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NAVIGATING EXTREME CLIMATE EVENTS:

UNCOVERING THE CHALLENGES OF SOCIAL-ECOLOGICAL SYSTEM GOVERNANCE IN THE ANTHROPOCENE

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Dissertation

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- and -

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This dissertation is dedicated to my grandparents, who encouraged me in word or in spirit every step of the way, and who lit the path with their own endeavours to leave the world a better place than they found it. Mahalo nui loa to Lois-ellin and Padma Datta, and to Maureen and Henry Kelley.

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Abstract

A warming climate brings fundamental transitions to social-ecological systems (SES), threatening to degrade already strained relationships between people and nature. Extreme climate events can create crises that provide an opportunity for examining how resource managers, scientists, policy-makers, and others who make or influence decisions about SES (i.e. "governance actors") understand and respond to climate change. Previous research indicates that extreme climate events may present opportunities for governance actors to evolve new priorities and approaches that improve governing SES as climate change bears down. However, there has been little empirical research to understand how governance actors respond to extreme climate events in practice, and what their responses reveal about the challenges of evolving SES governance.

In this dissertation, I examine how governance actors' priorities and visions for the future evolve or not after experiencing extreme climate events that impact a large SES. The specific example I investigate is governance of the Great Barrier Reef (GBR) after mass coral bleaching events. Governance refers to the rules, processes, norms, and interactions between diverse actors (e.g., government, community groups, industry) that shape policy and other aspects of decision-making. To do so I integrate approaches from social network science and political science and concepts from adaptive governance studies. This combined approach enables me to uncover the priorities amongst networks of organizations engaged in GBR governance. Further, it enables me to investigate how influential governance actors in decision-making or advisory positions in this system conceive the problems facing the GBR and construct narratives about its future. My second chapter presents a longitudinal analysis of organizations' attendance at forums focused on issues facing the GBR region from 2012 to 2019; I find that the types of governance actors engaging in governance across the GBR region stay relatively stable before and after extreme climate events, and that these actors hold relatively stable priorities for the GBR. My third describes governance actors' differing perspectives on the implications of bleaching for the GBR, and the multiple pathways they suggest for shaping future governance. My fourth chapter considers how governance actors' differing visions for the future align or conflict with each other, and what this reveals about controversies and barriers for steering reefs through climate change.

Through this dissertation I open a window into a moment in time when governance actors face one of the first acute, large-scale climate impacts to coral reefs, and to large-scale SES in general. I find that in the GBR region extreme climate events did not dramatically affect the priorities of governance networks but did change the way high-level governance actors envision the future for this SES. However, their perspectives change in different ways that suggest lingering cross-level and cross-sector tensions are continuing to prevent a coordinated response to extreme climate events and transition towards more adaptive ways of governing SES. This suggests that extreme climate events can affect different aspects (e.g. forums, actors' visions) and levels (i.e. individuals, networks) of SES governance in myriad ways. Through this work I deepen and broaden theoretical understanding of the role of crisis in shaping environmental governance. I simultaneously uncover the difficulties governance actors face in navigating these events, and consider what opportunities lie ahead for more coordinated governance of SES in the Anthropocene.

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List of Acronyms

AIMS	Australian Institute of Marine Science
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
RAD	Resist-Accept-Direct (a climate adaptation framework)
RRAP	Reef Restoration and Adaptation Program
RRT	Resistance-Resilience-Transformation (a climate adaptation framework)
SES	Social-ecological system(s)
UNESCO	United Nations Educational, Scientific, and Cultural Organization

Chapter 1: Introduction

Climate change is causing fundamental shifts in society and ecosystems that are projected to become more severe over coming decades (Grimm et al. 2013, Carleton and Hsiang 2016, Pörtner et al. 2022). A warming climate affects people and ecosystems at all levels from local to global, impacting everything from human health, migrant flows, and wealth inequality, to species distributions and the very structure and function of ecosystems (Grimm et al. 2013, Carleton and Hsiang 2016, Pörtner et al. 2022, Cevik and Jalles 2022). The severity of climate change and other human impacts on ecosystems has led some to refer to the current geologic era as the "Anthropocene" (Lewis and Maslin 2015), a term I adopt here to focus attention on these impacts. Social systems and ecosystems are closely intertwined, and therefore climate impacts in either or both systems also impact the relationships between them (Jannsen and Ostrom 2006, Ostrom 2009, Fedele et al. 2019). The term "social-ecological system" (SES) is used to refer to intertwined social and ecological systems, with emphasis on the ways the many components of each system feedback into one another at nested levels (local to global) (Ostrom 2009, Berkes 2017). Climate change brings both slow, inching change to SES (e.g. shifts in forest distribution), and short, acute impacts (e.g. cyclones, coral bleaching, wildfires), both of which challenge attempts to govern these systems effectively (Folke 2006, Brunner and Lynch 2013, Berkes 2017).

Environmental governance of SES involves interactions between individual actors, institutions, and networks that manifest through rules, institutions, laws, collective action, social norms, protests, and other activities that influence decision-making (Lebel et al. 2006; Table 1). These many aspects of governance are important to investigate in the context of climate impacts because they will affect what decisions are made and what SES outcomes are realized in the Anthropocene. Decisions made about SES are influenced by governance actors. Governance actors are individuals or organizations that make, advise on, influence, or are affected by decisions about the goals of SES management, the strategies and processes by which to reach those goals, and who should be engaged in these strategies and processes (Lebel et al. 2006, Morrison et al. 2019, Angst et al. 2022, Morrison et al. 2023). In this dissertation the term "governance actors" includes policymakers, resource managers, NGO professionals, researchers, industry representatives (i.e., tourism, mineral resources,

fishing, agriculture), coordinators who engage with communities and Traditional Owners. Governance is effective when governance actors are able to respond to emergent problems, achieve collectively agreed upon goals (e.g., sustaining food sources, preserving species, protecting habitats, etc.), or evolve goals and strategies through social learning to better account for emerging problems (Morrison 2017, Pahl-Wostl 2017). Climate change challenges effective governance by creating uncertainty about what long-term changes will occur, and by triggering shocks or crises that can rapidly shift ecosystems (Renaud et al. 2010, Filatova and Polhill 2012, Grimm et al. 2013). These short- and long-term changes can shift what goals are achievable, or perceived to be achievable, for SES (Renaud et al. 2010, Fedele et al. 2019). These changes thus have profound consequences for people, who depend on ecosystems for food, livelihoods, recreation, cultural, and spiritual practices, and who therefore have a vested interest in continuing to manage and govern these systems in ways that perpetuate these desired outcomes (Fedele et al. 2019, Weiskopf et al. 2020). The need to continue realizing desired outcomes despite rapidly changing circumstances has inspired substantial research on innovative approaches to governance that bolster the flexibility, creativity, and overall capacity of governance actors to navigate change in SES (Folke et al. 2005, Jannsen and Ostrom 2006, Chaffin et al. 2014, Cumming et al. 2020); these approaches are collectively referred to as "adaptive governance".

The decisions that governance actors make about SES governance as climate change progresses will affect whether desired outcomes are achieved, and whose desires these outcomes reflect (Chaffin et al. 2016b, Blythe et al. 2018, Bennett et al. 2019, Múnera-Roldan et al. 2022). Substantial research has examined how adaptive governance approaches emerge to support governance actors pursuing a desired state amidst change in SES (Hahn et al. 2006, Olsson et al. 2008, Chaffin et al. 2016a). However, there has been much less attention to how this desired state is defined and by whom, and how this might co-evolve with changes to SES (Wyborn 2015, Chaffin et al. 2016b, Cleaver and Whaley 2018). The ways governance actors conceive of the desired state is especially important to explore as climate impacts shift the fundamental structure and function of ecosystems potentially affecting what outcomes governance actors believe are desirable or possible (Múnera-Roldan et al. 2022, Schuurman et al. 2022). Extreme climate events (e.g., cyclones, fires, coral bleaching) are acute events that occur when an unusual climatic period causes

persistent shifts in the structure of natural systems and the services they provide (Smith 2011) and may therefore serve as catalysts for changes in governance actors' goals for SES management. However, there is little empirical research examining how governance actors perceive the impact of extreme climate events, or what outcomes they consider desirable or achievable for SES in the aftermath of such events. Through this dissertation, I investigated how governance actors perceive extreme climate events and their implications for governing SES through a case study of the Great Barrier Reef (GBR), a world-famous SES of global biodiversity significance (Day 2016).

My dissertation chapters attend to: 1) how the priorities of the large network of organizations engaged in GBR governance shift or not after extreme climate events (Chapter 2), and 2) how high-level decision-makers and their advisors imagine the future for the GBR, including what desired outcomes they aspire to (Chapter 3). In Chapter 4, I examine how multiple visions for the future identified in Chapter 3 align or come into tension with one another, and what challenges this reveals for governance. My dissertation builds on a preliminary study conducted to understand governance actors' responses to mass coral bleaching events (Barnes et al. 2022); this study is included as Appendix A. Through the remainder of this introductory chapter, I situate this research within existing literature on the role of crises in shaping adaptive governance (Olsson et al. 2006, Chaffin and Gunderson 2016, McHugh et al. 2021, Patterson et al. 2021). I also introduce concepts from social network science, climate adaptation frameworks, and political science research on policy narratives, and their relevance to expanding theory on crisis within adaptive governance scholarship. Theories and methods from each stream of research are further elaborated in the chapters to which they are relevant. In the final section of this introduction, I describe the methodology and GBR case study. The three chapters that follow present empirical research that has been published or is currently in review for peer-reviewed journals. In the final discussion chapter, I examine how my findings broaden and deepen theoretical understandings of the role of crises in shaping adaptive governance by bringing needed empirical attention to the differing normative desires of governance actors.

Table 1. Summary of key terms.

Term	Definition
Social-Ecological System (SES)	Linked ecological and social systems, the concept originally developed to emphasize the idea of humans as part of nature rather than separate from it. This implies that the delineation between social and ecological systems is artificial, and that neither system should be analyzed in isolation from the other (Walker and Meyers 2004, Berkes et al. 2000, Folke et al. 2005).
Anthropocene	A proposed term for the current geologic era, which acknowledges the extensive ways that humans are altering and even fundamentally transforming ecosystems (Lewis and Maslin 2015).
Governance	Interactions between individual actors, institutions, and networks and the way these manifest through rules, institutions, laws, collective action, protests, and other activities that influence decision-making (Lebel et al. 2006, Bevir 2012).
Governance Regime	The collection of institutions, actors, and interactions between them, as defined under "governance" above, which govern a particular SES (Epstein et al. 2020).
Governance Network	The individuals and organizations that interact to govern SES (Barnes et al. 2017). In Chapter 2 this term specifically refers to organizations who convene at forums (i.e. meetings, collaborations) to make decisions about GBR governance and management.
Adaptive Governance	Governance institutions (e.g. laws, policies, social norms, decision-making processes) that support actors' ability to navigate change by supporting self-organization, learning, knowledge integration, and the ability to address problems at all relevant levels (e.g. local to national) (Dietz et al. 2003, Folke et al. 2005, Chaffin et al. 2014).
Governance Actors	Governance actors are individuals or organizations that influence make, advise on, or are affected by decisions about the goals of SES management, the strategies and processes by which to reach those goals, and who should be engaged in these strategies and processes (Lebel et al. 2006, Morrison et al. 2019, Angst et al. 2022, Morrison et al. 2023). Here this term includes policymakers, resource managers, NGO professionals, researchers, industry representatives (i.e., tourism, mineral resources, fishing, agriculture), coordinators who engage with communities and Traditional Owners. I use the term to refer to these individuals in Chapters 3 and 4, and to refer to the institutions with which they are affiliated in Chapter 2.
Extreme Climate Events	These are acute events that are triggered by an unusual climatic period and that cause persistent shifts in the structure of natural systems and the services they provide (Smith, 2011).

Crisis	A crisis is "a period when alternative processes control system dynamics…characterized by uncertainties of outcomes", and stands in contrast to stable periods, which "occur when system drivers are known and outcomes are assumed to be predictable" (Chaffin and Gunderson (2016), p. 83).
Great Barrier Reef (GBR) Region	For the purposes of this thesis, the term "GBR Region" is used to describe the collection of reefs and other marine habitats in the GBR Marine Park, as well as the catchment adjacent to the GBR Marine Park.

1.1 Governing SES: A changing relationship with change

Climate change challenges environmental governance actors because it drives extensive shifts in SES, but the need for governance actors to deal with SES change is not new. Developments in environmental governance over recent decade can be described as an evolution in the way that governance actors and the governance systems they are embedded within deal with SES change. Initial command-and-control approaches to environmental governance assumed ecosystems were predictable and could be controlled, and therefore sought to limit change in ecosystems whenever possible (e.g. fire suppression (Stephens et al. 2016)), and manipulate them as needed to reach desired outcomes (e.g. introducing species to support a fishery (Liu et al. 2007)) (Holling 1973). These approaches are still used in many places (e.g. U.S. forest management (Stephens et al. 2016)), but the assumptions they are based on are now thought to be erroneous, and therefore the cause of governance failures (Holling 1973, Milich 1999, Morrison et al. 2020a). Failures include the exacerbation of wildfires due to build-up of detritus under forest management focused on fire suppression (Stephens et al. 2016), or the introduction of smelt to feed walleye resulting in the smelt instead consuming juvenile walleye (Liu et al. 2007). Researchers now conceive of SES as inherently unpredictable, characterized by non-linear change at multiple levels (local to global), feedbacks across spatial and temporal scales that are difficult to model, and inevitable surprise events (Holling 1973, Levin 1998, Walker et al. 2004). For example, Chaffin and Gunderson (2016) describe how long term drought at the regional level in the Klamath basin (ecosystem component) in the United States interacted with the over-allocation of water (social system component) to cause an unanticipated crisis in the form of social unrest (i.e. protests) and litigation that changed how federal statutes (i.e. Endangered Species Act 1973) were implemented, therefore affecting water resource use

by local communities and viable fish species habitat conditions. In short, change in SES is now seen as inherent rather than avoidable, which implies that governance actors need processes for navigating change, particularly as climate change accelerates.

The need for governance actors to respond to and anticipate change in SES has spurred extensive research regarding management approaches that better deal with uncertainty (e.g. adaptive management) (Holling 1978, Gunderson and Light 2006, Lynch et al. 2022), and the environmental governance arrangements that facilitate these management approaches (e.g. adaptive governance) (Folke et al. 2005, Huitema et al. 2009, Chaffin et al. 2016b, Alexandra et al. 2023). Management refers to on-the-ground actions that affect use and conservation of natural resources (Chaffin et al. 2016b), while governance refers to the formal and informal structures, processes, and norms that shape decision-making about SES management, including the distribution of power between actors in an SES (Folke et al. 2005, Lebel et al. 2006). In this dissertation I focus on governance, but also attend to management, as the two are intertwined. This body of research has contributed to the rejection of command-and-control approaches, and adoption of resilience-based approaches to managing and governing SES (Gunderson and Holling 2000, Walker et al. 2004, Folke et al. 2005, Garmestani and Benson 2013). Resilience-based approaches are aimed at building ecological resilience, most simply defined as the amount of disturbance an ecosystem can absorb without changing state (e.g. forest transitioning to grassland) (Gunderson and Holling 2000). The concept of resilience has been extended to SES (Walker et al. 2004, Folke 2006), where SES scholars define it as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain...the same function, structure, identity, and feedbacks" (Walker et al. 2004, p.3). This extension of resilience theory is not without critique (see Cote and Nightingale 2012, Fabinyi et al. 2014, Olsson et al. 2015, Cleaver and Whaley 2018), which is further discussed below, but has nonetheless led to an outpouring of scholarship on approaches for measuring, managing, and governing SES resilience (Folke 2006, Lebel et al. 2006, Garmestani and Benson 2013, Cinner and Barnes 2019). A review by Chaffin et al. (2014) explains how adaptive governance theory emerged concurrently from this stream of research (Folke et al. 2005), and from research on community-based management (e.g. Brunner et al. 2005) and collective action (e.g. Ostrom 2010).

Adaptive governance research focuses on institutional structures (e.g. advisory panels), processes (e.g. public participation), and norms (e.g. preference for science-based decision-making) that support actors to be flexible, creative, and inclusive in the ways that they navigate environmental change (Folke et al. 2005, Chaffin et al. 2014). Adaptive governance is characterized by approaches aimed at supporting governance actors to realize democratic ideals (e.g. inclusive participation), address problems at multiple levels (local to global), integrate multiple types of knowledge, and experiment and adjust approaches as needed to navigate ongoing change and strive for equitable outcomes (Dietz et al. 2003, Folke et al. 2005, Berkes 2007, Armitage 2008, Chaffin et al. 2014, Blythe et al. 2018, Morrison et al. 2019). Governance scholars suggest that polycentric decision-making structures, which involve overlapping, nested decision-making centers across networks of organizations and actors, can support adaptive governance (Ostrom 2010, Chaffin et al. 2014, Morrison 2019). It is important to note here that command-and-control governance with government as a central actor is now supplemented with more polycentric, "networked" environmental governance in recent decades, paralleling the transition beyond simple command-and-control management (Armitage et al. 2012, Bixler et al. 2016). This makes the broad networks of actors now engaged in polycentric governance a key element of adaptive governance (Chaffin et al. 2014).

Though adaptive and polycentric governance enables greater flexibility and is more accepting of change than command-and-control paradigms, the extent of climate-induced change to SES in the Anthropocene presents serious challenges for the theory and practice of this approach (Brunner and Lynch 2013, Morrison et al. 2017). Adaptive governance theory rejects ideas about total control or suppression of change, but remains oriented around the aim of maintaining desired states (i.e. adapt) or transitioning towards new desired states (i.e. transform) by supporting iterative management processes (i.e. adaptive management) that enable cycles of setting goals, monitoring outcomes, and revising goals accordingly (Walker et al. 2004, Folke et al. 2005, Chaffin et al. 2016b). This implies that governance actors are seeking to retain some degree of control over the state of an ecosystem, which leaves open the question of how these actors navigate situations where that control is uncertain or very limited. Climate change is making such situations more and more frequent, as it poses the ultimate cross-scale (e.g. temporal, geographic) and cross-

level (i.e. local to global) challenge for governance actors given the global scale origins of fossil fuels and the both slow and rapid ways this impacts SES. For example, increasing CO_2 concentrations are slowly increasing the acidity of global oceans (Hoegh-Guldberg et al. 2017), while also leading to acute extreme climate events like cyclones and heat waves capable of causing unexpected but persistent shifts in ecosystems (Hughes et al. 2017, Vercelloni et al. 2020). These climate impacts (among other anthropogenic impacts) are forcing governance actors to face critical choices about whether, and at what level (e.g. local, regional), to resist, accept, or attempt to steer changes in SES (Petersen-St.Laurent et al. 2021, Clifford et al. 2022, Schuurman et al. 2022). These are ultimately normative choices about what desired states are possible to achieve and what kinds of management approaches can be implemented to achieve these goals.

The normative dimension of how the desired state is defined, by whom, and to what effect for different actors, has been under-attended to in adaptive governance scholarship and resilience research more broadly (Olsson et al. 2015, Wyborn 2015, Chaffin et al. 2016b, Cleaver and Whaley 2018). Critics have therefore called for greater attention to differing priorities amongst governance actors, and to how the inevitably uneven distribution of power across different actor groups in an SES affects who wins or loses as a result of the SES outcomes governance actors choose to pursue (Olsson et al. 2015, Wyborn 2015, Blythe et al. 2018, Morrison et al. 2019). As climate change raises the possibility that governance actors need to re-evaluate their priorities (Petersen-St. Laurent et al. 2021, Clifford et al. 2022), the need to respond to this call is even greater than before. The choices that governance actors make when responding to climate change today will shape not only future ecosystem states, but also which actor groups' interests are bolstered or hindered in the process of navigating these changes (Blythe et al. 2018, Bennett et al. 2019, Morrison et al. 2019). Empirically investigating governance actors' perspectives on the desired state in the context of climate change is thus essential if governance researchers are to support these actors in finding creative and inclusive responses to climate change (Chaffin et al. 2016b, Múnera-Roldan et al. 2022).

Extreme climate events confront governance actors with clearly visible climate impacts, and may therefore provide an opportunity to address the lack of critical attention to how and by whom the "desired state" of SES are decided (Birkland 1998, Chaffin and Gunderson 2016,

Farhidi et al. 2022). Political scientists and governance scholars have indeed long debated whether crises like extreme climate events provide opportunities for adjusting governance to better support governance actors as they navigate change (Birkland 1998, Olsson et al. 2006, Chaffin and Gunderson 2016, Nohrstedt et al. 2021). In the next section I elaborate on how crisis has been examined within adaptive governance literature, and identify shortcomings in these analyses related to unattended to normative assumptions by governance researchers embedded in these previous studies.

1.2 Adaptive Governance and Crises

The challenges and opportunities that crises present for adaptive governance are just beginning to be explored (Olsson et al. 2006, Chaffin and Gunderson 2016), leaving much room for further theoretical and empirical research. Here I follow Chaffin and Gunderson (2016), who draw on Gunderson et al. (1997) definition of crisis as "a period when alternative processes control system dynamics…characterized by uncertainties of outcomes" (p. 83), and contrast crisis with stable periods, which "occur when system drivers are known and outcomes are assumed to be predictable" (p. 83). Previous case studies illustrate how governance actors can sometimes leverage crises as windows of opportunity to transition towards different elements of governance of SES, which may improve outcomes for people and ecosystems in the long run (Birkland 1998, Olsson et al. 2006, Brunner and Lynch 2013, Chaffin and Gunderson 2016, McHugh et al. 2021). For example, crises (e.g. algae blooms, coral bleaching, drought) have provided opportunities for governance actors to bring about more inclusive participatory processes (Chaffin et al. 2018), and improved fit of institutions to the scale of environmental problems (e.g. Olsson et al. 2004, 2008). These cases of governance actors leveraging crisis to catalyze shifts towards adaptive governance all follow a similar narrative. Consider the following three well-cited examples.

First, Hahn et al. (2006) describe that the executive director and assistant director of a small nonprofit in Sweden were able to lead a transition towards collaborative governance of a wetland. These leaders encouraged farmers traditionally opposed to conservation actions to reconsider their assumptions about the relationships between nature and people, and thereby become more interested in conserving bird populations (Olsson et al. 2004, Hahn et al. 2006). Similarly, research in the Everglades shows how key scientists led stakeholder

engagement processes to introduce actors to a resilience approach and ultimately to reach a consensus on restoration guidelines (Gunderson and Light 2006, Olsson et al. 2006). In a third case, a chair and directors within a government organization were found to be successful because they built support for a transition to ecosystem-based management of the GBR among managers within the organization, as well as amongst the public and politicians (Olsson et al. 2008). Across these cases, the story goes as follows. Key leaders step up after crisis, along with informal "shadow" networks of individuals who support them (Olsson et al. 2004, Olsson et al. 2008). These leaders and their networks build a vision for the future of the SES, and work hard to rally support for this vision until it is shared across different actors (Olsson et al. 2004, Olsson et al. 2008, Chaffin et al. 2018). The vision is then implemented, for example through the drafting of new shared management strategies (e.g. the Klamath River agreements (Chaffin et al. 2018)) or legislation (e.g. the re-zoning of the GBR (Olsson et al. 2008)). In essence, adaptive governance scholars indicate that at the micro-scale, successful transitions to adaptive governance often involve key leaders with a specific perspective (e.g. resilience approach) or vision (e.g. a certain desired regime) that have enough agency to convince others in the SES to adopt their conceptualizations of the system. It follows that the way governance actors conceive of SES problems, and build visions for the future after crisis may limit or open up possibilities for how governance evolves in the context of climate change (Pahl-Wostl 2009, Chaffin et al. 2016b, Baird et al. 2019, Muiderman et al. 2022). This subjective aspect of how governance actors understand the impacts of crisis, choose management priorities, and construct new visions (or reinforce old visions) is implicit in stories of the emergence of adaptive governance, but is yet to be made explicit and critically examined through empirical analysis within adaptive governance scholarship (Chaffin et al. 2016b, Clifford et al. 2022).

