2010 Research Portfolio

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Project Summary

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Author:
Great Barrier Reef Foundation

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Great Barrier Reef Foundation
Unit 1, 9 Longland Street Newstead Australia
PO Box 2725 Fortitude Valley BC QLD 4006
Phone +61 7 3252 7555

www.barrierreef.org

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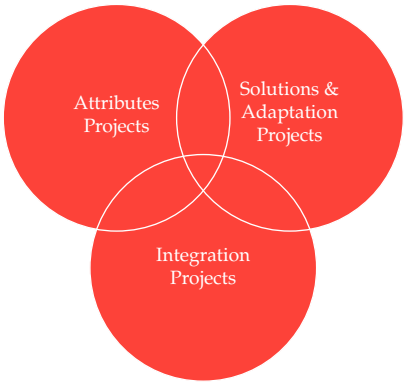
Culcita nuze (Pin Cushion Sea Star)

A Portfolio of Important and Interrelated Projects

A Portfolio of Important and Interrelated Projects

Introduction

This Portfolio takes a landscape view of what is needed to be done to address the inevitable impacts of climate change on the Great Barrier Reef system, incorporating projects from three distinct but interrelated areas:



The first group consists of the projects developed by the Attributes working group. These critical baseline studies will together create a definitive snapshot of the resilience of a coral reef to climate change based on the key indicators of ecosystem well-being. Understanding these baseline states is very important to assessing progress towards sustainable coral reef ecosystems.

The second group of projects, developed by the Solutions & Adaptation working group tests a number of new physical or ecological interventions, which might be deployed to improve the prospects of a coral reef system as it copes with the impacts of climate variability. Looking beyond the interventions to how best to facilitate broader adoption—by the community, by industry and various governance structures, is a further facet of this important endeavour.

The final group of projects will see the results of the first two project groups aligned and integrated—an important priority for the Foundation. Two vital tools will also be developed—a Reef Resilience Index which tracks the performance of individual reef health indicators, integrates them and conveys the result in robust and readily understandable terms, and eReefs as a master integration and visualisation tool.

By addressing all three project areas the Foundation is confident that many of the learnings will be able to be shared with those who use and manage other coral reefs around the world.

Document Overview

This document provides specific information about each of the three groups of projects commencing with an overview of the project grouping and summarising important information about the form and purpose of specific streams of work within each project group:

Attributes

Information about the Attributes group of projects focuses on the two streams of Attributes research:

- Biophysical
- Socio-economic Systems

Solutions & Adaptation

Solutions & Adaptation projects target the development of two complementary strategies:

- Ecological and Physical
- Enabling

Integration Projects

Three key projects are directed at integrating the research in this Portfolio:

- Reef Resilience Index to Climate Change
- From Understanding to Action
- eReefs

Attributes
Projects

Foreword

Coral reefs are the most biologically diverse ecosystem in the ocean, providing habitat for over a million species and ecosystem services important to millions of people worldwide. Each year in Australia alone, the Great Barrier Reef earns over $6 billion in tourist and fishing revenue. This income employs over 63,000 people and is a major contributor to Australia's GDP. Rapid changes in the temperature and acidity of tropical ocean waters, however, are combining with local pressures such as overfishing and declining water quality to seriously threaten this valuable ecosystem. At the current rate of climate change, conditions will soon exceed the known tolerances of coral reefs, not only here in Australia but internationally. Action on the issue of climate change is therefore an urgent priority.

While reducing the rate of climate change through deep cuts in fossil fuel emissions remains a major goal for the international community, adaptation strategies must be developed if we are to help coral reefs survive the impacts of climate change already in the system. The Great Barrier Reef Foundation is dedicated to tackling the challenge of developing adaptation strategies that will allow coral reefs and their ecosystem services to survive the coming decades and centuries.

In order to do this, the Great Barrier Reef Foundation has convened the Attributes Working Group to identify key biophysical and social features or 'attributes' that are typical of a resilient (healthy) Great Barrier Reef. This has been done in order to develop a monitoring and evaluation framework that will enable us to understand and measure progress towards reducing climate change impacts on the key attributes of a healthy Great Barrier Reef.

This research programme is unique worldwide but must be made a priority if we are to develop effective solutions to climate change and its impact on coral reefs like the Great Barrier Reef. Hopefully, the resulting research effort will identify important research gaps and in doing lead to the tools that reef managers need to monitor, measure and report on the state of the Reef in a changing global climate.

—

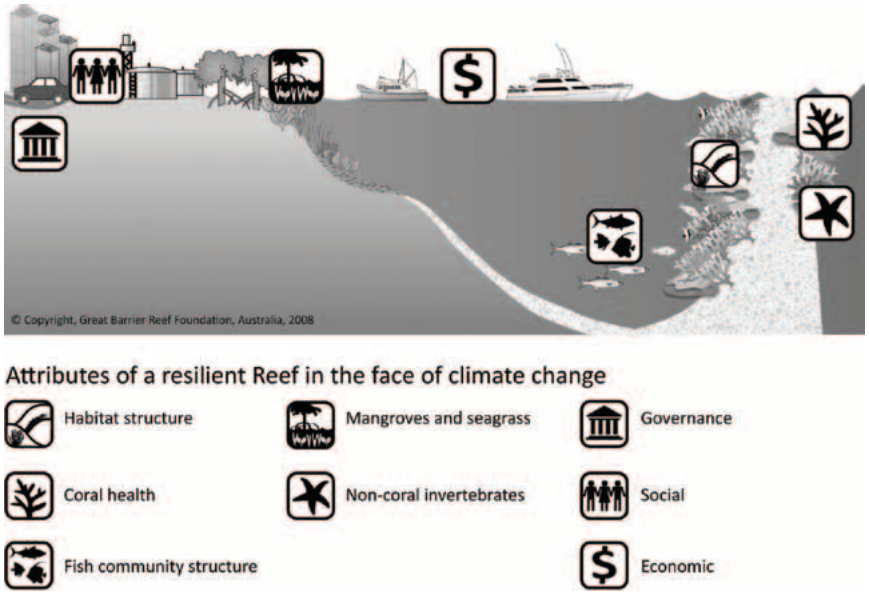
Professor Ove Hoegh-Guldberg,
Chair, Attributes Working Group

Introduction

The Attributes of a Resilient Reef in the Face of Climate Change

The Attributes Working Group identified eight key Attributes of a resilient reef in the face of climate change. Five attributes focus on biophysical reef characteristics, and three are relevant to the socio-economic systems associated with the Reef.

