12-2015

Analysis of Coastal Wetland Geography and Policy in Humboldt Bay: Adapting Wetland Policies for a Changing Climate"

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ANALYSIS OF COASTAL WETLAND GEOGRAPHY AND POLICY IN HUMBOLDT BAY:

ADAPTING WETLAND POLICIES FOR A CHANGING CLIMATE

By

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A Project Presented to

The Faculty of Humboldt State University

In Partial Fulfillment of the Requirements for the Degree

Master of Sciences

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December 2015

ABSTRACT

ANALYSIS OF COASTAL WETLAND GEOGRAPHY AND POLICY IN HUMBOLDT BAY:

ADAPTING WETLAND POLICIES FOR A CHANGING CLIMATE

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Humboldt Bay has lost 90% of its tidal salt marsh and an unknown amount of freshwater marsh due to human impacts over the past two centuries. Sea level rise due to climate change has the potential to cause even greater loss of coastal wetlands. This project sought to model the potential loss of tidal salt marsh around Humboldt Bay due to sea level rise and, in light of sea level rise, examine the difficulties in the permitting, planning and implementation processes of wetland projects. Tidal salt marsh migration potential was modeled using MaxEnt, a habitat suitability modeling package. Wetland policies were analyzed qualitatively through document data and interviews with regional actors.

The salt marsh migration potential model predicted that with one meter of sea level rise the acreage of land capable of supporting salt marsh could increase slightly, but with two meters of sea level rise the acreage of land capable of supporting salt marsh could decrease by over half under a best-case scenario. The policy analysis found that risk aversion played a large role in causing timeline and cost increases for wetland

projects, causing some projects to fail, and that the No Net Loss of Wetlands policy may not be adequate for a changing climate.

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CHAPTER ONE

1.1 Introduction

Wetlands were historically regarded as economically useless land. Their destruction through draining, filling and diking was considered positive land use change and was supported by governments and communities throughout the historical record (Dahl, 1990). Wetland loss occurred on a large scale prior to the Clean Water Act of 1972, and continues to occur to a lesser degree. The United States has lost approximately 53% of its pre-European settlement wetlands, from approximately 221 million acres to 104 million in the lower 48 states (Dahl, 1990). More recently, the inventory of wetlands in the contiguous United States has been estimated at 110.1 million acres, a slight increase from Dahl's 1990 estimate. In some parts of the world reclamation of wetlands for agricultural purposes is still a government mandate and is supported by communities and government agencies (Crooks et al., 2011).

In the 20th century scientists documented the importance of wetlands in providing ecosystem services such as pollutant removal, storm buffers and sediment trapping (Mitsch and Gosselink, 1993; Table 1). A more complete understanding of the benefits supplied by wetlands led the U.S. government to pass legislation protecting wetlands, culminating in the No Net Loss of Wetlands policies. The new legislation sought to create regulatory policy and enforcement measures that minimize and mitigate the loss of wetlands, and to promote the creation of new or restored wetlands to replace those that had been lost.

Table 1: Beneficial Wetland Functions

Benefits	**Description of Wetland Function**
Flood Control	Moderate flow events, buffer coastal areas from storms and slow the progress of flood waters.
Water Quality	Take up excess nutrients (N and P), remove sediments, reduce turbidity, absorption and precipitation of trace metals, phytoremediation, groundwater recharge, and used in wastewater and stormwater treatment.
Climatic Stability	Modify temperature and moisture content in lower atmosphere, maintains humidity, and cycles atmospheric gasses (O_2, CO_2, CH_4 and N_2).
Wildlife, Fish and Aquatic Organisms	Support high diversity of plants and organisms, 90% of fish and shellfish are harvested in coastal wetlands, breeding and nesting areas for waterfowl and birds, and shelter and feeding areas for wildlife.
Economic	Provide recreation (bird watching, fishing and aesthetics), wild rice farming, carbon sequestration, and waste and stormwater treatment.

Bastian and Hammer, 1993; Knight et al., 1993; Boyt et al., 1977; Gibbs, 2000; Gundersen, 2010; Hammer 1989; Mitsch and Gosselink, 1993

Since the arrival of Europeans to Humboldt Bay in the mid-1800s, 90% of tidal salt marsh and an unknown amount of seasonal freshwater wetland and riparian habitat have been lost through conversion. Tidal salt marsh is a sensitive resource because it only occurs in limited areas along the margins of bays and lagoons. Wetlands were converted mainly into agricultural land, but also include commercial and industrial developments (Barnhardt et al., 1992). The loss of wetland acreage and function around Humboldt Bay reduces the quality of what is one of the more pristine coastal bodies of water in California (Whittaker, 1975). Sea level rise has the potential to further impact coastal resources by destroying the remaining 10% of tidal salt marsh and other brackish and freshwater marshes.

Global mean sea level rise scenarios estimate 17 to 200 cm of sea level rise by the year 2100 (Parris et al., 2012). Humboldt Bay has been experiencing the most rapid sea level rise of any area in California (Laird, 2013) and sea level is forecasted to rise in California by anywhere from 10 to 143 cm by the year 2100 (Jevrejeva et al., 2012). Accelerating sea level rise means that there is a need to increase wetland restoration, protection, creation and enhancement in order to maintain the amount and quality of the wetlands that currently exist. I am going to answer the question, “How can the community increase and improve wetland projects in Humboldt Bay to keep pace with sea level rise”.

Humboldt Bay has had a number of projects that sought to restore former tidelands (Table 2). The largest restoration projects completed recently have been the

McDaniel Slough tideland restoration project near Arcata, the Humboldt Wildlife Refuge's ongoing freshwater and saltwater restoration projects in the South Bay, the Jacoby Creek Restoration/Enhancement project and the Freshwater Farms tideland restoration project near Eureka.

Table 2: Recent wetland project acreages in Humboldt Bay, California

Project Name	Tidal Marsh Acreage	Freshwater Acreage	Mixed Acreage (Total)	Project Owner
McDaniel Slough	222	24.5	250	City of Arcata
Humboldt Wildlife Refuge	77.85		77.85	USFWS
Jacoby Creek	n/a	n/a	127	City of Arcata
Freshwater Farms	35		35	North Coast Regional Land Trust
Total	**334.85**	**24.5**	**489.85**	

Sources: Humboldt Bay National Wildlife Refuge; City of Arcata; North Coast Regional Land Trust.

Although there have been a number of wetland projects in Humboldt Bay, the current wetland inventory is still a fraction of what it was before European colonization. Many projects have been proposed, planned and never constructed, or failed to meet their goals. If coastal wetland resources are to be maintained, the community may need to be proactive about creating, restoring and enhancing wetlands that Humboldt Bay has lost.

Understanding the difficulties in planning, permitting and implementing wetland projects should encourage consideration of alternatives that may reduce the time and economic costs associated with wetland projects. This study therefore seeks to answer the question "How could wetland regulatory policy improve and encourage wetland restoration, enhancement or creation, and why is this necessary?" This will be achieved through two specific research objectives:

1. Analysis of potential change of tidal wetlands around Humboldt Bay due to sea level rise, and

2. In light of sea level rise, examination of the difficulties in the permitting, planning and implementation processes of wetland restoration, creation or enhancement projects.

1.2 Rationale: A History of Wetland Destruction and Revitalization

Prior to the mid 1900's, the filling of wetlands was largely unregulated and often encouraged as the reclamation of valueless land, and substantial wetland areas were destroyed. This changed when the federal government began to regulate activities in wetlands and aquatic environments as a result of research indicating the social, economic and ecologic benefits of maintaining viable wetland ecosystems (Whittaker and Likens, 1975; Preston and Bedford, 1988). Currently, wetlands are regulated by a variety of agencies, and a number of permits are required to do work in wetlands depending on where the work occurs. Table 3 lists the permits generally required for wetland work around Humboldt Bay.

Table 3: Permits required for wetland restoration, creation and enhancement projects

Agency	**Permit**
United States Army Corps of Engineers	Clean Water Certification, Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act
United States Environmental Protection Agency	Clean Water Certification, Section 403 of the Clean Water Act
U. S. Fish and Wildlife Service	Incidental take permits and habitat conservation plan
California Coastal Commission	Coastal Development Permit
California Department of Fish and Wildlife	Streambed Alteration Agreement (1603) permit
California Regional Water Quality Control Board	National Pollution Discharge Elimination Permit and Federal Clean Water Act Section 401 Water Quality Certification

President Jimmy Carter instigated the first legal protections for wetlands in 1977 when he signed Executive Order 11990 requiring federal government agencies to avoid impacts to wetlands whenever possible (Executive Order No. 11990, 1997). This was replaced by the current dominant federal policy for protecting wetlands known as No Net Loss (NNL), which first appeared in 1987 when it was recommended as a national policy at the National Wetlands Policy Forum (Ohio State University, 2014).

In 1989 “No Net Loss” was adopted by President George H. W. Bush through an announcement at a United States Environmental Protection Agency (USEPA) press conference. It is composed of four fundamental strategies: wetlands protection, creation of new wetlands, restoration and enhancement of wetlands, and education about and research on wetlands (USFWS, 1994). The policy is achieved through the use of policy tools, primarily the Clean Water Act and its Section 404 permits which regulate fill and dredging in waters of the United States. There are four types of actors who participate in this system: regulatory agencies, regulators, project proponents and developers. Regulators work for regulatory agencies and issue permits for projects that may impact wetlands. Developer refers to people or organizations undertaking projects that will impact a wetland. Project proponent refers to people or organizations undertaking projects that are beneficial in nature, such as wetland restoration, enhancement or creation.

Each subsequent presidential administration has endorsed but also sought to alter the policy of No Net Loss. President Clinton increased funding for wetland restoration measures to achieve a net gain of 100,000 acres per year and expedite permit issuances for dredged/fill material under Section 404 of the CWA (Blumm, 1993). President George W. Bush sought to clarify and redefine wetlands under the CWA with a 2003 proposal to not require CWA permits for non-navigable and isolated wetlands (Healy, 2003), effectively weakening the policy. President Obama sought to increase funding for the North American Wetlands Conservation Act (providing matching grants for wetlands projects), but the Obama administration has been limited in achieving its goals by budget limitations.

In June 2015, the Army Corps of Engineers (ACOE) and USEPA published a "Final Clean Water Rule" (33 CFR Part 328) that took into account the United States Supreme Court decisions in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001) and *Rapanos v. United States*, 547 U.S. 715 (2006). This rule clarified the scope of the CWA in determining that regulatory wetlands follow the Supreme Court decisions that limit isolated wetlands from being covered unless they form a *significant nexus* with traditional navigable waters of the United States. Wetlands do not count as wetlands under the CWA unless they are connected to and part of the nexus that makes up navigable waters of the United States.

Despite these political shifts, all governmental bodies have committed to the basic concepts of No Net Loss. Policy implementers, the national and state wetland regulatory agencies, attempt to achieve the policy of No Net Loss of wetlands through regulations and policies designed to protect existing wetlands and require extensive mitigation for impacts. Impacts from development often require compensation at ratios of greater than one to one to comply with the No Net Loss policy. However, many wetland creation and restoration projects do not provide the same functional benefits as impacted wetlands. Often they do not even sufficiently replace the area of wetland impacted (Kihslinger, 2008).

As coastal communities face potential climate change and sea level rise, preserving our natural wetland resources and increasing the capacity, resistance and resilience of these ecosystems is a primary concern for maintaining their ecosystem services. The issue of how policies and regulations address conserving, protecting and restoring wetlands has been studied extensively (Turner et al., 2000; Gardner, 2011; La Peyre et al., 2001; Ambrose, 2011), but there is a dearth of research which explores the difficulties and costs associated with coastal wetland project planning and permitting, specifically on the northern California coast. The following literature review covers criticism and analysis of national wetland policy, failure in California wetland projects and the evolution of wetland mitigation policy, including the efforts of other regions in creating more effective wetland policies, and wetland policies that address climate change.

1.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Critical Analysis of the No Net Loss Policy

Many researchers have found that the No Net Loss policy has failed to achieve the goal of stopping overall net wetlands loss (Haynos, 2001;National Research Council, 2001; Turner at al., 2001; Zedler, 1996; Cole, 1998). Regulatory agencies have been unable to accurately track wetland impacts and wetland acreage changes, leading many to argue that there is no proof that the No Net Loss policy is achieving its stated goals (Haynos, 2001). A 2001 report by the National Research Council (NRC) found that mitigation efforts have not achieved the national policy of No Net Loss of Wetlands. In a follow up to the 2001 NRC report three of the committee members synthesized others' research to show that the footprints of actual mitigation projects ranged from 28-100% of the mitigation acreage required in their section 404 permit documents (Turner et al., 2001). A 1996 study of 80 permits for projects in Orange County, CA showed that two mitigation projects were never attempted, 13 never reached completion and 25 met some or no of the permits' requirements. Of the 80 total permits issued, only 30 actually met the permit conditions (Sudol, 1996). Similar patterns of non-compliance have been observed across the country (Lowe et al., 1989; Johnson et al., 2000; Brown and Veneman, 2001; and Matthews and Endress, 2008).

Many scientists have argued the No Net Loss policy places too much emphasis solely on achieving No Net Loss of wetland area, neglecting the loss of wetland functionality (Zedler, 1996; Sibbing, 2008; Cole, 1998). Measuring whether wetland acreage is being replaced at a 1:1 or greater ratio is relatively simple, requiring only follow up with permitted mitigation projects and tracking acres impacted to acres replaced. Achieving the goal of No Net Loss of wetland function is a more complex issue and can be quite controversial. Measuring wetland function can be difficult to achieve due to the complexity of wetland ecosystems and the problems inherent in comparing mitigated wetland functions to baseline data (Zedler, 1996).

There are few claims that the No Net Loss policy has been entirely successful. One statement by the George W. Bush Administration in 2006 claimed that they had achieved no net loss of wetlands based on United States Fish and Wildlife Service (USFWS) data, but the claim was refuted quickly by critics who acknowledged that while actual acreage of wetlands may have increased, much of it was low quality pond, lake and other deepwater habitat (Associated Press, 2006). At around the same time in 2005, a study of seven ACOE district offices resulted in a report by the U.S. Government Accountability Office which found that the ACOE did not verify mitigation as actually being performed on thousands of acres (USGAO, 2005).

More recently, the USEPA has reported “no net loss” of wetlands for the fiscal years 2009 through 2011. When this assertion was questioned, the USEPA conducted an internal review and identified that they needed to clarify the claim of “No Net Loss” of wetlands. They acknowledged that their claim was based on the assumption that all mitigation projects meet the performance standards that are set in their Section 404 permits, while research shows that mitigation success rates (reaching performance standards) are approximately 75% not 100% (USEPA, 2014; Hill et al., 2013).

2.2 California Wetland Mitigation and Permit Compliance

One of the first critiques of wetland mitigation policies in California came from Margaret Race at Stanford University in 1985, who found that wetland project sites in San Francisco Bay were deficient, and that few if any could be described as “completed, active or successful” (Race, 1985). She explained that the cause for failure rested on the inability of regulatory agencies and project managers to track site data, and poor maintenance of sites after initial construction, primarily a failure to replace plants lost to mortality. Her study prompted additional analysis of the success of wetland projects in California and the Pacific Coast region. Her methods have been criticized by those who argued that Race was too focused on results of experimental planting and ignored the fact that many wetlands were created because of these policies, even if the projects were not entirely successful (Harvey and Josselyn, 1986). Regardless of the accuracy of Race’s study, this exchange led to an ongoing debate about the efficacy and success of wetland mitigation projects.