The lack of empirical attention to the subjective aspect of governance actors' reactions to crisis may in part be a reflection of adaptive governance scholars' lack of critical attention to their own normative assumptions. I do not raise this to degrade previous work—these case studies provide an invaluable demonstration that adaptive governance can become an on-the-ground reality rather than just an idealistic theory. Instead, my concern is that there are several unattended to normative assumptions within adaptive governance scholarship that may hinder efforts to realize the aims of adaptive governance in both research and practice.

As described, adaptive governance theory evolved around the aims of supporting the flexibility, creativity, and inclusivity of governance actors and governance processes as they seek to adapt to (and even anticipate) change in SES (Folke et al. 2005, Chaffin et al. 2016b). Adaptive governance scholarship can better address these aims by taking a critical approach that questions three normative assumptions about how change should occur embedded in previous work: 1) governance change is galvanized primarily by specific leaders, 2) creating and implementing a shared vision is essential for successful adaptive governance, 3) crisis is important to adaptive governance primarily because it opens a window of opportunity for change. These assumptions should be questioned based on the aforementioned critiques of adaptive governance scholarship (e.g. Olsson et al. 2015, Cleaver and Whaley 2018), as well as recent developments both within environmental governance scholarship and in three streams of research that intersect with adaptive governance scholarship—social network science (e.g. Bodin and Prell 2011), political science (e.g. Stone 2002, Jones and McBeth 2010, Nohrstedt et al. 2021), and futures-thinking (Vervoort and Gupta 2018, Wyborn et al. 2020). In the next section I elaborate on how these three streams of research offer insights that challenge current assumptions, and highlight what can be gained from incorporating these insights into future research.

1.3 The need to broaden and deepen attention to crisis

1.3.1 Broadening from leaders to networks

First, though cases of adaptive governance emerging illustrate that key leaders are critical in this process (Assumption #1), recent shifts towards networked governance (e.g. Bixler et al. 2016), and the study of the networks of actors that compose this approach (e.g. Bodin and Crona 2009, Bodin and Prell 2011), suggest that the actions of other actors can be equally important in bringing about change. The term "leader" is rarely explicitly defined in adaptive governance scholarship, but tends to refer to individuals in formal decision-making roles (e.g. an elected official in the Great Barrier Reef region (Olsson et al. 2008)) or to charismatic conservation or resource management professionals who may not have formal jurisdiction but appear to have strong influence in governance networks (e.g. a nonprofit director in the wetland landscape around Kristianstad, Sweden (Hahn et al. 2006)). Contrary to the previous focus of adaptive governance research on these types of leaders, research on network governance recognizes that changes in governance do not just depend on the

actions of a few leaders, but also on collective action across the large number of organizations and actors that engage in SES governance, particularly in large SES governed through polycentric arrangements (Ostrom 2010, Bixler et al. 2016, Morrison et al. 2023). Governance of SES, and especially of large SES, involves a range of actions by a myriad of organizations and individuals who work on different issues (e.g. water quality, climate change), in different sectors (e.g. government, industry), and at different levels (e.g. state, international) (Bodin and Crona 2009, Morrison 2017). Substantial research in environmental governance has used both qualitative and social network approaches to explore this "social fabric" of governance (Bodin and Prell 2011), and understand the ways in which governance outcomes are shaped by collaboration, conflict, social influence, and other social processes that occur as networks of individual actors and organizations interact with one another and with the environment (Janssen et al. 2006, Ostrom 2010, Bodin and Prell 2011, Bixler et al. 2016, Bodin et al. 2016, Barnes et al. 2016, Morrison et al. 2023). Considered in the light of this research, the focus by adaptive governance scholars on the leadership of specific actors within high-level decision-making spaces fails to bring attention to the much broader networks of actors who may take action in response to crises, regardless of what actions are taken in high level decision-making arenas (e.g. policymaking, legislation, or government-led regional strategies).

Investigating the activities of entire networks of actors working across the geographic expanse of SES can uncover whether or not crises catalyze broader shifts in the types of issues actors organize around both within high-level decision making spaces and far beyond. Understanding whether or not these broader shifts occur is important for understanding whether or not the aims of adaptive governance are being realized at large scales after crisis. For example, the emergence of new priorities in a network might indicate creativity, changes in patterns of collaboration around priorities might indicate flexibility, and changes in which types of actors are entering or leaving a network can shed light on whether governance is becoming more or less inclusive after crisis, which relates to who benefits or is hindered by governance decisions after crisis. A new method in social network analysis make investigation across large geographic and long temporal scales possible by examining organizations' attendance at forums (i.e. meetings, advisory panels), although only a few network analysts have explored this to date (e.g. Berardo et al. 2015, Berardo and Lubell

2016). This approach is yet to be applied by adaptive governance scholars to explore how crisis affects flexibility, creativity, and inclusivity across governance networks, and is further described and applied in Chapter 2.

1.3.2 Broadening the definition of "leaders"

In addition to broadening attention to entire networks of governance actors, there is also a need to broaden how "leaders" are conceived within the high-level decision-making spaces that typically garner attention in cases of adaptive governance emerging (e.g. advisory panels, policy-making, regional management strategy development). Research elsewhere in environmental governance, and in political science, points out that choosing to frame certain governance actors as "leaders" who "succeed" or "fail" is a normative exercise (Evans et al. 2015). This research points out that in any given decision-making space, there exist a variety of governance actors who hold different priorities and ideals for the future (Stone 2002, Evans et al. 2015, Louder and Wyborn 2020). Reviewing cases of the emergence of adaptive governance with this in mind reveals that an over-emphasis on the role of key leaders (assumption #1 above) may be obscuring the more complicated ways that crisis impacts governance actors' priorities and visions for SES futures. Adaptive governance scholars' give selective attention to individuals whom they regard as "leaders" because they act in pursuit of a certain desired regime, likely one that scholars themselves agree with (e.g. a restored wetland (Hahn et al. 2006) or an ecosystem-based management approach (Olsson et al. 2008)). This is confirmed by the way these researchers describe other actors as "failing" to bring about adaptive governance when they attempt to bring about visions with more narrow interests (e.g. a regime that scholars' view as undesirable) (e.g. Olsson et al. 2006). This neglects to bring attention to the other important decision-makers and advisors who exist in this space but are leaders for other interests beyond those of adaptive governance scholars. Yet bringing about any policy change or collaborative vision in the wake of crisis requires negotiating conflicting values and visions as different actors contest proposed solutions and the nature of the problem itself (Leach and Mearns 1996, Birkland 1998, Shanahan et al. 2011, Baird et al. 2019, Parker et al. 2020, Múnera-Roldan et al. 2022). How governance actors interpret crises and frame certain solutions and outcomes as "desirable" will vary based on their interests and will lead to different

outcomes for different actors (Stone 2002, Morrison et al. 2020a, Múnera-Roldan et al. 2022).

Ignoring these deeply political dynamics is problematic for instrumental reasons because this overlooks how alignment or conflict between actors' perspectives creates potential barriers (or opportunities) for governance actors to bring about adaptive governance arrangements after crisis (Warner 2019, Angstadt 2020). It is also problematic for achieving the normative goal of inclusivity in processes to address change by privileging certain actors' perspectives without at the least describing alternative perspectives. This is especially important to attend to as climate change potentially affects diverse actors' perspectives on what outcomes are desirable and feasible to achieve in different ways, and the perspectives that come to dominate will shape which actors benefit or lose as a result of new governance directions (Louder and Wyborn 2020, Múnera-Roldan et al. 2022). Research on the effects of crisis therefore needs to examine: 1) how a range of governance actors (e.g. NGOs, industry representatives, community groups) in decision-making spaces conceive of SES goals after crisis, 2) how these differing perspectives may align or conflict and thereby affect whether and how governance changes, and to whose benefit. This can be accomplished by drawing on policy narrative analysis, an approach developed by political scientists seeking to understand processes of policy development (Stone 2002, Jones and McBeth 2010, Shanahan et al. 2011). This research points to the ways in which governance actors construct stories about policy problems, how they originate (including who caused them), what solutions should be implemented, and by whom (Stone 2002, Jones and McBeth 2010). I provide a more in-depth description of this approach and its value to adaptive governance scholarship in Chapter 3. I then apply this approach in both Chapters 3 and 4 in order to explore the different ways that governance actors who make and advise decisions about SES interpret crises and re-imagine social-ecological futures, and how their views align or conflict with one another.

1.3.3 Deepening attention to conflicting visions beyond a shared vision

Inherent to previous case studies of crisis is the assumption that governance actors can best adapt to change by building and implementing a shared vision (assumption #2 above) (Hahn et al. 2006, Olsson et al. 2008, Chaffin et al. 2016b). The leaders discussed in the previous section are typically the focus of study because they have succeeded in building support for

a specific vision that comes to be shared across multiple actors. Yet recent research in climate adaptation and futures-thinking suggest that pursuing multiple visions simultaneously may be a more effective strategy for navigating climate-driven change (Paschen and Ison 2014, Vervoort and Gupta 2018, Louder and Wyborn 2020, Wyborn et al. 2020, Múnera-Roldan et al. 2022). "Futures-thinking" is here used to refer to the collective body of work on how governance actors anticipate and imagine the future for SES, including "anticipatory governance" and "foresight" research (Vervoort and Gupta 2018, Muiderman et al. 2022, Alexandra et al. 2023). Attending to the views of the full range of governance actors in an SES may not only improve inclusivity (see previous section), but can also paint a more detailed picture of the dynamics of how a crisis is interpreted and leveraged (or not) to make changes to SES management or governance. This includes governance actors representing a variety of interests (e.g. industry representatives, Traditional Owners) beyond the specific "leaders" typically focused on in adaptive governance scholarship (see extended definition of "governance actors" in Table 1). Considering the multiple ways actors envision the future can encourage creativity by opening up new options for management, and inclusivity by bringing a range of actors to the decision-making arena even if they do not all agree on one way forward (Vervoort and Gupta 2018, Muiderman et al. 2022, Múnera-Roldan et al. 2022). Research on climate adaptation frameworks offers a foundation for investigating governance actors' varying perspectives on the future. These frameworks present suites of options for how to respond to change. For example, one framework allows actors to discuss options to "resist", "accept", or "direct" change (Schuurman et al. 2022). In Chapter 3 I describe how I combined climate adaptation frameworks with the narrative analysis approach described above in order to articulate governance actors' differing visions for the future. I then compare and contrast these visions to understand points of tension and alignment, and what this implies for finding a shared vision or multiple paths forward after crisis.

1.3.4 Extreme climate events: crisis as more than an opportunity

The idea in adaptive governance scholarship that crises can be opportunities for change (assumption #3 above) originates in political science research and is also prevalent in natural hazards research (e.g. Birkland 1998, Norhstedt et al. 2021). This research shows that crises can shift who influences the political agenda, what topics receive attention, and who

benefits or loses as a result (Birkland 1998, Albright 2011, Liu et al. 2011, Berardo et al. 2015, DeLeo et al. 2021). However, research in environmental governance, political science, and natural hazards has also shown that crises do not always lead to change, or in some cases the changes that do occur are unsustainable or maladaptive (Birkland 1998, Olsson et al. 2006, Nohrstedt et al. 2021, Morrison et al. 2020a). Research in these areas suggests that crises may entrench existing inequities (Blythe et al. 2018) or fail to trigger actors to make adjustments needed to effectively govern SES (i.e. achieve goals and respond to emerging problems (Morrison 2017)) (Morrison et al. 2020a, Norhstedt et al. 2021). A holistic understanding of how crises affect the ability of governance actors to realize the normative aims of adaptive governance therefore requires investigating cases where crises change actors' priorities or visions for the future, and also cases where they do not. Considering cases where crises do *not* change governance actors' priorities despite extensive changes to an SES, or cause conflict rather than a shared vision, can shed light on the barriers to navigating climate change in SES (Morrison 2017, Nohrstedt et al. 2021). The impacts or lack of impacts of crisis on governance are particularly important when considering extreme climate events. Extreme climate events fit Chaffin and Gunderson's (2016) definition of crisis as these events are periods where temperature becomes the "alternative" driver of system dynamics (p. 83), manifesting as more intense cyclones, fires, marine heat waves, among other phenomena. As acute, visible impacts of climate change with potential or actual harmful effects, extreme climate events would seem to offer the quintessential "window of opportunity" associated with crisis (Birkland 1998, Chaffin and Gunderson 2016). Yet given the cases illustrating that crisis does not always catalyze governance change (Nohrstedt et al. 2021), extreme climate events may not either. Whether and how extreme climate events impact environmental governance is particularly important to investigate given the pressing need for developing adaptive governance approaches capable of supporting governance actors as they navigate the uncertain SES transitions triggered by climate change (Brunner and Lynch 2013, Hurlbert and Gupta 2016). Whether extreme climate events provide opportunities, or create new conflicts and challenges, is of equal relevance to this effort to develop adaptive governance. The way that extreme climate events play out will vary widely based on the specific ecological, political, social, and other characteristics of a given SES context. In the final discussion chapter of this dissertation, I consider what my findings in

each chapter reveal about how extreme climate events do or do not catalyze change in the GBR, and what implications this has for adaptive governance of SES more broadly.

1.4 Summary of Research Gaps and Objectives

This dissertation expands on the treatment of crises in adaptive governance literature. I examine the case of an extreme climate event as a crisis that brings attention to the challenge of climate change for adaptive governance. As just described, the majority of empirical studies to date focus on the activities of key leaders and shadow networks that leverage crisis to realize a particular vision that aligns with adaptive governance scholars' own normative position on what management and governance responses should be taken within a SES, and give little attention to when crisis does not catalyze change. Expanding the treatment of crisis in adaptive governance scholarship is essential for understanding what opportunities, challenges, and other implications extreme climate events have for governing in the Anthropocene. Below I present my research questions and describe how my chapters collectively address these questions in order to contribute to broadening and deepening the understanding of crisis in the four ways described in the previous section.

Overarching Gap (see 1.3.4): Adaptive governance research has focused on cases where crises created opportunities for the emergence of governance arrangements but give little attention to what can be learned from instances where crises occur, but do not lead to the manifestation of desired changes in governance, or have a mixed effect on governance.

Overarching Research Question: What are the implications of extreme climate events for the opportunities and challenges to realizing adaptive governance of SES in the climate change era?

Overarching Objective: Consider how extreme climate events create opportunities or barriers for adaptive governance to meet the challenge of climate change. This overarching objective drives this dissertation research, and is addressed through the three research questions below.

In my Discussion Chapter I reflect on the findings of the three chapters of this thesis and highlight major insights related to the role of extreme climate events in shaping GBR

governance, and what implications this has for governance of SES in the context of climate change.

Research Gap 1 (see 1.3.1): Governance scholars have focused on the activities of key leaders after crisis and the networks of individual "shadow" actors that support them, but there has been little empirical attention to how the activities of entire networks of organizations do or do not respond to crises.

RQ 1: Are there shifts in the topics that receive attention or the organizations that participate in governance networks in a large SES before, during, or after extreme climate events?

Objective 1: Examine whether there are changes in the topics that receive attention or the organizations that participate across entire networks of organizations after crisis.

In Chapter 2 I address this research gap by expanding on recently developed social network analysis methods of examining organizations' attendance at forums (e.g. meetings, collaborations) (e.g. Berardo et al. 2015) to understand how networks do or do not shift after an extreme climate event. I examine the topics of forums as a proxy for organizations' priorities (e.g. improving water quality), and assess what types of organizations (e.g. government, NGO) attend forums to detect changes or stability in who participates in governance after a crisis. Note that in this chapter "governance actors" refers specifically to organizations, whereas in chapters 3 and 4 this refers to individual governance actors and at times to the actor groups they represent (this is specified in the chapters).

Gap 2 (see 1.3.3): Existing cases of governance actors' responses to crises focus on examples where a single, shared vision for the future of an SES is developed and implemented, yet attending to the potentially varying visions amongst governance actors may bolster creativity and better include the perspectives of various actor groups within decision making. This is yet to be the subject of empirical investigation of crises within adaptive governance scholarship.

Research Question 2: How do governance actors representing a range of interests in high-level decision-making processes envision the future after extreme climate events?

Objective 2: Examine the multiple visions emerging after extreme climate events amongst governance actors representing different groups.

In Chapter 3 I draw on narrative analysis methods from the political sciences to analyse dominant narratives that arise amongst individual governance actors after an extreme climate event. I specifically articulate narratives about different futures for an SES, and about what management approaches need to be prioritized to realize those futures. Through this analysis I encourage a pluralistic response to crisis that fosters creativity in the context of adaptive governance.

Gap 3 (see 1.3.2 and 1.3.3): Previous research focuses on specific governance actors with particular visions for the future, framed as "leaders", and ignores the visions of governance actors leading other interests. This glosses over the potential conflicts and synergies that arise in situations where multiple visions emerge.

Research Question 3: What do conflicts and synergies between governance actors' multiple visions for the future of an SES indicate about political dynamics between actors, and the barriers and opportunities this creates for governing in the Anthropocene?

Objective 3: Analyze tensions and synergies between dominant narratives in order to unpack sources of conflict and opportunities to collaborate amongst governance actors.

In Chapter 4 I simplify the narratives uncovered in chapter 3, then expand the analysis by identifying points of tension and synergy between dominant narratives. I discuss the possible sources of these tensions, including how governance actors representing different groups resist or embrace each narrative. Through this analysis I unpack conflicts over priorities after crisis and consider the opportunities a pluralistic approach may offer to adaptive governance.

In this dissertation I examine recurrent mass coral bleaching events as a case of extreme climate events impacting a large SES – the Great Barrier Reef. Mass coral bleaching is a useful case for investigating climate impacts in a SES because it is driving regime shifts in some reefs (i.e. shifts from hard coral dominance to algae dominance) (Hughes et al. 2017, Bellwood et al. 2019) and has also harmed human well-being (Marshall et al. 2019). I investigate the GBR as a study site because recurrent mass coral bleaching events impacted this SES in 2016 and 2017, gaining global attention (Hughes et al. 2017). The GBR is seen as a global leader in coral reef management, making its governance opportunities and challenges an interesting point of reference for reef management globally (Day 2016). In the next section I elaborate on the GBR and why I selected this site. Each of my following chapters presents a separate component of my PhD research that answers each of my research questions, with my overarching research question then explored at length in my Discussion chapter.

1.5 General Methodology

1.5.2 Case Study Approach

I chose a case study approach because my research questions require building an in-depth understanding of a phenomenon (i.e. mass coral bleaching events) that in no way can be separated from its real-world context (i.e. coral reef governance, particularly GBR governance) (Yin 2014). I was interested in how governance actors respond to and interpret these events in real time, which is deeply affected by the context in which these actors are embedded. A case study approach is an ideal way to account for this context in my analysis (Yin 2014). This approach does not seek to run multiple experiments in order to statistically generalize results, but instead takes a single case as analogous to a single experiment, and seeks an "analytic generalization" that utilizes empirical findings to contribute to theory (Flyvbjerg 2006, Yin 2014). In this study, I took the GBR as a "revelatory case" in order to generalize to theory on how extreme climate events affect adaptive governance, and thereby contribute to efforts to better govern in the context of climate change (Yin 2014); my first chapter on networks is also a "longitudinal" case because it draws on data from multiple years. Revelatory cases are those that provide an opportunity to investigate a new phenomenon that has not been previously accessible to researchers (Yin 2014). While extreme climate events have occurred in reef SES (e.g. cyclones), mass coral bleaching

events have a much more extensive footprint, affecting reefs and interconnected communities of people across entire regions (e.g. across the 344,000 km^2 GBR system), and have not occurred in back-to-back years on the GBR until the 2016 and 2017 events (Hughes et al. 2018b). In seeking to generalize to theory, I differentiated between aspects of my case that can be generalized to other SES, and aspects that are specific to the GBR. For example, specific aspects of GBR governance, such as its status as a World Heritage Area, affect the political dynamics of the GBR in specific ways. However, this more generally suggests that international governance arrangements may have a bearing on how an extreme climate event is interpreted within an SES. The elements of this case that are generalizable versus specific to the case are further elaborated in the final discussion chapter of this thesis.

In carrying out this case study I adopted a "post positivist" (Clark 1998, Panhwar et al. 2017) or "critical realist" approach (Robbins 1999, Fletcher 2017; similar to "critical pluralist" Patterson and Williams 1998) that rejects the notion that an absolute truth is knowable, and embraces different ontological and epistemological perspectives on SES research. Post-positivism seeks to balance positivist and interpretivist perspectives by seeking out the "diversity of facts researchable through various kinds of investigations while also respecting their differences (Clark 1998, Panhwar et al. 2017). In my second chapter on governance networks, I adopted a slightly more positivist approach (i.e. rationalist) (Patterson and Williams 1998). Here I sought to uncover the objective reality of forums attended by representatives of organizations before, during, and after bleaching events, while still recognizing that this research inevitably paints an incomplete picture that does not perfectly represent the reality of every forum that occurred. In my latter chapters, I was more interested in the subjective realities experienced by different governance actors and thus took a more relativist approach (Patterson and Williams 1998). In taking both approaches across my chapters, my assumption was that both objective occurrences and subjective experiences shape the ways that an extreme climate event affects governance actors' views and actions.

My methods and means of building construct validity vary across chapters; in Chapter 2 I utilized document analysis and Chapters 3 and 4 I drew on interview data. Construct validity refers to selecting the right measures for the concepts under study (Yin 2014). With the data I collected for the networks in Chapter 2, I aimed to represent the reality of forums and

organizations who attended them (i.e. triangulate in a more positivist sense) through iterative analysis of forum documentation and organizations' websites and reports referencing forums. In chapters 3 and 4 my aim was not to define a single reality but to accurately represent governance actors' subjective views in order to identify dominant narratives. I therefore did not seek to triangulate through multiple sources of evidence, but instead built a chain of evidence to support my conclusions (Yin 2014). I built reliability in these chapters in several ways. First, to build my chain of evidences I clearly recorded how interviews were coded and what interview questions were asked (Yin 2014). My interview consent form and interview guides are provided in Appendix B. I will also keeping my data for 5 years, which strengthens the replicability of my research and strengthens reliability by maintaining the pieces of my chain of evidence (i.e. it is possible to trace backwards from the narratives to the codes to the original transcripts) (Yin 2014). To build reliability I also discussed key findings with key informants familiar with GBR governance and bleaching events, and with other qualitative researchers studying the GBR governance in the wake of the bleaching events (e.g. professors, researchers, and other PhD candidates). Key informants included interview participants, and other researchers and practitioners to whom I presented findings at conferences, university required milestones (e.g. pre-completion seminar), and one-on-one meetings. I also reflected on the findings of other GBR studies published over the course of my research (e.g. Walpole and Hadwen 2022). These conversations and publications reinforced my interpretations or at times helped me to consider possible alternative interpretations of my findings, important for building reliability (Flyvbjerg 2006, Yin 2014). Lastly, reliability requires reflexivity, which can be achieved through the conversations and reflections described above as well as through awareness of how my position in the system affects how I collect data (e.g. influences my participants' responses) and how I interpret my findings. To build reflexivity I took notes reflecting on each interview (i.e. "memos") and created the positionality statement in the next section (Buraway 1998, Flyvbjerg 2006, Yin 2014). My methods are further elaborated within each chapter, alongside the theoretical frameworks they are nested within.

1.5.1 Positionality

A researcher's positionality affects the way in which they relate to their study subjects and conduct the entire research enterprise. Exercising reflexivity to understand this

relationship is core to building validity in qualitative research (Buraway 1998, Flyvbjerg 2006, Yin 2014). Conducting interviews with state and national decision-makers, researchers, policy-makers, and managers required awareness of the political context in which participants are situated and self-awareness of my own position and how they may react to it. This was particularly important due to the status of the GBR as a World Heritage area and a national icon, which frequently brings management of the reef into the political spotlight. Mass coral bleaching events in the GBR gained almost immediate national and international attention from scientists and media, wanted or unwanted by governance actors. I was positioned within this highly politicized governance space as a graduate student, a woman in science, and someone affiliated with both the University of Montana and the Australian Research Council Centre of Excellence for Coral Reef Studies. Also relevant are more personal aspects of my identity—that I am from Hawaiʻi – a place with its own reef management challenges, raised by a left-leaning environmentally conscious family on a farm. I was also a resident of Queensland for periods ranging from 9 to 18 months from January 2019 to December 2022.

