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How do Laws, Policies and Incentives Shape Landscapes

Spring 2022 LRES Capstone

Under the direction of Dr. William Kleindl

Our LRES Capstone course is designed to help our senior students begin to think of themselves not just as a student of environmental sciences but as an environmental scientist. Here we incorporate the ideas of applied practice to the life-long learning of the subject. We wish our students to be inquisitive about the broad topics related to natural resource management; know how to ask relative questions and find information to address those questions. To critique the relative quality of information sources. To be capable of dealing with uncertainty in science and negotiating conflicting interests when applying environmental science information to a resource management question. Finally, to communicate, both orally and in writing, technical information to either an expert or lay audience.

This year, we focused on how laws, policies, and incentives shape landscapes around. Actually, laws, acts, rules, ordinances, committee decisions, HOAs, economic incentives, all sorts of governance shape our landscapes. This semester we looked at what these are and how we can use them to help the environment; change them when they don't; be aware seemingly innocent

changes can actually be very detrimental to the environment; and how we can have a life-long career by understanding these conditions. Early in the semester, we had local legal experts interested in this topic visit our class. Below are the final reports from class groups that cover landscape, plants, water, soils and climate change.

William Kleindl, Ph.D.

How People and Policy Influence an Urban Landscape

Lyra Reynolds, Grace Wynne, Lauren Pierson

Introduction

When picturing a landscape, some people think of mountains towering over lush valleys whereas others may picture a pristine cityscape. Both of these environments share at least one similar trait: people can make extreme impacts upon them. These impacts may happen directly from vegetation removal or building developments, as well as indirectly from policy which creates a bridge between people and the environment. This relationship affects how landscapes evolve throughout time by placing limitations upon pollutants, dictating land use, and guiding specific management practices. Existing policy often addresses how people interact with a landscape, which can affect the landscape itself. The effects of legislation on a landscape can be amplified within urban areas. Due to the complex nature of a city, legislation must be able to provide solutions for waste management, infrastructure needs for growing populations, and other issues within a densely populated area. There is a need to understand the dynamics between people, policy, and an urban landscape to fully comprehend the impacts that legislation has on the evolution of a landscape.

Los Angeles Case Study -Background

Los Angeles, the most densely populated area in the United States, is a city of around 4 million people in southern California that spans 503 square miles. It is within Los Angeles County, which is the most populous county in the United States with a population of approximately 10 million people. The majority of the land in Los Angeles County is urban and built-up (43%) and land that falls into the “other” category such as vacant areas (41%). Agriculture accounts for about 15.6% of Los Angeles county's land use (California Department of Conservation, 2019). Los Angeles is the second most populous city in the United States and it grows by about .05% annually (US Census Bureau, 2021).

People have been drawn to Los Angeles for hundreds of years for many reasons, most significantly, its pleasant climate. Los Angeles is classified as having a Mediterranean climate, which is a semi-arid subtropical climate with a rainy winter season and a dry summer season. It

is known for mild weather, with an average annual low of 57°F and a high of 75°F. It receives 16 inches of rain on average per year and not uncommonly experiences drought (Bruno et al., 2000).

Although Los Angeles might be a desirable place to live for many people it has some pressing environmental issues - namely, its problems with air quality and pollution. According to a recent report on air quality, Los Angeles is the most polluted city in the United States, even though it had a 6% decrease in pollution in 2021 as compared to the previous year due to lockdowns (IQ Air, 2021). Fossil fuel reliance and increasing severity of wildfires have contributed to low air quality levels. However, Los Angeles used to have much worse issues with air quality in the 1950s and '60s before the passage of several laws to combat pollution. During and immediately after WWII, the smog was so severe that Los Angeles County created an Air Pollution Control District to address emissions by monitoring air quality as well as enforcing permits for sources of pollution, which was the first of its kind (Elkind, 2011). In 1970 with the passage of the federal Clean Air Act, there were even more positive changes in pollution regulation in California, which under the Act was permitted to set even stricter emission standards than the rest of the U.S. to combat the smog (Gerard & Lave, 2005). Policies such as these have helped to lower current ozone levels in Los Angeles to 40% of what they were in the mid-1970s (Bishop, 2019).

Ironically, the main factor that draws so many people to Los Angeles, the pleasant climate created by marine air from the Pacific, is also a huge contributor to its environmental issues. Los Angeles has an inversion ceiling caused by marine air that gets trapped by the mountains surrounding it and which traps pollutants that rise from the ground (Schroeder et al., 1967). Due to its location, Los Angeles and the surrounding area naturally traps pollution, so this combined with the large amount of people who live there causes it to have extremely poor air quality as compared to other areas. However, the successful attempts to improve air quality through legislation suggest that pollution, as well as other environmental issues that Los Angeles faces, can be improved through policy changes.

Resources in an Urban Area and The Need for Policy

Integrating environmental policy into a highly developed and densely populated area can be challenging, as there are various needs and wants of constituents that must be addressed. These desires span from development rules to economic changes to environmental concerns; the variety of demands can obstruct the passage of new laws and rules. Without improving older policies and developing new ones, it is becoming harder to protect resources and the communities that exist within urban areas like Los Angeles County. The lack of policy addressing the current and future needs of the changing world puts the existing landscape at risk. To understand the full impact of risk created by legislative shortfalls, the pieces that compose the landscape, need to be examined. Through an in-depth analysis of these resources and policy or lack thereof that surrounds them, we can fully understand the importance of improving legislation to preserve the landscape and the people that utilize it.

Water

In the 20th century, Los Angeles County was forced to develop infrastructure to import water to its rapidly growing population (Naik & Glickfeld, 2017). Unreliable, variable precipitation in the area necessitated the outsourcing of potable water, resulting in the pulling of more than half of its water source from three major outside suppliers (Naik & Glickfeld, 2017). The Los Angeles Aqueduct transports water from the Eastern Sierra watershed, the California Aqueduct transported water from the Western Sierra watershed, and the Colorado River Aqueduct transported from the Colorado River at Lake Havasu (Naik & Glickfeld, 2017). Only about “35% of the total water supply in the region” is pulled from groundwater (Naik & Glickfeld, 2017).

While Los Angeles County has faced water supply issues for centuries, with these problems becoming more and more amplified by climate change impacts. In a paper by Cousins & Newell, they explain that “climate models indicate that snowpack in the Sierras may decrease from its mid-20th century average by 25-40% by 2050 reducing the water available via the Los Angeles Aqueduct” (Cousins & Newell, 2015). Alongside persistent drought conditions, policy makers are forced to “rework the socio-technical systems delivering water to the region” (Cousins & Newell, 2015). Because of these challenges, officials must look at how the county is consuming water and come up with solutions to the declining water supply.

For the past decade, the Los Angeles Department of Water and Power (LADWP) has attempted to increase the local water supply by “focusing on projects that increase recycled water, expand water conservation, enhance stormwater capture, and establish green building initiatives” (Cousins & Newell, 2015). Through these practices, the county is attempting to develop water supply sources that will withstand the impacts of climate change as well as making water demands more efficient through more targeted uses and less demand overall (Cousins & Newell, 2015). These relatively new projects represent a departure from region infrastructure and focus more of a “distributed water framework that entails a re-scaling of ecological resources and infrastructures primarily through a market environmentalist framework to tackle both environmental and economic problems” (Cousins and Newell, 2015).

The county is calling on all of its water users to participate in conservation efforts. State Senate Bill 1420 is requiring suppliers to use the “AWWA [American Water Works Association] Water Audit methodology to monitor real water losses from infrastructure” alongside Senate Bill 555 which “mandates the annual submission of the AWWA water audit” (Naik & Glickfeld, 2017). Though residents are also being asked to participate in conservation, a study by Mini et al. has shown that water restrictions implemented on a voluntary basis have “not lead to significant reductions in water use and were found to be less effective than mandatory restrictions” (Mini et al., 2015). In order to make an impact on a household level, Los Angeles County must enforce “more stringent mandatory watering restrictions combined with a price increase” (Mini et al., 2015). These two factors showed greater savings in water usage than the voluntary restriction period that came before the mandatory restriction period during the drought in the early twenty-first century. Through the use of streamflow records, Manago & Hogue showed/proved

conservation efforts to be worthwhile, as they are having “a large, quantifiable impact on streamflow behavior in southern California, which shows significant changes relative to outdoor water use and management practices” (Manago & Hogue, 2017).

Some policies and regulations have needed to be integrated into these new practices to appeal to recent issues and fit into the pre-existing infrastructure. For example, importing water from the San Joaquin and Sacramento River deltas has been restricted due to the protection of delta smelt through the Endangered Species Act (Cousins & Newell, 2015). The “political ecology” of Los Angeles’s water interdependent infrastructure originated with its conception in the early 1900s and was sealed with a famous quote by political and economic supporter William Mulholland in reference to the water flowing through the Los Angeles Aqueduct: “There it is. Take it” (Cousins & Newell, 2015). Cousins & Newell put it best when they stated that “water capture and recycling technologies are technological fixes to overcome Los Angeles’s water supply deficit, ones that allow policymakers to temporarily avoid serious consideration of the many long-term trade-offs between different values and uses of water such as future development and growth” (Cousins & Newell, 2015).

Soil

Much like water, soil plays an important role in any ecosystem and can be impacted by changing climates and human inputs. Soils provide a plethora of ecosystem services, and much like non-urban soils, urban soils are important for carbon storage, nutrient cycling, food production, water purification and regulation, and are drivers of change in an ecosystem. Urban soils also act as the connection between researchers, communities, and policy. Unfortunately, when trying to quantify ecosystem services of urban soils as compared to non-urban soils, “there remains a gap in bringing together what is currently known” (O’Riordan et al., 2021). The disparities between the two soil environments may be a result of emphasis in research on the processes of soils. However, looking at only individual processes and their effect on ecosystem services results in scientists jumping over the specific multifunctionality of urban soils, like the need to act as water filters and building materials at the same time. By further investigating the multifunctionality of urban soils, scientists can work alongside communities and governments to develop management and preservation practices. An emphasis on multifunctionality allows researchers to better understand soils in urban, densely populated areas as well as investigate how anthropogenic activities and changing climates impact urban soils.

Anthropogenic changes have altered soil quality through contamination that poses a threat to human health, especially in densely populated regions like Los Angeles County. One such contamination is heavy metal pollution in urban soils. The presence of heavy metals in soils can influence the pollution of other resources, such as groundwater and food, and can be extremely harmful to humans. Due to the danger that heavy metal contamination poses, there are state and federal regulations in place to limit their concentration in soils. The limitations to contaminants in soil are characterized via their concentration in drinking water or food sources as Maximum Contaminant Levels (MCLs). When looking at soil directly, though, there are no

specific concentration limitations. Instead, the Environmental Protection Agency (EPA) has created Regional Screening Levels (RSL) that are “chemical-specific concentrations for individual contaminants in air, drinking water and soil that may warrant further investigation or site cleanup” (US EPA, 2015). Though RSLs can be used alongside MCLs and other EPA recommendations to regulate the levels of metals found in residential soils, there are not strict limitations in place for soil alone for metals like lead, cadmium, and arsenic. These recommendations are seen on the state levels as well. The California Office of Environmental Health Hazard Assessment (OEHHA) created screening levels for residential soils to be used alongside EPA limitations as “reference values for use by citizen groups, community organizations, property owners, developers, and local government officials to estimate the degree of effort that may be necessary to remediate a contaminated site” (Montserrat, 2016). By using the advisory values, communities and local governments can assess the landscape and quantify the risk of elevated heavy metal concentrations. However, the lack of strict regulations by federal and state governments can make it hard to establish acceptable levels of metals in soils, which can affect how the landscape is developed and preserved. The gaps in policy protecting soils, especially in urban environments, allows for the landscape to be changed without known consequences to the people living in cities.

To develop stricter regulations, research needs to be done to better assess the current presence of heavy metals in urban soils. A study conducted by researchers at both the University of California and University of Pittsburgh looked at the concentrations/amounts of heavy metals present in soils in LA County, particularly focusing on lead, cadmium, and arsenic. The investigation examined twelve community gardens across Los Angeles County that had varying development periods and proximities to roadways, which changes the concentration of heavy metals introduced into the urban system. The study found that soils around LA county had elevated concentrations of all three metals, with “total Pb, As, and Cd concentrations significantly correlated with each other” (Clarke et al., 2015). When looking at the age of a development, investigators found that lead, arsenic, and cadmium all increased as age increased. The results also indicate that cadmium and lead levels decrease as distance from the road increases, which suggests that community gardens closer to roadways have higher concentrations than those that are further from roads. By looking at the age and position of the developments, the researchers were able to observe the changes in heavy metal concentrations in urban soils around the county. This evaluation allows for the risk to communities to be quantified and can be further used to create limitations and policy. Through a better understanding of the hazard and its occurrence, governments and regulatory bodies can place stricter regulations to keep their citizens safe and guide what land use changes may occur in the future. These changes to policy may include where playgrounds or community gardens are placed proximal to roads. Adapting policies to consider current situations as well as what may come in the future, whether it is from direct anthropogenic inputs or climate driven changes, is an urgent matter needed to preserve the structure, function, and ecosystem services of the landscape.

Fire

Fire has been shaping the landscapes of California for thousands of years, as it is a key driver in the ecology of these areas, as well as a part of important cultural practices. Prehistorically, it is estimated that around 1,800,000 hectares of California's wildlands burned annually (Stephens et al., 2007). These fires were sometimes started by lightning, but more frequently were started by Native Americans for the purposes of clearing brush, maintaining grasslands, and improving production of basket making materials (Anderson & Moratto, 1996). These fires played a huge role in the distribution of vegetation throughout California and many of these ecosystems require fire. For example, chaparral, which is a plant community found in central and southern California, regenerates quickly after fires through basal sprouting. Fire is described as being the "pulse" that helps restart the chaparral's successional cycle (Barro & Conard, 1991). These and many other plant communities in California are not only extremely well adapted to fire but have evolved to require fire for their growth and development.

The importance of fire in California ecosystems wasn't always known and the history of fire policy reflects that. After the settlement of California by Europeans many Native Americans were displaced, which disrupted the existing fire regime. Originally, the settlers let wildland fires burn and only extinguished fires that threatened humans, but this changed in the early 1900s when national parks and preserves were created and wildland fire management began to occur (Wagtendonk, 2007). The creation of the National Park Service and the U.S. Forest Service that managed these lands led to a long period of fire suppression, as wildland firefighting was a main function of these organizations. In 1935 the Forest Service implemented the 10 a.m. policy, which stated that every fire should be suppressed by 10 a.m. the day after it was initially reported. This policy came in the wake of a proposal to let fires burn in backcountry forests, which was eventually overruled, and this policy was put into place and remained until the 1970s (J. Wagtendonk, 2007). These decades of fire suppression had extreme negative effects on the ecosystems of California, such as changes in wildlife habitats, increased fuel loads and increased tree densities, which led to catastrophic wildland fires when they eventually occurred, greatly damaging vegetation that was adapted to frequent, low-moderate fire regimes.

Currently this policy of fire suppression is no longer in place and prescribed burns are used in California to manage ecosystems such as forests, shrublands, and grasslands (Stephens et al., 2007). These prescribed fires are purposefully set to imitate past fire regimes and to clear underbrush and possible fuel, so fires do not become intense enough to destroy trees such as the Sequoia. However, the area burned and the frequency with which these fires are set do not match historical levels. These prescribed burns are limited by several factors such as smoke management and effects on endangered species. These factors need to be acknowledged when considering the improvement of the current prescribed burn system, which should be modified to set more frequent low intensity fires to better mimic past fire regimes. There have been some policy changes recently that are a step in the right direction for controlled burns in California, such as the new bill SB3 322, that was signed by the governor in 2021. This bill adds protections for groups that carry out prescribed burns for public benefit who may have otherwise been reluctant to do so. Bills like these are a good start since they take away some of the existing

barriers to setting prescribed burns and pave the way for prescribed burns to be set more frequently, although there is still a great deal more that needs to be done. Other policy changes such as increasing the use of wildland fire and appropriate management responses should also be undertaken to help increase the area of fires burned in California each year to imitate historical levels more closely (Stephens et al., 2007).

Currently there is a significant fire problem in southern California, with one of the most pressing issues being that human development is encroaching into fire-reliant plant communities. This not only causes huge losses of property and sometimes even human life when fires do occur, but also causes issues with the maintenance of the plant communities themselves, as fires near people are usually suppressed. This problem is also known as wildland-urban interface (WUI) which is the zone of transition between wilderness and developed land. The amount of property damage that has occurred due to fires in the WUI has increased over time, and these catastrophic fires are only expected to increase in size and intensity due to climate change's effect on fire-inducing factors such as higher temperatures and increased drought (Kramer et al., 2019).

The landscape of southern California is changing drastically as development continues and more people move to the area. This needs to be accounted for when considering how to best manage fires in the future. For example, development near fire-type plant communities should be discouraged and the public should be better educated on WUI and how this problem is only going to get worse as the severity of wildland fires is likely to increase in the coming years.

Current Policies and Incentives

There are many policies and incentives that impact how an urban landscape looks and functions, such as the Clean Air Act or Green Infrastructure Planning bills. While some policies dictate how buildings, water, soil, or fire may exist in a landscape, others regulate the anthropogenic impacts that change the environment. Incentives operate similarly through offering a type of “reward” for following certain directions. These various legislations may occur at the state or federal level, which may convolute the regulations set and grant access to loopholes for those that are looking for them. Through looking at the interactions of the people with policy and the landscape, we can better understand the impact that policy has on the landscape.

