SYNTHESIS SUMMARY 7

Marine biodiversity

Changes in ocean temperature and chemistry are already impacting our marine environments. This has implications for how we manage our fisheries, tourism, conservation zones and coastal environments.

NCCARF
National Climate Change Adaptation Research Facility

About this summary

This summary deals with marine biodiversity. The opening pages provide the context, including the nature of climate change and its impacts on marine biodiversity ('Why we need to adapt'), followed by a synthesis of research findings around climate change impacts and adaptation responses for marine biodiversity ('The research base …'). It concludes with a summary of how this new research knowledge might guide key adaptation challenges and actions. This final section is informed by a workshop held with practitioners ('Evidence-based policy implications').

This brief was developed by members and staff of NCCARF's National Adaptation Network for Natural Ecosystems, with input on the policy challenges and actions developed in workshops held in Hobart (Tasmania) and Canberra (ACT) in March 2016. The workshops were attended by practitioners, policymakers and managers from within local, state and federal government organisations, community service organisations, not-for-profit organisations and universities.

The key research reports used to develop this summary are highlighted in Section 4. To see all reports from the ARG Program, please visit **www.nccarf.edu.au/adaptation-library.**

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About this series

Between 2008 and 2013, the Australian Government funded a large nationwide Adaptation Research Grant Program (the ARG Program) in climate change adaptation. The overall Program was managed by the National Climate Change Adaptation Research Facility (NCCARF), with management of projects in the Marine Biodiversity discipline conducted by the Fisheries Research and Development Corporation. It resulted in over 100 research reports that delivered new knowledge on every aspect of adaptation. The aim of the Program was to help build a nation more resilient to the effects of climate change and better placed to take advantage of the opportunities.

This series of Synthesis Summaries is based on research findings from the ARG Program, augmented by relevant new literature and evidence from practitioners. The series seeks to deliver some of the policy-relevant research evidence to support decision-making for climate change adaptation in Australia in a short summary. It takes an approach identified through consultation with relevant stakeholders about the needs of the intended audience of policymakers, decision-makers and managers in the public and private sectors.

Key findings

Key recommended actions

1: Provide engagement, knowledge exchange and guidance for stakeholders

Support stakeholder decision-making based on what we value (e.g. biodiversity, industry survival and growth), now and in the future.

2: Foster resilience through habitat repair and protection

Building resilience and adaptive capacity in species, habitats and human populations through proactive approaches decreases vulnerability by reducing exposure, decreasing sensitivity, or increasing adaptive capacity. Climate change is already affecting the physical environment around Australia, through long-term change and extreme events.

3: Fine-tune fisheries management systems

The fishing industry can minimise negative impacts of climate change and take advantage of new opportunities if appropriate and targeted information is available.

4: Enhance whole of government approaches and policies

It will be important that government policy, regulation and support are flexible and responsive to deal with challenges as yet unknown and avoid conflicting policies across different levels of government.

5: Fund and finance adaptation planning and action

Most adaptation policies and actions will require investment of resources for success and these will need to come from both the private sector and government sources.

1. Why we need to adapt

The climate and environmental context

Australia's 60 000 km coastline spans tropical waters from the Torres Strait in the north to cool temperate waters off Tasmania and the sub-Antarctic islands. Australia's exclusive economic zone covers more than 8.1 million km^2 (excluding the Australian Antarctic Territory). Its marine ecosystems are considered globally significant—in particular the World Heritage-listed Great Barrier Reef—because they support many rare, endemic and commercially important species.[1] However its waters, like its landmass, are nutrient poor making marine Australia a low productivity environment.[8]

Anthropogenic climate change is already apparent in marine Australia and will continue to have significant, ongoing impacts on marine species and habitats. Ocean warming is particularly rapid in south-eastern and south-western waters, which are considered global warming hotspots[7], and is already leading to species range extensions.[23] Near-coastal sea surface temperatures around Australia are typically expected to rise by 0.4 - 1.0 °C by 2030 and as much as 2 – 4 °C by 2090 under a high emissions scenario (RCP8.5) compared to temperatures between 1986-2005.[4]

