The Interactive Effect Of Ocean Acidification And Rising Sea Surface Temperatures On Coral Microbiome Composition

Coral reefs are valuable ecosystems because they host a vast, diverse range of marine species within their area of growth. Unfortunately, the long-term survival of many coral reefs is becoming at risk due to significant anthropogenic CO2 emissions that have increased ocean acidification (OA) & sea surface temperatures (SST), as well as impacting other factors of coral health (Webster & Reusch, 2017). The future of coral reefs depends in part on how well they can tolerate thermal & acidity changes as well as their ability to adapt genetically and/or non-genetically to the interaction magnitude of these two increasing stressors (Grottoli et al. , 2018). The purpose of this paper is to review how the interactive pressure of OA & elevated SST might affect the coral microbiome composition and possible mechanisms for coral microbiomes to adapt and/or acclimatize across generations. Before the first half of this decade, there had been few studies on the interactive effect of these stressors on the composition of coral microbiomes.

Ocean acidification had been linked to increased frequency of virulence-related genes, albeit coral microbiome outcomes tends depends on the sensitivity of each coral species to pH changes; microbiome composition shifts favoring opportunistic and pathogenic members have been identified with both thermal and OA stress independently (Bourne, Morrow, & Webster, 2016). In an in situ study of crustose coralline algae (CCA) located on the Great Barrier Reef, Diaz-Pulido, Anthony, Kline, Dove, and Hoegh-Guldberg (2012) found that elevated SST amplified the adverse effects of OA, causing significantly increased CCA mortality rates and endolithic, skeleton-eroding abundance, relative to ambient conditions of pH 8. 0-8. 4 and a temperature of either 25-26?C or 28-29?C that reflect the current Great Barrier Reef quality. This synergistic effect between OA and SST stressors suggests that the prior studies that drew conclusions from manipulating the s independently cannot accurately predict how CCA populations will be impacted at the end of the twenty-first century, assuming that projected 2100 seawater conditions by the Intragovernmental Panel on Climate Change (IPCC) are reached (Diaz-Pulido et al. , 2012). Reyes-Nivia et al. (2013) studied the combined effect of OA and elevated SST on the microbioerosion of Isopora cuneata & Porites cylindrica coral skeletons; at end-of-century low pH/elevated SST conditions, they found significantly increased biomass and respiration rates of endolithic microboring algae as a result of increased coral skeleton dissolution rates.

This finding suggests that these endolithic microborers had increased metabolic activity under projected near-future ocean conditions, but provides little insight regarding how other members of the coral microbiome are impacted (e. g. , symbiont shifts and/or switches in beneficial microbes of the microbiome) (Bourne et al. , 2016). Prada et al. (2017) found that dual exposure to projected end-of-century low pH/elevated SST conditions had a synergistic effect on the mortality rates of in situ coral species Balanophyllia europaea (colonized by photosymbionts), Leptopsammia pruvoti, and Astroides calycularis (both lacking symbiont colonization) at a volcanic CO2 seep near Panarea Island. Coral mortality rates were greater under exposure to low pH/elevated SST conditions. This finding complements the synergistic effects of OA & elevated SST observed on CCA by Diaz-Pulido et al. (2012), but does not elucidate how those coral microbiomes may have been affected (i. e. , by symbiont shuffling and/or de novo switching) under the combined stressor exposure. Webster et al. (2016), who studied the microbiomes of coral species Acropora millepora and Seriatopora hystrix in response to short-term exposure to IPCC projected end-of-century climate scenarios.

After 8 weeks in seawater of either pH 8. 10 or 7. 90 and temperature of 28 (ambient) or 31?C, they found stable coral microbiome compositions and still-healthy coral holobionts between the two pH treatments at ambient temperature, though they recognize that this perceived stability may be due to insufficient exposure to the low pH/elevated SST conditions. Although no significant interactive effect between stressors was identified for either coral species, Webster et al. (2016) did note the trend of a greater OA effect at the elevated SST. Their findings suggest that dual exposure to these two stressors has a disproportionate impact on the microbial community composition. More recently, Grottoli et al. (2018) studied how microbiome composition and coral physiology in species A. millepora (with its thermally-sensitive endosymbiont) & Turbinaria reniformis (with its thermally-tolerant endosymbiont) under projected end-of-century low pH/elevated SST conditions.

For 24 days, these corals were exposed to either control (26. 5?C and pCO2 of 364 µatm/8. 07 pH) or low pH/elevated SST conditions (29. 0?C and pCO2 of 750 µatm/7. 81 pH). These control and treatment seawater temperatures matched the average summer temperature of the coral’s source location (northwest Fiji) and the upper limit of current summer temperatures, respectively; consequently, these were relatively lower SST conditions than those used by Weber et al. (2016) (Grottoli et al. , 2018). Relative to the conditions used by Webster et al. (2016), the control and treatment pH were 0. 03 and 0. 09 units lower, respectively, (to match ambient Fiji conditions) and the corals were maintained at ambient-temperature seawater for approximately ten weeks longer before experimentation began and were not starved. They suggest these as possible explanations for why no significant change in A. millepora microbiome composition was found, contrary to the findings of Webster et al. (2016). The health of a coral reef intimately depends on the state of the coral holobiont, which is composed of the coral animal and all of its eukaryotic, prokaryotic, and viral symbionts (Webster & Reusch, 2017). Beneficial symbiotic microorganisms play key roles in carbon uptake, nitrogen & sulfur cycling, coral larvae recruitment, and the production of antipathogenic agents & metabolites that provide ultraviolet radiation protection. However, other pathogenic microbes (that may be low in abundance at ambient “control” pCO2 levels) can displace beneficial ones as temperatures continue to increase, thereby preventing symbiotic microbes from carrying out their functional, symbiotic role(s) and decreasing coral host health (Bourne et al. , 2016).

As climate change increases SST (thereby limiting vertical mixing between surface and deep-ocean waters due to an increased difference in density across the layers) and OA, these microbiomes will be vital players in determining how successfully coral reefs will be able to acclimatize and/or adapt. Microbiomes that confer a fitness advantage (either by their overall community composition or by individual microbe genomes and/or gene expression) may be transferable to the next coral generation by one or more methods of transgenerational acclimatisation, such that coral host fitness may be maximized through selection for complete community units or individual fitness-incurring members (Webster & Reusch, 2017). Due to limited current research, we cannot conclude how different microbiome compositions and individual microbe genomes & gene expressions may influence the long-term survival of coral holobionts. Future studies should examine the long-term stability of coral microbiome changes in response to dual exposure to predicted OA and SST conditions.