Current Policies

The policies examined in earlier sections focus on the individual resources that compose an urban landscape. While these pieces of legislation are essential, there are rules and regulations that interact with human activities that also directly influence the development of urban areas. In Los Angeles County, many of these policies come from state and local governments. One legislative action that exists for the entire state is the California Environmental Quality Act (CEQA). The act “requires government agencies to consider the environmental consequences of their actions before approving plans and policies or committing to a course of action on a

project” (*CEQA: The California Environmental Quality Act - Office of Planning and Research, 2021*). The act’s original purpose was to preserve and protect the conditions and wildlife of an area as any proposed change must be approved. The projects that fall under the discretion of this act are any that cause environmental change. This may be development of housing or businesses in a city, or environmental cleanup projects. Since its inception in 1980, the CEQA has had many amendments that change how the act is used and its benefits to different communities in California. Some of the amendments focused on involving landowners more, like the inclusion of local American Indian tribes, in decision making while others focused on land use regulations. The act, alongside its recent amendments, has allowed for local governments to create plans that combat climate change in wilderness areas and develop sustainable infrastructure planning. However, it has been weaponized in recent years to block planning that would provide infrastructure to support rapidly growing populations. Through this act, the landscape is directly changed through what buildings are placed or what land use changes may occur. Though the CEQA may create some roadblocks for growing areas like Los Angeles County, it sets a framework for more specific policies in urban areas that affect the composition of a landscape.

The Green Zone Program is an example of legislation that is urban area specific. This program was created by the Los Angeles County local government and “seeks to enhance public health and land use compatibility in the unincorporated communities that bear a disproportionate pollution burden” (*Green Zones Program | DRP, 2009*). Its components include land use policy, community engagement, environmental justice screening, and prevention and mitigation strategies. The program aims to create Green Zone districts around the county that have sensitive use areas where ordinances are heavily enforced. These ordinances have rules around industrial land uses, like waste management and where gas stations and drive through establishments can be placed (*Green Zones Program - Documents | DRP, 2009*). The Green Zone program places restrictions on development which impacts how future businesses are placed around the county. It also helps manage the waste that occurs around the metropolitan area, which makes a cleaner looking landscape. Through the ordinances, policy directly influences where development occurs, which further impacts how the landscape changes. This policy also allows for the county to establish plans that prepare the landscape for the future as populations increase and climate continues to change.

Current Incentives

While policy is important to creating a healthily regulated landscape, incentives contribute valuably to regulatory policy in creating a healthy landscape. Incentives can be anything from government subsidies to grants from businesses or nonprofits to simply wanting to make where you live a better place. For example, the Build Green Infrastructure and Jobs Act was first brought to the United States senate floor on March 18th, 2021. The focus of this federal act is to help the Department of Transportation in establishing more green programs that will “provide competitive grants to states, local governments, and other entities for capital investments in electrified surface transportation infrastructure projects” (Warren, 2021). As this

act would focus on emphasizing sustainable infrastructure, it would include projects that “promote the electrification of all public transportation, contribute to climate resilience and mitigation, reduce air pollution and greenhouse gas emissions, and achieve energy savings and reduce energy usage” (Warren, 2021). While this legislation could be an incredible step in the right direction, it has yet to pass the senate.

Los Angeles has developed its own incentives when it comes to access to green transportation options. In their 2014 paper, Nahlik and Chester claim that in order for positive urban change to happen “policies that provide incentives for transit, walking and biking” must be implemented and “single occupancy automobile use” must be disincentivized. In order to better access public transportation options in the city such as the Orange Bus Rapid Transit line and the Gold line, the city’s Department of Transportation encourages development in these areas through the use of “public subsidies, reduced parking requirements, and changes to open space requirements” as well as a “low cost permitting process” (Nahlik & Chester, 2014). Unfortunately, developers are reluctant to participate due to various risks. To convince developers to build in these areas, monetary incentives can be created in order to “protect developers from major unforeseen site costs that may help to overcome development barriers, enable construction in ideal locations, and ensure that energy-efficiency measures are integrated” (Nahlik & Chester, 2014).

As for water management and conservation, “multiple agencies offer turf replacement incentive funding” in order to get rid of water-intensive lawns and replace them with more water-friendly options such as artificial turf or better yet, native plant species (Pincetl et al., 2019). In 2014, the Mayor of Los Angeles, Eric Garcetti, influenced the addition of monetary incentives to turf removal, focusing on the removal of non-native monoculture lawns. Through the Los Angeles Department of Water and Power, residents were able to receive “\$3.75 per square foot for the first 1,500 square feet” of turf removed (Reicher, 2014). Because of this incentive, residents became more inclined to replace their turf with more drought-tolerant landscaping.

Local non-profits are also calling for a greater integration of grants to support sustainable practices on both a residential and a business level. Southern California organization TreePeople works towards the mission of engaging and supporting individuals in making urban environments better places to live through sustainability. In their “Healthy Soils for Healthy Communities” initiative, TreePeople stresses the importance of community outreach. To “raise awareness, to build capacity, and to provide technical and financial support for communities,” they are trying to implement “community small grants (where possible), communications and marketing, training and education, employ community-based science projects, and community-oriented events” (Chen et al., 2021). The ultimate first step towards building healthier, more sustainable communities is taking care of the natural resources that support and sustain them.

Conclusion

While incentives and policy are a good place to start, community members must be personally invested to maintain important natural resources and landscapes around their home. To properly comprehend how legislation influences the evolution of a landscape, the interactions between natural resources, people, and policy needs to be understood. Businesses and individuals alike are responsible for mitigating the negative impacts that they have on the environment as well as advocating for more positive ones. Making conscious decisions about land use and management and understanding the consequences of environmental effects is an integral piece to treating the landscape kindly.

California's policies concerning natural resource management have shifted drastically over the years and have made great strides in the conservation of its ecosystems and natural resources. Legislation addressing controlled burns has made it easier and safer to carry out prescribed burns, which imitate natural fire regimes more closely and have made progress towards restoring California's fire-adapted ecosystems such as coniferous forests to their original state. Other policies such as the Clean Air Act have also greatly impacted people as well as natural resources, decreasing the smog and air pollution in Los Angeles and improving quality of life for residents.

While there have been great improvements in California's management of natural resources there is still a lot more that needs to be done to improve both landscapes and human well-being. As discussed previously in this paper, more research needs to be done on the presence of heavy metals in urban soils to help inform policies that would impose more stringent regulations on metal concentrations in urban soils, which would be beneficial to both people and ecosystems near urban areas. Stricter watering regulations would also help improve California's ecosystems by saving water and helping restore streamflow's to be closer to their original levels. The success of past legislation in improving California's landscapes lends hope to the future, and policies such as these would make even more progress in restoring and conserving California's amazing natural resources.

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Managing Invasive Plants: A Case Study on Addressing Environmental Issues on National, State, Departmental, and City Levels.

By: Michael Coppola, Mickayla Johnson, Elise Reynaud, and Josie Rodrigue

Introduction

The United States' governmental priorities and policies have been known to shift throughout history following changes in public opinion. In recent years, this has resulted in an American policy priority shift towards addressing environmental issues, with about 64% of Americans feeling that the environment is a top policy priority (Pew Research Center, 2020). This shift raises the question of how different institutions within the current governmental system will rise to the challenge of tackling these issues on a range of spatial scales under different authoritative powers. This paper seeks to explore this idea by asking how legislation and regulations are used to combat environmental concerns on a federal, state, departmental, and city-level by analyzing an issue that has plagued the United States since before the nation was even established: the fight against invasive species.

As defined by Executive Order 13112, invasive species are organisms that are non-native to the ecosystem with an introduction that causes harm to human health, economic status, or the environment (National Invasive Species Information Center, 2011). Environmental harm is prevalent in spaces where invasive species are present as they have numerous impacts that affect the structure and functioning of ecosystems and landscapes. For example, the presence of invasive plants decreases biodiversity in landscapes. The fast-spreading nature of invasive plants can displace native plants, preventing plant growth and creating monocultures (City of Portland, 2022). Another ecosystem function that is damaged by invasive plants is the habitat required by fish and wildlife. Invasive plants can compete with native vegetation that wildlife requires for food and shelter. Many plants and animals are listed on the Endangered Species List due to loss of habitat and changes in land use that is caused by invasive plant species (National Wildlife Federation, 2022).

The adverse effects of invasive species start within the landscapes and expand to ecological and societal impacts across landscapes. Nonnative plants negatively affect soil structure by decreasing the biodiversity of plants present and therefore decreasing root structures required to avoid erosion. Therefore, areas invaded by invasive plants may be more likely to erode in a flood than landscapes with more root structure diversity. Soil erosion leads to lower water quality due to sediment deposits in streams (National Wildlife Federation, 2022). The contaminated stream water is then directed to irrigation or into the city for human use, possibly resulting in negative effects on humans. Fire risk is one of the greater dangers associated with invasive plants. Monocultures of invasive species, such as cheatgrass that is dry in the summer, create fuel for wildfires (City of Portland, 2022). Cost is another negative side effect of invasive species. The cost of controlling invasive plants and the damage done by nonnative plants take away from conservation efforts and other projects that benefit natural landscapes. To combat the adverse environmental and human effects of invasive species, legislation needs to be implemented at the national level down to city ordinances to control management.

National Legislation:

Currently, the Plant Protection Act of 2000 is the main piece of legislation that dictates the management of invasive species on a national level. The Plant Protection Act of 2000 “prohibits a person from importing, exporting, or moving in interstate commerce an unauthorized plant pest” (Canady, 2000). The Secretary of Agriculture is granted the authorization to manage the importation and movement of plant pests to avoid introductions in the U.S (Canady, 2000). The Secretary of Agriculture is also in charge of listing noxious weeds and biological control agents, as well as private petitions to add or remove listings (Canady, 2000). Authorization is given to the Secretary of Agriculture to take specified remedial and emergency measures to treat plant pests and noxious weed spread (Canady, 2000).

Management mostly falls under the Department of Interior and the Department of Agriculture. The larger-scale management implications are handled by the National Invasive Species Council (NISC) and the Secretary of Agriculture, whereas concentrated local projects are completed through the Fish and Wildlife Service and the National Park Service. For example, the Fish and Wildlife Service has an “Aquatic Nuisance Species Task Force Strategic Plan for 2020-2025” that outlines six main goals to protect waters in the U.S (U.S. Fish & Wildlife Service, 2020). Within this plan, there is an emphasis on collaboration with federal agencies, states, tribes, industries, nonprofits, and stakeholders (U.S. Fish & Wildlife Service, 2020). This effort is important as it allows for research to be connected between organizations at a larger scale. However, this task force only addresses aquatic nuisance species and there is no national concurrent plan for rapidly spreading terrestrial weeds. State Fish and Wildlife agencies often have noxious weed management plans and research being conducted at a local scale. Despite state efforts, the loss of connectivity between these state agencies and federal agencies can lead to discrepancies between tactics leading to a loss of time and control. Consequently, invasive species can establish across state boundaries with ease.

The NISC does have an annual work plan to address invasive species at a national level. This plan works more closely with the Plant Protection Act of 2000 to regulate the spread and introduction of new invasive species. This plan highlights the importance of using new technologies to develop the most cost-effective solutions. For example, one objective was to use Environmental DNA (eDNA) as an early detection device for aquatic species and better implement this technology within federal agencies (NISC Guidance Documents, 2016). The objectives of this plan also revolve around the inclusion of natural disasters in plan management. Extreme weather events and increased wildland fires due to climate change are an imminent threat to the greater spread of invasive species. Formulating a proactive plan to address these events is a crucial step in maintaining the current levels of noxious weeds and aquatic nuisance species. Continuing to update this plan based on new research is critical in making progress in aggressive nationwide management.

Case Study:

Although the Animal and Plant Health Inspection Service (APHIS) is continuing to improve its management strategy, there are still loopholes that are currently being exploited. Genetically modified (GM) plants have become a debated issue in invasive status within federal jurisdiction. APHIS has authority over genetically modified plants based on their status as a “plant pest” under the Plant Protection Act (Montgomery, 2012). This is due to the GM plants using a material, like a virus or bacteria, that defines it as a plant pest (Montgomery, 2012). Companies such as Scotts Miracle-Gro have created types of GM plants, such as a strain of Kentucky Bluegrass, that can tolerate the application of the herbicide glyphosate (Montgomery, 2012). Although this bluegrass met the criteria for a noxious weed under the Plant Protection Act, a risk assessment determined that it did not warrant regulation

(Montgomery, 2012). This decision set a precedent that GM plants are not harmful enough to justify regulation, despite their status as a noxious weed. Developers may use this loophole to evade USDA regulations by utilizing non-pest triggers (Montgomery, 2012). This precedent can lead to landscapes being overtaken by noxious weeds that are resistant to current mitigation strategies, drastically impacting the function of ecosystems. For example, the herbicide resistant Kentucky bluegrass could create monocultures within wetland ecosystems, outcompeting native vegetation. With the growing use of genetically modified organisms, this could become a large-scale management concern.

Under the Plant Protection Act, APHIS has authority over GM plants, but the focus is heavily on crop species. This leaves ambiguity for other genetically altered plants or trees not used in agriculture (National Academy of Science, 2002). Genetically engineering trees could provide substantial benefits for industrial wood production, toxic remediation, and species restoration (Sedjo, 2004). However, the process of determining whether a genetically altered tree poses an unacceptable risk and reaches a deregulated status is nearly impossible (Sedjo, 2004). Deregulation requires field-testing, statistical analyses, and literature review processes (Sedjo, 2004). Although these steps are important to ensure the ecosystem is not at risk, the approved applications for field testing are mostly for agricultural crops (Sedjo, 2004). Only 124 field tests of genetically altered trees have been authorized, most of which are for agricultural purposes (Sedjo, 2004). The narrowed agricultural lens limits the creative solutions being researched for restoration purposes and allows for non-agricultural invasive plants to continue to damage natural ecosystems.

Determining the level of acceptable risk can be an extensive and biased process due to the criteria format. In the U.S, the criteria denote that the product must have “no significant or unreasonable adverse risks” (National Invasive Species Information Center, 2011). This open-ended criterion allows for the U.S to allow some “reasonable risk”, especially when it comes to crop species. Allowing for an interpretation of risk can further encourage developers to neglect cautious regulations that restrict the establishment and spread of listed weeds in favor of greater yields. However, the U.S does require regulation of all transgenic plants and trees to automatically be regulated. This can limit standards based on species type (National Academy of Science, 2002). To solve this concern, it is argued that plants should be regulated based on the plant attributes, rather than the genetic engineering process (Sedjo, 2004). This regulatory process would revolve around “novel” plants, those that are modified genetically or by traditional breeding (Sedjo, 2004). Ultimately, this approach argues that plants should be regulated based on the attributes of the plant that may pose a risk, rather than automatically ruling out all genetically modified processes.

Future Steps:

The current regulatory system under the Plant Protection Act allows for non-pest triggers but eliminates innovations in genetically altered gene processes. Using the novelty of the new plants approach, where attributes are measured instead of transgenics (altered genomes), will allow for new innovations in transgenics to enter the testing phase. However, the aggressive nature of the deregulation process is still needed to reduce new introductions, without limiting growth in innovative solutions. Overall, there is still a lack of management of invasive species that do not directly interfere with agricultural practices. As climate change and development continue the spread of invasive species, it will become increasingly more important to broaden the viewpoint and management tactics of all invasive species.

State Legislation: Montana

Management of invasive species on a state level is crucial due to the economic, environmental, and societal effects of invasive plants. For example, economic impacts on grazing and wildlands in Montana, North Dakota, South Dakota, and Wyoming due to the invasive species leafy spurge was approximately \$130 million (Leitch et al., 1996). Additionally, there are \$42 million of direct and indirect impacts on Montana's economy due to spotted, diffuse, and Russian knapweed (Hirsch & Leitch, 1996). Environmental losses due to invasive plants include negative impacts on wetlands, waterways, soil health, biodiversity, native plant populations, and ecological processes. Societal losses due to invasive plants include detrimental effects on wetlands, hay and pasture, fur harvest, migratory bird hunting expenditures, and wildlife observation and photography (Duncan et al., 2004).

Currently, there are several acts and programs that are in place to assist with the management of invasive plant species. Although there are programs and policy on other legislative levels, most of the invasive species management is left to each state. Montana is a state with a heavy focus on invasive species management due to the importance of agriculture to the state's economy. Montana has split the state into weed management districts that have specific legislation as well as state-wide legislation on the management of invasive plants. Below is a list of Montana's weed legislation (McKlosky & Scott, 2002):

- 1) County Noxious Weed Control Act: This law establishes weed management districts throughout Montana. Each county have the responsibility to develop and administer the district's noxious weed program, establish criteria for noxious weed management, and develop and implement a noxious weed program that covers all land within the district.
- 2) Montana Weed Control Act: This act gives technical assistance and embargoes.
- 3) Montana Noxious Weed Trust Fund Act: This act is a grant program to provide funding for the development and implementation of weed management programs. Additionally, the Act provides for research and development of new weed management techniques and supports educational projects for Montana citizens.
- 4) Montana Noxious Weed Seed Free Forage: This program works in conjunction with a state noxious weed seed free forage certification program. The purpose of this program is to provide forage materials such as hay, grain concentrates, and straw that are free of noxious weed seeds.
- 5) Montana Agricultural Seed Act: This act states the restricted weed seed levels that have to be maintained within state certified seed.
- 6) Montana Commercial Feed Act: This act restricts the presence of noxious weeds in commercial feed.
- 7) Montana Environmental Policy Act: This act must be considered by any state actions that may have environmental or socioeconomic impacts, including actions regarding invasive plants.
- 8) Montana Nursery Law: This law allows for the inspection of all nursery stock for listed weeds.
- 9) Aquatic Invasive Species Laws: These laws allow Montana to detect, control, and manage invasive species. These laws cover departmental responsibilities, rulemaking authority, invasive species management area authorization, and regulation, arrangements with landowners, check stations, emergency responses, penalties, enforcement, the invasive species trust fund and grant account, and how the possession and transfer of invasive species are prohibited. (Montana FWP, 2022)

- 10) Aquatic Invasive Species Rule 12.5.706: This rule works to identify areas that are threatened with aquatic invasive species and the appropriate quarantine measures that will be put into place. The main mechanism for this rule is through department inspection stations. All aquatic vessels and equipment coming from out of state must stop at an inspection station before launching into Montana waters. Any vessel that is found to carry invasive species will be decontaminated at the inspection station. Additionally, after the removal of vessels from any surface waters, any aquatic vegetation must be removed from the vessel and all equipment by the recreator (Montana FWP, 2022).