Marine communities are affected by extreme climate events such as floods, marine heatwaves and tropical cyclones [10], and such events are projected to increase in frequency and/or intensity in the future. Increases in atmospheric carbon dioxide levels result in changes to ocean chemistry, notably uptake of CO_2 that lowers pH. This process of ocean acidification, while slow, will persist for centuries. Calcifying organisms, such as corals and some plankton, already show effects such as weaker skeletons and shells from declining pH with more dramatic changes projected for the future.[5,16]

Key risks

Even if greenhouse gas emissions are reduced, there will be sustained changes to marine environments. Climate change will have a range of direct effects on the physiology, fitness, and survival of marine species as well as indirect effects via habitat degradation and changes to ecosystems. Effects will differ across populations, species and ecosystems, with some impacts being complex and causing unexpected outcomes.

Climate change will also impact on people and communities that depend on marine species for food (e.g. fishing) or livelihoods (e.g. marine tourism). Inevitably, adapting to a new climate regime will require trade-offs between preservation of some biological assets and socioeconomic drivers.[13] As a result of these changes, biological and human systems will not function as they have in the past.

2. The research base informing adaptation

The research base informing adaptation

Australia's oceans, marine biodiversity, and dependent industries (for example, fisheries and aquaculture) are already experiencing and responding to a changing and more variable climate.[10,11,12,20] Marine systems are experiencing flow-on effects from climate through ecological and economic change at a more rapid rate compared to terrestrial systems.[21] Coastal systems, including estuaries are subject to multiple threats aside from climate change[6,22], and repairing and improving estuarine management would deliver major benefits for fisheries.[2]

Impacts of climate change on marine systems

Impacts of climate change on Australian marine systems indicate widespread changes in many regions and throughout all levels of the food webs (Table 1). In south-east Australia for example, biological impacts include poleward range shifts of 50 per cent of intertidal invertebrates and more than 50 coastal fish species. Arrival in Tasmania of the habitat-modifying sub-tidal urchin *Centrostephanus rodgersii* exemplifies marine climate change in the region. Community-wide impacts are evidenced by changes in phytoplankton and zooplankton communities, recruitment in lobster populations, and availability of prey for small pelagic fishes. Along the west coast of Australia, many seaweeds have also extended southwards, while a marine heatwave in 2011 dramatically changed the balance between algal and coral species across a number of locations. Experimental evidence from Australia's tropical reefs shows that ocean acidification will impact habitat quality, coral growth, and even fish behaviour, by the end of the century. The sensory abilities of juvenile reef fish are compromised at high CO_2 levels, which affects predator recognition and avoidance, and settlement in appropriate habitats.[18]

Commercial marine fishing and aquaculture contribute more than $2 billion annually to the Australian economy, and have great importance for coastal communities. Climate change presents significant challenges for Australia's seafood industries through direct changes and access to fisheries resources, as some commercial species move their range or disappear; and indirectly through habitat changes[11] and through disturbances from extreme events disrupting operations.[10] The magnitude of future impacts, and whether marine ecosystems and fisheries can adapt, depends on the rate of change, the response of the marine system to climate change, and other drivers both social (e.g. markets, policy, governance and management) and ecological (e.g. habitat declines and pollution).

Identifying vulnerable species, habitats, communities, and dependent human systems

Vulnerability assessments in natural and human systems highlight the co-dependency of many marine ecological and social subsystems, with the vulnerabilities of both intrinsically linked (Figure 1). A number of vulnerability assessments, some using variations of Figure 1, identify the species, habitats, and communities that are at greatest risk.[15,19,24] Examples of identified vulnerabilities are outlined in Table 1.