Many of my interview questions required participants to engage in thoughtful reflection, politically sensitive topics, and areas of deep personal and professional uncertainty (and thus for some, deep angst). As someone chronically empathetic, I focused substantial attention on finding areas of common ground as part of building rapport. To me, part of building rapport is being intentionally open and genuinely interested in my participants' views, especially where they differ from my own. I was clear about my position as a graduate student and my institutional affiliation, and named my two primary advisors in my consent form. I promised my participants that I would be the only one to read the raw interview transcripts, though advisors may review coding of de-identified manuscripts. During interviews, I frequently sought to identify and explicitly reference aspects of my identity that my participants could relate to. For example, I would often mention I was from Hawaiʻi, and sometimes mentioned Hawaiʻi had experienced bleaching events as well. This was to build connection with most participants regarding familiarity with living in the tropics, valuing tourism, and experiencing mass bleaching events (these occurred in 2014 and 2015 in Hawaiʻi). This built bridges with most Queenslanders, tour operators, and environmentalists/conservation participants. In connecting with agriculture-oriented participants, I would think about my experiences growing up on a small farm and raise these

experiences where relevant. For example, I understand the economic stresses of farming and how water quality legislation might affect that, even if I also believe water quality issues are important to address. The group that is furthest from my own life experience is the coal and mineral resources sector, although there was only one participant from this sector. Here I focused on reality that coal is currently a part of our economy and a part of my life (I drive a car and use electricity), and on the experiences of my acquaintances and friends in Queensland, who work in or have retired from jobs in the mining sector. I also considered the role mining will have in the transition to renewables—e.g. battery building. The reality I perceived from living in Queensland is that many working-class people depend on mining jobs and many enjoy these jobs—any realistic transition will need to take these needs and values on board.

Although I did aim to build rapport by sharing relevant bits about myself, I tried to avoid providing so much information that it might affect how participants responded to open-ended questions about reef governance and bleaching. I did not talk about my political affiliation, or indicate whether I agreed or disagreed with particular statements. I may have come off as being fairly agreeable with whatever was being said by focusing internally on my own curiosity and my value for making other people feel understood; I would often respond with a mild "yeah" or "that makes sense." I would frequently repeat back to participants what they had said, to confirm I had understood it correctly. I would also try to encourage them to get specific. For example, if participants said "they" or "we," I would ask who they meant. If terms such as "resilience" or a "healthy" reef were used, I asked for further definition where possible without disrupting the participants' thought process.

Beyond the personal level, my professional affiliation mattered in this region. Emphasizing University of Montana leads to confusion about why I was doing reef research based out of a terrestrial-focused institution, but emphasizing James Cook University and especially the ARC CoE for Coral Reef Studies (i.e. the "Centre") put some participants on edge due to strong views on coral bleaching espoused by prominent researchers affiliated with the centre. When I encountered hesitation amongst participants, I emphasized that my interest stems from my experiences living in Hawai'i, and found that this was more helpful for building rapport than either affiliation. Some resonated strongly with the views espoused by those in the Centre, while others were more sceptical; researchers in the Centre hold differing views themselves, so participants' responses generally varied based on

which researchers they knew. Some participants reported being personally offended by some researchers who questioned or insulted their work, particularly over social media. This raised two concerns for me as a researcher: 1) all participants mentioned climate change, but would that have been the case if I were not affiliated with the Centre? 2) Did participants who were offended by researchers really feel comfortable saying everything they would have said if I were affiliated elsewhere? In regard to the first question, several sources suggest climate change is front of mind for many decision-makers and stakeholders after the bleaching events. Monitoring reports by the Australian Institute of Marine Science (AIMS), outlook reports and public statements from the Great Barrier Reef Marine Park Authority (GBRMPA), and communiques from the Reef Advisory Committee and Independent Expert Panel all cite climate change as a major impact (not just threat) to the reef. In addition, a recent study of the evolution of attention to climate change in GBR management, involving document analysis and interviews (likely overlapping participants with my study), found that climate change is increasingly seen as the number one impact on reefs (although the study questions whether it is being adequately addressed) (Walpole and Hadwen 2022). Regarding the second question, when people seemed really uncomfortable, I tried to just address it head on (e.g. by acknowledging that I am aware that some researchers have caused offense, and being up front about who my advisors are (and are not). In all cases, participants appeared to eventually relax and seemed reassured that they could speak openly. I am confident of this because they became more direct in naming how they felt wronged by specific researchers. These interactions were a bit awkward, however as a governance researcher, these experiences were useful for reflecting on the roles researchers in particular can play in controversy over interpreting a crisis—researchers are uniquely positioned to speak freely where others are not.

1.5.3 A dramatic case of an extreme climate event: recurrent mass coral bleaching

1.5.3.1 Reefs and Mass Coral Bleaching Events: At the intersection of coral reefs and climate change

The invisible but ominous warming of the world's oceans due to carbon emissions has been underway for decades (IPCC 2019). Coral reefs are particularly vulnerable to the effects of anthropogenic climate change (Hughes et al. 2017, IPCC 2019). Coral animals grow in colonies, with each tiny coral forming a calcium carbonate housing structure. These

structures provide a safe haven for *Symbiodinium* algae species, which form symbiotic (i.e. mutually beneficial) relationship with corals (Spalding and Brown 2015). Algae provide food to corals resulting from photosynthesis, while corals provide nutrients necessary for photosynthesis (Spalding and Brown 2015). This relationship between corals and colorful algae brings the rainbow of color that coral reefs are known for. These "underwater rainforests" provide habitat and food to support an estimated 1-9 million species, in addition to buffering coasts from erosion by waves (Reaka-Kulda 1997, Hoegh-Guldberg et al. 2017). Coral reefs thus support valuable services to the approximately 275 million people who live near them (Spalding and Brown 2015). These services include the provision of protein (e.g. fish), supporting livelihoods (e.g. commercial fishing), protection from storm surge, and cultural values such as self-provisioning through subsistence (Vaughan et al. 2013, Woodhead et al. 2018). The symbiotic relationship between corals and *Symbiodinium spp.* is the foundation that underpins reef structures and thus the biodiversity of coral reefs and reef ecosystem services. Yet it is precisely this symbiosis that is sensitive to warming ocean temperatures and other stressors (Spalding and Brown 2015, Hughes et al. 2017).

Symbiodinium algae exit their symbiosis with corals when under stress, leaving coral colonies bone white (Spalding and Brown 2015, Hughes et al. 2017). These events are thus referred to as "coral bleaching". Bleaching can be driven by a number of stressors (e.g. water quality, temperature), but the largest documented occurrences are caused by marine heatwaves—these events are termed "mass bleaching events" (Hoegh-Guldberg et al. 1997, Spalding and Brown 2015, Hughes et al. 2017). Mass bleaching is an acute event that typically lasts a few weeks to a few months, often during El Nino Southern Oscillation episodes that have become amplified by global warming (Spalding and Brown 2015, Elma et al. 2023). Coral colonies can recover from bleaching if heat stress resides and algae return after a short period, but sustained heat stress can cause coral mortality; susceptibility to bleaching and to mortality post-bleaching varies by species of coral and algae, among other factors (Marzonie et al. 2022, Elma et al. 2023). Large-scale recovery of reefs depends on spatial patterns of bleaching and how these relate to the larvae dispersal abilities of different coral species (e.g. are severely bleached reefs close enough to receive larvae dispersed by currents from reefs less affected by bleaching?) (Dietzel et al. 2020). Coral mortality caused by bleaching events is leading the shifts in the composition of corals on

reefs (i.e. "species assemblages") Marzonie et al. 2022, Elma et al. 2023, in turn changing the ecosystems services reefs provide to people (Woodhead et al. 2018).

Mass coral bleaching events were first documented in the late 1970's and researchers found that the events were occurring much more frequently after 1979 compared to previous decades (Hoegh-Guldberg et al. 1997). By the late 1990's, a subset of coral researchers began to discuss whether coral bleaching would come to be inconsequential or catastrophic for the vitality of coral reefs (Hoegh-Guldberg et al. 1997). In 1998, severe global bleaching events impacted an estimated 40-50% of global reefs (International Coral Reef Initiative 1998), ranging from the Indian Ocean to Australia's GBR (Berkelmans and Oliver 1999, Spalding and Brown 2015). These 1998 events caused researchers and practitioners to re-evaluate the potentially catastrophic effects of bleaching and suggest management and policy responses (e.g. improve rapid assessment capacity, improve reef modelling, curtail emissions) (International Coral Reef Initiative 1998, International Coral Reef Society 1998, Goreau et al. 2000, Reaser et al. 2000, Schuttenberg 2001). These events also helped catalyze major changes in GBR management and governance (see next section) (Olsson et al. 2008). Lastly, these events expanded research attention from the ecological realm to the exploration of the socioeconomic effects of mass bleaching, with the International Coral Reef Symposium hosting a special session on this topic (Schuttenberg 2001). Coral scientists at this time recognized the gravity of the threat of coral bleaching, with some writing that they met to find "a possible strategy for response beyond…resorting to anti-depressants" (Schuttenberg and Obura 2001, p. 1). However, although coral bleaching began to reach public consciousness through news articles at this time (e.g. CNN 1999a, CNN 1999b), it would be well over a decade before the true severity of coral bleaching impacts gained substantial public attention.

An unprecedented series of record-breaking hot years from 2014 to 2017 brought "the most severe, widespread, and longest-lasting global-scale bleaching event ever recorded" (Eakin et al. 2019). The formation of two successive El Niño events drove substantial declines in reef coral cover in reefs ranging from Hawaiʻi (Couch et al. 2017) to the remote atolls of the Indian Ocean (Head et al. 2019) to the GBR (Hughes et al. 2017). Different reefs bleached at different times during this period, but several experienced mass coral bleaching in back-to-back years (e.g. Guam, Hawaiʻi, GBR, etc.) (Couch et al. 2017, Hughes et al. 2017, Raymundo

et al. 2019). News articles shifted from pre-2014 headlines like "Bleached coral could be environment warning" (CNN 1999b) to dramatic titles featuring the GBR, such as "Obituary: GBR (25 million BC-...)" (Outside 2016) and "Large sections of Australia's Great Reef are now dead, scientists find" (New York Times 2017). This dissertation focuses on the back-to-back mass coral bleaching of the GBR that occurred in 2016 and 2017 as part of this global event.

1.5.3.2 Study site: the Great Barrier Reef

The GBR is an internationally significant Australian icon that stretches 344,000km^2 and generates $6.4 billion of economic revenue each year (GBRMPA 2019b). The GBR is composed of over 3,000 individual reefs and a myriad of islands, seagrass, mangroves, and other habitats (Day 2016)—which I refer to collectively as the "reef system." The reef system includes ~1,625 fish species, 56% of the world's hard coral species, 54% of global mangrove diversity, six of the world's seven turtle species and a globally important population of dugongs (marine mammal) (Day 2016). The GBR is a mecca for dive tourism, in addition to being of high recreational and cultural value to local residents from all walks of life (Marshall et al. 2018). The GBR and its adjacent catchment are home to a variety of actor groups concerned with the reef. I refer to the GBR and its adjacent catchment as the "GBR region", which constitutes the focal scale of the SES for the purposes of this dissertation. These include farmers, recreational and commercial fishers, dive tour operators, Traditional Owners, and mining industry professionals, among others. The term "Traditional Owners" refers to the Indigenous peoples of Australia with historical connection to Australian land and coastal areas. The most recent economic assessment of the GBR region consists of: mineral production (47% of gross value for region), tourism (29%), agriculture (21%), recreational fishing (2%), and commercial fishing (1%) (Hug and Larson 2006). Mining and agriculture are valuable to the Queensland economy but agriculture leads to runoff that degrades water quality of the GBR (Thornburn et al. 2013) and mining of coal contributes to global warming when the coal is exported and burned elsewhere (Grech et al. 2016); both of these industries thus effect the health of the GBR, which much of the tourism industry depends on for revenue. Governing the GBR thus requires careful and consistent navigation of the range of competing interests in the region (see next section) (Day 2016, Vella and Beresi 2017).

The GBR is governed through a complex array of international, national, and state arrangements. The Australian Government developed extensive management and governance arrangements to protect the GBR, earning it recognition as a global example of reef governance (Day 2019) and of adaptive governance of SES more generally (Day 2002, Olsson et al. 2008). The GBR is inscribed as a World Heritage site and is also a national marine park governed jointly through a bilateral agreement between the Australian Commonwealth and Queensland (State) governments (Figure 1). The Reef 2050 Long-Term Sustainability Plan (henceforth "Reef 2050") provides the overarching framework driving management efforts of both governments (Commonwealth of Australia 2021). The Australian Government is responsible for all areas below the low tide line, while the Queensland Government has jurisdiction over coastal areas, most islands in the region, and the catchment adjacent to the marine park. At the national level, the marine park is managed by the GBRMPA. The GBRMPA was created under the Great Barrier Reef Marine Park Act, which established the park in 1975 to protect it from mining interests (McCalman 2013, Day 2016). The GBRMPA works with the Queensland Wildlife and Parks Service and other ministries to manage the reef day-to-day. At the state level, the Office of the Great Barrier Reef manages the GBR catchment and primarily focuses on water quality issues. The Commonwealth also distributes funding for GBR management through the Reef Trust Partnership. This partnership has been administered through a private foundation, the Great Barrier Reef Foundation, since 2018. The Reef Trust Partnership disperses funds to industry peak organizations, research institutions, and private sector companies to research and develop solutions for the GBR primarily related to water quality, crown-of-thorns starfish removal, reef restoration, Traditional Owner and community engagement, and monitoring and reporting to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) regarding World Heritage Area priorities (Figure 1).

In addition to government entities, a myriad of NGOs, research institutions, individual researchers, Traditional Owner groups, local government peak organizations, community groups, and dive tourism, agriculture, and mining industry peak organizations (i.e. advocacy organizations) engage regularly with reef management. Each type of organization or user group is represented on the Reef Advisory Committee, and individual researchers engage with reef management through the Independent Expert Panel. These two advisory panels

provide recommendations to the federal and state ministers on implementing the Reef 2050 plan, a regional strategy to meet World Heritage goals in the GBR. Traditional Owner groups engage with the Reef Advisory Committee and other reef institutions, but many groups (at least 70) additionally have "rights, interests or aspirations" to govern Sea Country (i.e. marine and coastal areas) across the GBR (Dale et al. 2018). These Traditional Owner groups engage with reef governance through a myriad of mechanisms, including claims to native land (and sea) title and voluntary Traditional Use of Marine Resource Agreements with the GBRMPA and Queensland Department of Environment and Science regarding management of culturally significant species like dugong and sea turtle (see Dale et al. 2018 for detailed description of Traditional Owner governance mechanisms).
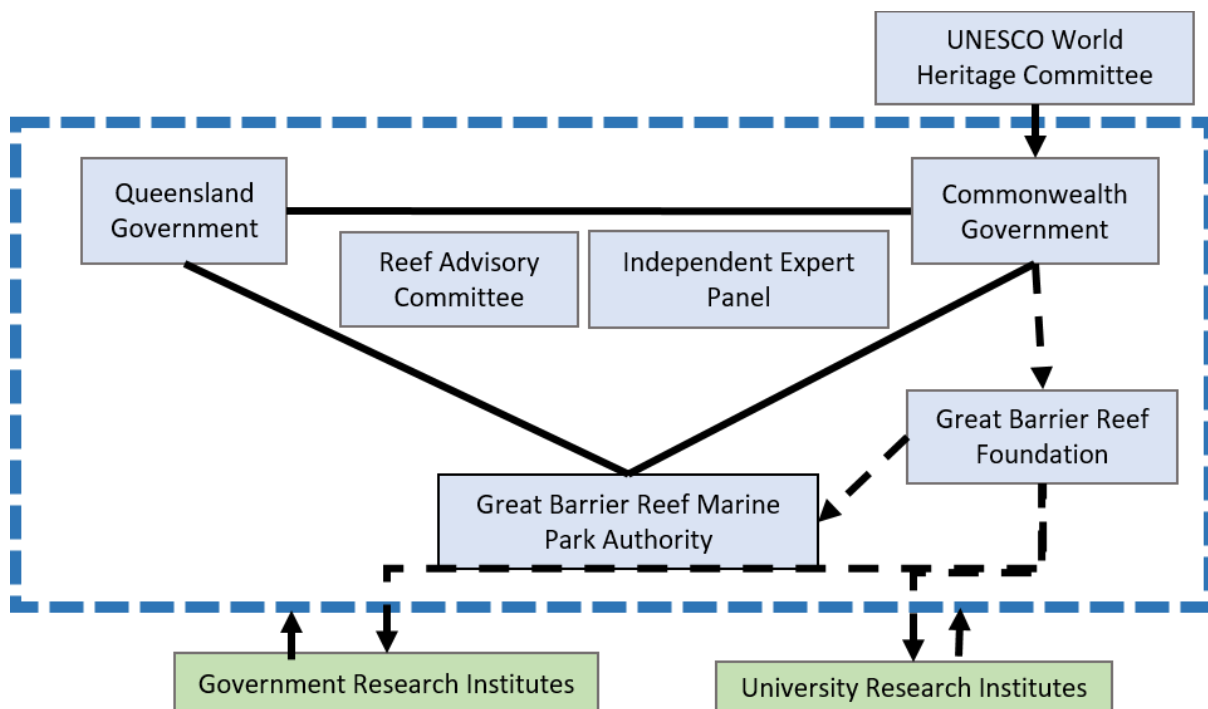
Figure 1. Governance of the Great Barrier Reef. Decision-making organizations encompassed by the blue dashed line. The Commonwealth and Queensland government share responsibility for the Great Barrier Reef Marine Park (solid black lines). The Great Barrier Reef Foundation distributes Commonwealth funding through the Reef Trust Partnership for research and management activities (dashed black arrows). Government and university research institutions (indicated in green) regularly provide data and advice to these entities. Participants from each of these organizations and advisory groups are included in this study.

The GBR was recognized by Olsson et al. (2008) as a rare example of adaptive, ecosystem-based governance after the radical re-zoning of reef uses to better protect the biodiversity of the reef (GBRMPA 2021a). Today, GBR governance actors still pursue adaptive governance aims (Day et al. 2019, Barnes et al. 2022), such as the engagement of diverse actors and ability to address problems at local and regional levels (i.e., bioregional fit)

(Olsson et al. 2008, Huitema et al. 2009, Wyborn et al. 2015, Day et al. 2019). However, some have questioned the ability of the system to cope with all relevant stressors, especially climate change, which threatens the environmental and economic value of the reef (Hughes et al. 2017, Morrison 2017, Bellwood et al. 2019, Hughes et al. 2019).

1.5.3.3 Management and Governance Responses to Mass Coral Bleaching Events affecting the GBR

Once viewed as "too big to fail", climate change is now fundamentally shifting the composition and functions of the GBR (Hughes et al. 2018a, Bellwood et al. 2019, Dietzel et al. 2021). Mass coral bleaching events in 1998, 2002, 2016, 2017, 2020, and 2022 have collectively impacted the north, central, and south regions of the reef, leading to changes in coral species composition across the reef system (Hughes et al. 2018b, Dietzel et al. 2021, AIMS 2022). The first *recurrent* events occurred in 2016 and 2017; this phenomenon was not expected to affect reefs until the 2030s or later in the century based on climate modeling (Donner et al. 2018). Although disturbances have always shaped reef ecology, the scale and frequency of these events presents an unprecedented challenge that is causing researchers and practitioners to re-evaluate strategies for reef management and governance (Bellwood et al. 2019, Morrison et al. 2020a, Dietzel et al. 2021, Kleypas et al. 2021, Barnes et al. 2022). Some researchers suggest that the impacts of bleaching on some reefs within the GBR have been extensive enough to be deemed "transformations", meaning the events have fundamentally changed the structure and function of the reef ecosystems (Hughes et al. 2018a, Dietzel et al. 2021, AIMS 2022). My research centers on the 2016 and 2017 events as this is the first recurrence of the bleaching events, and thus received national and global attention and caused reef managers, decision-makers, and reef actor groups to dramatically re-evaluate priorities for GBR governance (Hardisty et al. 2019, Morrison et al. 2020a, Dietzel et al. 2021, Kleypas et al. 2021, Barnes et al. 2022).

Previous studies indicate that after recurrent mass bleaching events climate change has become widely recognized as the number one threat to the GBR (Barnes et al. 2022, Walpole and Hadwen 2022), leading GBRMPA to issue a public statement on climate change (GBRMPA 2019a). In addition, bleaching events have reinforced attention on water quality as NGOs and the Office of the Great Barrier Reef seek to build the local resilience of the GBR (Barnes et al. 2022). Additional efforts to build resilience have led to a dramatic shift

towards developing high intensity interventions to restore corals and reduce exposure to marine heatwaves through geoengineering technology (e.g. cloud seeding). This catalyzed the AU$100 million Reef Restoration and Adaptation Program (RRAP) through the Reef Trust Partnership, which focuses on research and development of novel interventions.

At the international level, bleaching events gained the attention of international NGOs who lobbied the UNESCO World Heritage Committee to consider climate change in its World Heritage decisions (Morrison 2021). In 2022, a reactive monitoring mission led by representatives from UNESCO and the International Union for the Conservation of Nature led to the recommendation that the World Heritage Committee list the reef as "in danger" if adequate progress is not made towards improving water quality and taking climate action (Carter and Thulstrup 2022). These responses involve action at the local, regional, national, and international level, and are relevant to actors operating across different levels and sectors. Controversies have emerged in the region over the relative importance of adaptation (e.g. coral restoration and approaches to return reefs to their previous state) versus climate mitigation, a debate that is also reflected in global discussions of coral reef management (Bellwood et al. 2019, Abelson 2020, Morrison et al. 2020a). The chapters in this thesis, particularly Chapters 3 and 4, dig deeper into understanding this controversy and its implications for future governance of the GBR.

The global importance of the GBR region as a biodiverse ecosystem with myriad social actors and complex governance arrangements, and the severity of mass coral bleaching events, make it a useful case for understanding how extreme climate events affect governance in large SES. In the next chapter, I explore how governance networks change (or not) before and after mass coral bleaching events, with particular attention to organizations' priorities and the types of organizations that engage in reef governance. In Chapters 3 and 4, I dig deeper into governance actors' various perspectives on the bleaching events, including how they envision the future (Chapter 3) and how tensions and synergies in these visions point to political dynamics amongst governance actors (Chapter 4), which in turn affect barriers and opportunities for adaptive governance of the GBR in the context of climate change. I then reflect on the collective implications of the findings of these chapters in my final Discussion chapter.

Chapter 2: Big Events, Little Change: Extreme climate events have no region-wide effect on Great Barrier Reef governance networks

Abstract

This chapter leverages the power of social network analysis to detect potential changes in governance actors' activities in the GBR SES before, during, and after an extreme climate event. Specifically, I build on existing methods (e.g. Berardo et al. 2015, Berardo and Lubell 2019) to demonstrate how network analysis of actors' attendance at decision-making forums can be used to evaluate whether shifts in the interests, participation, and influence of governance actors occur after extreme climate events. *Forums* include venues where diverse governance actors exchange information or make decisions, such as meetings, conferences, partnerships, or advisory panels (Berardo et al. 2015, Berardo and Lubell 2019). This chapter aims to detect potential changes in governance actors activities after an extreme climate event by: 1) determining whether or not governance actors convene new forums, 2) detecting whether there are changes in the management issues that garner governance actors' interest by examining the topics of forums, and 3) examining whether there are any changes in two aspects of governance actor engagement: (A) actor participation in forums; and (B) the relative influence of actors attending forums.

This chapter is exploratory in nature and therefore rather than identifying hypotheses, I organize my theoretical framework in the next section around the gap in understanding how governance actors' activities shift (or not) across a geographically extensive SES after crisis, and the contribution of a network analysis of forums to addressing this gap. I describe the details of my social network analysis in the methods section. My analysis reveals general consistency and only minor shifts in the priorities and relative influence of hundreds of actors responsible for governing a large SES. I reflect on what these findings imply about the challenges of navigating extreme climate events and provide insight into the benefits and limitations of this method for investigating governance of SES after such events.

