适应海平面上升的生物多样性保护规划：
美国佛罗里达州瓜纳-特罗马特-马坦萨斯
国家级河口研究保护区案例

BIODIVERSITY CONSERVATION PLANNING
ADAPTIVE TO SEA LEVEL RISE:
THE CASE OF THE GUANA TOLOMATO
MATANZAS NATIONAL ESTUARINE
RESEARCH RESERVE IN FLORIDA

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摘要

目前，海平面上升成为了全球沿海低洼地区生物多样性保护最大的威胁之一，为了应对这一挑战，我们亟需对沿海保护区加以调整。本文介绍了位于美国佛罗里达州的瓜纳-特罗马特-马坦萨斯国家级河口研究保护区的案例，该项目通过运用综合保护规划模型来辨识适应海平面上升的优先保护区。结合美国案例的经验，本文继而对中国沿海城市和地区开展适应海平面上升的生物多样性保护规划提出了相关建议。

关键词

海平面上升；适应性规划；生物多样性；沿海地区；模拟

ABSTRACT

Currently, sea level rise becomes one of the biggest threats to biodiversity conservation in low-lying coastal areas, and coastal conservation areas need to be optimized to the rising sea level. This paper introduces the case of the Guana Tolomato Matanzas National Estuarine Research Reserve in Florida, which shows that the key conservation areas adaptive to sea level rise can be identified by modeling with integrated protection planning. Combining the American case’s lessons, the paper further comes up with suggestions on biodiversity protection adaptive to sea level rise for China’s coastal cities and regions.

KEY WORDS

Sea Level Rise; Adaptive Planning; Biodiversity; Coastal Region; Simulation

1 海平面上升带来的挑战

根据政府间气候变化专门委员会（IPCC）的报告，全球年平均气温在20世纪大约上升了0.7℃。气候变化给生物多样性及生态系统保护带来了巨大的挑战^[1]。研究表明，气候变化会导致风暴潮、飓风的加剧以及全球海平面的上升^[2]，同时也是物种灭绝的主要因素之一^{[3][4]}。

在全球气候变化所导致的影响中，海平面上升被认为是最确定、最直接、最显而易见以及影响最广泛的后果^[5]。全球沿海观测站的统计数据显示，20世纪至21世纪初期，全球海平面平均每年上升大约3.3mm^[6]。IPCC在其最新的评估报告中预测，全球海平面将在21世纪末上升0.4~0.6m，最坏的结果可能是上升1.0m。但该报告也指出，这是基于南极海平面以下的冰川未融化的前提下的预测，如果冰川融化，全球海平面上升的幅度将会远远超过该预测范围^[6]。海平面上升主要由全球气候变暖导致的海水增温膨胀以及冰川融化等因素造成^[7]。在地表风向、各地海水增温膨胀以及冰川融化程度不尽相同的条件下，全球各地海平面上升的速度存在着差异。

海平面上升将给中国沿海地区带来巨大挑战，很多低洼地区将被海水淹没（图1）。在生态环境方面，海平面上升将对沿海地区的动植物栖息地、物种以及生态系统等造成一系列影响^[8]。沿海湿地将被海水

1 Challenges Brought by Sea Level Rise

According to the report released by Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased about 0.7 °C in the 20th century. Climate change poses a huge challenge to biodiversity and ecosystem protection^[1]. Researches show that climate change aggravates the intensity of storm surge and hurricane, and encourages the global sea level rise^[2], becoming one of the main reasons to species extinction as well^{[3][4]}.

Sea level rise is thought to be the most definite, immediate, obvious and influential consequence caused by global climate change^[5]. The data of global coastal observatories showed that in 20th and early 21st century the global sea level had been rising about 3.3 mm per year on average^[6]. According to the latest IPCC report, it is predicted that the global sea level would increase by 0.4 ~ 0.6 m at the end of the 21st century, 1.0 m as the worst. But the report also stated that the prediction is based on the premise that Antarctic glaciers below sea level do not melt; if the glaciers would melt, the extent of global sea level rise will far exceed the predicted result^[6]. The thermal expansion of seawater and the melting of glaciers due to global warming contribute to the accelerated rise in global sea level^[7]. Because of the different conditions of surface wind direction, thermal expansion of seawater, and glacial melting, the speed of sea level rise varies around the world.

