, to be included. Areas must contain similar land cover types. This ensured the study is not comparing a developed area to an herbaceous wetland. A land cover map from 2017 was gathered from the National Land Cover Dataset (NLCD) and used to show the different types of land that are with the extent of the study region. Most of the land cover in this region is either forested or cultivated cropland. The final step to selecting the sites was to find three different sites per study region. These three areas would be represented equally across all three study areas totaling in nine study sites. The sites would be made up of an area of land that is close to a stream or river, an area that has streams or rivers running through the site, and an area that has no from streams and rivers. The areas of the study sites were also considered and kept between 500 to 1000 acres of land. Larger areas were not feasible in all three study regions due to lack of overall area when accounting for the selection criteria. The nine study regions selected for analysis can be observed above in Figure 2.

Upon selecting study regions, aerial photography was collected from the (Penn Pilot, 2019) Farm Service Agency (FSA) for the 1939 and 1959 time series. The U.S. Geological Survey (USGS) supplied the 1993 image and the National Resource Conservation Service (NRCS) for the 2017 National Aerial Imagery Program (NAIP). Table 1 shows the complete data dictionary regarding the aerial photography collected.

Table 1: Aerial Photograph Data Dictionary

Year	Film Color	Scale	Season	Source
1939	Black and White	1:20,000	Leaf On	FSA
1959	Black and White	1:20,000	Leaf On	FSA
1993	Black and White	n/a	Leaf On	USGS
2017	Full Color	n/a	Leaf On	NRCS

Aerial Photo Image Registration

The 1939 and 1959 images were georeferenced using ArcGIS Desktop 10.6 (ESRI, 2018) based on the NRCS imagery as the reference map. The 1993 and 2017 data were registered to the appropriate coordinate system and ready to use upon downloading. Four to six control points were used in the

process to mark known locations that are shared between the photo and the NRCS imagery. The control points "pin" the image to its correct place spatially on the map. Four control points were used on images that either were heavily forested/ vegetated land or the landscape has changed dramatically. This resulted in less reliable control points that were unevenly distributed, such as road intersections. For photos that were viable, six control points were used to more accurately "pin" the image. The accuracy of each image is represented by a total RMS error. The evaluation of accuracy for images with four and six control points is different. Photos with four control points must have RMS errors below 10, while photos with six control points must be below 1. These are accepted values for accuracy. In some instances six the RMS error value was higher than what is accepted. This was unachievable due to factors such as an uneven distribution of control points which distorts the image slightly. Also, the lack of precision of the control points and inability to correct for terrain displacement. Accuracy is also evaluated comparing the map, analyzing its fit when the photo flashes on or off. The flashing of the image was compared to the 2017 aerial photography. Visual analysis of roads, fields, tree lines and buildings during this should not appear to move or shift when the georeferenced photo is selected and appears on the map.

Wetland Delineation

The NWI provided by the USFWS as well as soil zones maps from the NRCS were utilized to aid further analysis and digitization of wetlands within the study regions. In order to uniformly digitize the boundaries of wetlands from each time series, certain characteristics of the maps must be present to qualify an area as a wetland. Since the 1939, 1959, and 1993 time series were in black and white, the first characteristic needed were dark areas on the map. This is because water absorbs light, resulting in the areas to show up darkly colored on the maps. To separate these areas from coniferous trees and shadows from sunlight, the areas had to appear relatively smooth and homogeneous in texture. Topographic and stream maps were used to ensure the areas were relatively flat or depressed topography as well as within its respective relationships to streams. This was necessary to digitize the areas where water will most likely collect or flood into. These decisions may have left out some vegetated wetlands as they could not be considered due to the uncertainty. This was not as significant of a problem in the NAIP 2017 data due to the visual depth presented by a full color range. Vegetated wetlands are hard to observe in black and white aerial photography. The vegetation reflects the light before the water can absorb, sometimes only leaving stream channels visible. This is the concern when trying to identify vegetated wetlands. They can be easily misidentified as a wetland when in reality they could be a stream in an open field or pasture. The digitization of wetland boundaries were completed and maintained a scale 1:2500 throughout the process. GIS was used to calculate the area within the boundaries of the wetland polygons.