Figure 1—
The Eight Attributes of a Resilient Reef in the face of climate change



The biophysical Attributes span coral health, habitat structure, fish community structure, non coral invertebrates as well as seagrass and mangroves.

The social systems Attributes, on the other hand, include social, economic and governance.

The identification of these eight Attributes involved:

- An assessment of climate change threats to the Great Barrier Reef at global and local scales;
- Identification and refinement of the Attributes based on their capability to reflect such threats and to represent a reef ecosystem;
- Detailed discussion papers on each Attribute to assess further their suitability;
- Development of a monitoring and evaluation framework including indicators and metrics;
- Development of a framework for a Reef Resilience Index to climate change to facilitate a trial line of indicators and metrics;
- Development of a Research Process Framework designed to deliver the research components and integrate the outcomes into a Reef Resilience Index.

The Nature of Attributes

The ability to quantitatively measure the impacts of climate change on these key Attributes is pivotal to determining the effectiveness of potential climate change solutions & adaptations that may be deployed within the Great Barrier Reef.

To this end, the following definitions are relevant to discussion of the Attributes.

An attribute is a feature, either biophysical or socio-economic, of Reef resilience in the face of climate change. They could be considered the 'vital signs' of Reef health under climate change.

An indicator is defined as a specific measure which can be used to evaluate the given Attribute. The indicators that are to be developed and tested through the Attributes research projects could be used individually to monitor a single attribute over time, or in aggregate to produce an index, or report card, of reef resilience.

A metric is the quantifiable component of the indicator.

Biophysical Attribute Research Projects

Research will be undertaken over a three year period for each biophysical attribute to:

- Establish the responsiveness of indicators to the climate change factors of increasing sea surface temperature and ocean acidification
- Validate the indicators in the field
- Determine baseline levels and tipping points.

The Biophysical Attributes

The five biophysical attributes identified by the working group are:

- Coral Health
- Habitat Structure
- Fish Community Structure
- Non Coral Invertebrates
- Seagrasses and Mangroves

Attribute Project 1— Coral Health

Why is coral health important?

Hard corals are the cornerstone of the coral reef ecosystem, with their skeletons forming the framework of coral reefs. They provide shelter and habitat for a diverse range of other reef organisms.

Coral reefs are dynamic systems that have always been subject to many kinds of disturbance, including tropical storms, floods, predation, diseases, and major changes in sea level. Climate change related impacts are increasing the frequency and intensity of disturbances, and slowing the time interval for recovery, as corals become increasingly stressed by cumulative or chronic pressures.

How do you measure coral health?

A range of indicators will be relevant to coral health. However, indicators of highest priority identified by the working group include: the prevalence of coral disease and rates of coral growth, recruitment (reproduction), bleaching and calcification.

Project Objective:

To test the viability of the proposed indicators—as a means to measure the impacts of climate change on Coral Health.

Attribute Project 2—Habitat Structure

Why is habitat structure important?

Habitat Structure is the physical and biological characteristics of coral reef habitats that generally support high abundance and diversity of coral reef organisms. It is a key driver of biodiversity, sustainability and resilience for coral reef ecosystems.

In general, healthy coral reef habitats are expected to have limited growth of macroalgae and high abundance of many different corals, providing a complex physical habitat in which motile organisms can live and hide. Reef environments with reduced habitat complexity will support only a fraction of the species and individuals found in complex flourishing reef habitats. Loss of species may lead to reduced productivity, as well as loss of key ecological functions.

Global warming and ocean acidification are expected to cause significant and ongoing changes in both the biological and physical structure of coral reef habitats. These changes will be of major significance to Reef resilience.

How do you measure habitat structure?

The followingi ndicators of habitat structure are considered to be important: habitat complexity, coral community structure (variety of species), algal calcification rates and phase shifts between algal dominated and coral dominated systems.

Project Objective:

To test the viability of the proposed high priority indicators as a means to measure the impacts of climate change factors on Habitat Structure.

Attribute Project 3—
Fish Community Structure

Why is fish community structure important?

Coral reef fish communities represent the most high diversity vertebrate communities on earth. They are a critical component of resilient reef ecosystems, contributing to reef resilience through a suite of important functional roles. They are also considered to very sensitive to changes in reef health.

Fish Community Structure relates to the size, abundance and diversity of fish associated with coral reefs and other linked coastal habitats.

Herbivorous reef fish are thought to be critical to the resilience of coral reefs as they remove algae and maintain suitable habitats for coral settlement. Other reef fish from a wide range of trophic groups also contribute to ecosystem function, including top predators which are thought to be vital to maintaining biodiversity and productivity on coral reefs. Finally, fish provide one of the most critical links between the coral reef ecosystem and human society, providing food, sustaining fishing, tourism and other reef-related industries.

How do you measure fish community structure?

Changes in fish communities may be measured directly, or detected through changes in biological processes that will ultimately affect community structure. High priority indicators include patterns of resilience across spatial scale, recruitment success of species and the exchange of individuals among populations (connectivity).

Project Objective

To test the viability of the proposed high priority indicators as a means to measure the impacts of climate change factors on Fish Community Structure.

Attribute Project 4— Non-Coral Invertebrates

Why are non-coral invertebrates important?

Non-coral invertebrates are a critical Attribute of a resilient Reef, accounting for the greatest biodiversity on the Reef. They range from organisms less than a millimetre to several metres in length across a range of life styles, reproductive and feeding strategies. Many have important roles within coral reef ecosystems, and many are yet to be discovered by science.