2.1 Theoretical Framework: Network analysis of forum attendance

While much previous research to detect change after crisis focuses primarily on policy agendas or change in specific organizations (e.g. Birkland 1998, Bellwood et al. 2019, Nohrstedt et al. 2021), examining governance actors' activities beyond policy development, such as engagement in meetings and other informal aspects of governance, can broaden empirical understanding of whether or not crises catalyze a response in SES governance. By examining these activities in this chapter I can detect shifts in the relative influence of different governance actors, or in the topics that draw actors' attention, which is relevant for understanding how actors may or may not realize adaptive governance of SES in the wake of extreme climate events (Berardo and Lubell 2016, Chaffin et al. 2016b). First, examining the topics that governance actors engage with after crises can shed light on whether or not the adaptive governance aim of addressing problems at multiple levels is being met. Second, assessing shifts in *who* engages in governance and how influential they are can reveal winners and losers as a result of governance (Angst et al. 2022, Olivier and Berardo 2021), which relates to the adaptive governance aims of inclusive participation and equitable outcomes (Chaffin et al. 2014, Blythe et al. 2018, Morrison et al. 2019). However, detecting shifts in these two areas is challenging because it is difficult to procure longitudinal data on entire landscapes of governance actors, particularly in large SES (Chaffin et al. 2016a, Berardo et al. 2015). Here, I demonstrate how social network analysis can be utilized to undertake such a large-scale analysis.

Social network science is increasingly utilized by environmental governance scholars to uncover the relationships between actors (in this case, organizations) in formal and informal social networks, and to investigate the implications of these patterns of relationships for social and ecological outcomes (Bodin and Crona 2009, Bodin and Prell 2011, Barnes et al. 2016). Taking a network approach allows us to quantify and analyze the "big picture" of interactions between organizational actors, which is particularly useful in geographically extensive and institutionally complex SES, where a plethora of governance organizations interact simultaneously (Morrison 2017). Recent research on organizations' attendance at forums (e.g. Berardo and Lubell 2016) offers an approach that can be utilized to broaden analyses of governance regimes after crises.

As venues where multiple actors come together to exchange information and make decisions, forums present opportunities for organizational representatives to connect with one another, further their agendas, defend their positions, and gather information about other organizations' intentions (Berardo et al. 2015, Berardo and Lubell 2016). Forums are thus venues for organization representatives to influence one another as they negotiate governance strategies and decisions. Past research has investigated actor attendance at forums to identify fragmentation and gaps in governance systems coping with climate change (Lubell 2017). Previous research investigates how actors' characteristics and patterns of participation in forums drive the structure of institutionally complex governance regimes (Berardo et al. 2015, Berardo and Lubell 2016). Other research has demonstrated that the structure of governance networks they create can evolve over time to meet the ongoing threat of climate change (Lubell & Robbins 2021). Additional research demonstrated that new forums can arise and become more popular than old forums after a crisis (e.g. widespread fires) in situations where the old forums are ill-equipped to deal with new problems that arose from the event (Berardo et al. 2015). Much of this research has focused on how network structure affects actor collaboration (Berardo et al. 2015, Berardo and Lubell 2016), or why actors chose to engage in forums or not (Angst et al., 2021 Olivier and Berardo 2021). There has been little longitudinal research over consecutive years on the effect of extreme climate events on what forum topics gain attention (Berardo et al. 2015, Berardo and Lubell 2016), or how participation in forums changes over time. This gap is in part due to the challenge of collecting annual data by survey (Chaffin et al. 2016a, Berardo et al. 2015). Here I follow Berardo et al.'s (2015) approach of analyzing forums and adopt a document-based method of data collection (Chaffin et al. 2016a, Schoon et al. 2017) to examine the topics of forums and characteristics of participants before, during, and after an extreme climate event in a large SES.

2.2 Research Questions: Applying network analysis to understand SES governance after an extreme climate event

Here I demonstrate how a network analysis of forums can be used to examine three questions about the governance of a geographically extensive SES after extreme climate events— the GBR after mass coral bleaching. I describe my three research questions below and provide additional information about the GBR case in Section 3.

Research Question (RQ) 1: Do extreme climate events catalyze governance actors to convene new forums detectable across a large SES?

If actors are utilizing extreme climate events as windows of opportunity as posited above, I expect that new forums emerge in reaction to the events (henceforth "event-related forums"), and participation in these new forums is higher than in forums not related to the events (Berardo et al. 2015).

RQ 2: Do extreme climate events affect which topics receive attention from governance actors?

Given that extreme climate events have global level drivers (e.g. emissions) (Hughes et al. 2017, Bellwood et al. 2019), I expect that topics related to global drivers, as well as impacts at lower levels (e.g. state) will be reflected in the topics of forums in the governance regime. Specifically, governance actor responses to extreme climate events may include an increasing proportion of forums on topics related to climate mitigation (e.g. emissions reduction), climate adaptation (e.g. restoration), or building resilience through ecosystem-based management (e.g. water quality improvements) (Morrison et al. 2020a, Kleypas et al. 2021). If an extreme climate event does not trigger change, topics will remain the same as prior to the events, or shift for reasons other than the event. This situation might indicate actors are struggling to address the multi-level problem presented by climate change.

RQ 3: Are there shifts in the relative representation or influence of governance actors after extreme climate events?

I am concerned with whether the proportion or influence of actors representing particular types (e.g. government, NGO), focuses (e.g. water quality, fisheries), or levels (e.g. local, national) remains stable, increases, or decreases after extreme climate events. Previous research posits that including diverse actors in management and decision-making supports adaptive and equitable outcomes (Folke et al. 2005, Huitema et al. 2009, Bennett and Satterfield 2018). Stability or an increase in the diversity of actors participating in governance may indicate that a system is attaining the same or improved inclusivity after an extreme climate event. A decrease in overall representation or overall influence of particular actor groups may indicate their exclusion from participation and/or benefits

from governance outcomes. I demonstrate how network analysis of forums can identify potential shifts that would then warrant further qualitative investigation.

If extreme climate events catalyze actors to pursue adaptive governance aims, I would expect to see changes in at least one of the three aspects described above. Previous research investigated the impacts of bleaching on GBR governance actors' priorities at the organizational level (Bellwood et al. 2019, Lubell and Morrison 2021, Barnes et al. 2022), but no empirical research has examined possible effects of bleaching events on what topics attract attention or which actors engage in governing across the entire SES. I demonstrate how network analysis of actor attendance at forums helps to measure whether individual actors' actions are detectable at the regional scale. I discuss how unveiling this big picture is useful to augment detailed qualitative analyses of participation, equity, and multi-level problems in adaptive governance. It is essential to explore these methods for detecting such dynamics at a time when climate change is triggering extreme events globally with the potential to disrupt those governance actors' who are seeking to pursue desirable ecological states and equitable social outcomes (Chaffin et al. 2016b, Blythe et al. 2018, Bellwood et al. 2019, Morrison et al. 2020a).

2.3 Methods

2.3.1 Scope of the network analysis

I analyzed a two-mode social network created from archival online data based on organizations engaged in forums related to the management and governance of the GBR and the catchment area adjacent to the reef. Two-mode networks includes two types of nodes (i.e. modes, entities)—here these are organizations and forums (Borgatti & Everett 1997). As described earlier, the Great Barrier Reef Marine Park Authority (GBRMPA) is the central agency responsible for the reef, and regularly engages with research institutions, reef-dependent industries (e.g. fisheries, dive tourism), industries relevant to the GBR watershed (e.g. agriculture, mining), and Traditional Owners. These organizations convene at forums focused on a broad range of issues related to the GBR (e.g. water quality, fisheries, reef-wide planning) (Morrison 2017, Bellwood et al. 2019). I henceforth refer to these interacting actors as the "GBR governance network," which is embedded within the

broader GBR governance regime (includes all elements of environmental governance as defined in Table 1).

I included forums that serve as venues where members from multiple organizations come together to share information, provide advice, and make decisions on issues related to the GBR. Specifically, forums included projects, meetings, programs, and other venues where organization members: 1) make decisions about reef policies or management strategies for the entire, or at least majority of, the reef SES (e.g. Reef 2050 plan development); 2) provide advice to decision-makers (e.g. Reef 2050 Plan Independent Expert Panel); 3) engage in partnerships to implement policies and management strategies (e.g. Eye on the Reef monitoring program); or 4) share research, monitoring, or management project findings to inform management decisions (e.g. 2017 Reef Summit). The topics of these forums are considered to represent priority areas for action by governance actors, allowing for assessment of actors' attention to problems at nested spatial levels (e.g. water quality is a regional problem, whereas restoration is site-specific).

I included forums that focused on multiple reef management issues or single issues relevant to the entire region (e.g. coral restoration, invasive species), referred to here as "reef topics". Localized, site-specific reef management projects and individual research or decision tool development projects not intended to have a bearing on the rest of the reef system were not included. International and national forums inclusive of the GBR, but not primarily focused on the GBR, were also excluded (for example, national marine forums like the Australian Marine Debris Initiative were excluded). I did not include forums occurring in 2020 because not all forums had been held or had documentation published at the time of data collection (August 2020-January 2021). Further details on data collection and analysis for forums is elaborated in Section 2.3.2.1.

2.3.2 Data collection

The dataset includes network data on organization members' (n= 451) attendance at forums (n= 145) related to coral reefs in the GBR region each year from 2012 to 2019. This allows for a comparison of the composition of the GBR governance network before (2012-2015), during (2016-2017), and after the bleaching events (2018-2019).

Following Berardo et al. (2015), I created a two-mode network by defining network ties based on organizational members' attendance at forums. Two-mode networks include two types of nodes; in this case nodes were forums and organizations. Data on forums was collected from publicly available documents and organizations' websites (Chaffin et al., 2016a). Specifically, I collected data on forums present in the network between 2012 and 2019 from documents and websites published between 2012 and 2020. Documents included reef management reports, strategies, reef program brochures, meeting minutes, and other forum documentation that included information about the forum topics and lists of participants. I created an initial list of forums and organizations from overarching reef strategy documents primarily produced by GBRMPA and the Queensland Government, which serve a central role in management of the GBR. I examined documentation of forums on this initial list to identify organization members participating in these forums. Forum documents and highly active organizations' websites were further screened to identify additional forums. This process was continued until saturation was reached and no additional forums or organizations were identified.

2.3.2.1 Forums

I classified each forum according to type (e.g. advisory panel) and topic (e.g. water quality). In addition, I classified forums into a binary category of "event-related" or "other," where "event-related" forums were those explicitly formed in response to bleaching events (e.g. GBRMPA 2016 Bleaching Event Impact Assessment and Incident Response), or were motivated broadly by climate change impacts and cited bleaching as a major impact (e.g. RRAP). Some event-related forums focused on topics beyond bleaching, such as restoration, but documented that they were motivated by the bleaching events. A list of types and topics of forums is provided in Table 2.

Forums relating to regional strategies were considered as two separate types of forums, one for strategy development, and the second for strategy implementation, because these two activities typically involved very different sets of actors that do not all interact with one another. Some forums were connected to multiple other sub-forums (e.g. Blueprint for Resilience implementation linked to multiple projects and programs underneath it). In these cases, separate nodes were included for all relevant sub-forums and participants were listed for each of these—the umbrella forum listed only the lead actor(s) (e.g. GBRMPA led

Blueprint for Resilience implementation). This avoids redundant listing of participants in sub-forums and umbrella forums, which would cause them to be overrepresented in the network.

Forums focused on the catchments adjacent to the GBR were included only if they were convened with a primary focus on the reef. Forums with very limited participant information were excluded. For example, forums consisting of private citizens or anonymous industry interests (e.g. unspecified fishing companies, dive tour companies) often lacked detailed participant lists, and were therefore excluded. Forums that included a mix of anonymous participants and specific organizations were included, but only the specified organizations were added as nodes in the network. There were two forums where data was available for most years but missing for two to three years (the Mackay-Whitsunday-Isaac Partnership and the Regional Report Card Technical Working Group). Due to the consistency of attendance by primarily the same actors in documented years, participation in years with missing data was presumed to be the same as the nearest year for which data was available (e.g. if data was missing data for 2018, data from participation in 2017 was used). I deemed this to be a more accurate representation of the network than removing the forum in years where data was not available.

2.3.2.2 Organizations

Organizations present in the network were categorized into type (e.g. government, NGO), focus (e.g. fisheries, infrastructure), and level (e.g., local, national). For example, SCUBA tour operators were classified as industry organizations, with a focus on tourism, operating at the local level. Note that references to "NGO" category throughout this article includes NGOs, intergovernmental organizations, not-for-profit organizations, foundations, and environmental lobby groups. When participants were listed as individuals, the organizations they represented were identified; if an individual represented more than one organization at a forum, ties were identified between each organization and that forum. A complete list of the types, focuses, and levels of organizations is included in Table 2.

Table 2. Forum and organization attributes.

Forums	Examples
Types	
Advisory panel or decision-making group	Reef 2050 Advisory Committee
On-ground projects, programs, partnerships & monitoring	Reef Report Cards
Assessment, planning, policy, and management review	GBR Outlook Report 2019
Research	Reef Restoration and Adaptation Program
Community engagement & training	Master Reef Guide Program
Topic	
Climate & coral bleaching	Climate Change Strategy and Action Plan
Reef restoration & adaptive interventions[a]	Reef Havens
Reef health, biodiversity and conservation[a]	Fight for the Reef Partnership
Fisheries	Queensland Sustainable Fisheries Strategy
Water quality	Fitzroy Partnership for River Health
Tourism & recreation	High Standard Tourism Program
Traditional Owners and cultural heritage	Indigenous Reef Advisory Committee
Shipping	Ports Memorandum of Understanding
Reef-wide multi-issue	Reef 2050 Plan
Organizations	
Type[b]	
Local government	Cairns Regional Council
State or territory government	Queensland Parks and Wildlife Service
Federal government	Australian Fisheries Management Authority
Consultancy	EarthCheck
Industry	Canegrowers
NGOs[c]	World Wildlife Fund
Community & Indigenous groups[d]	Gurang Traditional Owners
Science & Research	University of Queensland

Focus

    Infrastructure & development   Lendlease

    Business, finance & law   Business Council of Australia

    Energy & mining   Rio Tinto Alcan

    Agriculture   Queensland Cane Growers Association

    Cultural heritage & Traditional Owners[d]   Australian Heritage Council

    Environment, climate & marine   Wet Tropics Management Authority

    Tourism   Tourism and Events Queensland

    Public health, community & education   Cairns Regional Council

    Fisheries and aquaculture   Queensland Game Fishing Association

    Other   Australian Government

Level

    Local   Palm Island Aboriginal Shire Council

    State   Tourism Queensland

    National   Australian Institute of Marine Science

    International   Pew Trust

[a] The 'reef health, biodiversity, and conservation' category refers to forums focused on the overall status of the reef and its maintenance, whereas 'reef restoration and adaptive interventions' refers more specifically to more direct interventions to restore damaged reefs, including experimentation with new approaches and technologies.

[b] Lobby groups are included in the following categories: Industry, NGOs, Community & Indigenous groups.

[c] This includes NGOs, intergovernmental organizations, not-for-profit organizations, foundations, and environmental lobby groups.

[d] Many "community & Indigenous groups" organizations focus on "cultural heritage & Traditional Owners," but these categories do not entirely overlaps as some focus on broader local level concerns (e.g. the Local Government Association of Queensland focuses on "Public Health, Community & Education."

2.3.3 Data analysis

A summary of my empirical strategy is provided in Table 3. A detailed description of each stage of my analysis is provided in the sections below (2.3.3.2-2.3.3.4).

Table 3. Summary of my empirical strategy in relation to my three research questions

	Objectives	Data	Analysis
RQ 1: Do extreme climate events catalyze governance actors to create new forums?	A. Detect whether new event-related forums emerge.	Two-mode network data[a]	Presence or absence of event-related forums; number of event-related forums if present.
	B. Determine whether any detected event-related forums attract higher participation than other forums.	Two-mode network data; only years 2015-2019.	Independent t-test for difference of means between in-degree centrality of event-related forums and other (non-event-related) forums. In-degree centrality represents attendance (Freeman 1978, Borgatti et al. 2018).
RQ 2: Do extreme climate events affect which topics receive attention from governance actors?	A. Assess the topics of event-related forums.	Two-mode network data	Proportion of event-related forums focused on different reef topics.
	B. Assess the topics of all forums.	Two-mode network data	Proportion of all forums focused on different reef topics in each year.
			General linear model testing the impact of forum topic and type on the in-degree centrality of forums (Freeman 1978, Borgatti et al. 2018).
RQ 3: Are there shifts in the representation or influence of governance actors after extreme climate events?	A. Assess participation in event-related forums.	Two-mode network data	Proportion of organizations participating in event-related forums.
	B. Assess participation in all forums.	One-mode network data[b]	Proportion of organizations co-attending all forums collectively, classified by organization type, focus, and level.
	C. Analyze participant influence across all forums.	One-mode network data	General linear model testing the impact of actor type, focus, and level on the beta centrality of governance actors co-attending forums. Beta centrality of governance actors represents their potential social influence.

2.3.3.1 Transforming to co-affiliation networks

Transforming the data to one-mode networks (i.e. networks with only one type of node) makes it possible to apply the techniques of network analysis, with careful attention given to how network theory is applied (Borgatti and Everett 1997, Borgatti et al. 2018). These one-mode networks are referred to interchangeably as "co-affiliation" or "co-attendance" networks (Borgatti and Halgin, 2011). Co-affiliation networks rely on the assumption when organizations attend the same forums this provides the potential for interaction related to a topic of shared interest, creating conditions for the development of various relationships between actors (i.e. organizations in the GBR governance network) (Borgatti and Halgin 2011). For example, organization representatives at GBR forums are likely to communicate information and opinions on management of the GBR while participating in forums; thus, co-affiliation ties serve as a proxy for communication ties. Building co-affiliation networks from two-mode data based on document analysis also offers a convenient method for collecting near-comprehensive data on forum attendance in the GBR region (Borgatti and Halgin 2011). By contrast, a survey method would be difficult to distribute across such a large network, and would likely result in missing data due to reliance on actors' likely inability to remember who they have attended forums with, and even what forums they have attended, given the time frame of the past eight years.

One important limitation of co-affiliation networks is that they do not account for how the size of forums may affect the quality (or even existence) of relationships between co-attending actors (Borgatti and Halgin 2011). Very large forums (i.e. greater than 1,000 participants) may lessen the likelihood of interactions between all attendees) (Borgatti and Halgin 2011). However, across all years the majority of forums had less than 30 participants, making communication between actors likely. Only three forums had more than 30 participants in some years: Reef 2050 (plan development), GBRMPA's 2017 Reef Summit (including development of Blueprint for Resilience), Wet Tropics Healthy Waterways Partnership. Based on network data and information from documents, the first two forums

involved communication between actors meeting to develop strategic documents, while the third is a long-term partnership between actors where many of the same actors partnered across many years (started in 2015 and still ongoing). The Reef 2050 plan development involved several small meetings with overlap in actors, though not all actors attended every meeting so some may not have interacted directly with others. However, overall these forums involved frequent meetings and long term partnerships, making communication between most actors likely.

2.3.3.2 RQ 1: Analyzing bleaching event-related forums

I identified event-related forums and calculated the average in-degree centrality for event-related forums and for all other forums in the network in each year from 2015 to 2019, which includes the years following the initial bleaching event in 2016. In-degree centrality is the number of organizations attending a forum (Freeman, 1978, Friedkin, 1991, Borgatti et al., 2018). For all analyses of forums, I used normalized in-degree centrality to control for differences in overall network size between the multiple networks in my data for each year, where 0 indicates no in-coming ties from actors and 1 indicates that a forum is received in-coming ties from all actors in the network (Berardo et al. 2015). I included forums in 2015 because one forum was formed in anticipation of the bleaching events (see 3.2 Results). Difference of means tests were conducted to detect any significant differences in in-degree centrality between event-related forums and other forums in the network for the years 2016 to 2019, excluding 2015 as a test is not possible with only one forum.

2.3.3.3 RQ 2: Analyzing priorities via forum topics

I used the two-mode network data to assess attention to topics addressed by all forums in each year (2012-2019). I examined: 1) the proportion of *event-related* forums that focused on each reef topic (e.g. water quality, fisheries) in each year, 2) the proportion of *all* forums focused on each topic in each year, and 3) attendance at *all* forums focused on different topics (i.e. forum activity). To understand whether the topics of forums were associated with how active they were (i.e. how many participants attended), I ran a series of General Linear Models (GLMs). I modelled each year individually and tested for the main effects of forum type and forum topic on normalized in-degree centrality. I describe this procedure in detail at the end of section 2.3.3.4.

2.3.3.4 RQ 3: Analyzing representation and relative influence of governance actors

To analyze the representation and potential influence of organizations, I used the two-mode network data to first assess the proportions of governance actors of each organization type, focus, and level that participated specifically in *event-related* forums (e.g. percentage of government versus NGOs). Next, to assess trends in participation across *all* forums collectively, I transformed the two-mode networks into one-mode, co-affiliation networks of organizations (Figure 2) (Borgatti and Everett, 1997, Borgatti and Halgin, 2011), which reflect co-attendance by organization members at reef-related forums. The co-affiliation networks have valued ties, with values representing the number of forums two actors co-attended in a given year. I generated eight separate networks, one for each year (2012-2019).
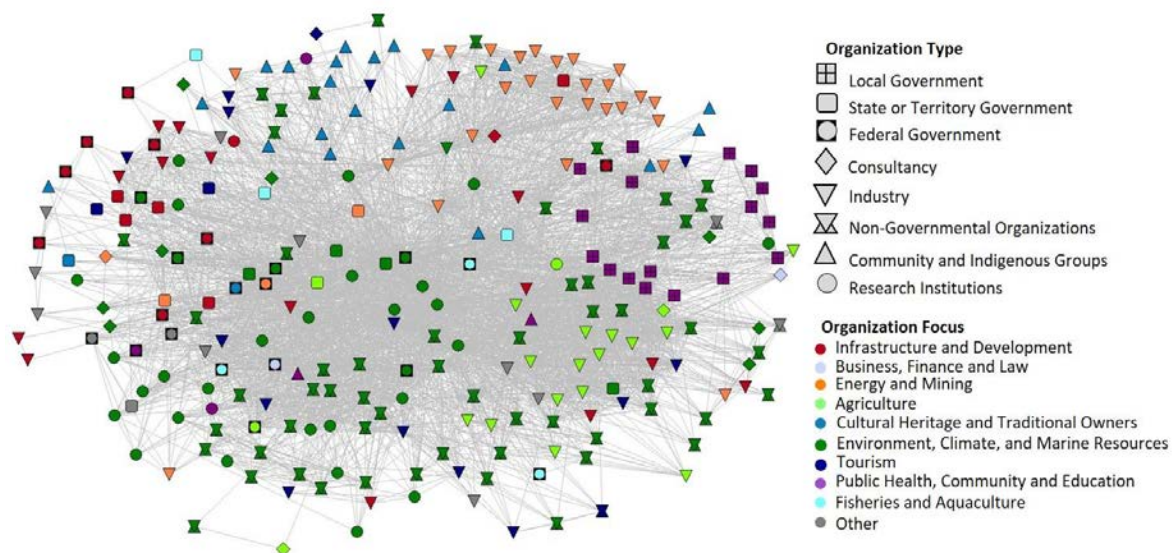
Figure 2. Example of the co-affiliation GBR governance network representing co-attendance of different organizations at reef-related governance forums in 2017.

To evaluate governance actors' potential influence over governance priorities, I first assessed their representation in the co-affiliation network by examining the proportions of governance actors represented across *all* forums in terms of organization type, focus, and level (e.g. state). Next, to measure the potential influence of governance actors, I calculated the beta centrality score for each actor in each year (Bonacich 1987, Hanneman and Riddle 2005). Beta centrality measures the extent to which an actor is connected to well-connected actors (i.e. actors with many ties to others)—the higher the centrality, the more potential influence the actor has (Bonacich 1987). I calculated beta centrality using a positive

coefficient, which allows us to measure the extent to which each node is connected to well-connected nodes (i.e. nodes with many ties to others). The higher the beta centrality of a node, the more social influence it is theorized to have in a network (Bonacich 1987). This measure weights ties with higher values more heavily and is commonly used in analysis of co-affiliation networks (Borgatti and Halgin 2011). I used a positive, standard coefficient (0.999) for calculating beta centrality, which takes all nodes in the network into account when determining the centrality of each node. To understand whether certain attributes of governance actors are related to their beta centrality, I ran a series of GLMs, modelling each year individually (2012-2019). Specifically, I tested for the main effects of all organization attributes (i.e. type, focus, and level) on beta centrality.