For the 2017 NAIP, the wetland areas were much easier to delineate due to the presence of water. The coloration of the images allowed for easier visual recognition of wetlands. The shades of vegetation and dirt showed areas of wetlands during wet seasons, but show an exposed substrate during dry seasons. The use of infrared bands of light highlighted the areas of wetlands better and showed more visual depth in relation to trees and vegetation. The use of color photos and infrared light greatly increased the ability to delineate wetland boundaries. The digitized wetlands were categorized as natural made or man-made impoundments and sorted by where the wetland is located, either the ENWR, PGL #69, or private. Man-made impoundments are characterized as having and unnatural type of wall that controls the water level. These embankments are straight across and are sometimes mowed. These differ a lot from the natural backing up of water by beavers and landscape features. Beaver dams do not span from bank to bank of a stream in a perfectly straight line. Visually, natural wetlands tend to have more vegetation and small visual channels through the vegetation while man-made tend to resemble a pond. In summation, natural wetlands were observed when a stream enters a body of water with no clear embankment to hold back water. Man-made structures were categorized as having the large embankment as well as wetlands that weren't historically present in earlier photos and appear to be a result of the man–made structure.

Results

The results are shown as the acreage of wetlands in the three different study regions and sorted by natural or man-made wetlands and by time series. These numbers are represented in Table 2.

Table 2: Acres of wetlands by study site and time period.

Time Series	Wetland Classification	ENWR	SGL 69	Private	Total
1939	Natural	193.4	32.2	34.1	259.8
	Man- Made	--	--	--	
1959	Natural	108.3	17.8	15.0	166.7
	Man- Made	24.3	1.3	--	
1993	Natural	160.4	11.3	61.3	474.9
	Man- Made	130.2	108.8	0.7	
2017	Natural	157.0	3.4	53.3	480.3
	Man- Made	128.2	108.8	0.7	

As observed in the results table above, a decline in wetlands is shown from 1939 to 1959. The total area declined by nearly 90 acres during this time period. Following the 20 year decline, an increase a roughly 300 acres was observed in 1993. Wetland acres plateaued between 1993 and 2017, increasing slightly by five acres. A graph showing the trend of wetland change in acres over the time studied can be observed below in Figure 3. The areas that observed the most losses from 1939 to 1959 were site 1 in the ENWR

and site 3 in the Pennsylvania State Game lands 69. These two areas also are observed to have the most gains in wetlands from 1959 to 1993 and 2017. This is significant because the wetlands lost due to land practices at the time were naturally fixed and rebuilt by humans. Essentially, the wetland conservation policies reverted the past impacts to the land, allowing wetlands to recover and be reestablished on the