Inescapably, sea level rise is also being a challenging issue to China's coastal areas, where many low-lying areas are under the risk of being inundated (Fig. 1). Sea level rise causes a series of impacts on coastal habitats, species, and

- 1. 海平面上升对中国和部分相邻国家及地区的影响
- 1. Impact of sea level rise on China and some surrounding countries and areas

所淹没或向内陆迁移，但这种迁移通常受到已有或未来建成区的限制^{[9][10]}。杨耀中等指出海平面上升对中国沿海地区的主要影响包括海水入侵及土壤盐渍化、海岸侵蚀、风暴潮加剧及滨海湿地的退化与推移^{[11]~[14]}，这将威胁沿海基础设施安全，给沿海地区的经济社会发展带来诸多不利影响^{[15]~[17]}。

意识到海平面上升将给沿海地区，特别是沿海保护区带来巨大挑战，美国的保护生物学家们于2010年1月在佛罗里达州的阿基博德生物站举行了研讨会，并确立了未来应对海平面上升的主要研究方向^[18]，包括：

- （1）现有沿海自然保护区范围应该如何调整以适应海平面上升？
- （2）在哪里建立海岸-内陆的生态廊道以协助栖息地和物种随海平面上升而迁移？
- （3）在哪里建立新的保护区从而更有效地保护栖息地和物种免受海平面上升的威胁？

基于对以上研究的迫切需求，在美国国家海洋与大气管理局（NOAA）下设的国家级河口保护区研究系统（NERRS）科学合作基金的资助下，位于美国佛罗里达州的瓜纳-特罗马特-马坦萨斯国家级河口研究保护区（以下简称“马坦萨斯保护区”）联合佛罗里达大学开展了海平面上升对自然保护区的影响评价及保护区应对海平面上升的适应性策略研究^[19]。

虽然在土地权属、保护区管理体制等很多方面与中国有较大差异，美国应对海平面上升的经验，特别是适应性规划方法对我国沿海地区的管理仍然具有借鉴意义。本文将详细介绍美国佛罗里达州马坦萨斯保护区应对海平面上升的适应性保护规划案例，并结合中国沿海自然保护地的实际情况提出适合我国的海平面上升的适应性保护建议。

2 美国马坦萨斯保护区应对海平面上升的保护规划

2.1 研究区域背景介绍

马坦萨斯河流域位于美国佛罗里达州东北部的大西洋海岸，是佛罗里达州海岸受海平面上升威胁最大的流域之一^[20]。流域范围包括圣奥古斯丁市和棕榈海滩镇之间的区域，以及河流西岸的大片农田区。整

ecosystems^[8]。Coastal wetlands might be submerged by sea water or move into inland, but the movement is often limited by the existing or potential built-up areas^{[9][10]}。Yaozhong Yang et al. pointed out that the main impacts caused by sea level rise on China’s coastal areas include sea water intrusion and soil salinization, coastal erosion, storm surge enhancement, and coastal wetland degradation and movement towards inland^{[11]~[14]}, which would threaten coastal infrastructure and impact the economic and social development in coastal regions^{[15]~[17]}。

Responding to the challenge by sea level rise to coastal regions, particularly the coastal reserves, conservation biologists in the United States held a seminar in January 2010 at Archbold Biological Station, Florida, on which future research directions were emphasized^[18], including:

- (1) How to optimize the areas of the existing coastal natural reserves adaptive to sea level rise?
- (2) Where should the coast-inland ecological corridors be established to facilitate the migrations of habitats and species as the sea level rising?
- (3) Where should the new reserves be established so as to more effectively protect habitats and species from the impact of the sea level rise?

Guana Tolomato Matanzas National Estuary Research Reserve (hereinafter referred to as Matanzas Reserve) conducted a study on the assessment to the impact of sea level rise on the natural reserves and adaptive strategies to cope with sea level rise, jointly with the University of Florida, funded by National Estuarine Research Reserve System (NERRS) Science Collaborative, which affiliates to National Oceanic and Atmospheric Administration (NOAA)^[19]。

Although different in land ownership and management mechanism of conservation areas, the American experience responding to the issue of sea level rise, especially adaptive planning methods, provides reference to the management and development of coastal regions in China. This paper will introduce the case of the conservation planning adaptive to sea level rise for the Matanzas Reserve, and come up with some suggestions for China’s situation.