Case study:

Agriculture is a large contributor to Montana's economy and supports the livelihoods of many citizens. Out of Montana's 93 million acres of land, 62% is used for agricultural production (Montana State University, 2022). Therefore, how agriculture is conducted has a large effect on Montana landscapes. Invasive plants are one of the leading problems facing agriculture in Montana and there has been legislation put into place to combat this issue, such as the Montana Agricultural Seed Act. The purpose of this Act is to provide licenses to seed dealers to ensure accurate labeling and accordance with regulations. Rather than working towards removing invasive plants after they have grown, the Seed Act works to prevent the establishment of invasive species at the source: by looking in depth at the seeds. Some of the seeds included in this program are grass seed, forage seed, lawn seed, and any other kinds of seed commonly recognized within the state as agricultural seeds (Montana Department of Agriculture, 2022). This statewide program provides regulatory services to agriculture companies and the general public (Montana Department of Agriculture, 2022). Seed samples are submitted to Montana State University's Seed Testing Laboratory which analyzes the samples for purity, germination, noxious weed seeds, restricted weed seeds, total weed seed content, and seed from other crops (Montana Department of Agriculture, 2022). Through this program and testing, it is ensured that there are no restricted weed seeds present in seeds being sold for agriculture or general use. This Act plays a large role in preventing invasive species from being planted unknowingly on agricultural land, restoration areas, lawns, and public land.

Future steps

Considering that the majority of invasive plant species management occurs at the state legislative level, state policy must continue to be developed and maintained with regard to invasive plants. It has been found that active management significantly decreases the area affected by invasive plants. Strategies such as early detection and small patch control have outperformed other weed management strategies and have been suggested by researchers as an efficient management method in Montana (Frid et al., 2013). According to researchers, the best strategy to apply depends on the landscape and the stage of invasion. In addition, support for the funding of grants for weed management by the federal and state government will assist in the continued financial support required to manage invasive plant species. As seen in the Montana Agricultural Seed Act, the legislation put forward by the state has large implications for the livelihoods of Montana's residents. Therefore, input from Montana citizens as well as scientific research will be integral in continuing the invasive species policy.

Federal Agency Support: United States Department of Agriculture

As mentioned in the previous sections, several federal departments and agencies share the responsibility of addressing invasive species. However, the United States Department of Agriculture has a particular

interest in this issue due to the consequential threat that invasive plants pose in agricultural systems. Invasive species that are considered “weeds” on crop and pastureland can result in yield loss due to competition, the contamination of harvest materials and seed, damage to equipment, and harm to grazing animals due to plant defenses such as spines or toxins (PennState Extension, 2009). Economically speaking, agricultural weeds were estimated to cause an annual monetary loss to the industry of \$4.1 billion in crop loss according to data from 1991 (Bridges & WSSA, 1992). These high economic stakes for the agricultural industry translate to invasive species containment and management being a key objective for the USDA.

USDA programs influence the management of approximately 1.4 billion acres of non-federally owned range, forest, pasture, and cropland along with 192 million acres of publicly owned range and forest lands, giving the department the jurisdiction to push for large-scale land-use changes across the nation (USDA, 1990). The department has a variety of opportunities in policies and legislative directives at its disposal to address the invasive species issue, the first of which is the Noxious Weed Control and Eradication Act. This act, which was enacted as an amendment to the Plant Protection Act in 2004, authorized the Secretary of Agriculture to establish a program to control or eradicate noxious weeds. This grant program provides financial and technical assistance to weed management entities and allows them to enter into cooperative agreements with the USDA to fund weed eradication projects (Craig, 2004). The USDA also influences invasive species management through research, incentives, funding, and program requirements provided by various agencies within the department as listed below.

- 1) Agricultural Research Service (ARS): the primary research agency of the USDA. Provides scientific and technical resources to inform the policies of the regulatory agencies (CRS, 2017). Current invasive species research includes cultural and biological weed control and management systems (USDA ARS, 2021).
- 2) Farm Service Agency (FSA): offers a variety of farm programs that offer payments in return for various compliance requirements, including noxious and invasive species management for certain programs.
- 3) Forest Service (FS): manages invasive species on 193 million acres of national forest and grasslands across the U.S. (CRS, 2017)
- 4) Natural Resource Conservation Service (NRCS): provides technical and financial support as well as implements specific conservation initiatives to address invasive species. Also provides Conservation Innovation Grants to support the development of new control and management strategies (USDA, 2010)

Case Study

With the USDA’s influence over the management of such a large quantity of land, their programs provide strong economic incentives that can determine trends in agricultural production across the nation. This influence can be seen in the evolution of the industry through history. The 1930s brought the mechanization of U.S. agriculture, and along with it the widespread use of herbicides. The era’s farm policy pushed for increased productivity and was reflected in the government program payments subsidizing more productive practices. These payments provided economic incentives for farmers to trade their diversified, small-scale systems for larger-scale, highly specialized production systems. These operations were inherently dependent on chemical weed control due to their size and lack of weed-

suppressing crop rotations. The reliance upon chemicals can also be attributed to the cost of applying herbicides equating to about one-third that of previously utilized mechanical tillage control (Ikerd, 1996).

The widespread use of herbicides has many benefits, such as preserving soil structure and reducing erosion rates by replacing mechanical tillage practices. The ability to produce abundant food and fiber globally can largely be attributed to the yield gained through more successful weed management by chemical means reducing interspecific competition. However, this dependence on herbicides has resulted in the evolution of herbicide-resistant weed populations. Herbicide resistance is defined as the inherited ability of a weed individual or population to survive an herbicide application that would normally be considered lethal and is a result of natural genetic variation within a population that gives some individuals the ability to survive an herbicide's specific mode of action. This process is accelerated during large mortality events such as herbicide applications, as the surviving resistant plants can produce a disproportionate number of progenies in the next generation (Powles et al., 1996). Currently, 266 plant species are known to have developed herbicide resistance globally to 21 of the 31 known herbicide sites of action and 165 different herbicides (Herbicide Resistance Action Committee, 2022). This increasing prevalence of resistance poses a threat to the productivity of agricultural operations and their ability to meet global food and fiber needs.

The issue of herbicide resistance, along with increasing pressure from the public for agricultural policy to shift its priorities away from industrialization and towards sustainability, has resulted in changes in USDA policies. This includes supporting alternative cropping systems that have a heavy focus on diversification of both crops and practices (Ikerd, 1996). For invasive species management, this means pushing for integrated weed management (IWM), which utilizes a range of control techniques including physical, chemical, and biological approaches in an integrated system that avoids overreliance on a single method (Powles et al., 1996). These integrated practices include the mixing of multiple herbicides with different modes of action, as well as tillage, crop rotations, cover crops, and the introduction of biological predators, among many other weed control practices.

Efforts by the USDA to embrace IWM throughout their programs and agencies include the formation of the Federal Integrated Pest Management Coordinating Committee (FIPMCC) in 1979, which is tasked with heading the department's efforts to manage and coordinate pest issues (USDA, 2020). On a USDA agency level, the NRCS has shown special interest in the issue of herbicide resistance due to the threat it poses to soil conservation gains as tillage becomes the easiest weed management solution for producers. The agency has developed several Best Management Practices (BPM) and provides technical and financial assistance to producers fighting resistance through their Environmental Quality Incentive Program (EQIP), which provides payments in exchange for implementing an integrated herbicide resistance activity farm plan approved by the agency. They also partner with the FSA, ARS, and extension services to develop and integrate weed management strategies into USDA services and policies (CAST, 2012). Overall, the department's shift towards more integrated systems is shown through changes in its incentives, policies, and programs with the hopes of guiding the country's agricultural industry towards more sustainable practices.

Future Steps

This policy shift by the USDA seems to signify the department's willingness to continue to drive the development and implementation of the best control options for invasive species in agricultural settings, including the refinement and expansion of integrated weed management. However, currently the

NRCS's efforts to expand integrated management through their EQUIP programs are not given the necessary priority status to be listed and funded on a local level. There is also a significant lack of adequate educational outreach on these programs, preventing effective implementation by landowners (CAST, 2012). By raising the priority of this issue and providing more educational opportunities on the best management practices they endorse, the USDA can help to solve the growing issues surrounding invasive plants in agriculture, specifically by emphasizing education and awareness of herbicide resistance. This increased emphasis may then lead the industry towards more long-term, sustainable, and effective methods of controlling invasive species. With their widespread influence, it is the USDA's responsibility to utilize the various management tools at their disposal to produce sustainable change.

Local Support: City of Bozeman

Cities or other local municipalities may also mandate the management of invasive plant species. In Bozeman, the City's municipal code regulates weed management for property owners and business owners. A property owner can be held liable if nuisance weeds on their property grow over a public sidewalk at a height below seven feet (BMC, 1982). The cost of removing the nuisance weeds falls on the property owner. If no action is taken, then that would be considered maintaining a nuisance for which the property owner can be charged with a misdemeanor. This power was given to the City in the Montana Code, however, in the code noxious weeds are not permitted to be defined as nuisance weeds (MCA, 1985). Business owners that place planting pots and boxes on sidewalks are required to be watered and maintained in good condition or face a fee (BMC, 2019). Good condition is left undefined.

Noxious weeds are considered topographic features that must be included in a subdivision's pre-application plan (BMC, 2021). Noxious weeds must be identified and mapped in developments. A county weed control district-approved management and revegetation plan must be submitted with subdivision applications. A revegetation plan for disturbances from the construction of the subdivision must also be submitted (BMC, 2021). A memorandum of understanding (MOU) between the weed control district and developer must be submitted with the final subdivision plat application. What must be understood by the memorandum of understanding is not outlined in the current municipal code of Bozeman. MOUs are not legally binding either (BMC, 2021).

Regulated activities that have unavoidable impacts on federal, state, or city-regulated wetlands must be mitigated by developing new wetlands. Wetland mitigation plans have to include a planting schedule with at least 80% of the plants being native species. It is also required that this schedule include weed control. To maintain 80% native species composition, monitoring has to be conducted for at least 3 years after planting, and the responsibility for the removal of noxious weeds following this period must be determined (BMC, 2021). Developments that cross or are next to a watercourse also have to take steps to mitigate impacts on it. To ensure the watercourse is not impacted by the development mitigation should focus on bank stability, sediment, nutrient and pollution removal, and flood control. It is required that existing vegetation should continue to cover watercourse setbacks or native grasses be seeded as soon as possible. These actions are in an attempt to prevent the invasion of noxious weeds and to ensure bank stability (BMC, 2021).

Developers may be required to submit covenants that may require that noxious weeds will be controlled as required by the state legislation (BMC, 2021). Proposed landscaping also has to be maintained in a "healthy, growing condition at all times" (BMC, 2021). Once development is underway developers are responsible for maintaining landscaping installed in common areas until the property is transferred to a

property owners' association. If a building is demolished on the property, redevelopment can include reclamation. If the site is being reclaimed, any weeds on the property must be controlled (BMC, 2021).

Stormwater retention or detention facilities in developers' landscaped areas must have 75% plant cover. These plants have to be native grasses, indigenous plants, and wet root tolerant plant types. (BMC, 2021). Bozeman's municipal code even regulates drive-through lane visibility by requiring a planting strip. This landscaping is supposed to comply with division 38.560, although this division in the code pertains to signs, not landscaping. This presents a loophole created by a typo, since it is division 38.550 that concerns landscaping (BMC, 2021). Landscaping that is required by the City needs general maintenance, which includes regular weeding. Failing to maintain landscaping in a healthy, growing condition can result in the revocation of an occupancy permit (BMC, 2021). Division 38.550 requires that of the proposed trees and shrubs, 75% must be drought tolerant. Street rights-of-way for developments not in R-S districts must have landscaping with one large canopy tree for every 50 feet of street frontage. Acceptable trees to be planted are determined and permitted by the forestry department. A plan review process for street median islands must determine landscaping requirements (BMC, 2021).

Development on city rights-of-way and parks need to have drought-tolerant grasses seeded or planted in these areas. Maintaining landscaping within the boulevard portion of public right-of-way falls under the responsibility of the adjacent property owners. Developers must maintain landscaping along external streets, parks, and other open spaces until 50% of their lots are sold. Then the property owner's association is responsible for maintaining these areas. The city is responsible for maintaining landscaping within the public right-of-way or other public lands. Adjacent property owners are responsible for maintaining state rights-of-way landscaping (BMC, 2021).

Weed control is permitted to be conducted in a wetland without approval by the wetland review board, as long as it is consistent with a Noxious Weed Management and Revegetation Plan approved by the Gallatin County Weed Control District (BMC, 2021).

Case Study:

Climate change has the ability to make non-native plant species invasive. Ornamental or horticultural species that have yet to naturalize to the local area have an increased ability to do so with the correct climate, availability in nurseries, and higher successful naturalization elsewhere (Haeuser et al., 2018). The next step for a species after naturalization is invasion. Documented non-native species in Bozeman for a single drought-tolerant median landscaping includes: *Aurinia saxatilis*, *Caragana pygmaea*, *Nepeta x faassenii*, *Centranthus ruber coccineus*, *Salvia yangii*, *Salvia nemerosa*, and *Calamogrostis x acutiflora* (COB, 2022). Most of the invasive woody plants in the United States were introduced for horticulture (Reichard & White, 2001). Bozeman's forestry department tries to deter this by supplying species native to North America, but this year's stock includes species that are non-native to Gallatin County (COB, 2022). One such species, *Syringa reticulata*, is considered to be invasive by the Adirondack Park Invasive Plant Program of the Nature Conservancy (APIPP 2020). There are approximately 22,000 potential weed species that have yet to be introduced outside of their native ranges around the world (Reichard & White, 2001). With Bozeman's population growing, people's demand for horticulture may increase, increasing the potential introduction of invasive plants (Hoeller, 2020). The North Carolina Botanical Garden implements a strategy to reduce the spread of potential invasives by not shipping seeds outside of their bioregion. The Lyon arboretum in Honolulu carefully considers each plant species it exchanges with non-Hawaiian botanical gardens (Reichard & White, 2001). Such considerations realize the potential for

introduced species to become invasive. In order to reduce pressures on native plant species in the urban ecosystem, the city should stop introducing species that are non-native and have the potential to become invasive with the climate changing.

Future Steps:

The frequency and severity of droughts will increase with the warmer climate predicted for the Greater Yellowstone Area, which encompasses Bozeman (USGS 2021). Maintaining landscaping in good condition may not be viable under worsening droughts. In the case of a drought emergency, where conditions are extremely dry in Bozeman, the City plans on prohibiting the watering of turfgrass, new seed and sod, flowers, vegetables, community gardens, athletic fields, and golf courses. Trees, shrubs, and perennials may be allowed to get one day of watering a month under the most stringent stage in the city's drought management plan. Golf courses are allowed to water trees and greens when there is a drought warning in effect, but these other planted areas are either restricted to watering schedules or watering them is banned (COB, 2017). The Bridger Creek golf course has Kentucky bluegrass, as do most, if not all of the golf courses in the Bozeman area. This presents the opportunity for the invasive Kentucky bluegrass to receive more resources than neighboring ecosystems and proliferate. Requiring more restrictive water use during droughts and plantings of native and drought tolerant species can prevent the invasive golf course monoculture from engulfing the Gallatin Valley.

There are also typos in the code that must be revised to reduce loopholes. Monitoring and testing of non-native plants for the increasing potential of invasibility due to changing climate is advisable.

Conclusion:

National, state, departmental, and city authorities appear to operate hierarchically in regard to their scopes and levels of influence, starting with nationwide acts and laws that set broad rules and expectations that apply across the country, down to city code that regulates finer scale activities within city limits. While each of these entities is working towards the same goals, each seems to have its own approaches and motivations. As a result, each level of authority plays a unique role in addressing invasive species, which can serve as both a strength and a weakness in addressing the overall issue.

Several federal agencies have their own agendas to combat invasive species, but there is a lack of nationwide regulations that delegate a needed aggressive approach. The U.S Department of Interior and the Department of Agriculture often have differing priorities in management strategy that can slow the pace of implementation. Since the Secretary of Agriculture is in charge of the authorizations under the Plant Protection Act, there is more of a focus on crop management instead of the protection of biodiversity within landscapes (Sedjo, 2004). The Plant Protection Act was established in 2000, making a gap in regulation regarding new genetically modified species and technologies. The outdated listing requirements of species and slow-response times could lead to greater introductions. At a national level, continued research and inclusion of non-agricultural impacts will be necessary to combat the loss of native species. Overall, it is crucial to develop a cohesive, updated management plan that allows for aggressive approaches to eliminating encroaching invasive species.

Invasive species legislation at the state level allows for more personalized management that is appropriate for each state's situation. Thus, the majority of invasive weed legislation is conducted at the state legislative level. Since Montana's economy is heavily supported by agriculture, the state laws regarding invasive species management are more evident and structured than other states. It is important that

legislators consider scientific evidence as well as input from citizens when considering invasive species legislation. Additionally, continued funding and legislation for invasive species management are critical considering the potential impacts invasive species have on Montana's economy and environment.

The USDA seems to serve as a means of getting feet on the ground to address the issue of invasive species within the nation's agricultural and forest lands. Through research, technical assistance, funding, and economic incentives, their agencies, and policies influence land management decisions, allowing them to encourage invasive species management on private lands. This influence can be seen in action in the department's recent priority shift towards integrated weed management to address herbicide resistance issues. This initiative, however, requires higher priority status and educational opportunities to gain traction but has the potential to make a widespread change in agricultural practices across the nation.

At the city level, noxious weeds are regulated to be managed through a collaboration between the county weed district and developers within Bozeman. Management of noxious weeds is delegated to the City where land is public and to property owners where private. The changing climate of Bozeman is recognized by regulations that require drought-tolerant species to be planted. The potential of non-native species that are drought tolerant to become invasive, however, is not a currently recognized consequence of climate change. Native, non-native, and invasive species' responses to a drier climate in Bozeman should be studied to inform the city legislature.

The outcome of invasive species management has major ramifications for our nation's landscapes. As discussed previously, invasive species infestations can be detrimental to biodiversity and ecosystem function, resulting in landscapes that suffocate under invasive monocultures. Successful management through legislation is vital to protecting our lands and remediating those that are degrading due to invasive species disrupting their balance. However, since this issue involves many different species across numerous regions and situations, it is difficult to assess progress on a large scale. Therefore, smaller scale, case-by-case instances provide a better reference for evaluating our current practices.

