How can “Super Corals” facilitate global coral reef survival under rapid environmental and climatic change?

Running Title: "Super corals" and future reef survival

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Abstract
Coral reefs are in a state of rapid global decline via environmental and climate change, and efforts have intensified to identify or engineer coral populations with increased resilience. Concurrent with these efforts has been increasing use of the popularised term “Super Coral” in both popular media and scientific literature without a unifying definition. However, how this subjective term is currently applied has the potential to mislead inference over factors contributing to coral survivorship, and the future trajectory of coral reef form and functioning. Here we discuss that the information required to support a single definition does not exist, and in fact may never be appropriate, i.e. “How Super is Super”? Instead, we advocate caution of this term, and suggest a workflow that enables contextualisation and clarification of superiority to ensure that inferred or asserted survivorship is appropriate into future reef projections. This is crucial to robustly unlock how “Super Corals” can be integrated into the suite of management options required to facilitate coral survival under rapid environmental and climate change.

Body
Recent studies have documented the rapidly accelerating global demise of coral reefs, prompting an unprecedented need for a new suite of innovative management tools (Anthony et al. 2017). Such innovations are largely centre around reefs that have disproportionally high conservation value, such as natural refugia or environmental extremes that potentially enhance coral tolerance to future conditions (Camp et al., 2018), as well as biological and reef habitat engineering solutions (van Oppen et al., 2017). Regardless of whether coral populations persist under stress exposure through refuge or enhanced tolerance, the term “Super Coral” is increasingly being applied to describe corals with superior survivorship, with the term indiscriminately used in popular media and no unifying definition in scientific literature (Darling & Côté, 2018; Grottoli...
et al., 2017). As we discuss, the information required to support a single definition is currently not available. With growing popularised use of “Super Coral”, caution must be urged given the term’s subjective nature, which could potentially mislead inference over factors contributing to coral survivorship. We call upon the community to rapidly adopt a workflow to contextualise any future use (Fig. 1) – importantly ensuring clarity over the factors that result in “superiority” and how this contributes to coral survival.

The term “Super Coral” is synonymously associated with superior survivorship when subjected to stressors and rapid environmental change. Consequently, it is imperative to initially distinguish intrinsic factors that promote stress tolerance versus survivorship from refuge, i.e. survival in an area where favourable environmental conditions are maintained that are being lost elsewhere (Keppel and Wardell-Johnson, 2012). Fully reporting local environmental conditions over both immediate and historical timescales is fundamental to distinguish refuge from resistance, but current capabilities to characterise micro-environments restricts the scale of refuge that can be identified. Solving this problem is critical since micro-environmental refugia appeared key in aiding survival of individual colonies during the 2016-17 mass-bleaching event on the Great Barrier Reef (Hoogenboom et al. 2017).

Survivorship during times of stress or environmental change that does not occur due to refuge, requires stress tolerance, either through genetic selection from prior pulse stress events, such as marine heatwaves, or persistent (press) conditioning to suboptimal conditions, e.g. corals within shallow back-reef pools (Palumbi et al. 2014). In the latter case, corals adapted to thrive in marginal environments and ‘natural extremes’ seem logical candidates for assisted migration
(Anthony et al. 2017). However, this raises several issues in terms of ascertaining whether survival to future stressors is guaranteed:

Firstly, press environmental conditioning does not mean organisms are conditioned to tolerate pulse stressors. For example, the intertidal corals of the macrotidal Kimberley region in north-western Australia are regularly exposed to extremes (press stressor) of temperature, pH, salinity, and air, thereby potentially selecting for traits needed to survive under future climates. However, corals here experienced mass coral bleaching during the 2016 marine heatwave event (pulse stressor, Le Nohaïc et al. 2017). Similarly, survivorship to pulse stress events does not guarantee superiority to tolerate press stressors.

Secondly, identifying the spatial scale over which survivorship to stress operates is critical to distinguish locally restricted highly stress-tolerant populations (e.g. corals in macrotidal pools or mangroves, Fig. 1), versus organisms that exhibit cosmopolitan resistance across broad scales (e.g. *Acropora tenuis* demonstrating superior survival along the Great Barrier Reef during the 2016 marine heatwave, Fig. 1). The ability for locally adapted superior populations to maintain their competitive advantage across broader scales and into the future is a desperately understudied research area, but one that requires immediate attention to resolve the practicality of assisted migration (Anthony et al., 2017).

Thirdly, superiority in tolerating one stressor does not ensure enhanced tolerance to another stressor. Corals that have adapted to persist within continued low pH around natural CO₂ vent sites have been found to downregulate molecular chaperones that may impact their stress
response capacity to deal with other climate related stressors, notably heat stress (Kenkel et al., 2017). While some corals have shown the ability to tolerate several stressors simultaneously, e.g. corals living in hot, acidic and low oxygen mangrove lagoons, there are presumably “costs” associated with such survival (Camp et al., 2018). A cost-benefit approach is therefore required to assess what trade-offs come with superiority under different long-term multi-factor environmental change scenarios.

Ultimately, use of the term “Super Coral” requires information on the underlying factor(s) contributing to coral “survivorship” thereby contextualising how “Super” a “Super Coral” can be; specifically, over the different temporal scales (press versus pulse) and across the multitude of environmental stressors corals will ultimately need to contend with (e.g. low pH, increased sea surface temperatures, deoxygenation) (Fig. 1). Efforts to engineer superiority similarly need to consider the scenarios under which increased survivorship can operate, and thus how any given genotype-phenotype may simply favour enhanced competiveness under one set of environmental condition over another (van Oppen et al. 2017). Sophisticated stress-based experimentation will be central to establish the dynamic environmental range with which organisms not only survive but also remain ecologically competitive, and how this relates to future predicted stress scenarios.

Popularised terms have proven central in broadly disseminating fundamental problems and paradigms to the wider scientific and public communities. By their very nature as ‘survivors’, “Super Corals” will unquestionably play an important role in the future of how the world’s coral reefs look and function. However, what constitutes a “Super Coral” will likely take many forms
and thus adopting a single definition is not appropriate. Consequently, the use of the term should be adopted with immense caution, and in many cases will simply prove unsuitable beyond a social “buzz word” without sufficient context. Therefore, whilst we do not offer a framework of definitions per se here, we do suggest a workflow with which its usage can (and should) be contextualised. In doing so, identifying the nature of superiority will ensure inferred or asserted survivorship is appropriate into future projections. Such knowledge will support the capacity to effectively integrate “Super Corals” into the portfolio of management options required to facilitate coral survival under rapid environmental and climate change.

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**Reference List**


