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硕士学位论文

佛罗里达州应对海平面上升：基于其他沿海州的经验
Sea Level Rise Adaptation in Florida: Using experiences from other Coastal States

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List of Abbreviations

CHNEP	Charlotte Harbor National Estuary Program
CRMC	Coastal Resources Management Council
CSC	Chinese Scholarship Council
CA	California
CSA	Canadian Standard Association
CSO	Central Statistics Office
DE	Delaware
EPA	Environmental Protection Agency
FL	Florida
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
LIDAR	Light Detection and Ranging
LIDR	Light Detection and Ranging
MA	Massachusetts
MD	Maryland
ME	Maine
NC	North Carolina
NOAA	National Oceanic and Atmospheric Administration
NY	New York
PRBO	Point Blue Conservation Science
PSA	Public Service Announcements
SLAMM	Sea Level Affecting Marshes Model
SLAWG	Sea Level Rise Adaptation Working Group

SLOSH	Sea Lake and Overland Surges from Hurricanes
UMASS	University of Massachusetts
UNC	University of North Carolina
UNEP	the United Nations Environmental Program
USGS	the United States Geological Survey

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摘要

海平面上升对沿海栖息地和沿海社区是一个潜在的影响。海平面上升应该予以认真考虑，因为超过一半的美国人口生活在海岸 50 英里半径范围内。为了提出佛罗里达的社区如何更好地应对海平面上升的建议，本文以其他沿海国家适应气候变化所做的努力为视角。为此，从美国沿海各州和城市中选取了三种类型的海平面上升应适应对策。本文研究了这三种类型的海平面上升的影响，州和社区级别的项目，以及适应计划。佛罗里达州和包括加州、北卡罗来纳州、马里兰、纽约、特拉华、缅因州和马萨诸塞州在内的美国沿海地区都得到了检验。

通过文献总结三种海平面上升的适应性技术，在线收集沿海国家在适应气候变化所做的努力的信息和个人见解来完成以下四个步骤的研究：1) 分析了七个所选州在应对海平面上升时所做的努力；2) 识别这些努力的优点、缺点和最佳实践做法；3) 比较佛罗里达州与其他州的应对措施；4) 提出未来佛罗里达沿海社区如何更好地应对海平面上升的建议。

本研究发现，佛罗里达州在适应海平面上升的早期阶段存在优势，例如识别影响和增强意识。但是在改变阶段和解决即将出现的问题方面，该州的做法存在缺陷。其他州的适应对策将作为有用的指南和灵感来源帮助佛罗里达进行必要的调整，以更好地应对海平面上升。尽管如此，在帮助佛罗里达应对海平面上升采取合理的措施取得进展方面，本文提到的三种适应气候变化的应对措施每一个都被证明是非常重要的部分。希望未来这一进展仍将继续。

关键词： 全球变暖；海平面上升；适应策略；沿海州

Abstract

Sea level rise has the potential to affect a variety of coastal habitats and coastal communities. Sea level rise should be given serious consideration especially since more than half of the U.S. population lives within a 50 mile radius of the coast. In this thesis insight from other coastal states adaptation efforts will be gathered in order to develop recommendations for how Florida can better prepare its communities for sea level rise. In order to do so, three types of sea level rise adaptation efforts were selected in a select number of coastal states and municipalities within the United States. The three forms of adaptation efforts chosen to be examined in this thesis are studies of the impacts of sea level rise, state-level and community-level projects, as well as adaptation plans. Along with Florida the other coastal location within the United States examined include California, North Carolina, Maryland, New York, Delaware, Maine, and Massachusetts.

For all of the three types of sea level rise adaptation techniques mentioned above, existing literatures on adaptation have been reviewed, as well as information found on coastal states' adaptation efforts from online research, and personal insight to complete the following four steps: 1) Analyzed what the seven selected coastal states have already done to address rising sea levels; 2) Recognized strengths, weakness, and best practices among the efforts in those selected coastal states; 3) Compared the efforts that Florida has already undertaken to the efforts of the other coastal states and; 4) Developed recommendations for Florida's coastal communities on how to better prepare for sea level rise in the future.

This study found that Florida, demonstrate strengths when it comes to the beginning stages of sea level rise adaptation, such as identifying impacts and raising awareness, but the state's efforts are weaken when it comes the process of actually making changes and dealing with the issue that are soon to come. The adaptation efforts of other states that are taken will serve as useful sources of guidance and inspiration to help Florida makes the necessary adjustments to its coasts to better prepare for rising sea levels. Nonetheless, the three types of adaptation efforts mentioned throughout this thesis each prove to be a very important part in helping Florida makes progress towards reasonable action that will protect its coast from sea level rise, and it is hoped that the progression continues in the future.

