



Research

Extreme events, loss, and grief—an evaluation of the evolving management of climate change threats on the Great Barrier Reef

Lisa C. Walpole^{1,2} and Wade L. Hadwen^{3,4,5,6}

ABSTRACT. Coral reefs across the world have demonstrated an incredible resilience to disturbance, having persisted for over 200 million years withstanding local, short-term shocks such as cyclones and bleaching events, as well as large-scale, long-term global changes such as sea-level fluctuations. However, there are now many persistent and growing threats to the health and productivity of global reef systems such as the Great Barrier Reef (GBR), including water temperature change and subsequent coral bleaching, invasive species, severe weather events, and water quality degradation. Among these, it is widely acknowledged that climate change is the greatest threat to the GBR, with the GBR Marine Park Authority (GBRMPA) releasing a position statement on climate change in 2019, compellingly arguing the urgent need for climate change action for the GBR. For the past two decades, researchers have strongly emphasized the need for vigorous implementation of management strategies that support global reef resilience. This study provides a critical review of the response to this call to action and the barriers and opportunities for implementing transformative resilience actions across a range of social-ecological and natural resource management contexts. Bringing the concepts of environmental grief and resilience thinking together, this study reflects on how back-to-back coral bleaching events in 2016–2017 have changed the framing of GBR management. However, there is more work to be done to ensure that all actors responsible for GBR management accept and embrace change in order to enable transformative resilience, which, for an environment feeling the heat of climate and non-climate pressures, will maintain at least some of their critical environmental, social, and economic values.

Key Words: *climate change; environmental grief; Great Barrier Reef; resilience*

INTRODUCTION

It is widely acknowledged that climate change is the greatest threat to the Great Barrier Reef (GBR) (Hughes et al. 2003, De'ath et al. 2012, Fidelman et al. 2013, Intergovernmental Panel on Climate Change (IPCC) 2018, Great Barrier Reef Marine Park Authority (GBRMPA) 2019b) and coral reefs globally (Hoegh-Guldberg 1999, Graham et al. 2014, Nyström et al. 2000). In recent years, the GBR has been exposed to several unprecedented climate-related events, including three coral bleaching events in 5 years (2016, 2017, 2020) coupled with the impacts from severe tropical cyclones, poor water quality from catchment run-off, population increase and urbanization, port expansion, fishing, and habitat loss (Prideaux et al. 2018, GBRMPA 2019a, Smith and Spillman 2020). These events and pressures have been instrumental in driving strategic investments to manage the GBR system (GBRMPA 2017, Commonwealth of Australia 2018a, Great Barrier Reef Foundation (GBRF) 2019). This has included the Strategic Assessment (GBRMPA 2014b), Climate Change and Adaptation Plan (GBRMPA 2012b), and the Reef 2050 Long-Term Sustainability Plan (Commonwealth of Australia 2018a), along with significant regional and sectoral planning and action (Roocke 2013, Pickering et al. 2017).

Despite the huge ongoing investment in reef protection, few components of the reef management program have fully incorporated climate change and recognized that changes in the ecosystem are occurring now and are inevitable (Graham et al. 2014, Tan and Humphries 2018). Instead, management approaches have sought to resist change and to maintain a “sustainable optimal state” (Walker and Salt 2006). For the GBR, the primary focus of plans, strategies, and actions (Commonwealth of Australia 2018b, 2019) has been to increase

system “resilience” to shocks and pressures that may be exacerbated by climate change and support ecosystems to return to a pre-disturbance condition (Morrison et al. 2020). This has led to a strong focus on improving water quality and managing species of concern, like the crown of thorns starfish (COTS; Hughes et al. 2015, Babcock et al. 2016). Fundamentally, these approaches assume that by controlling these non-climatic environmental stressors, the GBR can be protected and maintained in its current state. It remains to be seen whether these “building resilience” management approaches can safeguard the reef from significant climate impacts in the long term, but regardless, recent widespread and unprecedented coral bleaching events on the GBR in 2016, 2017, and 2020 signal the need for action and management responses that consider the future climatic state, rather than managing the system as a static state (Morrison et al. 2020). Although coral reefs are frequently exposed to disturbances and have shown the capacity to reassemble following disturbance (Nyström and Folke 2001, Hughes et al. 2003), a new sense of urgency has been reflected in more recent documents released by the Great Barrier Reef Marine Park Authority (GBRMPA 2019b) and the Intergovernmental Panel for Climate Change (IPCC 2018), with multiple lines of evidence indicating that tropical coral reefs are likely to disappear even if global warming is constrained to 1.5°C of warming.

An urgent need to address change in the condition of the GBR aligns very well with the core concept of resilience thinking, with the appearance and application of multiple meanings emerging and diverging since the 1970s (Gunderson 2000, Folke 2016, Nyström et al. 2008). Walker and Salt (2006) defined resilience as “the capacity of a system to absorb disturbance and still retain its basic function and structure.” They go on to note that “at the

¹Alluvium Consulting, ²International Water Centre, ³School of Environment and Science, ⁴Australian Rivers Institute, ⁵Griffith Climate Action Beacon, ⁶Griffith University

heart of resilience thinking is a very simple notion—things change—and to ignore or resist this change is to increase our vulnerability and forego emerging opportunities.” Compellingly, Walker and Salt (2006) explain that the configuration and reconfiguration of our natural and social systems are often driven by extreme events rather than average conditions, and that “there is no sustainable “optimal” state of an ecosystem, a social system, or the world.” This contradicts the philosophy underpinning many natural resource management (NRM) strategies, which are based on the premise of trying to keep things as they are, or return them to how they were.

The concept of resilience has been defined in various ways in different arenas, but it goes well beyond the “return to normal” operational definition currently favored for the management of many natural systems (Nyström and Folke 2001, Grafton and Little 2017, Sinclair et al. 2017). Masnavi et al. (2019) and Chelleri et al. (2015) provide valuable literature reviews and critique resilience, resilience thinking, and resilience trade-offs in the context of urban systems. They define resilience as three (partially overlapping) stages that have short, medium, and long-term perspectives (Table 1). These range from resisting change as “resilience as recovery,” accommodating some change as “resilience as adaptation,” through to “resilience as transformation,” which embraces change by acknowledging alteration of the fundamental attributes of a system. This shift in the state of a system, within and beyond thresholds, is often shown as the “ball-in-a-basin” model (Fig. 1). In this study, using the definitions of Chelleri et al. (2015), resilience as recovery aims to “bounce back” following a shock, whereas adaptation seeks to adjust to actual or expected changes “by moving thresholds in order to make the system persist within the same regime.” Resilience as transformation “refers to the alteration of fundamental attributes of the system, which will allow it to enter a new regime.”

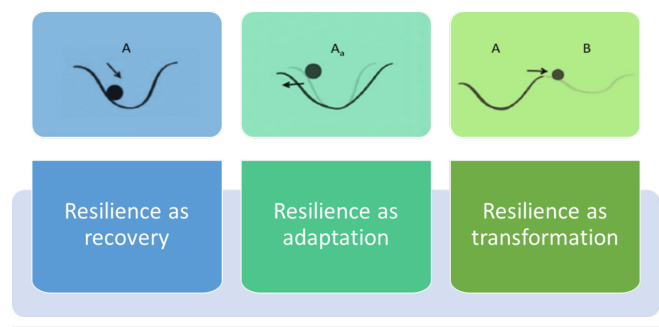
Chelleri et al. (2015) argue that “a sustainable transformation should be the long-term goal, operationalized through the management of (different scales and approaches of) resilience.” They note that shifting resilience thinking toward transformation is a “critical and complex socio-political choice,” and that it usually only happens once the system is approaching dangerous thresholds. Anthony et al. (2016) suggest that reef managers globally are shifting focus from solely reducing stressors, to “supporting ecosystem processes that lower sensitivity, promote recovery and enhance adaptive capacity.”

In this study, we sought to critically evaluate shifts in the narrative around management of the GBR to explore whether there is growing acknowledgment of climate-driven change (in species, processes, or habitats) and the need to reconsider what protected areas are designed to achieve. To undertake this analysis, we coupled an evaluation of historical management documents with key informant interviews, in a bid to understand both individual and organizational views on the current state and likely fate of the GBR. Based on the above concepts of resilience thinking and recognition of the dangerous thresholds being approached for the GBR ecosystem (IPCC 2018, GBRMPA 2019b), the three-stage model of resilience thinking (Fig. 1) was used as a lens through which current management responses to the climate change threat could be explored.