Non-coral invertebrates exhibit a range of biogeographical patterns, indicating that some species have wide temperature tolerances, others narrow. Temperature is an important cue for many species to spawn, and rising water temperatures will often lead to reproductive changes in these species. Increasing temperatures will also increase rates of development and growth while ocean acidification may modify shell formation in non-coral invertebrates and potentially modify bioerosion making reef layers more susceptible to physical deterioration.

How do you measure non-coral invertebrates?

High priority indicators of non-coral invertebrates include their diversity, abundance and reproductive capacity; the abundance of those invertebrates (e.g crown-of-thorns starfish, bioeroders) that directly affect coral health and the exchange of individuals among populations (connectivity).

Project Objective

To test the viability of the proposed high priority indicators as a means to measure the impacts of climate change factors on Non-Coral Invertebrates.

Attribute 5— Seagrasses and Mangroves

Why are seagrasses and mangroves important?

Seagrasses and mangroves are the foundation of important coastal ecosystems that occur throughout the Great Barrier Reef region. Mangroves, trees and shrubs that grow in saline coastal habitats, fringe the coastline of the mainland and many reef islands throughout the GBR. They act as protection to reef habitats by absorbing nutrients, toxicants and stabilising soils and sediments.

Seagrasses, or submerged marine flowering plants, are also critical habitats in the GBR as they provide food for dugong and turtles, absorb nutrients and toxicants and stabilise sediments. Seagrasses and mangroves provide nursery grounds for numerous reef species, as well as supporting their own unique, diverse communities. There is a strong connection between seagrass meadows, coral reefs and other habitats, such as mangroves.

Climate change is expected to have impacts on both mangroves and seagrass meadows by affecting critical survivorship factors such as sea-level, sub-surface light availability, temperature and disturbance regimes.

How do you measure seagrasses and mangroves?

The high priority indicators of seagrasses and mangroves identified by the working group include: growth rates, composition, reproductive success distribution and the exchange of individuals among populations (connectivity).

Project Objective

To test the viability of the proposed high priority indicators as a means to measure the impacts of climate change factors on Seagrasses and Mangroves.

Socio-economic Attributes

There is growing recognition that in order to be effective, ecosystem management approaches must adequately address the social dimensions of environmental problems. This fledgling area of environmental management requires further development to determine which social, economic and governance conditions are essential for a resilient Reef in the face of climate change. As a consequence for this group of Attributes, the research approach will differ from that of the biophysical attributes.

For each social attribute research will be undertaken over a 3 year period to:

- Conduct an initial scoping study on the use and application of social indicators, and their role as drivers rather than indicators of reef resilience;
- Develop and test the proposed indicators;
- Validate the indicators in a climate change context;
- Determine baseline levels.

Social Systems Attributes

The three socio-economic attributes are

1. Social
2. Economic
3. Governance

1— Social

Why is a social attribute important?

With sea level rise, increasing temperatures together with the risk of more intense cyclones, all Great Barrier Reef regions face uncertain social, economic and environmental futures. Building social resilience is required if some of the worst impacts of climate change on the Great Barrier Reef are to be avoided or mitigated. Resilience thinking contributes a dynamic element to the goal of sustainability: a striving to meet sustainability principles in recognition of change and uncertainty. This project will systematically develop and review a set of indicators to monitor and evaluate the social Attributes that enhance Reef resilience in the face of climate change.

How do you measure social resilliance?

The high priority indicators of social resilience identified by the Attributes working group are: aspirations and stewardship, and capacity to learn, plan and manage risk and uncertainty.

Project Objective

To develop and test the feasibility and viability of the proposed high priority indicators as a means to measure the adaptive capacity of communities to climate change.

2—
Economic

Why is an economic attribute important?

A resilient Reef helps build and maintain a resilient economy. This is at least partially evidenced by the substantial contribution which both the Reef-based tourism and the fishing industries make to Queensland's economy. But the Reef contributes much more than just income and employment; its World Heritage status is symbolic of other, 'non-use' values. For example, it provides a safe-shipping channel for thousands of vessels each year. Less positively the Reef lagoon provides a convenient receptacle for bi-products of land-based development and activity (e.g. sediment, nutrients and pesticides) which occur as a result of economic 'pressures'.

A resilient Reef is one that is able to continue to contribute to a resilient economy. Nor is it simultaneously, under threat from the economy to which it contributes.

How do you measure economic resilliance?

The high priority indicators of economic resilience identified by the Attributes working group are: indirect use values (such as shore protection), non-use values (option, bequest and existence) and pressure which the economic system places on the Reef.

Project Objective

To develop and test the feasibility and viability of the high priority indicators as a means to measure the Economic Attribute.

3—
Governance

Why is governance importantant?

Adaptive governance relies on robust and responsive institutions that can effect change and respond to changes that affect the Reef's resilience.

In this context, governance institutions are systems of established and prevalent social rules that structure social interactions. Governance systems are the operational expressions of institutions and their dynamics, determining how change is enacted.

How do you measure governance resiliance?

The high priority indicators of governance resilience identified by the Attributes working group are: agency, continuity and decision support.

Project Objective

The focus of this project is to develop and test indicators of adaptive governance that show how institutional practice (e.g. knowledge integration) and interactions (e.g. through collaborative partnerships) promote resilience in Reef ecosystems. It will develop and test the feasibility and viability of indicators as a means to measure the Attribute, Governance.

Solutions & Adaptation Projects

Foreword

Increasing temperatures, changing rainfall patterns, retreating glaciers, rising sea levels and altered ecosystems provide compelling evidence that we are experiencing climate changes that are occurring at a rate that is highly unusual in the context of recent human history. Even more concerning is that recent observations show that global greenhouse gas emissions are tracking at the highest end of the IPCC emission scenarios and that the pace of climate change is, if anything, likely to accelerate, leading to an increasing risk of abrupt or irreversible climate shifts.

The best way to protect the Great Barrier Reef will be to reduce the world's emissions so that we can avoid dangerous climate change. However, because of lags in the system we are now faced with some unavoidable climate change that will put the Great Barrier Reef at risk. This means that in addition to cutting greenhouse gas emissions to avoid dangerous levels of climate change, we also need to prepare for the changes that are now unavoidable, and begin adapting to life in a constantly changing climate.