Although there are improvements to be made in management throughout all levels, there are instances of successful management that prove control of invasive species is possible. For example, in 5 years the National Park Service has been able to reduce the spread of Spotted Knapweed in Big Hole National Battlefield to eight percent of the peak population (U.S. National Park Service, 2019). This feat, among others, displays the possible success that comes from thorough and aggressive management. By implementing a strong plan at the national level, successful management can further cascade to city limits.

The roles that these authorities have played in the fight against invasive species can be used to predict the type of structure that may emerge in the coming years as more environmental issues are addressed through legislation. At the national level, precedents and priorities are set, providing an overall framework for states, agencies, and cities to follow while developing their own laws and regulations. State legislation is used to individualize management goals and strategies to meet state-specific needs and issues. Departmentally, the focus is given to incentivizing practices, managing public lands, and providing technical assistance to landowners according to federal and state directions. Finally, at a city level, municipal code can be used to manage issues more intensively within city limits, more directly addressing the issue within a smaller area. Through close collaboration, progressing strategies, and cohesive efforts, this framework has the potential to be successfully utilized for addressing future

environmental issues. However, it is essential to learn from the strengths and weaknesses of past and present efforts to find future success in this area of legislation.

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An Analysis of Modern Water Issues and Management Strategies

By: Greg Wilson, Joey Kane, Susanna Walsh

ENSC 499 Water Group

Introduction

Aquatic ecosystems are important globally for the biodiversity and biological activity they support. Water is essential to life and connects all environments above and below ground. From an anthropogenic perspective, water is necessary for food production, transportation, manufacturing, and recreation. Water has the power to carve canons and define an ecosystem. The United States, a country of almost three million square miles of contiguous land and a population of over three-hundred million people, is lucky to have exclusive sovereignty over most of its watersheds. This makes it simpler to govern the quantity and quality of the water. This paper will explore how laws and incentives that oversee water quantity and quality have the power to change the landscape of the United States.

Water Quality

In the United States the title “Waters of the United States” (WOTUS) exists to define the waters under the protection of the Clean Water Act (CWA). There have been many changes and the extent of WOTUS since the CWA was originally passed in 1972 WOTUS was not defined, giving discretion to the agencies and departments. Since then, is still debated. Until the mid-1980s the definition included lakes, ocean, rivers, streams, wetlands, land that is wet occasionally, and water that can be used for industry or production. Excluded under this definition were wastewater treatment systems and prior converted cropland. As of June 2020, WOTUS includes four categories of water (US EPA, 2017). These are the territorial seas and traditional navigable waters; tributaries of such waters; certain lakes, ponds, and impoundments of jurisdictional waters; and wetlands adjacent to other jurisdictional waters (other than waters that are themselves wetlands) (US EPA, 2017). The narrowing of the WOTUS definition was driven by the interests of corporations and individuals that want less restriction on use of land that could be valuable to develop. The definition effectively removed half of the nation’s wetlands and a fifth of streams and tributary headwaters from federal oversight, but these remain protected by many states. Although, there are inconstant protections from state to state. This loss of federal protection disregards the value of isolated wetlands and small ephemeral tributaries as a part of a functioning aquatic ecosystem. Even if they are not connected to flowing surface water, they are connected to our water supply by subsurface water movement. By removing protections for these waters, they are put at risk to receive unregulated pollution or outright destruction through fill and grading (Jackson, 2020).

Companies, governments, and individuals actively or passively pollute water with nutrients, toxic chemicals, and waste because it is too expensive or inconvenient to prevent. Some sources of pollution are not known, such as nonpoint source (NPS) pollution, which occurs if the pollution is from a broad area and the exact source is not clear (US EPA, 2015a). NPS is prevalent in areas with high agricultural activity where fertilizer runoff occurs. Pollution and water quality cannot be tightly regulated when the source is unclear. This requires innovative research and mitigation strategies like modeling where the pollution could be coming from. Modeling technology has been largely successful in several large

watersheds and estuaries. The use of technology and research is important to understanding pollutant dynamics and making good management decisions to maintain and protect the landscape.

The United States has laws to protect people's rights to water and its cleanliness. There has been a prioritization of solving issues related to water pollution beginning in the 1970s. The Clean Water Act guides the actions of the Environmental Protection Agency (EPA). The EPA is an independent executive agency of the federal government established in 1970. It addresses and recommends water quality criteria for aquatic life, human health, and organoleptic effects (e.g., taste and odor). Section 304(a) of the Clean Water Act requires these criteria be published to provide guidance to states and tribes establishing water quality standards. Approximately 150 pollutants are addressed in this list (US EPA, 2014). Even with these water quality standards, pollution can be extremely difficult to control or minimize. That is why actions like education and incentives for implementing natural nutrient cycling and pollution reduction systems are so important. It is difficult and time-intensive to make changes like these at the federal level, so many water quality regulations vary by state and even by county. These changes are also dependent on the type of pollutant that is regulated.

Nutrient Pollution

Nutrient pollution refers to pollutants like excessive nitrogen and phosphorus, usually in organic forms. Sewage, stormwater, agriculture, fossil fuels, and products like soaps and detergents all contribute to nutrient pollution. Nutrient pollution leads to eutrophication, or excess growth of aquatic phototrophic organisms like algae and plants. As they grow and eventually decompose, dissolved oxygen in the water decreases because it is being consumed to produce energy and break down organic matter. This process is called eutrophication and causes massive die-offs of aquatic animals in the area and has far-reaching consequences.

A concerning source of nutrient pollution in areas where there has been an increase in population or increased severity of storms is sewage overflow. Sanitary Sewer Overflows (SSOs) are a release of untreated or partially treated sewage from a municipal sanitary sewer. SSOs can be caused by blockages, leaky sewers, breaks, and a system that is not maintained or designed for an increase in volume. This is not only a huge human health issue but a risk to the environment and the landscape. Untreated sewage can contain fats, oils, grease, and "flushable" household products. SSOs can make waters essentially unusable. SSOs stop recreation, fishing, shellfish harvesting, tourism, and the use of water for manufacturing or drinking (US EPA, 2015b). One of the best ways to reduce the impact of SSOs apart from education to reduce harmful inputs is to improve infrastructure. The Infrastructure Investment and Jobs Act passed by the Biden administration in 2021 includes \$55 billion allocated to drinking water, wastewater, and stormwater infrastructure. This includes \$11.7 billion over 5 years and \$1 billion now for the Clean Water State Revolving fund which provides funding for capital projects to control SSOs (Tuser & Crossen, 2021; US EPA, 2015b).

It is important to note that the costs to rehabilitate and maintain water systems vary widely by community size and system type, and costs only increase when the system is not maintained regularly. Funding for the maintenance of infrastructure like this can depend on the allocation decisions of legislators and can be subjective, leaving communities already living in poverty and in unhealthy environments the most at risk for unsafe water.

To prevent nutrient pollution and address eutrophication, the Environmental Protection Agency (EPA), in addition to overseeing existing regulatory programs, is implementing a mixed strategy. First, they are maintaining relationships with stakeholders and non-governmental organizations. This allows them to provide incentives and increase awareness of the dangers of nutrient pollution (US EPA, 2013a). Raising the public's awareness of this issue is a main goal of governments and organizations around the world (Selman & Greenhalgh, 2009). The EPA is raising awareness by conducting outreach. For example, the EPA holds an annual "SepticSmart Week" to encourage homeowners and communities to care for their septic systems. They also provide funding and support for research and development of better wastewater treatment systems. For example, natural wetlands support high productivity organisms capable of organic matter decomposition and nutrient cycling (Fennessy et al., 2008). The natural ability of wetlands to mitigate pollutant effects can be used by livestock producers to reduce their nutrient pollution. There are voluntary incentives for producers to adopt fewer polluting technologies. Finally, the EPA supports the passage of legislation and amendments that include numeric water quality criteria for nitrogen and phosphorus (US EPA, 2013a).

Harmful Algal Blooms

Nutrient pollution, which increases the growth of algae and aquatic plants, can also increase the density and productivity of organisms that are toxic or pathogenic. People can get sick by drinking or encountering unsafe water and they can also get sick if they consume tainted fish or shellfish (US EPA, 2013c). Harmful algal blooms (HABs) are becoming more prevalent and in some places can last for over a year (Backer, 2002). An estimated 40 genera of organisms cause HABs and produce cytotoxins, which target specific cells, and biotoxins, which have a broad range of negative effects including neurotoxins and hepatotoxins (Carmichael, 2001).

In Lake Erie, runoff from farm fields causes a seasonal overload of nutrients and a bright green patch of cyanobacteria. *Microcystis*, the genus of organisms that dominate these summer blue-green algae blooms, appear as spherical cells a few micrometers in diameter. They contain gas vesicles to rise to the surface for light and deflate to scavenge nutrients. *Microcystis* communities outcompete other phytoplankton by resisting predation by zebra mussels and zooplankton like *Daphnia*. Zebra mussels spit them back out undigested; zooplankton cannot eat *Microcystis* because of the way it clumps. *Microcystis* communities also produce protease inhibitors that can stop digestion (Levy, 2017). Organic toxins themselves contain high amounts of nitrogen, so a bloom caused by excess nitrogen will also increase the production of toxins (Gobler et al., 2016). Even after all the available nitrogen has been depleted, *Microcystis* maintains high biomass by competing for ammonia (Levy, 2017). Another harmful algae bloom is "red tide" which is caused by dinoflagellates called *Karenia brevis* in marine and brackish waters, including estuaries (NCOOS, 2022). For example, on the east coast of the US from Maine to New York a toxic dinoflagellate produces a neurotoxin that accumulates in shellfish to cause paralytic shellfish poisoning in human consumers (NOAA, 2022).

Some states rigorously monitor toxin levels to control water recreation and fish and shellfish harvesting. The Virginia Department of Health updates a HAB surveillance map from May through October showing reported and under investigation blooms (Virginia DOH, 2022). Other states provide some information on blooms but do not directly monitor them, relying on federal monitoring by agencies like the National Oceanic and Atmospheric Administration (NOAA) or by crowdsourced resources like the BloomWatch App (US EPA, 2018). The Maryland "Eyes On The Bay" program with the Maryland Department of

Natural Resources has been suspended since 2020 (Maryland DNR, 2020). Fourteen states have a shoreline on the Atlantic Ocean, so monitoring and regulation require cooperation.

Marine and lentic landscapes are forever changed by HABs and the ineffective action of relevant governments to control them. In Florida, 277 manatee deaths were attributed to or suspected to be caused by a red tide of *Karenia brevis* in 2013. In Florida, manatees are a threatened species under the Endangered Species Act and they are considered a keystone species (NOAA, 2021). HABs and nutrient pollution are extremely destructive and result in landscapes that cannot support aquatic life and eventually degrade to a point of no return. Normally functioning aquatic ecosystems are buffers and have a variety of microorganisms to adapt and balance the effects of low levels of pollution. A system's biodiversity is a key factor in its resilience (Darwall et al., 2018).

Other Pollution

Industrial pollution not only takes cold water and returns it warm; it also produces wastes such as heavy metals, industrial by-products, organic pollutants, and other hazardous chemicals and substances. In aquatic landscapes, this pollution kills fishes, aquatic plants, marine organisms, birds, invertebrates (R. Qadri & Faiq, 2020). It also harms other organisms that may have nutritional value to humans, especially native peoples (Richter & Kolmes, 2005). Each pollutant has direct and cascading effects. Heavy metals like cadmium, copper, chromium, mercury, lead, nickel, and zinc are generally toxic to a variety of biological processes. Directly, this can result in the death of any organism encountering the metal at too high a concentration. Indirectly, metals can have dramatic effects on ecological dynamics and chemical ecology (Boyd, 2010). For example, Lefcort et al. (2002) reported that the heavy metals lead, zinc, and cadmium accumulated in snails in a polluted lake. The snails were less sensitive to the metals than their internal parasites, so the pollution appeared to increase the snail's abundance.

Total Maximum Daily Load

A prominent issue in the regulation of pollutants is defining parameters for the measurement of pollutant concentration. Total maximum daily load (TMDL) is the amount of a quantifiable pollutant that achieves compliance with the locally or regionally regulated standard (Elshorbagy et al., 2005). TMDLs were conceptually introduced by the EPA in the 1972 CWA and have since become a standard process for the regulation of pollutants. Section 303(d) of the CWA requires individual states to develop TMDLs for water bodies that are failing to meet their designated uses (Elshorbagy et al., 2005). While these requirements are beneficial at state-level management, watersheds do not follow state boundaries and there can be conflicts between state regulations within watersheds. These conflicts can result in lower efficiency and effectiveness of policies and TMDLs (Paolisso et al., 2015). Additionally, the different stakeholders involved in nutrient pollution can vary greatly, from urban development to agriculture and industrial activities, resulting in even more conflict.

Chesapeake Bay Case Study

The impact of water pollution can be greatly amplified in estuaries that have large watersheds and large areas of development or agriculture. In estuaries, nutrient-rich sediments accumulate as stream velocity decreases, leaving them more vulnerable to ecological impact (Craft, 2007). Relationships between the hydrology, land use, and nutrient dynamics of a watershed can be essential parameters for management and policymaking (Paolisso et al., 2015). The Chesapeake Bay watershed (CBW) covers most of the

District of Columbia and six east coast states including New York, Pennsylvania, Maryland, Delaware, West Virginia, and Virginia (Paolisso et al., 2015). The CBW is said to be the largest, most productive, and most ecologically diverse estuary in the continental US (Hood et al., 2021). The CBW encompasses about 165,000 square kilometers, 24% of which represents agricultural land (Paolisso et al., 2015). The CBW was determined to have an annual economic value of about \$100 million in 2014 (Hood et al., 2021). The high natural resource value has made the CBW a management priority for many federal and state organizations.

The fact that the CBW falls under many different state and local jurisdictions makes management of stakeholder and public interest a challenge. Nutrient load increases have been documented in the literature for the last 50 years, and ecological issues facing the watershed have gained notable attention. One example of an issue is discussed by Breitburg, 1992, which examines the effects of hypoxia on the CBW's ecological diversity. The current primary management priorities are aimed at three water quality parameters: 1) dissolved oxygen standards; 2) chlorophyll standards; and 3) water clarity standards (Paolisso et al., 2015). These parameters can be considered standard for water quality and are relatively easy to measure and monitor. Existing literature strongly suggests that anthropogenic activity is the primary cause of eutrophic conditions continuously impacting the recreational and economic value of the CBW (Hagy et al., 2004; Murphy et al., 2011).

In the 1970s and 1980s, stakeholders noticed the anthropogenic impacts on the CBW, and regional programs were created with the intention of mitigating these impacts. The Chesapeake Bay Program (CBP) is a partnership founded in 1983 that includes all six states the watershed encompasses, as well as hundreds of federal and state government entities, educational programs, and non-profit organizations with the goal to restore the CBW (Hood et al., 2021). Large, multi-jurisdictional organizations can be beneficial to organizing and delegating management appropriately. Over the last 30 years, the CBP has developed the Chesapeake Bay Modeling System (CBMS) to accurately portray transport, transformation, and deposition of anthropogenic pollutants within the CBW. Most notably, several forms of nitrogen pollutants have been accounted for in the CBMS (Paolisso et al., 2015).

Modeling for Informed Decisions

Modeling technologies can be extremely useful to policymakers and land managers by informing their decision-making. Large watersheds can present challenges when quantifying nutrient pollution for management decisions. Point source and nonpoint source pollution can be difficult to locate and quantify at a large scale, but modeling technologies can help to create more accurate depictions (Paolisso et al., 2015). By examining the CBMS we can gain insight into the practical advantages of watershed-scale management and how to effectively mitigate anthropogenic impacts. These mitigation strategies must also involve all stakeholders and engage them in a way by which the management decisions and policies are abided by.

The CBMS combines data with the EPA National Inventory to establish the most educated estimates of appropriate TMDLs for the CBW. The CBMS can be considered the most comprehensive assessment of the CBW's nutrient dynamics due to its acknowledgment of multiple factors and its ability to compile data. The use of both raw data and modeling techniques allows the CBP to assess watershed and bay-scale pollutants and the determination of adherence to water quality standards (Paolisso et al., 2015; Figure 1).

Since its inception, the CBMS has helped partner jurisdictions of the CBP make informed decisions on TMDLs and best management practices. Partnership with state and local jurisdictions as well as multiple stakeholders allowed the CBMS to become more refined and accurate over time. Eventually, the CBP implemented Tributary Strategies which assisted in dividing the watershed into smaller tributary scale components to better quantify land use and watershed impact. Jurisdictions developed teams of managers, scientists, citizens, and other stakeholders to develop management plans at smaller scales. However, tributary strategies were not effectively implemented in most cases, having little impact on the pollution load of the CBW. Part of this lack of implementation may be due to a failure to properly engage the multitude of stakeholders involved. As a result of this slow progress, an EPA-mandated bay-wide TMDL was established in 2010. This mandate was justified by the CWA and required TMDLs to be met by 2025 (Archaimbault et al., 2010). The implementation of this mandate and the management practices required to meet it are extremely expensive for some of the involved jurisdictions. Notably, city jurisdictions will be required to vastly decrease stormwater runoff which involves a massive infrastructural change (Paolisso et al., 2015).

