

**Reef Resilience and Assisted Evolution:  
What Do These Terms Mean for Belize, and What Role Do Coral Restoration Efforts Play?  
A Review of the 2017 Bleaching Event with this in Mind, and with Historical Context**

**Resistencia de los Arrecifes y Evolución Asistida:  
¿Qué Significan estos Términos para Belice y qué Papel Juegan  
los Esfuerzos de Restauración de los Corales?**

**Una Revisión del Evento de Blanqueamiento de 2017 con esto en Mente y con Contexto Histórico**

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Tenant Compte de Cela et du Contexte Historique**

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**ABSTRACT**

Belize experienced a severe coral bleaching event in 2017. How severe was it? How do we compare to previous years and how do we plan for future events? Shared here are the bleaching results for over 20 sites in Belize, compared to previous years going back to 2008, coupled with *in situ* temperature data 2009 - 2017 (where available). Also shared here is what we know, and what we still don't know, in terms of corals' resilience (e.g. coral host and symbiont genetics), and what evidence we have for adaptation to higher temperatures in the context of reef restoration efforts, ongoing for over a decade now in southern Belize. Specifically, are some shallow acroporids now more temperature tolerant than other coral species, when once they were most susceptible? What are the applied management strategies we can implement to improve Belize's resilience to future bleaching events?

KEYWORDS: Acroporids, Belize, bleaching, restoration, resilience

**INTRODUCTION**

The first large-scale coral bleaching event in Belize was documented in 1995 and a rapid 'swim-bar method' created to quickly evaluate the health of corals by site (McField 1999). Other major bleaching events in Belize were in 1998 and 2005 (Kramer and Kramer 2000, Aronson et al. 2002, McField et al. 2005), and although coral bleaching events have long been predicted to become annual (Hough-Guldberg 1999), it wasn't until 2008 that Marine Protected Area (MPA) managers organized a nationwide, synchronized monitoring effort, via the National Coral Reef Monitoring Network (NCRMN) in Belize. The NCRMN was formed in 1999, and its members consist of all MPA Non-Governmental Organizations (NGO's) co-managers, the Belize Fisheries Department, the University of Belize and a few other key NGO's involved in coral reef monitoring. While there have been other bleaching events in Belize since 2008, synchronized nationwide monitoring had tapered off until 2017, partially due to lack of funding. Fragments of Hope (FoH), a member of the NCRMN, has been focusing on acroporid restoration in Belize since 2006, and also tracking the bleaching history of individual transplanted acroporid colonies over time coupled with their host and symbiont genetics analysis (Bowden-Kerby and Carne 2012). Based on long term mapping of extant shallow acroporids in Belize during warmer months, collecting *in situ* temperature data, and choosing the most thermally tolerant genotypes for propagation and outplanting, results are shared here from Belize's 2017 nationwide bleaching event, compared to previous bleaching events, and compared to acroporid replenished sites in southern Belize suggesting that assisted evolution, at least in Belize, need not involve land based nurseries and may be happening in already in the short term (less than 10 years).