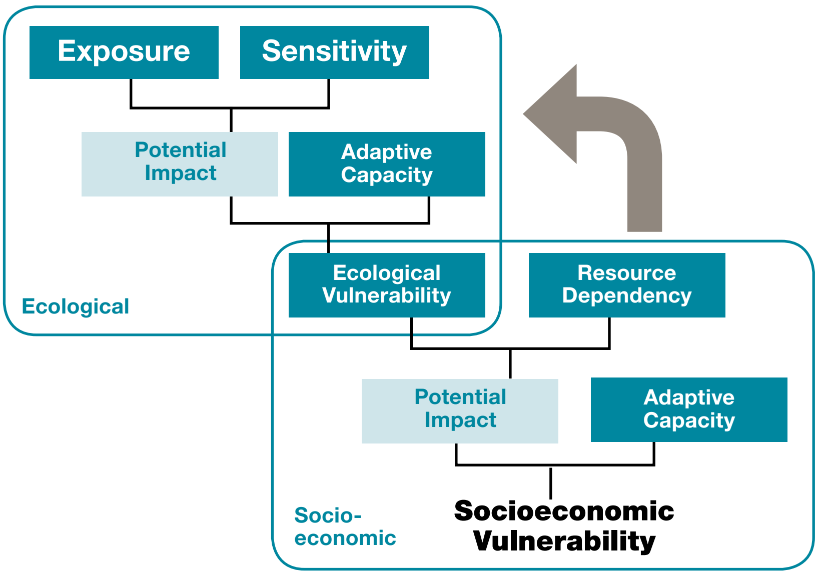


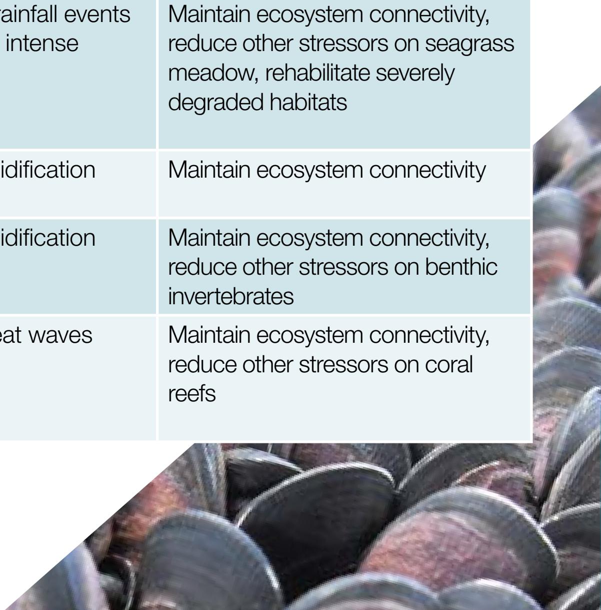
Figure 1. A conceptual framework for assessing vulnerability to climate change in climate-sensitive socio-ecological systems. The co-dependency of ecological and socio-economic subsystems means that their vulnerabilities are intrinsically linked.

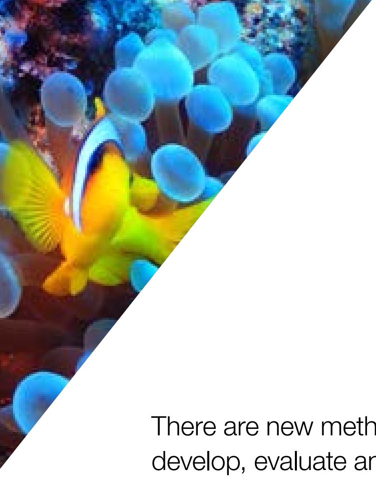
Potential adaptation options for marine biodiversity and dependent industries

The range of adaptation options will largely depend on the vulnerability of species and habitats. While some projected climate-related changes are within the historic range of variability experienced by marine species, the global rate of change is projected to exceed the exposure that has been experienced in the past.[17] Natural adaptation and resilience are unlikely to be sufficient to cope with projected changes and may require appropriate strategic conservation.[12] The range of strategies to enhance resilience of marine ecosystems will vary over space and time depending on (i) the response of species, communities, and ecosystems to climate change, (ii) their current condition, (iii) trade-offs with other socioeconomic imperatives, and (iv) existing governance arrangements and management paradigms.[12] Likely strategies include habitat protection and restoration, species translocation, predator control, and reduction of non-climate stressors such as over-fishing and pollution.