2 The Conservation Planning Adaptive to Sea Level Rise for the Matanzas Reserve

2.1 Research Background

Located on the Atlantic coast in northeast Florida, Matanzas River basin is one of the areas highly threatened by sea level rise along the Florida coast^[20]。The basin consists of the area

个流域面积约400km²，其中约90%的土地未被开发或城镇化。流域内的自然景观类型主要有马坦萨斯河入海口，以及河口附近的海岸森林、沼泽、湿地、高地、海滩等。区域内的保护地包括国家级河口自然保护区、马坦萨斯堡国家纪念地、马坦萨斯国家森林和费沃-戴克州立公园（图2）。

马坦萨斯河流域的主要栖息地类型包括高地森林（约55%）、海水/淡水沼泽和开阔水面，保护区内生物多样性高。在保护区内记录有40种哺乳动物、350种鸟类、40种爬行动物、20种两栖动物、300种鱼类和580种植物^[21]。在已知的物种里，有包括佛州地鼠龟、佛罗里达松蛇、穴蛙和海滩鼠等在内的48种保护动物和8种保护植物。

如何有效地对保护区的范围和区位进行调整以应对海平面上升带来的威胁，成为了相关部门决策者需要探讨的紧迫问题。为了更准确地分析海平面上升对马坦萨斯河流域的生物多样性和生态系统带来的影响，本项研究将马坦萨斯河流域及其边界外5km的区域划定为研究范围。

between St. Agustin and Palm Coast, and the large farmland on the western bank of the river. The whole basin covers an area of approximately 100,000 acres, and about 90% land remains undeveloped or non-urbanized. The natural landscapes within the basin include the Matanzas estuary and the coastal forest, marsh, wetland, upland, and beach in its surroundings. The national estuary natural reserve, Fort Matanzas National Monument, Matanzas national forest, and Faver-Dykes State Park are located within the basin (Fig. 2).

With a high biodiversity, the Matanzas river basin includes highland forest (55%), marine / freshwater marsh, and open water. According to the records, 40 mammal species, 350 bird species, 40 retile species, 20 amphibian species, 300 fishes, and 580 plant species are found in the conservation area^[21]. The known species include 48 species of protected animals, such as gopher tortoise, Florida pine snake, gopher frog, and beach mouse, as well as 8 protected vegetation species.

How to optimize the extent of the existing reserves responding to the threat of sea level rise now becomes a pressing issue to decision makers. In order to more accurately dissect the sea level rise impacts on biodiversity and ecosystem in the basin, the research not only studies the Matanzas river basin itself, but also analyses the area outreaching 5 km along the basin.

2. 研究区域概况
2. Overview of the study area

2-1

2-2

2-3

2.2 研究方法和数据

本项目依托地理信息系统平台，在保护生物学、景观生态学和空间生态学等多学科的交叉背景下，通过建立一个整合了海平面上升影响湿地模型（SLAMM）^[22]、物种栖息地模型以及空间保护规划软件 Zonation^[23]的综合框架，来辨识适应海平面上升的优先保护区。总体技术路线如图3所示。

2.2.1 海平面上升远景

由于海平面上升高度的不确定性，本研究采用了低（0.5m）、中（1.0m）、高（2.5m）三个不同程度的21世纪末海平面上升远景值：假设0.5m为本世纪末海平面上升的最低值，这个值符合IPCC第五次气候变化评估报告中的0.4~1.0m的范围；1.0m为中间值，此值也是IPCC预测的21世纪末在南极海平面以下的冰川未融化的情况下可能发生的最严重的情况；2.5m为最高值，是基于南极海平面以下的冰川融化的假设。

2.2.2 SLAMM

SLAMM是由美国沃伦-匹诺克环境咨询公司开发的用于预测沿海湿地和海岸线随海平面上升而变化的模型。自20世纪80年代被开发以来，SLAMM已被NOAA广泛应用于美国境内的海平面上升影响预测中。相比其他海平面上升影响模型，SLAMM的优势包括可应用于各种研究

2.2 Research Methods and Data

Based on the platform of Geographic Information System (GIS) and the multidisciplinary knowledge of conservation biology, landscape ecology, and spatial ecology, the research identifies the key conservation areas adaptive to sea level rise through an integrated framework which is composed of Sea Level Affecting Marshes Model (SLAMM)^[22], habitat model for simulating species distribution, and Zonation, a conservation planning modeling software (Fig. 3)^[23].

