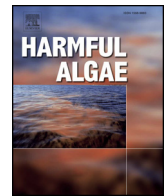




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Over 30 years of HABs in the Philippines and Malaysia: What have we learned?

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ABSTRACT

In the Southeast Asian region, the Philippines and Malaysia are two of the most affected by Harmful Algal Blooms (HABs). Using long-term observations of HAB events, we determined if these are increasing in frequency and duration, and expanding across space in each country. Blooms of Paralytic Shellfish Toxin (PST)-producing species in the Philippines did increase in frequency and duration during the early to mid-1990s, but have stabilized since then. However, the number of sites affected by these blooms continue to expand though at a slower rate than in the 1990s. Furthermore, the type of HABs and causative species have diversified for both toxic blooms and fish kill events. In contrast, Malaysia showed no increasing trend in the frequency of toxic blooms over the past three decades since *Pyrodinium bahamense* was reported in 1976. However, similar to the Philippines, other PST producers such as *Alexandrium minutum* and *Alexandrium tamiyavanichii* have become a concern. No amnesic shellfish poisoning (ASP) has been confirmed in either Philippines or Malaysia thus far, while ciguatera fish poisoning cases are known from the Philippines and Malaysia but the causative organisms remain poorly studied. Since the 1990s and early 2000s, recognition of the distribution of other PST-producing species such as species of *Alexandrium* and *Gymnodinium catenatum* in Southeast Asia has grown, though there has been no significant expansion in the known distributions within the last decade. A major more recent problem in the two countries and for Southeast Asia in general are the frequent fish-killing algal blooms of various species such as *Prorocentrum cordatum*, *Margalefidinium polykrikoides*, *Chattonella* spp., and unarmored dinoflagellates (e.g., *Karlodinium australe* and *Takayama* sp.). These new sites affected and the increase in types of HABs and causative species could be attributed to various factors such as introduction through mariculture and eutrophication, and partly because of increased scientific awareness. These connections still need to be more concretely investigated. The link to the El Niño Southern Oscillation (ENSO) should also be better understood if we want to discern how climate change plays a role in these patterns of HAB occurrences.

1. Introduction

Harmful algal blooms (HABs) have been observed in Southeast Asia (Fig. 1(A)) since the 1970s and continues to be of concern in the region. There have been several previous reviews collating the HAB events in Southeast Asia, their causative species and potential patterns in relation to environmental conditions. Azanza and Taylor (2001) reviewed the occurrence of *Pyrodinium* blooms which started in 1976 in Malaysia and Brunei. They concluded that for both Malaysia and Brunei, *Pyrodinium* blooms have expanded in time, while for the Philippines these have expanded in both frequency and spatially. Fukuyo et al. (2011)

provided a review of different HAB species distributions, impacts and ecology around Southeast and East Asia, whereas Lim et al. (2013) detailed HAB occurrences for Malaysia, documenting more types of HABs that have bloomed and led to human poisonings and fish kills. The most recent review was by Furuya et al. (2018), primarily describing various HAB occurrences in East Asia, both previous and newer types/species that had harmful effects or those species whose presence have been observed in water samples. In this study, we aim to provide a more quantitative assessment of the increase and expansion of HAB occurrences in Southeast Asia using available long-term monitoring data in the most heavily-affected countries in the region, i.e., the

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