Two other studies in the 1980s found that projects failed to meet their stated goals most likely due to lack of enforcement, improper planning and/or poor project implementation (Eliot, 1985; Zentner, 1988). The shortcomings of wetland projects in the 1980s were summarized and evaluated in a 1990 paper in which the authors created a set of recommendations that could be applied to ensure future project success (Josselyn et al., 1990). Many recommendations of Josselyn et al. (1990) have been incorporated into permitting requirements, but some have not been implemented successfully. Recommendations that were not incorporated were a desire for more detailed permits, greater specificity in project design, stricter monitoring requirements and criteria for evaluating success/function between impacted and mitigated wetlands. Regulatory agencies have also failed to integrate recommendations that mitigation should be conducted prior to the associated impact in order to guarantee replacement of lost function. If the impact occurs before the mitigation occurs there is no guarantee that the impacted wetland functions will be replaced. There was also an ongoing concern that once a permit was issued for a mitigation project there was almost no follow-up to ensure or document compliance (Mager, 1990).

In the decade following initial identification of the limitations and failures of wetland mitigation projects in California, Race and Fonseca found that political and regulatory bodies had not been able to improve their performance. In 1996, they conducted a study to review wetland mitigation policies and practices and evaluate wetland mitigation as a tool for managing wetland loss and impacts in the United States. Their results were similar to the studies conducted in the 1980s: that compliance was poor and poorly enforced by regulatory agencies, actual acreage of wetlands mitigated did not reach desired goals and maintaining baseline data from reference sites to evaluate success criteria was inadequate (Race and Fonseca, 1996). Another issue identified was that policies were in place which promoted performance standards that did not effectively replace the functions and services of the impacted ecosystems (Bies, 2006; Zedler, 1996). This led to compensatory wetlands being considered successful even though they provided a fraction of the services of the wetlands they replaced (Dale and Gerlak, 2007; Krogman, 1999; Zedler and Callaway, 1999).

Success of a wetland was most often defined as achieving similar vegetation complexity as a reference wetland. However this ignored many of the other factors that fully explain wetland function. A 2002 study of Orange County mitigation sites used a hydrogeomorphic approach to assess 40 sites using 15 habitat functions, and compared the results to seven reference sites (Sudol and Ambrose, 2002). This study showed that one of the primary reasons for mitigation failure was that the hydrologic conditions on the project sites were inadequate for successful development of wetland functions. The study also found mitigation projects were sometimes never attempted after being permitted, and when they were attempted they often did not meet their stated success criteria (Table 4). A 2004 study found that only 46% of California compensatory mitigation projects had 100% compliance with fully complied with all of their permit conditions (Ambrose and Lee, 2004).

There has since been little research into project success rates in California. Kihslinger (2008) confirmed in a review of the previous authors that many projects failed to meet success criteria. Her review found that failure rates ranged from 4% to 49%. However in North Carolina, a recent study (Hill et al., 2013) found that wetland mitigation success rates had increased from 50% to 74%.

Table 4: Success of mitigation projects based on permit compliance, Orange County

Category	*N*	Impact (ha)	Mitigation (ha)	Percent of Total
Total permits	70	136	152	
No project	13	8	13	18.6%
No attempt	2	1.6	1.6	2.9%
Projects evaluated	55	126	138	
Success	30	91	72	54.5%
Partial Success	19	24	45	34.5%
Failures	6	11	21	10.9%

Source: Sudol and Ambrose, 2002

2.3 Changes in Wetland Mitigation Sequencing Polices: The Prioritization of Wetland Mitigation Banks

In 1980 the USACE and USEPA adopted sequencing, a policy which set priorities for dealing with wetland related impacts: first to avoid, then minimize, and as a last resort, mitigate impacts to wetlands (USEPA and USACE, 1990). On March 31, 2008, the USACE and the USEPA released revised regulations regarding Section 404 of the Clean Water Act. Whereas there was originally no prioritization of mitigation techniques, the revised order of preferred compensatory mitigation is currently: mitigation bank credits, in-lie fee credits and permittee-responsible mitigation (Federal Register, 2008;Table 5). The vast majority of compensation for wetland impacts has been in the form of permittee-responsible mitigation, but the new 2008 Final Rule is intended to push wetland impact compensation towards mitigation banking and in-lieu fee credits where feasible. California regulatory agencies still prioritize on-site compensatory mitigation over mitigation banking or in-lieu fees, although there have been efforts to promote mitigation banking as an alternative to project-by-project mitigation (California Department of Fish and Game, 2010). Generally this is a move towards a market-based mitigation system.

Table 5: Descriptions of wetland mitigation methods

Method of Mitigation	**Description of Mitigation Method**	**Pre-Impact vs. Post Impact**
Mitigation Banking	Wetlands are preserved, enhanced, created or restored in a mitigation bank. A mitigation bank is given credits based on the type of wetlands, function of wetlands and area of wetlands in the bank. Credits are sold to developers and are used to compensate for impacts to wetlands under the CWA.	Occurs Pre-Impact
In-Lieu Fee Credits	Funds are paid by the developer to a natural resource management entity, often a government agency or non-profit organization. The in-lieu fee sponsor uses the funds for specific or general programs protecting aquatic resources. Formal agreement may be similar to a mitigation banking instrument.	Occurs Post-Impact
Permittee Responsible	Wetland preservation, enhancement, creation or restoration to mitigate for impacts, at 1:1 or greater ratios.	Generally occurs Post-Impact

2.3.1 The growth of wetland mitigation banking

In 1992 there were only 46 wetland mitigation banks in the U.S, but by 2005 there were 450 mitigation banks, an increase of 978% (USEPA, 2013; and ELI, 2002). A current estimate based on the Regulatory In-Lieu Fee and Bank Information Tracking

System counts approximately 1736 Section 404, including streams and wetlands, mitigation banks in the United States including both streams and wetlands (ACOE, 2014). The growth of wetland mitigation banks as a compensatory mitigation tool should continue to increase with its support from the USACE. Emphasis on a market driven approach has been supported by the USACE for over two decades (USACE, 1995), and market-based solutions will likely continue to play an integral role in our impact mitigation and wetland protection policies.

Many researchers have identified wetland mitigation banking not as a panacea to the current problems, but as one strategy to realize the goal of No Net Loss of wetlands (Silverstein, 1994; Schenck, 2000; and Haynes and Gardner, 1993). Wetland mitigation banking was first utilized as a compensatory mitigation tool for state departments of transportation in 1985, and a set of guidelines were released in 1995 by the USACE and USEPA for their use in private mitigation efforts (USACE, 1995). Wetland mitigation banks are understood to have a wide range of benefits over traditional permittee responsible mitigation projects: they may be more efficient at providing functions and benefits than on-site compensatory mitigation projects; they are generally of a larger size and they are continuous, un-fragmented wetlands, which are considered to have greater function than smaller, fragmented wetlands (Neal, 1999).

Banks are created prior to the impacts and are able to minimize or negate the temporal losses of functionality that generally occur when there is a time lag between an impact and the realized functions of mitigation efforts (Bendor, 2009). They are also more likely to be built by entities which specialize in wetland construction and have proven records of successful projects (Silverstein, 1994). As a result, banking may be a regulatory tool that helps to avoid the failure rate of smaller on-site and off-site mitigation projects and has been adopted as a possible solution to the failure rates being experienced in traditional wetland mitigation projects.

Advocates of a market-based approach to compensatory wetland mitigation argue that private sector markets are the most effective means to finding low-cost, effective methods of restoring, protecting and creating wetlands (Robertson, 2006). They also argue that the prices customers pay for mitigation credits is an accurate method for measuring the relative value of ecosystem services and function (Robertson, 2006, and Gomez-Baggethun et al., 2010). However, dissenting researchers claim that a market-based approach allows developers to simply pay for impacts and may contribute to greater wetland loss (Smoktonowicz, 2005; Edwards, 2003; and Desma, 1994). Mitigation banks could potentially incentivize landowners to convert their land to wetlands if land becomes less valuable with sea level rise.

2.4 How other regions are planning for sea level rise

Humboldt Bay is unique because it is a relatively pristine water body on the Pacific Coast in California with intact, but limited, salt marsh. As such, there is little room to experiment with possible treatments for salt marsh loss due to sea level rise. However, other regions have similar predicaments with regards to salt marsh loss and sea level rise, and a review of their efforts.

In 2007 the San Francisco Bay Conservation and Development Commission (BCDC), a sister agency to the California Coastal Commission, developed a sea level rise strategy for San Francisco Bay to address sea level rise. The strategy is not comprehensive, but it does detail what is necessary to develop an actual sea level rise plan. It encourages regional coordination, and a joint policy committee oversight to facilitate coordination between regulatory agencies (BCDC, 2008).

New Hampshire has convened planners, scientists and practitioners to develop a statewide plan to address sea level rise using available journal articles and data sources to identify priority areas based on the input of the participants (West, 2014). This strategy is designed to facilitate coordination between practitioners, regulators, scientists and governments in order to guide mitigation efforts.

The state of Maryland developed a sea level rise response strategy in 2000 in order to improve their ability to respond to sea level rise. They identified four components to their strategy, one of which was to incorporate sea level rise planning mechanisms into existing State and local management programs and on-going coastal initiatives (Johnson, 2000).

While it appears that a number of regions and localities are preparing strategies to address sea level rise, there are few that actually have implemented plans. While researchers have documented sea level rise planning efforts, there are very few examples of successfully developed and implemented sea level rise plans. The sea level rise plans that have been implemented are generally for cities and are incorporated into their general plans, but they are generally for small areas that lack a coordinated regional plan (City of Novato, 2015; Baker et al., 2012; Measham et al., 2011). Strategies are abundant, but plans are not readily available. Humboldt Bay is currently developing a sea level rise adaption plan, but as of yet it is incomplete and unimplemented (HBHRCD, 2015).

2.0 CHAPTER THREE: MODELING SALT MARSH MIGRATION WITH SEA LEVEL RISE

3.1 Geospatial Analysis Methods

The study area for the research was Humboldt Bay, bounded roughly by the watersheds that feed it and six meters of elevation above and below the Mean High Higher Water line. I chose the study area so that it would encompass all areas where tidal marsh could reasonably exist (Figure 1, Figure 2, and Figure 3). The study area was also limited to the bay side of the coastal dune complexes.

I acquired data sets from multiple sources (Table 6) and compared data sets with tidal salt marsh occurrences. Datasets included as predictor variables in my model were elevation, slope, land cover and tidal connectivity. The Digital Elevation Model (DEM) used for the analysis was transformed using raster calculator to represent sea level rise of one meter and two meters. One meter and two meters of sea level rise were used for the analysis because they are easy to visualize benchmarks within predominant sea level rise scenarios, and have been used by prior studies in Humboldt Bay (Laird, 2015). The models for one meter and two meters of sea level rise should be considered scenarios, and should not be considered as attempting to predict future conditions. Each predictor variable was clipped to the study area and down sampled to 10 meter resolutions. Tidal connectivity was a polygon layer, so it was converted into a raster with a 10 meter resolution and also clipped to the study area. Down sampling occurred in R Studio. 150 sample points were created randomly from the salt marsh polygons, causing the salt marsh polygons to act as occurrences rather than static features.