There is a major challenge for adaptation in our vulnerable ecosystems like the Great Barrier Reef because our ability to intervene is much less than in human mediated systems such as the built environment or agriculture. There is some prospect that ecosystems and species will naturally adapt but it is likely that the speed of climate change will outpace evolutionary adaptation for many species and ecosystems. This is where management interventions are required.

Much prior research has focused on keeping ecosystems healthy and minimising existing threats such as pollutants or invasive species.

However, with the combined threats of rising temperatures and sea levels, declining calcification rates of corals and low thresholds of sensitivity, just relying on building ecosystem health and resilience is not sufficient. We also need to at least embrace the notion of more innovative interventions to conserve biodiversity.

This has been the driver for the work of the Solutions & Adaptation Working Group, where people from a diverse range of disciplines have come together to discuss innovative solutions to help the Great Barrier Reef adapt to climate change.

—

Dr Andrew Ash,
Chair, Solutions & Adaptation
Working Group

Introduction

Solutions & Adaptation Defined

Solutions seek to minimise or reduce climate change impacts on the Reef. By contrast, adaptation strategies seek to best manage and respond to those impacts across the biophysical, institutional and socio-economic domains.

Streams of Work

Solutions & Adaptation projects address two streams of work:

1. Ecological and physical solutions & adaptation strategies.
2. Enabling strategies

Research Approach

Solutions & adaptation research is carried out in the form of either:

1. Initial feasibility studies which assess the ecological and technical potential of a concept. These studies are largely undertaken in a laboratory or modelling environment. The majority of solutions & adaptation projects in this first Portfolio are feasibility studies.
2. Proof of concept studies which are undertaken following a successful feasibility assessment. These studies consider in greater detail the ecological, technical and socio-economic potential of a concept and its scalability. It is generally not until this stage that any assessment is undertaken on the Reef itself. These studies may take place over several iterations of time and scale to fully assess viability.

The goal at the completion of these studies is to provide management and policy makers with proven concepts which they can adopt and implement.

Ecological and Physical Concepts

This ecological and physical stream of work seeks out and develops strategies which directly address the primary threats of increasing water temperature and acidification and:

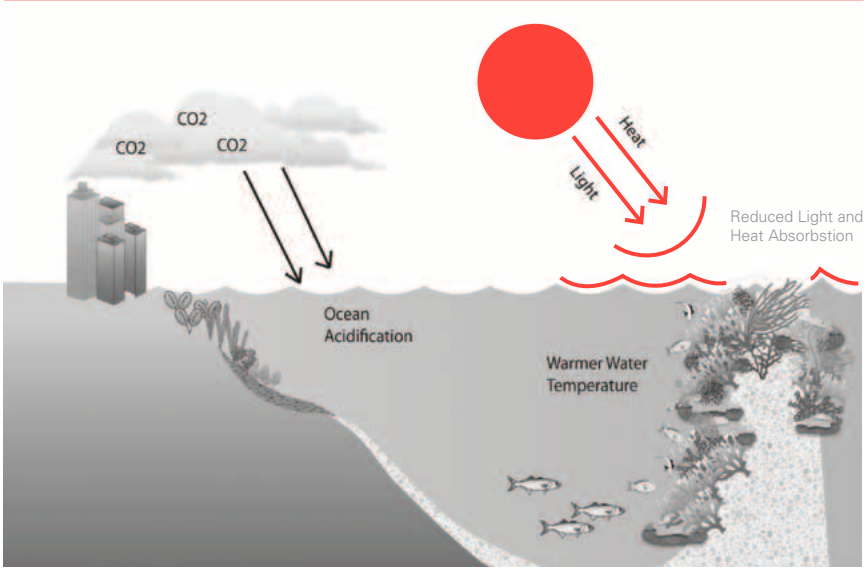
- Reduce the effects or penetration of heat and light on water temperature;
- Reduce the impacts of ocean acidification; or
- Assist species and ecological communities to adapt.

For each of the concepts described below, research will be undertaken to:

- Assess the technical feasibility of the concepts;
- Assess their potential ecological impacts (both positive and negative);
- Identify risk management strategies to mitigate or avoid any negative impacts;
- Assess their socio-economic impacts;
- Understand the scale at which such interventions might be applied;
- Assess implementation requirements (e.g. resources, technology)

All research outlined in the following projects will be conducted off-reef with the exception of seagrass monitoring and sampling which will be conducted once the relevant permits are obtained from Reef management agencies.

Figure 2—
Solutions & adaptation strategies seek to reduce the effects of climate change on coral reefs



Reducing the Effects of Heat and Light

Rationale

Sea temperatures of 1–20°C above the long term average maximum are the primary trigger for coral bleaching. However, high light intensity has been shown to be a significant co-factor of coral bleaching. In this regard, light intensity has been shown to increase the severity of bleaching events. The rapidly warming waters that trigger the most severe coral bleaching often occur during calm, clear weather, causing increased light penetration.

Objectives

This group of ecological and physical solutions & adaptation intervention concepts seek to reduce the effects or penetration of heat and light by shading areas of the Reef particularly at risk from coral bleaching, during periods of high sea temperatures. Shading would reduce the intensity of light being absorbed by Reef waters during these 'at risk' periods.

Concept 1— Physical Shade Structures

The use of shade cloths and screens to protect corals in large aquariums and research institutes is common practice as a means of reducing both light and temperature stress on corals.

The application of this technology to coral reefs and tourism operator pontoons was trialled on the Great Barrier Reef in the summer of 2005–2006. While results from these trials indicate that light-related stress diminished considerably by using shade cloths, major challenges were identified in relation to fouling of the shades and larger scale deployment.

Further research is required to investigate the engineering and technology requirements related to the deployment and maintenance of more effective and scalable physical shade structures.

Concept 2— Biopolymer Shading

Biopolymers are capable of altering properties at the air/water interface. They are being applied to water storage in dams, as a means of reducing evaporation.