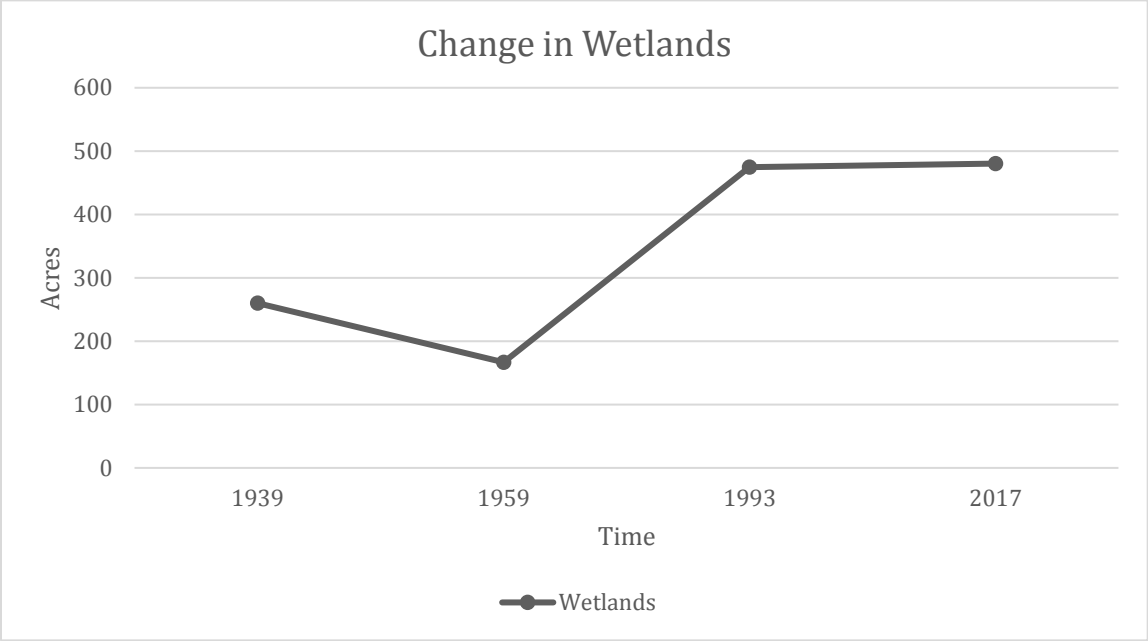


Figure 3: Wetland changes over time.

landscape. Finally, it was that wetlands have increased largely in the Pennsylvania State Game lands 69 and ENWR. The trends for this can be observed in Figure 4 below.

As observed in Table 2, both natural and man-made wetlands observed an increase from 1959 to 1993 and 2017. Man-made saw the biggest increases in that time period in the ENWR and PGL #69. Although in private land areas, natural wetlands were observed having larger increases than man-made wetlands. The ENWR had a large amount of wetlands from the 1939 to 2017 time series. The total acreage observed in this study showed that there were never less than a sum of 130 acres in all of the ENWR study sites. Even with this amount of wetlands, the ENWR still proceeded to show a gain of almost 100 acres since 1939 and about 200 acres since 1959 up till 2017. Below in figure 5, a study site is showing an example of how wetlands have changed across the four time series.

