Sediment Deposition in Wetlands and Effects on Near-Shore Marine Ecosystems in Hawai'i: An Analysis and Comparison to Wetlands Loss in Louisiana

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Abstract

Throughout the United States, wetlands act as a sanctuary for fish, birds, amphibians, plants, and other unique species that thrive nowhere else. These wetlands also act as a filtration system for terrestrial runoff, protecting and preserving our oceans and marine ecosystems. Through fieldwork in O'ahu and the He'eia wetlands this past summer, I examined the turbidity of water pre- and post-wetland filtration and observed the connection between the land and the sea. By looking at my data, other studies, and general trends, I concluded that the He'eia wetlands are most critical to lessening sediment deposition immediately following major rainfalls and are a crucial "barrier" for protecting and preserving coral reefs. I continued this research by looking at another example, Louisiana, and the current environmental issues facing this state's wetlands. Various laws and regulations regarding wetlands and clean water are also examined, and the issue of federal vs. state regulation is discussed.

Introduction

Wetlands, lowland areas that are consistently saturated with water, are some of the most biodiverse yet fragile ecosystems. Across the nation, they are disappearing at alarming rates, as humans and natural causes degrade and damage these wildlife "hotspots". The loss of wetlands affects the health of near-shore marine ecosystems. These ecosystems decline as a direct result of sediment deposition, or the process by which sediments, soil, and rocks are added to an area. This process occurs when the forces in control of sediment transportation are no longer enough to overcome the forces of particle friction and weight, and the sediments are quickly "dropped." Coral reefs are a marine ecosystem particularly affected by this deposition. If a significant amount of silt and dirt enter the ocean in a relatively short span of time, it blocks out sunlight into the ocean and hampers the process of photosynthesis which is essential to coral survival, coats the coral in layers of silt and other pollutants, and negatively alters the overall water quality.

The loss of wetlands can also result in increased floodwaters, species extinction, and a shortage of fresh water. Two states, Louisiana and Hawai'i, are seeing particularly extensive wetland damage. The aim of my paper is to link the harmful effects of sediment deposition to the importance of wetlands and the biome's corresponding influence on near shore marine ecosystems in Hawai'i. Through this paper, I analyze the effects of wetlands

loss in Hawaiʻi interpreting the research I performed this summer, compare to losses in Louisiana, and examine the national and state laws and regulations protecting this biome.

Background: The Importance of Wetlands

Wetlands themselves have four main functions: water filtration, water storage, biological productivity, and a habitat source for wildlife. As discussed above, wetlands function as a filter, removing sediment from water before it enters into oceans or other bodies of water. Their use as a water storage source is also vital, as they store significant amounts of floodwater. This process slows the water's momentum and erosive potential, allows for ground water recharge, and lowers potential flood heights. For example, the U.S. Army Corps of Engineers found that protecting wetlands along the Charles River in Boston saved $17 million in potential flood damage (Legacyenved.org). Wetlands are also significant sources of biological productivity, as they cover only five percent of U.S. land surface but support thirty-one percent of plant species (epa.gov). In fact, they are comparable to coral reefs and tropical rain forests in the diversity of species they support and their productivity. Wetlands are key to stable environmental health, and the services they provide to humans are numerous and invaluable.

Wetlands provide these crucial services in various forms. More than three billion people, around half of the world's population, obtain their basic water needs from inland freshwater wetlands (International Water Management Institute). Wetlands are also a valuable source of fuel, food and medicinal plants. The most significant food source from them is fish, many of which live all or part of their life cycle within a wetland system. In addition, fishing and its byproducts create an industry that supports eighty percent of the income and employment to the residents of developing countries (Unwater.org). Several plants found in marshes and swamps are also useful in treating various ailments. Bogbean, a wetland species found in shallow water, is used traditionally for digestive ailments and is approved commercially for loss of appetite in Germany. In Hawaiʻi, *Nasturtium officinale,* which frequently grows in marshy areas, is used to treat severe asthma. Similarly, in Louisiana, *Nelumbo lutea* can be used medicinally, as a nutritional supplement and as immune system protector.