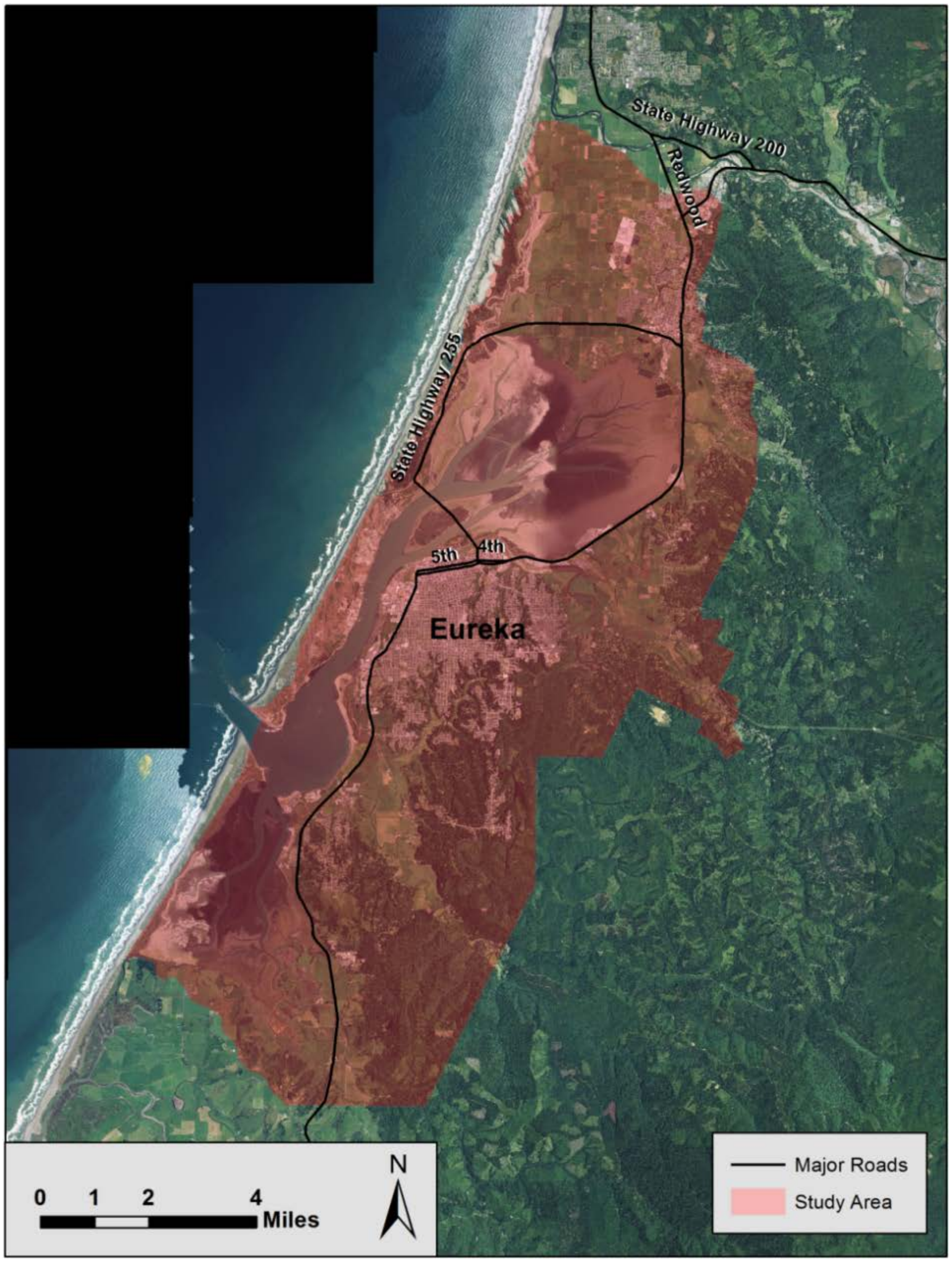

Figure 1: Project study area

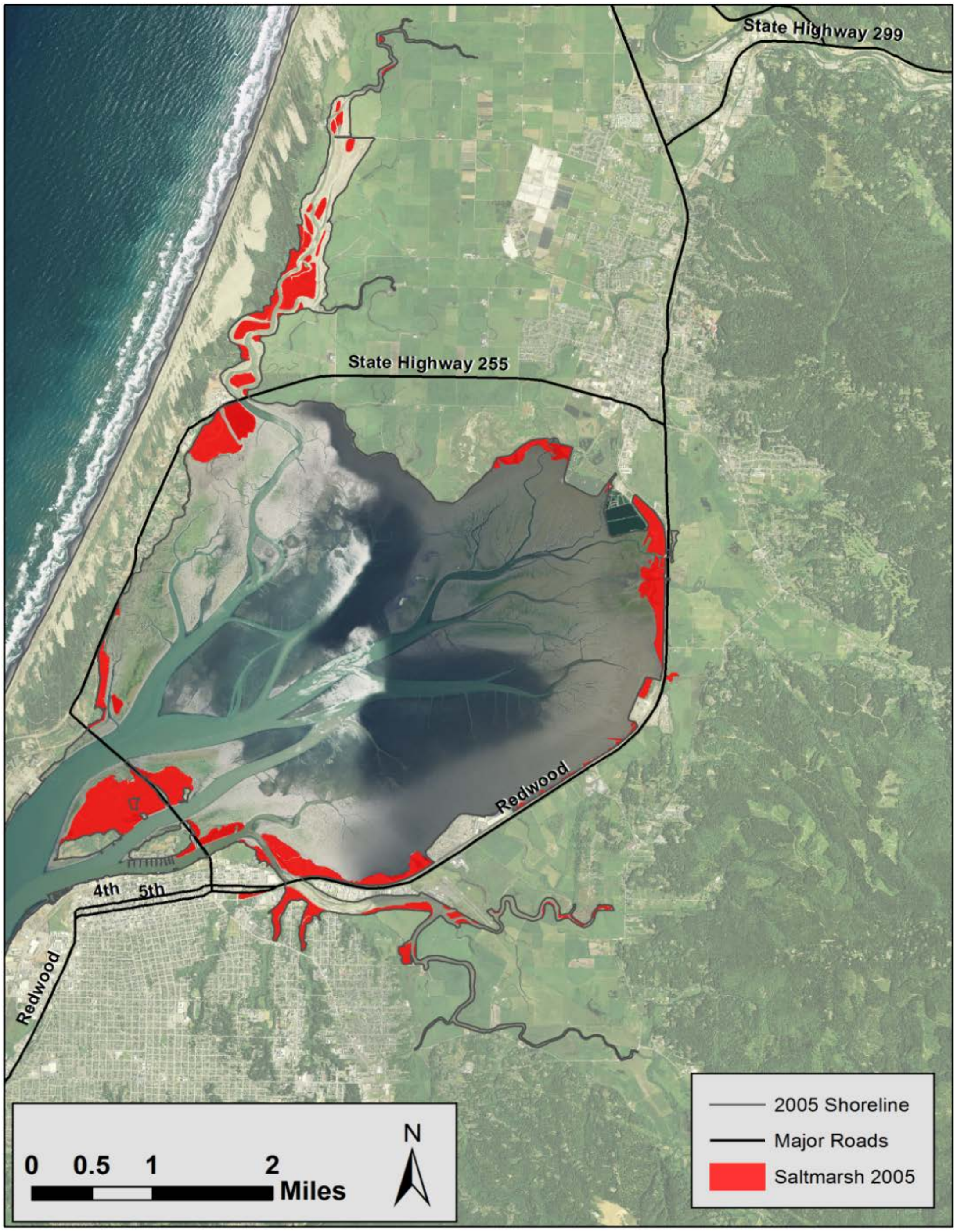

Figure 2: Current salt marsh occurrence. North Humboldt Bay

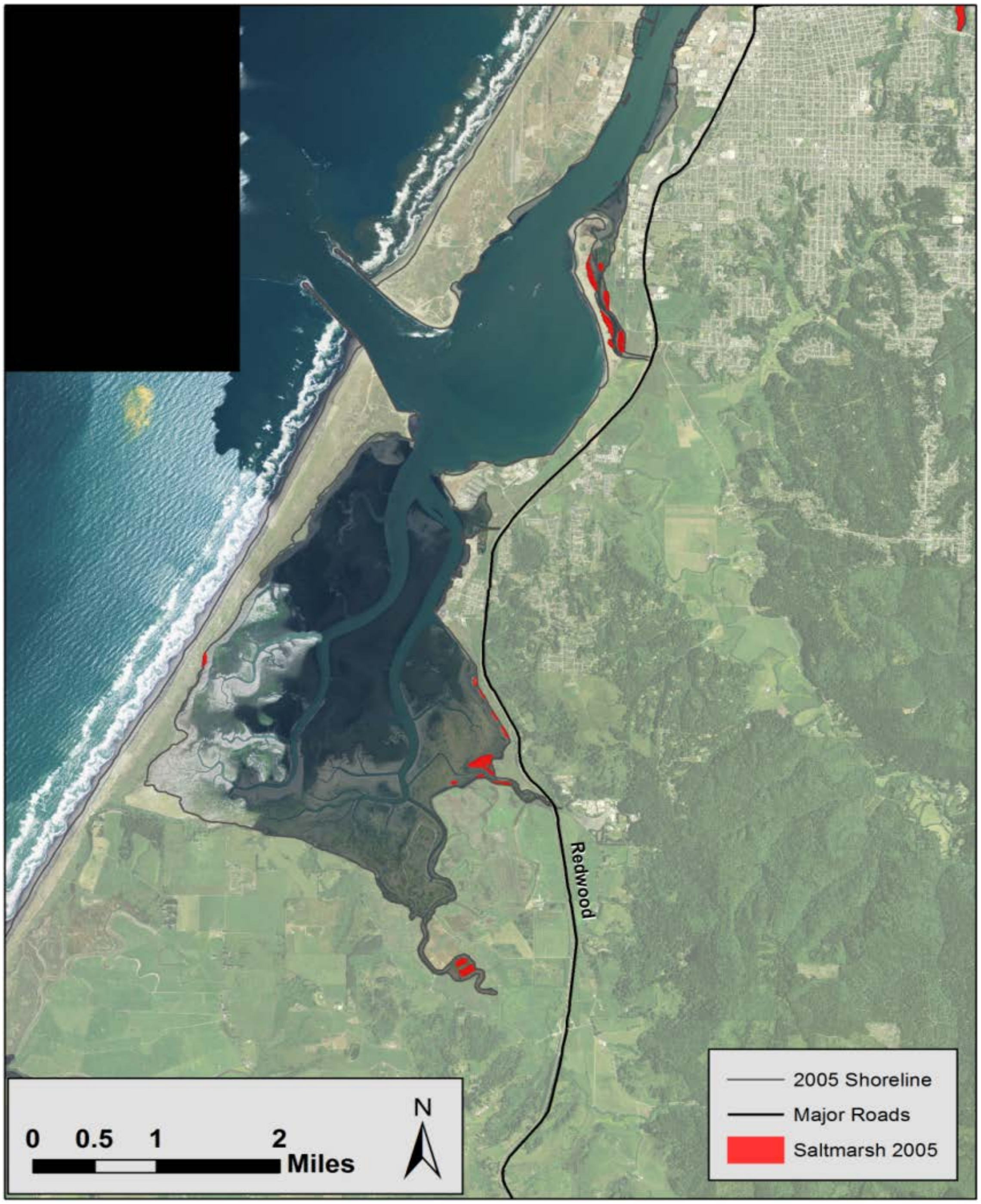

Figure 3: Current salt marsh occurrence, South Humboldt Bay

Table 6: Data sets used in the MaxEnt model

Data Set	**Source**
DEM	National Oceanic and Atmospheric Administration
Slope	National Oceanic and Atmospheric Administration
Land Cover	Fire and Resource Assessment Program (CalFire)
Tidal Connectivity	Digitized from Aerial Imagery and Shoreline Shapefile
Wetlands	National Wetland Inventory (United States Geologic Survey)
Aerial Imagery	National Agriculture Imagery Project (United States Department of Agriculture)
Watersheds	National Hydrography Data Set (United States Geologic Survey

To find probability distributions, I used Maximum Entropy Modeling, a technique that creates probability distributions from sample data when the modelers only have partial knowledge. The distribution with the greatest entropy is considered the proper distribution. The software MaxEnt is used to model phenomenon with occurrence only data (most other models use occurrence/absence data), and was created to model habitat suitability. MaxEnt was used in order to create a probability distribution of salt marsh occurrence for the current sea level, which was then projected into the future into one meter and two meter sea level rise scenarios.

The datasets were run through MaxEnt in Bluespray in order to process them prior to the actual MaxEnt run. Bluespray has the ability to clip and ensure the geographic conformity of each layer in order to meet MaxEnt’s requirements for analysis. Once the data were ready for modelling, the model for predicting salt marsh migration potential was generated in MaxEnt using the following parameters:

- 150 presence records used for training.
- 10149 points used to determine the MaxEnt distribution (background points and presence points).
- Regularization values: linear/quadratic/product: 0.050, categorical: 0.250, threshold: 1.000, hinge: 0.500
- Feature types used: product linear quadratic hinge threshold
  response curves: true

Once the initial model was complete, I validated results by comparing the prediction of the model to actual salt marsh occurrence and distribution. The comparison was done in two steps. First the area of predicted salt marsh (highest occurrence probability classes) was compared to the actual existing salt marsh area. Secondly, a visual assessment of the model output and the existing salt marsh distribution was conducted. I selected 10 random points from the high potential classes that the model output, and conduction field visits to ground truth them. All 10 of the points were salt marsh and validated the model. The model output was very close to the distribution of existing salt marsh and I was able to verify that the model was classifying the highest probability of salt marsh occurrence in the locations where salt marsh actually exists.

The next step was to project the model into the future using the one meter and two meter sea level rise scenarios. I used the *project* option in MaxEnt to apply the model to the DEMs representing one meter and two meters of sea level rise, while using the rest of the data sets in the original model. In projecting the model with future sea levels in MaxEnt, the parameters for the predictor variables other elevation are kept the same, and only the elevation variable is changed, thus representing a rise in sea level while all of the other variables remain constant.

3.2 Salt Marsh Migration Modeling Results

The tidal salt marsh migration model had a strong Area Under the Curve (AUC) score of .937 (Figure 4). This score is well above what would occur under random prediction (AUC = 0.5), demonstrating that the model correctly classified salt marsh occurrences using its prediction output.

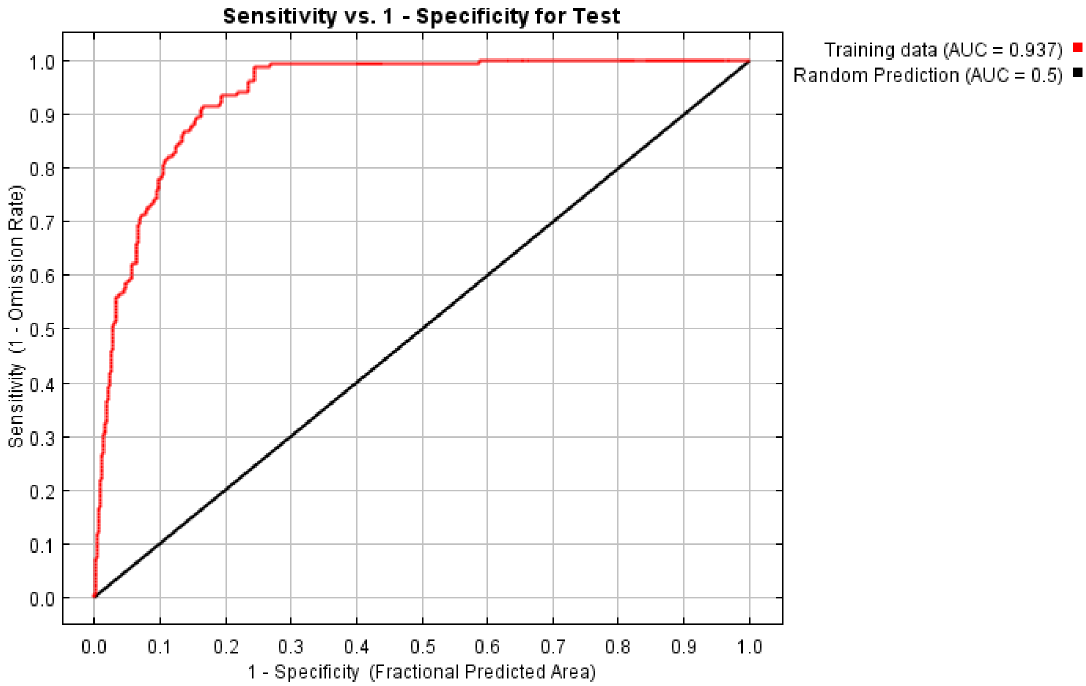

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Figure 4: Area Under the Curve of the MaxEnt Model

The variable names used in the model are described in Table 6. Response curves for predictor variables demonstrate distinct response ranges for salt marsh occurrence (Figure 5). The closer a response is to 1.0, the more accurately that value predicts occurrence. Response curves for models based on each individual variable, while excluding the rest, are shown in Figure 6. The response curves show the modeled probability of occurrence for each variable when the variable is modeled by itself (Figure 5) and when it is modeled with the other variables (Figure 6). What the response curves tell us about the model is that elevation and tidal connectivity's importance to the model does not change when modeled separately versus with all of the other variables. Slope and land use show much different responses when modeled separately versus with all other variables. The response curve tells us that slope and land use are not as important in modeling salt marsh occurrence as the other two variables.

Table 7: Dataset names in the MaxEnt model

Variable Name	Data Type
10mdem_1	Elevation (Meters)
LandCover1_2	Land Cover Type
dikedgood1_0	Tidal Connectivity
slope10m_3	Slope Percent

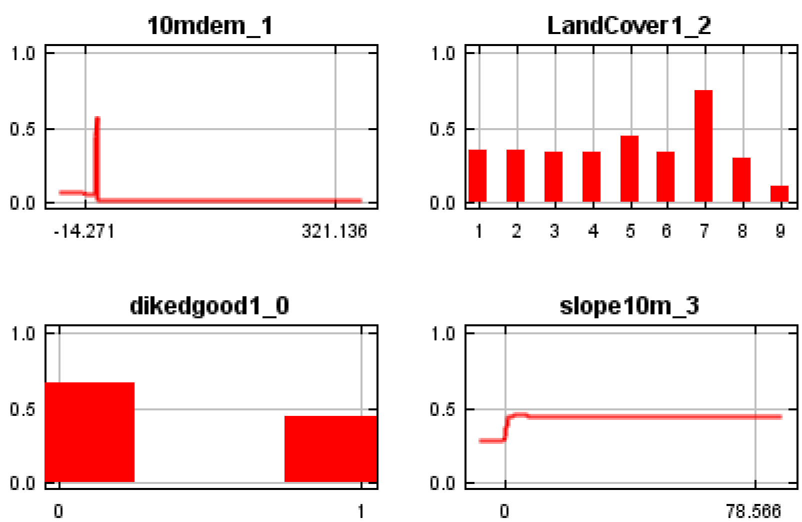


Figure 5: Response curves for the MaxEnt model with all predictors included in the model

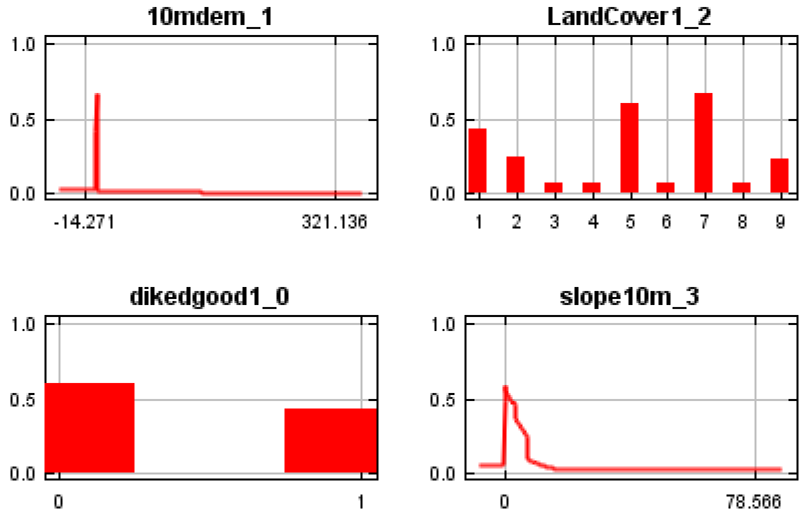


Figure 6: Response curves for the MaxEnt model when each predictor is modeled individually

The model for current salt marsh habitat closely fits current distributions of salt marsh (Figure 7 and Figure 8). The highest probability areas (those in the .7-.9 value range) overlay existing salt marsh very well, with the exception of some anomalous areas on the western shore in the South Bay. The new California Department of Fish and Wildlife refuge in the North Bay (McDaniel Slough Restoration) is also identified as high probability salt marsh habitat, it is an area that should become salt marsh in the future but was just recently restored and reconnected to the tidal prism. The site is 250 acres and would decrease the discrepancy between predicted salt marsh occurrence and existing salt marsh if added to the existing salt marsh dataset. Predicted salt marsh occurrence is confined to seaward sides of dikes and levees, and is also confined to a narrow set of elevations relative to sea level. The salt modeled marsh along the west shore in the South Bay represents the largest miss in the model, there is no actual salt marsh there.