2.2.1 Scenario of Sea Level Rise

Due to the uncertainty of rising height of sea level by the end of the 21st century, low-, medium-, and high-sea level rising scenarios are adopted in the research. The low rising height (0.5 m) is designed according to the range from 0.4 m to 1.0 m predicted in IPCC’s Fifth Assessment Report. The medium rising height (1.0 m) is designed according to the worst prediction by IPCC based on the promise that the Antarctic glaciers below sea level unmelt at the end of 21st century. The high rising height (2.5 m) is designed as one possibility that occurs in the case that Antarctic glaciers below sea level melt.

2.2.2 SLAMM

Developed by Warren Pinnacle Consulting, SLAMM was designed to predict the change of coastal wetlands and shorelines affected by sea level rise. Since its development in the 1980s, it has been widely used by NOAA to predict the impact of sea level rise in the United States. Compared to other models, SLAMM is

3. 技术路线图。虚线方框表示输入的数据，实线方框表示用到的模型，虚线椭圆表示模型的输出结果。
4. 不同海平面上升水平下湿地的分布
3. The general technology roadmap, in which dashed line boxes denote input data, solid line boxes denote models, dashed ovals denote the output of models.
4. Distribution of marshes under 0.5 m, 1.0 m, and 2.5 m sea level rise.

尺度的模拟、能够描述物种栖息地的脆弱性，以及能够模拟海水入侵对土地覆盖的影响等^[24]。地形和土地利用数据是运行SLAMM所必须的输入数据。本项目的地形数据来自于佛罗里达州鱼类与野生动物保护委员会（FWC）、棕榈海滩镇以及圣约翰斯县，而土地利用数据来自于圣约翰斯河水资源管理区和马坦萨斯保护区。图4分别显示了高、中、低三种海平面上升预景下的沿海湿地分布情况。

2.2.3 物种栖息地模型

本研究采用了由佛罗里达大学景观设计系的汤姆·霍克特研究副教授与FWC的专家们共同开发的物种栖息地模型来模拟物种栖息地的分布^[23]。物种栖息地模型建立在每一物种对栖息地的独特要求上，以土地利用数据为基础数据，辅以土壤类型、水文状况、鸟类筑巢地等其他输入数据。这些数据可从佛罗里达州地理信息数据馆获取。本研究

often applied, for example, to operate on a variety of research scales, identify the vulnerability of the habitat of certain species, and simulate the impact of seawater invasion on land cover^[24]. Topographic information and land-use data are necessary for SLAMM. In this research, the topographic information are sourced from the Florida Fish and Wildlife Conservation Commission (FWC), Palm Coast city, and St. Johns County; the land-use data are sourced from St. Johns River Water Management District and Matanzas Reserve. Figure 4 shows the changes of coastal wetland in low-, medium-, and high-sea level rise scenarios.

2.2.3 Habitat Model for Simulating Species Distribution

Jointly developed by Thomas Hocht, research associate professor of the Department of Landscape Architecture at University of Florida and the experts from FWC, the habitat model is used for simulating species distribution^[23]. It is built on the unique requirements of each species on habitat in which the land-use data are fundamentally necessary, with other supporting input information on soil, hydrology, and bird nesting sites, etc. All relevant data are sourced from the Florida

在SLAMM的模拟结果的基础上，分别在不同的海平面上升远景方案中识别物种的潜在栖息地的分布，共选择38种关键物种进行物种栖息地的模拟，包括美洲蛎鹬（图5）、秃鹰、佛州地鼠龟和海龟。