To successfully apply this technology to coral reefs, it will be critical that any biopolymer developed is able to decrease the transmission of light at the air/water interface without negatively affecting other reef processes.

The technology must also be able to remain in place in spite of currents and winds. As such it is fortunate that biopolymers work most effectively under calm and still conditions—the same conditions (known as doldrum periods) likely to cause the most pronounced effects of adverse temperature rises and light intensity on reefs.

This project will develop and test the potential benefits and limitations to the use of biopolymers as a means to reduce the effects or penetration of heat and light on the Reef.

Reducing the Impacts of Ocean Acidification

Rationale

Oceans absorb approximately one-third of the carbon dioxide produced by human activities. Increasing emissions result in more acidic oceans which in turn reduce the ability of corals and other invertebrates to grow their skeletons. Recent research shows that the ability of corals to form their skeletons is 15% lower than what it was prior to 1990[1].

It is also important to note that temperature and acidity have been shown to interact together resulting in a greater impact on corals and invertebrates than either factor has on its own.

Concept Objectives

This group of ecological and physical adaptation intervention concepts seeks to reduce the impact of ocean acidification by moderating CO^2 levels in reef waters.

Concepts include:

1. Exploiting natural systems such as seagrasses and their ability to assimilate CO^2 and bicarbonate as part of normal physiological processes.

   Seagrasses, or submerged plants, are critical habitats in the GBR as they provide food for dugong and turtles, absorb nutrients and toxicants and stabilise sediments. As with most plants, seagrasses sequester carbon through photosynthesis (releasing oxygen in the process) and release some CO^2 via respiration. This project explores the potential of seagrasses to sequester more carbon than they produce. This concept has been demonstrated at the micro-scale but at a broader reef scale the capacity for seagrass to offset ocean acidification has not yet been researched or modelled effectively.

2. Neutralising ocean pH through chemical buffering. Active management of pH is routinely undertaken in aquaria using this approach. This concept explores the potential of neutralising agents to combat ocean acidification levels within the unique Reef conditions (currents, winds etc.) without negatively impacting on the Attributes of a resilient Reef.

Assisting Organisms to Adapt

Rationale

It is well known that certain coral populations are more susceptible to climate change impacts than others. Currently however, we do not know the genetic basis of this variation.

The concepts explored in this Portfolio will investigate the genetic and evolutionary capacity of reef organisms to adapt or acclimatise to climate change impacts. It will also develop the fundamental tools and techniques required to assist such adaptation.

To determine the cost-benefits to ecosystem function of assisting organisms to adapt requires a rigorous assessment of their feasibility, effectiveness and biosafety. Such activities are core to this research.

This Portfolio further explores the potential of tapping into expertise and learnings from the terrestrial adaptation sphere and the rapidly advancing field of medical science, to identify possible additional marine adaptation options.

Studies incorporated into this research area will explore:

Genetic Markers—

This research will identify DNA markers for physiological tolerance in corals to environmental parameters that are expected to be severely affected by climate change, such as increasing seawater temperature and acidity. After being identified, these markers can be used to investigate variability in important tolerance traits.

Evolutionary Capacity—

This research will increase understanding of the evolutionary capacity of Reef biodiversity to adapt to climate change disturbances. While evolution is a very slow process, the extent to which coral communities can shift in response to selection pressure needs to be investigated.

Coral Husbandry—

This research will develop optimal methods for coral husbandry on the GBR, for both larvae/juveniles as well as adults, and techniques for the establishment of coral gene banks.

[1] De'Ath et al, 2009

Assisted Migration—

Coral reefs are located across a range of temperature zones. This research will explore the concept of translocating coral species which have adapted to warmer temperatures into cooler regions that are warming. Through interbreeding (conducted within a laboratory environment), warm-adapted genes could potentially be incorporated into the receiving population thereby increasing its thermal resilience and long-term survival. Exploration of the risks and rewards of this strategy need to be pursued[2].

Selective Breeding—

This research will develop knowledge and methods for successful breeding of corals to enhance their tolerance to increased sea temperatures and acidification.

Marine Refugia—

This research will identify areas which are either relatively protected from climate change effects (for example they are naturally shaded or have cooling currents) or have high resilience in their coral community. From this research further studies will be undertaken of genetic connectivity and the extent to which marine refugia are able to act as source reefs which replenish heavily disturbed reefs.

[2]Hoegh-Guldberg et al. Science, July 2008

Enabling Strategies

These address industry, community and management capacity to adapt to climate change and to adopt solutions. These initiatives are developed alongside ecological and physical strategies in order to support the socio-economic systems so inextricably linked to the Reef's ecological well being.

The enabling strategies consider:

- The engagement of communities and industries around the climate change agenda and their capacity to adapt to the impacts of climate change;
- Dynamic spatial management approaches; and
- New mechanisms for managing property rights and incentives.

Concept 1— Engagement

Community and industry engagement research projects will benchmark and monitor community attitudes towards different adaptation interventions and implement a regional climate plan to help build adaptive capacity in communities.

Industry engagement research activities will focus on increasing understanding of the economic impacts of climate change at an industry level. One of the likely impacts of climate change will be increased intensity of extreme events such as cyclones. As extreme weather events are already experienced, better understanding of the impacts of current events will provide a window into understanding future impacts. This activity will therefore involve assessing the immediate economic impact of extreme weather events such as cyclones on key reef industries (e.g.tourism and fishing) and the potential long lasting effects of extreme weather events on other related sectors.

Concept 2—
Spatial Management

Spatial management (or more generally, conservation planning) is recognised as an essential component of the effective management of marine natural resources (Douvere 2008). Spatial management is usually targeted toward the improved management of "features" of a region such as species or habitats. A key gap in current theory and practice is the adaptation of spatial management to include flexible arrangements that can adjust to changing situations (Hyrenbach et al. 2000).

Spatial management may assist reef managers with protection of "hot spots", more dynamic marine planning for both extreme and regular events; marine island conservation and the possibility of managed reef-based activities when required.

