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厦门大学

硕 士 学 位 论 文

中国海岸带自然栖息地在应对自然灾害及区域弹性转型中的作用

Past, Present, and Future Dynamics of Natural Hazards in China's Coastal Region: Resilience Implications and Role of Natural Habitat

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Acronyms

ACE : Accumulated Cyclone Energy

APDI : Annual Accumulated Power Dissipation Index

CMA : China Meteorological Administration

CNN : Cable News Network

EIA : Environmental Impact Assessment

ESV : Ecosystem Services Valuation

FAO : Food and Agriculture Organization

GDP : Gross Domestic Product

GHGs : Greenhouse Gasses

GIS : Geographic Information System

GNP : Gross National Product

ICZM : Integrated Coastal Zone Management

InVEST : Integrated Valuation of Ecosystem Services and Tradeoffs

INWEH : Institute for Water, Environment and Health

IPCC : Inter Governmental Panel for Climate Change

ISME : International Society for Mangrove Ecosystems

ITTO : The International Tropical Timber Organization

JWTC : Joint Typhoon Warning Center

LUCC : Land Use Cover Change

MAB : Man and the Biosphere Program

MODIS : Moderate-resolution Imaging Spectro-radiometer

NASA : National Aeronautics and Space Administration

NHI : Natural Hazard Index

NOAA : National Oceanic and Atmospheric Administration

NTC : Number of Tropical Cyclone

PDI : Power Dissipation Index

RACE : Revised Accumulated Cyclone Energy

RCP : Representative Concentration Pathways

RPDI : Revised Power Dissipation Index

RS : Remote Sensing

SLR : Sea Level Rise

TC : Tropical Cyclone

TCD : Total Cyclone Day

TM : Thematic Mapper

TNC : The Nature Conservancy

UNEP : United Nations Environment Program

UNESCO : United Nations Educational, Scientific and Cultural Organization

UNU : United Nations University

UTC : Universal Time Coordinated

VHR : Very High Resolution

WCMC : World Conservation Monitoring Centre

WNP : Western North Pacific

WPR : West Pacific Region

WRI : Water Research Institute

摘 要

随着全球气候变化，海岸带区域正面临着自然灾害的严重威胁，逐步加剧了海岸带地区的脆弱性以及风险性。研究海岸带地区典型自然灾害（台风）的历史演变趋势及地区的脆弱性与恢复能力，寻求有效的生态环境弹性手段来降低灾害带来的风险，对于未来海岸带地区风险预测与提升海岸社区抵抗自然灾害能力至关重要。

本论文重点以台风为例，以功耗指数（PDI）作为评估历年登陆型台风破坏性的指标，基于ArcGIS中地理空间分析方法，利用中国气象局（CMA）的台风数据，分析时间序列上台风登陆频率和破坏性及其空间分布特征。同时，综合利用斯坦福大学开发的生态系统综合估值与权衡模型（InVEST）和ArcGIS的海岸带脆弱性优化模型，基于海平面上升（IPCC海平面上升预测）与自然栖息地（中国过去25年的填海造地数据）背景预测不同情境下当前与未来海岸带地区面临风暴潮的脆弱性。并且，基于自然栖息地设置了不同的海平面上升的情景，分析海岸带不同地区不同程度的自然栖息地对于减弱海岸带社区风险的潜力。最后，通过构建海岸社区弹性承载力指标评估受台风影响较为严重的沿海省份总体弹性状态，预测不同情境下海岸带社区应对台风的弹性。

研究结果表明：1）中国沿海地区历年台风登陆频率和破坏性时空趋势和模式均经历巨大变化；近年来大多数省份台风登陆频率虽略有下降，但不同热点省份PDIs（中国东南部沿海省份）有显著增加趋势。2）约25%的海岸线和500万居民分布在中国沿海高脆弱地区，到2100年预计将增加一倍；同时，围填海区域如果进行自然栖息地修复和保护工作，将减少45%的海岸带脆弱性地区。3）海岸带社区大部分省份在生态与社区安全维度的弹性有所欠缺。沿海地区政府应高度重视海岸带自然栖息地和生态社区安全弹性发展，尤其需要充分利用自然栖息地在防御沿海自然灾害与提供相关服务价值等方面的作用。

关键词：海岸带自然灾害; 时空模型; InVEST模型; 脆弱性; 弹性

Abstract

Coastal areas are facing severe threats from coastal natural hazards i.e. storm surges, typhoons, and the intensity of these hazards appear to increase due to dramatic climate change. This situation exacerbates coastal vulnerabilities, and indicates increasing future risks. Therefore, it is critical to explore the present status of community resilience to cope with natural hazards. It is also of great importance to seek the more cost effective and environmental friendly tactics to mitigate risks from these natural hazards.

We took typhoon activity as a most representative of disastrous hazards for the assessment of historical spatial-temporal trends and patterns in frequency and destructiveness and sea level rise to predict future vulnerabilities in terms of storm surges under different scenarios of sea level rise and natural habitats. We also estimated the potential of coastal natural habitats to shield the populations that where and to what extent these habitats can lessen the risks for coastal communities from coastal natural hazards. We analyzed previous temporal trends and regime shifts (if any) in frequency, as well as destructiveness of landfall typhoons. The utilized best-track dataset was downloaded from Chinese Meteorological Administration (CMA) and assessments were made by using Power Dissipation Index (PDI) as an indicator of destructiveness. For spatial analysis, we used spatial statistical approach based on geospatial modelling methods in ArcGIS package. For current and future vulnerability from sea level rise induced natural hazards, we used coastal vulnerability model from Integrated Valuation of Ecosystems and Tradeoffs (InVEST) integrated with ArcGIS. To quantify the potential of natural habitats in reducing the risks from natural hazards, different sea level rise (based on IPCC sea level rise projections) by natural habitat (based on LUCC data of coastal reclamation for last 25 years) scenarios were produced. Ultimately, an overview of current resilience status was assessed based on capacity indicators of community resilience. A list of very important indicators was also formulated through partial least squares regression based on the contribution of each variable in shaping the overall community resilience score.