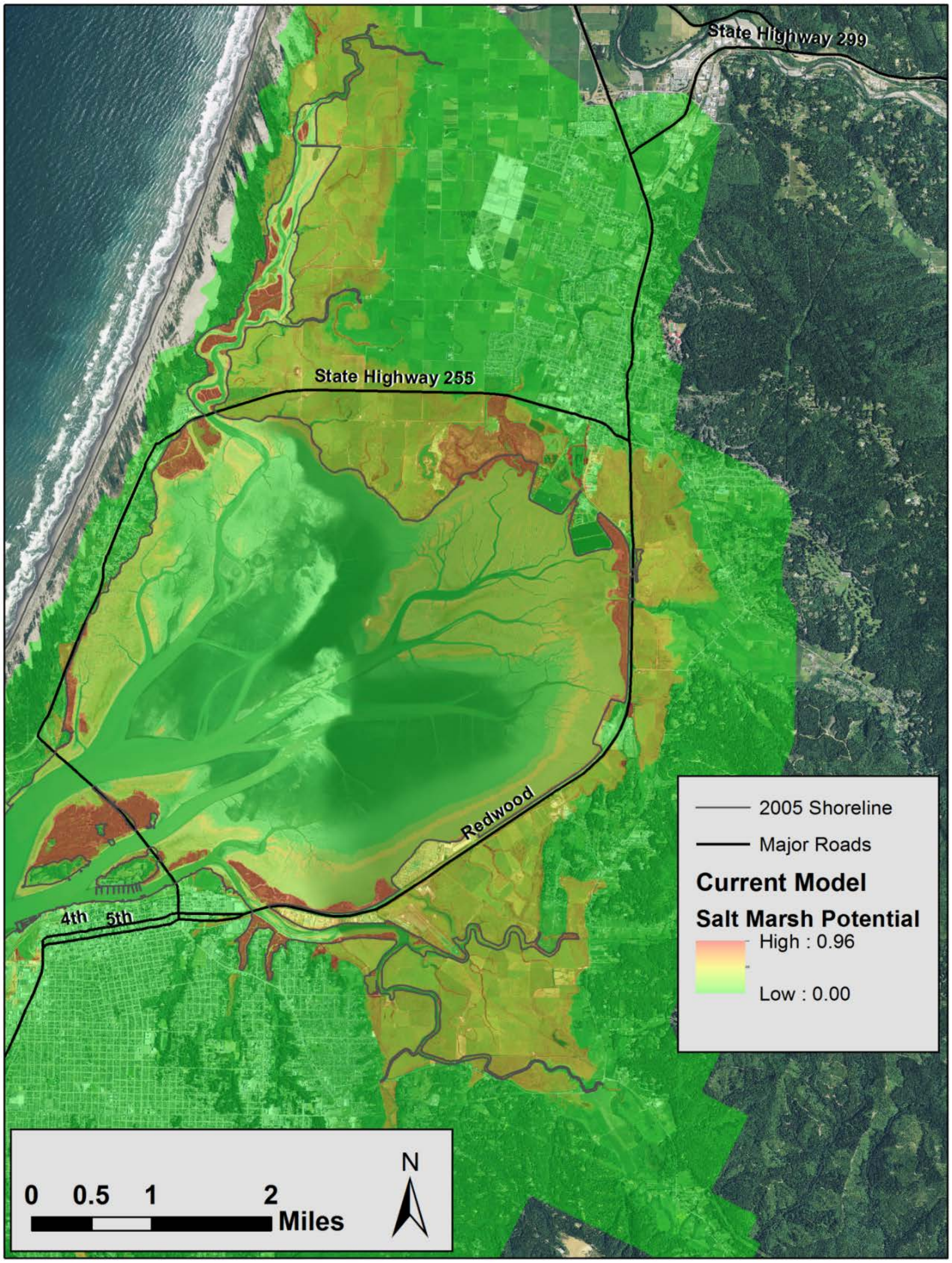


Figure 7: Salt marsh occurrence potential in 2005, North Humboldt Bay

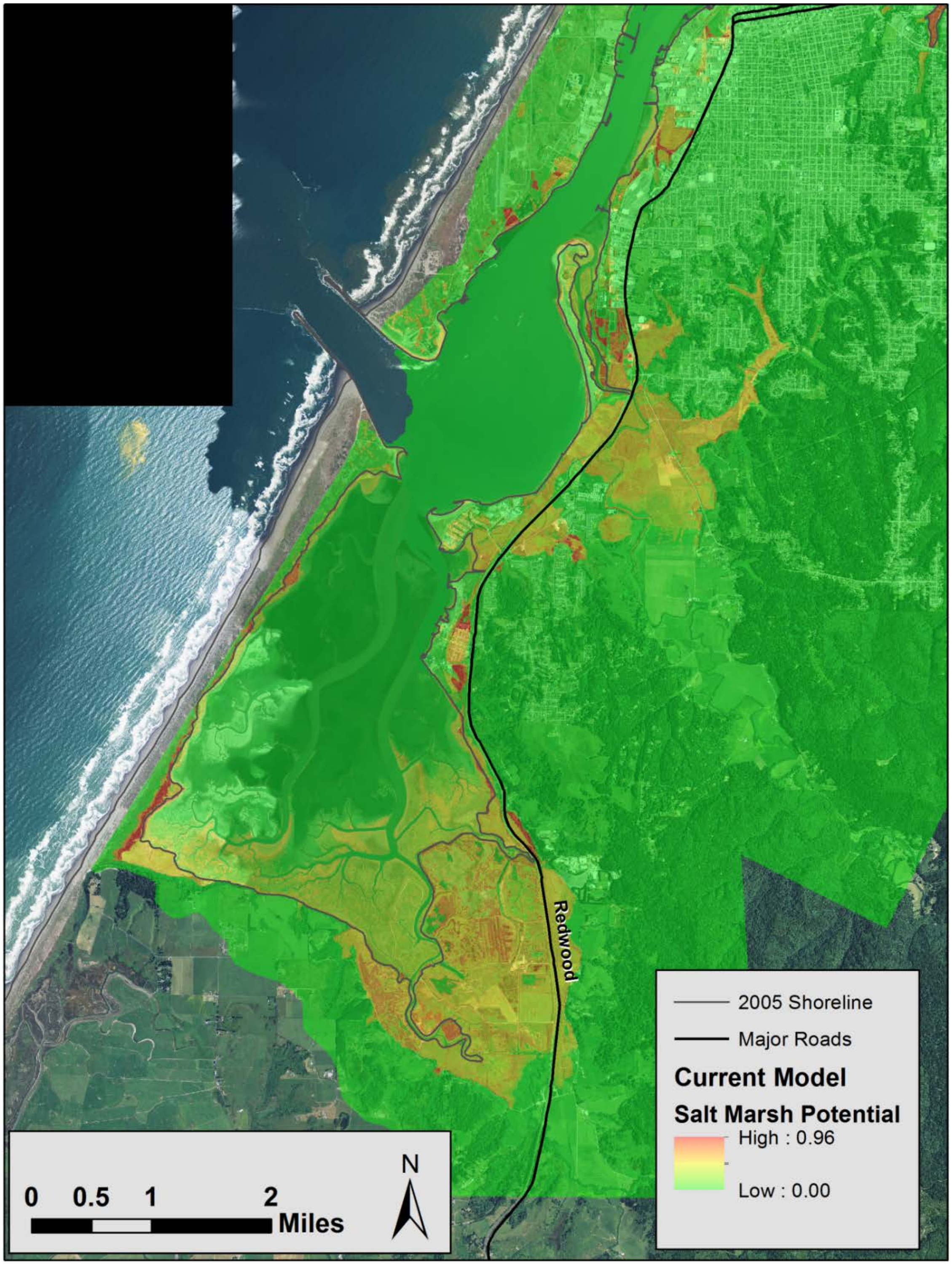
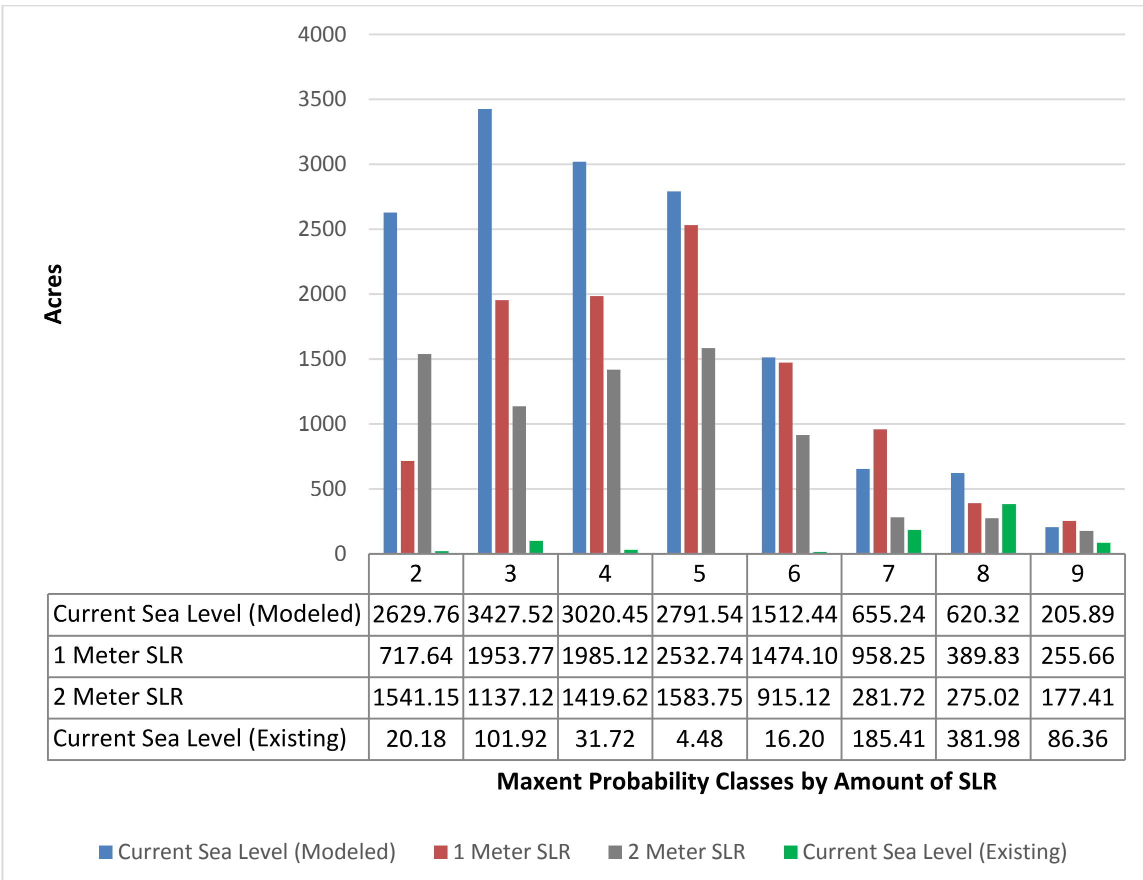


Figure 8: Salt marsh occurrence potential in 2005, South Humboldt Bay

The future scenarios along with the current model were converted into a graph which shows changes in potential salt marsh acreage under probability ranges (Table 8). In bright green, the existing salt marsh clipped with the MaxEnt model's current sea level output, to show how the model actually classified existing salt marsh. The majority of existing salt marsh is classified as being in the .7, .8 or .9 (High Probability) probability classes, which shows that the higher probability classes do the best job of predicting actual locations of salt marsh and the model works. The salt marsh dataset used to train the model was from 2005, and there are 250 additional acres which are currently being converted to salt marsh. If we include these 250 acres, then there are 1072 acres of existing salt marsh and 1480 acres predicted by the model of the current sea level. The difference between existing salt marsh and predicted salt marsh at the current sea level indicates that the model was overestimating the area where salt marsh could exist by approximately 38%.

The results of the model predict that with one meter of SLR, there is a maximum potential of 1602 acres of High Probability area, a slight increase of 8.2% from the current sea level estimate of 1480 acres. The increase is due to the pasture land surrounding Humboldt Bay which is currently disconnected hydrologically from the tidal prism. With one meter of sea level rise, it would be at the correct elevation to become salt marsh, if it were reconnected to the tidal prism. At two meters of sea level rise, the maximum acreage of High Probability land decreases by over half to 733 acres. If the results are accurate, they describe how with two meters of sea level rise the amount of land capable of supporting salt marsh would decrease by over half.

Table 8: Salt marsh acreage estimates by probability range for the model and predictions



	2	3	4	5	6	7	8	9
Current Sea Level (Modeled)	2629.76	3427.52	3020.45	2791.54	1512.44	655.24	620.32	205.89
1 Meter SLR	717.64	1953.77	1985.12	2532.74	1474.10	958.25	389.83	255.66
2 Meter SLR	1541.15	1137.12	1419.62	1583.75	915.12	281.72	275.02	177.41
Current Sea Level (Existing)	20.18	101.92	31.72	4.48	16.20	185.41	381.98	86.36

Figure 9 and Figure 10 show the model applied to North Humboldt Bay with one and two meters of sea level rise. Figure 11 and Figure 12 show the model being applied to South Humboldt Bay with one and two meters of sea level rise. Notably, the band of suitable salt marsh habitat moves landward and upward at varying distances depending on the gradient of the shoreline. The results of the model are intended to be reviewed at smaller scales, but the overall shift inland can be observed. Figure 13 shows a close-up comparison of the current sea level model, one meter of sea level rise and two meters of sea level rise.

The maps of the model output have a certain degree of error in them and should only be used as a reference for potential future conditions, however, these maps still have valuable management implications. The model outputs can contribute to regional planning for sea level rise, and help identify areas of high priority for wetland projects in anticipation of coastal wetland loss. If the model’s predictions are overlaid with parcel layers, they can be used to help identify landowners with land that may be suitable for an easement or outright purchase.

