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Effects of substratum and depth on benthic harmful dinoflagellate assemblages

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Microhabitats influence the distribution and abundance of benthic harmful dinoflagellate (BHAB) species. Currently, much of the information on the relationships between BHABs and microhabitat preferences is based on non-quantitative anecdotal observations, many of which are contradictory. The goal of this study was to better quantify BHAB and microhabitat relationships using a statistically rigorous approach. Between April 2016 to May 2017, a total of 243 artificial substrate samplers were deployed at five locations in the Perhentian Islands, Malaysia while simultaneous photo-quadrat surveys were performed to characterize the benthic substrates present at each sampling site. The screen samplers were retrieved 24 h later and the abundances of five BHAB genera, *Gambierdiscus*, *Ostreopsis*, *Coolia*, *Amphidinium*, and *Prorocentrum* were determined. Substrate data were then analyzed using a Bray–Curtis dissimilarity matrix to statistically identify distinct microhabitat types. Although BHABs were associated with a variety of biotic and abiotic substrates, the results of this study demonstrated differing degrees of microhabitat preference. Analysis of the survey results using canonical correspondence analysis explained 70.5% (horizontal first axis) and 21.6% (vertical second axis) of the constrained variation in the distribution of various genera among microhabitat types. *Prorocentrum* and *Coolia* appear to have the greatest range being broadly distributed among a wide variety of microhabitats. *Amphidinium* was always found in low abundances and was widely distributed among microhabitats dominated by hard coral, turf algae, sand and silt, and fleshy algae and reached the highest abundances there. *Gambierdiscus* and *Ostreopsis* had more restricted distributions. *Gambierdiscus* were found preferentially associated with turf algae, hard coral and, to a lesser extent, fleshy macroalgae microhabitats. *Ostreopsis*, almost always more abundant than *Gambierdiscus*, preferred the same microhabitats as *Gambierdiscus* and were found in microbial mats as well. With similar habitat preferences *Ostreopsis* may serve as an indicator organism for the presence of *Gambierdiscus*. This study provides insight into how BHAB-specific microhabitat preferences can affect toxicity risks.

Benthic harmful algal blooms are important due to their potential health and ecological impacts, as well as their detrimental effects on commercial fisheries and tourism[1]. Many species of benthic dinoflagellates in the genera *Gambierdiscus*, *Ostreopsis*, *Fukuyoa*, *Prorocentrum*, *Coolia* and *Amphidinium* have been implicated in production of a diverse array of bioactive compounds that impact human health and disrupt marine ecosystems. Most notably, *Gambierdiscus* produce ciguatoxins that bioaccumulate in marine food webs[2–5]. Consuming fish or shellfish contaminated with ciguatoxins results in ciguatera poisoning (CP)[1,6–9] and symptoms of intoxication range from mild gastrointestinal or neurological disturbances to several prolonged illnesses or death[10]. CP is the most studied of the BHAB caused illnesses and is a recognized health threat throughout most tropical regions[11,12]. Certain *Ostreopsis* species produce palytoxin-like compounds and analogues[13–15] that have been related (although

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