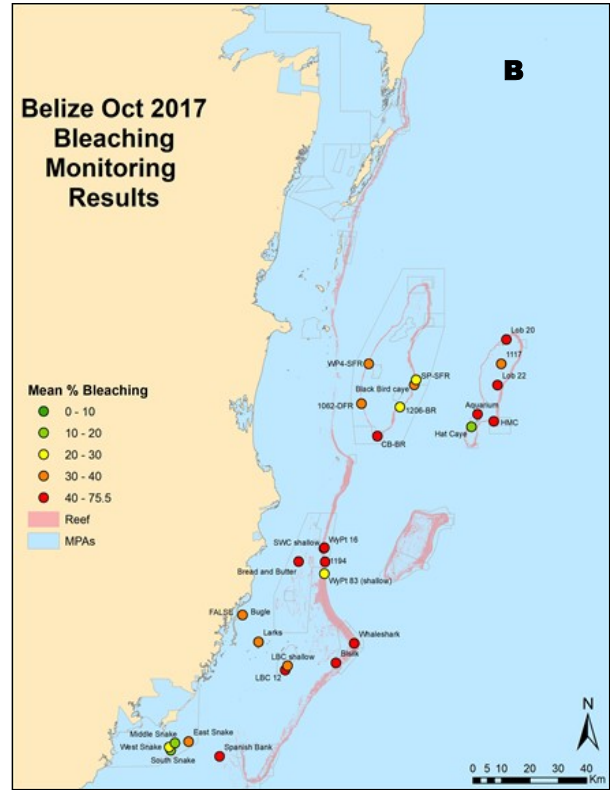
**METHODS**

Bleaching surveys were completed using the rapid swim-bar drop methodology (McField 1999), and as recommended by the Belize Coral Bleaching Response and Management Plan (Searle et al. 2014), where 200 corals per site are assessed for bleaching status (pale, partially bleached, wholly bleached), presence of disease, and percent old or recent mortality is also recorded. Because the "pale" category is so subjective per data collector, only partially and whole bleached corals are recorded in the final graphs (percent bleached corals of 200 surveyed by site.) Less sites were monitored in 2017, then in 2008, but they include data from over 20 sites in the following MPAs: Lighthouse Atoll Marine Reserve (LHMR), Turneffe Atoll Marine Reserve (TAMR), South Water Caye Marine Reserve (SWCMR), Gladden Spit and the Silk Cayes Marine Reserve (GSSCMR), Laughing Bird Caye National Park (LBCNP) and Port Honduras Marine Reserve (PHMR), and three sites outside of any MPA, near Placencia in southern Belize. There are additional data sets from some southern Belize sites that FoH has been monitoring more consistently than the national surveys. *In situ* temperature data are collected every hour, and uploaded annually, using HOBO U-22 ProV2 data loggers. Reef replenishment methods used in Belize are

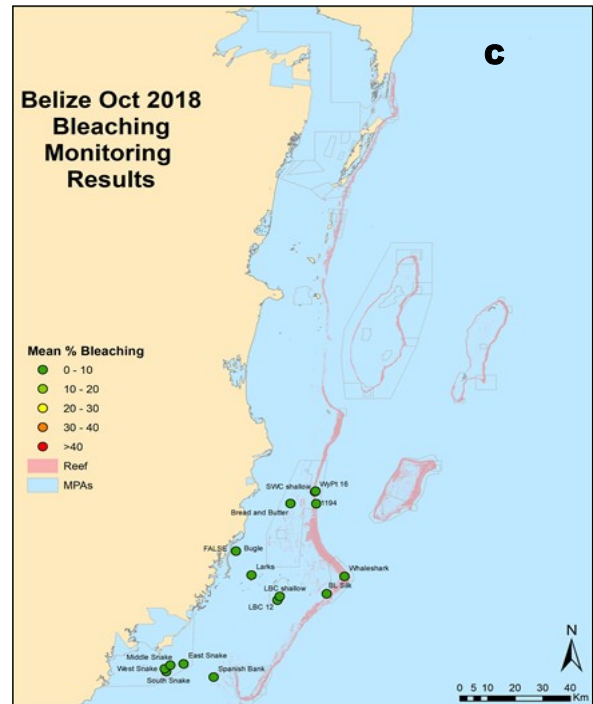
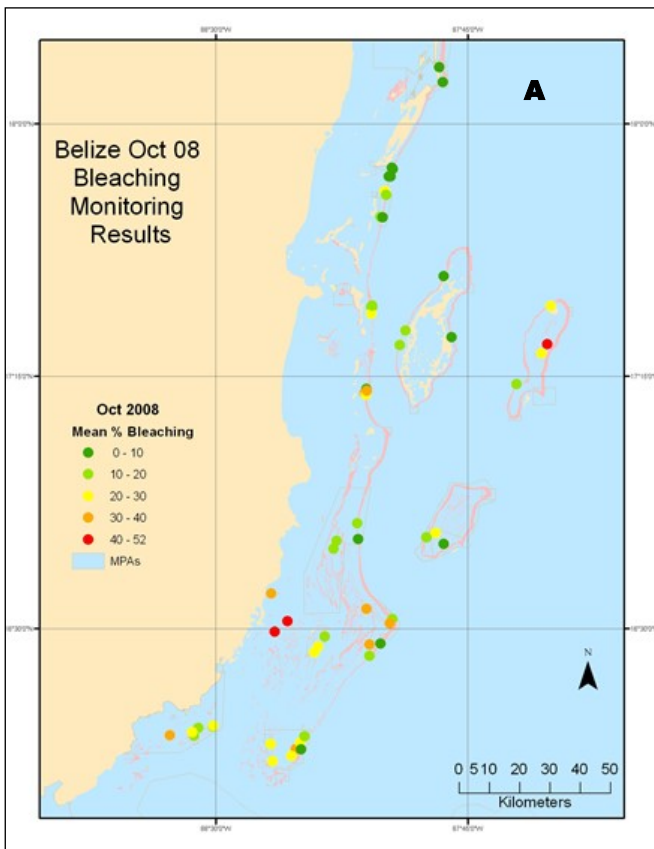
outlined in Carne et al. (2016) and in the Fragments of Hope manual (V2 2019). General reef health surveys are conducted every two years in Belize using the Atlantic Gulf Rapid Reef Assessment ([www.AGRRA.org](http://www.AGRRA.org), Lang et al. 2018) and published in the Healthy Reefs Initiative Report Cards ([www.healthyreefs.org](http://www.healthyreefs.org)).