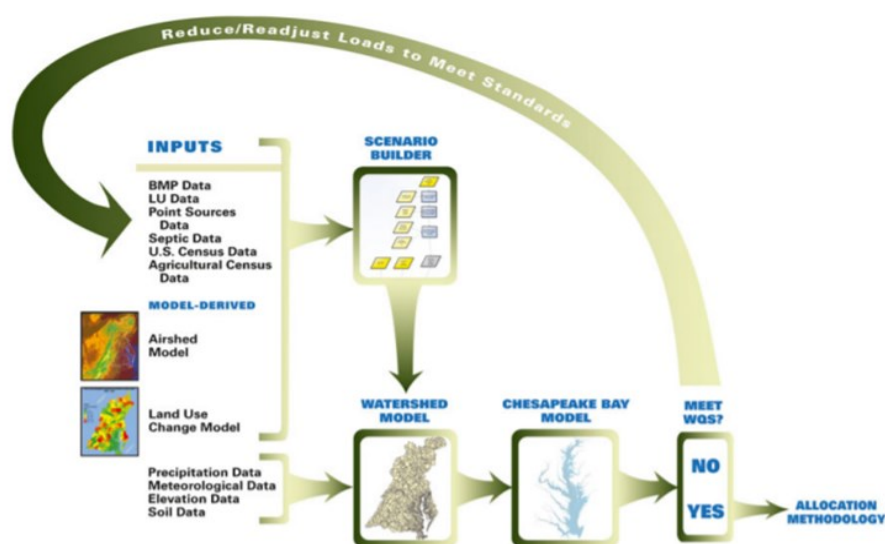


Figure 1. Chesapeake Bay Modeling System (CBMS) (Paolisso et al., 2015)

An advantage of the CBMS is that it can predict land use impacts on the watershed and can inform managers on the prioritization of certain pollution sources. Also, the CBMS is improving vastly over time due to having been designed in a way that it is constantly being refined in quality and scale. A disadvantage of the system is that the modelers at CBP have historically neglected to compute estimates of uncertainty for the model's output (Paolisso et al., 2015). This is likely a result of resource and time constraints. However, it decreases jurisdictional confidence in the data. Having uncertainty values in the data is important because the application of the CBMS involves essential decision-making processes that may involve copious amounts of funding. Fortunately, there are other models such as the Chesapeake Assessment Scenario Tool (CAST) that can be used for cross-referencing and increasing confidence in the models' outputs (CAST, 2012). The CBMS is a valuable tool for the mitigation of anthropogenic impact and the protection of the CBW's natural resources. However, the model has its disadvantages and must be

refined to entail good management decisions. Overall, watershed modeling systems can be largely effective at providing lawmakers and policymakers with accurate data.

Water Quality and the Landscape

But nonpoint source pollution poses one of the most extreme risks to aquatic landscapes. Funding and conducting research into the sources of pollution, especially on a watershed level, supports the construction of better landscapes. Inputs which are known to have excessive nutrients should build mitigating systems like wetlands and buffers. The earth has lost an estimated 75% its wetlands in the 20th century (Darwall et al., 2018). The processing that wetlands do so efficiently is important to maintaining the health of the planet. Wetlands systems also sequester carbon, a necessary part of mitigating human-caused climate change (Fennessy et al., 2008). Sections 401 and 404 of the CWA state that wetlands are protected, and those wetlands that must unavoidably be impacted must be compensated for by creating and restoring lost wetlands (US EPA, 2013b). A decision like this is incredibly important and has cascading effects. Restoring or creating natural pollution solutions will inherently support the success of native plants and animals. Decreases in pollution through legislation would also increase the sustainability and supply of aquatic food sources, decreasing reliance on land-based food which has a dramatic effect on the landscape.

Water Quantity

An even older precedent than the CWA is water law which are laws that govern allocation and use of water. In the US, water law is not quite about who *owns* the water as much as who has the right to *use* the water (Craig, 2019). In the US, water is a resource that falls under the public trust doctrine, the principle that certain resources are preserved for public use and that the government has a responsibility to protect and maintain these resources for public use. Water can be appropriated though and, in the US, you can own rights to use water for a beneficial purpose (Cornell Law School, 2022). Especially in the Western US water law is based on the Doctrine of Prior Appropriation. The first entity to put the water to beneficial use was given priority over later individuals and still, even if the priority user is downstream, they can take up to their limit of water. These priority rights to water transfer with the real property unless described otherwise in the transfer (Craig, 2019). Changes in who owns the water also affect what the water is used for. Currently, water rights are in high demand to maintain agricultural production. Even where water is scarce, Americans demand water to maintain their lawns and high consumption lifestyles, resulting in less flow for entities with lower priority rights. Due to climate change, increasing drought severity and frequency, and an increasing population, there is less and less water in the landscape to begin with. The US is a country that has a range of diverse climates. As the climate changes, drought-struck regions and regions of degraded water quality are facing situations where people just do not have access to clean water (OECD, 2015). Hotter and drier seasons in the American West are causing changes to be made to prior appropriations of water law (Craig, 2019).

Unprecedented droughts throughout the western United States foreshadow a water supply dilemma. Climate change is altering the timing, location, and storage patterns of water and precipitation events (OECD, 2015). This impacts water availability, unpredictably affecting consumptive industries and municipalities. Historically dry regions with crucial agricultural and urban communities are of notable concern. Some 80% of watershed basins in the American West are experiencing decreasing water yields, with many of the same areas also seeing rapid population growth and proportional increases in

consumption (Warziniack & Brown, 2019). Strain on water resources often extends to groundwater sources, which in some locations could become detrimental to allocation. In response, state and local governments are passing legislation to restrict individual water use, but the success of these policies is limited.

Water resources have always been a contentious issue. Fully appropriated surface waters, perpetual consumption rights, contamination, and the difficulty of changing the methods of water allocation make the system difficult to adjust to changing regional climates and populations (Craig, 2019). Many western states allow the transfer of water rights between individuals, but this process is slow and painstaking in most cases. Groups such as the Organization for Economic Co-operation and Development have outlined frameworks regarding the components for water allocation regimes (OECD, 2015). Water resource reform must work along a multitude of legal constraints depending on governmental bodies, private rights, and reduced water availability.

The Water Market

Water rights are a form of property rights, they may be separated from the land which provides beneficial use. In Montana, the exchange of water rights requires the approval of the Montana Department of Natural Resources and Conservation (DNRC) (Montana Watercourse, 2014). The focus of a water market is to transform the use of water rights from appropriations to a tradable commodity (Warziniack & Brown, 2019). Water trading is a popular concept in the American West, researchers found an increase in water rights leasing in regions with reduced water supplies (Ghosh, 2019). Individuals with relative water resource security can benefit immensely by leasing to other consumers in need.

On the market, rights are either outright sold or leased to a consumer, such as private users and institutional bodies. Short-term leases provide a low-cost solution to increasing water demand management, where water can be beneficially stored for later use. Long-term leases and water right sales provide future resource security for higher demand requirements. Leasing markets are greatest in regions with fully appropriated water sources, the outright sale of these rights could hinder future production of the seller (Ghosh, 2019).

Water rights transfers from private individuals to municipal or government bodies can benefit both parties. In past times of water shortage, allocation of resources typically benefited water use efficiency and reduced total water used (Warziniack & Brown, 2019). However, agriculture operations that surrender their ability to irrigate crops can fall into a 'buy and dry' dilemma that harms rural communities, where the loss of irrigated land may reduce future crop production.

Bozeman, Montana Case Study

Given the rapid growth of Bozeman, nearby agricultural operations are already in conflict with urban development and needs. Water rights transfers may lead to changes in how water influences landscapes. The allocation of Montana water is subject to multiple guidelines from federal to city policy. Federal law affects the Waters of the United States through legislation such as the Clean Water Act, Safe Drinking Water Act (SDWA), Flood Control Act (FCA), and Endangered Species Act (ESA) (Montana Watercourse, 2014). Historically, water use rights were based on the Doctrine of Prior Appropriation, where the first to put this resource to beneficial use was given priority over later individuals. After the State of Montana rewrote its constitution in 1972, the existing Montana water rights were acknowledged,

and a permit system was established for new water rights (Montana Watercourse, 2014). On the local scale, the City of Bozeman has policies enforcing the well-being of its water resources under Chapters 38 and 46 of the Bozeman Municipal Code (Municipal Code Corporation and the City of Bozeman, Montana, 2011). These policies do not extend beyond natural resource protection and waterway usage.

The State of Montana recognizes and acknowledges water rights claims existing before 1972. The rights of those individuals to appropriate water are inalienable. This begs the question; how can the City of Bozeman increase its water supply to satisfy the growing population given these guidelines? Like private landowners, the City of Bozeman can and does possess water rights in multiple tributaries throughout the Gallatin Valley (City of Bozeman, 2013). Climate modeling shows vulnerability to Sourdough and Hyalite Creek, two of the three largest water bodies Bozeman has rights to, both of which have access to the City's water treatment plants. The third large source, their most climatically resilient tributary, comes from the dammed Hyalite Reservoir, with modern yields expected to remain unchanged 40 years from now (City of Bozeman, 2013).

In addition to the current water rights owned by the City of Bozeman, they retain the ability to claim unused water rights through annexation via formal application (City of Bozeman, 2013). The confiscation of these rights occurs by forfeiture of appropriation or payment to retain them. The current total available water of the unused rights is equivalent to 6,750 acre-feet/year from three sources. However, this does not satisfy the lowest predicted water demand imbalance by 2062 of 7,000 acre-feet/year (City of Bozeman, 2013).

The City of Bozeman addresses alternative sources of water conservation in its 2013 Integrated Water Resources Plan. Here they estimate water demand reduction of low, medium, and high degrees of effort for moderate and high population growth rates. However, the potential efficacy of water restriction legislation has been found limited and vague, not to mention the uncertainty the City of Bozeman holds in future population growth and climate impacts on water supply (City of Bozeman, 2013, 2017; Warziniack & Brown, 2019). With decreasing water supplies and increasing demands, alternative options may also be required in the short term.

To offset water withdrawals, studies have attained highly feasible, yet costly, mitigation strategies by increasing reservoir storage and groundwater mining, mechanically reducing instream flow, and ag-to-urban water rights transfers. (Brown et al., 2019). Increasing reservoir storage found limited promise, while groundwater mining and instream flow reduction hold serious costs economically and environmentally. From the City's perspective, purchasing water rights may prove beneficial to long-term water security. Exchanging water rights was not considered in Bozeman's Integrated Water Resources Plan (2013). Bozeman also needs to make improvements to water infrastructure, so it is used efficiently.

It is important to note that the costs to rehabilitate and maintain water systems vary widely by community size and system type, and costs only increase when the system is not maintained regularly. Funding for the maintenance of infrastructure like this can depend on the allocation decisions of legislators and can be subjective, leaving communities already living in poverty and in unhealthy environments the most at risk for unsafe water.

Water Quantity and the Landscape

There is less water than ever pumping through the American West and there are effects on the landscape from this shortage. If Americans and industries keep consuming at the level we are without intervention,

wetlands will dry up, river flow will decrease, and riparian systems will be reduced. Decreased flow contributes to increased water temperatures and relative pollution. Dams, which are helpful for creating reservoirs and preserving water, have up- and down-stream effects on the landscape. In fall of 2021 the dam on Hebgen Lake malfunctioned resulting in a drastic decrease in flow below the dam and stranded fish (Associated Press, 2021).

Conclusion

Freshwater ecosystem services alone are valued to be worth over \$4 trillion annually despite covering less than 1% of the earth's surface (Darwall et al., 2018). The best way to protect our nation's waters is to continue passing legislation that limits sources of pollution and incentivizes initiatives to develop alternative processes that are less harmful to the landscape. This legislation should be informed by scientific research and technology such as the CBMP.

It is hard to imagine anthropogenic sources of freshwater pollution drastically decreasing inputs anytime soon. Pollution prevents normal ecosystem function and compounds negative effects by limiting the system's ability to be resilient without long-term effects. If the effects of pollution continue, species will go extinct, parts of the US will be uninhabitable, and recreational activities will become more difficult and unsafe. Additionally, climate change will dramatically exacerbate all these negative effects. Extreme weather events like drought and flooding, atmospheric temperature increases, and a change in CO₂ concentration will make pollution worse and put the environment more at risk. Getting pollution levels to a minimum is imperative for the continuation of life as we know it.

By looking at the Chesapeake Bay Watershed, you can see how difficult it can be to understand where pollution is coming from on the landscape. Initiatives like the CBMS are expected to have cascading effects on the aquatic landscape of the area, allowing scientists to target areas of high nutrient pollution to implement mitigation measures. Other sources of water pollution are monitored by agencies like the EPA and controlled by legislation like the Clean Water Act. Since the creation of these policies around the 1970s there has been an increase in awareness and a decrease in the severity of water pollution. Many states and local watersheds need stricter and more tightly enforced water quality standards.

Analysis of Bozeman, Montana provides an example of a western city's consideration of their future water security. Municipalities across this nation may not be able to provide such a flexible adaptation plan for sustaining this invaluable resource. Regardless, the present droughts will continue to become more severe and the effects that human water consumption has on the landscape will become more pronounced. In 2015, 34% of freshwater withdrawals in the US went to thermoelectric power, 42% went to irrigation, and 14% went to public supply. The remaining 10% of freshwater withdrawals are attributed to industrial, aquaculture, livestock production, domestic uses, and mining (Dieter et al., 2018).

Rules like those in the CWA that require wetlands to be replaced are good but lack specificity about what is required to fully make up for the loss of value the original ecosystem provided. The EPA and other government agencies need to continue to support research to determine the effects of freshwater pollutants and how those effects can be reversed or mitigated. Environmental education is also essential to informing stakeholders and coming generations about the problems at hand. We not only need stricter laws and policies that are informed about the function of aquatic ecosystems in this country but more effective action to uphold and enforce the existing laws and policies. The scientific community needs to keep people informed and afraid of what will happen in fifty years if we do nothing; governments need to

hold corporations and themselves accountable and provide awareness to the public about what they can do to help.

The aquatic landscape is as diverse as the issues it faces. United States law shapes the way we use, pollute, and clean our waters. It has the power to create a wetland or take it away. It has the power to save a species or let it go extinct. It has the power to dam a river or let it flow naturally.

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Pierson, Lauren

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Introduction

Legislation is an integral aspect of the United States' environmental protection enforcement, with differing laws implemented at both federal and state levels to regulate different aspects of environmental health. There are five laws that have forced governments, companies, and individuals to pay attention to the environmental degradation and the impacts to human health they may cause with poor practices that, in some cases, lead to catastrophic environmental impacts. The five laws are the:

- Comprehensive, Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (Office of the Federal Register 2002),
- National Environmental Policy Act (NEPA) of 1970 (Office of the Federal Register 2022a),
- Resource Conservation and Recovery Act (RCRA) of 1976 (Office of the Federal Register 2022b),
- General Mining Law (GML) of 1872 (Office of the Federal Register 2022c), and
- Mine Metal Reclamation Act (MMRA) of 1971 (State of Montana 1971).

Current and historic mining are a particular example of practices that have led to very destructive environmental outcomes. Overall, environmental protection and mining law in the United States has been largely inadequate for protection of the environment. Waters and soils are subject to acidification and metals contamination from adit and tailings drainage, large tracts of earth are disturbed by mining activity, removing vegetation, compacting soil, and altered stream flow are some of the landscape impacts that land has suffered despite the many laws governing it (Woody et al. 2010).

These laws have impacts beyond mined areas, where communities are dealing with degraded landscapes. According to data from the 2020 census, Gallatin County is the fastest-growing county in Montana, and the Bozeman area is one of the fastest growing micropolitan areas in the United States (Shelly 2021). As the area continues to experience rapid growth, the city has already moved to increase urban in-fill. Here, development repurposes previously developed land rather than raw land on the urban fringe. Although this practice fights urban sprawl, it has revealed sites that were

previously contaminated. Despite its reputation as a place near to wilderness in big sky country, Bozeman is not immune to the concerns of environmental contamination—the former site of the Idaho Pole Company’s manufacturing plant still has institutional controls in place due to pentachlorophenol contamination (US EPA 2017), and four sites in Bozeman are currently listed by the Montana DEQ as state superfund sites (MT DEQ 2020). Proper management of these sites will be essential in successfully handling the rapid growth of cities like Bozeman.

In this paper, the histories of these laws, their impacts over time, how compliance is currently enforced, and how the laws can be improved are all evaluated. The many environmental legislative acts of the United States have shaped the way that the country behaves in regards to hazardous waste and contaminated sites. CERCLA, RCRA, NEPA, and the GML have all influenced the implementation and enforcement of state laws, such as the MMRA, within Montana. Creating more powerful incentives for following these laws, and changing the laws themselves to focus on environmental standards (in addition to human health), will allow us to become proper stewards of the land.

History

Comprehensive, Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, the main act surrounding the cleanup of toxic waste around the United States, was primarily created as a response to the tragedy of Love Canal, NY (OA US EPA 1979a). A small community was built upon a landfill that contained chemicals from decades of unregulated dumping (Figure 1). After a record rainfall event, the rotting drums of chemicals under homes and schools leached incredible amounts of chemicals—at least 82, with 11 suspected carcinogens—and began to push upwards through the soil. Puddles of chemicals could be seen throughout the affected areas, children received chemical burns, adults showed elevated levels of white blood cells (a precursor to leukemia), miscarriages occurred, and at least five birth defects were recorded. This tragedy sparked enough outrage about the dangers of hazardous waste that CERCLA was created and enacted by 1980 (OA US EPA 1979b). It establishes the National Priority List, a list of sites with toxin levels high enough to cause potential human and environmental harm. Since the act was passed and the list established in 1980, 1800 sites have been added to the list, with 400 cleaned up to acceptable human health levels (OLEM US EPA 2015).



Figure 1. Hazard waste dump Love Canal (circa 1940) (Christensson 2019)

National Environmental Policy Act of 1970 (NEPA)

NEPA is the first comprehensive environmental legislative act passed in the United States, passed on January 1st, 1970 (DOE 2020). With little statutory guidance as a precursor to the act, it entered the country relatively quietly. Now, most agencies have adopted the environmental assessment process into their day-to-day operations, and automatically follow NEPA, without the need for civil suits or post-development statements. The real excitement surrounding the Environmental Impact Statement (EIS) came in the first few years after inception, when hundreds of lawsuits were taken up against the federal government, citing flawed or no EIS as the reason for the suits. This action, taken by many environmentalists, stopped or halted more than 350 federal projects (Kershner 2011). The provision was used mostly for good, such as when the Atomic Energy Commission's nuclear licensing process was stopped for more than a year, delaying the production of a new nuclear power plant in Maryland. Another project delayed was Outer Continental Shelf oil drilling—it was held up until a proper environmental impact statement was prepared (Kershner 2011). Sometimes this ability was used to further entrench environmental racism in cities, using the challenging of public housing projects as a guise to delay or stop affordable housing for underrepresented communities (OA US EPA 2022). Overall, NEPA has had a great impact on environmental development, whether it be good or bad.