This project will develop new approaches to spatial management that address dynamic processes related to disturbances (e.g. coral bleaching, cyclone damage, river plumes) and resources (e.g. shifting concentrations of productivity related to upwellings or ocean fronts on which fish and seabirds depend).

Concept 3—
Economic Solutions to Reef Management

The balance between biophysical Reef resilience and socio-economic resilience is a delicate one. This project seeks to identify ways to manage property rights and to develop and deploy economic incentives to build reef resilience to climate change, including the reduction of compounding threats.

Integration Projects

Foreword

Many of the projects described in this Portfolio demand an analysis of vast, dynamic, complex and connected systems.

From the outset, the Foundation has adopted integration as the basis of its approach to objectively understanding and promoting the resilience of coral reefs, like the Great Barrier Reef, to climate change. This approach brings the framework, which stems from the Foundation's research vision, to life—ensuring this Portfolio is more than the sum of its parts.

This integrated approach is designed to depict the state of the Reef as well as the ability to monitor that state over time and scales, against different courses of management actions, all of this in an easily communicated manner.

Each of the integration projects discussed here, contribute to the overarching goal of integration for this Portfolio. The first of the integration projects, the Reef Resilience Index, brings together each of the Attributes and indicators of a coral reef resilient to climate change into an easy-to-understand and robust composite index which can be applied at various scales over time.

The second project focuses on moving from understanding to action. It integrates the outcomes of the Attributes research with research into potential Solutions & Adaptation concepts. Finally, the eReefs project will be fundamental to synthesis of research outcomes and the all-critical communication of information—from headlines to detailed analysis—to a range of Reef stakeholders.

The end point of integration is information for decision making by Reef managers, users and policy makers. Their responsibility, to determine what action to take and when, will be enabled by the integrated picture which this Portfolio provides.

—

Dr Eva Abal,
Chief Scientific Officer,
Great Barrier Reef Foundation

Introduction

Streams of Work

The three streams of work within integration are:

1—
Reef Resilience Index to Climate Change

Having identified eight Attributes of a resilient Great Barrier Reef to climate change, this integration initiative aims to bring the Attributes into a composite Reef Resilience Index which can be applied at appropriate scales to communicate the resilience of the Reef to climate change.

2—
From Understanding to Action

This workstream is specifically designed to ensure the outcomes of Attributes and Solutions & Adaptation projects are aligned with, and inform, one another. This work also has a strong focus on successfully moving between spatial (local, regional, whole of Reef) and temporal scales (hindcasting, forecasting, scenario generation) across the Attributes and Solutions & Adaptation concepts.

3—
Decision Making and Communications Tools

This suite of work focuses on a specific project—eReefs—which will provide the tools to integrate, visualise and communicate results so that decisions about the past, present and future of the Reef can be made effectively and efficiently.

Integration Projects

Project 1— Reef Resilience Index

The Foundation has identified 8 Attributes of a resilient Reef in the face of climate change, with the intention of integrating these Attributes into a composite Reef Resilience Index. This index will provide the basis for a rigorous monitoring and evaluation framework, required to measure the effectiveness of any interventions to mitigate or reduce the impacts of climate change on the Great Barrier Reef.

This integration project consists of the following research activities:

- Developing models for the spatial and temporal integration of data across multiple indices, including hydrodynamics and patch dynamic models as well as a numerical data integration and modelling framework.
- Piloting of ocean acidification sensor technologies;
- Designing a monitoring and evaluation program around the index;
- Developing an integrated communication and visualisation toolkit across the reef monitoring landscape.

These integration activities will be overseen by an expert integration panel.

A more comprehensive summary of this project is provided in Appendix A.

Project 2— From Understanding to Action

This workstream is specifically designed to ensure the outcomes of Attributes and Solutions & Adaptation projects are aligned with, and inform, one another. In particular, this work will ensure that the measurement framework established via the Attributes projects is fit for purpose (i.e. it is suitable to assess the effectiveness of the solutions & adaptation concepts being trialled).

A strong focus will also be given to successfully moving between spatial (local, regional, whole of Reef) and temporal scales (hindcasting, forecasting, scenario generation) across the Attributes and Solution & Adaptation concepts.

Work will commence as the results of Attributes and Solutions & Adaptation projects are realised and will be overseen by a working group with both Attributes and Solutions & Adaptation expertise.

Project 3—
eReefs

The Great Barrier Reef is a complex environment spanning paddock, coast and ocean. Managers face a difficult task as they grapple with multiple threats and enormous spatial and temporal dimensions.

Managers use research, monitoring, modelling, management interventions and reporting programs, all of which are underpinned by large investments from governments. However, the sources of data available to them are vast, the means to collect data are constantly changing and the modelling tools are incomplete. It is not currently possible to consider all these dimensions at once to determine the best and most effective response.

Without a comprehensive data integration and visualisation framework there are significant constraints on the development, implementation and evaluation of the very best management practices for the Reef and its catchments.

eReefs presents a significant step forward in addressing these challenges.

A pilot of this project is presently underway and clearly demonstrates the value that will be delivered by this transformational project.

Valued at $25 million, eReefs is a very significant project within this Portfolio.

Accordingly, a more comprehensive summary of the project is provided in Appendix B.

Appendices

Appendix A— The Reef Resilience Index

What is the Reef Resilience Index?

Having identified eight (8) Attributes of a resilient Great Barrier Reef in the face of climate change, the Foundation's intention is to integrate the Attributes into a composite Reef Resilience Index.

The research task comprehended in this large project takes in separate studies on each of the Attributes. This acknowledges the primary importance of being able to first understand and quantitatively measure the performance of key Attributes in order to determine the effectiveness of potential solutions & adaptation strategies that may be deployed on the Reef.

The secondary integration task will then enable the measurement of the pressure (in this case, climate change) and evaluate the resilience of the Reef, across different spatial and temporal scales, in the face of that pressure.

Valuing the Reef Resilience Index?

In order to make the best decisions, the managers of the Great Barrier Reef Marine Park must understand changing states of the ecosystem as a whole and at various scales, measured against ever changing physical and ecological conditions over multiple periods of time.