2.2.4 Zonation软件

空间保护规划软件Zonation是通过分析和预测生物多样性特征（如物种多样性、栖息地多样性等）的分布来确定空间保护优先级。Zonation可用于识别保持多个物种的栖息地质量和连通性（或其他生物多样性特征）的重要区域，从而为生物多样性得到长期保护提供具体的用地决策和措施。Zonation的主要输出数据有：1）对研究区域内保护区的优先级排序；2）描述在不同尺度的景观变迁过程中各物种的表现的坐标图。这些结果可用于：1）对现有或计划中的保护区域进行评估；2）扩大现有保护区；3）为达到特定的保护目标识别出新的保护

Geographic Data Library. Based on the SLAMM’s simulation, the research identifies the potential distribution of habitat respectively under the three scenarios, simulating the habitat distribution of 38 kinds of key species, including American oystercatcher (Fig. 5), bald eagle, gopher tortoise, and sea turtle.

2.2.4 Zonation

Zonation, a spatial conservation planning modeling software, is designed to identify spatial conservation priority through analysis and prediction of the distribution of biodiversity characteristics, such as species diversity and habitat diversity. Zonation can help identify the key areas with quality and continous habitats of multiple species, or with other biodiversity characteristics, in order to inform specific land-use decision making and measures for the long-term protection of biodiversity. Zonation’s main outcomes include: 1) ranking of the priority of the conservation areas; and 2) coordinate graph, which can describe the performance of various species in the process of landscape changes on different scales. These outcomes can be applied in: 1) assessing

- 5. 不同海平面上升水平下美洲蛎鹬栖息地的变化
- 6. 不同海平面上升水平下的保护优先区
- 5. American oystercatcher habitat under 0.5 m, 1.0 m, and 2.5 m sea level rise.
- 6. Key conservation area under 0.5 m, 1.0 m, and 2.5 m sea level rise.

区。本项目中，Zonation的输入数据为在现状以及各海平面上升预景条件下的物种栖息地栅格数据，以及物种的权重等其他数据。

2.3 结果

2.3.1 不同海平面上升预景下的优先保护区

图6表示了低、中、高三个不同水平的海平面上升预景下的生物多样性优先保护区域。红色表示场地中保护价值最高的区域，而蓝色表示场地中保护价值最低的区域。通过对比可以发现，随着海平面的上升，生物多样性保护的优先区也在发生着变化，尤其是在高海平面上升预景下，场地的中西部及东南部将出现大片区域被辨识为高价值的优先保护区，而这些区域在海平面上升0.5m和1.0m的预景条件下未能被辨识出。

the existing or planned conservation areas, 2) expanding existing conservation areas, and 3) identifying new conservation areas for specific protection purpose. In this research, the input data to Zonation include the grid data of habitats and other required data, such as the weight of species, under the existing conditions and the three sea level rise scenarios.

2.3 Results

2.3.1 Key Conservation Areas under Different Sea Level Rise Scenarios

Figure 6 shows the key conservation areas of biodiversity under the scenarios of low-, medium-, and high-sea level rise. The red areas represent the most valuable sites in the region, while blue areas representing the conservation areas with the least value. Through comparison, it is found that the key conservation areas of biodiversity changes as the sea level rising, which is most obvious in the high-sea level rise scenario that large areas in the mid west and southeast of the region are identified as key conservation areas, being unidentified under the 0.5 m and 1.0 m sea level rise scenarios.

2.3.2 对现有沿海自然保护区的评价

对比现有保护区与各个海平面上升预景条件下的优先保护区可以发现，有大量的优先保护区存在于现有保护区的范围之外。图7表示了不同海平面上升预景下，位于现有保护区之外的场地中生物多样性保护价值前10%的区域。如果这些区域不能得到有效的保护，海平面上升后，各物种及其栖息地都将受到很大的威胁。在未来可以将这些区域作为保护区来进行规划，以有效应对海平面上升对于生物多样性的威胁。

3 对于中国海平面上升适应性规划研究的借鉴与启示

近些年，海平面上升适应性规划已经成为了美国研究领域的一项热点。在NOAA海洋基金以及其他研究基金的资助下，沿海各州开展了大量针对海平面上升适应性的研究。美国在此领域积累的经验 and 成果对我国沿海地区开展海平面上升适应性规划工作具有重要的借鉴意义。

2.3.2 Evaluation of the Existing Coastal Nature Reserve

By comparing the existing conservation areas with the key conservation areas under different sea level rise scenarios, it is found that a large number of key conservation areas exist outside the extent of the existing conservation areas. Figure 7 shows the top 10% areas with high biodiversity under different sea level rise scenarios which are outside the extent of the existing conservation areas. If these areas cannot be effectively protected in advance, species and their habitats will face great threat, for which they should be planned as potential key conservation areas in order to respond to the threat of biodiversity loss by sea level rise.

