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Liqiang Xu

Impact of Climate Change and Human Activity on the Eco-environment

An Analysis of the Xisha Islands

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Impact of Climate Change and Human Activity on the Eco-environment

An Analysis of the Xisha Islands

Doctoral Thesis accepted by
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8. Liu X.D.*, **Xu L.Q.**, Sun L.G.*, Liu F., Wang Y.H., Yan H., Liu Y., Luo Y.H., Huang J. A 400-year record of black carbon flux in the Xisha archipelago, South China Sea and its implications. Marine Pollution Bulletin 62: 2205–2212, 2011. [Reproduced with permission from Elsevier]

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Supervisors' Foreword

On 27 September 2013, Working Group I of Intergovernmental Panel on Climate Change (IPCC) published a report namely "Climate Change 2013: The Physical Science Basis, Summary for Policymakers." According to this report, multiple independent proxy data showed that Earth surface temperature increased by 0.85 °C (0.65–1.06 °C) over the period 1880–2012. Moreover, the past three decades (1983–2012) are likely the warmest period over the past 1,400 years. The warming seems worse than we thought in 2007 when IPCC released its fourth assessment report (AR4). Whatever the reason is, global warming is an inconvenient fact and has drawn increasing attention from scientific groups, as well as political organizations. For example, the 2007 Nobel Peace Prize was awarded to former vice president of the United States Al Gore and IPCC.

As human beings, we are more concerned about the future of the Earth under successive warming. The question is what will happen to ecosystems on the Earth, and whether lives can bear such a rapid temperature change. To a geologist, it is a basic principle that the past is the key to the future. In other words, to well predict the future, we need to understand climate change in the past and its impacts on ecosystems. Although we cannot go back to the past by something like time-travel, natural archives can tell us the history of the Earth. Scientists have obtained a large number of reliable climatic records at different timescales by myriad archives, e.g., ice cores, loess, deep-sea sediments, stalagmite, coral and tree rings, etc. The responses of earth ecosystems to climate change, however, have been less documented. Our research group has been working on the topic of ecological responses to climate changes over the last decade.

In addition to abrupt climate change, influences of human activities nowadays on the environment has been unprecedented, and also imposed significant impacts on the environment. In the year 2013, a new scientific journal "Anthropocene" was published to address the extent of interactions that human have with Earth. We also would like to identify any evidence of past human activity and examine its possible impacts on the environment.

We have studied ecological changes in birds and mammals, for example penguins and seals, within the past 3,000 years in high-latitude Antarctica and Arctic.

Eleven years ago, we began to study a new low-latitude area, the Xisha Islands in the central South China Sea. The evolution of the ecosystem on these coral Islands was developed, which is very different from that of the Antarctica and Arctic. A study on the island ecosystem is a new challenge for us. The Xisha Islands have been a world-famous seabird habitat, but birds have almost completely disappeared today. Based on our earlier research, Dr. Xu started his Ph.D. study. It is expected to find the answer or some clues in this Ph.D. thesis.

Using bird-affected sediments (ornithogenic sediments) and avian subfossils, Dr. Xu reconstructed seabird ecology, including seabird population and dietary changes, over the last 2,000 years in this Ph.D. thesis. The changes in seabird ecology in response to climate change and anthropogenic activity is discussed in-depth. It is found that both are partly responsible for changes in seabird ecology. This work provides a scientific basis for future ecological study and resource exploitation on these coral islands.

Hefei, August 2014

Prof. Liguang Sun
Dr. Xiaodong Liu

Abstract

Global warming significantly impacts on ecosystems and has drawn increasing attention in recent years. However, how climate changes affect lives and the environment remains unclear. Seabirds move across aquatic/terrestrial ecosystem boundaries and their fossil remains have been widely used for studying ecological responses to climate change. Five sediment cores from Ganquan (GQ), Guangjin (GJ3), Jinqing (JQ), Jinyin (JY2), and Chenhang (CH) islands of the Xisha archipelago, South China Sea, were collected during field investigations. Well-preserved seabird remains were observed in these sediment cores.