**RESULTS AND DISCUSSION**

The bleaching event in 2017 was more severe in 2017 than even in 2008 (Figures 1a-b), with many sites in 2017 experiencing greater than 40% bleaching (of 200 corals surveyed per site). It was also more consistently severe in 2017 from north to south, than in 2008. However, looking closer at near shore versus off shore sites in southern Belize (Figure 2), site names False, Larks and Bugle, bleaching severity was slightly less in 2017 than in 2008 or 2010, despite higher *in situ* temperatures in 2017 (Figure 3) and analysis of the 2017 bleaching event by degree heating weeks revealing it as unprecedented in severity. While some shallow, transplanted *Acropora palmata* did bleach in 2017 at Laughing Bird Caye National Park (LBCNP), they fully recovered with no mortality within two months, defining resilience (Figure 5). Most other nursery-grown, outplanted shallow acroporids at LBCNP did not bleach at all during 2017's severe bleaching event (Figure 6a) compared to other species near the outer reef, at slightly deeper sites (~ 5m), even in a channel with higher water movement (Figure 6b). This data is encouraging for continued reef replenishment efforts, since the methods to date include scoping for naturally thermally tolerant corals



**Figures 1a-b.** Maps comparing the results of bleaching surveys by sites in October Belize 2008 (left) and 2018 (right). Color codes: red is <40%, orange is 30-40%, yellow is 20-30%, light green is 10-20% and dark green is < 10% corals bleached or partially bleached of 200 corals surveyed.