Before GLMs for forums and organizations, I performed a logarithmic transformation to account for the non-symmetric distribution of the in-degree (forums) and beta (organizations) centrality data. All results were exponentiated to show the estimates and confidence intervals in terms of in-degree centrality. Network measures are generated from data on relations between organizations and forums that do not meet the assumption of independence needed for computing standard errors (Hanneman and Riddle 2005). I used 1,000 bootstrap samples (with replacement) which is equivalent to the number of samples used in the regression procedure in UCINET (Borgatti et al. 2002, Barnes et al. 2016), due to the non-independent nature of my data. I evaluated statistically meaningful relationships based on 95% confidence intervals. All network transformations and calculations of centrality measures were performed in UCINET 6.716 (Borgatti et al., 2002). All statistical analyses were performed in R (R Core Team, 2021).

2.4 Results

2.4.1 New forums in the wake of mass coral bleaching events

Fifty new forums emerged in the period after the first and second bleaching event occurred (2016 to 2019). Of these, 15 (30%) were event-related forums that were initiated and/or continued in response to the bleaching events and associated impacts. One additional

forum (National Coral Bleaching Taskforce) formed in 2015 in anticipation of the bleaching event based on projected summer temperatures for 2016.

Event-related forums were not meaningfully more or less central than other forums in any year. Table 4 includes mean scores of in-degree centrality and Table 5 shows results of the difference of means test. A qualitative assessment of my 2-mode network data and forum documents indicates this may be because governance actors largely chose to engage with existing, long-standing forums to grapple with the aftermath of mass coral bleaching events. For example, two cornerstone advisory panels for implementation of the Reef 2050 plan (the Reef Advisory Committee and the Independent Expert Panel) held special workshops with members of their existing forums to generate advice on how to respond to coral bleaching events. Both above-mentioned advisory panels specifically noted in forum documents that the Reef 2050 plan and associated pre-existing forums are the appropriate venue(s) for addressing coral bleaching.

Table 4. Mean scores of degree centrality for forums in the GBR governance regime in the period after mass coral bleaching events (2016-2019).

	Mean Degree Centrality				
	2015	2016	2017	2018	2019
All forums	0.020	0.020	0.021	0.020	0.018
New bleaching-related forums	0.018[a]	0.018	0.018	0.021	0.021
Other forums	0.020	0.020	0.020	0.020	0.018

[a] The Coral Bleaching Taskforce was the only forum preemptively created to address bleaching in 2015. The value in this cell only represents the degree centrality score for this forum.

Table 5. Difference of means test of degree centrality of event-related versus all other forums in the GBR network for each year 2016 to 2019.

Year[a]	Event-related forums[b]	All other forums[b]	Difference in Means	p-value
2016	0.018 (0.007)	0.02 (0.018)	0.002	0.83
2017	0.027 (0.021)	0.02 (0.017)	-0.008	0.17
2018	0.021 (0.01)	0.02 (0.017)	-0.001	0.87
2019	0.021 (0.01)	0.018 (0.015)	-0.003	0.55

[a] No analysis was run for 2015 as there was only one event-related forum in that year.
[b] Cells contain mean and standard deviation for each group.

2.4.2 Topics attracting attention in the GBR governance regime

2.4.2.1 Topics of event-related forums

Seven of the 16 event-related forums focused on the topic of restoration and adaptive interventions (Figure 3). Five forums focused explicitly on climate and bleaching; two arose

to assess and share information about the bleaching events; two were advisory panels providing recommendations to the GBR Ministerial Forum (responsible for implementing a region-wide "Reef 2050" plan); and the fifth was the launch of a "Super Coral Expedition" to find bleaching-resistant corals. The majority of the remaining event-related forums focused on general reef health (e.g., implementation of the "Blueprint for Resilience," which addressed multiple reef issues). The last event-related forum was a multi-issue strategy— the expedited review of a region-wide strategy for GBR management ("Reef 2050" plan).

Figure 3. Topics of event-related forums. Event-related forums are those created primarily to respond to bleaching events and or the aftermath of these events.
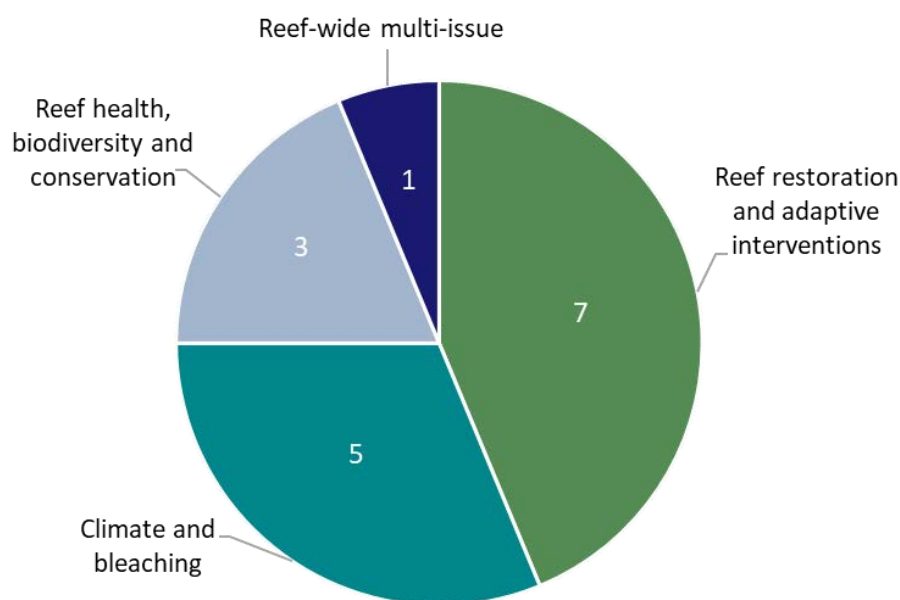
2.4.2.2 Topics of all forums in the network

Across all forums (event-related or not), I found that the proportion of forums focused on different topics did not dramatically shift after the coral bleaching events in 2016 and 2017 (Figure 4). However, there were some slight changes. Specifically, the proportion of forums focused on reef restoration and adaptive interventions increased from one forum before 2016, to eight by 2019. These forums are primarily venues to experiment with active interventions to restore coral reefs after bleaching events (e.g., dispersing coral larvae), or shelter reefs during heat waves in the future (e.g., microfilm screens to block sunlight). The proportion of forums focused on climate or coral bleaching was relatively small across all years (<1%), but increased from three in 2013 to seven by 2017, before decreasing to just two in 2018 and 2019. This decrease was due to the planned end of several long-term

climate programs, in addition to the culmination of forums reporting on the extent of bleaching events. The proportion of forums focused on fisheries increased from one or two forums before 2016, to seven to eight forums from 2017 to 2019; forum documentation (e.g. forum reports, meeting minutes, and program websites) indicated this was due to the development and implementation of the Queensland Sustainable Fisheries Strategy (2017-2027) and associated new fisheries advisory groups (i.e., not directly associated with the bleaching events). Last, the proportion of forums focused on water quality was greater in 2016 at 29%, compared to 25% or less in other years. Documentation of new water quality forums arising in 2016 indicates these were related to pre-existing management goals in the region and were not explicitly linked to the bleaching events. Documentation of forums focused on 'climate and bleaching' and 'restoration and adaptive interventions' indicated most *were* related to the bleaching events, as described earlier in section (2.4.2.1).

My GLM models of degree centrality in relation to forum topic and type indicate few statistically meaningful relationships, with some exceptions (Table 6). Forums focused on 'reef health, biodiversity, and conservation' were meaningfully less central than forums with other foci in 2018 and 2019. Research forums were meaningfully more central than other types of forums in 2012, 2013, 2018 and 2019 (Table 6). In 2018 and 2019, 'advisory or decision-making groups' and 'on-ground projects, programs, partnerships, and monitoring' forums were also meaningfully more central than other types. The GLM model indicates that although the number of forums on the topics of restoration and adaptation and fisheries increased (Figure 4), these forums did not attract greater participation than other forums in the network overall (Table 6).
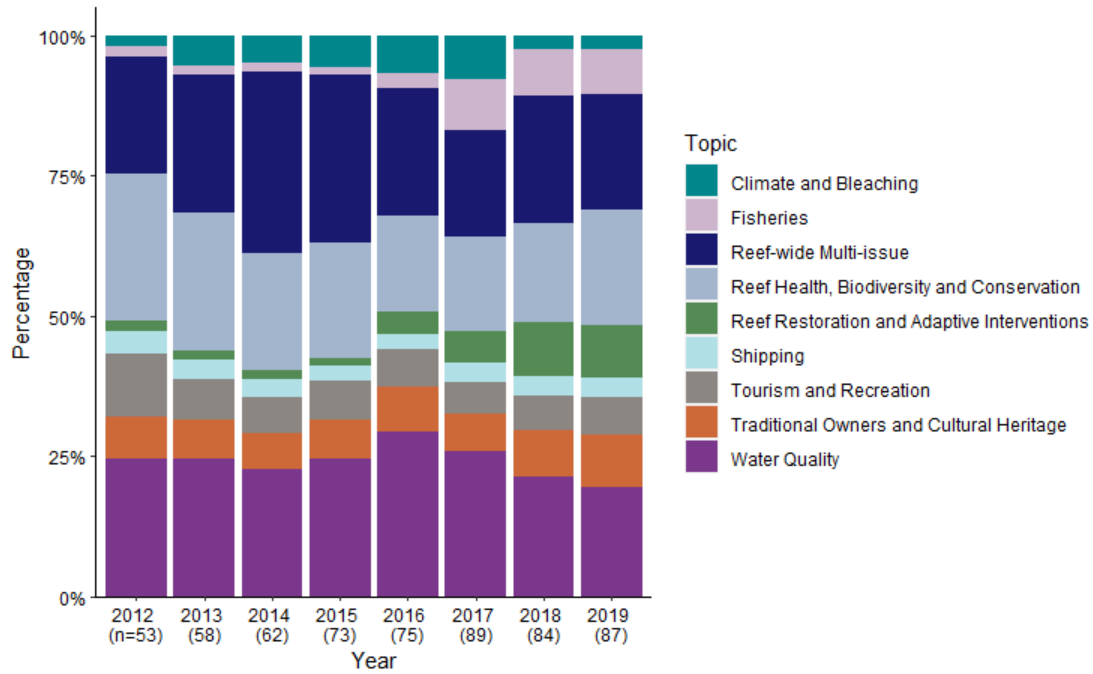
Figure 4. Regional attention to different reef issues: Proportions of forums focused on different reef issues from 2012 to 2019 (n=number of forums per year). Note that the 'reef health, biodiversity and conservation' category refers to forums focused on the overall status of the reef and its maintenance, whereas 'reef restoration and adaptive interventions' refers more specifically to more direct interventions to restore damaged reefs, including experimentation with new approaches and technologies.

Table 6. GLM parameter estimates from modeled degree centrality of forums using 1,000 bootstrap samples. Cells contain exponentiated estimates (i.e. multipliers) and bootstrapped standard errors in parentheses.

	2012	2013	2014	2015	2016	2017	2018	2019
n	53	57	52	73	75	88	84	87
<u>Forum Topic</u>								
Climate & bleaching	2.416 (0.491)	0.759 (0.615)	0.554 (0.579)	0.694 (0.536)	1.16 (0.469)	1.345 (0.423)	0.357 (0.535)	0.363 (0.532)
Fisheries	1.611 (0.334)	1.034 (0.239)	0.691 (0.323)	0.994 (0.205)	0.862 (0.426)	0.652 (0.323)	0.594 (0.367)	0.594 (0.359)
Reef-wide multi-issue	0.713 (0.37)	0.571 (0.334)	0.723 (0.346)	0.602 (0.3)	0.736 (0.304)	0.746 (0.319)	0.62 (0.304)	0.59 (0.304)
Reef health, biodiversity & conservation	0.914 (0.471)	0.554 (0.43)	0.452 (0.455)	0.634 (0.383)	0.687 (0.389)	0.666 (0.405)	0.382* (0.332)	0.397 (0.295)
Reef restoration & adaptive interventions	1.175 (0.312)	0.764 (0.316)	0.694 (0.298)	0.88 (0.228)	0.839 (0.53)	1.067 (0.285)	0.954 (0.321)	0.962 (0.303)
Shipping	2.271 (0.582)	2.666 (0.628)	2.207 (0.601)	1.286 (0.51)	1.575 (0.514)	1.272 (0.559)	0.904 (0.63)	0.864 (0.639)
Tourism and recreation	1.279 (0.391)	1.104 (0.538)	0.906 (0.551)	0.731 (0.371)	0.92 (0.398)	0.763 (0.338)	0.633 (0.383)	0.61 (0.36)
Traditional Owners & cultural heritage	1.478 (0.399)	0.536 (0.563)	0.498 (0.597)	1.011 (0.379)	0.795 (0.451)	0.678 (0.479)	0.454 (0.442)	0.473 (0.41)
Water Quality[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
<u>Forum Type</u>								
Advisory or Decision-Making Group	1.228 (0.325)	0.768 (0.356)	0.62 (0.436)	1.53 (0.298)	1.655 (0.338)	1.312 (0.299)	1.975* (0.314)	1.943* (0.309)
Community Engagement & Training	0.407 (0.527)	0.522 (0.556)	0.397 (0.65)	0.509 (0.519)	0.532 (0.577)	0.475 (0.662)	0.941 (0.538)	1.073 (0.418)
On-ground Projects, Programs, Partnerships & Monitoring	1.2 (0.35)	1.354 (0.349)	0.995 (0.347)	1.291 (0.265)	1.744 (0.299)	1.562 (0.311)	2.468* (0.311)	2.346* (0.294)
Research	2.684* (0.458)	2.745* (0.502)	2.866 (0.573)	2.343 (0.485)	1.356 (0.456)	1.354 (0.349)	2.811* (0.376)	2.785* (0.406)
Assessment, Planning, Policy & Management Review[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]

* 95% confidence interval for the parameter does not include the null value (0), indicating a meaningful relationship.

[a] This served as the reference category.

2.4.3. Engagement of governance actors

2.4.3.1 Engagement in event-related forums

I found that the type of organizations participating in event-related forums somewhat differed depending on the topic of the forum (Figure 5). Forums that focused on climate and coral bleaching were attended primarily by research institutions and NGOs; whereas participation in restoration and adaptive intervention forums was more varied, including a larger representation of industry and participation from some community and indigenous groups (Figure 5). Forums focused on the topic of reef health, biodiversity, and conservation were attended by a mix of NGOs, industry, and research institutions. The one reef-wide multi-issue forum, a review of the Reef 2050 plan in 2018, had participation only from research institutions and government.
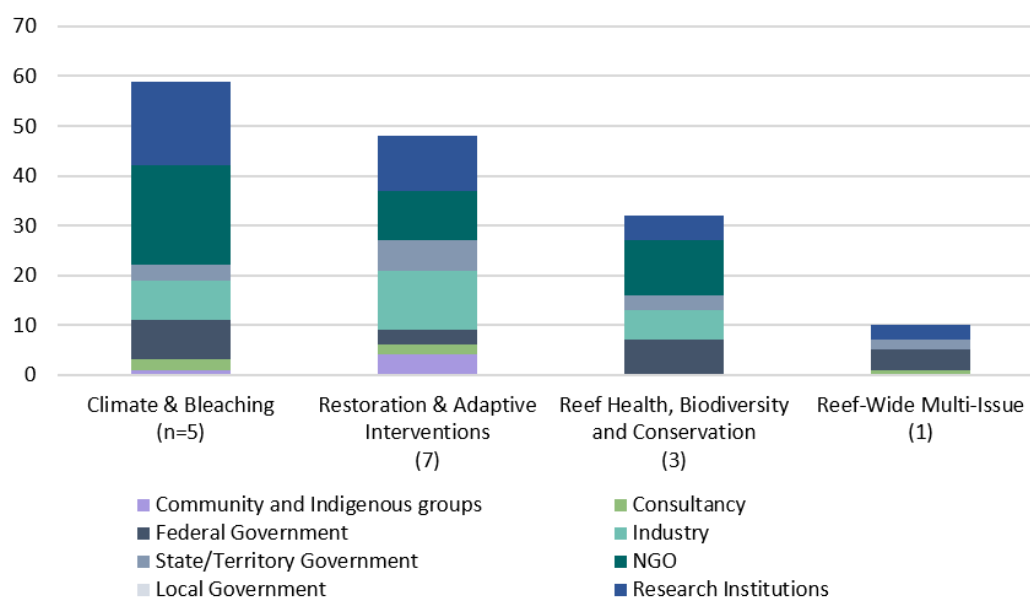
Figure 5. Proportions of different organization types participating in coral bleaching event-related forums. The number of forums for each topic is indicated parentheses.

2.4.3.2 Engagement in all forums in the network

The proportions of organizations indicate representation in the network (Figure 6), while the GLM model predicting beta centrality indicates the influence of organizations (Table 7); I consider these two sets of results together to understand changes in both the representation and influence of organizations. The proportion of different types of organizations engaged in GBR governance remained consistent from 2012 and 2019, as did the proportions of organizations operating at different levels; industry continued as the

most represented group, followed by NGOs (Figure 6). The proportions of organizations with different foci showed slight variation in some categories during and after the bleaching events, though organizations with a focus on environment, energy and mining, and infrastructure and development continued to have the highest representation (Figure 6). My GLM model indicated that organization level was a reliable predictor of beta centrality in only some years, whereas organization type was a reliable predictor in all but 2012 and 2015, and focus was a reliable predictor of beta centrality in all but 2012 (Table 7). Overall, there were some changes in the potential influence of different actors after bleaching events, but none that spanned more than one or two years with the exception of a decrease in the centrality of NGOs (Table 7).

The few minor changes in organization representation and in which specific organization types, focuses, or levels were potentially influential (i.e. associated with beta centrality) after the bleaching events in 2016 and 2017 are as follows:

- Agricultural organizations were more central in 2016 (Table 7)
- Business, finance, and law organizations were present in the network only in years 2014 to 2017 (e.g. banks and consultants) (Figure 6), and were less central than other organizations in 2016 (Table 7)
- The proportion of NGOs participating in the network remained relatively constant across years (Figure 6), but these organizations became less central from 2016 onwards (Table 7)
- There was not a noticeable increase in the proportion of community and indigenous groups (Figure 6); however these organizations were more central than other types in 2018 (Table 7)
- State level organizations were more central in some years both before and after bleaching events (Table 7)
- The proportion of organizations operating at the local level did not substantially increase after 2015 (Figure 6), but were more central in 2016 and 2018 (Table 7)

This indicates slight variation across individual years, but no lasting patterns indicative of substantial change in the wake of recurrent mass coral bleaching events.
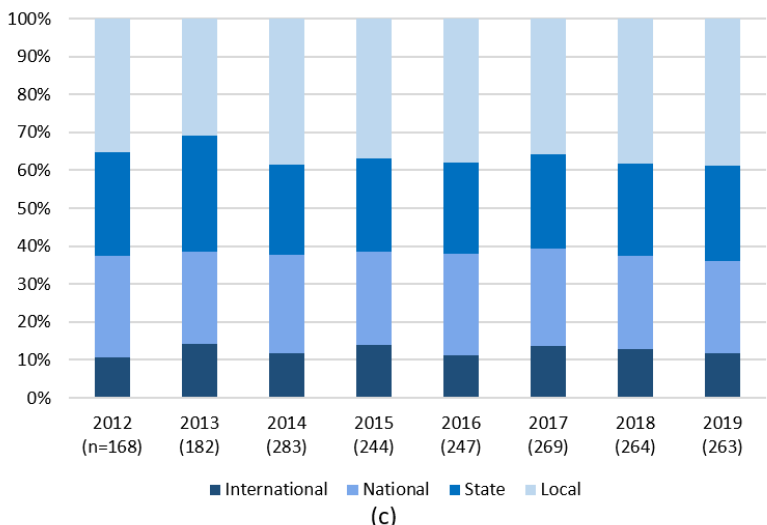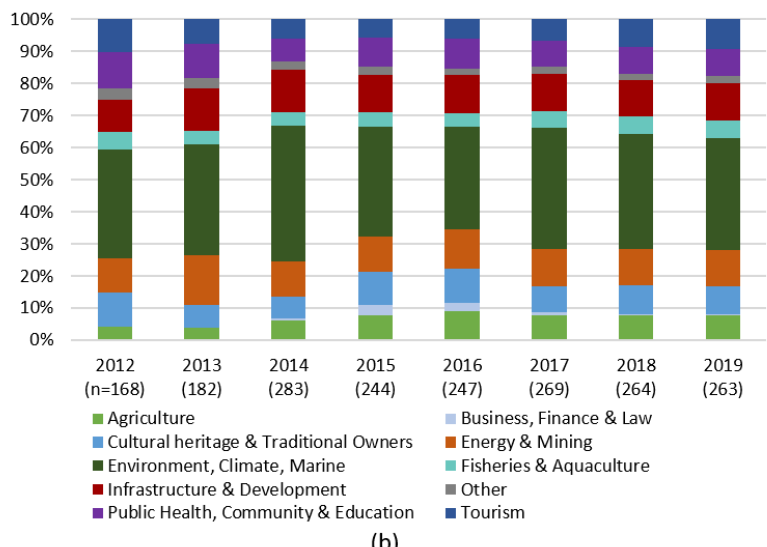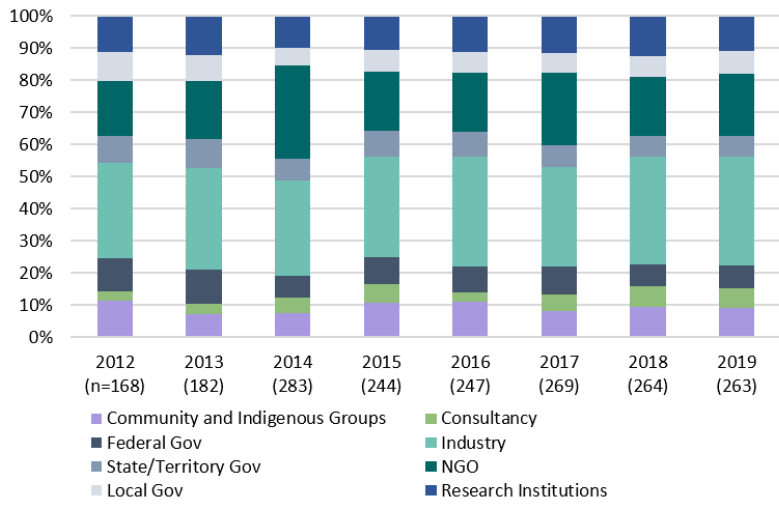
Figure 6. Organizations attending forums in each year (2012-2019). Proportions of organizations attending forums are shown by organization type (a), focus (b), and level (c).

Table 7. GLM parameter estimates from modelled beta centrality of organizations using 1,000 bootstrap samples.