Via analysis of several natural and anthropogenic radionuclides in the ornithogenic sediments, ^{210}Pb dating has been proven to be effective for coral sand sediments in the Xisha Islands. The average supply rate of ^{210}Pb was 126 Bq m^{-2} a^{-1}, very close to the flux of the northern hemisphere average (125 Bq m^{-2} a^{-1}). Radiocarbon analysis of ancient bones showed that the most ancient sample of these cores dated back to approximately 2000 years. Geochemical characteristics of four profiles GQ, GJ3, JQ, and JY2 were analyzed. The results suggest that the source materials of ornithogenic sediments have changed gradually from a two-component (coral sand, guano) mixture to a three-component (coral sand, guano, and humus) mixture, likely indicating the slow development of vegetation following seabird occupation. Cu, Cd, Zn, P, As, Se, and Ba were identified as a group of avian bio-elements. A 2200-year record of seabird population on Ganquan Island was further reconstructed by avian-bioelements and reflectance spectroscopy. A cool climate during the Little Ice Age (LIA) seems more favorable to seabirds on the Xisha Islands. Relative low sea surface temperature (SST), stronger monsoons, and weaker ENSO activity during the LIA might result in increase in marine nutrient mixing and high primary productivity. This provided high food availability and thus supported more seabirds. Moreover, a change in nitrogen/carbon isotope compositions in the collagen of seabird bones suggested that seabirds might dive deeper or travel further to catch prey, due to intra/inter-competitions. The abrupt decline in seabird population in recent times is probably attributed to human activity. The level of Hg in eggshells and the bulk ornithogenic sediments

was determined. Eggshell Hg and Hg flux well-recorded past human activity. We reconstructed a 400-year record of black carbon (BC) deposition flux from profiles GJ3, JQ, and JY2. In the recent 30 years, the BC flux displayed decreasing trend, very likely due to a change in energy structure and development of pollution control techniques. Preliminary analysis of DNA in ancient bird droppings suggests that the guano contains quite a low level of ancient DNA, due to possible severe degradation.

Keywords Climate change · Xisha Islands · Seabirds · Stable isotope · Ecological response · Human activity

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I am quite lucky to have the chance to study in Hefei, Suzhou, and Hong Kong and I would like to show my gratitude to all my team members in Hefei, Suzhou, and Hong Kong. Members of Dr. Liu's research group, including Jiang Shan, Chen Qianqian, Nie Yaguang, Ma Xiaorong, Lou Chuangneng, etc., helped me quite a lot during the past several years.

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Liqiang Xu

Contents

Chapter 1
Introduction

In the year 1962, American biologist Rachel Carson published her book "Silent Spring", which documented detrimental effects of pesticides on the environment. Since then, "environmental issue" appeared for the first time as a technical term. Of all typical environmental problems, global change has drawn increasing worldwide attention over the past decades. Climate change in the post-industrial era is unprecedented in human history. For example, the Earth surface temperature increased by approximately 0.85 °C over the period 1880–2012. The concentration of atmospheric CO_2 was above 400 parts per million (ppm) for the entire month of this April (2014). Such a CO_2 level deserves highest attention, as its concentration has never exceeded 300 ppm over the past 800,000 years.

Although the reasons for warming are sometimes debated, the theory of green house effect is overwhelming. Apart from its causes, global warming has been a painful fact we have to face. Large scale El Niño-Southern Oscillation (ENSO) and frequent extreme weather, e.g. floods, droughts and typhoons etc., are probably effects of global warming. So far, we know little about the impacts of global warming on organisms and the environments. The effects may be beyond our speculation and fatal to lives, including human being, on the Earth. Under a circumstance of successive warming, it is expected to know what will happen to creatures and ecosystems. This is of great importance for human social, economical and cultural development.

The Earth is a system that organisms interact with their inorganic surroundings. The science of Earth system studies interplay between the hydrosphere, atmosphere, lithosphere and biosphere. The present study is thus based on the rationale of Earth system science. Foremost, an ideal study area and some biological materials are required. The Xisha Islands in the central South China Sea is one of the perfect target areas, and the sediments influenced by seabirds serve as robust natural archives.

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