3 A Reference for China’s Research on Adaptive Planning to Sea Level Rise

In recent years, adaptive planning to sea level rise has become one of the most studied issues in the United States. Funded by the Sea Grant of NOAA and other research grants, a large number of research on the adaptation to sea level rise are conducted in American coastal regions. American efforts and research outcomes provide a valuable reference for the adaptive planning to sea level rise in China’s coastal regions.

7. 不同海平面上升预景下，位于现有保护区之外的场地中生物多样性保护价值前10%的区域

7. The top 10% areas with high biodiversity under different sea level rise scenarios which are outside the extent of the existing conservation areas.

3.1 重视应对海平面上升的适应性规划研究

在美国，诸如NOAA等联邦政府机构和沿海地区及城市都十分重视海平面上升的适应性规划工作。近年来，NOAA下设的海洋基金和NERRS科学合作基金资助了大量海平面上升适应性规划的项目。同时，沿海各州和城市也加大了对海平面上升的适应性规划研究，如FWC资助的佛罗里达州应对海平面上升的生物多样性优先保护区辨识的项目^[25]。美国各级政府部门对海平面上升适应性规划的重视以及为此提供的资助保证了相关研究工作能够顺利开展。近些年，中国在气候变化的影响以及适应策略等方面也开展了大量研究工作，但是却鲜有针对海平面上升这一气候变化所带来的最直接和影响最广泛结果的相关研究，海平面上升适应性规划方面的研究尤其欠缺。在海平面上升不可避免地将对中国沿海地区造成巨大影响的背景下，加大海平面上升适应性规划和策略的研究是十分必要的。在国家层面，需要有相关的政府部门来统领这项工作，协调各相关部门开展海平面上升的影响评估以及适应性规划工作；在地方层面，沿海地区的城市规划和建设需要将海平面上升作为重要的考量因素。

3.2 加强地理信息系统数据库的建设

从以上案例可以看出，海平面上升适应性规划对数据，特别是地理信息系统数据的要求较高。诸如高程、水文、土壤和土地利用等方面的地理信息数据对于物种栖息地模型和空间保护规划软件都是必不可少的。美国的地理信息系统数据库建设较为完善，许多州都建立了自己的数据库并且免费对外开放，例如上文中提到的佛罗里达州地理信息数据馆即依托佛罗里达大学地理规划中心而建立。中国在地理信息系统数据库建设方面缺乏面向研究人员和公众的数据共享平台，导致数据缺乏或无法获取，开展海平面上升适应性规划的相关研究面临着数据“贫瘠”的局面。鉴于此，建议加快我国地理信息系统数据库

3.1 To Devote More Attention to the Research on Adaptive Planning to Sea Level Rise

In the United States, federal agencies, such as NOAA, and coastal regions and cities have devoted great importance to adaptive planning to sea level rise. The Sea Grant of NOAA and NERRS Science Collaborative have funded a large number of projects in recent years. Coastal regions and cities have also encouraged more adaptive planning research, such as the study of identification of the key conservation areas of biodiversity responding to sea level rise funded by FWC^[25]. The emphasis and investment by the governments at various levels ensure the study on adaptive planning to sea level rise. In the past few years, China has also conducted extensive research on the impacts of climate change and adaptive strategies. However, there are few research on adaptive planning to sea level rise, the most immediate and extensive consequence of climate change. Realizing sea level rise is an inevitable fact which is and will continually impact on China's coastal areas, there is a pressing need for China to promote the study on adaptive planning and strategies to sea level rise. At the national level, governments should play an important role in facilitating and coordinating agencies and resources to conduct studies on the assessment of the impact of sea level rise and relevant adaptive planning; at the local level, the impact of sea level rise should be carefully considered in urban planning and construction of China's coastal regions.