Table 1. Types of resilience thinking (adapted from Chelleri et al. 2015)

Resilience type	Definition
Resilience as recovery	Resisting change Bouncing back to a previous state after system shock Ability of the system to absorb disturbances and achieve a balance through recovery
Resilience as adaptation	Accommodating some change Adjustment to actual or expected changes and their consequences to enable the system to support species and ecosystem functions Capacity to absorb pressures or destructive forces by adapting to the change
Resilience as transformation	Embracing change Alteration of fundamental attributes (habitats, species) of the system that will allow it to enter a new regime The ability of the system to absorb disturbances and adaptively respond to the change through transformation in terms of species diversity, ecosystem functioning, and habitat quality

Fig. 1. Stages of resilience (adapted from Chelleri et al. 2015).

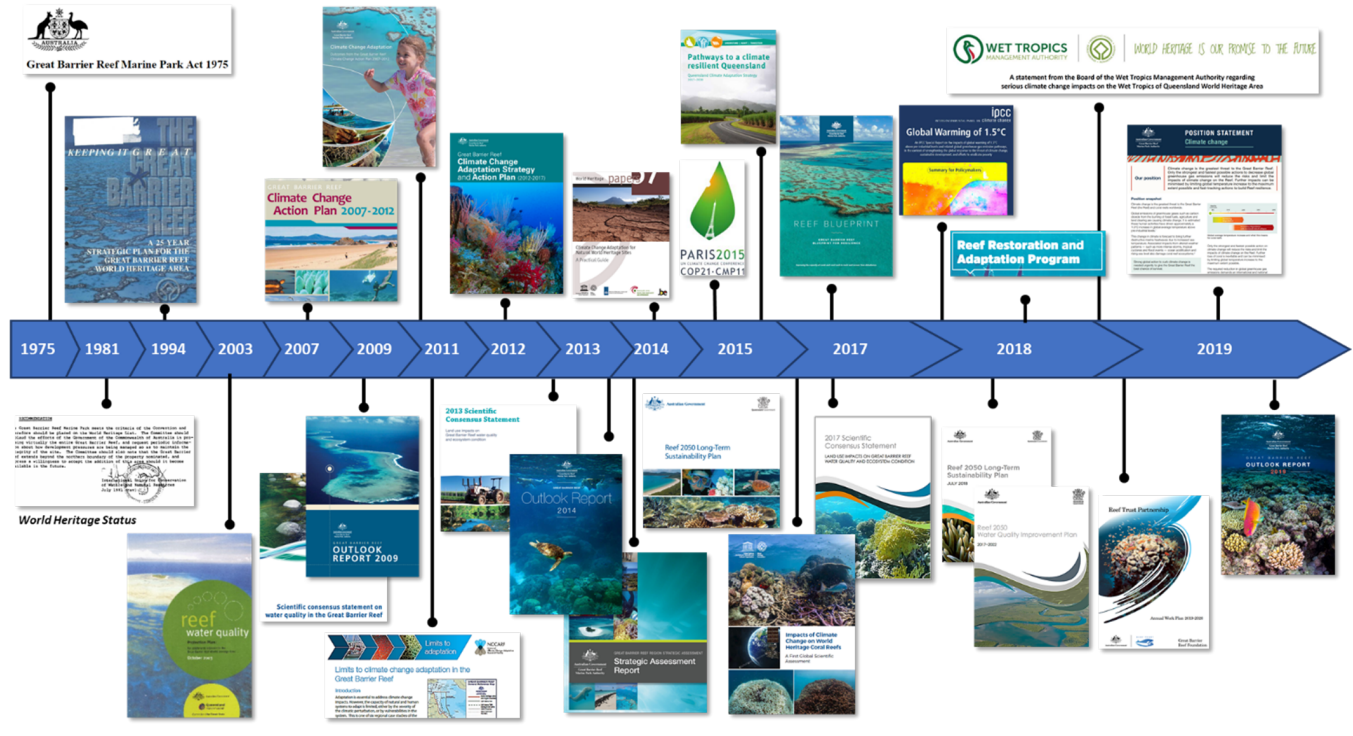


METHODS

The focus of the study was to develop an understanding of the management response to climate change threats, within GBR land-based catchments and the GBR marine system, and explore how resilience thinking can inspire management of the GBR that better accounts for climate variability and change. It did not seek to evaluate or address climate change mitigation efforts at the local, national, or global scales.

To explore how the focus and narrative around GBR management has changed through time, a critical review of key governmental policies and plans over the period 1975 to 2019 was undertaken. This review summarized the purpose, key themes and messages, and the degree to which climate change was considered in each policy, plan, or strategy. The analysis considered whether the key messages and priorities within each plan referred to climate change, and the degree to which actions and responses specifically addressed climate-related threats. Finally, these evaluations enabled each document to be mapped against the three theoretical types of resilience through a review of language and the intent around actions and priorities, to explore the degree to which management agencies have developed their thinking and planning with respect to resilience.

Fig. 2. Timeline of key Great Barrier Reef and climate change publications.



The critical review of policy documents was supplemented with a series of semi-structured interviews with key informants to understand how policies and strategies had transferred to on-ground action. A list of organizations critical to management of the GBR was collated, including federal and state government agencies, NRM groups, consultancies, research organizations and non-government organizations. From these organizations, a range of prominent actors in the GBR management and research space were identified as potential participants in the interview process, with 20 potential interviewees contacted. With some unable to participate, and others being identified through a “snowball” process, a total of 12 individuals were interviewed across nine organizations that collectively represent the reef governance space. Importantly, in the context of evaluating the evolving narrative around GBR management and climate change threats, all of our interviewees were well-placed to comment on management responses, as each has worked in GBR research or management for at least the past decade.

Most interviews were conducted over the phone, with notes taken and transcribed by the interviewer, coded, and de-identified for analysis. The interview questions (Append. 1) were approved under the University of Queensland Ethics Approval process, with individuals remaining anonymous with de-identified responses. Thematic analysis (Braun and Clarke 2006) was used to identify themes and patterns across the qualitative interview data.

A CHANGING PLANNING AND POLICY NARRATIVE

The GBR region provides a prime example of the multi-layered, fragmented, and evolving nature of environmental governance in

Australia’s complex political system (Fidelman et al. 2013). The GBRMPA and the Office of the Great Barrier Reef (OGBR) (within the Queensland Department of Environment and Science) are the primary agencies responsible for management of the GBR, with GBRMPA responsible for management of the Marine Park Area, in collaboration with Queensland Parks and Wildlife Service, and the OGBR leading the water quality improvement program by reducing land use impacts.

Great Barrier Reef Management Timeline

There have been many prominent strategies, plans, and reports that have been released since the establishment of the Great Barrier Reef Marine Park and its World Heritage listing in 1981 (Fig. 2). Many of these reflect medium to long-term (25–30 year) intentions for the management of the GBR. Interestingly, despite this long-term view, the majority of the documents are reviewed or superseded within 5 to 10 years, due to the rapidly growing scientific knowledge and shifts in local and global thinking. These changes could be a positive demonstration of adaptive planning or, alternatively, an indication of short-sighted and reactive planning and policy. Either way, the purpose, key messages, and level of climate change focus of these documents can help identify and assess trends in priorities, language, and concerns over time, and changes in the climate change narrative for the GBR, particularly as it relates to resilience thinking (Table 2).

The first strategic plan for the GBR was published in 1994 (GBRMPA 1994) as a “25 Year Strategic Plan,” aimed to maintain World Heritage values while allowing reasonable use of the Area’s resources, with minimal reference to water quality, resilience, or climate change. In 2003, the “Reef Water Quality Protection Plan”

Table 2. Summary of key plans, strategies, reports, and statements for the Great Barrier Reef