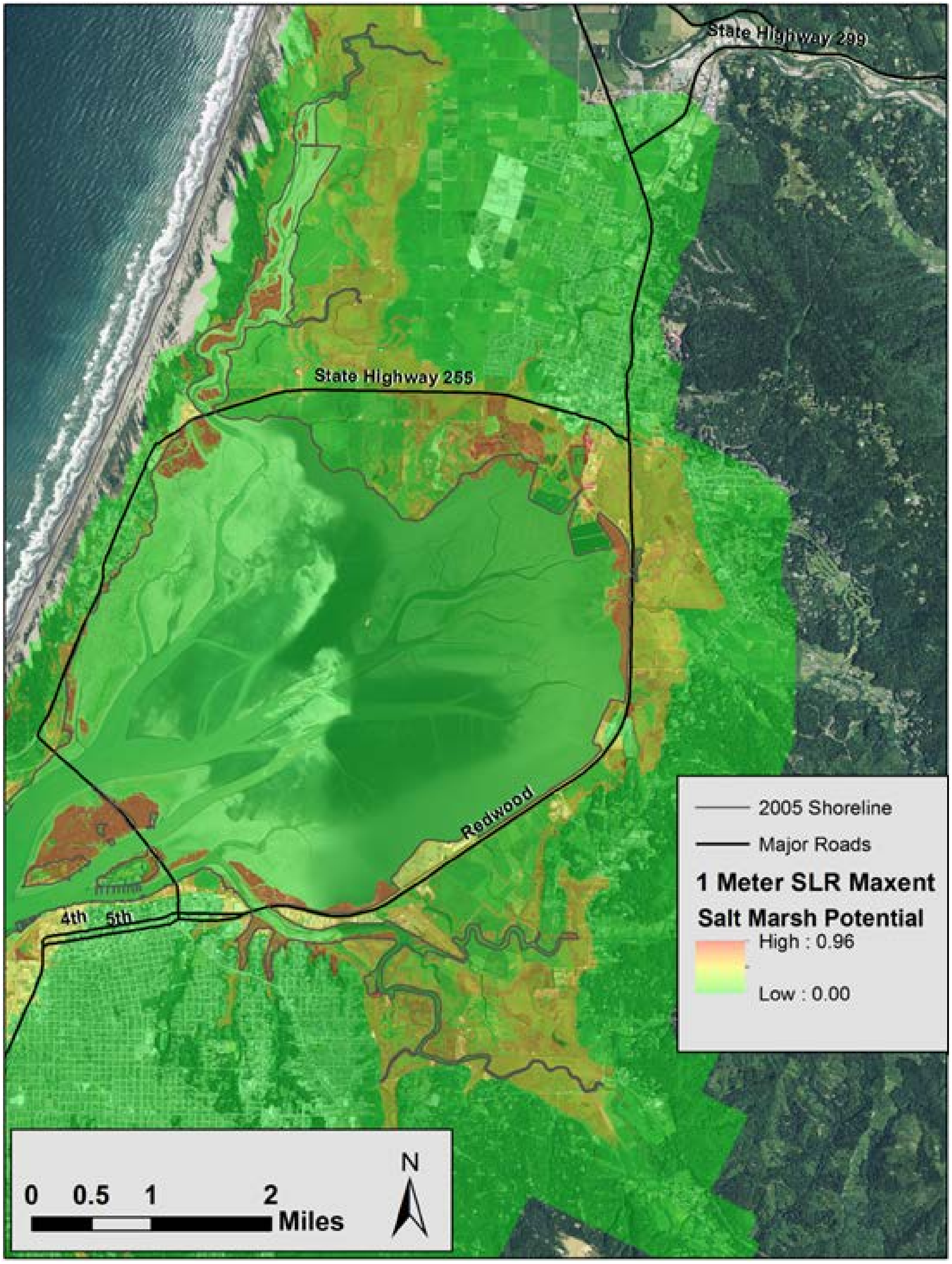


Figure 9: Salt marsh occurrence probability with one meter of sea level rise, North Humboldt Bay

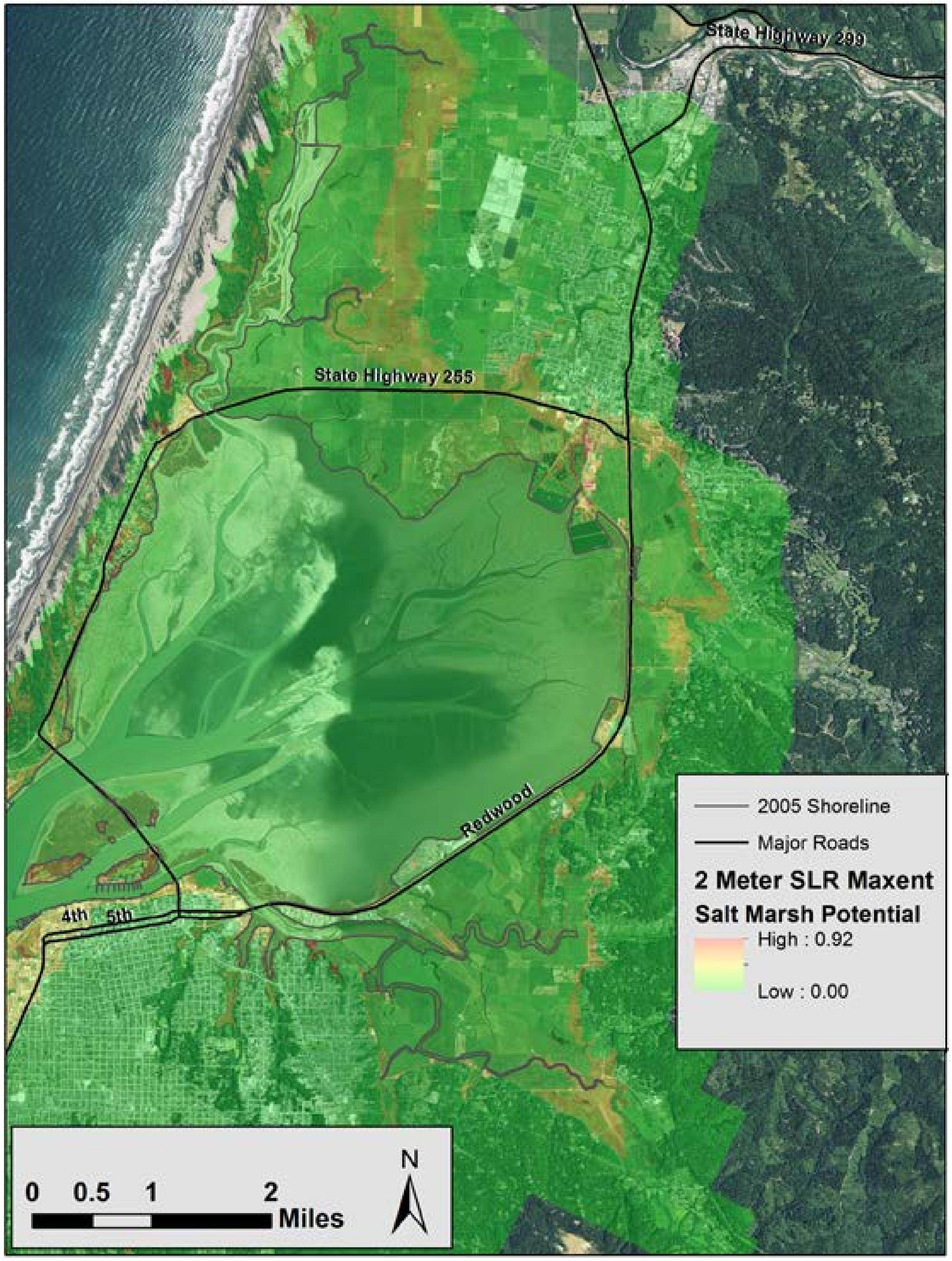


Figure 10: Salt marsh occurrence probability with 2 meters of sea level rise, North Humboldt Bay

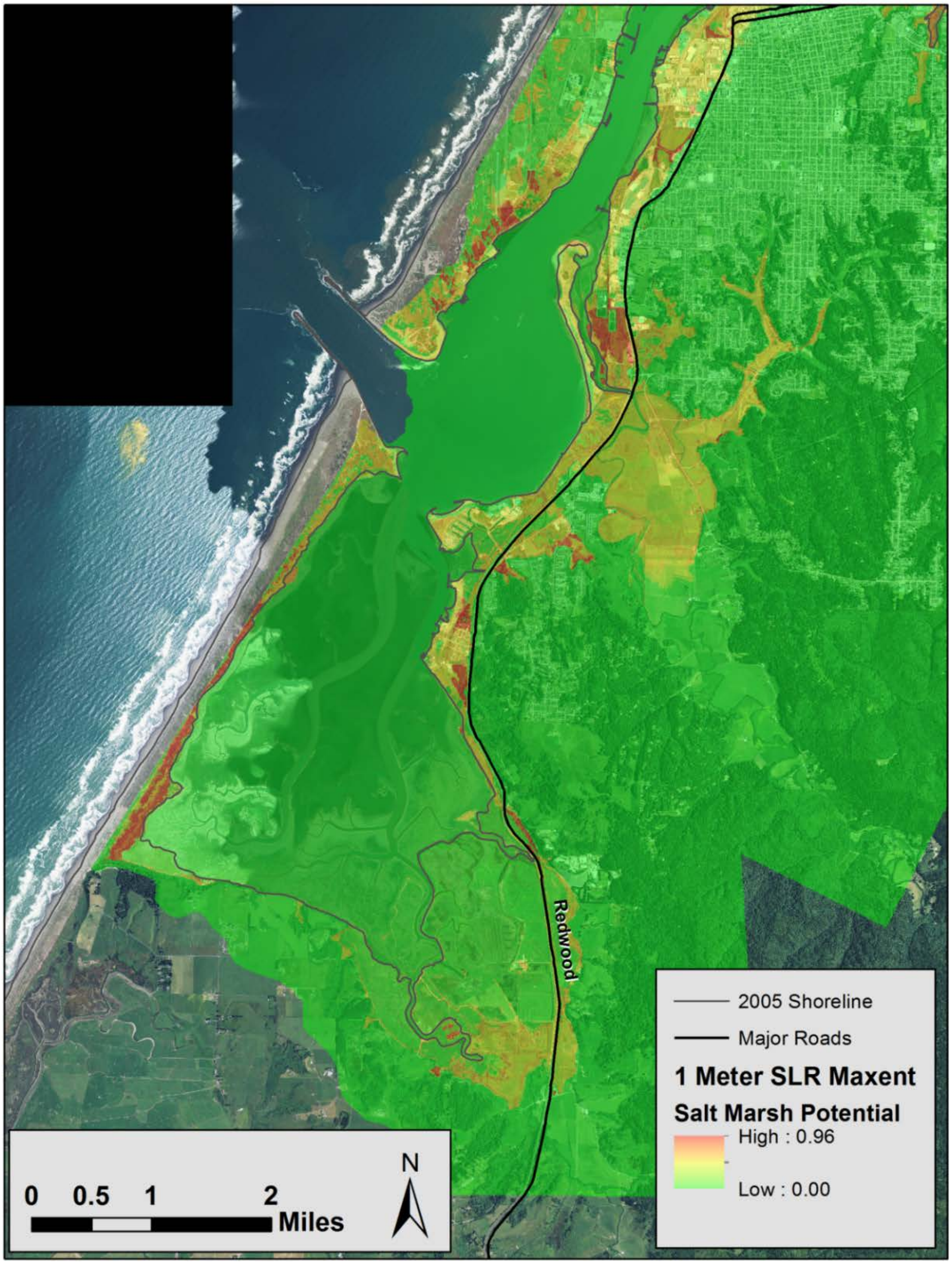


Figure 11: Salt marsh occurrence probability with one meter of sea level rise, South Humboldt Bay

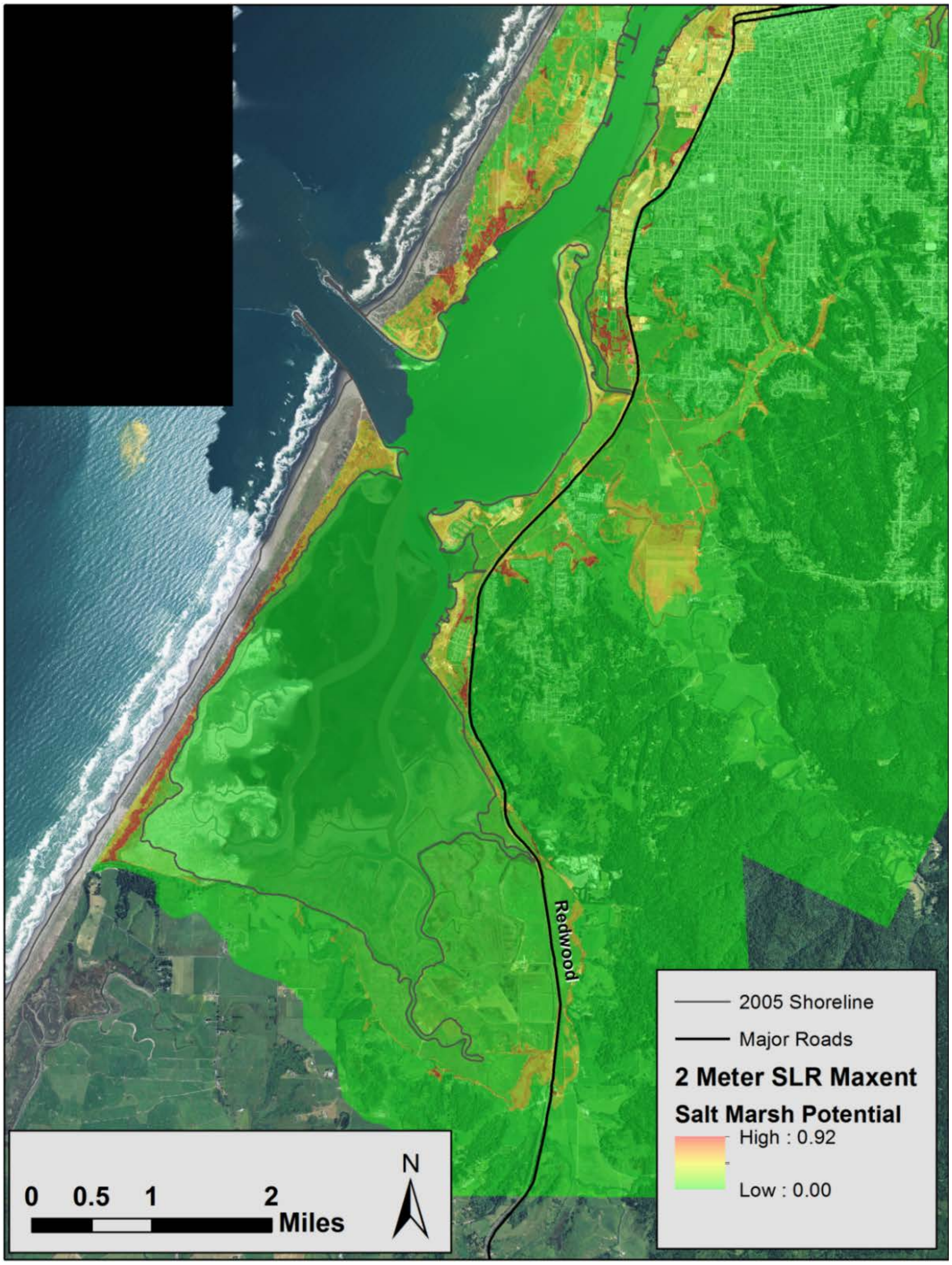


Figure 12: Salt marsh occurrence probability with 2 meters of sea level rise, North Humboldt Bay

The final figure is an up close comparison of potential salt marsh habitat at the current sea level and with two meters of sea level rise (Figure 13). While the maps are intended to be viewed dynamically on a computer, Figure 13 is an example of how a suitable area for a salt marsh project may be identified. What is important to observe is how the high potential area migrates from the bay side of the levee (represented by Redwood Highway [Highway 101]) into the far east side of the adjacent pasture land.

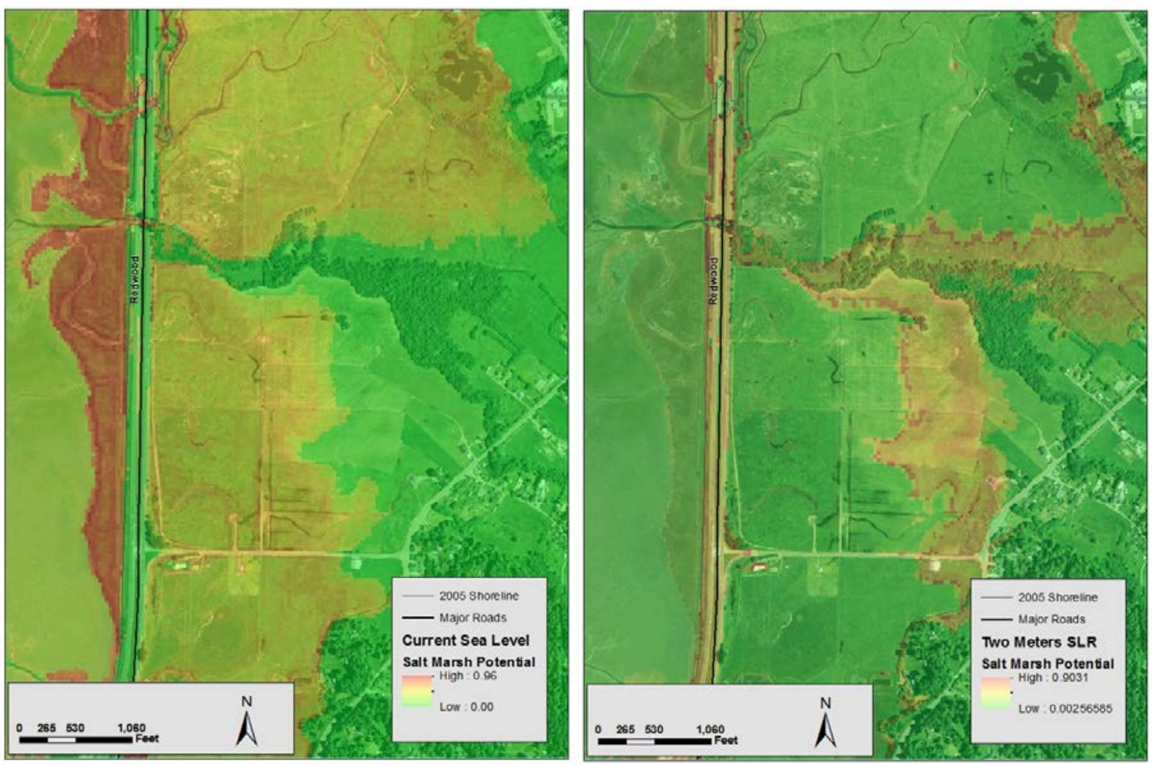


Figure 13: Up close comparison of salt marsh migration from current sea level to two meters of sea level rise

These results indicate that sea level rise will have a negative impact on salt marsh. In order to maintain wetland resources, the community would need to be proactive about performing wetland projects ahead of wetland losses. To keep up with sea level rise and the impacts to wetlands, projects may need to occur quickly and be successful.