Keywords: global warming; sea level rise; adaption strategy; coastal states

Chapter 1 : Introduction and Literature Review

1.1 Introduction

Being that greenhouse gas emissions are continuing increasing, the world is now facing great increases in global temperatures. Since 1990, the global temperature has been increasing at 0.2 °C per decade, a rate that is expected to continue (IPCC 2007). It is predicted that by the years 2090-2099 the average global temperature will increase significantly, temperatures are expected to rise anywhere from 1.1 to 6.4 °C warmer than they were back in 1980-1999 (IPCC 2007). With these increasing temperatures come negative impacts globally in all types of environments, yet these temperature increases especially pose significant risks to coastal regions. With these large scale temperature changes, ocean temperatures will rise from the melting of terrestrial ice sheets, world-wide glaciers and ice caps. These three changes are expected to lead to notable increases globally in sea level rise (Michener et al., 1997; Boesch et al., 2000; Frumhoff et al., 2007). This drastic increase in sea levels could in turn cause significant damage to coastal regions.

Since 2007 studies have been conducted on sea level rises and it is indicated that many coastal regions are expected to face severe complications from the rising sea levels. Being that sea level will most likely increase, causing sea-level rise by 2100 to reach about 0.5 meter to more than a meter (Cook, 2014). Much has yet to be learned before sea level can be projected with greater precision and certainty, but the differences are largely a matter of when, not whether, economically and ecologically critical levels will be reached.

With all this going on with the increase in global temperatures and rising sea levels the question for Floridians is not whether they will be affected by this, but how much—that is, to what degree sea-level rise will continue and how rapidly, what other climate changes will accompany sea-level rise, and what the long term effects of these changes will have on the state and coastal community. There are some detrimental effects from rising sea levels that are already well documented. Others will begin to occur in the coming years and decades, and the time is coming when the state will be simultaneously and continuously challenged by all of these effects.

Florida is especially vulnerable to the effects of sea-level rise. It has more than 1,200 miles of coastline, almost 4,500 square miles of estuaries and bays, and more than 6,700 square miles of

other coastal waters. The entire state lies within the Atlantic Coastal Plain, with a maximum elevation less than 400 feet above sea level, and most of Florida's 18 million residents live less than 60 miles from the Atlantic Ocean or the Gulf of Mexico. Three-fourths of Florida's population resides in coastal counties that generate 79% of the state's total annual economy. These counties represent a built-environment and infrastructure whose replacement value in 2010 is \$2.0 trillion and which by 2030 is estimates to be \$3.0 trillion (Cook, 2014)

In addition, Florida's coastal and marine resources comprise some of the nation's most diverse and productive ecosystems, supporting vast numbers of aquatic and terrestrial animals and plants—some of which exist nowhere else on Earth. These ecosystems include the coastal ocean, barrier islands, bays, estuaries, lagoons, sounds, tidal salt marshes and creeks, man grove swamps, shellfish beds, sea grass beds, coral reefs, and oyster bars. They are an important source of food and other products worldwide, as well as perform valuable and irreplaceable ecological functions at no cost, and they provide significant aesthetic and recreational opportunities for the coastal community and tourist from all around the world. Florida's life-support system, economy, and quality of life depend on preserving and sustaining these natural resources over the long term.

Moreover, a rise in sea level would increase the exposure of many communities to storm waves. This poses a significant threat to low-lying urban areas. At particular risk would be many areas of southern Florida -- the highest point in Florida is only 53 feet above sea level, and the Florida Keys are all less than 10 feet above sea level. Some property values will likely be reduced as the shoreline changes (Cook, 2014). Some property owners could lose homes, other buildings, and property with the long-term effects of sea-level rise even in the absence of storm wave impacts. The properties not lost to sea-level rise would still be at risk from the effects of hurricanes and the increased potential for storm wave damage. A final social effect of a rise in sea level would be the harm wrought to ecosystems valued by residents and tourists to the Southeast. Florida's Everglades are a national treasure appreciated by residents and tourists alike. In addition, coastal recreational opportunities, available at the vast expanse of beaches in Florida, could be compromised by the effects of sea-level rise (Cook, 2014). Also, a rising sea level could jeopardize recreational fishing and fowling through the loss of coastal wetlands and associated habitat or poor-quality forage.

As far as economic impacts, increases in storm waves associated with catastrophic storms, combined with growth in population and building in low-lying coastal areas, have increased

insurance claims in all coastal regions over the past decade. Over the past 20 years, Florida and other coastal regions have been the location of more than half of the nation's most costly weather-related disasters (Cook, 2014). Hurricanes, floods, droughts, tornadoes, and ice storms have resulted in over \$87.7 billion in damages. With an increasing rate of sea-level rise and the possibility that precipitation in the form of heavy and extreme events will continue, Florida has the potential for even greater damage to and loss of infrastructure to sea-level rise and its associated effects in the future. Damage to coastal wetlands from sea-level rise could also harm Florida's coastal fisheries.

Florida has undertaken many efforts related to protecting coastal ecosystems, developing outreach to the coastal communities while creating educational opportunities to help people become aware of risks that are being caused from sea level rise. Given these circumstances, Florida has already made notable progress in preparing its coastal municipalities for sea level rise. Nonetheless, most of the statewide policies are fairly new, having either been adopted in the late 2000s or just beginning to be developed. Meanwhile, although some coastal areas are putting forth efforts to adapt to coastal climate change, few have thoroughly planned for sea level rise (Dottai, 2010). Therefore, there is still a great deal of opportunity to improve current adaptation efforts in order to better protect Florida's coastal municipalities.