Table 1: Key observed impacts of climate change in Australian marine ecosystems. Reproduced from Johnson and Holbrook.[12]

Observed impacts	Locations of documented impacts	Climate driver	Management to support adaptation
Giant kelp decline by up to 95%	Eastern Tasmania	Increasing ocean temperature	Maintain ecosystem connectivity, interventions to replant communities
Changed structure of nearshore zooplankton communities	Eastern Tasmania	Increasing ocean temperature	Maintain ecosystem connectivity
Poleward range extension of the long-spined sea urchin causing habitat changes	Eastern Tasmania	Increasing ocean temperature	Interventions to rehabilitate degraded habitats, removal of locally invasive species, artificial habitats for displaced species
Poleward shifts of seaweed species	SE Australia, SW Australia	Increasing ocean temperature	Maintain ecosystem connectivity
Reduced resilience of kelp to disturbances at the northern limit of their range	SW Australia	Increasing ocean temperature	Maintain ecosystem connectivity, reduce other stressors on kelp communities
Range contraction of habitat forming seaweed and decline in habitat condition	SW Australia	Increasing ocean temperature	Maintain ecosystem connectivity, reduce other stressors on habitats in decline
Tropicalisation of fish communities	SW Australia, Tasmania	Increasing ocean temperature	Maintain ecosystem connectivity
Decline of 11.4%in coral calcification since 1990	Great Barrier Reef, northeast Australia	Ocean acidification and increasing ocean temperature	Maintain ecosystem connectivity
Declines in fish diversity after climate related habitat disturbances (coral bleaching and storms)	Great Barrier Reef, northeast Australia	Marine heat waves and more intense storms	Maintain ecosystem connectivity, reduce other stressors on affected fish populations during recovery
Reduced adult foraging and chick provisioning of some species of tropical seabirds	Great Barrier Reef, northeast Australia	Marine heat waves and more intense storms	Reduce other stressors on tropical seabird populations and breeding activities
Loss of primary seabird nesting islands	Great Barrier Reef, northeast Australia	Altered rainfall patterns and more intense storms (future sea-level rise)	Reduce other stressors on seabird nesting islands, rehabilitate degraded islands, provide artificial nesting sites
Declines in coral cover from 28% to 14% since 1985	Great Barrier Reef, northeast Australia	Marine heat waves and more intense storms (and crown-of-thorn starfish)	Maintain ecosystem connectivity, reduce other stressors on coral reefs
Declines in seagrass meadows since 2009 with 94% of sites surveyed classified as being “poor” or “very poor” condition	Great Barrier Reef, northeast Australia	Extreme rainfall events and more intense storms	Maintain ecosystem connectivity, reduce other stressors on seagrass meadow, rehabilitate severely degraded habitats
Reduced coralline algae biomass and recruitment	Temperate and tropical Australian reefs	Ocean acidification	Maintain ecosystem connectivity
Reduced calcification of benthic invertebrates	Experimental – projected Australia-wide	Ocean acidification	Maintain ecosystem connectivity, reduce other stressors on benthic invertebrates
Coral bleaching and mortality, and resultant habitat declines	Great Barrier Reef, northeast Australia, Ningaloo Reef, northwest Australia, Torres Strait, northern point	Marine heat waves	Maintain ecosystem connectivity, reduce other stressors on coral reefs





There are new methods to develop, evaluate and prioritize adaptation options for some iconic marine species, such as seabirds, marine mammals, and sea turtles.[9] Some adaptation options are being tested on representative populations, and these will support a process of learning about adaptation by managers and scientists. For instance, developing options for seabirds and marine mammals in southern Australia is empowering managers to begin to test these in the field.[9] In parallel, research is also investigating the evolutionary capacity for adaptation in a range of marine species.[17] Together, understanding of the success of both directed options and the capacity for autonomous rates of change will form the basis for future decision making for managing marine biodiversity under climate change.

The adaptation options and pathways are critical to the future sustainability of marine resources. Seafood industries will need to consider strategies that are both autonomous (e.g. fish moving to cooler waters) and planned (e.g. factoring climate impacts into stock assessments). Deliberate adaptation that seeks to avoid possible maladaptation needs to consider: (i) which species, communities or ecosystems are most vulnerable to climate change; (ii) the likelihood of climate-related ecological changes affecting dependent industries; and (iii) planned adaptations that support effective response to future changes.[11]

The future will depend on the seafood industry's capacity to identify and apply effective adaptation strategies for long-term viability and sustainability. Effective adaptation responses require knowledge of expected long-term changes in species distributions, improved weather and seasonal climate forecasts and their influence on focal species, and better understanding of species tolerances.[3] Models can be used to help predict trends and set priorities; however, these need to be based on the best available science and data, and to include fisheries, environmental, socioeconomic and political layers to support management actions for adaptation.[13]

