SUPPLEMENT

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Emerging filamentous red algae blooms: A rising threat to coral reef restoration

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ABSTRACT

Introduction: The *in-situ* cultivation of acroporid corals in Culebra, Puerto Rico, has been impacted by blooms of filamentous red algae in recent years. Since 2022, the onset of this bloom has occurred from March to the end of April, with a consistent recurrence pattern. The filamentous algae become entangled with corals both in nursery structures and after outplanting to the reef, often leading to partial or complete tissue smothering.
Objective: Document, for the first time, the recurrence and ecological impact of a filamentous red algal bloom observed since 2022 in the coral nurseries and restoration sites of Culebra, Puerto Rico.
Results: The mortality rate resulting from each bloom event, including corals on farms and transplants, ranged from 5 % to 20 %. The specific algal species or assemblage remains unknown; however, visual inspection is consistent with species of the genus *Cottoniella*, characterized by fine, red filamentous thalli, profuse branching, and the formation of dense, entangling mats.
Conclusions: The environmental factors that promote these blooms and their origin remain to be elucidated. Furthermore, the origin and the geographical distribution of these blooms have not been determined; at present, it is yet unclear whether they are a local or regional phenomenon. It is vital to note that these events, when considered in conjunction with other environmental disturbances, have the potential to compromise the success of coral reef restoration and conservation efforts.

Key words: Red Algal Bloom, coral farming, *Acropora cervicornis*, Culebra, Puerto Rico.

RESUMEN

Floraciones emergentes de algas rojas filamentosas: una amenaza creciente para la restauración de los arrecifes de coral

Introducción: El cultivo in situ de corales acropóridos en Culebra, Puerto Rico, se ha visto afectado por floraciones de algas rojas filamentosas en los últimos años. Desde 2022, el inicio de esta floración ha ocurrido de marzo a finales de abril, con un patrón recurrente constante. Las algas filamentosas se enredan con los corales tanto en las estructuras de vivero como después de trasplantarlos al arrecife, lo que a menudo provoca una asfixia parcial o total del tejido.
Objetivo: Documentar, por primera vez, la recurrencia e impacto de afloramientos de algas rojas observados desde el 2022, en fincas de corales y áreas de restauración de Culebra, Puerto Rico.

Resultados: La tasa de mortalidad resultante de cada floración, incluyendo corales en granjas y trasplantes, osciló entre el 5 % y el 20 %. Se desconoce la especie o conjunto específico de algas; sin embargo, la inspección visual es consistente con especies del género *Cottoniella*, caracterizadas por finos talos filamentosos rojos, profusa ramificación y la formación de densas esteras enredadas.
Conclusiones: Los factores ambientales que promueven estas floraciones y su origen aún no se han dilucidado. Además, no se ha determinado el origen ni la distribución geográfica de estas floraciones; actualmente, no está claro si se trata de un fenómeno local o regional. Es vital señalar que estos eventos, cuando se consideran en conjunto con otras perturbaciones ambientales, tienen el potencial de comprometer el éxito de los esfuerzos de restauración y conservación de los arrecifes de coral.

Palabras clave: Afloramiento de algas rojas, fincas de corales, *Acropora cervicornis*, Culebra, Puerto Rico.

INTRODUCTION

Macro-algae are essential components of coral reefs, providing shelter and food to a wide array of organisms and playing a key role in the nutrient cycle. However, disease outbreaks—such as the mass mortality events of *Diadema antillarum* in the early 1980s and again in 2022 (Rodríguez-Barreras et al., 2023)—along with the overfishing of key reef fishes and invertebrates, have contributed to a shift from coral-dominated to algae-dominated ecosystems. In response to current coral reef conditions, the conservation community has increasingly adopted active restoration strategies, such as human-assisted coral propagation. Coral farming has become a leading strategy for propagating and restoring acroporid populations in the Caribbean, largely due to the relatively high survival and growth rates of coral fragments during the nursery stage (Ruiz-Diaz et al., 2022). However, these operations face threats similar to those encountered by corals in the wild, including rising water temperatures, diseases, and hurricanes. In recent years, a new and persistent threat has emerged for coral farm managers: (Fig. 1).

These algal blooms have recurred annually from 2022 to 2025, persisting for only a few weeks between March and April. During bloom events, the algae form dense, pink-to-red, filamentous masses that drift within the water column and readily become entangled on the branches of *Acropora cervicornis* and *A. palmata*. This entanglement is associated with coral mortality rates ranging from 5 % to 20 % per event, which have been documented in both nursery-reared corals and corals outplanted onto restored reefs (Fig. 1B–E).

Although we were unable to conduct microscopic or molecular analyses to conclusively identify the species or species complex, visual inspection of the algal morphology suggests affiliation with the genus *Cottoniella*. The observed thalli exhibit a distinct pink-to-red coloration and consists of slender, delicate filaments with extensive, pseudodichotomous branching that produces a dense, bushy appearance. This combination of morphological traits, along with the algae's propensity to form drifting, entangling mats, is consistent with descriptions of *Cottoniella* spp.