Resource Conservation and Recovery Act of 1976 (RCRA)

As awareness of environmental risks increased in the US in the 1960s, legislators turned their attention to protecting human health. In 1965, the Solid Waste Disposal Act was passed, with the goal of helping to address the increase in waste production because of a number of factors, such as economic growth and increases in the mass of disposable product packaging (Office of the Federal Register 1965). Byproducts of pollution prevention technology, mandated by stricter controls on air and water pollution, increased the amount of waste generated by factories (Office of the Federal Register 1965). Unfortunately, this law was not effective—even in the decade after the law was passed, congress estimated that between 30 and 35 million tons of waste were being dumped straight onto the land every year (US EPA 2002). It was clear that further action was necessary, so in 1976, the original law was amended to include the Resource Conservation and Recovery Act, commonly known as RCRA. This act, like CERCLA, was born from anger over public health catastrophes like the one in Love Canal, New York, and hoped to set up a framework for addressing the fate of solid waste—especially toxic waste. RCRA set up a “cradle-to-grave” system for regulating hazardous waste, which allows regulatory bodies (principally, the EPA) to monitor hazardous waste at all stages, between its initial generation through disposal (Chambers and McCullough 1995). RCRA can sometimes be thought of as a kind of precursor to CERCLA, although the

scope of each law is slightly different—one initial gap was that RCRA was initially written to focus on operating sites, while CERCLA was written to facilitate cleanup of abandoned sites. In some ways, the laws are similar, as they both control hazardous waste sites to protect human health. This gap was bridged some in 1984, when the Hazardous Waste Amendments to RCRA increased its jurisdiction to include leaking underground storage tanks (Chambers and McCullough 1995).

General Mining Law of 1872 (GML)

The primary federal law governing hardrock mining in the United States is the General Mining Law, 30 U.S.C.A § 1-16, 21-54, 721, and 1201-1328. At the time the law was written, legislators wanted to facilitate the expansion of mining in the US, such that it is still interpreted that mining is a “highest priority and best use for public lands” (Woody et al. 2010). Approximately 60% of federally managed land is allowed for mining use without extensive restrictions (Humphries 2008).

Scientists assert that the law needs amending for further protection considerations (Sherwood 1970; Woody et al. 2010), though others argue that effort to expand the General Mining Law may be misplaced as it only governs rights to mineral resources, while other environmental legislation fills gaps left by the General Mining Law alone (Dobra and Dobra 2013). A criticism held against the law is that it requires no tax or royalty to be paid to the federal government, despite most mining occurring on federally owned land (Huber and Emel 2009), though royalties from mining may not be as lucrative as expected due to firms being incentivized to vertically disintegrate operations to minimize financial burden (Humphries 2008).

Mine Metal Reclamation Act of 1971 (MMRA)

The MMRA is Montana’s primary law regarding cleanup and mitigation of environmental degradation from mining activity. Though it is comprehensive, it still has much room for improvement. MCA 82-4-300s. MCA 82-4-301 lays out the legislative intent, which is to protect the environment from degradation and depletion, in both resources for extraction and ecological services; require adequately engineered, operated, monitored, and maintained tailings management and impoundment facilities to protect human and environmental health; and to press acknowledgement that mining activity may preclude complete environmental restoration.

Some strengths of Montana mining law are that the Montana Department of Environmental Quality (MDEQ) has enforcement powers over environmental protection and mine reclamation, streamlining enforcement. In the mining industry, recovering the costs of reclamation sometimes poses a challenge – the MMRA extensively covers

cleanup bonding. Under it, a bond must be paid before a permit for mining activity is issued, and the bond amount must be reviewed in three-year intervals to ensure it adequately covers potential cleanup costs (Kuipers and Carlson 2000).

Impacts Over Time

These five laws have influenced landscapes over the course of their implementation in the United States. They all have slightly different approaches to regulation, whether it be prevention of degradation, restoration after destruction has already occurred, or even just establishment of a practice. The landscape and socioeconomic impacts, whether intended or not, are vast, and are evaluated here.

CERCLA is a primary piece of legislation surrounding restoration after destruction (Office of the Federal Register 2002). Without CERCLA, contaminated and abandoned sites, mostly mines, would be left abandoned with no responsible party to clean it up. CERCLA enables these sites to be remediated, with the intention of improving human health that are adversely affected by them. More than 400 sites have been successfully remediated and taken off of CERCLA's National Priority List of contaminated areas. One effect of the industries that produce hazardous waste—mining, manufacturing, and energy production, to name a few—is that minority communities are often disproportionately affected by the adverse effects (OP US EPA 2015). For example, Black communities across the country carry 54% more of the environmental burden of pollutants compared to the overall population, and non-white people had a 28% greater burden as well (Mikati et al. 2018). These adverse effects to Black, Indigenous, and People of Color (BIPOC) populations has long been studied, but some legislation is being passed in an attempt to remedy the situation. In January 2022, a draft of an environmental justice action plan was proposed. It increased funding for 49 previously unfunded Superfund sites, and accelerated funding for others (OA US EPA 2021). This plan focuses CERCLA's jurisdiction on sites that impact BIPOC communities and will hopefully contribute to decreased health effects to them, as CERCLA intended.

RCRA, overall, has decreased the impact of hazardous waste. Its “cradle to grave” approach is more preventative than reactionary, as it seeks to prevent resource waste that would end up in landfills or repositories in the first place (Mufara 2022). RCRA influences companies to handle their waste better along the whole manufacturing process by using preventative measures like fines, requirements, and detection systems in underground storage tanks to catch non-compliance as early as possible. The EPA uses compliance monitoring to litigate the different kinds of waste an industry may produce. While RCRA does ban open dumping of municipal waste, many communities are still adversely affected by poor enforcement. In a landmark case in 1979, residents of

Houston, Texas filed a lawsuit against a waste management company—Southwest Waste Management Corp—for racial discrimination in the placement of waste disposal sites. Even though the Plaintiff lost the case, it brought to light the ways that marginalized communities, and the landscapes they live in, are affected by waste disposal (McDonald 1979).

NEPA, was the first significant piece of environmental legislation (Kershner 2011). Its impact on landscapes is less apparent now than it was in the 1970's, just after it was enacted. NEPA allowed environmentalists to file lawsuits against the federal government when they saw that projects did not have an EIS or felt that the EIS was flawed/improper. Environmental litigation through the EPA stopped or modified more than 350 federal projects in the first few years after implementation. This forced companies to consider the true environmental impact of the projects they were conducting (Kershner 2011). Now, EISs are an accepted part of the process of development. NEPA has showed that requiring EISs in development projects does usually end up with modification to decrease further environmental impacts, a testament to its success.

The General Mining Law of 1872 has changed landscapes over time for the worse. It has encouraged hardrock mining on public lands, wherever resources are found (Office of the Federal Register 2022c). This led to the creation of hundreds of thousands of hardrock mines throughout the country, with more than 140,000 of those abandoned today (U. S. Government Accountability 2020). These mines contribute to impacted biogeochemistry of the areas they reside in, with increased acid mine drainage, as well as metal pollution in water and soils (Sherwood 1970). These impacts then need to be mitigated by pieces of legislation such as CERCLA, or the MMRA.

The MMRA has lowered the environmental impacts of mines in Montana, especially compared to those only governed by the GML. With its required compliance to state air, water, and soil quality standards, it prevents some, but not all, degradation of the land. It does, however, enable the cleanup of mining sites once the mining has completed (State of Montana 1971). For example, it influenced the cleanup of Soda Butte Creek after the McLaren Mill and Tailings site leached toxic waste into the creek for over 80 years (National Park Service 2019). Figure 2 shows the before and after images of the restoration—the stream was previously heavily contaminated by metals and other toxins, rendering it almost uninhabitable to macro and microorganisms. After the restoration, the red color of the sediment in the creek bed is gone, obstructions have been added to the channel, and water is flowing swiftly through the creek, indicating the path to full restoration.



Figure 2: Pre-restoration image of Soda Butte Creek (left), and post-restoration image (right) (National Park Service 2019).

Compliance and Enforcement of Mining Law

Law compliance and liability in most mine operations is enforced by the EPA under CERCLA (Seymour 2004). Enforcement mechanisms granted to the EPA include civil penalty and power to file civil suits against alleged violators of environmental law (Siedenfled and Nugent 2004). Some environmental contamination of mined sites is considered unavoidable, and legislation has been passed to protect environments from too severe of degradation – the regulatory agencies and other authorities attempt bring the goals of profit and environmental protection into correspondence with one another (Seymour 2004).

Civil penalties can be imposed by the EPA for violations of these Acts. These fall under either Class I or Class II penalties. Class I penalties are fines of under \$25,000, and may only be imposed after the alleged violator has been notified, and the alleged violator

must be allowed a “reasonable opportunity to be heard and present evidence” (Siedenfeld and Nugent 2004). Class II penalties are penalties less than \$125,000, and follow the same guidelines as Class I penalties with the addition of a formal hearing as required by the Administrative Procedure Act (Siedenfeld and Nugent 2004). Amounts greater than \$125,000 must be pursued via lawsuit.

A suit in federal court, filed by the EPA against a party (rather than regulatory action by agency) may result in a court order or injunction, such as to cease a specified activity, or to impose fines greater than \$125,000. EPA legal offices advance and strengthen a case before it is passed to the Department of Justice, which handles all federal cases brought by the EPA (Siedenfeld and Nugent 2004).

The EPA may also issue orders to decrease or entirely prevent discharge of a toxic or hazardous waste or other material, or any activity that is causing or may cause detriment to the environment or human health – this power is provided by CERCLA. Should a mine operator or owner fail to follow such an order without valid legal basis to do so, the EPA may pursue treble damages (triple the original fine or cost brought by the action) from the operator or owner (Seymour 2004). Though immense power is given to the EPA to address mining-related pollution, said power can depend on the alleged violator’s finances and ability to contract cleanup – as a result, less than 40% of mining cases pursued by the EPA were enforcement-lead remedial action (Seymour 2004).

Reclamation Bonding

A reclamation bond relieves or reduces the financial burden of cleanup on the state should the operator or other liable party fail to reclaim a mine site. The ability of an alleged violator of environmental law to pay for remediation and damages is not always present – the mine operator or owner may lack sufficient liquid funds, have previously filed for bankruptcy, have been dissolved, or otherwise be unable to hold liable for violation of law or environmental damages. Due to this, payment of a reclamation bond is required for operations on federal land and on many other publicly owned and government-managed sites, providing funding for the government to clean the site should the liable party fail to do so. Bond forfeitures to the state of Montana between 1978 and 1996 totaled only about \$116,000 (Gerard 2000).

Enforcement of laws that protect the environment is costly in both money and time. Due to these significant costs, they require, enforcement can be lax. In tandem with this, firms have a financial incentive to cut the cost of environmentally protective activity in exchange for greater profits, which results in the degradation of environmental quality. In US mining, environmental protection standards defined by operating permits are a “product of negotiation” between the regulator and a mining firm (Gerard 2000). For

these permits, environmental law is often used as a standard or precedent from which negotiations can begin.

Cleanup bonding generally financially protects the government agency it is paid to should a mine operator fail to remediate their site. A bond amount that is not regularly reviewed may not cover the full cost if contracting or other reclamation expenses increase – hence the stipulation in MMRA requiring bonds to be regularly reviewed. Additionally, a firm paying a bond reduces the liquidity of said firm’s resources – though the bond is to be returned upon fulfillment of cleanup and remediation obligations, it is no longer a liquid (immediately usable) asset to the firm, and is not usable for site remediation or improvement of mining and refinement processes. To reduce the impact of this, firms may contract a surety to pay the bond, who becomes liable for cleanup actions. The firm is then liable to the surety for remediation costs (Gerard 2000). Loss of a cleanup bond is intended to be a deterrent against failing to remediate a site. Monitoring of mine sites is also deterrent against regulatory violations, and the practice of reclamation bonding compliments the concept of liability.

Regulatory failure and citizen involvement in enforcement

Frequent and intensive monitoring of all mine sites and surrounding natural resources is cost-prohibitive to be accomplished by state or federal regulatory authorities. Between this and agency failure to enforce environmental regulations, citizen involvement has been required to achieve enforcement at some mining sites.

Following the Summitville mine disaster in Colorado, in which metal-laden drainage compromised the Alamosa River in 1991-92 (Woody et al. 2010), Colorado passed new legislation to prevent such a disaster from occurring in the future. Stipulations of updated Colorado law include requiring companies to submit extensive baseline information about a proposed site, which must be certified by a state engineer, to prepare an Environmental Protection Plan prior to beginning of mining activity, and to pass construction and compliance inspections of mine sites (Porter 1997). Similar initiatives at the federal scale would be beneficial to enforcement of environmental regulation regarding mines.

The Zortman-Landusky mine in Montana, producing gold and silver via “heap leach cyanide processing” (Williams et al. 2009) is speculated to have been headed toward a similar fate of environmental disaster to that of the Summitville mine, had it not been for citizens filing notice of intent to sue (Porter 1997). Following this, the EPA issued a notice of violation of the CWA to the operators of the mine. Being on BLM land, the site remains under management by the BLM and MDEQ, which spend about \$800,000 per year combined on site operations (Williams et al. 2009).

Improvements

A common thread through most of these laws is that the focus is largely on impacts to humans, whether for monetary gain through resource extraction (General Mining Law) or for the good of public health (as in CERCLA and RCRA). In order to create a US code that is more amenable to the health of the environment and our ecosystems, a set of improvements could be made, both to make the impacts of these laws more equitable within our communities, and to ensure that our nation's ecosystems are stable and healthy.

As a landmark piece of legislation that has been amended numerous times, RCRA is not under very heavy fire to change. One important complaint is that the law needs to be consistent across all wastes and regulations—currently, byproducts of hydraulic fracturing (also known as fracking) are not held to the standards of many other similar waste products. Fracking often collects low amounts of radioactive elements like radium and aggregates those elements in waste products, leading to sludge with much higher concentrations of radioactive elements than that occurring on the landscape. In an industry where some facilities may produce 1,100 barrels of oil a day, there is a need for these toxic byproducts to be regulated with the same attention as all pollutants (Zelleke 2019).

CERCLA, on the other hand, is less well regarded. The initial act has a reputation for being written in a slapdash way and being designed with the intent to pass through the legislature right away. As a result, there are quite a few elements that critics of the act are calling to change.

First of all, many of the terms that are common in the language of the law are poorly defined, and there are many calling for clarification of those terms, such as “land use” and “disposal” (Weissman and Sowinski 2015). Making sure the language and standards are as clearly defined as possible will help maintain consistency across all cleanup sites, ensuring that sites located in communities with less lobbying power, like many minority communities, will see cleanup programs that are as effective as those in communities with more lobbying power (Marcos, 2021)

Another complaint is that liability assignment often gets tangled up in a web of litigation; in some cases, parties who were only partially responsible have ended up assuming disproportionately high costs, while others were able to walk away. This disincentivizes participation by other parties like lenders and parent companies, for fear of being unfairly assigned responsibility. Because of that lack of participation, cleanup

efforts often fall short—especially because, for many years, there was no tax funding cleanup (Marcos, 2021). The superfund tax has only recently been reinstated, and still includes all of the unjust exemptions included in the original version, such as the one excepting petroleum fuel products from taxation and coverage under CERCLA (Barnes, Hogan, and Mowbray 2022).

Finally, some complain that certain provisions under CERCLA can end up being “polluter-centric” or “developer-centric” (Fox 2012). Rules that deal with reporting spills, for example, are tailored towards responses addressing cleanup of recent or actively increasing hazardous waste releases (Schnapf 2011). This made sense when the act was written, as waste was being released onto new sites at alarming rates, but as waste control quantity and regulation under RCRA have strengthened, new sites that would qualify for superfund status are becoming rarer. While that is good news, unfortunately, there are quite a few “legacy” sites: places where pollutant levels are high, but enough time has passed since contaminant release that it may be unclear whether a “reportable quantity” of contaminant spilled over the 24-hour period that makes reporting mandatory. As a result of these contaminated sites going unreported, landowners are able to either abandon them, leading to brownfield creation, or attempt to sell them off without addressing the issue (Schnapf 2011). One major way to make these transactions more equitable would be to get rid of CERCLA’s 24-hour period for “reportable quantities” and make disclosure of contamination mandatory in all cases. This would help superfund sites do their main job and assign liabilities closer to the source of the contamination, rather than rely on voluntary cleanups and brownfield funding to clean up every site—there are simply too many of them for that to make a dent in the total number of legacy cleanup sites.

The federal General Mining Law is another set of legislation that could stand to see some improvements—it has even been referred to as a “holy grail” by some, who have spent years working for mining law reform (Dobra and Dobra 2013). Reform of mining law is important, and perhaps so difficult to achieve, because the current setup is heavily biased towards allowing resource extraction on public lands. In the law, mining is considered to be the ideal use for federal land, leading to generous permitting of projects, even if they would be environmentally damaging (Kuipers 2000). This issue is present internationally as well: in British Columbia, Canada, mining is also given priority over other land uses (University of Victoria ELC 2019). In British Columbia, calls for reform include greater input from indigenous communities, “increased penalties to deter illegal practices”, and prohibition of mine activity that would result in water needing to be treated in perpetuity. All of these would help prevent large-scale landscape damage right from the start (University of Victoria ELC 2019).

International working groups promoting safer mining practices, like the Initiative for Responsible Mining Assurance (IRMA), are instrumental in creating a future that ensures environmental health and safety. IRMA sets out “Standards for Responsible Mining”, which are updated regularly and reflect the best practices for modern mining. These standards address considerations across all areas of mine operation from exploration to reclamation, and serve as a resource that governments can draw on to establish more effective legislation regulating environmental safety in mining (IRMA 2020).