3.0 CHAPTER 4: HOW HUMBOLDT BAY IS RESPONDING TO WETLAND IMPACTS AND SEA LEVEL RISE

4.1 Qualitative Research Methods

I used a qualitative research approach to evaluate wetland policies, primarily interviews, analyzed alongside regulatory document data. This section will describe the theoretical underpinnings of the research methods used, the participant recruitment procedure, data collection and analysis.

4.1.1 Theoretical underpinnings

Grounded theory is an approach which uses inductive reasoning to generate conceptual categories from (usually) qualitative data, and then develop theories based on evidence collected. The grounded theory approach was pioneered by Glaser and Strauss and published in their 1967 work, *The Discovery of Grounded Theory*.

For the purposes of this thesis, I used a Straussian approach towards grounded theory research (Glaser et al., 1967). The assumption was that the different stages of the research, data acquisition, analysis and theory development, were not separate but were repeated until the evidence gathered was explainable and new data did not change the emerging theory(s), a point termed *theoretical saturation* (Glaser et al., 1967). Reaching theoretical saturation required systematically analyzing data as it was acquired and generating and testing hypotheses as more data was added to the analysis. Eventually some theories were dismissed while others become more explanative of the evidence gathered. Grounded theory methods were used to analyze participants' perceptions and experiences, and the results from the analysis were further validated triangulation; namely, using data from regulatory and policy documents.

4.1.2 Data collection: interviews

The interviews utilized a semi-structured format. A common set of questions were used for the interviews, but each interview was allowed to develop according to information addressed and uncovered. Each interview was recorded and transcribed into textual documents.

Key informants were initially identified through interviews with a preliminary contact at CalTrans, and additional participants were recruited using a snowball sampling format, which is sampling technique that identifies potential participants from interviewee’s social networks (Goodman, 1961). Potential participants were invited to participate in the study by e-mail and/or by phone calls. Participants were selected based on their experience working with coastal wetland projects. They had experience planning, preparing or analyzing potential wetland mitigation permits and projects. Participants included: regulators from government entities, planning consultants, scientists, and employees of NGOs (Table 9). Out of 21 people invited to participate in the research, 14 agreed and seven declined due to time conflicts. Two of the potential participants who agreed to be interviewed were unable to participate due to scheduling or other conflicts. 12 participants were interviewed for between ½ and two hours each.

Table 9: Participant affiliation

Participant Number	**Affiliation**
1	CalTrans
2	Redwood Community Action Agency
3	Coastal Commission
4	City of Arcata
5	City of Eureka
6	Regional Water Quality Control Board
7	Coastal Conservancy
8	Humboldt Bay Initiative
9	Real estate developer
10	Trinity Associates
11	Army Corps of Engineers
12	Pacific Coast Fish, Wildlife and Wetlands Restoration Association

4.1.3 Data collection: document analysis

Document analysis consisted of collecting and reading legislative documents, journal articles, government agency publications and newspaper articles that pertained to wetland policies and regulations. Documents were used as both preliminary background data sources that helped to develop research questions and guide the interviews, and later to verify and substantiate interviewees' claims. Documents assessed included: the California Coastal Act, Federal Clean Water Act and updates, Porter-Cologne Water Quality Control Act, California Environmental Quality Act and California Department of Fish and Wildlife documents. Minutes from the Humboldt Bay Watershed Advisory Council proceedings, and various project plans, permit documents and press releases.

4.1.4 Analysis: coding

Grounded theory methodology entails using codes to organize and analyze interview data. Open coding, also known as free coding, consists of applying codes to words, phrases or paragraphs to create a list of themes, topics and concepts that will inform subsequent analysis. Open coding occurred throughout the data collection process and incorporated in vivo coding as part of the process, using actual quotes as codes. Open coding generated a large number of codes, many of which were merged as the analysis progressed (Strauss and Corbin, 1998).

Focused coding was the next step in the process. Focused codes were applied to larger sections of text and were derived from the open codes, however only the most relevant open codes which had the most explanatory power were kept. Keeping only the most relevant open codes had the effect of focusing the scope of the analysis. Emergent themes helped to direct the analysis and identify which codes were more valuable.

The third coding step was axial coding, axial coding was used to structure and describe existing categories. It involved creating links between sub-categories, categories and open and focused codes. Creating links formed the basis for applying theoretical hierarchies to the data and performing advanced analysis. Categories were evaluated by their value in explaining observed/experienced phenomena. Categories with higher weight were considered core categories, and a web of relationships between categories, sub-categories and codes was constructed (Table 10).

Qualitative text analysis methods were used with regulatory and policy documents in order to 1) triangulate interview data, 2) gather background information to craft interview questions. The document data was analyzed using similar methodology as for the interview data, except that categories and themes generated from the interview data were used as the framework for evaluating document data.

Table 10: Examples of Coding Hierarchy[1]

Open/In Vivo Codes – 168 Total (Sample)	**Focused Codes – 29 Total (Sample)**	**Axial Codes – 5 Total (All)**
Regulatory agencies are worried about litigation.	Risk Aversion in regulatory agencies and regulators. Regional Planning	Project Failure/Success No Net Loss Effectiveness
Community should use Corps wetland definition.	Regulatory Adaptability	Risk Aversion/Litigation Concerns
Regulations are adequate.	Permitting Cost	Solutions to Permitting Issues
Restoring tidelands is expensive.	Adaptability to Sea Level Rise	
Some agency staff are easier to work with than others.		

4.2 Qualitative Research Results: How Wetland Projects Are Affected by Regulation and Policy

Wetland project permitting is expensive and time consuming, and this section explains why. In light of predicted wetland loss as a result of sea level rise, it is important that wetland projects are successfully implemented to maintain the current amount of wetlands; therefore there is a need for permitting processes to be time and cost efficient.

[1] Sample indicates that only a portion of all codes are shown while All means that all the codes are shown in the table.

What I have identified is that risk aversion to litigation and project failure (failure to create/restore/enhance functional wetlands) in regulatory agencies is the primary cause of increased cost and increased timelines for wetland projects. This section begins with an explanation of agency risk aversion, followed by a description of the wetland policy structure and how it affects the net loss of wetlands in the long term as the sea level rises.

4.2.1 Risk aversion in permitting

Interviews exposed a high level of risk aversion among regulatory agencies and regulators, driven by concerns about litigation and concerns that permitted projects may fail to result in functioning, high quality wetlands. Risk aversion can lead to inflexibility in permitting and expensive, rigorous requirements for project permit and design approval, causing projects to fail to be completed. Interview data also identified that different regulatory agencies showed different levels of risk aversion (Figure 13). Participant opinions of what constituted a failed project ranged from projects that never got off the ground to projects that failed to meet their success criteria or were only able to achieve a portion of their objectives. Project proponents and developers were more concerned about a project being successfully completed within the projects budget (but also being successful in terms of resulting in functional wetland), while regulators were more concerned about a project meeting permit requirements and performance criteria.

The main drivers of project failure in Humboldt Bay have been difficulty in obtaining permits in a timely manner and permitting costs. These drivers are described by participants as being directly related to the underlying issue of risk aversion among agency staff. In describing regulators risk aversion, one participant said “[Regulatory agencies] won't tell you what they want… they want to reserve the right to critique it and to cite you if it doesn't come out the way they want it” (Interview, [Redwood Community Action Agency]).

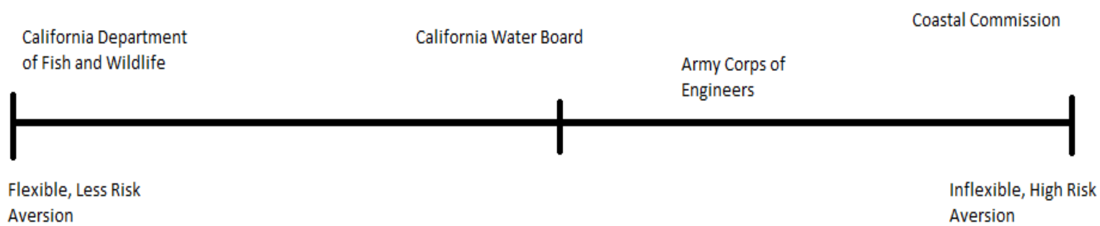


Figure 14: Conceptual scale of risk aversion and flexibility in permitting by agency (Personal interviews, 2015)

The quote points to two critiques. The first is that the participant has experienced a lack of clear expectations from regulators, and the second is that regulators are hesitant to make decisions without the ability to change their minds. It appeared that the more concerned an agency was about being sued for the decisions it makes, the more averse they were to making risky decisions that deviated from precedent. In interviews, it appeared that the Coastal Commission was the agency most concerned about litigation.

One participant describes the Coastal Commission's risk averseness, "They [Coastal Commission] have been sued so many times that they have many court opinions that say this is how you interpret what a wetland is and this is what you can ask for as mitigation and monitoring" (Interview, [Trinity Associates]). Any decision they make that deviates from precedent could leave them open to litigation from an entity affected by their earlier decisions. The Coastal Commission also operates under strict language in the California Coastal Act, for example,

> Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas (California Coastal Act, 2014).

This example of the language in the Coastal Act demonstrates that the Act limits any impact (even beneficial) to environmentally sensitive habitat unless the use is "dependent" on the coastal area.

Interviewees described the State Water Resources Control Board as varying in how risk adverse it can be. It could be very strict about adhering to its guidelines in some situations, while allowing moderate flexibility in others. The Board regulators could be subjective in how they apply their policies, and that could lead to decisions that vary by situation, illustrated here by a Water Board employee:

> I recall vividly a situation, a postage stamp [small wetland] issue, where CalTrans was going to be filling a wetland. Their designers said "Well we can actually recreate that wetland and the hydrology and we can move it over here." I thought fine, in the context with this isolated wetland it

> seemed to be ok for that to be made that way… They ended up not doing it, because the engineer at CalTrans didn't want to have the responsibility in case that wetland resulted in a failure of the roadway. He instead said, “I would prefer it if we could find a mitigation somewhere else.” We then agreed… to find some mitigation funds and apply that to projects through the Mendocino County RCD (Resource Conservation District) who had some shovel ready projects along the Navarro River. (There was) Some riparian planting, invasive species removal and other activities. That was an interesting example of cooperation, policy and how liability affects decision making. (Interview, [California Water Board])

The California Department of Fish and Wildlife (CDFW) was described by multiple interviewees as the most flexible in applying regulations of the four regulatory bodies most involved in coastal wetland mitigation in around Humboldt Bay. Their mandate is to protect endangered species and their habitat, and they have the ability to balance impacts based on how it may help other species. An example was the Salt River Restoration project near Ferndale, wherein CDFW allowed destruction of riparian forest (a protected habitat type) in order to restore the river for salmonid and other aquatic species habitat. A participant involved in funding the project describes the conflict,

> To do the restoration project we have to remove this riparian forest along the channel. There was going to be a temporal lag before we replanted the riparian plants. It was this freshwater marsh that we were going to turn back into tidal salt marsh, and it was still providing habitat for animals and waterfowl (as freshwater marsh) …. Because there were willow and birds nesting there, but there is no river anymore, you are worried about our impacts to riparian habitat that has no river, how is that really riparian habitat? (Interview, [Coastal Conservancy])

The CDFW has a commitment through its Lake and Streambed Alteration Program to protect waterbodies, including riparian areas adjacent to rivers and streams, and they coordinate with California State Water Resources Control Board to apply their Wetland and Riparian Area Protection Policy (Resolution No. 2008-0026; Fish and Game Code Section 1602). At the same time, they also have an obligation to uphold the Endangered Species Act, and this project would improve habitat for state and federally listed species. Through discussion with the project proponents and other regulatory agencies, CDFW was able to balance multiple policies of protecting riparian habitat and restoring watersheds for listed species, and find a solution that was acceptable for all parties.

4.2.2 Biological complexity

The Army Corps of Engineers is moderately risk averse (Figure 13) but in a somewhat distinct way; it is mostly concerned about the longevity and feasibility of projects. The Army Corps is a branch of the Army concerned with the construction of civil works for military and water resource purposes. They approach projects from an engineering standpoint and use their powers under Section 404 of the Clean Water Act to regulate dredge and fill activities in waters of the state. Dredging is the removal of soil, weeds or rubbish from the bed of a body of water, fill is the placement of any material in waters of the United States. The Corps' main concern regarding wetland projects is project longevity and how the project could affect waters of the state.

An example is a *Spartina Densiflora* (invasive species) removal project in South Humboldt Bay that was allowed through the planning process, but was ultimately canceled because it couldn't be guaranteed that the *Spartina* would not come back in 50 years. This specific example is of a project that was wholly under Army Corps jurisdiction, and illustrates how the Army Corps had trouble working with a wetland project that was more ecologically complex than a simple infrastructure project. A participant gave an example of an Army Corps project that never got completed,

> We got $300,000 from Army Corps to eradicate dwarf eelgrass. Ultimately we couldn't meet the conditions that AC requires… we couldn't guarantee maintenance after the life of the project that there wouldn't be this species for 50 years, it never got approved (Interview, [RCAA]).

The participant goes on to say how, "Invasive species are dynamic, we couldn't say that in 50 years there wouldn't be any dwarf eelgrass in Humboldt Bay. There is a difference between infrastructure and a dynamic biological system."

4.2.3 Effects of risk aversion: increased costs and delays

Up front mitigation permitting costs were described as expensive enough to prevent a project from being viable. Expressing a viewpoint common among participants, a project manager with the Redwood Community Action Agency explained planning cost expenses:

> Planning costs have increased to the point where the construction costs are eclipsed by the CEQA and permitting/planning costs… We pay for regulator's time as part of projects, fees associated with their time. The very people who give us grants take 15-20% off the top for their time. (Interview, [RCAA])

Similarly, a local planner said that

> An unsuccessful [project] would be one that spends a lot of money on engineering and permitting and does not get what they want… We spend more money now on permitting and design then we ever spent on an entire project when we started doing this work in the 1980s-90s. (Interview, [Trinity Associates])

Regulatory agencies' concern about guaranteeing project success can result in requirements of expensive, lengthy studies for approval of permits. An interviewee explained how planners are required to, "Use the best possible science to study everything about a project, whether it really fits the scope of a project or not, in order to protect the government agencies that are permitting or funding a project against litigation" (Interview, [RCAA]).

