Numerical Modelling of River Discharge Effects on Hypoxia and Its Long-term Responses to Climate Change in the Ariake/Yatsushiro Sea, Japan

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論 文 名　： Numerical Modelling of River Discharge Effects on Hypoxia and Its Long-term Responses to Climate Change in the Ariake/Yatsushiro Sea, Japan
（有明・八代海域における貧酸素に対する河川流量の影響と気候変動への長期的な応答に関する数値モデリング）

区　　分　：甲

論 文 内 容 の 要 旨

Climate change is driving dramatic transformations in the natural environment of coastal marine areas. The consequential shifts in seawater temperature, ocean acidification, rising sea levels, and resulting damage to marine ecosystems have drawn considerable attention from scientists, policymakers, and the broader public. These changes not only impact marine life directly but also have indirect consequences, altering weather patterns, affecting coastal communities, influencing economies, and impacting global biodiversity. Dissolved oxygen (DO) serves as a critical indicator for sustaining the health of marine ecosystems. Nonetheless, reports of declining DO levels have been reported in numerous oceans, shelf seas, and lakes worldwide since 1950. Hypoxia, defined DO below 3 mg/L, is considered to be strongly associated with the amplified frequency of extreme rainfall events driven by climate change, which poses a mounting threat to marine ecosystems on a global scale. However, in many estuarine and coastal waters, DO levels are intricately linked to the interaction of complex physical and biochemical processes. This complexity poses a significant challenge in assessing DO dynamics and maintaining a balanced aquatic ecosystem, presenting an ongoing issue within oceanography.

The Ariake/Yatsushiro Sea is a semi-enclosed coastal water area characterized by features resembling a Region of Freshwater Influence (ROFI).In recent years, the Ariake Sea and Yatsushiro Sea have faced pronounced water quality deterioration, including hypoxia and red tides, significantly impacting local fisheries. After 2000, the decline of Nori (seaweed) has emerged as a crucial concern in Ariake Sea fisheries, while clam farming has become a focal issue in Yatsushiro Sea fisheries since 2010. An increasing number of studies have substantiated that hypoxia, as a significant contributor to the degradation of marine ecosystems in the Ariake/Yatsushiro Sea, has shown a steady increase in both its duration and spatial extent over time. However, a comprehensive analysis of the duration and spatiotemporal distribution of hypoxia attributed to climate change remains incomplete. Two primary reasons contribute to this: Firstly, conducting long-term assessments of hypoxia development through field observations faces challenges due to inadequate data support. Secondly, the intricate nature of the estuary's physical ecology demands models capable of thoroughly analyzing and simulating hydrodynamic and ecological processes, thereby imposing limitations on their utility. In this study, we utilized numerical models that involved coupling a general three-dimensional (3-D) hydrodynamic coastal model with a lower-trophic ecosystem model. We aimed to find out the potential causes behind seasonal hypoxic events and to evaluate the long-term responses to climate change.

The study within this thesis is structured across seven chapters, outlined as follows:

Chapter 1 outlines the research background, objectives, and overall study outline.

Chapter 2 provides an overview of the present conditions and challenges faced by the Ariake/Yatsushiro Sea, exploring the impact of climate change on shallow sea aquatic environments and ecosystems through literature review.

Chapter 3 presents the evaluation of the impacts of extreme summer precipitation events on the marine environment of the Ariake Sea. It aims to illuminate the relationship between salinity stratification and variations in DO levels. This study particularly focuses on investigating the influence of the historic 2020 Kyushu Floods, one of the largest rainfall events in history, on the development of hypoxia. Findings suggest that large-scale effluent events could exacerbate salinity stratification, leading to hypoxic conditions.

Chapter 4 examines the influence of summer effluent on bottom hypoxia within the Yatsushiro Sea. Results highlight that the 2020 Kyushu Floods induced severe hypoxia across extensive areas. Persistent low DO levels in the southern region may be attributed to limited flow velocity and changes in water exchange.

Chapter 5 explores the correlation between river discharge and the duration of hypoxia in Ariake Sea during the summer rainy season. The analysis provides insights into varying effluent scales on environmental dynamics. The study also assesses Ariake Sea stratification due to freshwater inflow using a stratification index. The results indicate that the duration of hypoxia displays a strong positive correlation between hypoxia duration and effluent volume near the river mouth, supported by notably high correlation coefficients.

Chapter 6 comprehensively analyzes the Ariake Sea's long-term water quality changes, emphasizing increasing hypoxia trends across spatial scales. The investigation explores climate change impacts on critical variables—temperature, salinity, DO, and nutrient levels. Findings over the past three decades highlight distinct responses in environmental factors to climate change, resulting in notable shifts in temperature patterns and altered precipitation trends.

Chapter 7 summarizes the conclusions obtained from this study and future work.

The escalation and prevalence of hypoxia pose a growing challenge in global coastal waters. Current water quality management strategies may prove insufficient in addressing deteriorating water quality due to climate change. Innovative, integrated basin-wide hydrology and water quality management strategies hold promise in mitigating hypoxia within the Ariake/Yatsushiro Sea.