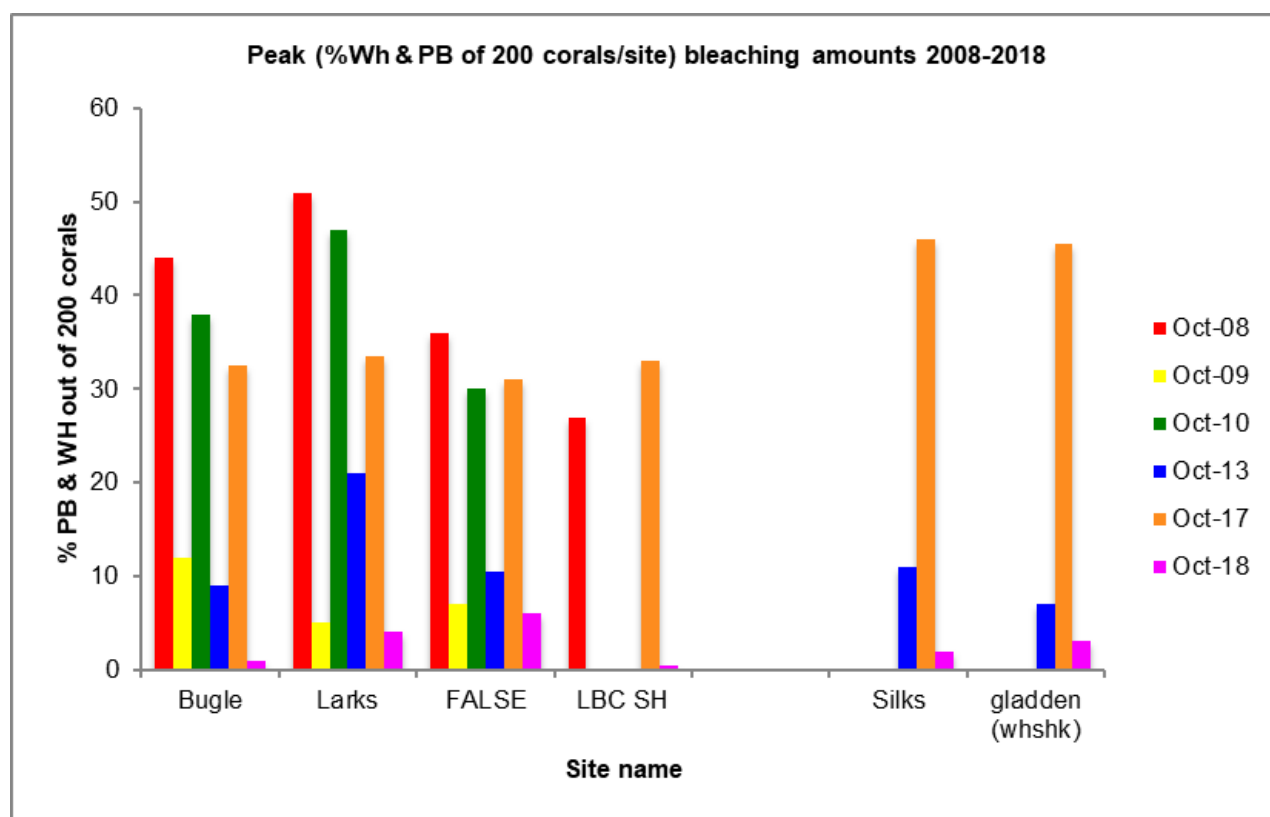
**Figure 1c.** Map of bleaching survey results by site in October 2018.

as donor colonies, in the warmer months. Since bleaching events are becoming annual, as predicted, only differing in the severity each year (Figure 1c), it is recommend to:

- i) Plan and budget for annual bleaching monitoring,
- ii) Use this date to select more thermally tolerant corals for reef replenishment efforts, and
- iii) Use long term resilience maps to guide more focused enforcement of the best reef sites, since manglers resources are often limited.

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**Figure 2.** Bleaching survey results at three near shore sites in southern Belize 2008-2018, and at two off shore sites (2013, 2017 & 2018). Numbers reflect number of bleached or partially bleached corals per 200 colonies.