Wetlands Loss and Degradation:

Tragically, wetlands are disappearing at alarming rates all across the conterminous United States. In the 1600s, over 220 million acres of everglades are thought to have existed in the forty-eighty continental states. Since then, extensive losses have occurred. Over half of our original wetlands in these states have been lost—drained and/or converted to other uses. In Hawaiʻi alone, 7,000 acres of wetlands have vanished. And in Louisiana, if the current land loss rates continue unabated, by the year 2040 Louisiana will have seen a loss of more than one million acres of coastal environments.

In addition to wetlands destruction, degradation of this biome has also led to a decline of wetlands overall. Additional threats such as excess of nutrients, contamination due to chemicals, high levels of sediment from air and water, the introduction of nonnative species,

sea level rise, and droughts have degraded them nationwide. Together, all of these impacts could affect wetland functions, reducing their effectiveness as a barrier against sediments entering the ocean and consequently, negatively impacting the health of coral reefs in surrounding areas. When coral reefs become covered in silt, massive die offs are often observed. The Status of Coral Reefs of the World (2004) report stated that sediment run-off is the major stressor to reefs in Hawaiʻi, Guam, and the Northern Mariana Islands. (USGS Pacific Coral Reefs).

The Importance of Wetlands in Hawaiʻi: An Example

The connection between sediment deposition and its effect on coral reefs can be seen in a case study of the Heʻeia wetlands and the closely linked Kāneʻohe bay—two locations on eastern Oʻahu, Hawaiʻi that I studied this past summer. The He'eia wetlands were originally used for cultivation of taro, a staple crop in Hawai'i, and rice. However, with rapid development of the Kāneʻohe area in the 1950s, the taro and rice patches slowly fell into disuse and are now degraded and taken over by invasive species. The proposed (and currently ongoing) project, Māhuahua Ai' o Hoi, will establish a land management program to restore these areas to their original health. The health of the Heʻeia wetlands is crucial because wetlands act as a very important filtration system, and as a barrier, from terrestrial runoff from the land entering Kāneʻohe bay. This bay supports valuable reef systems, unique natural communities, and has some of the greatest diversity of algae, invertebrates, and fish in Hawaiʻi. Kāneʻohe Bay is also the only area in all of the main islands known to possess all three major reef habitats: fringing reefs, patch reefs, and a functional barrier reef. Due to these facts, University of Hawaii and the Hawaiʻi State Division of Aquatic Resources identified the reefs near Heʻeia as a "priority area of near shore biological significance".

The full importance of these wetlands to the Hawaiian people can be seen in the deep roots that the wetlands and the plants they contain have in Hawaiʻi's history. Taro, a traditional form of food, sustenance, and nutrition, is one of the most common plants found in near-shore wetlands. In Hawaiian culture, taro plays a much larger role beyond a mere dietary staple. It was the economic, political and spiritual center of Hawaiian agricultural society—and the tale behind taro's origin directly links it to the Hawaiian people. In the past, taro was commonly grown in wetland areas. Recently, there has been a push to revert to more traditional farming methods such as growing it directly in the wetlands and the old ahupua`a system where land was divided in narrower wedge-shaped land sections that ran from the mountains to the sea. Rather than plowing over wetlands and developing massive farms that utilize machinery and other more modern agricultural tools, taro can be grown directly in the wetlands without causing harm to the natural wildlife and native plants. Because of this push and the obvious environmental benefits, the Māhuahua Ai' o Hoi project has been working to restore taro in the marsh area. This will not only restore an important component of the Hawaiian culture, but also aid in filtering terrestrial runoff.

The levels of this harmful terrestrial runoff in the He'eia wetlands can be numerically analyzed by looking at the research I performed this summer while in Hawai'i, and the

corresponding research by Dwayne Minton. By looking at turbidity levels from our two studies, one can form a clearer idea of how significantly wetlands impact sedimentation.

My Research

In June 2013, I performed a study as part of a larger project with The Nature Conservancy of O'**a**hu. I measured levels of turbidity as water entered (pre-filtration) and exited (post-filtration) a taro wetland plot located in the He'eia wetlands. I predicted that turbidity out of the plot would be lower than turbidity into the plot.