In Western Australia, home to the ecologically important Jarrah forests, relatively strict legislation has proven to be critical for managing the landscape impacts of mines, with a focus on responsible closure and cleanup. These forests are among the world’s largest biodiversity hotspots, and in some cases sit on large deposits of bauxite, a mineral that is key to aluminum production (Galatowitsch 2012). In Western Australia, the ability to lease lands from the government for mining is contingent upon following agreed-upon conditions for maintaining the land. Because these bauxite mines are in biodiversity hot spots, standards for reclaiming mines are very high. Restored areas are monitored closely, and adaptive management practices are followed to ensure that restoration is meeting goals (Galatowitsch 2012) This means that monitoring emphasizes finding emerging issues and challenges on each site, and practices are adjusted in order to solve them. Mandating practices like this in the United States will be a key step in balancing demand for mining with the protection of our environment.

Conclusion

Over the course of this paper, five laws that govern how the United States acts in regards to environmental degradation were evaluated for their impacts on land over time, how compliance is enforced, and how they can be improved to increase ecosystem health. They’ve influenced how the land has been shaped, and how citizens are impacted by them. These laws are certainly not perfect, and we have some recommendations for improvements to be made. For CERCLA, clearer definitions for the already-vague terminology are essential for the continuance of the law’s relevance. The law should also be amended to increase the focus on environmental health factors, as opposed to purely human health standards. This developer-centric language is detrimental to the protection of the environment, as well as the eventual human health impacts it could lead to. CERCLA should also incentivize party accountability, because as it stands, developers too often get let off the hook for the degradation they cause. RCRA also needs to have clearer language. This improvement would streamline the hazardous waste production

industry, and lead to an increase in overall environmental health. The GML could be improved with increased indigenous community input, as well as more permit denials overall. Creating incentives to follow higher business practice standards, such as IRMA, would increase the quality of resource extraction as well.

The various landscape impacts of these laws have been documented, as well as the socioeconomic impacts. The acts, while well-intentioned, have led to the destruction of ecosystems and creation of toxic waste that's costly to clean up. Disproportional environmental burdens have also affected BIPOC communities across the country, as increased resource extraction has occurred within the United States. While it has improved with the introduction of various environmental justice plans and increased funding for cleanup of marginalized communities, thousands of sites across the country are still reeling from the effects that contaminated sites have wrought on their lives.

CERCLA, RCRA, NEPA, GML, and the MMRA have impacted the people and land of the United States in multiple ways. There are currently compliance incentives in place, but they could be improved with an overhaul of the laws themselves. Shifting the focus from economic and human health damage and towards environmental degradation is essential to the upkeep of the lands we call home.

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Laws and Landscapes in the Face of Climate Change

Erin Bjorklund, Madeline Bunce, Melissa Widas, Nicole Ellis, Shay Luck

Montana State University

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Introduction

What is Climate Change?

As the Earth's climate changes, rapidly bringing in unprecedented disasters, there has been talk amongst leaders and citizens about what to do to mitigate damage to the world's natural resources. One of the main contributors to climate change is the emission of greenhouse gases. These gases absorb outgoing radiation from the earth, which traps heat in the atmosphere. The rise in greenhouse gas emissions has exacerbated warming conditions all over the globe. Since the 1970s, greenhouse gas emissions have been steadily increasing (Figure 1). This increase in emissions mirrors the rapid growth of the human population.

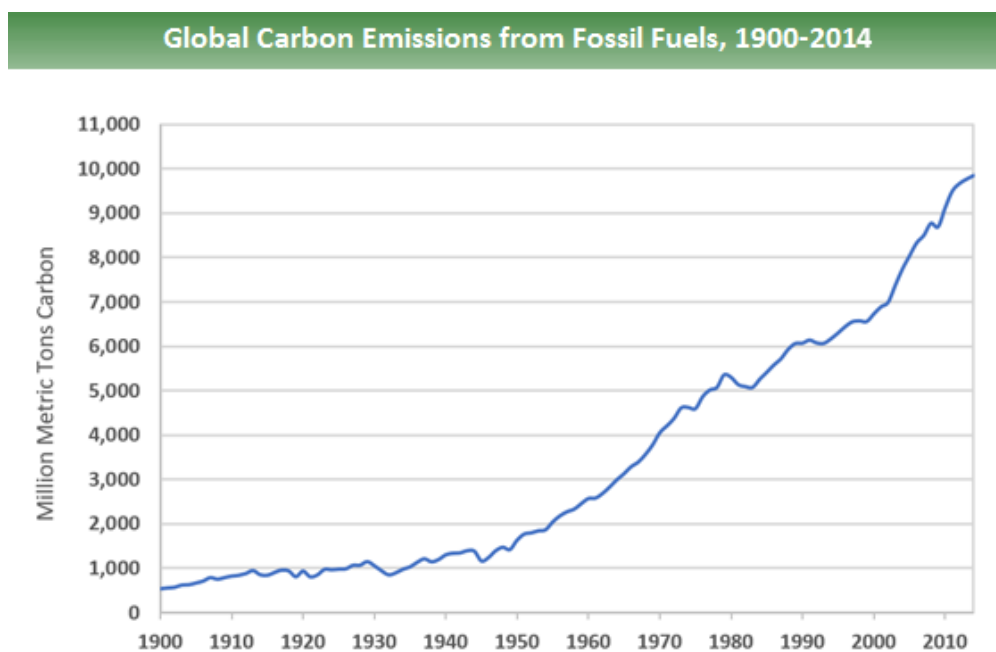


Figure 1: Global Carbon Emissions from Fossil Fuels (Bennetzen et al., 2016).

The Intergovernmental Panel on Climate Change (IPCC) has indicated potential warming hazards at different concentrations of carbon dioxide (CO₂) in the atmosphere: levels of 450 parts per million (ppm) could lead to a mean temperature change of 1-2 °C by 2100, and levels at or above 550 ppm could lead to a mean temperature increase of 1.5-3 °C (Shaheen & Lipman, 2007). The current concentration of carbon dioxide in the atmosphere is at 412.5 ppm (NOAA, 2022). There are many contributors to greenhouse gas emissions, of which the largest culprits are

energy systems, industry, buildings, transport, and land use (including agriculture and forestry) with varying trends across regional and global scales (Lamb et al., 2021).

In 2019, the Environmental Protection Agency (EPA) found that the U.S. emitted 6,558 million metric tons of greenhouse gases (United States EPA, 2016). Greenhouse gases are byproducts of coal, oil, and natural gas use. The continued use of these fuel sources will make warming more extreme (Silvio, 2020). Increasing global temperatures exacerbate changes to landscapes ranging from a surge in hurricanes and drought frequency, melting of polar ice sheets and permafrost, extinctions, rising sea levels, and increased storm severity (Shaheen and Lipman, 2007). If no protective measures are enacted, climate models predict increasing temperatures and decreasing snowpack in the Northern Hemisphere (Collins & Senior, 2002). Snowpack and winter precipitation are a critical input of freshwater for spring and summer in the western U.S. (Silverman et al., 2013). Consistently low water levels will alter stream morphology, which changes stream bed erosion patterns, canyon and valley paths, aquatic species abundance and diversity, riparian habitats, and other important ecosystem functions across the U.S. To give snowpacks and river corridors in the U.S. any real protection, climate solutions need legislative backing. Without more rigorous legal protection, freshwater systems in the U.S. are at risk of irreversible damage or even a complete collapse.

The current regulations in the U.S. fail to adequately address climate change and therefore have dramatic impacts on landscapes. To combat the changing climate, laws must encourage innovative solutions that address all aspects of the environment. This paper will examine the laws and legislation currently in place to combat climate change and the innovative solutions being employed to address it.

Current U.S. Regulations

Clean Air Act

The Clean Air Act (CAA) is arguably the biggest shaping factor in environmental law regarding greenhouse gas emissions. The CAA was created to both enhance air quality due to health concerns and protect the stratospheric ozone layer (Clean Air Act, 2021). The EPA gained the legal jurisdiction in 2013 to “issue standards, regulations, or guidelines, as appropriate that address carbon pollution” (Harvard Law Review, 2016). In response, the EPA proposed to cut CO₂ emissions from 2005 in the power sector by 30% by 2030 and this was to be done through state-specific standards and goals based on emissions of CO₂ (Harvard Law Review, 2016). The CAA is effective when it has the power to regulate specific pollutants. In the last three decades, the combined emissions of common air pollutants were reduced by up to 78% between 1990 and 2020 as seen in Figure 2_x and CO, are greenhouse gases. The overall environmental damage and pollution have been reduced, public health and quality of life have increased, cleaner engines and fuels have been incorporated, and pollution control devices have been installed on coal power

plants (EPA, 2021).

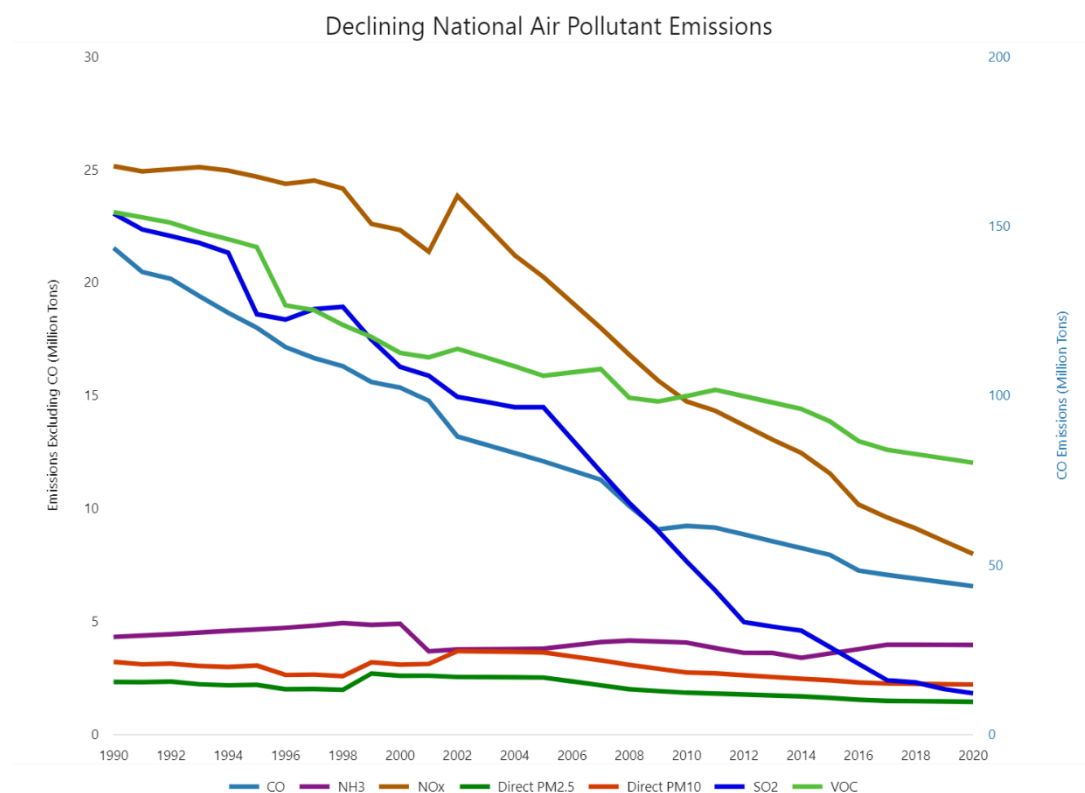


Figure 2: Air pollution emissions from 1990 to 2018 (EPA, 2021).

One of the benefits of the CAA is the cost-benefit relationship. The CAA helps to reduce air pollution and benefit human health while also generating revenue from the taxpayer dollars put into it. In 2020 the cost of the CAA was \$65 billion which is a \$45 billion increase in cost since 2000. While this may seem like a big cost, annually the CAA generates \$12 trillion in revenue in 2020 alone. This equates to a net benefit of \$770 billion dollars in just 20 years from 2000 which is a 30-fold increase in revenue (Craig, 2010). The CAA is also cost-effective because a lot of the cost is borne by the polluters and not the taxpayers. Pollution that ends up in the atmosphere is addressed by the CAA because the act binds polluters to pay for the reduction of their own emissions meaning the taxpayers are not bearing this cost (Holladay, 2011).

One of the primary criticisms of the CAA is the fact that since the CAA is regulated by the EPA and therefore enforced on a federal level, the EPA sets uniform emission standards for all 50 states (Sunstein, 1999). This means that even though different states have varying emission rates as well as varying air qualities, they are all subject to the same federal standard. Air pollution is not a one size fits all for all the states and therefore the enforcement of a uniform emission standard will penalize and benefit certain states more than others. If the EPA limit is set too high, it means that most states will not be able to comply and therefore will be in violation of the set emission standards. This could be detrimental for both the citizens and federal government because if emission targets are not met by different states, private citizens can sue

the EPA. On the other hand, if emission standards are set too low this means that the EPA cannot ensure that citizens in all fifty states are getting equitable access to clean air.

Another criticism of the CAA, which also points to a larger problem involving the U.S. Congress, is that the EPA is increasingly limited about what it can do to enforce global warming pollution (Union of Concerned Scientists, 2011). In 2007 the U.S. Supreme Court ruled that under the CAA global warming emissions should be covered by and enforced by the EPA (Union of Concerned Scientists, 2011). Global warming has negative effects on both the health of U.S. ecosystems and citizens which is why the Supreme Court voted to have warming added to the Clean Air Act. This addition would therefore set emission standards for greenhouse gases that increase global warming. However, the U.S. Congress has been continually fighting the amendment of the CAA to include global warming. This means that the EPA is essentially powerless when it comes to controlling emissions that cause global warming which is another criticism both scientists and citizens alike have of the CAA.

The CAA has had the greatest effect on reducing greenhouse gas emissions from restrictions on cars, industries, factories, and coal-fired power plants (Greenbaum, 2018). However, a plateau has been reached in attempts to further reduce emissions of greenhouse gases. Human health impacts from air pollutants are no longer a major concern due to the effectiveness of the CAA. The next steps of further reduction and mitigation appear to be a challenge for citizens and lawmakers to achieve. The CAA fails to address the current threats posed by climate change. The act must be altered to encourage a reduction of greenhouse gases through the use of innovative solutions to reach greenhouse gas levels that promote both human and environmental health.

Clean Water Act

Another act that had a major influence on the U.S.' ability to address climate change is the Clean Water Act (CWA). The basis for the CWA was a law from 1948 called the Federal Water Pollution Control Act. In 1972 there were growing concerns about controlling water pollution and so the Federal Water Pollution Control Act was amended and became the CWA. The CWA was a response to unswimmable and unfishable freshwaters in America which posed large health risks to local communities and resulted in a major loss of recreational and economic value. The main driver of the CWA was a 1969 fire on the Cuyahoga River, which had experienced fires every decade starting in 1868 (Keiser & Shapiro, 2018). The goal of the CWA was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," (EPA, 2022). This was passed with large support in the congressional house and passed unanimously in the senate despite its \$24 billion price tag.

The amendments in the CWA create a basic structure for regulating pollution discharges into waterways by making point source discharge illegal without a permit. Point sources are sources of pollution that come from a single, identifiable source (sewer plants, automobile factories, paper mills, etc.). Nonpoint sources are sources of pollution from which there isn't a traceable location from which a pollutant is released. In addition, the amendments maintained

existing water quality standards and funded sewage treatment plant construction. The EPA was given the jurisdiction to set wastewater standards.

The CWA had several goals including making all U.S. waters fishable and swimmable by 1983, no water pollution discharge by 1985, and prohibiting toxic amounts of pollutant discharge. There are decreases in oxygen deficits, and an increase in fishable and swimmable water, which is seen in figure 3 (Keiser & Shapiro, 2018). There is also a decrease in fecal coliforms, and a decrease in total suspended solids (Devine, 2019). This is due to the \$650 billion spent on 35,000 grants the EPA gave to improve wastewater treatment plants, each grant decreased pollution for 25 miles of the downstream area, and that decreased pollution lasted about 30 years. There was also an increase in the amount of fishable water with a 12% growth since the CWA was enacted (Keiser & Shapiro, 2018). The CWA has improved U.S. waterways, but the act has not fully accomplished its ambitious goals.

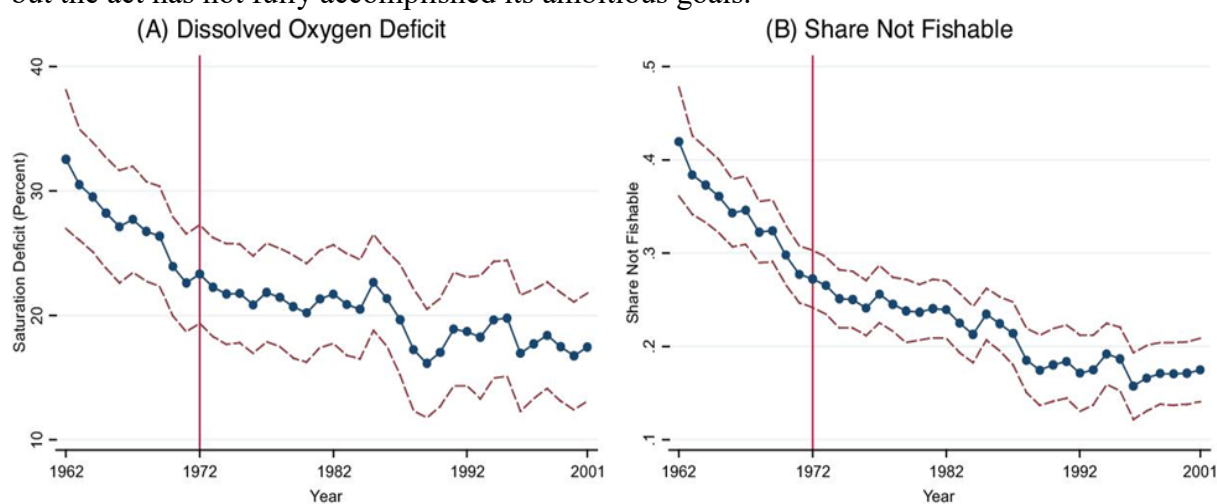


Figure 3: Water pollution changes from 1962 to 2001 (Keiser & Shapiro, 2018).