Based on the results of typhoon activity, the coastal region of China has experienced huge variation of spatial-temporal trends and patterns in both frequency and destructiveness of typhoons. There has been a decline of landfall frequency in most of

the provinces along coastal area recently. However, there was a significant increasing trend in PDIs of typhoons hotspots in different provinces (in South-eastern China, except Hainan). This province has a decreasing trend due to a northward shift of landfalling typhoons. Moreover, today, about 25% of the coastline and more than 5 million residents are located in highly vulnerable coastal areas in China. By 2100, this is expected to be doubled. The analysis of different scenarios reveals that the restoration and conservation in recently reclaimed areas are critical in reducing the vulnerability to coastal natural hazards by 45%. This also compliment the notion that natural habitats are believed to be great defense against coastal hazards such as typhoons and storm surges and there is a high confidence that resilience of coastal communities highly relies on the coastal ecological system. Based on the 25 potential indicators of community resilience to coastal natural hazards, the resilience assessment reveals that most of the coastal provinces in China lack in ecological and safety dimension of community resilience. Therefore, it is critical for Chinese government to consider the conservation and restoration of coastal natural habitats in view of their pre-disaster defense against coastal natural hazards and other associated services.

Keywords: Natural Hazards, Spatial-Temporal Modelling, InVEST Model, Coastal Vulnerability, Resilience.

Chapter 1 Introduction

1.1 Background

"What is the worth of an ecosystem? — A marsh, a meadow, a bunch of shrubs? It could be tough to put a value on these kinds of places, which is why a lot of them are being bulldozed and turned into something with an obvious economic benefit"[1].

Today, the most challenging issue coastal communities are facing is flooding in the context of deviations in storms (intensity as well as frequency), sea level rise and change in shoreline (Woodruff et al., 2013). Coastal storms and intense typhoons activities as a consequence of rising sea level can have devastating societal impact. Approximately, 600 million people are living in low-laying coastal areas around the world and about 0.8-1.1 million people are flooded on a global scale every year (Muis et al., 2016). It is well argued that coastal flooding can experience high peaks due to intense typhoons and sea level rise is also a contributor worldwide. Therefore, it is critical to investigate these two natural hazard activities both spatially as well as temporally to formulate positive tactics in this regard. Moreover, it is crucial to put forth cost effective, environmental friendly and adaptable approaches to mitigate the current exposure and future vulnerabilities to cope with coastal natural hazards.

Natural Habitats offer a diverse range of services including climate regulations, provisioning of food and most importantly, shield from natural hazards in coastal regions around the world. Merriam-Webster defines natural habitats as "an ecological area that is inhabited by a particular specie, animal, plant or any other kind of organism". In coastal zones, most commonly found natural habitats are mangrove, seagrass beds, kelps, coral reefs, and sand dunes etc. (Clark et al., 1992). Among all natural habitats, coastal mangrove forests are believed to be most important to safeguard the coastal communities from natural hazards such as typhoons (Giri et al., 2011; Latief & Hadi, 2007). They provide protection from the flooding, surges and strong waves during typhoons. Moreover, it also helps communities to adapt to climate change through increasing the defensive capabilities of communities against sea level rise and adverse

[1] https://www.pri.org/stories/2013-11-29/saved-mangroves-philippine-town-dodges-haiyans-storm-surge (*(*Marianita Calbao, 2013*)*)

typhoons if coupled with engineering infrastructure (Ramesh et al., 2015; Temmerman & Kirwan, 2015). This approach is known as hybrid and can enhance the coastal defenses under current and future climate change (Sutton-Grier et al., 2015).

Recently, both developed and developing countries have faced large number of devastating natural hazards around the world with a loss of thousands of people in the Indian Ocean tsunami, hurricane Katrina, typhoon Yolanda and many more (Sakai et al., 2017). These disasters often result in severe damages to communities, environment, economy and societies (Fang et al., 2017).

However, the grave consequences of these disasters are more severe in developing countries as compared to the ones which are developed due to ill equipped management and lack of appropriate information about the physics of these disasters (Peduzzi et al., 2009). The risk of these hazards in coastal regions of the world is higher as compared to inland areas due to high population and higher capital investments in coastal areas. Annual Disaster Statistical Review (2014) reveals that China, USA, Philippine, Indonesia and India are the top five countries that were most frequently hit by natural disasters in last decade. In the regions where these natural disaster hit/affect, it is believed that tropical cyclones are often the most destructive catastrophes which make them of primary concern and importance when assessing the coastal vulnerability and risk especially under current and future projections of changing climate (Woodruff et al., 2013).

Typhoons (also known as Hurricanes and Tropical Cyclones in some regions) are common among several regions worldwide affecting almost all the tropical regions and are one of the most disastrous natural hazards instigating severe wreckage in coastal regions (Fakour et al., 2016; Reed et al., 2015). Moreover, it is obvious from latest statistics that coastal communities are becoming more prone to extreme typhoons recently (Peduzzi et al., 2012) as there is a growing evidence among scientists that these typhoons most probably will observe a shift in their intensity towards stronger storms in near future (Knutson et al., 2010). Historical analysis shows that the rising population in coastal regions and increasing value of infrastructure is a major cause behind large scale economic damage and disruption due to typhoons (Joel et al., 2008). Among all major typhoons basins worldwide, on an average, approximately 90 typhoons occur every year (Frank & Young, 2007) with a varying number of landfall with the intensity