Water and natural resource managers in Australia and overseas have recognised the value of having an instrument to which they can turn, which can track the state of the system. To be effective, a tool like this must take into account the full complexity of the system, be underpinned by a strong scientific understanding of essential ecosystem Attributes and be used to communicate information effectively with audiences varying in appetite and understanding, from the technical to those with a more elementary stake in its future, with the aim of instilling cost-effective, timely, and relevant decision making.

The Reef Resilience Index, which this project will develop, will meet this need.

The Reef Resilience Index will:

1. Be robust and defensible—depending as it does on analysis of key Reef Attributes;
2. Be scalable to different spatial areas (local, regional, whole of Reef);
3. Highlight hot spots for urgent and immediate action;
4. Be able to be scrutinised to identify critical issues;
5. Complement other types of indices or reporting instruments (such as those developed to assess water quality on adjacent land);
6. Synthesise what is vast and complex to provide a strong but simple basis for effective communication;
7. Provide direct impetus for management to act confidently by substantiating the case for action;
8. Add significant value to the primary research effort on the Attributes;
9. Be transferable, in terms of the concept and process, to other reefs; and
10. Ground an efficient, effective and targeted monitoring program to track the response of the Reef to climate change.

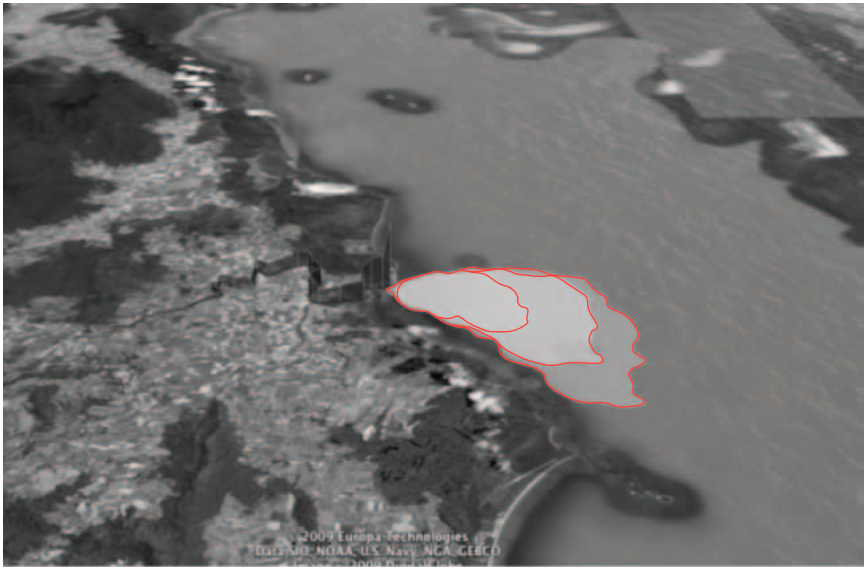
The Index and Biodiversity

The Reef Resilience Index will reflect if not depict the biodiversity of the Great Barrier Reef ecosystem.

What makes the Reef Resilience Index attractive is that key species components can be assessed alongside biophysical pressures such as temperature and pH as part of an overall assessment of the Reef's connectivity.

The Reef Resilience Index goes beyond base measurements of biodiversity at discrete points in time and looks at the Reef's resilience to multiple system pressures, tracking changes in biodiversity over time.

Appendix B—
eReefs



What is eReefs?

eReefs is an integrated system of data, models, visualisation and reporting tools that span the entire Reef area from paddock to catchment, estuary, Reef lagoon and ocean.

eReefs will provide the most comprehensive picture of the Reef as it is, has been and will be to Reef managers, policy makers, researchers, industry and communities.

eReefs will deliver for the first time:

1. Expanded and improved monitoring data by applying the latest in measurement technologies (e.g. mobile and internet tools);
2. Integrated spatial and temporal data from a wide variety of sources;
3. A suite of new and integrated models across paddock, catchment, estuary, Reef lagoon & ocean;
4. A framework to explore the fate and impact of multiple factors such as temperature, nutrients, turbidity and pH;
5. An interactive visual picture of the Reef and its component parts, accessible to all; and
6. The basis for more rigorous and transparent decision making by many users.

Great Barrier Reef Foundation
Unit 1, 9 Longland Street Newstead Australia
PO Box 2725 Fortitude Valley BC QLD 4006
Phone +61 7 3252 7555