Document	Purpose	Spatial focus	Key messages	Reference to climate change	Type of resilience (Recovery-Adaptation-Transformation)	Reference
GBR Outlook Report 2019	Fulfills the requirements of Section 54 of the Great Barrier Reef Marine Park Act 1975	GBR-wide Catchment and marine	Achieving outcomes on the ground continues to be difficult for complex and spatially broad topics, such as climate change, land-based run-off, and biodiversity. Integrity of World Heritage Area outstanding universal value is being increasingly challenged. Overall outlook is very poor	Major focus	Approaching transformation	GBRMPA 2019a
July 2019 - GBRMPA Position Statement - Climate Change	Position statement. Calling for urgent action on climate change in Australia	GBR-wide Catchment and marine	Only the strongest and fastest possible actions to decrease global greenhouse gas emissions will reduce the risks and limit the impacts of climate change on the reef	Primary focus	Approaching transformation	GBRMPA 2019b
Reef Trust Partnership Annual Work Plan 2019–2020 and Investment Strategy 2019	The Reef Trust Partnership operates within the context of the Reef 2050 Plan	GBR-wide Catchment and marine	\$443 million Reef Protection program. Three focus areas: COTS control, water quality, and reef restoration and adaptation science, to be achieved through integrated monitoring and reporting and community and traditional owner reef protection	Limited focus	Adaptation, some components moving toward transformation	GBRF 2019
Wet Tropics Climate Impact Statement	A statement from the Board of the Wet Tropics Management Authority regarding serious climate change impacts on the Wet Tropics of Queensland World Heritage Area	Regional Catchment focus	Some of the key species for which the Wet Tropics World Heritage Area was listed are at imminent risk of extinction. Urgent action and investment from governments are needed	Primary focus	Approaching transformation	Wet Tropics Management Authority 2019
Reef Restoration and Adaptation Program (RRAP)	Research project (Australian Institute of Marine Science (AIMS), CSIRO, James Cook University, the University of Queensland, Queensland University of Technology, the Great Barrier Reef Marine Park Authority, the Great Barrier Reef Foundation, as well as many other leading research universities and institutes) to investigate the best science and technology options to help the GBR resist, repair, and recover	GBR-wide Marine focus	\$6 million design phase of the RRAP is for the initial planning and feasibility assessment phase of a 10-year program to develop new technologies to assist reef recovery and adaptation “Protect and restore ecosystem health”: develop technologies to facilitate recovery of degraded reefs and to build increased resilience under forward climate scenarios, including assessing the feasibility of increasing the thermal tolerance of GBR corals	Major focus	Approaching transformation	AIMS 2018
Reef 2050 Long-Term Sustainability Plan (Revision)	Originally released in 2015, the plan was revised July 2018 to take into account unprecedented climate-driven mass coral bleaching events in 2016 and 2017 and severe Tropical Cyclone Debbie in 2017	GBR-wide Catchment and marine	The revised plan identifies climate change as “the most pervasive and persistent risk to coral reefs world-wide” and adopts the Blueprint for Resilience	Major focus	Adaptation	Commonwealth of Australia 2018b
Reef 2050 Water Quality Improvement Plan (WQIP)	The Reef 2050 WQIP is included as an action within the water quality theme of the Reef 2050 Plan	GBR-wide Catchment focus	Damage to reefs associated with climate change arises from sea surface temperature increases, ocean acidification, altered weather patterns, and rising sea levels. Emphasizes importance of reducing pressures on the reef, most importantly poor water quality	Major focus	Approaching adaptation	Commonwealth of Australia 2018a
Reef 2050 Water Quality Research, Development and Innovation Strategy 2017–2022	Prioritizes knowledge needs	GBR-wide Catchment focus	Biophysical themes - sediment, nutrients, pesticides, marine and coastal, wetlands. Human dimensions theme - policies, partnerships, networks, land managers As with the previous RDI Strategy, the strategy does not cover climate change research specifically, but the importance of investigating interactions between water quality and climate change is recognized	Limited focus	Recovery	The State of Queensland 2018
Global Warming of 1.5°C Summary for Policymakers	Presents the key findings of the special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways	Global Land and marine focus	Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. (high confidence). Coral reefs are projected to decline by a further 70–90% at 1.5°C (high confidence) with larger losses (>99%) at 2°C (very high confidence)	Primary focus	n/a	IPCC 2018

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2017 Scientific Consensus Statement	Reviews and adds to the scientific knowledge of water quality issues in the GBR from the 2013 statement. Provides the scientific understanding underpinning the design and implementation of the Reef 2050 Water Quality Improvement Plan	GBR-wide Catchment focus	Poor condition of GBR ecosystems largely due to the collective impact of land runoff from catchment development, coastal development activities, extreme weather events, and climate change impacts such as the 2016 and 2017 coral bleaching events. Current initiatives will not meet the water quality targets	Acknowledgement as key driver	Recovery	Waterhouse et al. 2017
GBRMPA Blueprint for Resilience	Response to 2016 and 2017 coral bleaching events	GBR-wide Catchment and marine	Outcomes from Great Barrier Reef Summit - Managing for Resilience May 2017 The future of coral reef ecosystems, including the GBR, will ultimately depend on the success of global efforts to reduce the extent of climate change Build a resilience network - identifying coral reefs that are disproportionately important to the reef's resilience (i.e., areas that best support ecological, social, economic, cultural, and heritage values across the entire reef system), determine the best resilience-building activities, focus collaborative efforts on delivery of resilience-based actions	Major focus Change in management approach	Adaptation	GBRMPA 2017b
Impacts of Climate Change on World Heritage Coral Reefs	Global scientific assessment	Global (coral reefs) Marine focus	World Heritage properties containing coral reefs have been increasingly exposed to heat stress during recent years Local management is no longer sufficient to ensure the future of coral reefs. Protecting World Heritage reefs requires complementary national and global efforts to limit warming to 1.5°C	Primary focus Climate change mitigation essential	Adaptation	Heron et al. 2017
Queensland Climate Adaptation Strategy (2017–2030) Pathways to a climate resilient Queensland	Overarching framework for climate adaptation planning and action in Queensland	State-based Land and marine focus	Recognize risks, equip with science and risk analysis tools, integrate climate adaptation, and collaborate for effective climate adaptation	Primary focus	Adaptation	Department of Environment and Heritage Protection (DEHP) 2017
Reef 2050 Long-Term Sustainability Plan	Provides the overarching framework and shared pathway for traditional owners, government agencies, industry, researchers, and the broader community to work together for the future of the GBR Responds to the 2011 World Heritage Committee's recommendation that Australia develop a long-term plan for sustainable development	GBR-wide Catchment and marine	Vision: to ensure the GBR continues to improve on its Outstanding Universal Value every decade between now and 2050 to be a natural wonder for each successive generation to come	Acknowledges that climate change is the single biggest threat to coral reefs world-wide Focus on ecosystem resilience	Recovery	Commonwealth of Australia 2015
Paris Agreement 2015	Global climate agreement was agreed under the United Nations Framework Convention on Climate Change (UNFCCC) at the 21st Conference of the Parties (COP21) in Paris	Global Climate change mitigation focus	A global goal to hold average temperature increase to well below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels All countries to set mitigation targets from 2020 and review targets every 5 years to build ambition over time, informed by a global stocktake	Primary focus	Adaptation	United Nations 2015
GBR Outlook Report 2014	Fulfills the requirements of Section 54 of the Great Barrier Reef Marine Park Act 1975	GBR-wide Catchment and marine	Four key factors influencing ecosystem and heritage values: climate change, coastal development, land-based run-off, and direct use Includes explicit assessment of the GBR World Heritage Area's outstanding universal value Overall outlook for the GBR is poor and getting worse	Identified as primary issue, explored in exclusive chapter	Adaptation	GBRMPA 2014a
Strategic Assessment Report	Under the Australian Government's national environmental law—the EPBC Act—a strategic assessment may be conducted as part of the environmental impact assessment process. Formed part of the Australian Government's response to the World Heritage Committee's concerns regarding development impacts on the World Heritage Area, raised 2011	GBR-wide Catchment and marine	An “ineffective” rating for the achievement of biodiversity outcomes was assigned to the Authority's management of climate change and extreme weather. Despite significant progress in building the ecological resilience of the reef, and the social and economic resilience of reef industries, the assessors reported that the Authority's work cannot make the region and its industries invulnerable to the impacts of climate change and extreme weather	Acknowledgement of climate change as significant threat and the ineffectiveness of current management efforts in response to climate change	Recovery	GBRMPA 2014b