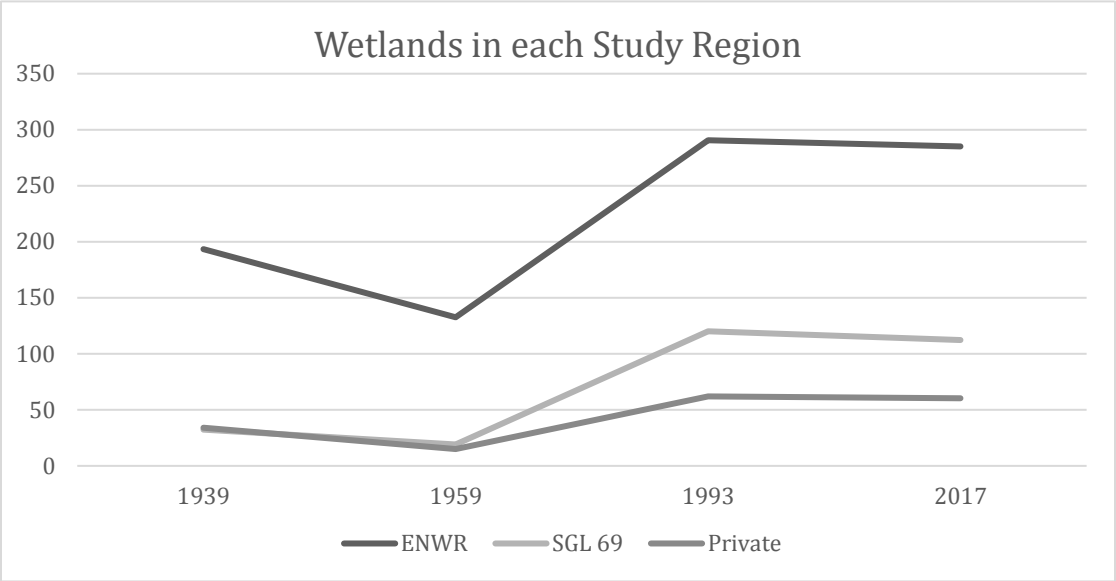


Figure 4: Change in wetlands per study region.

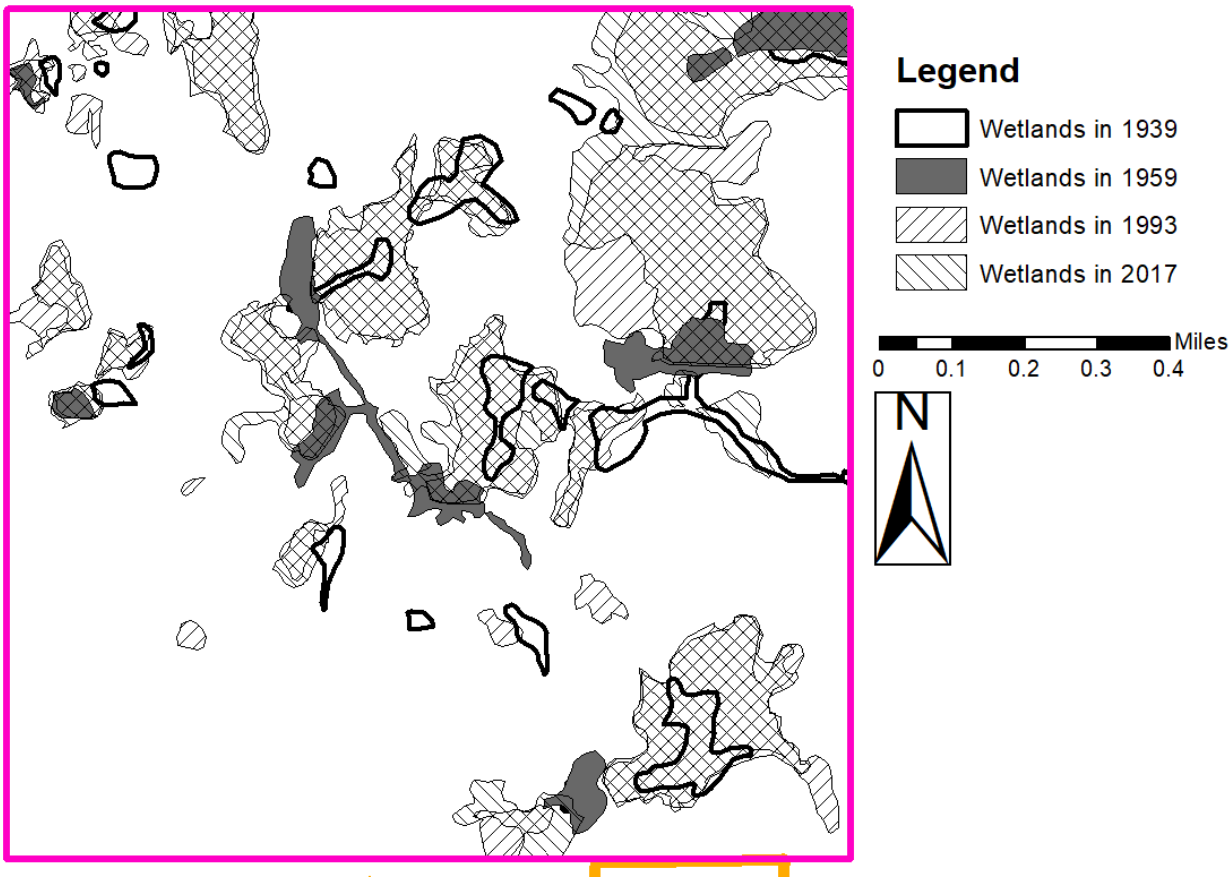


Figure 5: Wetland distribution over time.