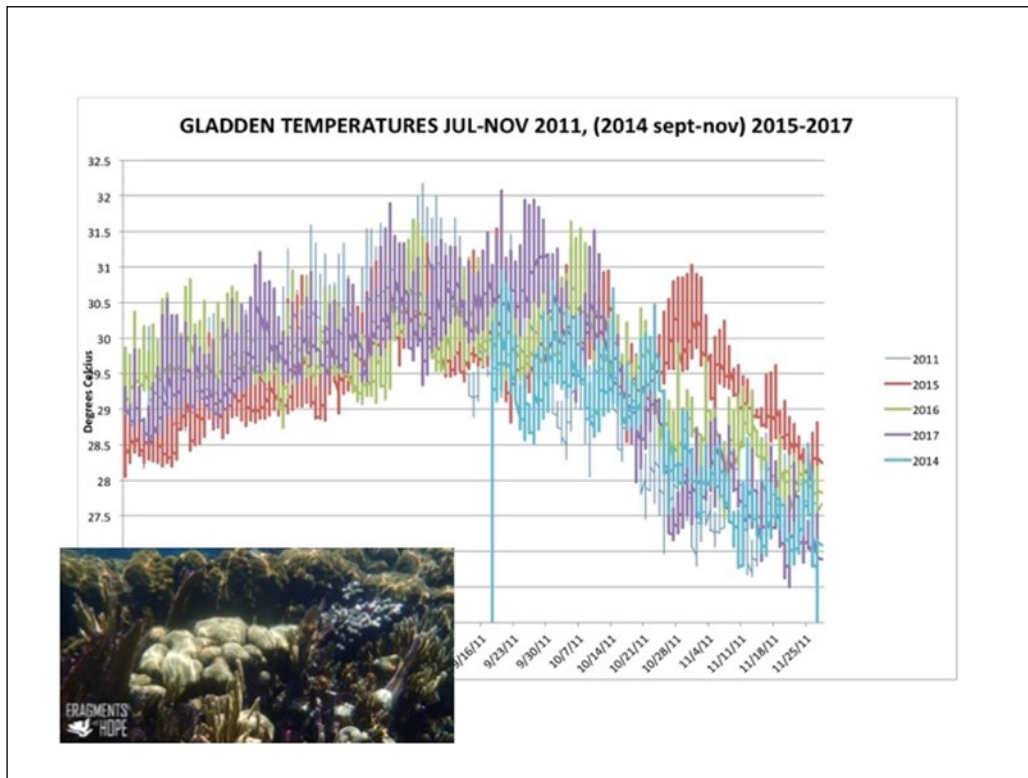


Figure 3. *In situ* temperature data at Gladden Spit, southern Belize for 2011, and 2014-2017.

