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The Impact of Coral Bleaching Severity on the Species Richness of Reef-Associated Swimming, Benthic and Coral Organisms in High-Risk Coral Reefs of Phuket

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Abstract. Coral reefs are one of the most important ecosystems, supporting at least 25% of marine life. However, coral bleaching due to stress decreases reef cover and structure complexity, leading to a reduction of small fish and long-term dearth of fishery productivity. This paper investigates the relationship between the severity of coral bleaching and species diversity of reef-associated swimming organisms, benthic organisms, and corals in two high-risk coral reefs of Phuket, Stonecoral garden (SG) and Ko Pling island (KP). Bleaching severity was quantified through CoralWatch colour scoring, which involved averaging colour differences. These values were compared across coral types using one-way ANOVA with post-hoc Tukey tests, while linear regression was applied to examine the relationship with species richness.. In KP, branching corals showed a significant difference in bleaching ($p<0.05$) compared to soft and boulder corals. In SG, no significant difference ($p>0.05$) in coral types was observed. At SG, benthic and swimming species richness decreased with increased coral bleaching, suggesting that coral health and biodiversity are related, though small sample sizes limit statistical inference. These findings suggest that coral morphology affects bleaching severity, and the effects of bleaching severity on species richness are site-dependent, likely reflecting different anthropogenic pressures, with implications for reef health and management in Phuket.

Keywords: Coral bleaching, Species richness, Reef biodiversity, Phuket coral reefs, Coral morphology

1. Introduction

The abundance and biodiversity of reefs are largely impacted by coral bleaching, making coral bleaching a marker to indicate concern, given the role of coral death in driving potential ecosystem collapse.

In response to bleaching, after >10% local coral loss, fish decline in number, with diversity hotspots equally susceptible to threats [1], which leads to a bleaching and loss of habitat where benthic species saw increased homogenisation and taxonomic similarity, while coral communities became randomly distributed, not clustered, showing overall unpredictability and biodiversity loss [2]. Ultimately, this triggers an ecosystem collapse caused by extensive coral bleaching that may

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decrease both abundance and species richness by >60%, with its impact extending beyond species normally reliant on reefs [3].

Prior studies from recent decades primarily focus on a single taxon or reef, with few simultaneously comparing multiple taxa and reefs subject to different levels of anthropogenic interference, especially in Thailand. By comparing SG and KP, which vary largely in protection levels, the effects of human activity on bleaching severity and consequently species richness can be examined.

This study investigates whether coral bleaching severity significantly predicts species richness of swimming organisms, benthic organisms, and corals across two reef sites in Phuket, and suggests ideas for future solutions and regulations.

This paper is focused on understanding the effects of coral bleaching, specifically in vulnerable reefs like Phuket. In addition to being situated in the Andaman Sea, which was subject to major bleaching events since 2010, Phuket's reefs face the combined threat of rising sea temperatures, high tourist density, and coastal development, making it representative of high-risk reefs in the Indo-Pacific region. The multi-taxa, dual reef analysis of bleaching severity and Phuket community responses can act as a baseline database to guide local protection efforts and inform future conservation projects.

2. Materials and methods

2.1. Study site

Phuket, Thailand's largest island, hosts some of the most thermally stressed reefs in the Andaman Sea. During April and May of 2024, Thailand experienced its most severe heatwave. Investigations were conducted in two reefs, SG and KP, near Nai Yang beach, with locations as seen in Figure 1. KP and its surrounding islands were closed on May 9th, 2024, and reopened in late 2025, when they were available for data collection again, while SG remained open the entire time. The difference in protection status provides a natural comparison for the impact of anthropogenic disturbances on coral bleaching.

Figure 1. Satellite map of the locations of SG, KP and Nai Yang, Phuket, Thailand

2.2. Reef surveys

Field surveys were conducted on 33 dates between December 2nd, 2023, and March 29th, 2026, totalling 13 surveys at SG and 20 surveys at KP. Surveys were conducted in the daytime (13:00 to 14:00) at depths of 3-10 metres.

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Species richness was surveyed using a 10m transect line, set randomly and parallel to the reef crest. The data were recorded as accumulation curves over five-minute intervals for twenty minutes, and the terminal value was used as measurement for species richness. On each sampling date, two independent groups of four recorded the species richness for reef-associated swimming organisms, benthic organisms, coral, and extent of coral bleaching of four types of coral (branched, boulder, plate, soft).

In this study, reef-associated swimmers were defined as actively swimming fauna, including fish, eels, and other mobile taxa. Benthic species were defined as all non-coral species confined to the sea floor. Coral species were defined as the number of distinct coral colonies observed along the transect.

2.3. Data analysis

Data for each survey date are averaged between two groups, to find one species richness per organism type per date. Coral colours are measured based on the CoralWatch Coral Health Chart, a unified scale in which bleaching severity ranges from 1-6. Bleaching severity for each date was calculated as the average colour difference for each coral, where the darkest colour score was subtracted from the lightest colour score, resulting in values ranging from 0 to 5, where 0 is perfectly healthy and 5 is severely bleached. This standardisation allows for comparison across dates.

