Dramatic reduction in colony size, but not abundance, in a major Caribbean reef building coral inside a no-take area in Barbados between 1997 and 2023

Reducción dramática del tamaño de las colonias, pero no de su abundancia, en un importante coral constructor de arrecifes del Caribe dentro de una area marina protegida en Barbados entre 1997 y 2023

Réduction dramatique de la taille des colonies, mais pas de leur abondance, dans un important corail constructeur de récifs dans la Caraïbe à l'intérieur d'une aire marine protégée à la Barbade entre 1997 et 2023

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EXTENDED ABSTRACT

Coral reefs worldwide are experiencing rapid shifts in species composition due to climate change, threatening their long-term viability. While local conservation efforts such as no-take marine reserves can help mitigate climate impacts, their effectiveness depends strongly on local context (Bruno et al., 2019). Understanding the impact of these measures requires baseline studies and long-term monitoring of coral populations. Traditionally, coral reef health has been assessed using coral cover percentages, but this metric does not capture important demographic changes. Instead, tracking colony size-structure over time provides valuable insights into coral population dynamics and resilience (Edmunds and Riegl, 2020).

In Barbados, coral cover has declined significantly since the 1980s, which prompted the establishment of the Barbados Marine Reserve (BMR) in 1981. The BMR includes Bellairs reef, which has been under no-take protection since the BMR designation. In 1997, Lewis (1997) conducted a study on the colony-size structure of the massive starlet coral, *Siderastrea siderea*, at Bellairs reef and six other sites along Barbados' west coast. His findings indicated that the Bellairs reef had one of the healthiest *S. siderea* populations, with high colony density, a wide size distribution, and relatively low partial mortality. Given the increases in anthropogenic and climate-related stressors globally over the past 26 years, this study aimed to re-measure the *S. siderea* population size-structure at Bellairs reef to determine whether the no-take status has effectively protected it from these stressors.

In 1997, Lewis (1997) surveyed *S. siderea* by deploying 80 quadrats (10m × 10m) along perpendicular transects on Bellairs reef, counting colonies, and measuring their diameters. In 2023, this study repeated the survey using 49 quadrats along seven transects at depths of 0.5–7m. Colony measurements included width, length, and height. Lewis (1997) did not provide raw colony size data but instead presented a size-frequency distribution of colonies grouped into 50 cm diameter classes. These data were thus extracted using imagery software. To compare size-structure between 1997 and 2023, colony diameter estimates from the 2023 dataset were binned into the same size classes. A Mann-Whitney test assessed changes in mean colony size, and a chi-square test examined shifts in colony size distribution.

The extraction of the 1997 data successfully replicated Lewis's reported colony counts (493 colonies across 80 quadrats), confirming the accuracy of the approach. The estimated mean colony diameter in 1997 closely matched Lewis's reported value, indicating minimal data loss during extraction. In 2023, 225 colonies were recorded across 49 quadrats. The 1997 size-frequency distribution exhibited a right-skewed shape, with small colonies (0–50 cm) making up 53% of the population but larger size classes also well-represented (Figure 1). In contrast, the 2023 distribution was much more heavily skewed towards small colonies, which accounted for 96% of the population (Figure 1). The largest colony observed in 2023 was only 150–200 cm, with no colonies in larger size classes (Figure 1). Thus, mean colony size decreased 2.5-fold between 1997 and 2023 (Mann-Whitney test: $W=101171$, $p<0.001$), with significant changes in colony size class distribution (Chi-square test: $X^2=124.08$, $p<0.001$). Interestingly, despite the strong shift in size structure, mean colony density remained stable between the two periods, as evidenced by the overlap in 95% confidence intervals (1997: 5.0–7.4 colonies per 100m²; 2023: 4.4–7.7 colonies per 100m²). In both years, similarly high variance-to-mean colony density ratios (1997: 5.1; 2023:

5.4) indicated that colonies remained highly clustered in distribution.

In 1997, Bellairs reef hosted one of the healthiest *S. siderea* populations in Barbados, potentially playing a key role in the replenishment of this coral in Barbados. However, this study has shown a dramatic shift in colony size structure over 26 years, with a significant disproportionate decline in moderate-to-large colonies. Multiple factors likely contributed to this shift. According to Bak and Meesters (1999), chronic environmental stressors such as sedimentation, nutrient loading, and turbidity should lead to lower recruitment and higher mortality in smaller colonies, shifting the population towards larger sizes. However, the observed pattern was the opposite: mean colony size decreased, despite historical evidence of nutrient pollution along Barbados' west coast. This suggests that *S. siderea* may be relatively tolerant to eutrophication but vulnerable to other stressors. Other potential contributors to colony loss include thermal-induced bleaching, disease outbreaks, and episodic environmental disturbances. Barbados has experienced multiple mass bleaching events since the 1990s. Larger *S. siderea* colonies have been shown to be more susceptible to bleaching (Brandt, 2009), which increases mortality risks. Additionally, *S. siderea* was affected by the 2023 outbreak of Stony Coral Tissue Loss Disease (SCTLD) in Barbados, which seemed to have also disproportionately impacted larger colonies (H. Vallès, unpublished data). These factors, coupled with chronic environmental stressors, might have been driving the observed size-structure shift. Interestingly, despite significant changes in colony size structure, overall colony density and highly aggregated colony distribution remained stable. This pattern is likely due to the fission of large colonies, turning them into smaller daughter colonies. The current lack of both moderate-to-large colonies, combined with increasing environmental stressors, suggests that *S. siderea* at Bellairs reef may be at risk of further decline despite its location within a no-take marine reserve.

This study reveals that while *S. siderea* abundance at Bellairs reef has remained stable over 26 years, its size structure has shifted dramatically due to the disproportionate loss of moderate-to-large colonies. Chronic and episodic stressors, including bleaching, disease, and water quality deterioration, likely played key roles in this shift. Despite the protection afforded by the no-take status within the BMR, this population is at risk of further decline due to continued stress exposure. Future monitoring efforts should increase the frequency of surveys while focusing on colony size-structure and coral recruitment to accurately forecast demographic trends in this coral population.

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