Science Forum Communiqué | 2015

Reef scientists, supported by the Great Barrier Reef Foundation, met in Brisbane on 4-5 August 2015 to discuss the latest scientific evidence on the resilience of the Great Barrier Reef to the impacts of climate change and other pressures. This communiqué summarises the key messages from the event.

Strategic research catalysed and supported by the Great Barrier Reef Foundation

Each research project supported by the Foundation forms part of a holistic research strategy addressing the vision of a resilient Great Barrier Reef. No one group alone can address this vision; such a challenge requires leadership and innovation. The ability to measure, monitor and communicate the effects of climate change on coral reefs is crucial. A range of adaptation options to address: the effects of warming waters; more acidic oceans; and organisms that are struggling to adapt, are being investigated. Embedded in the strategy is the development of novel decision making tools and the generation of knowledge. These are to assist managers, end users and policy makers to determine where, when and how to deploy management options. Every research project supported by the Foundation is strategically selected to build this holistic vision and is mapped onto a path to impact.

What do we know now?

Attributes of a resilient Reef

Innovative technologies show promise for assessing critical and complex aspects of reef resilience:

- **Coral metabolomics**[1] can detect the strength and type of **sub-lethal stressors** (temperature, water quality, and potentially ocean acidification).
- 3D reconstructions of reefs and coral colonies (generated using geo-referenced stereo-images collected by autonomous underwater vehicles) can be used to map aspects of **habitat structure** critical to resilience, including repeatable high-precision measures of reef roughness, complexity and species diversity.
- Rates of **net CCA (crustose coralline algae) calcification** (i.e. the balance between formation of new skeleton and dissolution of existing skeletons) are particularly sensitive to ocean acidification and can be easily monitored *in situ*.
- **Seagrass energetic** status (productivity and growth) is the foundation for seagrass resilience, is highly sensitive to temperature and water quality and can be modelled from high precision measures of the environment.
- The resilience of corals, and other organisms, can be related to the presence/absence of **acclimation conditions** prior to acute stress events. It is known that as ocean temperature patterns change, the ratio of lethal to sub-lethal bleaching events will increase, thereby reducing the opportunities for coral to acclimatise prior to more extreme exposure.

Ocean Acidification

Ocean acidification is a strong driver of Reef ecosystems' vulnerability and resilience, and is a serious threat to the Great Barrier Reef.

- **Patterns in the carbonate chemistry** across the Great Barrier Reef are now emerging based on measurements and oceanographic modelling.
- Coral reefs will gradually change as oceans acidify, with **decreasing hard coral diversity, increasing boulder coral** dominance and eventually no reef development below a pH of 7.8. The impact of ocean acidification is predicted to be worse if combined with other stressors (e.g. warming temperatures, poor water quality).

[1] **Metabolomics** is the study of the unique chemical signals left behind, at a given point in time, by individual or groups of cells as they carry out the various functions.

- Coral larvae naturally exposed to high CO_2 (at volcanic seep sites in Papua New Guinea) have low settlement rates, suggesting **recruitment will be a major bottleneck**[2] for coral reef ecosystems under ocean acidification.

Solutions – local scale innovations

Although very early in the R&D phase, innovative solutions show positive results for reducing pressure and increasing resilience at small local scales:

- **Artificial settlement surfaces,** such as tiles, with specialised designed surfaces (i.e. patterns of circular micro-pits) can increase the success of larval settlement. This advances the science of reef restoration.
- **Surface films**, when applied to water, can control the amount of light entering the water column and theoretically represent an innovative solution to combat coral bleaching at a local scale. Surface films comprise of naturally occurring molecules that spread across the water's surface to form a very thin layer, one molecule thick.
- **Seagrass productivity** can increase with ocean acidification and their productivity, if high, may increase pH in surrounding waters **potentially buffering** against ocean acidification at a local scale.
- Very preliminary genetic analysis indicates **heritable genetic differences** between corals exposed to different environmental pressures (specifically 3 genotypes of *Pachyseris speciosa* correlate to different depths and latitudes along the Great Barrier Reef).

So What?

Research discoveries can be applied to manage Reef resilience.

Attributes of a resilient Reef

- Indicators of a resilient reef can be used as **early-warning tools** to detect eroding resilience and the likelihood of 'phase shifts'.
- Monitoring both status and resilience is critical. Individual indicators can be integrated into an **index of resilience**, for communication and management decision making.
- Understanding resilience can inform a **cost-benefit analysis** for management actions and prioritisation.