Discussion

Interpretation of Results Comparing Wetland Trends and Policy

Policies created at the state and federal levels have influenced wetland change throughout the years. There is a correlation in the gains and losses of wetlands with policies and other trends that have been influential to those changes. The correlations begin in 1939. In the early 20th century, agriculture ruled the landscape. The labor intensive lifestyle took place on small family farms. This also employed close to half of the United States workforce (Dimitri et al., 2005). By 1930, the percentage of the workforce employed in agriculture fell to 21%. The decline in percentage of the workforce in agriculture remained and is still constant today. Since 1900, the number of farms has decreased by 63 percent, while the average farm size has risen 67% (Dimitri et al., 2005). The increase in farm size is attributed to the farms still operating, leasing fields from land owners that own historically farmed land. More specifically, the majority of farms in Pennsylvania are dairy farms. Following industrialization and urbanization in 1913, Pennsylvania farmers noticed an increase in milk demand rather than the demand for butter and cheese (Smith, 2001). The number of farmers may have decreased however the size did not (Dimitri et al., 2005). This trend may accounts for the continued loss of wetland areas observed due to the implementation of drains to lower the water table in fields. The results were dryer conditions that were more favorable to grow crops.

This analysis began in the year 1939, where a total of 259.9 acres of wetlands were delineated for this time period. The 1939 time series is the oldest aerial photograph series available. This time period presents the baseline from which gains and losses were derived from. The results showed that about 36% of the historically natural wetlands present in 1939 were lost by 1959. A decline was observed in multiple study sites and can most likely be attributed to anthropogenic causes such as the conversion of land for agriculture and market trapping of beavers for their pelts (PAGC, 2011). Land at this time that was already in use for agriculture practices, were observed expanding and encroaching upon wetlands, attributing for the recorded loss in acreage. Water was drained and diverted utilizing tile lines, underground drain pipes that lower the water table. Wetlands were also filled to create land that was more useful to humans. A contributing factor to wetland decline during this time period is the lack of state and federally owned managed land in the area. This was the time period prior to the ENWR being established in 1959 (USFWS, 2018). The Pennsylvania Game Commission purchased the first game preserve in 1913, and by 1919, had 20 preserves. The exact date of when the SGL #69 was established could not be identified. However the amount of fields and fragmented areas within the SGL #69 boundary decreased from 1939 to 1959 (Kosack, 1995). This could place the date of establishment sometime before 1959.

In 1959, the ENWR was established and began protecting wetlands within its boundaries for migratory waterfowl habitat. Around this time, the SGL #69 was also most likely established. The SGL #69 is managed at the state level, while the ENWR is managed federally. The creation of these two areas were to establish and protect crucial habitats. The ENWR was established as a result of the USFWS concern regarding wetland losses and their impacts to wildlife populations, specifically waterfowl and other migratory birds utilizing wetlands (Tiner, 1984; USFWS, 2018). Tiner also went on to mention that in the 1960's the general public became aware of wetland values and services, causing them to be concerned with their losses (Cole & Somerville, 2014; Tiner, 1984). This change led to multiple federal statutes being emplaced, intended to regulate activities and protect the nations natural resources. The shift in the view of wetlands from being regarded as "wastelands" to being acknowledged for their environmental and public benefits. This shift in public opinion as well as the establishment of the ENWR, and protection of beavers are factors, contributing to the increase of wetlands observed from 1959 to 1993. In the 34 year time gap, wetlands increased drastically from 166.7 acres to 474.9 acres. Larger wetlands were more prevalent in 1993 and 2017, than were seen in 1939, as well as numerous man-made wetlands that did not exist during at the time. These man-made wetlands in both SGL #69 and ENWR were created to provide habitat for mostly for migratory birds but the created habitat also benefits aquatic mammals, reptiles, and amphibians.