Additional support for a tentative assignment to the genus *Cottoniella* comes from its known biogeographic distribution and ecological traits. The genus was first described from the Antilles in the early 20th century and exhibits a broad geographic range, extending from the southern coast of Brazil to the Florida Keys, as well as the Mediterranean Sea and the Canary Islands (Gavio, 2021; Gil-Rodríguez et al., 1985). To date, seven species and one variety of *Cottoniella* have been recognized, four of which (*C. arcuata, C. filamentosa, C. fusiformis, and C. sanguinea*) have been reported from tropical and subtropical regions of the western Atlantic (Freshwater & Idol, 2013). Species within this genus are commonly observed as epiphytes on macroalgae such as Sargassum (Fig. 1A; Suárez et al., 2015) and have also

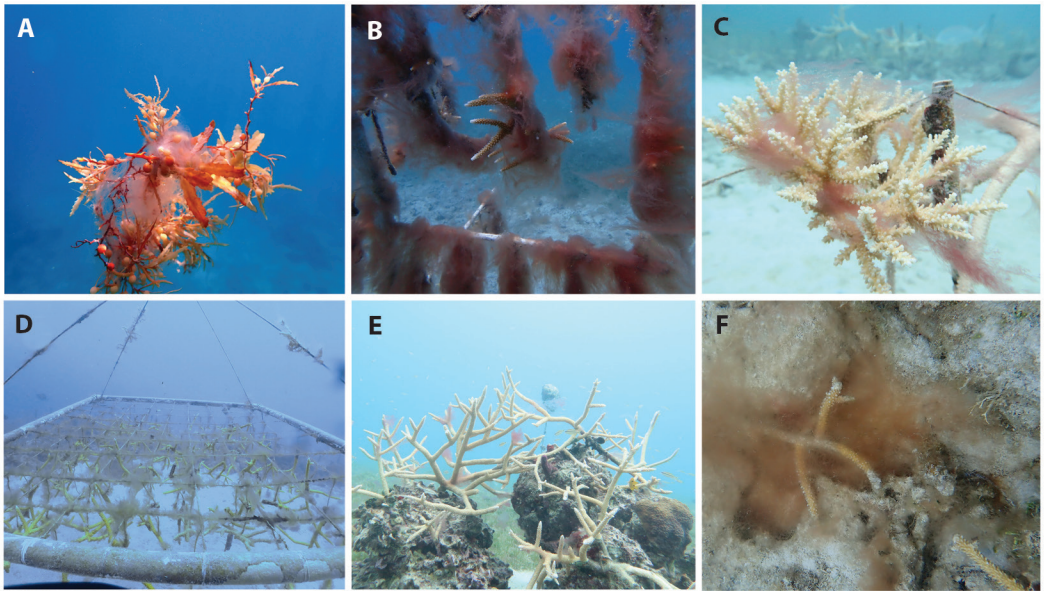

Fig. 1. Images of algae belonging to the genus *Cottoniella* spp.. **A**. A floating *Cottoniella* spp. entangled in a branch of *Sargassum* spp. (image taken in 2022). **B**. Image from the 2022 event of *Acropora cervicornis* nourished in tree farms entangled with *Cottoniella* spp.. **C**. Image from 2023 of *Cottoniella* spp. entangled in an individual *A. plorifera*. **D**. Image from 2025 showing *Cottoniella* spp. entangled in an *A. cervicornis* set on a floating coral farm. **E**. Image from 2023 of *Cottoniella* spp. entangled in an outplanted colony of *A. cervicornis*. **F**. Image taken in 2024 showing *Cottoniella* spp. entangled in an outplanted *A. cervicornis*. Notice that some sections of the colony are dead.

been documented in deeper reef environments, occurring at depths of up to 92 m (Gavio, 2021; Suárez et al., 2015; Taylor, 1972).

Currently, two fundamental taxonomic and ecological questions remain unanswered regarding these algae blooms: (1) The species composition (whether single or multiple species) has not been confirmed. This challenge stems from the unpredictable nature of the outbreaks, which complicates the availability of materials, such as chemical solutions, that preserve the physical integrity of the collected specimens to perform the necessary microscopic and genetic analyses. (2) The source(s) of these blooms and the environmental factors driving them remain unknown. Understanding whether these events are localized or occurring across the wider Caribbean is crucial for the success of coral restoration efforts (Fig. 1F).

Given their relatively high prevalence in the last couple of years and their detrimental effects on acroporids, addressing these questions are essential to mitigate the impact of these floating algae blooms on coral rehabilitation initiatives. To bridge the knowledge gap, establishing a regional network or similar initiative to report, monitor, and document floating algae blooms will be vital. This note represents an initial step toward documenting these events and highlighting an emerging issue that, if persistent, could significantly impede reef restoration initiatives and add yet another stressor to the already vulnerable coral reef ecosystem.

Ethical statement: The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we

followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

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