From a climate adaptation perspective, Creighton et al.[3] generated a checklist of 13 elements to assess and steer progress towards improving marine policy and management (Table 2). These elements are grouped in three broad areas: preconditioning; future proofing; and transformational changes and opportunities. Arising from these elements is a suite of priority strategies that provide guidance for marine managers, policy practitioners, and stakeholders as they prepare for a future under climate change.[3] Regions where warming is most rapid will be among those to experience impacts first, will need to develop early responses to these impacts, and can provide a guide for management elsewhere.[7]

Table 2. Summary of the elements for guiding and assessing marine policy and management change, in each of three phases. These high level elements can inform development of specific policies and goals within the diverse marine sectors.[3]

Phase	Element
Preconditioning	• Policy and management need to respond to changing social-ecological conditions, so interventions must be flexible and adaptive • Action for climate adaptation must be a part of larger social and economic adaptations to changing circumstances • Climate policy should be implemented as part of integrative, multi-objective policy and management • In responding through management intervention to changing social-ecological system interactions, it is essential to climate influences
Future proofing	• Fostering resilient healthy ecosystems is an imperative for policy and management • Policy and management must address spatial and temporal scales that match the values and issues of concern • Catchment management is essential for positive marine outcomes • In responding to threatening processes, it is essential to ensure ecosystem integrity • In protecting key species, site- and species-specific strategies are essential
Transformation and opportunity	• Changes brought about by a changing climate must be assessed for beneficial opportunities • In responding to increased climate variability and change, a transition towards flexible total stock or population management systems is essential • Policy and management must take advantage of the key role marine ecosystems can have in carbon sequestration • Carbon sequestration in marine systems is best done as part of a multi-objective approach

3. Evidence-based policy implications

To continue to derive myriad benefits from the oceans, the rate of adaptation in human systems needs to at least keep pace with the rate of ecological change.

ADAPTATION ACTION 1:

Provide guidance and engagement and knowledge exchange opportunities for stakeholders

This challenge is not unique to adaptation, but is important given the significant risks from climate change and the possible need for transformational change.

Marine ecosystems will change and adapt in response to changing environmental conditions. Stakeholders need to decide what we value (e.g. biodiversity, industry survival and growth), now and in the future. Polarisation of views tends to be underscored by a lack of knowledge, so improved decision-making processes will be enabled by greater knowledge sharing. There is also considerable private investment needed for some adaptation options and so it is important these stakeholders understand what the science is saying, what options are available, and the costs and benefits of different adaptation options.

Stakeholders are actively seeking help and support to make pragmatic decisions in an environment of a shrinking network of engagement and outreach – particularly government supported services. Identified knowledge needs include translation of complex science to advice for end-users, summaries from trusted sources to help engage senior management and mechanisms for dealing with information gaps. There is a clear need for messaging around what different futures for ecosystems will look like. There is a need for support on how to use new knowledge in decision-making.

ADAPTATION ACTION 2:

Foster resilience through habitat repair and protection

Building resilience and adaptive capacity in species, habitats and human populations experiencing marine climate related vulnerabilities is important.

Developing adaptation strategies to decrease vulnerability by reducing exposure, decreasing sensitivity, or increasing adaptive capacity in the face of climate change risk should be priorities for researchers and decision makers. Approaches that are proactive rather than reactive are likely to be more cost effective and work better in the long term. There is a need to understand any limitations associated with this form of adaptation, and how to build pathways of action.

Plans for habitat repair and protection might also consider other co-benefits. For example, will protection of a particular area provide productivity gains elsewhere?

Monitoring will be a critical element to ensure habitat repair and protection is building resilience. The difficulty is to determine who should be responsible for monitoring and how it should be carried out. Key questions to help guide both repair and protection activities and monitoring will need to be considered, including:

- What threshold of change leads to species and ecosystem disruption?
- What is the rate of change that marine systems can handle without intervention?
- Can building resilience to climate extremes support long-term resilience?
- How should conservation managers and planners modify their practices to reduce or manage climate change risks and enhance adaptation options?