	2012	2013	2014	2015	2016	2017	2018	2019
Type								
Federal Government	1.62[a]	1.73	1.3	1.58	1.51	2.14	1.81	1.62
	(0.52)	(0.47)	(0.44)	(0.42)	(0.39)	(0.41)	(0.44)	(0.48)
State or Territory Government	1.84	2.17*	1.76	1.28	1.36	1.8	1.46	1.86
	(0.47)	(0.37)	(0.35)	(0.37)	(0.36)	(0.36)	(0.39)	(0.4)
Local Government	0.87	0.75	1.36	1.42	1.61	0.94	1.33	1.59
	(0.43)	(0.47)	(0.56)	(0.56)	(0.44)	(0.46)	(0.34)	(0.5)
Industry	1.05	1.17	1.91*	0.75	0.8	1.06	0.95	0.88
	(0.44)	(0.36)	(0.32)	(0.35)	(0.32)	(0.35)	(0.35)	(0.32)
NGO	0.99	0.74	1.34	0.56	0.49*	0.57*	0.49*	0.36*
	(0.27)	(0.28)	(0.24)	(0.28)	(0.28)	(0.27)	(0.27)	(0.3)
Community & Indigenous Groups	1.07	1.44	1.31	1.09	1.42	2.24	2.78*	2.93
	(0.43)	(0.57)	(0.64)	(0.76)	(0.69)	(0.58)	(0.44)	(0.59)
Consultancy	0.72	1.06	0.62	0.61	0.67	0.52	0.54	0.49
	(0.43)	(0.5)	(0.28)	(0.38)	(0.84)	(0.37)	(0.33)	(0.36)
Research Institution	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
Focus								
Agriculture	1.83	2.13*	0.41	1.41	2.05*	1.67	1.66	0.8
	(0.34)	(0.3)	(0.53)	(0.35)	(0.33)	(0.31)	(0.31)	(0.3)
Business, Finance & Law	-	-	1.31	0.18	0.25*	1.82	1.09	0.84
			(0.3)	(0.53)	(0.67)	(0.49)	(0.36)	(0.37)
Cultural heritage & Traditional Owners	1.13	1.03	1.25	0.91	0.59	0.47	0.4	0.45
	(0.46)	(0.54)	(0.7)	(0.76)	(0.67)	(0.59)	(0.52)	(0.65)
Energy & Mining	1.06	1.33	0.92	1.35	1.33	1.06	1.22	1.13
	(0.3)	(0.24)	(0.3)	(0.31)	(0.29)	(0.27)	(0.23)	(0.23)
Environment, Climate, Marine	1.86	2.51*	2.1*	2.48*	2.97*	2.76*	2.55*	2.07*
	(0.44)	(0.39)	(0.35)	(0.37)	(0.37)	(0.29)	(0.3)	(0.29)
Infrastructure & Development	0.75	0.97	1.45	1.26	0.96	0.75	0.84	0.78
	(0.31)	(0.24)	(0.29)	(0.3)	(0.3)	(0.27)	(0.22)	(0.25)
Other	1.68	2.23	2.66	2.51	2.81	1.84	2.26	0.73
	(0.67)	(0.69)	(0.68)	(0.76)	(0.87)	(0.74)	(0.8)	(1.02)
Public Health, Community & Education	0.82	1.02	0.88	0.57	0.61	1.12	0.75	0.63
	(0.49)	(0.52)	(0.63)	(0.62)	(0.5)	(0.43)	(0.43)	(0.53)
Tourism	1.29	1.06	0.95	0.94	0.96	0.97	0.89	0.94
	(0.32)	(0.26)	(0.35)	(0.35)	(0.35)	(0.3)	(0.24)	(0.25)
Fisheries and Aquaculture	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
Level								
Local	1.24	1.19	0.87	1.32	1.59*	1.22	1.39*	1.13
	(0.19)	(0.16)	(0.18)	(0.2)	(0.2)	(0.18)	(0.17)	(0.23)
State	1.91*	1.37	1.46	1.99*	1.82*	1.45	1.57*	1.59
	(0.24)	(0.19)	(0.21)	(0.21)	(0.23)	(0.21)	(0.19)	(0.24)
National	1.41	1.21	1.27	1.16	1.3	1.11	1.14	1.29
	(0.2)	(0.22)	(0.19)	(0.25)	(0.23)	(0.22)	(0.22)	(0.29)
International	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

2.5 Discussion

The impact of extreme climate events on governance actors' activities is underexplored, in part due to the challenge of collecting longitudinal data for a large and complex SES (Chaffin and Gunderson 2016, Herrfahrdt-Pähle et al. 2020, Levin et al. 2021). Using the GBR region as an example, I demonstrated how social network analysis can be used to analyze forum attendance to investigate environmental governance networks before and after extreme climate events. I uncovered governance changes in regard to only the first of the three research questions I considered—new bleaching event-related forums did emerge, but were not more attended than other forums (RQ 1). The overall lack of change in actors' topics of interests (RQ 2), and the relative stability in the representation and relative influence of different actors (RQ 3), suggests coral bleaching events catalyzed only mild change in governance actors' activities. Here I discuss the implications of the overall stability of this regime for adaptive governance in the era of climate change. I then highlight the few slight changes in the GBR governance network I observed, and what this may indicate about the future of the system. Last, I reflect on the benefits and limitations of my network analysis approach, and discuss future directions for research and practice.

2.5.1 Stability and trajectory of the GBR regime

Three aspects of my results suggest that the GBR governance network remained relatively stable after mass coral bleaching events: (1) though new event-related forums emerged, they were not more attended than other forums (RQ 1); (2) there was limited change in the proportion of forums focused on different topics, and in which forum topics attracted attendance (RQ 2); and (3) there was limited change from 2012 to 2019 in the representation or relative influence of actors (RQ 3). These findings reinforce the idea that governance regimes may remain stable in the wake of extreme climate events (Nohrstedt et al. 2021), providing a contrast to Berardo et al.'s (2015) findings that new event-related forums were more attended than older forums. These contradictory findings may be explained by the differences in the composition and structure of governance actor communities in each context (Birkland 1998, Johnson et al. 2005, Berardo et al. 2015). For

example, Berardo et al. (2015) hypothesized that new forums would be more attended in the Paraná River delta in Argentina because pre-existing forums would be ill-equipped to deal with new problems; but in the GBR case, governance actors appeared to identify pre-existing forums as appropriate venues for responding to bleaching (e.g. forums related to the region-wide Reef 2050 strategy). Here, governance actors' decisions about the value of existing governance institutions (e.g. Reef 2050) for solving new problems may have impacted the extent to which an adaptive governance regime changes after extreme climate events. This demonstrates that understanding the factors that affect actors' decisions to continue with existing forums over time versus creating new ones is critical for understanding when extreme climate events do or do not influence the structure and function of governance (see Angst et al. 2022, Olivier and Berardo 2021).

The persistent balance of attendance across forum topics before and after bleaching events sheds light on the capacity of governance actors to address problems at nested levels. Addressing problems at multiple nested levels first earned the GBR recognition as an example of adaptive governance (Olsson et al. 2008). My results indicate that governance actors continue to address problems at multiple spatial levels after bleaching events, from climate adaptation (e.g. restoration of specific reef sites) to ecosystem-based management (e.g. reducing runoff pollution from the GBR catchment). However, though new forums focused on climate mitigation (e.g. emissions reduction or carbon sequestration) might also have been expected given that coral bleaching results from climate-driven warming of oceans (Hughes et al. 2017), no forums on these national and global level topics appeared in the GBR region after mass coral bleaching events. While national emissions reduction efforts beyond the boundaries of the GBR were outside the scope of this study, venues hosted by GBR governance actors seeking to connect GBR management to higher level efforts to mitigate emissions would have been detected. This result may be explained by previous research findings that many organizations in the GBR region consider mitigation to be beyond their jurisdiction or abilities, and most favor adaptation (e.g. Hoegh-Guldberg et al. 2018, Morrison et al. 2020a, Lubell and Morrison 2021, Barnes et al. 2022). However, widespread support for climate action on organizations' websites and in forum documentation suggests that there is interest in such efforts, but that governance mechanisms that empower actors to connect regional impacts to national and global drivers

of change are still needed to fully realize the adaptive governance aim of addressing multi-level problems.

The overall persistent balance of participation amongst actors in the GBR regime suggests that extreme climate events do little to shift pre-existing patterns in the relative influence of actor groups, implying that a status quo distribution of benefits was maintained. Well-represented groups such as industry actors may have benefited from this stability. My results align with concerns that climate change may entrench existing inequities (Blythe et al. 2018, Morrison et al. 2019, McHugh et al. 2021) or at least do little to empower previously marginalized groups as found in other cases (Birkland 1998), even within adaptive governance regimes. Further qualitative investigation of impacts on specific GBR actor groups is needed to examine the influence of these organizations and consequences for how benefits are distributed after extreme climate events.

Although I did not detect statistically meaningful changes in participation across the network up until 2019, the topics and participants at new event-related forums shed light on emerging priorities in the region and who may benefit from these priorities. My findings demonstrate for the first time that responses to coral bleaching events previously documented at the level of individual organizations were also reflected at the level of the region-wide governance network—namely a focus on restoration, adaptation, and water quality; with less attention to climate mitigation (Bellwood et al. 2019, Morrison et al. 2020a, Lubell and Morrison 2021, Barnes et al. 2022). The majority of event-related forums were focused on climate adaptation (e.g. the RRAP), where dive tour operators, NGOs, and research institutions had strong representation. Partnerships between dive tour operators, researchers, and government organizations like GBRMPA are utilized for the implementation of trial restoration projects at tourism sites (GBRMPA 2017). These mutually beneficial partnerships offer payments to tour operators and have recently been formalized under GBRMPA's "Tourism Industry Activation and Reef Protection Initiative" (GBRMPA 2017, GBRMPA 2021b). The development of restoration solutions may also benefit NGOs (includes not-for-profits, foundations) that may receive additional attention from donors, and research institutions that receive grants to test and later potentially sell their new technologies (e.g. Small Business Innovation Research program (Queensland Government 2021)), though exact benefits are difficult to quantify at this stage. Lastly, the

presence of four Indigenous and community organizations at restoration and adaptive intervention forums (see Figure 5) is notable because they tend to be poorly represented in the network overall. Their presence here contrasts with previous studies, which identify a lack of community engagement as a limitation on realizing the socio-ecological benefits of coral restoration (Hein et al. 2019). In the GBR region, the engagement of community and Indigenous groups in restoration and adaptation forums indicates potential benefits to these groups, and a potential increase in their influence. This suggests the GBR region may join a limited number of examples of coral restoration leading to job creation and other benefits to communities (e.g. Kittinger et al. 2016).

2.5.2 Opportunities, limitations, and future directions for analysis of forums and extreme climate events

The approach I adopted here revealed broad patterns in organizations' participation and influence in GBR governance, indicating its usefulness for longitudinal analyses of large SES. The scope of this study captured action at the regional level, but may have missed action on climate change (e.g. emissions reduction, carbon sequestration) occurring at the local and/or national levels, and in the geography of the GBR reef catchments if such actions were not explicitly linked to the GBR. Without action on climate change, the above-mentioned benefits of restoration and adaptive interventions will be short-lived (Norström et al. 2016, Morrison et al. 2020a). Future research could use network analysis coupled with qualitative methods to expand this analysis to examine reef actors' involvement in forums to mitigate emissions or sequester carbon at the local, national or international levels, as well as any terrestrial efforts within the region.

Although my analysis indicates that by 2019 there was little attention given to the cross-level issue of climate mitigation, such efforts may yet emerge as a delayed response to mass coral bleaching events. More recently, at least a few efforts to transition from coal towards renewables in the GBR catchment (e.g. Renewables Nation), and at least one blue carbon sequestration effort (e.g. Blue Carbon Lab 2021 (Deakin University 2021)) have emerged. There is thus a need for continued longitudinal research. Uncovering the mechanisms behind the growing engagement of reef actors with emissions reduction, carbon sequestration, and a transition to a low carbon economy could inform the evolution of the theory and practice of how actors in a given SES can address global challenges within

adaptive governance regimes (Grech et al. 2016, Chaffin et al. 2016b, Morrison et al. 2020a, Levin et al. 2021). Such an analysis might survey the broad suite of institutions, activities and norms under the umbrella of "governance" (Bevir 2012, Lebel et al. 2006), ranging from re-framing reef problems (e.g., Morrison et al. 2020a) or public protests, to cross-level interactions in networks (e.g., Hamilton and Lubell 2018) and changes in formal policy (e.g. Grech et al. 2016).

One limitation to my approach is that it does not allow me to elaborate the nuances of the role of social influence in shaping whether or not actors collectively respond to crisis events. Future research might use qualitative network analysis, interviews, and/or participant observation to examine how governance actors influence one another's decisions regarding priority actions and what forums to attend (new or existing), as well as what role extreme climate events versus other drivers played in these decisions. This approach may expose further nuances of the impact of bleaching as a catalyst for change (or not) by making it possible to decipher the extent to which bleaching events versus other ecological, social, or political factors catalyzed action on pre-existing priorities, particularly given that these actions may be taking place largely within pre-existing forums.

Last, network analysis and qualitative methods could together be used to compare the extent to which different types of extreme climate events catalyze change within adaptive governance regimes. Political science research suggests that there may be substantial differences between events that directly harm people and ecosystems (e.g. cyclones, fires) versus those that directly harm ecosystems and indirectly harm people (e.g. coral bleaching) (Birkland 1998). Understanding what factors cause an extreme climate event to catalyze change or not can inform efforts to cope with ongoing climate change impacts across multiple SES. Examining why some events are particularly good catalysts may also inform efforts to re-frame the climate change problem in order to make it a more salient concern in the public eye (Morrison et al. 2020a).

2.6 Conclusion

Extreme events place the daunting task of climate adaptation and mitigation on the doorstep of social-ecological governance actors. This study contributes a broad spatial and temporal perspective on the priorities and activities of hundreds of governance actors

participating in over 150 forums in an adaptive governance regime over eight years. My analysis goes beyond studies of individual organizations or forums by revealing the collective priorities and influential organizations that emerge from actual activity (i.e., forum participation) across an entire region. By bringing this focus to forum topics and the composition of participants, I expand the application of network analysis of forums in environmental governance research. My results suggest that mass coral bleaching events can catalyze some action on restoration and adaptive interventions, but may primarily reinforce existing priorities and do not ultimately change the relative influence of actors across a SES. This implies that extreme climate events may fail to unseat the entrenched the status quo influence of (and benefits to) governance actors. I also find that emerging priorities in this region indicate the ability of actors in an adaptive governance regime to address the drivers of global climate change is thus far limited, even as climate change causes damage within the bounds of the system. The problem of addressing global drivers from within a SES has long been recognized (Cash et al. 2006, Morrison et al. 2020a), but my findings indicate that extreme climate events cannot be relied on to help governance actors overcome this challenge by catalyzing more inclusive participation or novel mechanisms for governance action across local to global levels. Future research must look broader and deeper to identify the causes of stagnating policies and practices, and uncover the seeds of change for governance transitions. Network research can broaden across different types of extreme climate events, intersecting governance networks (e.g. climate and reef networks), and even longer time frames. Complementary qualitative research can more deeply investigate the drivers of governance actors' decisions to convene at new versus old forums, and explore how and why diverse actors interpret extreme climate events in different ways.

Chapter 3: Imagining reef futures after mass coral bleaching events.

Adapted from **Datta, A.**, Wyborn, C., Chaffin, B.C., Barnes, M.L. (In review). Imagining reef futures after mass coral bleaching events. *Environmental Science & Policy.*

Abstract

In this chapter I investigate whether and how mass coral bleaching events inspire governance actors to re-envision SES futures and management approaches to realize those futures (Armitage et al. 2009, Schultz et al. 2011, Schuurman et al. 2022). As discussed in the introductory chapter, previous adaptive governance research focuses on the views of specific governance actors who serve as key leaders or members of 'shadow networks' that harness crises as windows of opportunity for building a shared vision to improve SES governance (e.g. Hahn et al. 2006, Olsson et al. 2008, Chaffin and Gunderson 2016, McHugh et al. 2021). Adaptive governance scholars' focus on stories of governance actors who successfully build a shared vision resonates with some areas of climate change adaptation literature that imply that actors should strive towards a collective, unified vision when identifying responses to climate change (Armitage et al. 2009, Petersen-St. Laurent et al. 2021, Schuurman et al. 2022). However other areas of research on climate adaptation, such as those focused on foresight processes (Venvoort and Gupta 2018), suggest that while a shared vision may suit some situations, a more pluralistic approach that considers the multiple visions that arise after crisis can foster creativity and inclusivity, two normative goals of adaptive governance (Paschen and Ison 2014, Chaffin et al. 2016b, Muiderman et al. 2022). Empirical approaches are thus needed to untangle not only *what* visions actors' hold for the future after crises, but also *who promotes* certain narratives, *who resists* these narratives, and *who may be affected* by the outcomes of realizing one narrative over another (Stone 2002, Jones and McBeth 2010, Morrison et al. 2022). In this chapter I use narrative policy analysis (Stone 2002, Jones and McBeth 2010) to empirically investigate *what* narratives actors deploy to build visions for the future of the GBR after mass coral bleaching. I additionally draw on climate adaptation frameworks to relate actors' visions for the future to current approaches for guiding decision-making in the context of climate change. In Chapter 4, I then consider *who* upholds or resists different narratives and the implications of tensions between the narratives for governance. For both chapters I analyze the same set of interviews with a subset of governance actors who are responsible for high-

level decisions, or who provide advice or research to inform those decisions. My findings in this chapter illustrate areas of overlap and tension between different governance actors' perspectives on what the future of the GBR will look like and how management efforts should influence that future. From these findings I develop a "governance pathways" framework and demonstrate its utility for addressing the limitations of the Resistance-Resilience-Transformation (RRT) and Resist-Accept-Direct (RAD) climate adaptation frameworks. I conclude with a discussion of how this approach can be used to navigate shared or conflicting visions and enable a pluralist approach to pursue multiple pathways simultaneously.

3.1 Theoretical Framework: Narrative Policy Analysis and Climate Adaptation Frameworks

How governance actors with jurisdictional authority or advisory roles understand change, imagine the future, and identify management solutions, affects how these actors shape governance after extreme climate events (Adger et al. 2009, Chaffin et al. 2016b, Louder and Wyborn 2020, Muiderman et al. 2022, Múnera-Roldan et al. 2022, Schuurman et al. 2022). Governance actors' interpretations of change are rooted in part in sociocultural factors such as how they know and understand a SES and what values they hold for its future (Adger et al. 2009, Paschen and Ison 2014, Múnera-Roldan et al. 2022). Governance actors, like others, engage in cognitive processes of building 'narratives' or 'stories' about problems and possible solutions (Adger et al. 2009, Paschen and Ison 2014, Múnera-Roldan et al. 2022). Not all governance actors have equal power to influence resource management; thus, not all narratives have equal impact on governance. Narratives employed by governance actors in positions of power have a disproportionate influence on the trajectory of the system (Leach and Fairhead 2000, Paschen and Ison 2014, Muiderman et al. 2022). However, little attention is given to the competing narratives amongst these powerful governance actors, despite the effects their narratives may have on what solutions and ultimate system futures are prioritized or excluded, and which actors benefit as a result (Muiderman et al. 2022). Instead, existing cases of leaders driving the emergence of adaptive governance can be seen as cases that follow specific leaders with specific narratives that dominate decision-making spaces and align with governance scholars' recommended governance arrangements (e.g. ecosystem-based management (Hahn et al. 2006, Olsson et al. 2008) or multi-stakeholder collaboration (Chaffin et al. 2018)). This leaves open questions about other narratives that may be present in formal decision-making spaces after crisis. Examining the narratives governance actors build around social-ecological challenges and possible management solutions sheds light on the rationale behind emerging management approaches, identifies areas of tension, and encourages a pluralistic approach that embraces multiple narratives to encourage creative responses to change (Shanahan et al. 2011, Paschen and Ison 2014, Louder and Wyborn 2020).

As governance actors experience acute crises such as extreme climate events, they update their narratives about problems and solutions for future policy and management (Birkland

1998, Pahl-Wostl 2009, Chaffin and Gunderson 2016). The period after extreme climate events is thus a useful time to investigate emerging narratives that will shape how SES governance approaches evolve (or not) after crisis. Narrative policy analysis and climate adaptation decision frameworks can inform empirical assessments that reach beyond a focus on 'key leaders' to paint a more dynamic picture of how governance actors with formal environmental governance authority interpret crises. The narrative policy framework provides a structure for understanding the multiple ways governance actors perceive SES management challenges and propose solutions (Jones and McBeth 2010, Shanahan et al. 2011, Paschen and Ison 2014, Shanahan et al. 2018). This can facilitate efforts to find consensus on a shared vision, or even encourage a pluralistic view in which multiple future pathways might be pursued simultaneously, rather than aiming for a shared vision (Paschen and Ison 2014, Louder and Wyborn 2020). Although useful in theory, this approach tends to be underutilized in research on governance responses to climate change, and empirical studies are needed to test its utility (Paschen and Ison 2014, Shanahan et al. 2018, Louder and Wyborn 2020).

In this chapter I followed Shanahan et al.'s (2018) assumptions that a) policy realities are socially constructed, b) narratives have specific structures that are stable over time, and c) narratives are core to human cognition, leading people to think and speak in story form. I then drew on core elements of the narrative policy framework (Stone 2002, Jones and McBeth 2010, and Shanahan et al. 2018), including: 1) context, i.e., who is speaking and what aspects of the GBR context do they highlight, i.e., bleaching, politics; 2) problem frame, i.e., problems and causes of problems; 3) solution frame, i.e., what outcomes are desirable and what actions are identified as solutions; 4) characters, i.e., who are the main heroes, victims, and villains; and 5) plot, i.e., what general plotline ties these elements together (e.g. identifying a "story of decline" (Stone 2002)). I considered all these questions during analysis, however, the results reported in this chapter center on problems, solutions, and the overall plot to identify several governance pathways emerging in response to bleaching events. Here I did not analyze policy content, but rather verbal narratives garnered through interviews with governance actors with decision-making authority or advisory roles relative to managing GBR.

When analyzing the solutions portion of narratives, I drew on recently developed climate adaptation decision frameworks developed and used by practitioners to navigate responses to climate change (Peterson-St. Laurent 2021, Schuurman et al. 2022). This allowed me to generate results in a format familiar to practitioners while also contributing insights on how a narrative approach can build on these frameworks. I specifically drew on two particularly popular frameworks: the "Resist-Accept-Direct" (RAD) (Schuurman et al. 2022) and "Resistance-Resilience-Transformation" (RRT) (Peterson-St. Laurent 2021) (Figure 7). These frameworks allow practitioners to choose from a suite of possible responses to climate-induced changes in the SES they manage. Schuurman's RAD framework has three options for action (resist, accept, direct) based on how much change in a system is deemed acceptable, and how intensively management should intervene. Peterson-St. Laurent et al. (2021) propose the RRT framework, which similarly considers how much change is acceptable but places greater attention on desired outcomes and integrating varying levels of management intensity into a single spectrum. Both frameworks consider actions ranging from "resist" as attempts to stop change, to "direct" (RAD) or "transformation" (RRT) as seeking to assist change (see Peterson-St. Laurent (2021) and Schuurman et al. (2022)). Here are some examples of how management actions are classified in these frameworks, though the frameworks sometimes use different terms: an action to resist change could be prescribed burns to prevent severe wildfires (RAD and RRT framework), an action to accept change (RAD framework) could be monitoring to understand system change, an action to support autonomous transformation (RRT framework) could be to connect relatively warmer and colder aquatic areas to create opportunities for species movement, and an action to direct change could be to revegetate a burned area with species expected to be adapted to anticipated future conditions (RAD and RRT framework) (Peterson-St. Laurent 2021, Schuurman et al. 2022). These two frameworks are still evolving and are in tension with one another. Peterson-St. Laurent et al. (2021) argue that the RAD framework gives inadequate attention to the desired outcomes of management, while Schuurman et al. (2022) contend that the RRT framework conflates outcomes and management approaches. I use the narrative analysis approach to address some of these limitations. Specifically, to analyze the solutions component of the narratives, I drew on these frameworks by explicitly considering participants' level of acceptance of change, views on appropriate level of management intensity, and desired outcomes. Separating out these components allows for

more a nuanced picture of actors' views than otherwise possible when using the RAD and RRT frameworks on their own. This attends to both outcomes and approaches without conflating them, making it easier to articulate differences and similarities amongst actors' narratives.
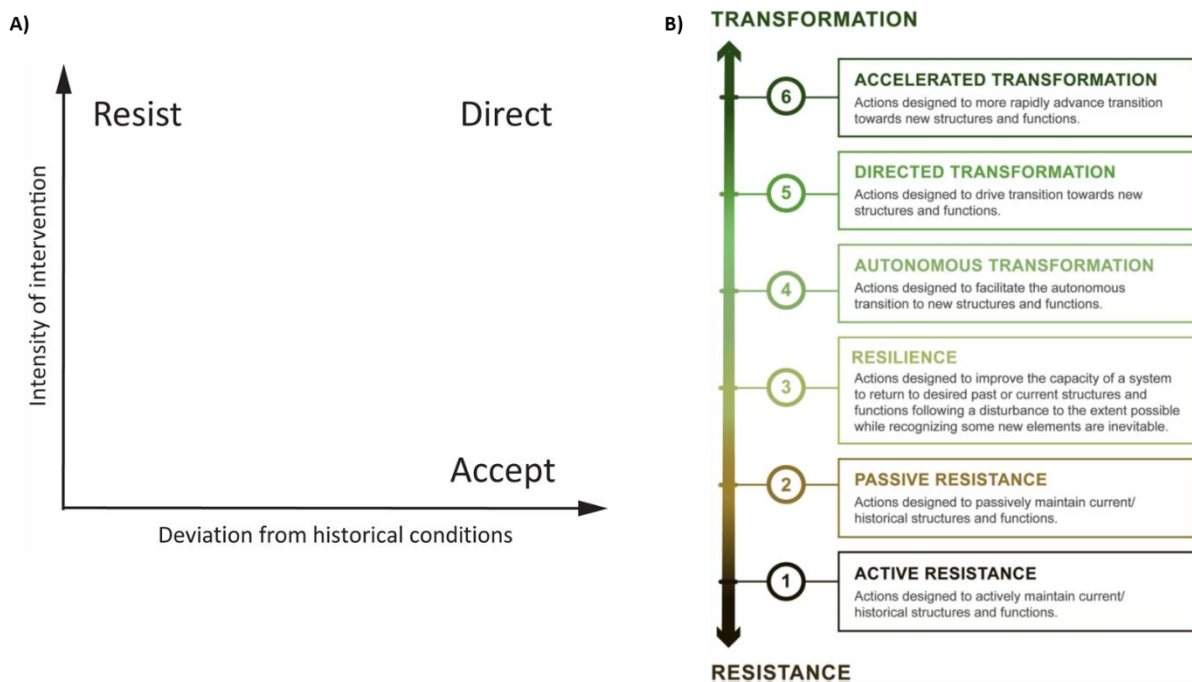
Figure 7. A) RAD framework presented by Schuurman et al. (2022), who described framework as follows: "where strong modern transformative forces are driving ecological change, managers may choose to resist, accept, or direct change. Rather than representing a spectrum, these three options differ in two distinct dimensions: intensity of intervention and resultant deviation of the system from historical ecological conditions. Unless transformative forces are absent, low deviation from historical conditions cannot be maintained with little or no intervention." B) RRT framework presented by Peterson-St. Laurent et al. (2021) as follows: a six-point continuous interval scale representing a continuum spanning from actively resisting changes to accelerating transformation towards new, more climate-adapted conditions.