3.2 To Improve GIS Databases

In the research of the conservation planning adaptive to sea level rise for the Matanzas Reserve, it is noticeable that adaptive planning essentially requires the support of data, particularly the GIS data. Geographic information, including elevation, hydrology, soil, and land use, etc., are necessary for habitat simulation and spatial conservation planning models. The United States has established a well-developed GIS database, while many states have also established their own databases which are freely accessible to the public. For instance, the Florida Geographic Data Library is established with the support from the University of Florida GeoPlan Center. Lacking of data sharing platform, China's GIS databases cannot yet be well used by researchers and the public; as a result, the study on adaptive planning to sea level rise lacks available data supports that substantially limits the promotion of relevant studies. Therefore, it is strongly recommended that Chinese government should facilitate the improvement of GIS databases by funding GIS databases, with the supports from

的建设，由政府出资依托大学或科研单位建设各省市的地理信息系统数据库。这个数据是可以共享的，尤其应该对于科研人员开放共享。

3.3 加强沿海城市政府管理机构与科研机构的合作

佛罗里达州马坦萨斯保护区应对海平面上升的适应性规划是由佛罗里达大学的科研人员和马坦萨斯保护区的管理者合作完成的。沿海地区面临着海平面上升的威胁和应对海平面上升的策略的需求，科研机构具备相关的人才和技术，能够很好地为沿海地区和城市提供应对海平面上升的适应性规划和咨询服务；同时，这种政府与科研机构间的合作也为城市规划者提供了很好的开展相关实践的机会。

4 总结

海平面上升给全球沿海低洼地区和城市带来了巨大威胁，沿海自然保护地以及其他具有高生态保护价值的区域将受到海平面上升的直接影响。美国佛罗里达州马坦萨斯保护区应对海平面上升的适应性规划综合运用了地理信息系统技术、水文模型、物种栖息地模型以及保护规划软件来辨识适应海平面上升的生物多样性优先保护区。美国相关案例为中国沿海保护地应对海平面上升提供了借鉴。本文认为，中国应尽早开展应对海平面上升的适应性保护规划工作，通过海平面上升影响评价和辨识适应海平面上升的优先保护用地来为保护区调整（如扩大现有保护区范围，建立生态廊道，以及增设新的保护区等）提供科学依据。此外，应对气候变化和海平面上升需要加强顶层设计，如在国家层面通过立法和制定法规来要求沿海地区和城市开展海平面上升的影响评估及相关应对工作。在地方层面，地方政府可以在城市总体规划和土地利用规划中制定相应的导则，并为保护区应对海平面上升所需要做的调整提供政策支持。**LAF**

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colleges or research institutions. All the data should be shared and open to the public, especially accessible to researchers and scientists.

3.3 To Facilitate the Cooperation between Governments of Coastal Cities and Research Institutions

The conservation planning adaptive to sea level rise for the Matanzas Reserve is a collaborative result between the researchers from the University of Florida and the administrators of Matanzas Reserve. Coastal regions are facing the threat by sea level rise and it is urgent to develop responding strategies to deal with it. Meanwhile, the research institutions can play as a think tank offering intelligent and technological support to the adaptive planning to sea level rise. This kind of collaboration can also bring opportunities to urban planners for practice in coastal regions.

4 Summary

Sea level rise threatens the low-lying coastal areas and cities all over the world, and coastal natural reserves and other areas with high ecological value will be directly and greatly impacted by sea level rise. In the research of the conservation planning adaptive to sea level rise for the Matanzas Reserve, GIS technologies, hydrological models, habitat simulation, and conservation planning models are combined to identify the key conservation areas of biodiversity. American lessons offer references to the planning of coastal conservation areas in China. This paper suggests that China ought to improve the research on adaptive planning to sea level rise which can provide scientific supports for the optimization of conservation areas (for example, expanding the extent of existing conservation areas, establishing ecological corridors, and adding new conservation areas) through the impact assessment of sea level rise and the identification of key conservation areas. At the national level, the top-level design adaptive to climate change and sea level rise should be underlined through laws and regulations which will ensure the implementation of the impact assessment of sea level rise and adaptive planning. Furthermore, the local governments should develop guidelines to the urban planning and land-use planning, and provide policy support to the optimization of conservation areas adaptive to sea level rise. **LAF**

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