One reason why the Clean Water Act has not fully accomplished its goals is because it does not address nonpoint sources of pollution. Nonpoint sources can include runoff from agricultural fields, sediment from mismanaged construction sites, and other untraceable sources. Since the CWA does not address nonpoint sources, it is missing a whole subset of pollution that is going unchecked and unregulated. For example, agricultural runoff is a big source of pollution in freshwater systems, causing eutrophication and contamination of water sources for both humans and other organisms. However, since it is a nonpoint source, it is not addressed in the CWA and therefore we currently have no way to regulate and remedy nonpoint sources (US EPA, 2013).

The CWA's lack of clearly defined jurisdictional boundaries is another reason why the CWA is often deemed ineffective. The CWA claims jurisdiction over "waters of the United States" and defines this as "navigable water," however the definition of these terms has changed and been debated since the passing of the act. In the 2001 U.S. Supreme Court ruling in *Solid Waste Agency of Northern, Cook County* determined that isolated intrastate non-navigable

waters were not protected under the CWA. But if isolated water has a “significant nexus” or connection to navigable water then it could be deemed “water of the United States” and protected under the CWA (Downing, et al., 2003). Since its establishment, there have been many similar cases and debates surrounding unclear definitions within the Act and the resulting jurisdiction. The disagreement over jurisdiction prevents the act from reaching its full potential. Many waterways within the U.S., such as isolated intrastate non-navigable waters, still have little to no protection because the language in the CWA does not include them. The uncertainty also provides opponents of the act the opportunity to argue against clean water protection or stall restorative efforts, leading to the act’s ineffectiveness.

Another controversy is whether the benefits of the CWA exceeds its enormous costs. Over \$1 trillion or over \$100 per person per year has been spent since 1972 on the act by the government and industries (Keiser & Shapiro, 2018). In the mid-1970s, this amount of spending made the act the single largest public works program in America. For reference, more was spent on the CWA than the U.S. has spent on air pollution and the CAA (Keiser & Shapiro, 2018). These large costs are attributed to the ambitious goal of restoring and maintaining the “integrity of the Nation’s waters,” the CWA had several ambitious targets including making all U.S. waters fishable and swimmable by 1983, no water pollution discharge by 1985, and prohibiting toxic amounts of pollutant discharge which came with a twenty-four-billion-dollar price tag (Keiser & Shapiro, 2018). These large costs would be worth it if the benefits outweigh them. Unfortunately, cost-benefit analyses of the CWA, including those completed by the EPA, estimate poor benefit/cost ratios (Keiser & Shapiro, 2018). This is yet another reason why the CWA is both controversial and ineffective in many cases.

As mentioned earlier, these issues with the CWA can have negative consequences for the freshwater systems that it attempts to protect. Healthy freshwater ecosystems promote important ecosystem functions and services such as water purification/filtration, carbon sequestration, biodiversity, recreational uses, and resource extraction. If there are no effective regulations or acts in place to protect these systems, their functions and services will be at risk.

The CWA is an important tool the U.S. can use to combat climate change. With a warming climate, there will be an increase in temperature and alterations in precipitation regimes, and storm intensity depending on the location within the U.S. A case study done in Bozeman, MT, predicts that by 2035 an increase of 2.1-3 °F would lead to a 1-5% increase in precipitation and storm intensity (EPA, 2022). A small increase in temperature can induce a great strain on the water supply. Increasing precipitation levels could partially negate the water supply issue, however increasing temperatures decrease snowpacks. These trends require an adjustment to Bozeman’s current water management. Increases in storm intensity can increase flood risk and cause water management systems to be overwhelmed. These issues will start as small problems but as climate change conditions persist temperature, precipitation, and storm intensity will continue to increase. Through the CWA, both federal and state-level governments should be using resources to prepare our water management systems for climate change.

Innovative Solutions

Carbon Credits

An innovative solution that supports some of the goals of the CAA is the carbon offset market. Carbon offset markets provide businesses with methods that can use greenhouse gases, like carbon, as a commodity by buying and selling carbon credits in the free market. Carbon credits are generated when an individual, business, or entity has a project or invests in a project that draws down carbon, removing it from the atmosphere, using techniques such as planting trees or following no-till practices. Once these credits are generated others are able to buy them as a way of offsetting their carbon production. This market could help address some of the components of the CAA by removing potent greenhouse gases from the atmosphere while generating profit, which is important in a mixed economy, such as the U.S. However, there is no legislature or certification to regulate the carbon offset market in the U.S. As of right now, the current legislation in the CAA does not certify the credibility of carbon credits, meaning that under the current market there is no way for individuals buying carbon credits to certify if the credits they are buying are sequestering carbon.

The five most common ways that carbon is captured for sale on the global carbon offset market are through renewable energy projects, bio-sequestration, methane drawdown, energy-efficiency/clean energy, and industrial gases drawdown (Zink et al., 2008). Of these, the most popular and efficient carbon drawdown methods are forest protection and reforestation because forests globally remove about 2.4 gigatons of carbon per year (Pan et al., 2011). The emission drawdown potential of forests is utilized in two main ways: through planting forests and enhancing an existing forest's ability to capture more carbon leading to an offset of 12-19% of fossil fuel production of greenhouse gases (Ryan et al., 2010). To preserve these valuable landscapes, laws, and regulations need to be put in place to ensure that carbon offsetting is done in a credible and viable way.

From a landscape perspective, the biggest impact that the carbon offset market has is expanding forests nationwide. In many countries, especially in South America, there is a large-scale conversion of forests to agriculture which strips the land of most of its ability to capture and store carbon. When thinking of forests as mechanisms of carbon drawdown, most of the carbon is sequestered via tree growth (Canham, 2021). In addition to drawing down carbon, forests also play a role in regulating water throughout forested ecosystems. Trees stabilize soil, which not only mitigates erosion and evapotranspiration but also helps to clean and purify water. The CWA works to preserve clean drinking water which means that the preservation and expansion of forests help support the goals of this act. This highlights the importance of taking care of our forests and keeping them healthy to extract the most benefit from using them as both a carbon offset project and a vital part of water cycling.

As carbon markets continue to expand, the interface between forest and current or abandoned agriculture could become the battleground for land use (Bowen et al., 2007). In fact, the U.S. is losing farmland at a rate of three acres per minute as a conversion from crop and

rangelands to development (Freedgood et al., 2020). This statistic does not consider the rate at which agricultural lands are getting abandoned due to factors like poor soil health, loss of nutrients, soil compaction, increased aridity, etc. This is where we see the highest potential for the carbon offset market to change and improve our landscape. The conversion of poor agricultural lands to carbon credit forests could give a new lease to land that has been left barren and unproductive. In North America, there are over 1,000 different tree species, each with different adaptations that make them viable in various environments. While different tree species draw down different amounts of carbon dioxide, on average a fully grown tree will capture more than 48 pounds (~22kg) of carbon dioxide in a year (Freedgood et al., 2020). Given the versatility of trees and therefore forests, the regulation of the carbon offset market could aesthetically improve landscapes while building soil health and ecosystem services.

The best way to regulate the market will be through incentives as well as amendments to current legislation. Incentives regarding the carbon offset market work by encouraging individuals and businesses to purchase and sell carbon offset credits by using financial motivations. There have been examples of carbon offset incentives benefiting both the seller and the buyer of the credits. If there were improved regulations then incentives could be widespread the market could greatly grow (Kleindl et al., 2018). To give an example of a carbon sequestration partnership, Westcarb, forest owners were encouraged to “avoid deforestation, increase afforestation, encouraging rapid tree generation”, etc. (Kleindl et al., 2018). This example shows that incentivization of carbon offset markets can lead to stakeholders getting engaged with reducing atmospheric carbon.

One legislative strategy would be amending the CAA. Amendments to the act would include designating a certifying body as well as regulating the buying and trading of carbon in the market. An oversight body that verifies the credibility of these offset projects, such as the U.S. Forest Service (USFS) when considering forest sequestration specifically, or the EPA regarding other offset credits would be necessary. In the CAA there is the ability to add a cap-and-trade system. Cap and trade systems are where the government sets the highest limit of emissions of a certain pollutant. If companies exceed this threshold, they must either buy carbon credits or use innovative solutions to limit their emissions. In the 1990s a cap-and-trade system was set up for sulfur dioxide and nitrogen oxide. This system was successful in dealing with increases in acid rain (Office of Air and Radiation, 2022). This system should be used for CO₂ and would lead to increases in the carbon offset market. There are states with variations in the cap-and-trade system, but a federal strategy should be implemented to further the carbon offset market. In short, bolstering the carbon offset market would decrease overall carbon emissions while increasing the extent and quality of forests countrywide.

Biosphere Reserves

As our country is faced with challenges to address climate change and ensure human health standards, innovative solutions are going to be integral to moving forward. One innovative solution that the U.S. is already enrolled in is Biosphere Reserves through the Man and

Biosphere program of the United Nations Environmental, Scientific, Cultural Organization (UNESCO). Biosphere reserves are swaths of land that are recommended and then certified through UNESCO as learning places for sustainable development. The Biosphere reserve program in the U.S. currently has 28 active biospheres and many of them are underutilized. They are mainly functioning as National Parks and are failing to address the outermost zones and their sustainability goals.

Biosphere reserves consist of three main areas that serve different purposes (Figure 4). The first area is the core zone which will ultimately impact the amount and quality of ecosystem services the area is able to offer. Ecosystem services are valued at hundreds of billions of dollars and can range from air purification to carbon sequestration (McNeely, 2020). The core is where genetic diversity, protection of threatened and endangered species, and intact large-scale ecosystems occur. The surrounding zone, the buffer zone integrates environmental protection as well as research, and some development. The outermost zone, the transition zone, lends itself to economic opportunities for those living in the vicinity of the core.



Figure 4: Example of a general biosphere layout (UNESCO, 2020).

Biosphere reserves have positive impacts in multiple categories in their surrounding communities including economic benefits, education, social justice, tourism, and environmental protection (Solecki, 1994). Landscape-scale changes would occur through the restoration of natural areas, sustained ecological services and functions, expanded habitat to support a variety of diversity, and preservation of freshwater ecosystems. Additionally, institutions surrounding the biosphere reserves are commonly a location of academic research (Franklin, 1997). The biosphere reserve program, if utilized effectively, can be a benefit to the CAA and CWA by promoting ecosystem services and education. There are many global examples of different ways biosphere reserves in the U.S. could be improved.

In Switzerland, the Entlebuch biosphere reserve has capitalized on its value-creating sustainable agricultural areas in the transition zone and the surrounding areas (Coetzer et al.,

2013). By creating a sustainable agriculture system, the biosphere reserve is creating a small carbon sink as well as creating a water filtration system. Which if implemented in the U.S. would support the goals of the CAA and CWA. Locals and tourists alike gain access to nutrient-dense foods that have lower carbon footprints than imported food. Projects of this scope could help address food inequality in marginalized neighborhoods in the U.S. as well as act as educational resources about food scarcity and the importance of agricultural lands.

In South Africa's Krugers to Canyon Biosphere Reserve, the buffer and transition zones are being used to benefit of marginalized communities. Some of the projects being conducted include carbon sequestration, harvesting, and propagation programs of endangered plants and resources. Additionally, the reserve is conducting a bio-cultural program that focuses on preserving traditional knowledge and medicinal practices to improve relationships between indigenous and non-indigenous communities (Coetzer et al., 2013). The reforestation efforts included in this project result in benefits that could aid the CAA by sequestering carbon from the atmosphere, reducing greenhouse gases, increasing clean air for the surrounding area, and creating an area of cooler temperatures that can improve air quality.

In Mexico, the Sierra Gordon biosphere reserve has prioritized projects that are involved in the carbon market. Farmers that pledge to reforest and conserve wetlands are given financial compensation for land that is preserved or improved. In addition, the farmers can receive and sell carbon credits (Coetzer et al., 2013). The payments generated from the reserve program and carbon offset market trickle through the communities where they live, to develop other projects. The creation of carbon credits in buffer and transition zones expands the impact of the core zone and helps mitigate the effects of development in and outside of the transition zone. These connections could result in greater ecosystem connections and the lengthening of protected water corridors.

The use of large landscape areas within the U.S. can be an integral tool to aid the goals of the Clean Air and Water Acts. Reserves can create protected areas for long-term reforestation and major waterways. By having these areas protected, studies can take place to monitor air and water quality so scientists and policymakers can learn from these areas and implement strategies across the U.S.

Conclusion

Currently, the regulations in the U.S. fail to appropriately address climate change. To combat the ever-changing climate, laws must encourage innovative solutions. The current laws in place that were addressed in this paper include the CAA and the CWA. Both laws were created in response to public calls for environmental regulation. They have been monumental in the reduction of pollution and the regulation of a human health-friendly environment which addressed the needs of their time. However, the needs of the American people have changed. While effective for treating pollution, climate change poses an even greater threat today. Climate change will impact all Americans regardless of economic class or political party. The CWA and

CAA were momentous pieces of legislation, now the U.S. is ready for their reimagined version that protects citizens and our planet.

From 1969 with a fire on the Cuyahoga River, there was a public push to fix our water systems. This set ambitious goals that are part of the CWA today. Although these goals were groundbreaking for their time, they were arguably over-ambitious and difficult to obtain. The CWA had several goals including making all U.S. waters fishable and swimmable by 1983, no water pollution discharge by 1985, and prohibiting toxic amounts of pollutant discharge (Keiser & Shapiro, 2018). Since its establishment, there have been decreases in oxygen deficits, an increase in fishable and swimmable water, a decrease in fecal coliforms, and a decrease in total suspended solids. These decreases in water pollution are attributed to the passage of the CWA, however the overall success of the CWA is more nuanced. Over half of the assessed rivers, streams, lakes, reservoirs, ponds, and bays in the U.S. are impaired. There are major eutrophication events occurring all over the U.S., harming aquatic life and stream ecosystems. In the face of climate change, these impairments are predicted to occur at a faster rate making amendments to the CWA more important than ever. Healthy freshwater ecosystems promote important ecosystem functions and services such as water purification/filtration, carbon sequestration, biodiversity, recreational uses, and resource extraction.

For similar reasons, the CAA was an important act for its time but requires amendments to meet its goals in response to climate change. The CAA is arguably the biggest shaping factor in environmental law regarding greenhouse gas emissions. It was set into motion by congress in 1990 to enhance air quality and protect the stratospheric ozone layer (EPA, 2021). The CAA has induced many positive outcomes including reduced pollution, increased public health and quality of life, cleaner engines and fuel, and the implementation of pollution control devices (EPA, 2021). Between 1970 and 2020, the CAA has reduced combined emissions of common air pollutants by up to 78% (EPA, 2021). While the CAA has been effective in reducing air pollution and greenhouse gases in the atmosphere, there is more to be done. In fact, a plateau has been reached in attempts to further curtail emissions of all greenhouse gases. In other aspects, the CAA is not as effective as the data suggests in terms of curbing greenhouse gases. The CAA is regulated by the EPA, which means it's enforced on general emissions standards across the entire country. Uniform emissions standards don't address states that have pollution levels above or below the average emissions. Ultimately, the one-size-fits-all greenhouse gas emissions standard could be detrimental if not customized to each state's emissions. Multiple factors must be considered when thinking of CAA regulations: set standards too high or too low and citizens are left with unattainable goals or unhealthy air to breathe.

Global warming, which is induced by increasing concentrations of greenhouse gases, has negative effects on the health of the environment and the human population. The CAA currently focuses on air pollutants that harm human health like lead and nitrogen oxides, but greenhouse gas emissions are not specifically targeted. The EPA is relatively limited about what it can do to enforce global warming pollution and emissions (Union of Concerned Scientists, 2011). While

the CAA has been an effective solution to decrease air pollution, the EPA has lacked both power and control over greenhouse gas emissions.

An innovative solution that supports the goals of the Clean Air Act is a carbon offset market. If the carbon offset market were to not only become regulated but incentivized as well, we could see a significant decrease in greenhouse gases, thus supporting some of the goals of the CAA. As summarized above, the CAA aims to reduce air pollution as well as protect our ozone, both of which will improve with the regulation of carbon offsets. Carbon offset markets, which allow individuals to buy and sell carbon credits, could be monumental in the drawdown of carbon dioxide in our atmosphere which would both protect the ozone and reduce air pollution countrywide. However, for this to work carbon credits need to be certified, meaning that there is a certifying body that ensures that people drawing down carbon are doing so at the rate at which they claim and that people who are buying credits can confirm that they are buying a legitimate product. This would be done through the amendment of the CAA which would not only designate a certifying body but would also incentivize the market so that carbon drawdown can be bought and sold legitimately on the free market. The certifying body would most likely be the EPA, which would be able to designate different federal agencies to certify different carbon offset projects. For example, for certifying the carbon sequestration of a forest project the USFS could certify the credits or for a renewable energy product, a branch of the Department of Energy could be tasked with the certification.

An additional solution that supports the goals of both the Clean Air and Clean Water Act is the implementation of biosphere reserves. For the benefits of biosphere reserves to be realized in the U.S., there needs to be a regulating body that ensures that the goals of the reserve program are being met and accounted for. Similarly, community engagement and buy-in from the areas adjacent to the zones are critical to ensure that the sustainable development goals are being met. If these goals are met along with renewed education on what a biosphere reserve is, the ability of these reserves to function successfully and increase their ability to conduct ecosystem services and encourage sustainable living. Biosphere reserves are a successful tool able to protect large landscapes and promote ecosystem services resulting in improved air and water quality which will benefit the amendments to the Clean Air and Water Acts.

If these innovative solutions were to be put in place in the U.S., we would see a change in the lands around us. The landscapes of the U.S. would be expanded in terms of forested areas and less abandoned agricultural land. This land would either be used as a forested area or a place where sustainable agricultural practices could be held. Additionally, there would be an expansion of land under the biosphere reserve program which would result in more regions under the transition and buffer zones where sustainable practices could be enacted. These two solutions would also result in an increase in groundwater storage and water filtration which results in healthier aquatic ecosystems and drinking water.

Laws can shape landscapes. Current legislation in the U.S. fails to appropriately address climate change and must be amended to include innovative solutions. Poor or outdated laws have

negative consequences on important ecosystem services and functions. In the face of climate change, updating current laws and regulations is critical to adapting in a timely and effective manner. Without adaptive legislation, American landscapes are at risk.

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