3.2 Research Questions: integrating narrative analysis and climate adaptation frameworks to explore multiple reef futures

This chapter is guided by my second research question: how do governance actors representing a range of interests in high-level decision-making processes envision the future after crisis? The objectives of this chapter are as follows:

1. Describe governance actors' narratives about reef futures and the role of reef management in realizing those futures after mass coral bleaching events.

2. Articulate how governance actors' narratives align or come into tension, and what implications this has for governance.

3. Use these findings to build a framework that builds on existing climate adaptation frameworks but enables easy comparison of multiple narratives.

3.3 Methods

I conducted 36 confidential semi-structured interviews identified through a purposive sample to represent the views of individuals within organizations with authority over, or an advisory role in, decision-making for the entire GBR (Figure 1 in Chapter 1). Organizations were identified through a review of literature and documentation of reef governance, and key informants from government ministries (e.g. GBRMPA) and high level reef advisory bodies (e.g. Reef Advisory Committee) helped to identify potential participants (Figure 1). Additional participants were identified through snowball sampling or referral.

Table 8. Description of study participants.

Organization Type[a]	Number of participants
Government	
National	5
State	2
Local	1
Research	
University	6
Government Institution	4
Elected Official	1
Environmental NGO	6
Consultants to NGOs or government	5
Recreational peak organization	1
Tourism peak organization	1
Agriculture peak organization	3
Mineral resources peak organization	1
Total	36

[a] Industry organizations, university researchers, consultants, and ENGOs were either formally represented on advisory councils or regularly consulted during policy-making due to their expertise on key issues (e.g. climate, water quality).

Final participants included State and Commonwealth government resource managers, researchers who regularly engage with management and participate in advisory panels, elected officials, professionals at NGOs, consultants to NGOs and government, Traditional Owners, one recreational fisher, and tourism, agriculture, and mining industry representatives in Queensland (Table 8). The proportion of participants from different actor groups reflects the representation of these groups at the highest level of decision-making for the GBR (i.e. coordinated by federal and state government) and thus all groups are not

equally represented. In addition, representatives of some groups were not represented in the study because they did not respond to interview requests. Traditional Owner and commercial fishing representatives were approached but also did not respond to interview requests. However, one participant from NGO and two from government research institutions specialized in engagement with Traditional Owners and other local communities in the GBR region (two of whom were Traditional Owners themselves, but not formally representing their groups). Traditional Owners who participated in this study were approached due to their professional roles and were not asked to speak on behalf of their Traditional Owner groups, but did offer general insight into the interests of Traditional Owner groups they connected with through their work. This study focused on the views of individuals who directly influence high level governance decisions and therefore did not include local level or grassroots actors unless they had a seat on an advisory council. The views of these actors (e.g. small NGOs or citizen science groups) are beyond the scope of this research, but are nonetheless important and are being explored in other research (e.g. RRAP). Interviews were conducted with approval of the University of Montana Institutional Review Board, protocol #69-20. Interview consent forms and question guides are provided in Appendix A.

Interviews were recorded and lasted 40-90 minutes, with most averaging an hour. Participants were invited to share their personal views based on their professional experience but were not asked to speak on behalf of their organization. Participants were asked about the reef's condition after mass bleaching events in 2016 and 2017 (the first recorded recurrent mass bleaching events in the region (Hughes et al. 2018b)), and what they expect the reef to look like in the future. Participants were then invited to discuss their views on high and low priority solutions for the reef, the role of resource management in achieving solutions, and what solutions are already underway. I cross-referenced and augmented this information with publicly available material from the relevant organization. Interviews were professionally transcribed and the lead author conducted, edited, and coded all interviews using Nvivo 12 qualitative analysis software. Transcripts were deductively coded, guided by the five components outlined in the theoretical framework (i.e. context, problem frame, solution frame, characters, plot). The problem frame section was further coded into "current state of the reef", "future state", and "key drivers of

change". The solution frames were further coded to "role for management", "key activities", and "big picture aims" (i.e. desired outcomes of management). These categories for solution frames were inspired by the focus of the RAD and RRT frameworks on not only what actions to take, but also towards what end (i.e. role for management and desired outcome). Transcripts were then inductively coded for key themes emerging within each of these categories. Problem and solution frames were identified when multiple participants expressed similar views, which were captured through coding for key themes (e.g. "highly degraded reef").

After coding deductively and inductively for key themes, all transcripts were further coded to the focus (e.g. research, management) and type (e.g. government) of participants' organization. I then performed matrix coding and used comparison diagrams to detect patterns of connections between specific problem and solution frames, and between participants' organizational focus and certain problem and solution frame. The former allowed for connecting problem and solution frames into "narratives". The latter allowed me to identify which types of actors preferred certain frames (e.g. are participants who favor coral restoration affiliated with certain organizations (e.g. research organizations)). As the compiled narratives are composed of participants' views on what the management problems are, and how an SES should be governed (i.e. solutions and desired outcomes), I refer to them as "governance pathways" or simply "pathways". These pathways essentially build on the RAD and RRT frameworks' focus on solutions by adding explicit attention to problem frames. This is elaborated extensively in the Discussion section. To build reliability, these narratives have been reviewed with key informants (e.g. GBRMPA professionals, other GBR governance researchers). These results will also be presented to GBRMPA for further feedback after thesis submission.

3.4 Results

Participants expressed a shared understanding of the current state of the GBR and related drivers. However, their perspectives on possible and probable futures varied, as did their views on the role of management. I first describe the mostly shared understanding of the current state of the reef. I then examine where actors' perspectives split in envisioning reef futures and what governance pathways are available (or not) to guide management. Finally,

I discuss which pathways and associated solutions are being implemented and how this shapes the programs and policies that govern the GBR.

3.4.1 Converging on climate: areas of shared understanding of the current and future state of the reef

From across all sectors, participants' views on the current state of the reef agreed on four key points:

- *The reef system is degraded after mass coral bleaching events.* Participants expressed that the reef is "in the worst condition it's ever been in", and used terms like "flipping states," a "significant phase shift" or "crossing a threshold" to express fear that the reef system is already (or at risk of) changing dramatically.

- *Climate change is the number one driver of decline.* Participants were shocked by the bleaching recurring in both 2016 *and* 2017, and affecting the far North region previously thought to be "pristine". That this occurred now was "terrifying," and a "major signal to virtually everybody" that climate is the leading driver of reef change.

- *Different localities face different issues.* Participants frequently identified stressors like water quality, crown-of-thorns starfish (a coral-eating invasive species), and fishing pressure. Nearly all participants emphasized that the reef is "complex" and "patchy", with stressors differing across localities.

- *The reef is in a recovery period (2017-2021).* Many participants mentioned that the reef recovered after the recurrent events in 2016 and 2017, with most citing the regularly released long-term monitoring report from the AIMS (AIMS 2021).

These points indicate that most participants' views are aligned on the current state of the reef and the issues it faces. Participants' widespread agreement on key issues may be explained in part by the fact that they often cited the same sources of information, such as AIMS, GBRMPA, and research from Queensland-based universities. Participants were not explicitly asked about the sources of knowledge they drew on, but this emerged frequently in interviews. There were some areas of debate, including participants' degree of optimism about recovery, discussed further in section 3.4.2. Interestingly, the few areas of divergence were also areas where sources of information were contested. For example, those who questioned the strength of reef recovery also criticized the metrics used in the AIMS report to measure reef health (e.g. coral cover). In addition, a few participants disagreed with the

majority perspective that water quality is major problem. In doing so, they questioned the quality of Queensland government's data and emphasized that they were developing alternative management goals based on their own data.

3.4.2 Four pathways for GBR governance

Participants imagined at least four possible future states for the GBR, which I refer to as "historic state" (i.e. pre-bleaching state), "key sites", "ongoing patchiness", and "undesirable state" (Figure 8). These four states are generalized to illustrate differences in how participants envision future reef states and the role of resource management in pursuing that state (Figure 8), and were associated with four possible pathways to govern reef management after mass coral bleaching events that emerged from this research: "natural return", "assisted return", "retain key sites", and "direct transitions" (Figure 8, Figure 9). I generalized these pathways from an amalgamation of participant responses, and leverage them to illustrate differences and similarities in the way governance actors are responding to change.

The pathways do not fully represent any one individual's perspective. An individual may pursue different pathways at different times, or pursue multiple pathways simultaneously. Across all pathways, participants emphasized that the future state of the reef is contingent on the following factors: the frequency of disturbance events (particularly bleaching and cyclones); the global emissions trajectory (e.g. IPCC 1.5 C vs 2 C); and the extent to which local and regional drivers are addressed. Below, I describe the four pathways for future reef management, highlighting the following: 1) desirable and undesirable outcomes for the reef system; 2) the role of management; 3) relevant management solutions; and 4) how bleaching events are interpreted within the pathway. The solutions are considered along a spectrum from low intensity (e.g. spatial planning, described as "passive" in other frameworks (Peterson-St.Laurent et al. 2021)) to high intensity (e.g. site restoration, aligns with "active" in other frameworks). The first pathway was generally agreed to be infeasible after bleaching events, but provides a point of contrast for the other pathways.
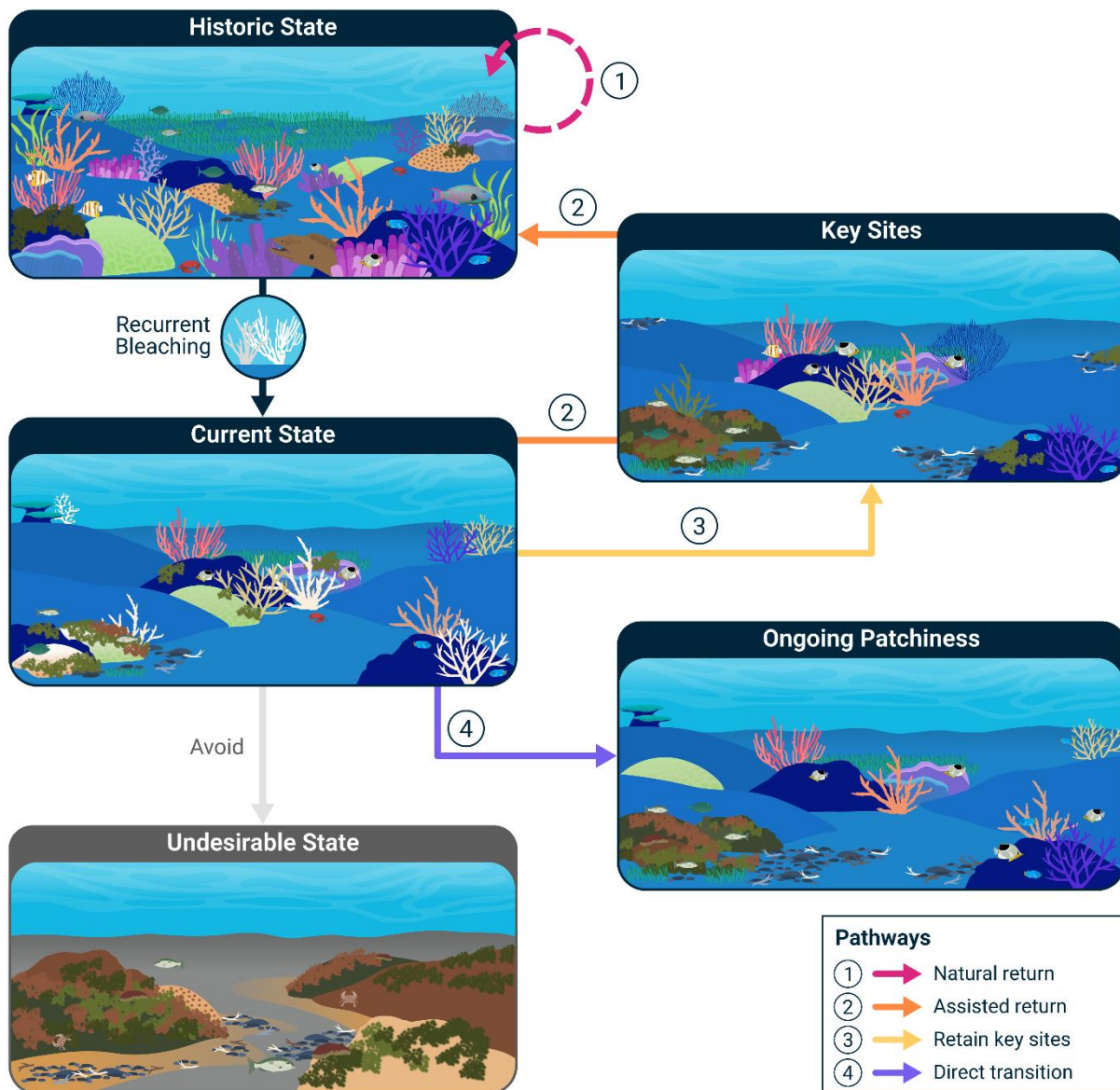
Figure 8. Four possible future states for the GBR were generalized from participants' perspectives. A) Historic state: the GBR returns to a composition and structure at least as vibrant as prior to mass coral bleaching events. B) Undesirable state: a bleak, algae-dominated system, with a few heat tolerant corals. C) Key sites: specific patches of reef are restored and maintained while the rest degrades. D) Ongoing patchiness: some reefs remaining structurally and functionally diverse and others flipping into states dominated by algae or fast-growing coral species with little structural diversity. These reef states were associated with four different pathways for responding to change, as described in Figure 9.
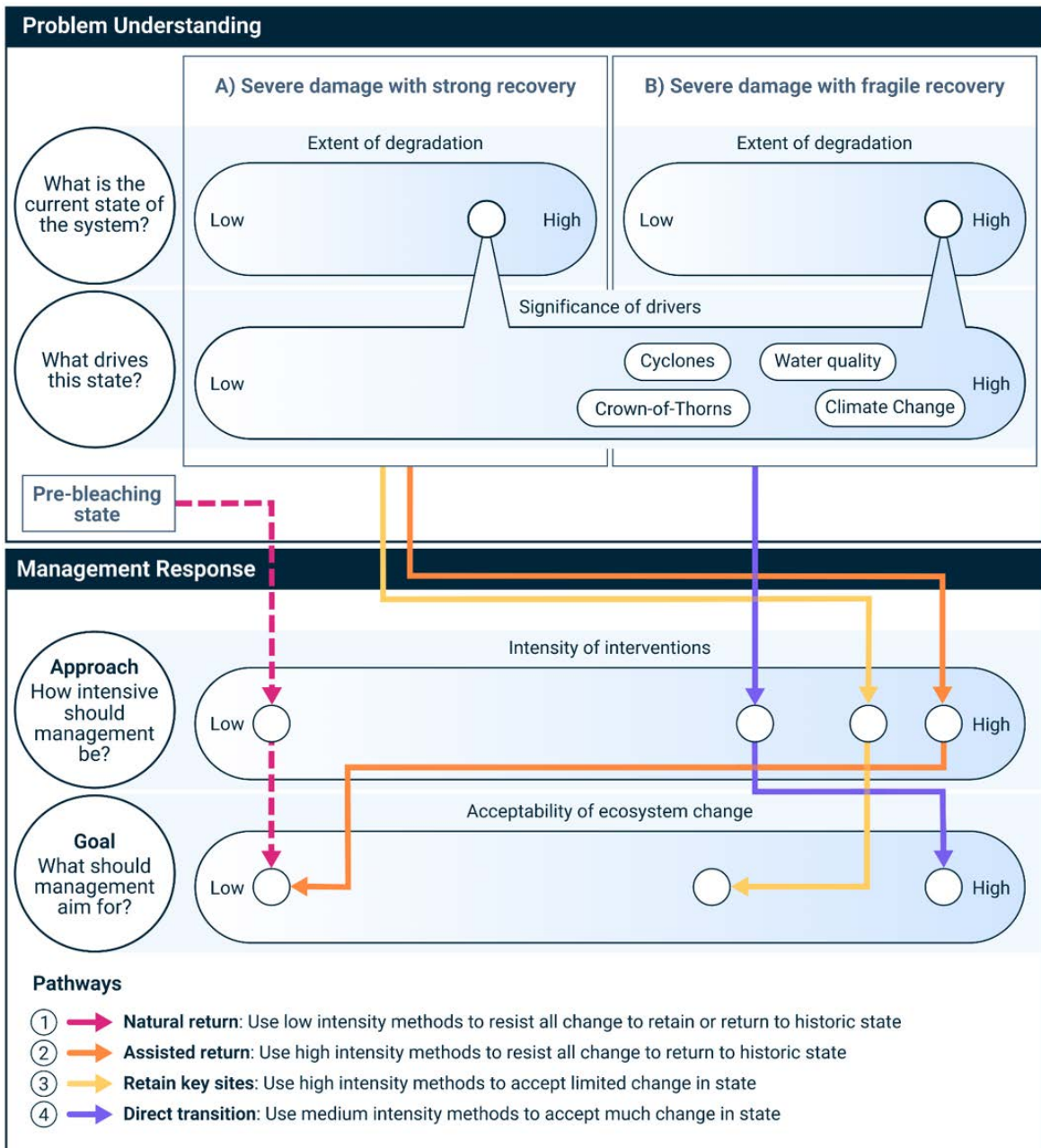
Figure 9. Four governance pathways for the Great Barrier Reef (GBR) amalgamated from interviews: 1) natural return (dotted line indicates this pathway is no longer considered viable), 2) assisted return, 3) retain key sites, and 4) direct transitions. All four pathways show that participants rank the drivers of change similarly, but there were differences in views on current recovery. Box A shows respondents' view that the reef showed strong recovery whereas box B reflects the view that the reef shows fragile recovery; the pathways further diverge from there. White dots indicate governance actors' generalized responses to each of the four questions on the left side of the chart.

3.4.2.1 Natural return to historic state

For this pathway, the desirable state is a reef system that naturally returns to historic diversity and structure of the GBR. Participants had different "historic" baselines, but generally imagined reefs in pre-bleaching condition or earlier. Here the reef is considered

capable of "bouncing back" on its own, resonating with the idea of "return" (Schuurman et al. 2021). The undesirable state is the GBR losing its natural resilience and degrading into a patchy and/or eventually algae-dominated state.

Management's role focuses on removing drivers of change rather than actively intervening via restoration efforts. The goal is to allow natural resilience to rebuild the historic state, rather than trying to direct a transition to a different state (see 3.4.2.3). Several participants described that prior to bleaching, the GBR management was primarily "hands off", and the reef was expected to naturally recover once stressors were removed. Relevant solutions in this pathway have included reef use zoning, banning gill nets, and regulating and promoting best practices to improve water quality.

After mass coral bleaching, most participants no longer considered a full return to a historic state feasible. One participant, a university researcher previously employed at a government agency reflected, "I'd like to see back to what, when I first started diving in the 80s. But…maybe that's being unrealistic" (Participant 1). A mining resources professional similarly suggested that a return to old reefs would be nice, "but realistically…it's never going to be like it was, it just can't be…not within 100 years" (Participant 21). Participants sometimes argued for management solutions similar to those previously used within this pathway, such as improving water quality or expanding "green zones" (no fishing) in the GBR marine park. However, they now incorporated these solutions into other pathways. Participants were explicit about abandoning the "natural return" pathway:

"…most of the conventional wisdom was remove the pressures from the park and then leave it well alone and it'll recover…Equilibrium management. And it's solid as a strategy. However, as…we get more and more mounting impacts and serious decline in the underlying habitats. Then you need to intervene more, which is where we're at." (Participant 4 Government professional)

Though this pathway was considered unviable, a few suggested it may become viable again in the future (see 3.4.2.2 and 3.4.2.3), but that other pathways (e.g. "Assisted return") are necessary for now.

3.4.2.2 Assisted return to historic state

Similar to the previous pathway, the desirable state is for the reef to return to pre-bleaching diversity and structure. Again, continued decline towards an algae-dominated state, or increasing patchiness (i.e. a mix of coral, rubble, algae, etc.) is seen as undesirable. However, two key features differentiate this pathway: intensive human intervention is considered critical for recovery, and a patchy reef is considered marginally acceptable in the short term. For example, one government researcher emphasized short term action to support eventual long-term recovery:

"The aim…is to…do what we can over the next few years so that we maintain some in-built resilience or the capacity of the reef to respond once those broader climate drivers hopefully start coming under control. So it's about leaving some gas in the tank so the reef has a capacity to recover in 20 years' time." (Participant 11)

Here reef "patchiness" is central to the idea of "building back" and is viewed as a temporary, intermediate step towards an ultimate return to the diversity of the pre-bleaching reef. Participants conceived of patches of healthy reefs as "bright spots" or "ecologically and culturally important sites" that could serve as "seed reefs" to help other reefs "bounce back" with time.

In this pathway, management's role focuses on intensive interventions aimed at restoring the reef (e.g., genetically engineering corals for heat resistance), and reducing exposure to stressors (e.g., cloud-seeding to shade reefs during heat waves). Most participants whose views aligned with this pathway were NGO or government professionals, along with some researchers. Participants emphasized that "business as usual" will not facilitate the desired return to a pre-bleaching state. Here this implied a rejection of "hands-off" management and a dire need to embrace intensive interventions. One NGO professional described that the aim is "just providing those interventions at the right point to keep… [reefs] self-sustaining" because "there's…a clear tipping point that we can't get past" (Participant 26). This participant suggested that it is important to gauge when interventions are feasible, as they require constant input unless the system quickly gets to a point where it can "bounce back". Most participants articulated that these types of interventions should be undertaken alongside a broader focus on reducing stressors (e.g. water quality).