ADAPTATION ACTION 3:

Fine-tune fisheries management systems

The fishing industry faces a number of challenges with a changing climate. Commercially valuable species are likely to move into new waters, or deeper waters. The fishing industry can minimise negative impacts and take advantage of new opportunities if appropriate and targeted information is available.

Where some fisheries are advantaged by new species or the increased abundance of species there will be opportunities to improve production or open new markets. Local businesses and industry bodies will need to decide if the there is value in investing in new production. For example, could Sydney Rock Oysters be put into production in Tasmania? The oysters have a long growth time, and have never been grown in Tasmania before but there is likely to be a low risk in bringing them into production. The capacity to change harvesting techniques, infrastructure and market reception will be a significant factor in determining the success of new commercial fisheries.

For wild catch species, changes to fish communities may raise jurisdiction issues and change access to cooperatively managed resources.

Responding to changes in fisheries is likely to result in problems to supply chains and markets, and these need to be considered when developing effective response plans.

ADAPTATION ACTION 4:

Enhance whole of government approaches and policies

While we have good science to help understand future challenges and opportunities there remain many others that we don't yet know about. In this environment, it will be important that government policy, regulation and support are flexible and responsive. A first important step is likely to be clarification of roles and responsibilities.

There is also often conflicting policy at different levels. Ideally, holistic approaches to managing coastal and marine resources would eliminate some of this. The coastal zone is difficult to manage because of multiple land managers, industries and fixed or unfixed boundaries of responsibility. The goal is to develop and implement decisions and policies for both land-based and marine climate change adaptation that are mutually supportive rather than counter-productive. The need for continual and wide engagement with all stakeholders is paramount.

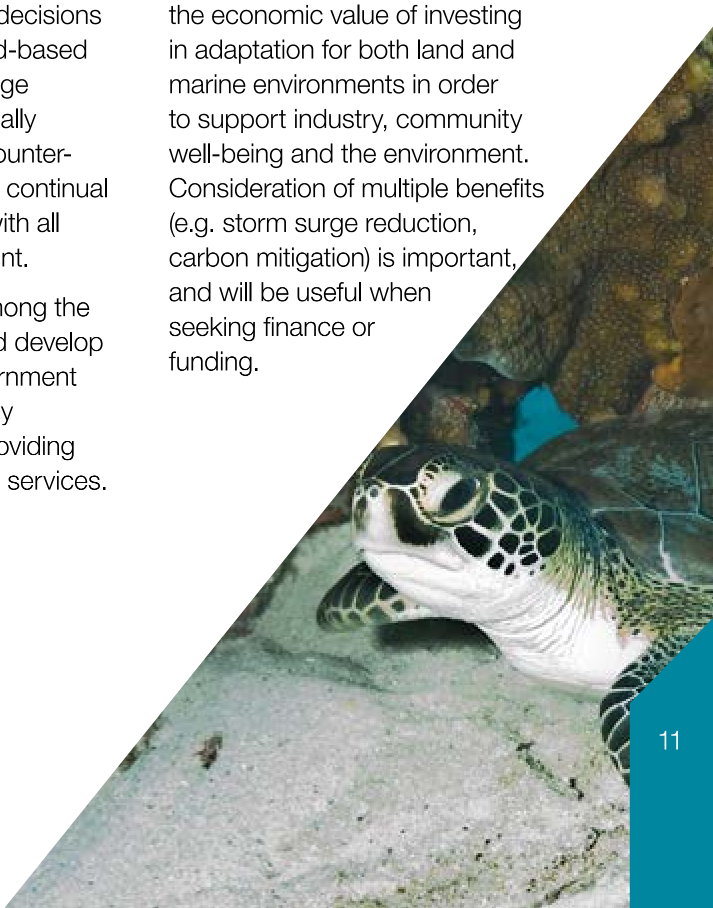
There is a perception among the stakeholders who helped develop this Summary, that government roles have become purely regulatory rather than providing education and extension services.

ADAPTATION ACTION 5:

Funding and financing adaptation planning and action

Most adaptation policies and actions will require investment of resources for success. Some of the investment will be needed from the private sector, while some is most likely to come from governments. There is a need to consider this early, and to establish partnerships and mechanisms to obtain finance. Ultimately this will require engagement and collaboration with different stakeholders.