One-way ANOVA and post-hoc Tukey are used to compare bleaching severity across coral types. Linear regression is used to examine the relationship between bleaching severity and species richness.

3. Results

3.1. Sites bleaching severity

As seen in Figure 2, mean bleaching severity was compared between sites descriptively. The mean bleaching of SG is 2.80, compared to mean bleaching of KP at 2.68. The differences between the two reefs were not significant ($p>0.05$). The distribution of SG is slightly bimodal, with fewer points clustered below the mean (2.2-2.3), and a denser cluster around or above the mean (2.8-3.3). The bimodal distribution could be attributed to two distinct stress periods, prior to and after the 2024 heat stress event. The distribution of KP appears unimodal and relatively symmetric, with most points clustered between 2.3-3.1.

Since KP closed due to a severe bleaching event, the extreme stress hit vulnerable corals like branching corals hardest, causing detectable differences between coral types. Meanwhile, SG, a reef constantly open to human activity, likely experienced uniform stress. Despite KP's worse starting point in bleaching severity, since the park closed temporarily following the stress event, its mean bleaching is lower than that of SG.

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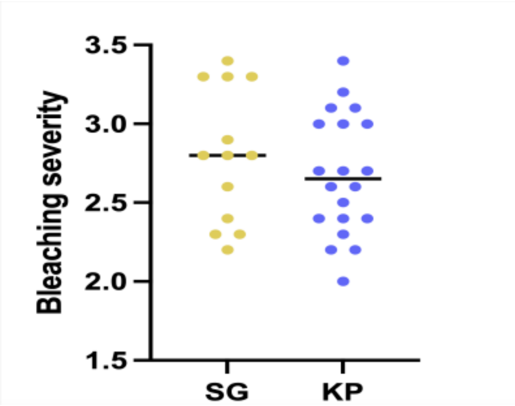

Figure 2. Bleaching severity of SG and KP

3.2. Coral bleaching - impact on species richness

As seen in Figure 3, linear regression was used to examine the relationship between bleaching severity and the species richness of benthic, swimming, and coral species. In SG, there is no correlation ($p>0.05$) between the species richness of benthic, swimming, and coral, and bleaching severity, though statistical power is limited by small sample size. The trend line of benthic species moderately decreases with bleaching, and swimming species are shown to slightly decrease. Unexpectedly, coral species are shown to slightly increase. This could be attributed to algae species that take over dead substrate and encourage coral growth, or the increase of heat-tolerant species which exceed pre-bleaching populations [4]. A study showed that following heat stress (a common cause of bleaching), benthic communities were impacted, a result similarly reflected in SG [5]. Swimming species' decrease is similarly attributed to coral bleaching, though bleaching may have little effect on fish in a short time period, hence the slight effect [6].

In KP, there is also no correlation ($p>0.05$) between the species richness of benthic, swimming, and coral, and bleaching severity, though statistical power is limited by small sample size. The trend lines of all three species are shown to increase with bleaching severity. KP's anomalous pattern of species richness increasing with bleaching severity could also be attributed to the natural park's closing. During the period of little human interference, biodiversity was able to recover, hence the growth seen in benthics, swimming, and coral species, while bleached coral took longer. Therefore, species richness and bleaching severity increased simultaneously, but were independent of each other. This would explain why the expected negative relationship between species richness and bleaching severity, observed in SG and consistent with literature, isn't seen in KP.

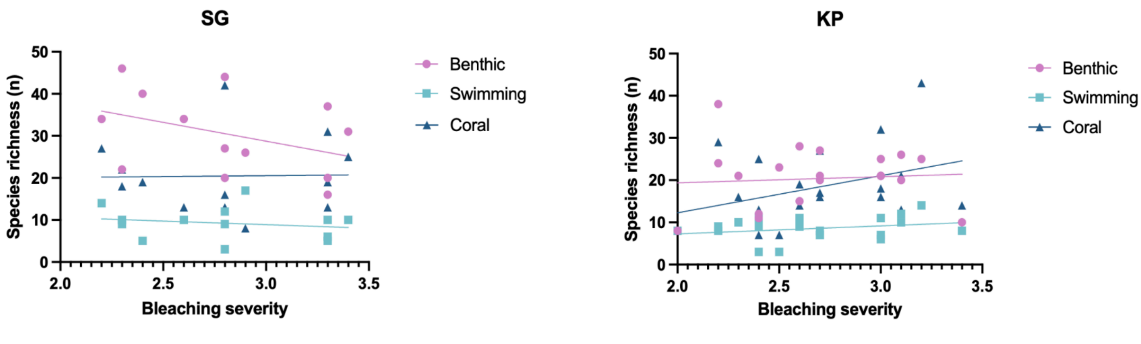

Figure 3. Linear regression of bleaching severity on benthic, swimming, coral species in SG and KP

3.3. Coral type bleaching sensitivity

As shown in Fighre 4, one-way ANOVA with post-hoc Tukey was used to compare bleaching severity across coral morphologies (soft, plate, branched, boulder). In SG, bleaching severity did not differ significantly ($p>0.05$) across all four coral types. Soft and plate corals have lower bleaching severity on average, compared to branched and boulder corals. SG, a reef consistently open to human activity, likely received uniform bleaching, making differences between coral types indistinguishable.

