

Investigating causes of increasing algal blooms along Vietnam's coast over the past decade

Final Report for the 2024 Marine Alliance for Science and Technology for Scotland (MASTS)
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Summary

Vietnam's economy is highly dependent on marine resources, with nearly 50% of the country's GDP coming from the marine economy. However, Vietnam's seas face challenges including pollution, overfishing, overexploitation, degradation of biodiversity, and natural disasters. Over the past decade, an increasing number of algal blooms have been reported along the coast of Vietnam. These bloom events were unusual in space and time because they occurred in places where they had not previously (e.g., in Phu Quoc), or with surprising changes in seasonality (e.g., NhaTrang, BinhThuan provinces). Some bloom events were reported to be harmful because they caused massive die-offs of wild and farmed fish due to oxygen depletion (e.g., Van Thanh community, Khanh Hoa Province in 2016; CaNa Bay in 2002 (Vo (2013)) or due to harmful algae in Binh Thuan Province 2002, 2007, 2008 (Doan et al. (2003), Quang et al. (2017))). Some events have been reported to have negative impact on tourism (e.g., MuiNe-HonRom, BinhThuan Province 2014). This suggests significant changes in the marine ecosystem along Vietnam's coast. These changes are very poorly understood, with in situ monitoring data very scarce (Huân (2012), Duong et al. (2021)), and modelling efforts limited not only by the lack of data but also limited computing resources (Huân (2012)).

In order to overcome the lacking in situ monitoring data and get insight into what are the triggers of unusual and harmful algal blooms (HABs) along the Vietnamese coast over the past decade, I develop a one-dimensional biogeochemical model (GOTM-ECOSMO) for the Vietnam's coast and Sobol' indices (Sobol' 1993, 2001) and Morris indices to find out which parameters and therefore associated process that control algal bloom timing and peak along the Vietnam's coast. From preliminary results, we found that for the two locations simulated, Sobol and Morris showed that parameters: nitrate half saturation rate, grazing rate of large zooplankton on phytoplankton, initial slope of the P-I curve (or photosynthesis curve), light attenuation of water column are most influence the bloom timing. The order of important of the four paramters is different between the 2 locations. As there is certain simplicity in the model, we continue to improve the model and find additional data for the model, the results on parameter influence bloom timing might change.

Background and Objectives

Vietnam's economy depends heavily on the sea, with almost half of its income coming from marine industries. But the country's coastal waters are under pressure from pollution, overfishing, loss of biodiversity, and natural disasters. In recent years, scientists have noticed more frequent algal blooms along Vietnam's shores. These outbreaks have appeared in unexpected places, like Phu Quoc, and at unusual times of the year in areas such as Nha Trang and Binh Thuan. Some blooms have been harmful, killing large numbers of wild and farmed fish by reducing oxygen in the water or releasing toxins. For example, major fish die-offs occurred in Khanh Hoa Province in 2016 and Ca Na Bay in 2002, while toxic algae were reported in Binh Thuan in 2002, 2007, and 2008. Tourism has also suffered, as seen in Mui Ne in 2014. These events point to big changes in Vietnam's marine ecosystems. Unfortunately, we know very little about what's causing them because there's not enough on-the-ground monitoring, and computer models are limited by scarce data and resources.

We have four hypothesis to these unusual algal bloom: (H1) *changes in transport* of blooms to the coast, (H2) *land-based waste linked to river discharge*, (H3) *point-source discharges* from industrial factories and aquaculture ponds, and (H4) *extreme ocean conditions* linked to climate change such as marine heatwaves. In this visiting fellowship we aimed to investigate hypothesis 3 and 4, which were addressed in following objectives:

Objective 1: Consulting with experts to build model setup and aquaculture scenarios

Objective 2: Model sensitivity analysis to evaluate competing hypotheses regarding algal bloom dynamics

Objective 3: Reporting and roadmap development

Activities and Achievements

Due to unpredictable work demands from my home institute, the start of the visiting fellowship was delayed. This was followed by challenges in finalizing the fellowship agreement, which resulted in the duration being significantly reduced from three months to one month, split into two separate visits. This undoubtedly affected the planned activities and overall achievements of the fellowship.

Unfortunately, we were unable to visit SAMS as originally planned because of scheduling conflicts, which was a great disappointment. We also had limited opportunities to engage with other potential researchers during this shortened fellowship period. The main outcome of the first visit, from September 30 to October 14, 2025, was the development of a model framework (combined 1D physical biogeochemical GOTM-ECOSMO and sensitivity analysis methods (Morris and Sobol in SALib)) to investigate unusual harmful algal blooms along the Vietnamese coast. Preliminary results from this work were presented in an E-Poster at the MASTS ASM 2025 during the second visit, from November 13 to 23, 2025. We benefited greatly from discussions with Dr. Bingzhang from the University of Strathclyde, who has over 10 years of experience monitoring the South China Sea. His valuable suggestions will help improve our model and guide future studies on the marine ecosystem along Vietnam's coast.

Attending the MASTS ASM 2025 during the second visit was both enjoyable and insightful. It provided an overview of marine research in Scotland and broadened my perspective on issues, approaches, and solutions that may be useful for my work. My e-poster on research in Vietnam, although outside the main context of Scottish studies, attracted interest from several attendees. One of them suggested connecting with a research group in Sweden working on blue carbon—the storage of carbon by coastal ecosystems such as mangrove forests in the Mekong estuary in Vietnam.

Remained Challenges

Although the Morris and Sobol sensitivity methods do not require prior knowledge of the data, achieving reasonable model outputs is still essential. Despite some similarities between sparse observational data and global datasets, these are insufficient for the model to accurately reproduce plankton and nutrient patterns along Vietnam's coast. Furthermore,

several key processes—such as horizontal and vertical advection—are currently neglected, which limits the model’s ability to capture realistic dynamics.

Prospects

One of the most significant outcomes of the visiting fellowship is the development of a model for Vietnam’s coastal region. Discussions with Dr. Banas and Dr. Bingzhang have provided valuable inputs for diagnosing issues and suggesting ways to improve model performance. The availability of the current model also serves as an important starting point for engaging with other researchers who are interested in marine research in Vietnam. For example, we can present our work to Vietnamese colleagues, gather feedback, and explore opportunities for collaboration. Moving forward, we plan to continue refining the model and actively seek opportunities to connect with other Vietnamese researchers.

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