Florida's current ecosystem conditions are currently at risk. Various kinds of plants, animals, and microorganisms are included in a typical ecosystem such as a particular kind of forest, prairie, swamp, lake, stream, or reef. Florida's natural ecosystems are especially valuable because of the disproportionately large contribution they make globally to biological diversity or "biodiversity." The state was colonized over evolutionary time by a diverse mixture of species from continental areas to the north and tropical Caribbean areas to the south. Semi-isolation by ocean on three sides subsequently contributed to a surprisingly high 8 percent of Florida's vascular plant, fish, amphibian, reptile, bird, and mammal species (and important subspecies) that are found nowhere else in the world, according to the Nature 2000 Task Force (Governor's Office, Tallahassee, 1990). Present-day Florida is considered a global "hot spot" for biodiversity by conservation organizations and by public agencies with strong conservation mandates. People have been interacting with and modifying Florida's ecosystems for at least 10,000 years. Over most of this time their use of natural resources was sustainable. Their activities did not cause any

significant decrease in the ability of the environment to maintain clean air and water, as well as productive, biologically diverse ecosystems. However, the massive human uses of Florida's natural environment in the twentieth century are clearly unsustainable. Deforestation in the north, wetland drainage in the south, agriculture in the center, and creeping urbanization everywhere have caused massive losses of natural ecosystem diversity and productivity. Perhaps the major challenge of the next century is to create an environmentally, as well as economically, sustainable way of living.

The purpose of this thesis is to try to identify the possible opportunities that Florida can use to help become better prepared for all the possible effects that may occur as the oceans temperature get warmer and the sea level rise. In order to do that this thesis is going to review an array of documents, reports and review that focuses on the studies of impacts of sea level rise, projects that are being conducted on both a state and community level that aid in assist with the current and future issues of sea level rise, and one that discuss the adaptation plans that seven selected coastal states have developed to adapt to sea level rise. These seven coastal states include Maryland, Delaware, North Carolina, New York, Maine, California, and Massachusetts. These states were chosen for this thesis because they have already started to make great efforts in addressing sea level rise and these states are in better position to help Florida address the issues of sea level rise.

For the seven states mentioned above, efforts that correlate with these three categories of sea level rise adaptation—impacts, projects, and plans—are examined, compared, and analyzed to help identify trends, strengths, and weaknesses to determine whether or not Florida need to make adjustments to the projects that the states already has. With that, the same thing will be done for the other states will also be one in Florida so the necessary comparison can take place. By doing this, it provides the chance to examine Florida's sea level rises adaptation efforts strengths and weaknesses as well as make comparisons with the other states efforts. Analyzing and comparing these others states to Florida, the thesis finds that Florida still has a lot of room for improvement. Also, this thesis finds that Florida could benefit a great deal from conducting more studies on the rises of sea level rise. Among other suggestions, the thesis finds that Florida could benefit from undertaking more studies of the risks of sea level rise, duplicating state and community level projects that other states have already conducted that work to identify vulnerabilities and create corresponding strategies, and improving state-level plans to better incorporate sea level rise risks without totally destroying the coastal areas. Much of the analysis and many recommendations were

developed using insights provided by recent literatures on climate change adaptation that is discussed below.

1.2 Literature Review

Reviews and reports on how coastal regions, such as those in Florida, can better adapt to the impacts of climate change are becoming more and more common as time goes by global warming starts to cause serious effect on coastal areas around the world. Some of these literature gave a list of steps that would be helpful to take into consideration when in the process of developing an adequate adaptation policy. While others literatures describe the different types of policies that would be suitable for different coastal regions. Together, all of these sources that will be mentioned provides useful guidelines and recommendations for any coastal region striving to better prepare itself for sea level rise. For this thesis in particular, many of these sources prove helpful in identifying characteristics that can be used to analyze states' sea level rise adaptation efforts.

1.3 General Literature on Climate Change and Sea Level Rise Adaptation

Let's begin with the basic principles, according to Richard Klein to the most widely accepted process for figuring out what the impacts climate change could cause and selecting and evaluating adaptation techniques is organized and listed in the IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations, as well as in the UNEP Handbook on Methods for Climate Change Impact Assessments and Adaptation Strategies (Klein et al. 1999). The general processes described in these documents are related to large areas like countries and as small as states or individual coastal communities ("UNEP Handbook" n.d.; "IPCC Technical" n.d.; Klein et al. 1999). However, Richard Klein suggested that these guidelines are inadequate, for they fail to consider several elements. The steps Klein believe these articles lack are ways to increase the public's involvement in the development of creating adaptation skills and when deciding how to go about choosing the appropriate techniques when it comes time to evaluate adaptation policies. The authors for these two handbooks instead suggest a much simpler set of steps that should be taken to address the issues. There are four steps that is being considered here. The first step increasing the quantity of data and information regarding potential climate change impacts. Also, increasing the awareness of coastal managers and coastal communities about these potential changes that may occur due to sea level rise. The second step is planning and developing appropriate adaptation strategies to the specific areas that include advice from coastal managers

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