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Climate Change Adaption for Natural World Heritage Sites	Practical guide to assist those responsible for the management of natural World Heritage sites to better understand how climate change may affect those features of the site that contribute to its Outstanding Universal Value and offer ideas for identifying options for adapting to climate change with tailored management responses	Global Adaptation focus	Climate change poses a major challenge to managers of protected areas	Primary focus	Adaptation	Perry and Falzon 2014
Reef Water Quality Research, Development and Innovation Strategy 2014-15-2018-19	Prioritize the generation of science and research to inform the development and adoption of practices beneficial to the reef as part of implementing the Reef Water Quality Protection Plan within the Long-Term Sustainability Plan.	GBR-wide Catchment focus	Focus areas: Farm management systems through management practice effectiveness, and decision support systems Prioritizing investment and responses for whole of catchment outcomes and reef water quality outcomes	No reference	Recovery	The State of Queensland 2014
2013 Scientific Consensus Statement	To support the development of the Reef Water Quality Protection Plan 2013 (Reef Plan) by reviewing and synthesizing the significant advances in scientific knowledge of water quality issues	GBR-wide Catchment focus	In addition to continuous improvement, transformational changes may be necessary to reach some targets. Catchment to reef connection most significant during extreme rainfall events	Some acknowledgement of climate change as a significant threat to the GBR	Recovery	The State of Queensland 2013
Climate Change Adaptation Strategy and Action Plan 2012–2017	Outlines a way forward for the Australian Government to comprehensively act to maximize the resilience of the reef. Second edition	National Adaptation focus	Adopts the key principles of ecosystem-based adaptation in describing its six core objectives: Focusing on reducing non-climate stresses Involving local communities Multi-partner strategy development Building on existing good practices in natural resource management Adaptive management approaches Integrating ecosystem-based adaptation with wider adaptation strategies	Primary focus	Adaptation	GBRMPA 2012b
The 2012 Review of the Climate Change Action Plan 2007–2012 (Climate Change Adaptation: Outcomes from the Great Barrier Reef Climate Change Action Plan 2007–2012)	Highlights key outcomes and lessons from activities under the 2007–2012 Action Plan based on more than 250 projects and activities Develops a vision for the 2012–2017 Action Plan	GBR-wide Catchment and marine	The debate moved to how we respond to global scientific consensus that the earth's climate is changing. From acceptance to action: identifying triggers for change	Primary focus	Adaptation	GBRMPA 2012a
Limits to climate change adaptation in the Great Barrier Reef	Researchers developed four scenarios for 2050 to explore potential future climate change impacts on the reef and the limits of ecological and social adaptation	GBR-wide Catchment and marine	The capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. Policies on economic development, environmental management, and adaptation to climate change should be integrated	Primary focus Adaptation capacity is limited	Adaptation (implicitly tending toward transformation)	Evans et al. 2011
GBR Outlook Report 2009	Fulfills the requirements of Section 54 of the Great Barrier Reef Marine Park Act 1975	GBR-wide Catchment and marine	Identifies climate change, continued declining water quality from catchment runoff, loss of coastal habitats from coastal development, and remaining impacts from lawful fishing and illegal fishing and poaching as the priority issues Resilience focus based on water quality improvement, coastal habitat protection, and increasing knowledge of effects of fishing Despite the introduction of significant protection and management initiatives, the overall outlook for the GBR is poor Water discharged from rivers to the GBR continues to be of poor quality in many locations Current management interventions are not effectively solving the problem Climate change and major land use change will have confounding influences on GBR health	Identified as priority issue, explored in exclusive chapter	Recovery	GBRMPA 2009
2008 Scientific consensus on water quality in the Great Barrier Reef	Review and synthesize advances in knowledge since Reef Water Quality Protection Plan established in 2003 and reach consensus on the current understanding of the system	GBR-wide Catchment focus	Water discharged from rivers to the GBR continues to be of poor quality in many locations Current management interventions are not effectively solving the problem Climate change and major land use change will have confounding influences on GBR health	Some acknowledgement of climate change as a significant threat to the GBR	Recovery	The State of Queensland 2008

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The Great Barrier Reef Climate Change Action Plan 2007–2012	Outlines a way forward for the Australian Government to comprehensively act to maximize the resilience of the reef. First edition	GBR-wide Catchment and marine	Climate change recognized as the greatest long-term threat to the GBR. The federal government allocated almost \$9 million over 5 years to implement the action plan. Focus on resilience-based management. Four main objectives: - Targeting science - Building ecosystem resilience - Supporting adaptation of industries and communities - Reducing climate footprints	Primary focus	Recovery	GBRMPA 2007
Reef Water Quality Protection Plan (Reef Plan)	Addressing diffuse pollution from broadscale land use	GBR-wide Catchment focus	Halting and reversing the decline in water quality entering the reef within 10 years	Negligible reference	Recovery	The State of Queensland and Commonwealth of Australia 2003 GBRMPA 1994
A 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area, 1994–2019	Reef-wide perspective on management of the GBR World Heritage Area. Seeks to reach agreement on “reasonable use,” set objectives and targets by which the effectiveness of management can be assessed, and address critical issues. The plan aims to maintain World Heritage values while allowing reasonable use of the area’s resources	GBR-wide Catchment and marine	Preliminary planning - minimal reference to water quality or resilience. Focus is on maintenance and enhancement of values	Negligible reference	Recovery	GBRMPA 1994
World Heritage Status	Recommended that the Great Barrier Reef Marine Park meets the criteria of the Convention and therefore should be placed on the World Heritage List, pursuant to the World Heritage Convention	GBR-wide Marine focus	GBRMPA, “through its many activities in research, publications, and management has demonstrated its capacity to manage the site. IUCN’s only concern is that the proposed site may be too large to ensure that a “precisely delineated area,” as defined in Article 2 of the Convention, can be effectively managed and protected as a World Heritage site.”	No reference	Recovery	IUCN 1981
Great Barrier Reef Marine Park Act 1975	Great Barrier Reef Marine Park and Great Barrier Reef Marine Park Authority (GBRMPA) established	GBR-wide Marine focus	Provides a framework for planning and management of the Marine Park, including through zoning plans, plans of management, and a system of permissions	No reference (for amendments up to and including 2018)	Recovery	1975

(The State of Queensland and Commonwealth of Australia 2003) was released, acknowledging the pressure that catchment runoff has on the marine system, but with negligible reference to climate change. The 2003 Reef Plan demonstrated steps forward within the resilience paradigm at the time, suggesting that improving water quality was the “silver bullet” for protection of the reef, despite the growing body of scientific evidence highlighting threats and impacts.

Interestingly, a “Great Barrier Reef Climate Change Action Plan 2007–2012” was released in 2007 (GBRMPA 2007), aimed at “maximising resilience of the Reef,” and was reviewed and renewed in 2012 adopting the principles of ecosystem-based adaptation, but still focusing on reducing non-climate stresses (GBRMPA 2012b) and “resilience as recovery” through maintaining or improving the current condition of the reef.

There are countless initiatives aimed at protecting the GBR, including acts, regulation, policies, zoning plans, environmental impact assessments, compliance actions, and investment partnerships. As a result of the level of investment, sediment, pesticide, and nutrient loads have decreased since the 2009 baseline (Commonwealth of Australia 2015). Government and NRM bodies are undertaking considerable research, monitoring, and modeling to understanding of processes from paddock-to-basin scale to better inform management plans and practice change. Investment has been focused on “resilience as recovery,”

aiming to reduce non-climatic pressures such as poor water quality, direct use, and COTS outbreaks, to improve the ability of the GBR to recover from climate-related pressures such as cyclones and water temperature-related coral bleaching events. The effectiveness, and cost-effectiveness, of these management actions are modeled using the paddock-to-reef model, which uses a climate time series from 1986–2014, which is limited in its representation of existing climate variability let alone future climate conditions (McCloskey et al. 2017).

Federal and state governments are investing more than \$600 million to deliver actions in the Water Quality Improvement Plan (WQIP) for practice change, regulation, extension programs, catchment restoration, research, and monitoring and evaluation (Commonwealth of Australia 2018b). The Reef Water Quality Report Card assesses the results of management actions against various targets, and the 2017–2018 Report Card shows reasonably poor results and little progress in recent years despite significant investment (Commonwealth of Australia 2019). A review of the investment actions for water quality improvement for 2017–2018 showed no explicit climate change-related investments.

Critical Evaluation of How Climate Change Threats Have Been Managed

In 2013, Fidelman et al. carried out a critical review of multi-level adaptation to climate change in the GBR, examining over 100 adaptation strategies from local to federal levels. They noted that

adaptation strategies often “report on intentions to act rather than adaptation actions” (Fidelman et al. 2013). Furthermore, immediate political imperatives were shown to often lead to short-term measures, without creating the conditions for proactive long-term transformative actions “that promote a fundamental change of the system once existing conditions are undesirable or untenable.”

Even though there has been a consistent message that climate change is the biggest threat to the reef since the 1990s, a change in strategic response that explicitly recognizes the impacts of climate change has been slow. However, recent publications, particularly those released by GBRMPA, have demonstrated a shift toward transformative resilience thinking and more interventionist approaches, rather than a focus on protection through “resilience as recovery.” There is also a clear trend in the narrative away from “resilience as recovery” to “resilience as adaptation,” and perhaps small but significant steps toward “resilience as transformation” (Table 2). Although interventionist approaches such as those in the Reef Restoration and Adaptation Program (RRAP) are now more accepted and in fact directly promoted in campaigns to “save the GBR,” it remains to be seen if they are designed to embrace change by recognizing possible alternative future species and ecosystem structures and functions (Graham 2014, Morrison et al. 2020). Indeed, many interventionist projects remain focused on addressing the symptoms and resisting change. Regardless of their intent, perhaps these interventionist approaches provide a bridge to transformative resilience even if they are not entirely transformative within the current planning context.