There is overlap between permit costs and obtaining permits in a timely manner. Expensive, long-term studies required for permit approval may take years to complete and may cause a project to never be constructed. When describing a project that failed because it was never completed, a participant explained,

> [We were] Moving toward construction level planning, [we had] delays because questions being asked were $100k questions that needed to be answered. Questions [that] were not budgeted for. It took so long that the

> land was sold, converted from cattle ranching to organic farming (Interview, [RCAA]).

This is an example of how a regulatory agency was cautious to take a risk on approving a project without requiring an expensive, long term study to remove any doubt that the project was feasible. According to the participant, the study was not necessary,

> [We had to] Study to see how long until off-channel ponds would fill with sediment…[which was a] 2 year delay to project. We modeled with rebar techniques, [which showed] about .5” a year. That wasn’t good enough, we had to do advanced computer modelling. Remote sensors with 24 hour information results. [Gave us the same results], about .5” a year. That was one situation that added time and money, ended up costing us time that ultimately lost us the project.

When asked if the standards regulatory agencies set for permit requirements are higher than they used to be, one local planner and project manager at the Pacific Coast Fish, Wildlife and Wetlands Restoration Association (PCFWWRA) responded,

> It used to be like "yeah, get a streambed alteration agreement and go for it." Now something as simple as putting woody debris structures in a stream has gotten overcomplicated…this is putting trees in a creek, it is an actual process that occurs.(Interview, [PCFWWRA])

Participants described how regulators showed an active interest in wetland projects and wanted them to succeed, most participants thought regulators sincerely wanted to be part of the restoration and wetland protection process. It is not that regulators want to make it difficult or expensive for wetland work to be performed; in fact it is quite the opposite. However, there are political and legal forces that act on regulators and encourage risk averse decision making that generates confidence in projects' designs and goals at the cost of time and money. Risk aversion may be

4.3 Wetland policies: wetland definitions and meeting No Net Loss

Wetland policies have inconsistencies between various regulatory agencies, shaped by the unique goals of the agencies. Even at the basic level of defining wetlands, there is no consistent definition agreed upon by regulatory agencies (Table 10).

The Coastal Commission has the broadest approach to defining wetlands, with only one wetland parameter (wetland vegetation, wetland hydrology or wetland soils) required for an area to be considered a wetland (CA Pub Res Code §30121). Using their definition, the Coastal Commission has a lot of leeway in determining what they consider a wetland. By comparison, the U.S. Army Corps has a strict three parameter approach, and a wetland must have wetland hydrology, vegetation and soil to be considered a wetland (Table 11). Around Humboldt Bay, Army Corps wetlands are almost always a subset of Coastal Commission wetlands, and it may be difficult to fully determine which regulatory agencies have jurisdictional authority.

Table 11: Wetland definitions

Defining Body	Definition of "Wetland"
United States Army Corps of Engineers	Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (US ACOE, 1987).
United States Fish and Wildlife Service	Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin, et al. 1979).
California State Water Board	• An area that is covered by shallow water or where the surface soil is saturated, either year round or during periods of the year; • Where that water coverage has caused a lack of oxygen in the surface soil; • And has either no vegetation or plants of a type that have adapted to shallow water or saturated soil. Some examples are fresh water marshes, bogs, riparian areas, vernal pools, coastal mud flats and salt marshes (California State Water Board, 2012).
Coastal Commission	Lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens (Coastal Commission, 2011).

Conflicting wetland definitions add complexity to the regulatory process. One city planner described working with regulatory agencies to delineate wetlands,

> I think that you need one scientific definition of a wetland that everybody recognizes… I think it makes it extremely confusing for an applicant to know if they have a wetland. If you are dealing with the corps you know if you have a wetland. If you are dealing with the coastal commission you don't know if you have a wetland. It is confusing and it is inefficient and patently wrong. Wetlands should be based in science. How you regulate the wetlands should be agency specific. But the wetlands definition itself I think should be universal across state and federal agency (Interview, [City of Eureka Planner]).

Navigating the complex regulatory requirements of different regulatory agencies increases the amount of planning necessary, which also increases the costs and timeline of projects. The California No Net Loss policy does call for the development of a consistent statewide wetland definition for state agencies, but that has never come to fruition, nor have California agencies' definitions been adapted to a consistent national definition (California Executive Order W-59-93).

4.3.1 Scientific uncertainty in meeting No Net Loss

Within Humboldt Bay, actual acreage loss of wetlands due to development is being mitigated. However, many participants stated that loss of wetland *function* is still occurring, and the failure of projects to achieve their success goals is a contributor to continued wetland loss. One problem may be a discrepancy between state and federal No Net Loss policies, as noted by one interviewee:

> It (Federal No Net Loss Policy) started off as No Net Loss of wetlands (acres), but has been reinterpreted to be no net loss of function or value. The state No Net Loss order is still acreage. They can't account for function or value to compensate for loss (Interview, [CalTrans]).

Six of the participants stated that there was a lack of clarity in the state's No Net Loss policy, and that the policy should include more direction on including beneficial wetland functions (as described in Table 1) as part of California's No Net Loss policy. The federal and California No Net Loss policies specify quantity and quality of wetlands as metrics for measuring loss (Executive Order W-59-93). There is little data in the literature that describes how function is accounted for in these policies. Function in wetlands is generally measured by: diversity of species, storage of water, nutrients, growth of living matter, carbon sequestration, ability to remove pollutants or habitat quality, to name a few (Novitzki, et al., 1996). However, anecdotal evidence describes a shift towards functional assessment as the standard for wetland impacts (Turner et al., 2001).

Regulatory agencies attempt to resolve a lack of functional evaluation metrics by requiring high impact to mitigation ratios, for example, one acre of impact would require three acres of mitigation. The theory behind high mitigation ratios is that if one acre of high quality wetland is destroyed, and three acres of low quality wetland are created, the function will be mitigated, but as discussed in Section 2.1 Critical Analysis of the No Net Loss Policy requiring high mitigation ratios is not always a successful strategy.

4.3.2 Short term impacts for long term gains

Participants said that the No Net Loss policy did not sufficiently provide for long-term wetland conservation and mitigation because it is focused on current impacts. In addition, it did not allow for current impacts to be mitigated with long term wetland projects, such as preparing or preserving land to become salt marsh in 50 years as sea levels rise. Explained a participant,

> If you want to save 100 acres of wetland over here, you are going to have to fill it so it stays high enough or you will have to dike it to protect it. One way or another something has to happen. Maybe you can fill it as enhancement, but if you had to mitigate for that? If you had 50 acres you wanted to fill so it wouldn't turn into mudflat, will you have to mitigate for that (Interview, [City of Arcata Planner])?

Wetland projects within the coastal zone can be complicated, and the interviewee is identifying two key issues. The first is that in order to conserve, create or enhance salt marsh for future sea level rise levels, existing wetlands would need to be filled, and that is not generally an allowable reason for wetland fill under the Coastal Act. The second is that when a wetland *is* filled in the coastal zone, that impact is required to be mitigated for, even if the goal of the project is wetland creation, restoration or enhancement (CA

Pub Res Code §30121). The Coastal Act does not differentiate between the filling of wetlands for environmentally beneficial purposes (ie. wetland enhancement, wetland restoration or wetland conservation) and the filling of wetlands for industrial, commercial or residential purposes (CA Pub Res Code §30121).

One project developer, the City of Arcata, emphasized that divergent project timelines are utilized by regulatory agencies. For them, the most troubling issue is getting permission to place fill in the bay and impact existing wetlands in order to prepare for sea level rise. A city employee said,

> I don't know how well regulatory agencies can take a long term view, and how long term of a view they will take, because I think the challenge is if they let us take the long term view and let us say we need to fill this and fill it now so in 50 years it can be tidal wetland, then they are actually not meeting the No Net Loss policy today. So I think it is really a pretty huge conundrum (Interview, [City of Arcata Planner]).

The City of Arcata desires to impact wetlands now in order to have wetlands in the future as the sea level rises, as well as to protect existing infrastructure. The regulatory agencies cannot allow a wetland to be impacted now without requiring immediate mitigation, or they are not meeting the requirements of No Net Loss, both federal and state policies.

Requiring mitigation for wetland impacts caused while constructing another wetland project can make beneficial wetland projects more expensive and cost prohibitive than development projects. In order to restore a former tideland that is now freshwater wetland/pasture land, the project would have to restore the site and then create, restore, enhance or preserve freshwater wetland/pasture somewhere else to mitigate the impacts from restoring the tideland, essentially two separate projects. A wetland filled for an industrial, commercial or residential purpose is required to mitigate only the impacts incidental to the development.

4.3.3 Adapting policies for sea level rise

Sea level rise poses the greatest potential threat to coastal wetlands in Humboldt Bay, but there is no comprehensive plan or policy which provides guidance on how to protect these resources from the threat. However, regulators are working to incorporate sea level rise planning into their regulatory policies. Most participants indicated that they thought current policies were not adequately addressing sea level rise. Several participants indicated that sea level rise adaptation planning was a very new science, and so projects and policies had not yet responded to new information. A Caltrans employee described incorporation of sea level rise into policies:

> It has recently become a part of planning, and it is what is considered cutting edge. You know everybody has been denying it. The Coastal Commission has been the first agency to ask us to prepare analysis of sea level rise for projects (Interview, [CalTrans]).

The employee then described how the Coastal Commission only requested sea level rise planning for infrastructure projects, and that restoration projects were not being required to include sea level rise adaptation into their design, “these are infrastructure projects we are talking about. They are the first to ask it.”

The Coastal Commission does have a Draft Sea Level Rise Policy Guidance document available, but it is primarily focused on protecting development, guiding Local Coastal Programs in drafting new development protocols and the science behind sea level rise. It does provide some guidance to Local Coastal Programs when it advises them to “reserve space for a ‘habitat migration corridor’ or areas into which wetlands and other habitats could migrate as sea level rise induced inundation of existing wetland areas occurs” (California Coastal Commission, 2015). It does not address mitigation and permitting requirements, or scales of mitigation. The integration of sea level rise planning into the Coastal Commissions regulatory requirements appears to be focused more on infrastructure development projects than protecting natural resources.

Other participants explained that the actual levels of sea level rise were difficult to quantify and as such were difficult to regulate or form policy around. When asked if current projects take into account sea level rise, a project manager at the Redwood Community Action Agency stated that, “I would say that none of the projects are. I don’t know a single project that is adequately preparing for that, not that they aren’t thinking about that, but because it is unknown” (Interview, [RCAA]). Uncertainty appears to play a large role in regulatory policy and permitting decisions. Uncertainty about the amount of potential sea level rise, coupled with risk aversion, makes it difficult to develop policies that are adaptive.

But there are also examples of projects that are incorporating sea level rise into their design. For example, the City of Arcata's living shoreline project to protect their wastewater treatment facility is designed to allow salt marsh to move uphill as the sea level rises. The common theme among participants is that they identify a lack of sea level rise planning being incorporated into regulatory agencies' policies and regulations as they pertain to coastal wetlands. All participants stated a concern that sea level rise may be occurring too quickly for planners to adapt to it, and policies are slow to change while sea level rise could be a rapid transition.

5.0 CHAPTER FIVE: DISCUSSION

5.1 Salt Marsh Migration Potential

This study sought to quantify the potential for salt marsh migration under sea level rise scenarios of one and two meters. The model created for this study predicted that salt marsh could be lost as the sea level rises, if it is unable to migrate inland. The model was developed in order to quantify and visualize the migration and potential loss of salt marsh, but also to contribute to sea level rise planning and decision-making. The maps created from the model may be used to help planners identify areas suitable for salt marsh restoration, creation or enhancements projects. The results may also be used by planners, natural resource managers, and wetland mitigation project developers to support converting freshwater wetlands to salt marsh by showing the potential migration of salt marsh to inland areas. The results show that salt marsh will be lost with sea level rise, and the data will lend support to projects that seek to address salt marsh loss with proactive projects.

The results of the model suggest that suitable salt marsh habitat may decrease from as much as 1400 acres currently to about 700 acres, and this is a conservative estimate. This is not the actual amount of salt marsh that could be lost, only an estimation of the acreage that may be able to support salt marsh under the two sea level rise scenarios. The model suggests that suitable areas for salt marsh will migrate inland from the bay, into freshwater pasture lands and against the toe slopes of the coastal hills.

In reality, much of the land behind the dikes may not be available for salt marsh because the land has subsided since it was disconnected from the tidal prism and may be too low an elevation to support salt marsh if simply reconnected to the tidal prism. If land owners receive funding and permits to raise and armor levees above future sea levels, there is the potential for much of the area with high potential to never become connected to the tidal prism. If the model is accurate and, at a minimum, half of the salt marsh in Humboldt Bay is lost, that is a significant loss of coastal wetland and would be a serious impact to the regional coastal ecosystem and the services it provides. The bay could lose bird, fish and amphibian habitat, storm surge protection, pollution removal services, carbon sequestration, biodiversity and economic benefits related to the crab, oyster and salmon industries (Reed, 1990; Novitzki et al., 1996).

The model did not successfully weight tidal connectivity appropriately. Tidal connectivity could have been weighted higher as a more important independent variable, and areas disconnected from the tidal prism should have been excluded as potential habitat. If this had occurred, the prediction from the model would show much less land being suitable for salt marsh. Additional constraints from environmental factors not accounted for in the model may severely affect salt marshes' ability to migrate to new locations. Areas forecasted to be higher relative probability locations with 1 meter and 2 meters of sea level rise may not be as likely as MaxEnt suggests. Much of the land in the 1 meter and 2 meter predictions is behind levees or dikes, and some of the area is on developed or impermeable surfaces. These areas would almost surely not be tidal salt marsh in the future, and the model may need to be improved in order to capture this.

Another limitation of the model is the inability to incorporate temporal factors. If a previously diked off pasture is exposed to the tidal prism and is suitable for salt marsh, it may take upwards of 10-50 years for salt marsh vegetation and wetland characteristics to actually develop. Sea level rise may occur more slowly or rapidly than is forecasted, and the speed at which the sea level rises will play a major role in determining how quickly areas may convert from pasture land and freshwater marsh to salt marsh.

The major source of uncertainty that I identified in this model was accuracy of elevation data. The base accuracy of the original elevation models was high, they are a mixture of LiDar (Light Detection) and monobeam echosounder (for the bathymetry). But the elevation datasets were down sampled from a one meter resolution to a 10 meter resolution. This increased the standard deviation the datasets as the range of values in each cell increased. I think the dataset is still accurate enough, especially since the most suitable range for salt marsh is on flatter slopes where elevation values do not change drastically over small distances. Where this may be of more concern is in the 2 meter sea level rise prediction along the toe slopes of hills.

For future salt marsh migration models, there are a few improvements that I would recommend. A detailed soil layer would help to prevent dune areasbeing identified as potential salt marsh habitat. It would improve the model to increase recognition of lands not connected to the tidal prism as being unsuitable for salt marsh. Improving the tidal connectivity layer would go hand in hand with improving the shoreline dataset to better capture the heights of shoreline infrastructure. Finally, levee and dike failure is a phenomenon which is difficult to predict, but it would be interesting to manipulate the tidal connectivity layer to represent breaches and levee failures to see if that improved the acreage of suitable habitat in some areas.

The model and its outputs may be a useful tool for planners, natural resource managers, and wetland mitigation project developers looking at long-term solutions to salt marsh habitat conservation. The projected output layers are not trying to imply that those are the only areas where salt marsh could exist, and the raising of former tidelands with soil would definitely create more potential salt marsh habitat. These results should be used as a reference to planners to visualize the potential future conditions and help them to think critically when attempting to identify where to preserve or improve tidal salt marsh in Humboldt Bay.

5.2 Improving Wetland Project Success and Rates

This project also examines the difficulties in planning and executing wetland projects around Humboldt Bay, in light of the need for functional wetlands and anticipated sea level rise. As demonstrated in the previous sections, wetlands are a valuable and necessary resource that have been impacted and destroyed by humans, but are now theoretically protected from human development through national and state policies. However, there are concerns about the effectiveness of national and state policies and how adequately they are protecting wetlands from natural impacts. The most serious threat to tidal wetlands in Humboldt Bay now is from natural sources, primarily sea level rise because it will drown the existing salt marsh as the levees and dikes stop the salt marsh from moving inland into the agricultural land.