In KP, bleaching severity differed significantly (one-way ANOVA, $p<0.05$) between coral types. Post-hoc Tukey revealed that boulder and branched corals ($p<0.001$), and soft and branched corals ($p<0.01$) were significantly different. Soft corals have the lowest bleaching severity on average, and plate and branched have the highest. Since KP experienced a significant bleaching event, the extreme stress was amplified on soft and boulder corals, causing a significant difference between coral types.

Out of the four coral types, branched corals are often most susceptible to bleaching, and large boulder colonies are the least, because massive corals have thicker tissue, giving them more immunity to heat and light stress [7]. The vulnerability of branched corals is reflected in both SG and KP. However, this pattern is not absolute. A study shows that as bleaching severity increases, massive porites (often taking the form of boulders) become most vulnerable. Since SG has higher average bleaching severity, its more bleached boulders could be due to this reason [8].

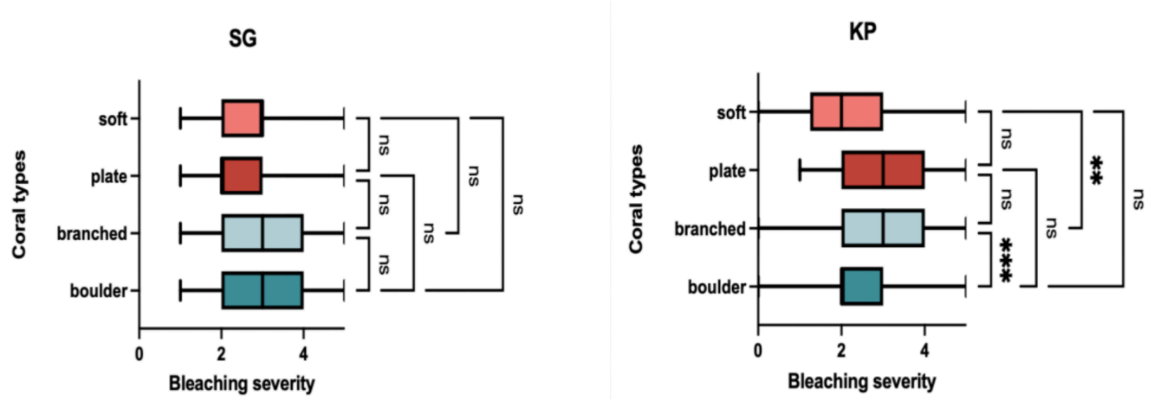

Figure 4. One-way ANOVA with post-hoc Tukey of bleaching severity on coral types in SG and KP

4. Conservation implications

From both SG and KP data, backed by literature, branched corals are most vulnerable to coral bleaching. Hence, translocation and protection of branched corals should be prioritised. The data collected across months could identify critical stress periods, to time future closures and promote coral health.

Although no data was available on KP prior to its closure, the closing was likely beneficial. Even though it was closed due to severe bleaching, meaning its coral were in far worse conditions than those of SG, in the year and a half of no human activity, KP's bleaching severity values were lower than those of SG (though without pre-closure baseline data, a direct causal relationship cannot be established). It suggests that even short-term closures are beneficial to coral health.

However, it is important to understand that the cause of major coral bleaching is often sustained heat stress, something park closure cannot solve. Instead, closure is the best solution to short-term, human-induced stress. To address long-term reef health, regular reef monitoring using the CoralWatch health chart could recognise stress periods before mass coral death, and enable earlier intervention. Additionally, future studies should expand to other reefs in the Andaman Sea, to confirm if patterns seen at KP and SG are applicable regionally. To address the root of the problem, thermal stress, coordinated policies need to limit anthropogenic carbon dioxide emissions and combat rising ocean temperatures.

5. Conclusion

This study demonstrates that the effect of bleaching severity on species richness varies based on human interference and protection, and suggests a reduction in biodiversity, and the effect of coral morphology on bleaching is only significant in large-scale stress events. By employing CoralWatch coral colour scoring, one-way ANOVA with post-hoc Tukey and linear regression, this study investigates the relationship between bleaching severity and the species richness of swimming, benthic and coral species across two reefs with differing human interference in Phuket, Thailand. Bleaching severity was found to be negatively associated with the species richness of benthic and swimming species in SG, while coral morphology significantly impacted bleaching severity in KP only. At SG, no significant difference in coral bleaching can be found across coral types, while an unexpected increase in coral count may indicate algae that facilitate coral growth and take over dead substrate. KP's temporary closure appears to be associated with biodiversity recovery, likely reflecting how the lack of human interference allowed for biodiversity recovery independent of bleaching. Without pre-closure data, though, this interpretation remains preliminary. Data for this study is solely collected in Phuket, an island with a unique reef-populated and tourist-heavy profile, distinguishable from other geographically similar locations. Future studies should include pre-closure data as a baseline, and expand to neighbouring Andaman reefs for a more complete overview of the effect of coral bleaching within the region and of whether SG and KP's patterns are reflected regionally.

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