One of the first steps in a changing narrative was the release of the Blueprint for Resilience (GBRMPA 2017), followed closely by the mid-term review of the Reef 2050 Plan. Critically, these documents emerged following the extreme and widespread coral bleaching events in 2016 and 2017. The Reef 2050 Long-Term Sustainability Plan (Reef 2050 Plan) (Commonwealth of Australia 2015) was released in 2015 as the overarching Australian and Queensland government action plan to work with partners to protect and manage the GBR, in response to the World Heritage Committee recommendation for Australia to develop a long-term plan for sustainable development to protect the outstanding universal value of the reef. The Reef 2050 Plan was updated in 2018 to include additional actions focused on adapting to a variable and changing climate, following the unprecedented coral bleaching events in 2016 and 2017 (Commonwealth of Australia 2018a).

As part of the Outlook Report 2019 (GBRMPA 2019a), Leverington et al. (2019) completed an independent assessment of management effectiveness for the GBR, which assesses the management effectiveness against 14 different themes, including climate change. The assessment showed that, in general, the management effectiveness for climate change for the GBR is partially or completely ineffective and has been trending downward since 2009. For the 13 other themes, management was found to be partially or completely effective, with stable or upward trends. This either demonstrates the difficulty associated with tackling climate change threats or represents the bias toward action addressing non-climate threats adopted through the resilience-building philosophies that have dominated the framing

of GBR management to date. One of the challenges here is that, even though the Reef 2050 Plan sets out the need for an adaptive management framework that recognizes that “to adaptively manage a system as complex as the GBR, its components and their cause-and-effect links need to be understood,” explicitly setting outcomes for social, economic, and environmental benefits, as well as recognizing the importance of effective governance arrangements (Commonwealth of Australia 2018a), there have been insufficient efforts directed at the first step of setting clear goals and then identifying gaps and preparing an effective action plan. This could be attributed to a general mindset of “building resilience” by reducing non-climatic pressures and supporting the reef to adapt through “resilience as adaptation” and not accepting the fundamental changes to the system that are likely to be generated by climate change.

There is no doubt that increasing the capacity of a system to recover from shocks is an important component of adaptive management, however, the cumulative impacts of recent coral bleaching events, cyclones, and COTS outbreaks with ongoing poor water quality and direct use impacts have demonstrated that increasing resilience as recovery or adaptation may not be adequate under future conditions (Hughes et al. 2017). In addition, progress made against water quality targets has been slow and limited (Commonwealth of Australia 2019, GBRMPA 2019a). More recently, interventionist approaches that may lead to more adaptive and transformative resilience are being explored through the RRAP and some of the Great Barrier Reef Foundation (GBRF) work.

The 2018 revision of the Reef 2050 Plan refers to new actions focused on “strengthening the resilience of the Reef to climate change impacts and preparatory activities to inform the comprehensive review of the Plan scheduled for 2020” (Commonwealth of Australia 2018a). These new actions are identified in the plan in “green” with a mid-term review (MTR) preface, but are otherwise largely unidentifiable as specifically targeted at reducing vulnerability to climate change. One of the new actions under “protect and restore ecosystem health” is to “develop technologies to facilitate recovery of degraded reefs, and to build increased resilience under forward climate scenarios, including assessing the feasibility of increasing the thermal tolerance of Great Barrier Reef corals” which has been implemented via the RRAP. The Australian Government provided \$6M for the concept feasibility phase for the RRAP to investigate the best science and technology options to help the GBR resist, repair, and recover. These intervention techniques include cooling and shading reef structures and stabilization, coral reproduction and recruitment, biocontrol, field treatments, and seeding, which suggest a paradigm shift from “resilience as recovery” interventions to “recovery as adaptation,” and perhaps even some “recovery as transformation.”

In 2018, as part of the Reef Trust, the Great Barrier Reef Foundation (GBRF) was granted the \$443.3 million Reef Trust project, the largest ever investment in reef protection. 2019–2020 projects are focused on Water Quality (\$23.5M), COTS Control (\$4.33M), Traditional Owner Reef Protection (\$16.3M), Community Reef Protection (\$2.6M), and Integrated Monitoring and Reporting (GBRF 2019). The GBRF workplan shows a more explicit focus on climate change response, indicating a strategy to

build both adaptive and transformative resilience. These responses to the threat of climate change may reflect the freedom that a non-government stakeholder has compared with state and federal agencies. Projects include:

1. Resilient Reefs Initiative - a globally significant project: the first integrated model for building the resilience of coral reefs and reef communities.
2. Protecting and restoring the bright spots - reef islands: with thousands of species relying on reef ecosystems for survival, we will focus on finding and restoring the spots we can and must save.
3. Reef restoration - coral IVF (larval reseeded) - we will crack the code to rebuild coral reefs, restoring coral cover and healthy, self-sustaining ecosystems, to survive with a changing climate.
4. Reef Restoration and Adaptation Science (RRAS) Component - annual work plan: based on the outcomes of the Reef Restoration and Adaptation Program (RRAP), which conducted a preliminary evaluation of the widest possible range of intervention techniques that could be used to protect the reef's ecological functions and economic and social values and recommend a comprehensive research and development (R&D) program to develop and test the underlying knowledge needed to successfully intervene on the reef, at scale.

In June 2019, GBRMPA released a position statement on climate change (GBRMPA 2019b), compellingly arguing that: "Climate change is the greatest threat to the Great Barrier Reef. Only the strongest and fastest possible actions to decrease global greenhouse gas emissions will reduce the risks and limit the impacts of climate change on the reef. Further impacts can be minimised by limiting global temperature increase to the maximum extent possible and fast-tracking actions to build Reef resilience." This call to arms seeks "transformative policy and cooperation" from Australian and international governments to take immediate action with regard to greenhouse gas emissions, in accord with the Paris Agreement (United Nations 2015), highlighting that mitigation is essential in parallel with adaptation efforts through building the reef's resilience to increased pressures from climate change (GBRMPA 2019b). Although this study focuses on adaptation, this position statement indicates a change in the conversation and a public assertion from GBRMPA that the current level of national response to climate change mitigation is inadequate and if it is not addressed, this will have devastating impacts on the GBR, its environmental, social, and economic value, and potentially, its status as a World Heritage listed site.

PERSPECTIVES ON THE CLIMATE CHANGE RESPONSE

As Fidelman et al. (2013) noted, many adaptation strategies and plans "report on intentions to act rather than adaptation actions." Given the importance of stakeholder perceptions and their efforts to protect the GBR, interviews with key informants in the GBR research and management space enabled a better understanding of personal and organizational perspectives on the response to climate change threats at the strategic and operational levels. In addition, responses also gave an indication regarding to what degree individuals, their own organizations, and other organizations have (or have not) accepted the severity of climate

change impacts and the likely unavoidable degradation in the health of the reef and its impacts on economic, social, environmental, and World Heritage values (IPCC 2018, GBRMPA 2019a).

Key Informant Perspectives on Climate Change Threats to the Great Barrier Reef

Climate change threat

All interviewees believed climate change to be the major threat to the reef. However, five participants noted that there remains a high degree of uncertainty around climate change, the ability to link cause and effect for various impacts to the reef, and the reef's ability to recover.

Responding to the climate change threat

Some participants revealed strong negative responses to the question of how well the sector is responding to the challenges of climate change. Comments such as "we're in desperate times," "nothing we can really do," and "we don't do anything" typified this reaction. A number of participants suggested that climate change is not a big enough part of the conversation (for example, not having a separate chapter in the Scientific Consensus Statement), and one participant expressed the view that "blaming" reef deterioration on climate change can "let other anthropogenic threats off the hook." One participant also projected the view that, at the individual employee level, climate change is front of mind, yet at the organizational level, there are still barriers to explicitly making climate change part of the strategic or operational response.

Resilience thinking

There was general agreement that "resilience as recovery" is an essential part of the management response. The views expressed by interview participants were consistent with the findings of Fidelman et al. (2013), in that there has been a lot of talk around the threat of climate change, but that explicit climate change action has been limited. Furthermore, actions have primarily focused on enhancing the ability of the reef to recover from increased disturbances from climate change, adopting the "resilience as recovery" view. Despite this strong focus on recovery, some respondents noted that there is an ongoing paradigm shift in thinking, with steps taken toward interventionist approaches that constitute a more adaptive, if not transformative, response to known climate change threats.

Five of the participants expressed the need for coordinated responses that match resilience efforts in the areas of water quality improvement and COTS management, with calls to adopt interventionist approaches, such as coral seeding. This approach requires coordinated, multi-disciplinary, and multi-stakeholder action, which will rely on collaborative approaches to define values and prioritize actions (Morrison et al. 2020). One of the challenges in this space comes with the fact that, owing to the governance arrangements, the strategic planning and prioritization for catchment-based and marine-based action are undertaken largely independently. A more coordinated prioritization approach will require not just a shift in governance, but also a shift away from "resilience as recovery" to "resilience as transformation;" this was reinforced by many of the statements made by the interview participants proclaiming that the current approach is not adequate and will fail.