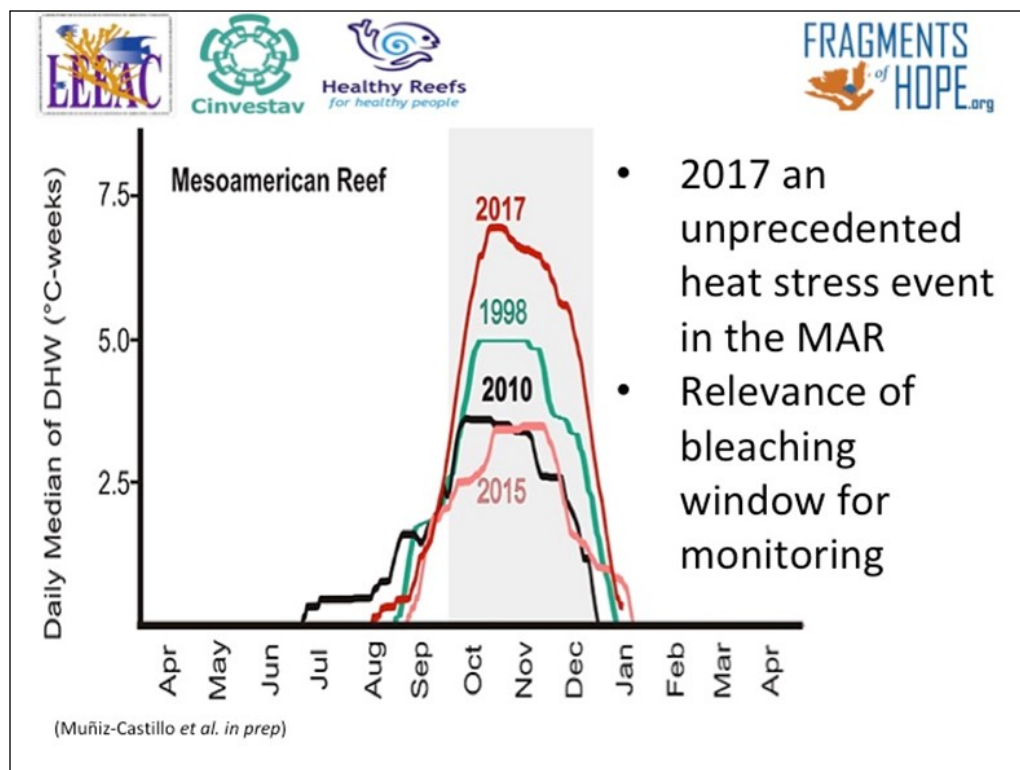
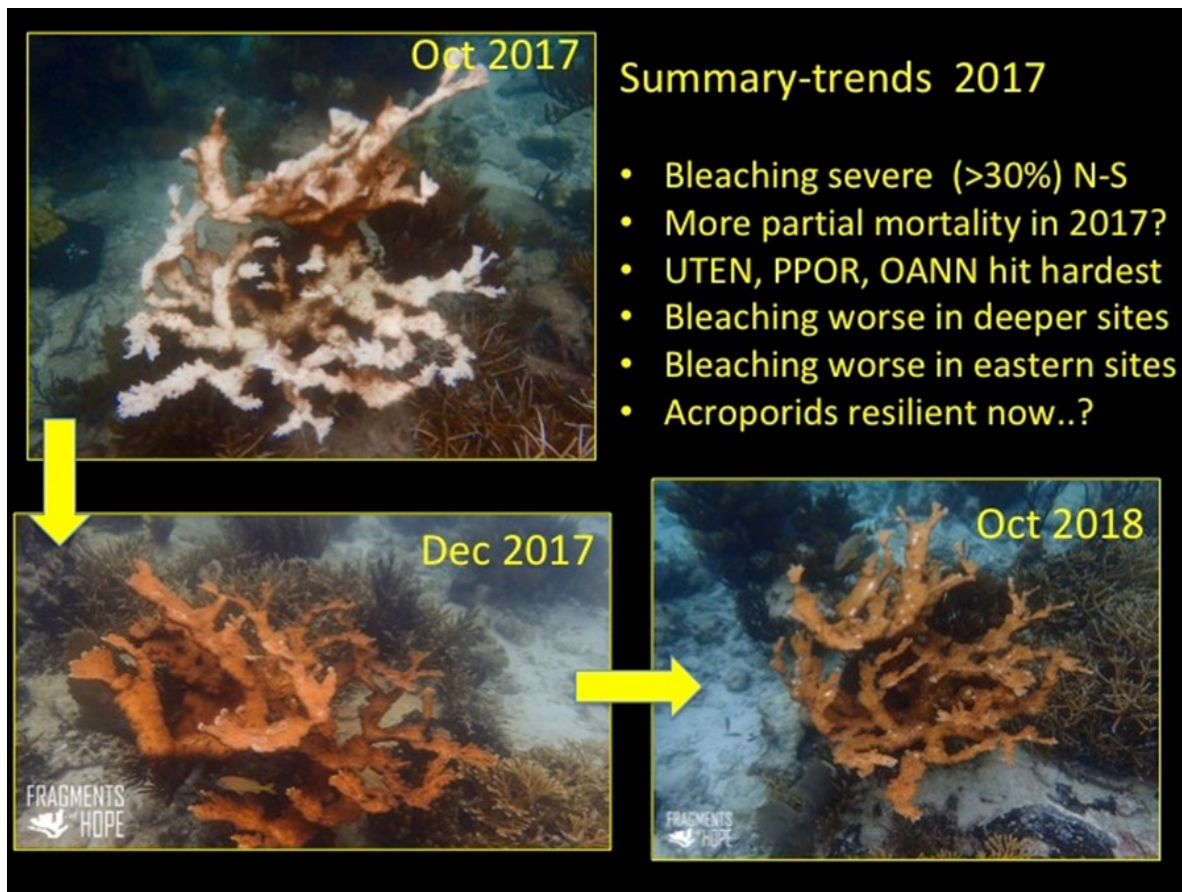
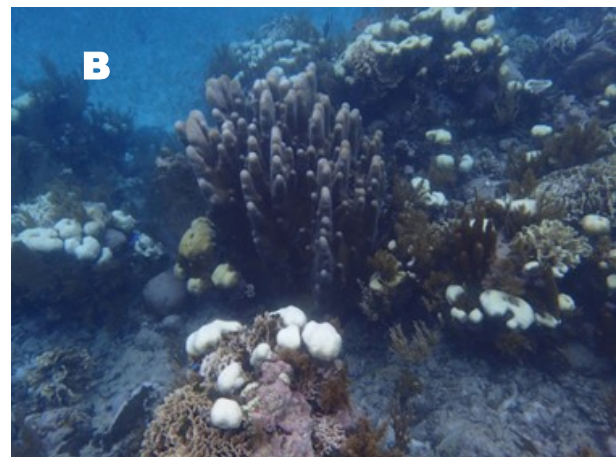


Figure 4. Analysis of Degree Heating Week data per major bleaching event in Mesoamerica (1998, 2010, 2015, 2017).



**Figure 5.** Defining resilience: although the transplanted *Acropora palmata* (transplant dates 2006 and 2010) bleached wholly in 2017, within two months the colonies are completely recovered with no mortality. Location: leeward side of Laughing Bird Caye National Park.



**Figures 6a - b.** Defining resilience: Nursery-grown, outplanted (2010) acroporids at Laughing Bird Caye National Park (~ 2 m, windward side) did not bleach in October 2017 (6a) versus other species at ~5m in a channel at SWCMR, photo also October 2017 (6b).