www.barrierreef.org

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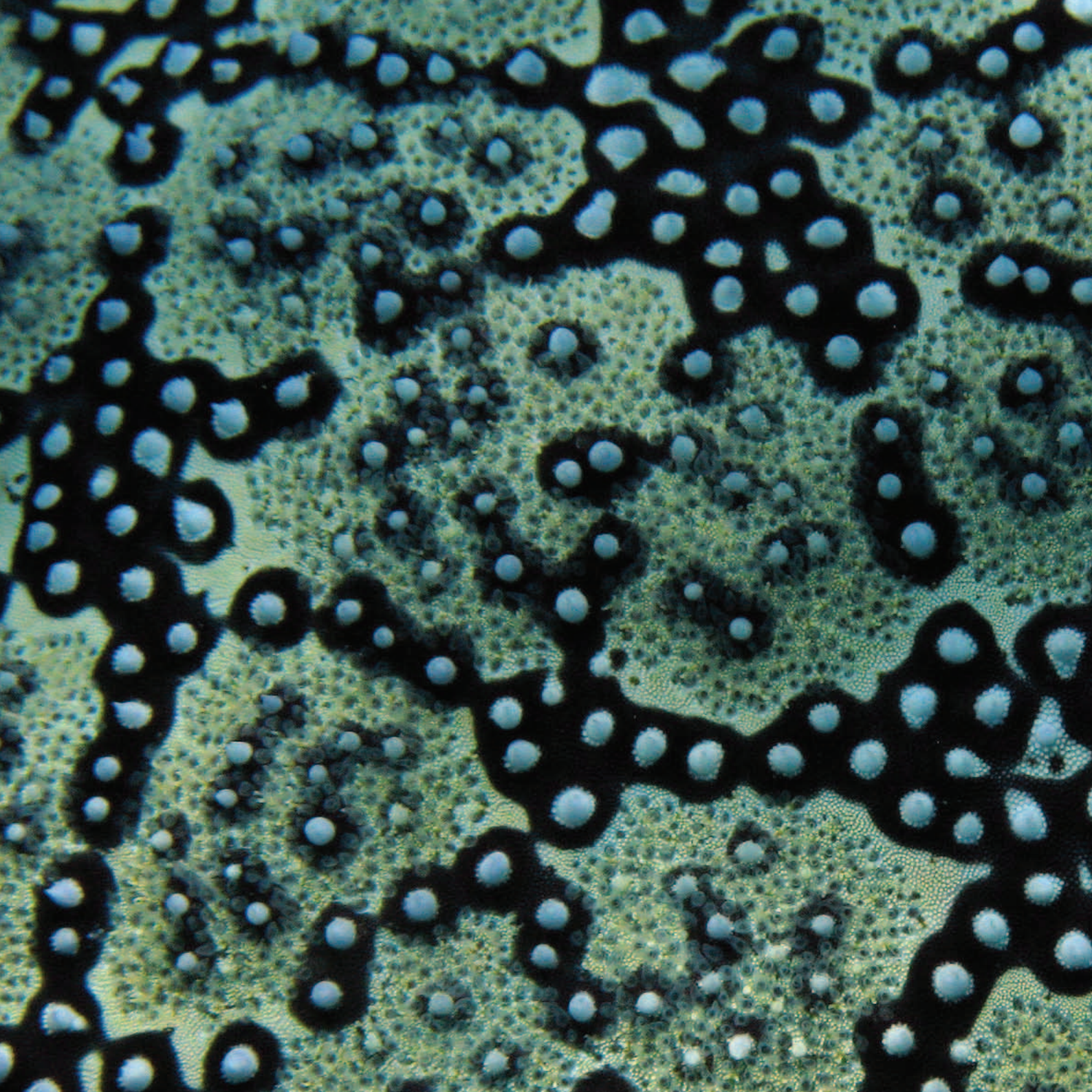

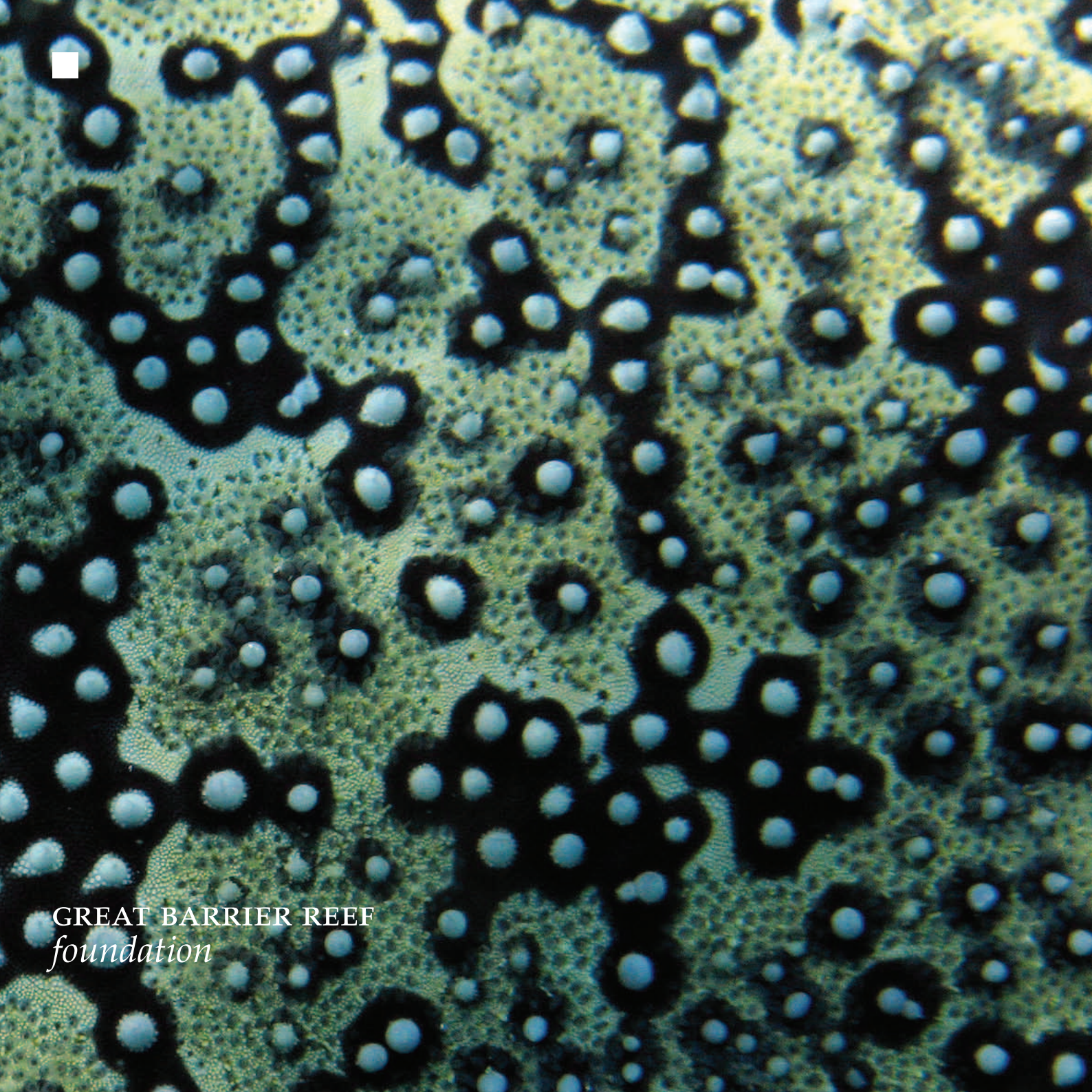
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