In Section 2 I modeled and described the potential for salt marsh to migrate inland as the sea level rises. In order to stay a step ahead of sea level rise and maintain or improve our wetland resources, we will need to proactively conserve, preserve, create, restore and enhance wetlands. But these activities are not easily accomplished and are not without their difficulties. I will discuss solutions to how risk aversion may be addressed in order to reduce the economic and temporal costs inherent in wetland projects, and how the problems recognized within the No Net Loss policy could be resolved in order to maintain coastal wetlands as the sea level rises.

5.2.1 Risk aversion

This section of the study sought to identify the causes of difficulty in permitting and planning projects, specifically issues that make projects expensive and increase the length of time they take to complete. By identifying what causes wetland projects to be expensive and take long periods of time to complete, it will be possible to create a roadmap for addressing these issues ahead of the projected sea level rise and wetland loss. I will discuss how we can reduce risk, and thereby economic and temporal costs, in four subsections; technological advancements, beneficial wetland projects versus development projects, how policy could better incorporate short and long-term goals, and how to adapt No Net Loss to sea level rise.

This research demonstrated significant risk aversion. From the interviews it was identified that risk aversion led to strict and expensive permitting requirements in order for permits to be approved. Risk aversion appeared to be both systemic, in that law and policy require regulatory agencies and regulators to be cautious about the projects they approve, and agent based, in that the strictness of permit requirements may fluctuate based on who is making the decisions.

Technology and Risk

With better wetland mitigation technology and expanding scientific knowledge, there is the potential for projects to be designed more accurately than in the past. In some cases this involves incorporating hydrogeomorphologic models and sediment transport modeling, which can improve the quality and results of a project. There are also cases like the example of the off-channel pond project, where a simple solution to a question exists, and a high-tech expensive study may be unnecessary. New technology and technical knowledge allow regulators to set higher standards for projects, which could backfire in the case that expectations of proponents become burdensome.

The use of technologically intense modelling can be problematic for wetland projects, as shown in the example of section 4.2.2 about an off-channel pond. An expensive, time consuming modeling technique was required when a cheaper solution existed. Wherever possible, the cheaper alternative should be required for beneficial wetland project permitting, provided the cheaper alternative is sufficient in meeting regulators’ requirements. When less funding is spent on designing and permitting projects, leftover funding can be directed towards actual construction costs and a greater number of wetland projects.

Another example is that of the ACOE cancelling a project during the planning stage, because the project designers could not guarantee their 50 year timeline would be 100% successful. With all of the technology and technical knowledge at their disposal, none of it could guarantee that if invasive species were removed, they would not return in the 50 year project time frame. This is a failure of interpreting information from technologically savvy analysis, which provides insight into how the ACOE approached this project. Rather than approaching the project from a biological standpoint, the ACOE approached it from an infrastructure engineering standpoint, which required a very long-term certainty of project success. Wetland projects have uncertainty built into them, they are natural systems and even with the most modern modelling and engineering techniques, they can never be guaranteed to succeed. Regulatory agencies should be open to allowing adaptive management of projects to occur, and identify how a more flexible method of permitting may be incorporated into existing policies and regulations.

Beneficial Wetland Projects versus Development Projects

Under current policies, impacts to wetlands during the course of beneficial wetland projects are treated the same as impacts to wetlands during the course of commercial development. This is a double standard that fails to take into account the intent of policies such as No Net Loss and the Coastal Commission's coastal dependent development clause to prioritize environmental protection. Wetland projects that have the inherent intent of restoring, creating or enhancing wetlands could be treated differently than wetland mitigation projects that are required because of incidental impacts to wetlands during other construction.

There are two ways this could be promoted, through updates to agencies' policies that explicitly allow for different treatment of different types of wetland projects and through the creation of permits specifically for beneficial wetland projects separate from current permitting requirements. For the Coastal Commission, this could require an amendment to the actual Coastal Act, to allow a beneficial wetland project to impact a wetland in order to create, restore or enhance a larger amount of wetland without requiring mitigation for the short-term impact as it does currently. Using the Public Trust Doctrine, a judge could decide that having separate requirements for beneficial projects versus commercial projects is legal and allow precedent to be set.

The second method for reducing requirements for beneficial projects is greater use of programmatic permits, and was supported by a majority of the participants. Programmatic permits allow for a broad number of projects to be permitted with standardized and more streamlined requirements. An example of programmatic permits is the nationwide permit issued by the ACOE under section 404 of the CWA. These are 49 different general nationwide permits that allow a wide range of activities while requiring standardized information. Similarly, the San Francisco Bay Area has a permit called the Joint Aquatic Resources Permit Application (JARPA). This is a comprehensive permit for clean water certification that consolidates federal, state and local permits for construction and fill activities in aquatic environments. It reduces the time it takes for the permits to be processed and reduces paperwork as well as fostering coordination among agencies.

One for the Humboldt Bay area would be a combination of the ACOE's nationwide permits and the San Francisco Bay JARPA. Regional permits for Humboldt Bay could be designed that allow certain activities to have associated streamlined permits that also consolidate the requirements of regulatory agencies. An example would be a programmatic permit for installing woody debris in a water body. The permit would be designed specifically for this activity, the requirements would be stated explicitly and directly, and the permit would have space for the requirements each agency has for project description, design and monitoring. It would reduce uncertainty on the planning and design side, and improve communication and cooperation between regulatory agencies as they would all be receiving the same information. In the long term this could save time and money for wetland project permitting and design (Riggs, 2015).

Short Term Impacts for Long Term Gains

While scientists have confirmed that climate change is occurring, this knowledge is only useful if we can adapt our policies and regulations to respond and prepare for future impacts, including sea level rise. What emerged as a major theme is the difficulty current policies have of allowing impacts to existing wetlands in order to promote the existence of coastal wetlands as the sea level rises.

However, the Coastal Commission could adapt wetland impact mitigation requirements to be more flexible in terms of allowing impacts to occur in the present with the intent of providing for the existence of wetlands in the future as the sea level rises. Currently policy requires immediate mitigation of any impact to a wetland, which has the effect of requiring two wetland projects: one to prepare areas for future wetlands, and one to mitigate for that project by creating, restoring or enhancing wetlands in the present. This puts undue burden on beneficial projects addressing sea level rise by also requiring projects to have an immediate result. Explicit attention by regulating agencies to the two timelines (short- and long-term impacts of projects) could highlight this issue, and policies may then be adapted that would address the two timelines separately.

No Net Loss Policy

It has been shown that No Net Loss is a failed policy both through academic studies and interviews with participants in Humboldt Bay. No Net Loss was considered a failure partially because function was not incorporated into mitigation requirements, impacts were mitigated on an acreage basis. Cole (1998) and Zedler (1996) identified that if you replaced an acre of natural wetland with an acre of created wetland, the created wetland would not be as high quality of the impacted wetland. The result was that wetlands would be destroyed and a similar acreage created or restored, but the overall function would decrease. Poor enforcement of mitigation requirements also resulted in projects required as mitigation to never be completed. Sudol (1996) and Johnson et al. (2000) also found that follow-up on wetland mitigation was lax, that there was a period in the 1980s and 1990s when mitigation monitoring was rarely completed. This was then remedied by requiring higher mitigation ratios, replacing one acre of impacted wetland with 2-5 acres of mitigation wetland.

Currently the Federal No Net Loss policy incorporates function as well as acreage into mitigation requirements for impacts to wetlands. Unfortunately, this only applies when wetlands fall under the jurisdiction of federal agencies. The California No Net Loss policy has yet to include function as a metric for measuring wetland loss and replacement. Including function as a metric would be an important step in standardizing the state policy to the federal policy, incorporating wetland function as a metric for measuring loss.

The premise of this study has been that making wetlands projects cheaper and faster would result in a greater number of wetland projects and an overall increase in wetland acreage, although in the case of salt marsh it may be simply maintaining the amount that currently exists. However, there is a split between cheap, fast projects and projects that incorporate functional monitoring to ensure functional wetlands. Including functional performance metrics into all wetland projects could be an expensive proposition, but that is not necessarily the case. In California, there is a relatively cheap functional assessment method called the California Rapid Assessment Method (CRAM), which is being developed and adopted by the State Water Board, but has not been incorporated into all state permitting requirements. CRAM facilitates rapid functional assessments of wetland sites based on landscape and species diversity, and could be used to provide basic functional values at a relatively cheap cost (Collins et al., 2006). Functional assessment of wetlands does not need to adversely effect the cost of project monitoring, and can be incorporated relatively cheaply (Sutula et al., 2009).

Pertaining specifically to Humboldt Bay, I also identified the concern that policy was focused on current impacts and had difficulty balancing current impacts with future benefits. In order to conserve salt marsh for future sea level rise conditions, current freshwater wetlands must be impacted. The solution suggested by participants is that a comprehensive coastal wetland plan could be developed by regulatory agencies in order to facilitate conversation about how to prioritize wetland projects and manage wetlands adaptively with sea level rise and potential salt marsh loss. A comprehensive plan to address wetland loss has also been identified in a number of other studies as a strategy to prevent wetland loss due to sea level rise (BCDC, 2008; Johnson, 2000).

Incorporating Sea Level Rise into Wetland Policies

As shown in the salt marsh migration model, sea level rise could result in a major impact on coastal wetlands that have already experienced centuries of anthropologic impacts. Delaying sea level rise adaptation incorporation into regulations and policies may be harmful in the long-term. Sea level rise is occurring, and the average sea level rise predicted by a number of studies through 2100 is approximately 1 meter (Parris et al., 2012). Participants in this study identified sea level rise as a serious concern, and one that was not being adequately incorporated into coastal wetland planning and policy.

The only regulatory agency to begin including sea level rise planning into their policies is the Coastal Commission, and their Draft Sea Level Rise Policy Guidance document has yet to be finalized as of the writing of this thesis. Even in the new document, protecting coastal wetlands takes a backseat to protecting infrastructure (California Coastal Commission, 2015). In the interviews, participants suggested that agencies were having difficulty taking a long-term view with regards to sea level rise and changing climatic conditions, which made it difficult to get approval for projects that sought to be proactive about converting freshwater wetlands to salt marsh ahead of a rising sea level. Being able to respond to changing climatic conditions rapidly through proactive wetland projects is one way in which we may be able to continue to have tidal wetlands as the sea level rises.

The solution in this situation would, again, be to develop a regional sea level rise plan that identifies areas that are more susceptible to sea level rise, and areas that may be suitable to mitigate impacts to coastal wetlands. Rhode Island has been working towards a regional plan to address salt marsh impacts due to sea level rise by hosting gatherings for researchers, restoration practitioners and natural resources managers, and by aggregating research articles into a database to help inform decision-making (West, 2014). A similar method could be used in Humboldt Bay to develop a regional plan, and the model developed during this study could be a useful tool to help inform decision-making. By developing a regional sea level rise plan, agencies, governments and non-governmental organizations could collaborate and agree on where the most vulnerable areas are (the model results), and where mitigation efforts should be focused.

A sea level rise plan would allow resources to be concentrated in high priority areas where they could be utilized to greater effect than if efforts were spread around the bay. Governments already have the tools address sea level rise and wetland protection, if not necessarily the funding. General plan updates, zoning changes and even *eminent domain* may all be necessary to ensure the existence of coastal wetlands as sea levels rise. Furthermore, as sea level rise reduces the profitability of coastal pasture land, landowners may be interested in selling land or obtaining easements for restoration work.

One tool which has not been utilized around Humboldt Bay is the wetland mitigation bank. Wetland mitigation banking has not been as common in California as it has in many other states. The California Coastal Commission allows for the use of mitigation banking within the coastal zone, but demand in the Humboldt Bay region was non-existent (California Coastal Commission, 1994). Wetland mitigation banking could be a useful tool for mitigating coastal wetland loss with sea level rise in Humboldt Bay, it could be used to protect inland areas that could potentially become coastal wetlands as the sea level rises.

Wetland mitigation banking has the potential to allow coastal wetland restoration to occur in anticipation of sea level rise, with the credits generated from the bank used in the future when impacts must occur in order to protect infrastructure. Wetland mitigation banking may be the most forward thinking tool that exists for preparing coastal wetland resources for a higher sea level. In order for wetland mitigation banking to be utilized effectively as a tool for preserving coastal wetlands around Humboldt Bay, policies must be adaptable to alternative wetland protection methods and agencies could experiment with locally unused forms of mitigation.

Giving Incentives to Develop Wetlands

Sea level rise opens up new opportunities for landowners to profit from converting agricultural land to wetlands. If agricultural land loses its value as pasture land due to sea level rise and salt water intrusion, the landowners will have options to sell the land, obtain an easement on it, or develop the land into wetlands. Organizations and entities that will impact wetlands to protect or armor existing infrastructure from sea level rise may need to purchase land to perform restoration and creation mitigation. Local non-profits such as the North Coast Regional Land Trust may be interested in obtaining an easement on land that could become salt marsh with sea level rise in order to move towards providing a protected place for salt marsh to migrate to in the future. Finally the landowner may find it of interest to work with an environmental firm to develop a wetland mitigation bank on their property. They could build salt marsh and obtain credits for the wetlands created, then sell those credits in the future as organizations and entities need to impact salt marsh to protect existing infrastructure.

Success Stories from Other Regions

Humboldt Bay could incorporate the strategies used by other regions to plan for sea level rise. This could include collaborating with non-profit organizations, researchers, city planners, landowners and government agencies to identify where the most vulnerable areas are and where conservation efforts should be concentrated. The difference between the sea level rise adaptation plans discussed in the literature review section (City of Novato, 2015; Johnson, 2000) and Humboldt Bay, is that Humboldt Bay has very limited wetland resources, and there is very little room to experiment with possible treatments. Humboldt Bay already has a good start with its Humboldt Bay Sea Level Rise Adaptation Planning Project. This project has identified vulnerable areas and modeled how sea level rise would impact agricultural lands and public infrastructure. What the current sea level rise planning lacks is an analysis of how the wetlands will be impacted, a gap which the model from this research could fill.

6.0 FUTURE RESEARCH

Preparing and responding to climate change and sea level rise is necessary in order to maintain our coastal resources. With technological advances, there is the potential to model and identify phenomena and prepare a response. What has been identified is that the sea level is rising quickly, and in Humboldt Bay it may rise quickly enough that coastal wetlands are inundated and lost. Fortunately, there is time to mitigate and minimize the effects of sea level rise through conservation and protection of coastal resources.

Reduced functionality and value of agricultural lands close to salt water due to sea level rise may provide opportunities to obtain lands for ecosystem improvements from owners who would otherwise not want to put their properties on the market. This could increase regional wetlands inventories and provide land in the appropriate location for conversion to salt marsh as the sea level rises.

Sea level rise may be occurring quickly, but there is time to change regulations and policies to be more responsive and adaptable to a quickly changing climate. Implementing changes that decrease the costs and timelines of wetland projects, and allow for projects focused on preserving and conserving resources under future sea level rise scenarios is one way we can be proactive about addressing potential resource loss due to climate change. One area that needs greater research is how regional and local policies are influenced by state and federal policies. California is a large state, and a policy that works in southern California may not be applicable in Humboldt Bay. Researching how policies and regulations could be adapted to address regional issues may help Humboldt Bay respond to its unique environmental issues.

To build on this research and encourage some of the changes I described, additional research could be conducted into the legal ramifications and obstacles of implanting sea level rise adaptive policies and regulations. It may be useful to further revise and model the potential impacts to coastal wetlands from sea level rise, but I think that threat is understood, and the pressure is now on the regulatory agencies to come together and create a regional plan to comprehensively address sea level rise.

As sea level rise potentially reduces the value of adjacent pasture land, landowners may find it economically beneficial to sell land or procure an easement for less productive land, but this needs to be researched further. Collaborative planning between agencies and policy changes could take time, as does building wetlands and developing a regional plan to address sea level rise.

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