Factors that contributed to the 34 year long increase of wetlands were acts such as the Federal Water Pollution Control Act (FWCPA), established in 1972, were intended to restore and maintain physical, chemical, and the biological integrity of the nation's waters. Congress granted jurisdiction of the new law only to "navigable waters" with no reference to wetlands (Cole & Somerville, 2014). This was done intentionally to avoid unnecessarily limited interpretation of the language regarding the term "navigable waters" (Downing et al. 2003). The FWCPA defined the term as waters of the U.S. (WOTUS), which included territorial seas. This broad term created controversy and the U.S. Army Corps of Engineers (USACE) was challenged in court to narrow its interpretation of "navigable waters." This resulted is the 1977 amendments known as the Clean Water Act (CWA) which gave the USACE and the U.S. Environmental Protection Agency (USEPA) congressional authority to regulate the proposed filling of waters in the U.S. with fill or dredged materials. The CWA section 404's definition was narrowed down to include "navigable waters, unnavigable tributaries, and the wetlands adjacent to both. This policy also included in the 1980 revised guidelines that "degradation or destruction of special aquatic site which included wetlands may represent an irreversible loss of valuable resources" (Cole & Somerville, 2014; 33 USC § 1251[a]). Dr. Scott C. Yaich, director of conservation operations at Ducks Unlimited, claims that the CWA did more to protect wetlands in the 20th century than any other policy (Yaich, 2018). In 1989, President George H. W. Bush established the policy, "no-net loss of wetlands." This set out to replace

each and every impacted wetland which was accomplished by creating a similar wetland in terms of size and function to replace the lost wetland (USDA). The combination of policies and inclusion of the ENWR protecting wildlife habitats can be attributed for the major gain in the acres of wetlands from 1959 to 2017. The Pennsylvania Department of Environmental protection (DEP). This is the state managed version of the EPA. The way that state policy works regarding the protection of wetlands is that the state takes authority over the Federal Section 404 program is a goal of the Clean Water Act. When the state assumes authority from the EPA, it is able to manage wetlands according to the CWA, but in their own way (Mitsch and Gosselink, 1993). The state manages wetlands similar to the federal government, but due to the scale, the state is able to manage wetlands more conservatively if desired. The EPA does however, have to ensure the state is meeting the needs of the CWA.

At the state scale, Pennsylvania manages beavers through the Pennsylvania Game Commission (PGC). Since the time of European Colonization beavers have been killed for their pelts which were very valuable in the fur market. Beaver populations were decimated and needed help from humans to revitalize their populations in their native range. Beaver trapping regulations in Pennsylvania began in in 1934, allowing an individual to trap six beavers per year. The following years until 1944, regulations weren't universal and there were numerous counties that had unknown bag limits. After 1944 until the early 1980's the bag limit stayed between three to five beavers per year. Following the early 1980's, beaver numbers allocated to be taken yearly rose largely in select counties, Crawford County being one of them for two years (Hardisky, 2011). Following this the management areas for the PGC moved from counties to larger zones that are still present today and are called Wildlife Management Units (WMUs). The number of beavers permitted to be annually harvested appears to have risen in correlation with the trend observed with the increase in wetlands. The now abundant population is forced to spread and can become a nuisances species. The allocated number of animals harvested could be raised to manage the beaver population.