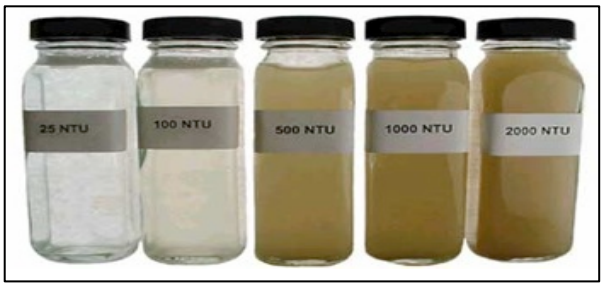

Figure 1:Range of turbidity levels from low turbidity (left) to high (right). Measured in Nephelometric Turbidity Units. Photo Credit: Dwayne Minton, TNC

Methods: To test the utility of wetlands in removing and capturing sediments, levels of turbidity were measured via a SONDES (Figure 3), a device that takes samples from the water and measures the concentration of sediment particles in the water, and one 650A, which connects to the SONDES and allows us to analyze our data and transfer it to the computer. One SONDES was submerged under water and placed at the entrance of the plot of the taro field, and the other device received the same treatment, but was placed at the exit of the plot (See Figure 2). The SONDES devices remained in these positions for weeks at a time. To collect the data, the 650A was connected to both of the SONDES devices and recorded turbidity levels for the water at noon from six selected days at the entrance and the exit of the taro fields. Data was then entered into spreadsheets and analyzed.

Figure 2: Shows placement of SONDES device to measure sediment load. Photo Cred: Minton

Figure 3: A SONDES (left) and a 650A device (right)

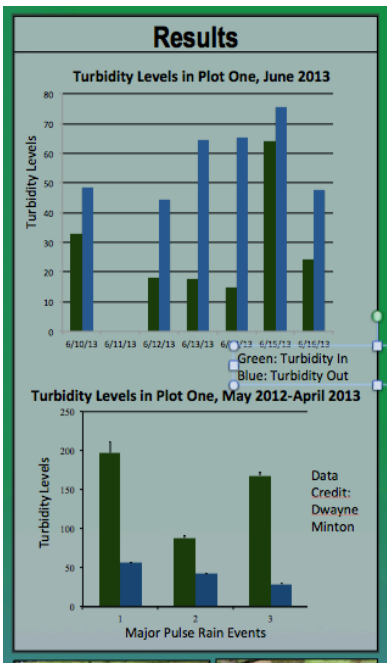

Figure 4: Turbidity levels pre and post wetland filtration, of Study 1 and Study 2

Results: As shown in Figure 4, Study 1 data showed the opposite of what was expected: turbidity levels out of the wetland were higher than turbidity levels in. This diversion from my hypothesis might be explained by the lack of pulse rain event in June and a high level of construction and manual labor in the fields that disrupted the sediment during the time of data collection. However, a previous study (Study 2-also shown in Figure 4) performed on the same plot by TNC scientist Dwayne Minton showed that the wetlands effectively reduced sediment levels, most significantly during pulse rain events. Pulse rain events are storms where a large amount of rain is released in a short period of time, resulting in massive runoff. For Study 2, data points over an extended time span (from May 2012-April 2013) were taken and turbidity levels were measured when no manual labor was being performed in the fields.

Conclusions: By looking at the larger data set and the general trends, we may conclude that the He‘eia wetlands are most critical to lessening sediment deposition immediately following major rainfalls and are a crucial “barrier” for protecting and preserving coral reefs.

Future directions: The levels of turbidity in He‘eia will continue to be analyzed. Ideally, the exact percentage of sediment that is filtered by wetlands should be calculated, as this value would be useful in modeling to other areas the benefit of wetlands in controlling sedimentation into near shore marine ecosystems. A statewide analysis of the connection between sediment deposition and corresponding invasive algae growth must also be put into action.

<u>Wetlands Degradation and Effects in Louisiana and the Gulf of Mexico: A Comparison to Hawai‘i</u>

Unfortunately, degrading wetlands are not unique to Hawai‘i. The particularly polluted Gulf of Mexico and disappearing Louisiana coastline are also an area of high concern. S. Jeffress Williams of the U.S. Geological Survey highlights this, stating,

> “The swamps and marshes of coastal Louisiana are among the Nation's most fragile and valuable wetlands…the staggering annual losses of wetlands in Louisiana are caused by human activity as well as natural processes. ” (USGS.org).

