Coral microbial ecology under the microscope

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Increasing episodes of mass coral bleaching and a growing number of reports of coral disease epizootics have led to an expanding research field investigating the microbial ecology of reef building corals. Corals reside in a complex ecosystem and form intimate symbiotic relationships with eukaryotic dinoflagellates (commonly called zooxanthellae), which have been well studied. Less understood is the complex interactions that corals form with Bacteria, Archaea and viruses, all of which play an important functional role in coral health. Understanding how the coral animal and its symbiotic partners (eukaryotic, bacterial, archeal and viral) are influenced by environmental perturbations such as global climate change, rising sea surface temperatures and increasing anthropogenic inputs into the ecosystem such as nutrients, is the driving factor behind this expanding microbial discipline.

The Great Barrier Reef (GBR) is the largest, and one of the most biological diverse reef systems of its kind worldwide (Figure 1). The GBR is of great social, economic and environmental value to Australia and understanding the impacts of environmental stress and disease is imperative if we are to understand the potential sustainability of this valuable system. Coral bleaching events have been increasingly reported on the GBR and like other reef regions, these have been closely followed by increasing reports of coral disease outbreaks [1]. To date over thirty different diseases of reef corals have been described, yet these descriptions, and our subsequent understanding of the diseases, are based primarily of macroscopic changes occurring to coral colonies. Determining the role of pathogens associated with many of these diseases has remained elusive despite extensive research in the past three decades. It has become increasingly evident that understanding

Figure 1. Healthy reef building corals off Heron Island on the southern Great Barrier Reef. Tabulate acroporids (TA) and branching acroporids (BA) both dominate this shallow (1 m) reef platform.

the diversity, complexity and inter-relationship of reef microbial systems is imperative for understanding the role of the microbial communities in stable and unstable reef systems, and within specific coral disease states.

Corals are known to support an abundant and diverse bacterial population and evidence supports the notion of corals harbouring specific microbial associations that play an important role in the health of the host [2]. Additionally, bacterial community shifts may indicate the health of a coral is compromised [3] and so could be used in determining coral stress resulting from a range of potential environmental triggers.

Although each suffers its own limitations, different molecular methods have enabled a greater understanding of the microbial community associated with both healthy and diseased corals. It has been found that distinct differences exist in the microbial community between the coral tissue, the coral surface mucus layer and the surrounding seawater [4,5]. Culture dependent and independent methods have also recently identified a high diversity of bacteria associated with coral diseases, which may play important primary and opportunistic roles. Members of the phylum *Bacteroidetes* and classes *Gammaproteobacteria,* and *Alphaproteobacteria* are some of the most common coral associated bacteria; many of which have been described within ocean systems as being the most abundant and dominant bacterial types. Members of the *Vibrionaceae* have also been identified in healthy and diseased coral reef systems, including those that share sequence homology with known pathogens, including *Vibrio harveyi* and *Vibrio coralliilyticus.* Yet the role of these has yet to be determined in coral reef systems. The difficulty in applying traditional microbiological techniques to these large, highly complex and diverse systems has proven a limiting factor.

The application of fluorescence *in situ* hybridisation (FISH) for identifying and visualising coral bacterial communities has provided a method to investigate the direct interaction that occurs between the bacterial communities and coral tissues. Corals and their endosymbiotic algae have extensive autofluorescence due to the presence of green fluorescent protein (GFP)-like proteins and chlorophylls [6]. FISH combined with spectral profiling has shown that bacterial interactions with coral tissues are highly complex and differ between different disease states and from the normal bacterial community dynamics [6]. Bacterial interaction, colonisation and proliferation with coral tissues occur in many diseases and the bacterial dynamics are highly variable. Members of the major bacterial groups can be found associated with disease lesions (Figure 2 a). Bacterial community dynamics in healthy tissues is limited mostly to the mucosal layer on the surface of the coral tissues (Figure 2 b) and the widely dispersed bacterial aggregates of the *Gammaproteobacteria* [7].

In conclusion, generally little is known regarding the role, diversity, ecological dynamics and stability of microbial communities within and between reef systems. However, using a variety of approaches to investigate microbial ecology and microbial-coral interactions we can begin to reveal the importance of the microbial communities associated with coral and the functional role these microbes play in determining coral health, especially in light of the increasing stress likely to be placed on reef systems as we move into the middle part of the century.

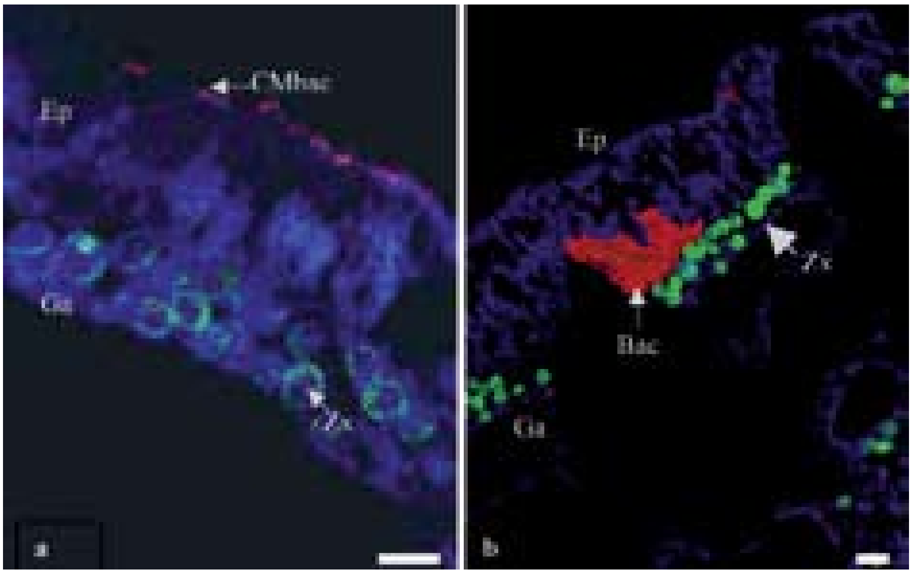

Figure 2. FISH showing bacterial interaction with the coral surface mucus layer indicated by arrowhead (a); and in Acroporid corals with coral tissues, with bacterial proliferation within the epithelial layer as indicated by arrowhead (b). Ep coral epithelial layer of the coral tissue (blue), Ga gastrodermis layer of coral tissue (blue), Zx Endosymbiotic dinoflagellate within the gastrodermis (green). Bac bacterial invasion of the coral epithelial layer tissues (red), CMbac bacterial populations associated with the coral surface mucus layer (red). Scale bars = 10 μm.

References

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