When asked about their views on “triage” approaches, which effectively sacrifice parts of the reef to focus efforts on those most valued, participants were reluctant to recommend a “sacrifice” approach, preferring a prioritization approach, even if the resultant outcomes are the same. Interviewees highlighted the importance of communication and language used around climate change and intervention. Participants also acknowledged the social, cultural, economic, and environmental trade-offs that are unavoidable through prioritization processes.

Views of the future of the Great Barrier Reef

Participants expressed noticeably emotive comments about the future of the GBR in the face of the climate change threat, suggesting varying degrees of optimism, desperation, and absence of hope. These views lend themselves to an exploration of how perspectives and actions map to the concept of “environmental grief.”

BUILDING LONG-TERM RESILIENCE AND ACCEPTING CHANGE

Observations from our interviews, which revealed hope, despair, and a sense of impending loss in the participant perspectives, led us to explore how the Kubler-Ross “Stages of Grief” model (Kubler-Ross 1973) may be broadly applied to approaches to environmental challenges and natural resource management. The Kubler-Ross psychological model was designed to explain the process of dealing with, and ultimately accepting, loss or change (Kubler-Ross 1973). Here, we built on the work of Shiffman (2013), who explored climate change and other anthropogenic pressures as an environmental crisis, with “the collapse of natural and biological systems well under way,” and “the challenge no longer to prevent this but to somehow manage the catastrophe.” Given this context, environmental grief seems an appropriate model for reviewing the mindset of individuals and organizations involved in management of a complex social-ecological system, like the GBR, which is being threatened by the realities of climate change (Shiffman 2013, Kevorkian and Meeker 2004, Willox 2012). Shiffman (2013) explored society’s response to climate change through the lens of Elizabeth Kubler-Ross’s “Five Stages of Grief,” moving through the following stages: denial, anger, bargaining, depression, and acceptance. Notwithstanding the clear scientific evidence that a given pressure (e.g., climate change) is happening, denial refers to the refusal to accept the diagnosis, particularly when symptoms are relatively mild. As anger sets in, there are often responses of blame and distrust, which may be somewhat justified, but do not work toward finding a way forward. In the bargaining stage, there is acknowledgment that something is happening, and the attempt to implement actions that are unlikely to respond to the reality of the situation. Depression refers to a feeling of loss of control or hopelessness with a situation, and recognition that some form of tragedy has become inevitable. Acceptance, the fifth and final stage of the Kubler-Ross model, refers to a “clear-eyed vision of reality,” making plans to move forward and taking ownership of the outcome.

Table 3 provides a discussion against each stage of grief based on an interpretation of interviewee responses and published reports and plans, where the loss (or change) being experienced is the loss of the current social, economic, and environmental values of the GBR. Application of the Kubler-Ross psychological model here,

in the natural resource management space, enables analyses of the implications of individuals and groups within a collective being at different stages of the grief cycle when coordinated action and consensus is required. In the case of the GBR, the acceptance stage refers to having accepted that some degree of loss of the current value of the GBR is inevitable. Acknowledgment and acceptance of loss raises the proposition that, by there being a level of agreement that there will be some loss, the level of loss can be reduced and somewhat managed. In the context of published management documents for the GBR, the 2019 Outlook Report (GBRMPA 2019b) and the GBRMPA (2019a) Climate Change Position Statement reveal a previously unstated level of acceptance of a change in the state of the reef, and related loss of environmental, social, and economic value. This sense of almost inevitable change and loss is also very strongly borne out in the IPCC’s Special Report on 1.5°C (IPCC 2018), which declares that “multiple lines of evidence indicate that the majority (70–90%) of warm water (tropical) coral reefs that exist today will disappear even if global warming is constrained to 1.5°C (very high confidence).”

To best understand where stages of grief can represent a barrier or a bridge toward resilience thinking, we propose that these conceptualizations can be aligned, as shown in Fig. 3. “Resilience as recovery” approaches reflect “denial” that climate change will lead to a change in the state of the GBR, and that business-as-usual approaches seeking to help the reef recover to how it has always been will be enough. “Resilience as adaptation,” however, reflects more of a “bargaining” mindset, whereby there is acknowledgment that there will be some change and that we can support the reef to stay within the bounds of its current state while supporting recovery within a confined degree of change. The state of “depression” could be seen as a state of hopelessness, as shown by some of the interview participants, and does not provide a strong basis for proactive, innovative, and optimistic planning and action. As indicated by Walker and Salt (2006), once change has been “accepted,” or ideally embraced, management actions that apply a philosophy of “resilience as transformation” can be enacted. Our grief-resilience thinking conceptualization highlights how all actors involved in management of the GBR must accept that change is inevitable in order to plan and implement a coordinated “resilience as transformation” approach that best protects the changing environmental, social, and economic values of the GBR.

Fig. 3. An alignment of the stages of grief model (Kubler-Ross 1973) and resilience thinking (adapted from Chelleri et al. 2015).

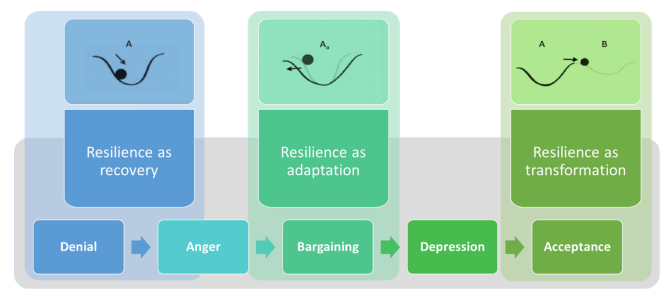


Table 3. Mapping attitudes toward climate change and the GBR to environmental stages of grief

Grief stage	Discussion	Stakeholder quotes
Denial	<p>There appear to be two forms of denial regarding deterioration in the health of the GBR, and the attribution of increased pressure due to the effects of climate change</p> <p>The Australian federal government is showing minimal leadership for reducing greenhouse gas emissions or acknowledging the implications of increased CO₂ concentrations on global systems, including the health of the GBR</p> <p>There are other players that are demonstrating a high level of commitment to protection of the GBR, but are perhaps not recognizing the seemingly inevitable change, and likely loss, of certain reef values based on existing and projected CO₂ concentrations</p> <p>There are likely to be many others in the Australian community who are completely unaware of the current health of the GBR and the increasing pressure from climate change combined with poor water quality, COTS outbreaks, and direct use impacts</p>	<p>“Easier not to look at climate change”</p> <p>“Small country, nothing to do with us is a pathetic excuse”</p> <p>“Mildly positive that we could preserve more than if we did nothing”</p>
Anger	<p>There are other stakeholders (directly involved in management, local communities, and communities outside of the GBR catchments) experiencing anger due to the lack of leadership and related funding and action, and frustration at lack of progress. The GBRMPA position statement on climate change (2019a) shows anger at the poor progress on Australian greenhouse gas emission reductions and commitment to climate change mitigation</p> <p>There are sectors of the community, who are under increasing pressure to change their practices to reduce impacts on the GBR, including agricultural producers within GBR catchments and traditional owners, who are likely experiencing anger and frustration</p>	<p>“Easier not to look at climate change”</p> <p>“Small country, nothing to do with us is a pathetic excuse”</p> <p>“Not enough money not enough capability”</p>
Bargaining	<p>There are players that give the impression that they believe that if a given set of actions (e.g., achieving water quality targets to increase resilience) are undertaken, then the impacts of climate change on the GBR can be overcome</p>	<p>“10 years ago struggling to understand the basics, now at a point where we understand more”</p> <p>“If you don’t try with water quality you’re not even giving it a chance”</p> <p>“Not saying a waste of time because we don’t have any other solutions”</p>
Depression	<p>There are others who are experiencing sadness due to a sense of inevitability of loss of the GBR system as we know it. These actors are demonstrating loss of hope that maintaining or improving the condition of the reef is possible, and that further deterioration is inevitable and likely irreversible</p>	<p>“High risk, low chance of success”</p> <p>“We’re in desperate times”</p> <p>“Nothing we can really do”</p> <p>“Situation is hopeless”</p> <p>“Coral in the GBR is a write off”</p>
Acceptance	<p>There are some who are demonstrating an acceptance that the pressures that the GBR is currently experiencing will be exacerbated by climate change even if levels of greenhouse emissions are reduced, and that this will result in fundamental changes to reef ecosystems, and loss of current environmental, social, and economic values</p>	<p>“No matter what, moving to intervention”</p> <p>“Not the time to give up, time to put the pedal to the wheel!”</p> <p>“Don’t want people to give up on it, but don’t want to pretend it’s not happening either”</p>