Funding for protection and repair of habitat tends to compete with more powerful bodies for funding. For example, investment in infrastructure and technology is usually prioritised over issues considered to be environmental. It will be important to understand the economic value of investing in adaptation for both land and marine environments in order to support industry, community well-being and the environment. Consideration of multiple benefits (e.g. storm surge reduction, carbon mitigation) is important, and will be useful when seeking finance or funding.



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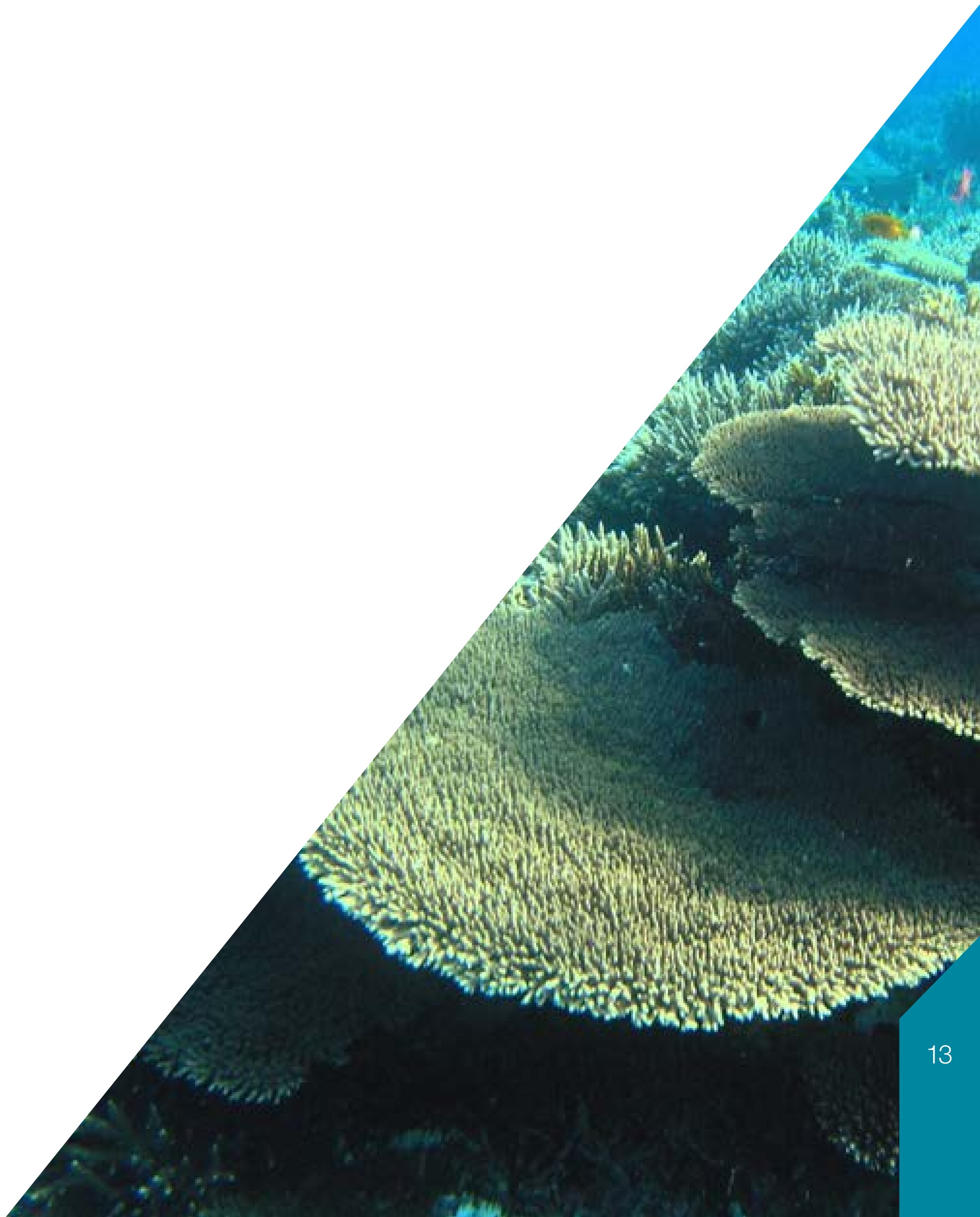

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