Wetlands were observed to have very little change from 1993 to 2017. The increase was by 5.4 acres which was found to occur in the ENWR. The acreage remained the same from 1993 to 2017 in the sites representing both private parcels and the SGL #69. Since there has not been any large wetland protection acts comparable to the CWA in this time period, and two-thirds of the study regions focus on protected lands, policy will have less of an impact in the most recent years. The slight increase may be derived from the newer, color photography in the 2017 time series. The coloration shows boundaries much clearer and allows for more accurate delineation of the vegetated wetlands. Those areas are difficult to differentiate from vegetated fields in the black-and-white photos. The color photos also allow for the use of infrared band of light. Infrared bands make the vegetation shades of red while water and other surfaces that would absorb light are shown in black. This method makes areas of water stand out on

the photo. It also, shows more visual depth in vegetation, making it easier to decipher a field of brush form vegetated wetlands. This technological advancement aided in the delineation of wetlands more accurately, allowing for areas which were difficult to delineate to be included.

The black and white imagery represented by the other three time series may be lacking areas of wetlands due to their appearance and lack of characteristics. Wetland delineation in these time series relied heavily on the dark contrast showing the presence of water to mark wetland boundaries. This excludes some areas that may be vegetated wetlands but remain uncategorized and therefore are not delineated. Other areas that are black or dark toned also may not be considered wetlands. For example, coniferous tree plots have dark tones as well and usually include shadows. These areas appear rough in texture and dark. The roughness and visible crowns of the trees are the determinant factors that would keep these areas from being labeled as wetlands.

This work is comparable in relation to GIS methods, to the USFWS initial National Wetlands Inventory (Dahl, 1990.) This report used similar aerial photography to come up with the wetlands of the United States. However, this study was more in depth and used techniques that are far more complex than the relatively simple selection method used in this research. No other research was able to be found that combined the methods of delineating wetlands and correlating the changes over time with policy changes. This research backs up federal and state policies, showing that their efforts conserve wetland habitats and allow for their overall increase across the landscape.

In the future, this analysis could be improved by using remote sensing technology to identify wetlands. Remote sensing uses spectral reflectance of the photos to classify them with pixels similar. In this case, water would be darker because it absorbs light, therefore any darker pixels would be classified as water. The actual technique of using remote sensing is more complicated that previously explained however. Furthermore, the black-and-white photos used in the 1939, 1959, and 1993 time series presented some wetland identification issues. The exact boundaries of wetlands, sometimes became difficult to identify due to vegetation. This creates some uncertainties with the data collected in these time series. The colored 2017, NAIP allowed for a less restrictive method for identification, since areas were easier to identify as wetlands. Although, we cannot go back in time to retrieve color photos of area, remote sensing may help to increase the accuracy, using technology to decide the colors that qualify as wetland and terrestrial. Also, including photos from the 1979 time series would include another era that has policies listed previously in the section. The addition of these photos would increase the data collected, allowing for a missing time period of wetlands to be included. This would enhance the overall trend of wetland change and show which time gap had the biggest impact on wetland conservation. The overall delineation of the ENWR SLD, SGL #69, and an equally represented area of private lands would increase the study size, allowing for more accuracy across the landscape as well. This study could even be

expanded to cover the entire state of Pennsylvania, analyzing areas across the state to better correlate wetland change with policy.

Conclusion

After analyzing the aerial photos using GIS, delineating wetlands, and categorizing them as natural or man-made, the conservation and management policies regarding wetlands show a correlation between the policies and the effect they have had on the change in wetlands. The data shows that overall wetlands have increased from 1939 to 2017. However there was a decline from 1939 to 1959. Both of these trends correlate with policies. The decline observed was attributed to the lack of any conservation policies at the time. Also, the abundance of agriculture on the landscape decreased wetlands to get more use of the land. In 1959, the ENWR was established and around the same time SGL #69. These areas began to protect and restore wetland habitats. Following this, people's perceptions changed and they began to care for the environment. Soon conservations policies were established such as the Clean Water Act that federally protected wetlands. The Pennsylvania Department of Environmental protection based their own conservation policies off of the Clean Water act. Policies like the Clean Water Act led to the overall increase in wetlands observed from 1939 to 2017, and more specifically, increases starting after the year 1959.

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