The losses Jeffress mentions are staggering—it is reported that Louisiana's one million acres of wetland disappear at the rate of about seventy-five square kilometers annually. And while Louisiana's wetlands today represent only about forty percent of the wetlands of the continental United States, they make up for about eighty percent of the losses. At this present rate, Louisiana will lose the entirety of its crucial habitat in about two hundred years. Hawai'i is also seeing a similarly significant drop in its swamp and marsh area—a twelve percent decrease reported from 1780 to 1980 (USGS.org).

This shrinking of wetland area comes with more than just a simple loss of land; these valuable near-shore ecosystems also have an important cultural significance to the people of the Bayou that stretches back hundreds of years into Louisiana's rich history. This area is perhaps most important to the Cajuns, an ethnic group spread throughout lower Louisiana. Some Cajuns who live along the wetlands rely upon them for fishing, hunting, and trapping. Numerous indigenous tribes in the Gulf of Mexico region are also closely connected with the swamps and marshes of Louisiana. Recent loss of this area has affected members of the United Houma Nation, as they, like the Cajuns, have depended on the wetlands for years to sustain their culture and way of life (Nationalparkservice.gov). Much of what gives Louisiana its unique heritage finds its roots in the coast, and it is vital that more conservation efforts are made to preserve this fragile place. To begin, one must look at some of the causes of this habitat destruction.

The rapid rate of wetland loss can be explained by major shifts in the course of the Mississippi River over time, reduction in the number of barrier islands fronting the Mississippi River delta plain, and human presence. The barrier islands act as buffers to lessen the harmful effects of ocean waves on the wetlands; however, they are eroding, much like the wetlands, at a rapid rate of up to twenty meters per year. We know that both the long shore movement of sediment and the general absence of sand-sized sediment is the principal cause of the islands' instability. In addition, long-shore currents redistribute the available sand from headland areas to embayments, depriving shorelines of much needed sand (Barrier Islands, USGS. Gov). As these islands disappear, the remaining protected wetlands along Louisiana's coast are privy to the full force of marine processes (including salinity intrusion, tidal currents, wave action, storm surge, and sediment transport). Without these barrier islands, Louisiana's coastal environments will be destroyed at even faster rates.

Not surprisingly, humans are also partly responsible for declining wetlands. Throughout the wetlands, methods of flood-control and a vast system of dredged canals have allowed salt water from the Gulf of Mexico to intrude freshwater wetlands, which kills both plant and animal life. Additionally, commercial and residential development has led to the forced drainage of wetlands across the state. This parallels Hawai'i, where coastal wetlands have been drained and filled for resort, industrial, and residential expansion.

Louisiana's wetlands are threatened by agricultural runoff. This runoff results in a tremendous increase in nitrogen and phosphorous in marine ecosystems, which directly leads to a hypoxic dead zone, or area of low oxygen that runs east to west along the Texas-

Louisiana coastline. In July 2008, researchers reported that between 1985 and 2008, the dead zone roughly doubled in size and now stretches from near Galveston, Texas, to Venice, Susiana (about 8,000 square miles). This dead zone has led to algae blooms, which is similar to the increase in invasive algae we have witnessed in Kāneʻohe Bay. This correlation is evidenced as Dr. Minton writes in his report that, "These land-based pollutants [terrestrial runoff], coupled with a lack of marine grazers, promote conditions where non-native algae now dominate and have biologically altered adjacent coral reefs, native algae and soft sediment habitat"(Improved Water Clarity in a Taro *loʻi*). Scientists have also observed occurrences of estrogen suppression in the Gulf of Mexico. An October 2007 study of the Atlantic croaker found a disproportioned sex ratio of sixty-one percent males to thirty-nine percent females in hypoxic Gulf sites. This was compared with a fifty-two percent to forty-eight percent male-female ratio found in reference sites. (Thomas, Peter). Ultimately, this study effectively highlights the detrimental effects that the agricultural runoff of the Mississippi River can have, effects that may continue to worsen if we do not begin to restore the wetlands of the Gulf.