Ocean Acidification

- Patterns in the carbonate chemistry will inform the **prioritisation of areas most vulnerable** to ocean acidification.
- Outcomes of research to date can be used for **vulnerability mapping**, to identify areas most vulnerable to stressors (such as ocean acidification) and help prioritise spatially explicit management.
- **Thresholds** identified (such as the extreme threshold of 7.8 pH for complete loss of coral) can be applied to set resilience thresholds and targets for ecosystem management.
- Identifying **bottlenecks**[2] is important and helps focus where and when best to target management interventions (e.g. reducing stress or supplementing recovery).

Solutions

- **Reef restoration** is a solution to ameliorate local reef degradation and increase Reef resilience, and research into the most effective and economical options can help guide restoration activities.
- If confirmed, **coral genes** promoting resilience can be used to prioritise protection and optimise reef restoration action, by focusing on the most resilient coral genotypes.

What are the gaps?

Key gaps in knowledge can direct future research needs.
Gaps in the research process can be addressed to optimise research adoption.

Observing Reef resilience – innovations in monitoring and reporting

- **Innovative methods for assessing stress, vulnerability and resilience** in corals and other organisms (e.g. metabolomics applications requires further investigation).
- Options for integration and **operationalisation of resilience indicators** into existing schemes (including monitoring, modelling and reporting).
- A **common habitat map** for the **whole Reef** supporting understanding of the Reef processes, connectivity and management, and supporting models and monitoring programs.

Reef resilience – experimental groundings

- **Resilience thresholds** and targets for whole ecosystems (ecological-based thresholds, as they are likely to vary from organism-based thresholds).
- Impacts of **cumulative stress** from multiple pressures at both the organism and ecosystem levels (much research to date has investigated the impact of individual pressures).

[2] **Life history or ecological bottlenecks:** the processes which exacerbate life history and ecosystem bottlenecks (e.g. reduced post settlement survival) threaten reef resilience. Reef organisms (corals, seagrass, crustose coralline algae) vary in their vulnerability to specific and cumulative pressures (ocean acidification, temperature, water quality) and the stress response varies as they grow. Sometimes juveniles are more vulnerable and sometimes it's the adults. Frequently, we find that a stress - such as seaweed proliferation which impacts coral recruitment - can cause a critical bottleneck for recovery

- Critical organism and ecological-based **bottlenecks**[2] that threatening resilience.
- **Adaptive capacity** of corals derived from analysis of coral genomes and coral genes across environmental gradients.
- Critical **acclimation** conditions (e.g. CO_2 and temperature) for optimal resilience of corals and other organisms.
- Sensitivity of **inshore reefs** to ocean acidification.
- Improved understanding of the **far north region of the Great Barrier Reef** (a region currently very data, research and model poor).

Translating science into ecosystem response – integrated modelling for management decision making

- **Integrated models**, across biophysical, social and management dimensions. Integrating previous and on-going research results, to understand the relationship between a management lever and the response of the wider ecosystem.
- Models supported by **experimental grounding** and a **parallel program of observations** ensuring accuracy.
- Models that are **adaptive and responsive** to new data and information.

The link between local responses (e.g. bleaching) and environmental futures for the whole of the Reef is still not clear, despite 40 years of Reef research. Integrated models are the vehicle that translates the science into something mangers can use to evaluate the likely consequences of pulling management levers. They can be used to answer strategic management questions, such as 'What will the reef look like in 2050?', 'What level of management investment is needed to reach a desired state of the reef?', and 'What are regionally-specific thresholds of water quality and resilience needed to achieve a successful outcome?'; or tactical management questions, such as 'Which reefs play a key role in facilitating recovery after a crown-of-thorns starfish outbreak?, or 'Where might a special management area have its greatest impact in either protecting coral or enhancing resilience?'

Pathways to impact – continuous engagement with stakeholders

- **Early engagement** with stakeholders in the research development phase.
- Establishing a **clear pathway to impact** in the research development phase.
- Maintaining a **continuous dialogue** with stakeholders throughout the research process.
- **Communicating the value** and critical need for **models** for decision making. The Great Barrier Reef is extensive and complex and models will be key to assessing ecosystem responses to stressors and prioritising management actions across the whole Reef system.

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