CONCLUSIONS

Despite decades of scientific evidence highlighting the climate vulnerability of the GBR, this analysis highlights how the strategic planning environment for the GBR is lagging behind the state of knowledge. Indeed, past and current management approaches do not adequately encompass the climate change threat and likely losses of species, habitats, and processes. Instead, efforts have focused on “resilience as recovery” and fall short of “resilience as adaptation” and the opportunities created by “resilience as transformation.” Despite the state of scientific understanding, it is clear that management sits within the human domain, and this study has revealed how the prevailing individual or collective mindset can support or suppress a “resilience as transformation” approach to management of the GBR. This is critical given the dire predictions for the future of coral reefs globally (IPCC 2018). Acceptance of a future change in state in terms of system structure and function, and related changes in environmental, social, and economic values, would lead to a significant shift in the way the GBR is managed, liberating

agencies and stakeholders to let go of the past and plan for the future. However, research has shown that this socio-political shift usually only occurs once a system is approaching dangerous thresholds (Chelleri et al. 2015). Perhaps we have reached this point for the GBR. Over the past 5 years, the GBR has been exposed to several unprecedented climate-related events, including three coral bleaching events and impacts from severe tropical cyclones, poor water quality from catchment run-off, population increase and urbanization, port expansion, fishing, and habitat loss. Given current evidence and projections, it is now time to accept change, explore possible future scenarios, and agree on the likely, acceptable, and aspirational future state(s) of the GBR (Morrison et al. 2020). To achieve this change in mindset, there needs to be increased dialog around the risks associated with a “resilience as recovery” approach when climate change forces the GBR over a threshold into a new state. It will also require a significant level of leadership at all levels—fortunately, GBRMPA is already demonstrating this with its most recent publications highlighting the need for stronger, more urgent climate action

(GBRMPA 2019b). Critically, without acceptance, at all levels of governance, of the severity of the threat of climate change to environmental, social, and economic values of the GBR, it will be near impossible to build commitment to a long-term “resilience as transformation” approach.

Communication and language around climate change, trade-offs, loss, and acceptance will need to be improved and developed to support long-term strategies for the GBR. This represents an opportunity to move away from the “doom and gloom” message around GBR management and move toward embracing and working with change. Indigenous custodians of the GBR have witnessed and adapted to significant change in the physical and functional state of the GBR for thousands of years, and there are important lessons that can be learnt from the past to plan for the future, although it is also important to take note of the scientific evidence, which suggests that climate change will result in an unprecedented rate and intensity of change. Language around climate change in the GBR space has been somewhat constrained by political agendas, which hinders the ability of agencies to move forward and address climate change explicitly. Indeed, recent politically motivated efforts to keep the GBR off the “threatened” list of World Heritage Sites, highlights what is at stake and reiterates the degree to which acceptance of loss or change in ecosystem condition has not yet occurred, at least publicly, within some government agencies. Communication and management strategies need to be able to overcome barriers and instability caused by changes in government.

There is a need for an action plan that explicitly responds to climate change by balancing efforts that support the reef to recover from individual disturbance events, and more interventionist approaches that guide the direction and achievement of a possible “new state.” Many of these actions may not be significantly different to those currently listed in the 2050 Plan (e.g., water quality improvement) but can be framed in a way that supports the investment and sets realistic future-focused targets, under both likely and desired future states. This will require a clear definition of the agreed set of environmental, social, and economic values that are to be protected, even if they are delivered in a different biophysical form.

Acceptance of change is also critical to ensure that management actions explicitly consider climate variability, future climate projections, seasonality, and extreme events. Prioritization of significant investment in water quality initiatives, many of which also have local and regional economic and social impacts, is currently based on cost-effectiveness analysis informed by paddock-to-reef modeling, which has limited climate variability and is reported at the average annual scale. This process must better account for future climate and the associated threats for the GBR ecosystem. Indeed, the paddock-to-reef modeling should explore future scenarios. Interventionist approaches, and supporting scientific research, should seek to better understand and consider future scenarios and the “thresholds” created by climate change that will push the GBR into different states, and implement actions now that will protect values in the future.

Responses to this article can be read online at:
<https://www.ecologyandsociety.org/issues/responses.php/12964>

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Data Availability:

Datalcode sharing is not applicable to this article because no datalcode were analyzed in this study.

LITERATURE CITED

- Anthony, K. R., P. A. Marshall, A. Abdulla, R. Beeden, C. Bergh, R. Black, C. M. Eakin, E. T. Game, M. Gooch, N. A. Graham, A. Green, S. F. Heron, R. van Hoooidonk, C. Knowland, S. Mangubhai, N. Marshall, J. A. Maynard, P. McGinnity, E. McLeod, P. J. Mumby, M. Nystrom, D. Obura, J. Oliver, H. P. Possingham, R. L. Pressey, G. P. Rowlands, J. Tamelander, D. Wachenfeld, and S. Wear. 2016. Operationalizing resilience for adaptive coral reef management under global environmental change. *Global Change Biology* 21(1):48-61. <https://doi.org/10.1111/gcb.12700>
- Australian Institute of Marine Science. 2018. Fact sheets and website. [online] URL: <https://gbrrestoration.org/the-program/>
- Babcock, R., J. Dambacher, E. Morello, E. Plagányi, K. Hayes, H. Sweatman, and M. Pratchett. 2016. Assessing different causes of crown-of-thorns starfish outbreaks and appropriate responses for management on the Great Barrier Reef. *PLoS One* 11(12): e0169048. <https://doi.org/10.1371/journal.pone.0169048>
- Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3(2):77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Chelleri, L., J. Waters, M. Olazabal, and G. Minucci. 2015. Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience. *Environment and Urbanization* 27(1):181-198. <https://doi.org/10.1177/0956247814550780>
- Commonwealth of Australia. 2015. Reef 2050 long-term sustainability plan—2015. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Commonwealth of Australia. 2018a. Reef 2050 long-term sustainability plan—July 2018. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Commonwealth of Australia. 2018b. Reef 2050 water quality improvement plan 2017–2022. Great Barrier Reef Marine Park

- Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Commonwealth of Australia. 2019. Reef water quality water quality report card 2017 and 2018. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- De'ath, G., K. E. Fabricius, H. Sweatman, and M. Puotinen. 2012. The 27-year decline of coral cover on the Great Barrier Reef and its causes. *Proceedings of the National Academy of Sciences of the United States of America* 109(44):17995-17999. <https://doi.org/10.1073/pnas.1208909109>
- Department of Environment and Heritage Protection (Queensland). 2017. Queensland Climate Adaptation Strategy (2017–2030) Pathways to a climate resilient Queensland. Department of Environment and Heritage Protection (Queensland), Brisbane, Australia.
- Evans, L. S., P. Fidelman, C. Hicks, C. Morgan, A. L. Perry, and R. Tobin. 2011. Limits to climate change adaptation in the Great Barrier Reef: scoping ecological and social limits. National Climate Change Adaptation Research Facility (NCCARF), Gold Coast, Australia.
- Fidelman, P. I. J., A. M. Leitch, and D. R. Nelson. 2013. Unpacking multilevel adaptation to climate change in the Great Barrier Reef, Australia. *Global Environmental Change* 23:800-812. <https://doi.org/10.1016/j.gloenvcha.2013.02.016>
- Folke, C. 2016. Resilience (republished). *Ecology and Society* 21 (4): 44. <https://doi.org/10.5751/ES-09088-210444>
- Grafton, Q., and R. Little. 2017. Risks, resilience, and natural resource management: lessons from selected findings. *Natural Resource Modelling* 30(1):91-111. <https://doi.org/10.1111/nrm.12104>
- Graham, N., J. Cinner, A. Norstrom, and M. Nystrom. 2014. Coral reefs as novel ecosystems: embracing new futures. *Current Opinion in Environmental Sustainability* 7:9-14. <https://doi.org/10.1016/j.cosust.2013.11.023>
- Great Barrier Reef Foundation. 2019. Reef Trust Partnership. [online] URL: <https://www.barrierreef.org/science-with-impact/reef-partnership>
- Great Barrier Reef Marine Park Authority (GBRMPA). 1994. A 25 year strategic plan for the great barrier reef world heritage area, 1994–2019. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2007. Great Barrier Reef climate change action plan 2007–2011. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2009. Great Barrier Reef outlook report 2009. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2012a. Climate change adaptation: outcomes from the Great Barrier Reef climate change action plan 2007–2012. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2012b. Great Barrier Reef climate change adaptation strategy and action plan 2012–2017. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2014a. Great Barrier Reef outlook report 2014. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2014b. Great Barrier Reef region strategic assessment: strategic assessment report. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2017. Great Barrier Reef blueprint for resilience. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2019a. Great Barrier Reef outlook report 2019. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Great Barrier Reef Marine Park Authority (GBRMPA). 2019b. Position statement—climate change, 25 June 2019. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.
- Gunderson, L. H. 2000. Ecological resilience—in theory and application. *Annual Review of Ecology and Systematics* 31 (1):425-439. <https://doi.org/10.1146/annurev.ecolsys.31.1.425>
- Heron S. F., M. Eakin, and F. Douvère. 2017. Impacts of climate change on world heritage coral reefs: a first global scientific assessment. UNESCO World Heritage Centre, Paris, France.
- Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50(8):839-866. <https://doi.org/10.1071/MF99078>
- Hughes, T., A. Baird, D. Bellwood, M. Card, S. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J. Jackson, J. Kleypas, J. Lough, P. Marshall, M. Nyström, S. Palumbi, J. Pandolfi, B. Rosen, and J. Roughgarden. 2003. Climate change, human impacts, and the resilience of coral reefs. *Science* 301 (5635):929-933. <https://doi.org/10.1126/science.1085046>
- Hughes, T., J. Day, and J. Brodie. 2015. Securing the future of the great barrier reef. *Nature Climate Change* 5:508-511. <https://doi.org/10.1038/nclimate2604>
- Hughes, T. P., J. T. Kerry, M. Ivarez-Noriega, J. G. Ivarez-Romero1, K. D. Anderson, A. H. Baird, R. C. Babcock, M. Beger, D. R. Bellwood, R. Berkelmans, T. C. Bridge, I. R. Butler, M. Byrne, N. E. Cantin, S. Comeau, S. R. Connolly, G. S. Cumming, S. J. Dalton, G. Diaz-Pulido, C. M. Eakin, W. F. Figueira, J. P. Gilmour, H. B. Harrison, S. F. Heron, A. S. Hoey, J. A. Hobbs, M. O. Hoogenboom, E. V. Kennedy, C. Kuo, J. M. Lough, R. J. Lowe, G. Liu, M. McCulloch, H. A. Malcolm, M. J. McWilliam, J. M. Pandolfi, R. J. Pears, M. S. Pratchett, V. Schoepf, T. Simpson,