Wetland Laws and Regulations

There are current laws and regulations in place that are attempting to counteract adverse effects and preserve near-shore habitat. The North American Wetlands Conservation Act of 1989 provides matching grants to organizations and individuals who have developed partnerships to carry out conservation projects in the United States, Canada, and Mexico for the benefit of wetlands-associated birds and other wildlife (FWS.gov). In 2013, Congress appropriated $33.6 million to fund the Act's Grants Program—with another $31.5 million coming from additional fund sources such as fines, penalties, and forfeitures collected under the Migratory Bird Treaty Act of 1918, fuel excise taxes on small gasoline engines, and from interest accrued on the fund established under the Federal Aid in Wildlife Restoration Act of 1937. This act has been very successful— from September 1990 through September 2013, approximately 5,000 partners in 2,326 projects received nearly $1.28 billion in grants (FWS.gov).

Louisiana currently has 47 NAWCA projects either complete or underway. In total, these projects have conserved 519,038 acres of wetland for wildlife habitat. Similarly, in Hawaiʻi, 7 NAWCA projects are either finished or ongoing. These projects have conserved a total of 7,384 acres of wildlife habitat and stimulated partner contributions of over $26.1 million (Ducks.org). In addition, as of 1993, 29 States had some type of wetland law—including both our focus states of Hawaii and Louisiana.

The Clean Water Act is another federal law that regulates coastal land and other water quality issues. Passed in 1972, the act established the goals of "eliminating releases of high amounts of water, eliminating additional water pollution by 1985, and ensuring that surface waters would meet standards necessary for human sports and recreation by 1983" (EPA.gov). Under the CWA, the EPA has implemented pollution control programs such as setting wastewater standards for industry. In addition, The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. Section 404 of the act specifically addresses and includes wetlands, through

establishing a program to regulate the discharge of dredged or fill material into waters of the United States. Activities in waters of the United States regulated under this program include, "fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects" (Many of these activities being activities that occur in wetlands) (EPA.gov).

In addition, numerous National Wildlife Refuge Acts that have been passed over the years have both directly and indirectly assisted in wetland conservation. The United States Fish and Wildlife Service manages these acts, with the first refuge created in 1903 under President Theodore Roosevelt. Since this first refuge, the system has grown to over 560 national wildlife refuges, plus 38 wetland management districts encompassing more than 150,000,000 acres (FWS.gov). The Featherstone National Wildlife Refuge of Virginia, approved on October 22, 1970, this protected a large wetland area and natural resources in Prince William County. Following the approval of this refuge, Virginia, as well as many other states, have begun to adopt their own programs to protect wetlands beyond those programs enacted by the Federal Government.

More and more, responsibility is delegated from the Federal Government to the States, and State wetland programs correspondingly gain in importance (Water.usgs.gov). This trend raises the question of whether more regulation power should be delegated to the states or to the Federal government. Many believe that it should be the states that possess the most power, as each state has its very own unique set of near-shore habitat issues. By allowing states to appropriate funds when necessary and come up with their own various acts and regulations, it is likely that an overall more specific and appropriate conservation system will be achieved. However, it is important that federal regulation of wetlands remain strong. For example, the wetlands of Louisiana are affected by the agricultural runoff of numerous states along the Mississippi such as Minnesota, Iowa, and Arkansas. If there were only state regulations in place, trying to manage the health of the wetlands in Louisiana would be near impossible as each state would undoubtedly have their own unique set of water laws that would likely come into conflict with one another. A powerful federal regulation is also important in the sense that it provides for a "stream-lined" sort of management of our wetlands across the country. If one state chose not to have any sort of water regulation, it would still have to abide by some sort of national conservation laws.

Conclusion

The research described above, the examples of Louisiana and the Gulf of Mexico, the Heʻeia wetlands, and Kāneʻohe Bay, show the negative effects of sediment deposition and the importance of wetlands in maintaining coral reefs and entire marine ecosystems. From Hawaiʻi to Louisiana and every state in between, these habitats protect the wildlife that inhabit them and provide us with immeasurable resources. By maintaining them we protect not just one biome but two (wetlands and coral reefs) from degradation, and preserve the fragile yet fundamental connection between the land and the sea for generations to come. This will only happen if we continue to enact laws and regulations protecting our country's marshes and swamps, and further appropriate more power to the states for delegating their own policies. At the same time, it is necessary that the federal

regulations remain cohesive as this allows for strong mandates across all fifty of the states and a more clearly organized set of laws than if each state had its own set of amendments.

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