W. J. Skirving, B. Sommer, G. Torda, D. R. Wachenfeld, B. L. Willis, and S. K. Wilson. 2017. Global warming and recurrent mass bleaching of corals. *Nature* 543: 373377. <https://doi.org/10.1038/nature21707>

International Union for Conservation of Nature (IUCN). 1981. Advisory body evaluation, world heritage nomination IUCN technical review. International Union for Conservation of Nature, Gland, Switzerland.

Intergovernmental Panel on Climate Change (IPCC). 2018. Summary for policymakers. Pages 3-26 in V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization, Geneva, Switzerland.

Kevorkian, K., and J. Meeker. 2004. Environmental grief!: hope and healing. ProQuest Dissertations and Theses, Ann Arbor, Michigan, USA. <https://doi.org/10.4324/9780429446054-21>

Kubler-Ross, E. 1973. On death and dying. Tavistock, London, UK. <https://doi.org/10.4324/9780203010495>

Leverington, A., M. Hockings, F. Leverington, C. Trinder, and J. Polglaze. 2019. Independent assessment of management effectiveness for the Great Barrier Reef outlook report 2019. Great Barrier Reef Marine Park Authority, Commonwealth of Australia, Townsville, Queensland, Australia.

Masnavi, M., R. Gharai, and F. Hajibandeh. 2019. Exploring urban resilience thinking for its application in urban planning: a review of literature. *International Journal of Environmental Science and Technology* 16(1):567-582. <https://doi.org/10.1007/s13762-018-1860-2>

McCloskey, G. L., D. Waters, R. Baheerathan, S. Darr, C. Dougall, R. Ellis, B. Fentie, and L. Hateley. 2017. Modelling pollutant load changes due to improved management practices in the Great Barrier Reef catchments: updated methodology and results. Technical report for reef report cards 2015. Queensland Department of Natural Resources and Mines, Brisbane, Australia.

Morrison, T., W. Adger, J. Barnett, K. Brown, H. Possingham, and T. Hughes. 2020. Advancing coral reef governance into the Anthropocene. *One Earth* 2:64-74. <https://doi.org/10.1016/j.oneear.2019.12.014>

Nyström, M., and C. Folke. 2001. Spatial resilience of coral reefs. *Ecosystems* 4:406-417. <https://doi.org/10.1007/s10021-001-0019-y>

Nyström, M., C. Folke, and F. Moberg. 2000. Coral reef disturbance and resilience in a human-dominated environment. *Trends in Ecology and Evolution* 15:413-417. [https://doi.org/10.1016/S0169-5347\(00\)01948-0](https://doi.org/10.1016/S0169-5347(00)01948-0)

Nyström, M., N. A. J. Graham, J. Lokrantz, and A. V. Norström. 2008. Capturing the cornerstones of coral reef resilience: linking

theory to practice. *Coral Reefs* Volume 27(4):95-809. <https://doi.org/10.1007/s00338-008-0426-z>

Perry, J., and C. Falzon. 2014. Climate change adaptation for natural world heritage sites: a practical guide. United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France.

Pickering, J. A., J. Hong, D. Hong, and M. Kealley. 2017. Applying behavioural science to the Queensland sugar cane industry and its relationship to the Great Barrier Reef. *Rural Extension and Innovation Systems Journal* 13(2):1-10.

Prideaux, B., A. Pabel, and J. Carmody. 2018. Impacts of the 2016 and 2017 mass coral bleaching events on the Great Barrier Reef tourism industry and tourism-dependent coastal communities of Queensland. Report to the Reef and Rainforest Research Centre Limited, Cairns, Australia

Roocke, N. 2013. Smartcane BMP launch. Australian Cane Grower, Brisbane, Australia.

Schiffman, R. 2013. The five stages of environmental grief. *Life Media*, Toronto, Ontario, Canada.

Sinclair, K., A. Rawluk, S. Kumar, and A. Curtis. 2017. Ways forward for resilience thinking: lessons from the field for those exploring social-ecological systems in agriculture and natural resource management. *Ecology and Society* 22(4): 21. <https://doi.org/10.5751/ES-09705-220421>

Smith, G., and C. Spillman. 2020. Ocean Temperature outlooks - coral bleaching risk: Great Barrier Reef and Australian waters. Bureau research report 43. Bureau of Meteorology, Department of the Environment, Melbourne, Australia.

Tan, P., and F. Humphries. 2018. Adaptive or aspirational? Governance of diffuse water pollution affecting Australia's Great Barrier Reef. *Water International* 43(3):361-384. <https://doi.org/10.1080/02508060.2018.1446617>

The State of Queensland. 2008. 2008 Scientific consensus on water quality in the Great Barrier Reef. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

The State of Queensland. 2013. 2013 Scientific consensus statement land use impacts on Great Barrier Reef water quality and ecosystem condition. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

The State of Queensland. 2014. Reef water quality research, development and innovation strategy 2014-15-2018-19. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

The State of Queensland. 2018. Reef 2050 water quality research, development and innovation strategy 2017-2022. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

The State of Queensland and Commonwealth of Australia. 2003. Reef water quality protection plan; for catchments adjacent to the Great Barrier Reef World Heritage Area. Queensland Department of Premier and Cabinet, Brisbane, Australia.

United Nations. 2015. Paris agreement to the United Nations Framework Convention on Climate Change. United Nations, Geneva, Switzerland.

Walker, B., and D. Salt. 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Bibliovault OAI Repository, the University of Chicago Press, Chicago, Illinois, USA.

Waterhouse, J., B. Schaffelke, R. Bartley, R. Eberhard, J. Brodie, M. Star, P. Thorburn, J. Rolfe, M. Ronan, B. Taylor, and F. Kroon. 2017. 2017 Scientific consensus statement: a synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Chapter 5: overview of key findings, management implications and knowledge gaps. State of Queensland, Brisbane, Australia.

Wet Tropics Management Authority. 2019. A statement from the Board of the Wet Tropics Management Authority regarding serious climate change impacts on the wet tropics of Queensland world heritage area. Wet Tropics Management Authority, Cairns City, Queensland, Australia.

Willox, A. C. 2012. Climate change as the work of mourning. *Ethics and the Environment*, 17(2):137-164. <https://doi.org/10.2979/ethicsenviro.17.2.137>

Appendix 1: Interview questions

1. How would you describe your current role in management of the GBR?
2. What would you currently consider to be the biggest priorities and challenges for management of the GBR?
3. How well do you think we, as a sector, are responding to these challenges?
4. How do you see climate change changing the pressures and threats to the GBR?
5. Do you think climate change is adequately considered in planning and action for reducing threats to the GBR? Strategic, operational, science?
6. In what ways do you think we as a sector could more proactively consider climate change in management actions to protect and restore the GBR?
7. How do you think your organisation specifically could better account for climate change your work? What are the barriers?
8. Are you aware of any other case studies where you think climate change has been considered in management decisions and trade-offs?
9. Is there anyone else you think I should be speaking to?