The post-bleaching recovery of reefs is front and center in this pathway. Participants acknowledged that a full return to pre-bleaching state is not possible without a rapid move onto a <1.5 C emissions trajectory. At the same time, participants here considered post-bleaching recovery to be strong at the time of interviews (late 2021, early 2022), with some framing recovery as a demonstration that an eventual return to a pre-bleaching state is plausible. Resource managers, politicians, NGO professionals, and tour operators emphasized that recovery is "strong" and going "very well," and some suggested that reefs could "u-turn" as demonstrated by the recent "massive bounce back." One tour operator emphasized:

"[Climate change] is not a battle that can't be won, and that's…really important…reef health, what we're seeing at the moment, it's on a strong recovery, and from a tourism perspective, the reef [has] not looked as good as it does now in a number of years." (Participant 24)

Although participants supported a wide range of solutions, those interested in intensive interventions also raised the prospect of triage (i.e. picking a few priorities due to limited resources). Participants across the study were hesitant to identify lower priority solutions, but when contemplating the realities of limited funding they suggested that choices would need to be made in the future. For example, a university researcher and government advisor suggested:

"…Ultimately, a political decision will end…up being made to say … we can only do so many [reefs] and we will do everything we can about global warming…But the ones we can go ahead and actively protect…for whatever reason, probably commercial… none of [the ministers] would like it…that'd be a truly tough call." (Participant 30)

The idea of triage, either picking certain reefs or certain issues over others (e.g. restoration over water quality), was noticeably uncomfortable for participants, and came up in both this pathway and the following "retain key patches" pathway.

3.4.2.3 Retain key patches

In this pathway, a reef system-wide return to historic conditions is considered impossible. Here the desired outcome is the recovery of key sites. As with the first two pathways, a reef system-wide shift to an algae-dominated state is undesirable, but here some degree of patchiness is viewed as unfortunate but necessary to accept. Most participants whose views

aligned with this pathway were professionals at NGOs or government ministries, as well as a few researchers.

"I think our goal has got to be that some parts of the reef are as good as we can possibly get them, which might mean that some parts of the reef look like they did yesterday…[but] I don't think that we'll have the reef as it was…no matter where you went, you would see beautiful life…" (Participant 30 University researcher).

Here, retaining key patches is recognized as a long-term goal, rather than as a means to the eventual ends of restoring the whole reef system (e.g. "assisted return"). Participants described these patches as "ecologically and culturally important sites" or "pockets in reasonable condition" maintained so that some parts of the reef "look like they did yesterday".

The solutions here are similar to the "assisted return" pathway, for example, planting heat-resistant coral or shading the reef. Yet participants adopted a pragmatic tone and expressed that given mass bleaching events, they had no expectations that a full return to historic reefs is possible. One NGO consultant was blatant: "the prognosis [after bleaching] really, was that our best endeavours…could well just end up with two or three pockets of fairly defined coral reef systems in reasonable condition. And everything else…in bad condition" (Participant 23). Another NGO professional pointed out "[the reef] management approach probably needs to be…different than how we viewed it a decade or two ago… this focus on interventions [e.g. restoration], while we do, hopefully…lift our game on climate action, is going to have to be part of the equation" (Participant 13). Similar to the previous two pathways, reducing major stressors like climate change and water quality was considered important, but even with these actions participants expected spatially limited outcomes in the long term.

In comparison to the previous two pathways, the perceived role for management after bleaching events mostly aligns with the "assisted return" pathway, but the desired outcome is different as a full "return" is no longer considered feasible. In the language of the RAD framework, this pathway allows some change at large scales but resists it at localized scales.

3.4.2.4 Directing transitions to future states

Here the desired future is not a specific reef state but rather the ability to navigate ongoing changes in the reef system. Here the reef is expected to continuously shift in structure and function as the effects of climate change and other stressors are realized. Returning to pre-bleaching structures and functions is considered unlikely or impossible, and reef patchiness is assumed as a future reality that must be accepted and actively directed when feasible. Contrary to other pathways, the exact state (e.g. structure and composition) is less relevant than key ecosystem functions and processes (e.g. nutrient cycling or fish stock reproduction). There were few participants whose views resonated with this pathway, and all were university researchers.

As elsewhere, a full regime shift to an algae-dominated state is seen as undesirable; however, because participants expected patchy reefs in the future they did not view a system-wide algae-dominated state as likely. One researcher instead suggested that "certain reefs… regions and… habitat are going to degrade more so than others" (Participant 5). Another researcher echoed:

"…depending on the species and location, there's going to be boom and bust and there's going to be beautiful places and…not so nice places, and it's going to be patchy. It's going to be changeable. But my overall feeling is reefs are amazingly resilient. They've been around for a long time and we overestimate humans' abilities to destroy reefs." (Participant 20)

Here patchiness is not considered equivalent to losing resilience, but is instead considered part of reef resilience. This researcher articulated that patchiness may be desirable because it creates diverse structures that facilitate reef processes. Consequently, an algae-dominated state is not the only undesirable outcome in this pathway—a monoculture of a single coral species is also something to avoid. For example, a reef covered in plate corals is "as good as sterile" because it lacks diverse resources for fish and therefore has limited fish species diversity (Participant 20). Thus, short-term recovery after bleaching events was regarded as unimportant because it involved a limited number of "weedy", fast-growing corals that did not provide structural diversity. Where recent recovery was cited as a hope in the "assisted return" and "retain key sites" pathways, here it was merely a temporary change of little long-term significance. Recovery is considered "fragile" and "could easily be wiped out" by another bleaching event.

This pathway stands in direct contrast to the "natural resilience" pathway in regard to both its desired state and the role of resource management. As with the "assisted resilience" and "retain key sites" pathways, participants suggested that "business as usual" is no longer sufficient after mass bleaching events. However, here this was interpreted to mean that managing for a stable desirable state is not feasible; rather than seeking to switch to intensive, restoration-focused management, this pathway is about addressing drivers of change and also changing desired management outcomes. University researchers articulated a paradigm for reef management that embraces extensive change, with one suggesting that management approaches must recognize that "further change is inevitable and maintaining the status quo is no longer possible" (Participant 35). Another emphasized that managers are currently "change avoiders" but need to be "change copers" and that "we're trying to resurrect the reefs of our childhood and dreams…[but] what we should be looking at for society is to cope with what we've got" (Participant 20).

Participants aligned with this pathway suggested that priority solutions should focus on reducing large-scale drivers of change (e.g. water quality). One researcher elaborated:

"…The number one priority has to be to address…the causes of coral loss before you even think about restoring reef or habitats… It's the old adage that prevention is better than cure. It's going to be much more effective to stop the loss of corals out there on the reef than to try and replace them once they're lost." (Participant 5 University researcher)

The focus on reducing drivers of change resulted in less interest in or downright rejection of smaller scale interventions (e.g. coral restoration). There was a clear focus on identifying important reef functions, but also a recognition that this requires a subjective value judgement by management agencies and reef actor groups. Several participants expressed that decisions about what is valued and why are needed. Participants suggested that managers, local communities, and others should be involved to determine these values.

3.4.3 On-the-ground solutions: footsteps towards multiple reef futures

Here I briefly highlight how governance actors take steps down three of the four pathways simultaneously ("natural return" was not actively pursued by participants) (Figure 10). Despite some disagreement about what specific solutions should be pursued, participants agreed that pursuing any solution should involve advocating for greater community

engagement and a stronger role for Traditional Owners in research, management, and decision-making.
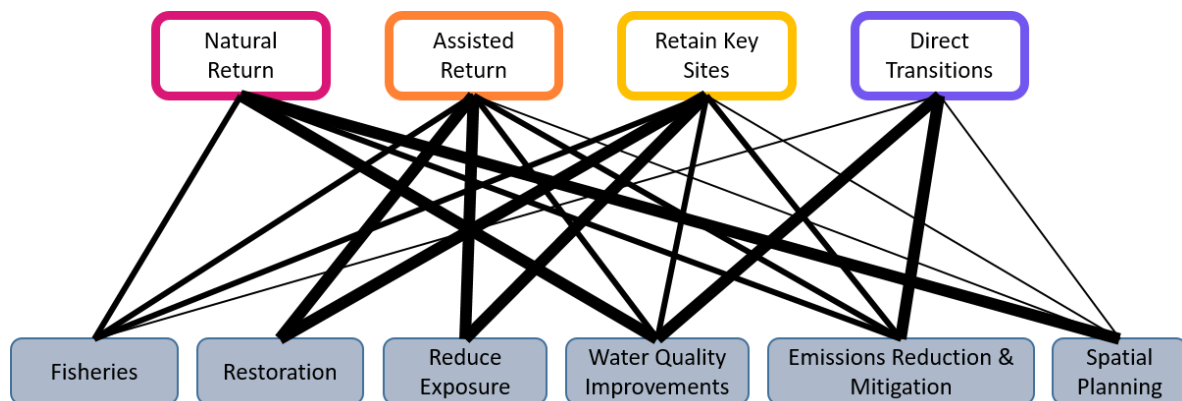
Figure 10. The four pathways relate to a range of different reef management solutions. Solutions are generalized from interviews into six general categories (grey boxes). The black lines are weighted based on a qualitative assessment of how much a given solution was emphasized in relation to the desired outcome of a given pathway—thicker lines reflect greater emphasis.

Activities related to all pathways included implementing best practices and enforcing regulations to improve water quality, typically carried out by state government, NGOs, and the agriculture industry. Addressing climate change and making water quality improvements are seen as key to restoring the historic reef state, or directing the degree of change in future reefs. Some larger NGOs and prominent researchers actively advocated for emission reduction and campaigned for renewable energy and stopping coal mining. Efforts to address water quality and climate change aligned most strongly with "natural return" and "direct transitions" pathway.

Restoration activities related primarily to "assisted return" and "retain key sites" take the form of government-funded programs (e.g. RRAP), NGO research and management (e.g. Crown of Thorns Starfish control program) and private sector research and development (e.g. Reef Ecologic coral gardening project). Other activities include developing policies and regulations for these new approaches, such as the GBRMPA "Policy on GBR Interventions." Some activities were initiated prior to mass bleaching events, but the events heightened their importance. For example, removing crown of thorns starfish was part of the "natural return" pathway prior to bleaching, but became part of the "assisted return" and "retain key sites" pathways after bleaching.

There is clear overlap in what solutions were described as relevant across the four pathways, but also some tensions. For example, actors pursuing the "assisted return" or "retain key sites" pathway usually focused on restoration and reducing stressors, whereas most actors pursuing the "direct transitions" pathway opposed this in favor of reducing drivers of change. In addition, actors interested in the "assisted return" and "retain key sites" pathway discussed triage, with a few tentatively suggested reallocating funding from water quality efforts towards restoration and adaptation interventions, whereas those in the "direct transitions" pathway opposed this.

3.5 Discussion

Climate-driven change in SES poses difficult, sometimes existential questions for decision-makers and their advisors about the purpose of resource management. The perspectives of this subset of governance actors are particularly important to understand because they influence decisions about the future of these systems. In exploring these perspectives, this narrative policy analysis brings attention to the notion that problems and solutions are framed in different ways by different actors (Sabatier 1998, Stone 2002, Jones and McBeth 2010, Wyborn et al. 2021, Múnera-Roldan et al. 2022). The four pathways that emerged illustrate that these actors imagine multiple futures for the GBR, and provide a starting point for negotiating which future(s) become a focal point for management efforts. Participants' responses tended to align with the second or third pathway, and a minority supported the fourth pathway.

My primary goal was to bring a focus to how governance actors understand problems, and connect different problem frames to solutions. The RAD and RRT frameworks skip over the question of how actors conceive of problems and move immediately to a focus on management approaches (Peterson-St. Laurent et al. 2021, Schuurman et al. 2022). In contrast, a narrative approach gives explicit attention to how actors frame problems (Stone 2002, Jones and McBeth 2010, Shanahan et al. 2018). By first asking actors about the current state of the GBR and what drives this, I was able to empirically demonstrate a relatively shared view of drivers of change, but also detect differences. The strong agreement on drivers was somewhat unexpected given the frequent conflicts between actors' perspectives within the GBR region, though this resonates with research showing that bleaching events brought commercial fishers, tour operators, and coastal residents into

greater alignment on perceptions of GBR threats (Thiault et al. 2021). Differences in interpretations of coral recovery marked the first major point of departure between pathways, with those ascribing significance to recovery tending toward different, higher intensity management, than those who considered recovery insignificant in the long term.

Second, I sought to consider, but not conflate, actors' views on solutions, management approaches, and desired outcomes. The RAD framework (Thompson et al. 2020, Schuurman et al. 2022) focuses on management approach (i.e. intensity level) and attends to actors' level of change acceptance, but is critiqued for not being specific about desired outcomes (Peterson-St. Laurent et al. 2021). The RRT framework (Peterson-St. Laurent et al. 2021) is criticized for conflating management approach and outcomes (Schuurman et al. 2022). My framework addresses these limitations by incorporating spectrums for management intensity and level of acceptable change from the RAD framework, but keeps them clearly differentiated and structured such that they can be connected to problem frames (Figure 11 'Management Response' box). I avoid conflating outcomes with approach, and are able to show how different pathways may include the same solutions but lead towards different goals, or include different solutions but lead toward the same goal. Both the RAD and RRT frameworks imply that management solutions (e.g. restoration) can be sorted into discrete categories (e.g. "resist" for RAD or "passive resistance" for RRT), but this did not align with my findings.

I found that different solutions are used to realize the same outcome simultaneously, or the same solution may be implemented in pursuit of entirely different outcomes. For example, the "natural return" and "assisted return" pathways share a desired outcome of an eventual return to historic reef composition, but differ in approach, with "assisted return" involving higher intensity interventions. On the other hand, the "direct transitions" pathway accepts change at all scales but adopts a role for management akin to the "natural resilience" pathway—focused on drivers of change but otherwise allowing ecological transitions to occur. This is similar to previous research that utilized the RRT and found that the implications of a solution are scale dependent (e.g. an action to "resist" at a local level can simultaneously realize a "resilience" outcome at the regional level) (Clifford et al. 2020). Here I found that even at a single level (e.g. regional) the same solution (e.g. water quality improvement) can realize different outcomes.

Lastly, the RAD and RRT frameworks posit that the biggest challenge to deciding on how to respond to change is a lack of clear frameworks, and that a clear framework will make it possible to achieve the assumed goal of collectively deciding on a single shared path forward (Peterson-St.Laurent et al. 2021, Schuurman et al. 2022). This follows a broader trend in adaptive governance and climate adaptation literature that assumes that convergence on a single shared vision is a core goal of resource management (Olsson et al. 2004, Schultz et al. 2011, Schuurman et al. 2022); this perspective was also prevalent amongst participants. Several participants identified the need for broad public engagement to democratically identify values and find shared management priorities especially in the context of ongoing change (Blythe et al. 2018, Louder and Wyborn 2020, Múnera-Roldan et al. 2022). However, the diversity of pathways evident in the wake of bleaching events suggests that reaching consensus may be unrealistic. Nonetheless, conducting research to articulate diverse approaches and desired outcomes, as I have done here, may encourage creativity and enable actors to understand each other's positions. From that basis of appreciating difference, they may then better navigate change even in the absence of consensus.

Depending on a shared vision negates the possibility that actors may not ever decide on a shared path forward and could instead take multiple paths simultaneously (Paschen and Ison 2014, Louder and Wyborn 2020, Wyborn et al. 2021). This more pluralistic approach aligns with adaptive governance recommendations for experimentation in the face of change, although this is typically considered in terms of specific management solutions rather than experimentation with overall management approach and desired outcomes (Huitema et al. 2009, Chaffin et al. 2014). My narrative-based pathways framework provides a starting point for expanding approaches to navigate change. A generalized version of my framework is presented in Figure 11, which is developed from the findings presented in Figure 9. In this framework, practitioners can start by selecting different problem frames (for example, Problem Frame A and B in Figure 11), then select desired intensity of interventions based on available resources and desired outcomes, among other outcomes (Management Response section of Figure 11). The result is a clearly articulated pathway to govern an SES based on how a problem is conceived *and* how management efforts should respond. My framework does not duplicate but rather builds on the RAD and RRT. My

pathways approach integrates easily with the six categories of the RRT, which could be incorporated as pathways across these two spectrums. For example, the "active resistance" category of RRT would map similarly to "assisted return" in the GBR case. However, I do not limit my framework to the six pathways in the RRT framework but instead use spectrums to emphasize that a plurality of other pathways are possible.

Future research could use this framework with a broader subset of governance actors to identify additional pathways envisioned by actors operating from the local to global level (Figure 11). Empirical research could also investigate whether multiple pathways are maintained or lost over time, why this occurs, and who benefits or loses as different pathways are pursued. Additional research could identify opportunities for building collaboration at points of overlap between diverse perspectives, and for increasing coordination when pathways diverge, so as to minimize degradation of other efforts. Lastly, consideration should be given to how to apply the pathways framework consistently to allow comparison across sites but prioritize relevance to specific contexts. The spectrums in my framework allow actors to sort problem frames and solutions relative to one another within a specific location. Future research could investigate the benefits and downsides of creating more standardized spectrums to enable cross-case comparison.
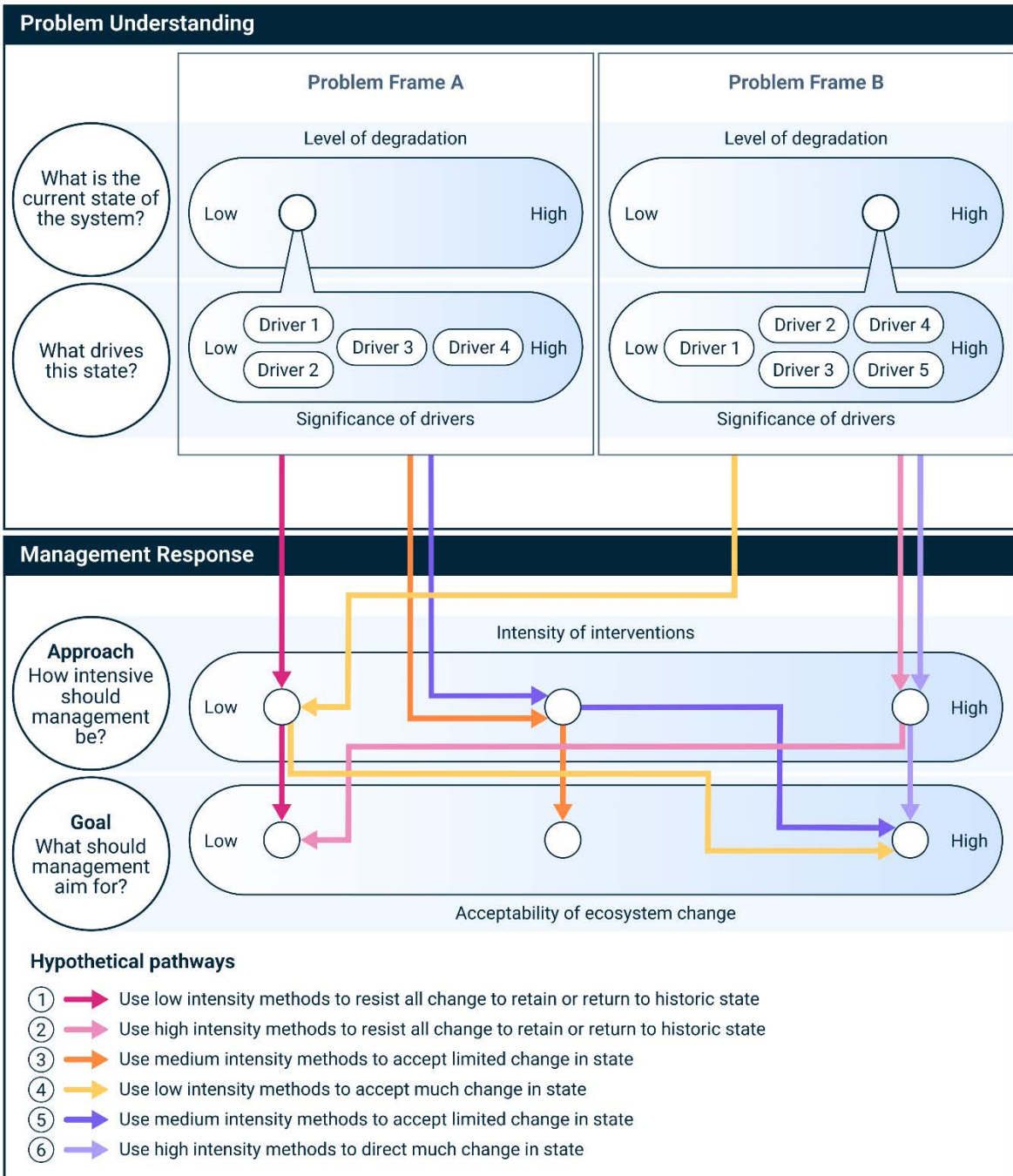
Figure 11. Generalized version of the Pathways Framework, developed from the findings shown in Figure 9. Pathways are indicated by colored arrows that begin from specific problem frames, consider management approach, and end with management goals. White dots indicate governance actors' hypothetical responses to each of the four questions on the left side of the chart.

3.6 Conclusion

Governance actors are faced with the daunting task of navigating climate-driven change in SES. I investigated the various ways that a subset of governance actors responsible for making or advising on decisions about the globally iconic GBR are grappling with devastating

recurrent mass coral bleaching events (Dietzel et al. 2021). I found that the experience of bleaching events has upended the dominant "natural return" paradigm for reef management and left actors seeking new pathways. Three pathways for future reef management emerged simultaneously—"assisted return", "retain key sites", and "direct transitions". Many participants seemed to expect to eventually settle on a single pathway, but the myriad of pathways being pursued suggests that this may not occur in the foreseeable future, and perhaps should not be the goal. Though this lack of consensus was a source of disappointment amongst participants, understanding multiple perspectives may prove more useful for navigating change through experimenting with a plurality of approaches rather than struggling for consensus. I developed the pathways framework to enable this understanding, integrating the RAD and RRT frameworks with narrative analysis to bring attention to how actors frame problems, and clearly articulating desired outcomes. My framework makes it easier to articulate nuanced but consequential differences in actors' views and expose the great diversity of perspectives at play even amongst this subset of governance actors. This opens up opportunities for pluralist ways of thinking about change in contentious democratic settings with diverse actors. I present this pathways framework with the hope that it will enable researchers and managers to creatively navigate future climate change impacts.

Chapter 4: How reef actors navigate the future for a social-ecological system in the wake of an extreme climate event

Adapted from **Datta, A.**, Chaffin, B.C., Morrison, T.M., Wyborn, C.W. (In prep). How reef actors negotiate the future for a social-ecological system after extreme climate events. *Regional Environmental Change*

Abstract

In this chapter I delve more deeply into the narrative analysis conducted in Chapter 3 by turning attention to questions about "who" is held responsible for causing problems and implementing solutions, and who stands to be positively or negatively affected by different solutions. Here I step back to consider the narratives of governance actors in the GBR region in the context of an ongoing global debate amongst reef researchers, managers, and decision-makers about the relative importance of building local resilience versus mitigating global and local stressors. The outcomes of this debate will shape which management approaches gain traction in local and regional areas, and consequently, the social-ecological futures that are produced. Previous research has engaged in this debate by advocating specific positions, rather than reflecting on the roots of tension between actors and a means to navigate a path forward. This risks exacerbating rather than effectively navigating inherent tensions between different actors, hindering more effective multi-level, cross-sector governance. I use narrative analysis in this chapter to explore synergies and tensions between dominant narratives shaping the trajectory of governance for Australia's GBR after recurrent mass coral bleaching. I show that the level and sector of environmental governance in which actors work shapes the narratives they construct, including who narratives implicate as accountable for reef problems, and who is held responsible for reef solutions. This research suggests that national and international actors emphasize assigning accountability for global and regional drivers of change, whereas actors operating at a regional level focus on local agency and action. I also uncover different ways actors shift accountability and responsibility between sectors and across levels. I find that local and regional actors are hesitant to assign accountability to one another, preferring to focus on actions where winners are obvious, and no (human) actors lose out. I conclude by exploring approaches for overcoming barriers to effective multi-level, cross-sector governance, and thereby assisting diverse actor groups to shape more sustainable SES futures.

4.1 Theoretical Framework

In Chapter 3 I discussed that the ways governance actors interpret extreme climate events and frame certain solutions as "desirable" in the aftermath of extreme climate events is deeply political (Stone 2002, Morrison et al. 2020a, Múnera-Roldan et al. 2022). This chapter builds on the previous chapter by exploring synergies and tensions between governance actors representing a range of interests in an SES after an extreme climate event, with the aim of contributing to the effective governance of SES in the climate change era. A critical component of effective governance is the need to coordinate management actions across sectors (e.g. government, industry) and levels (e.g. local, international) (Cash et al. 2006, Folke et al. 2005, Morrison 2019). Though actors in the GBR region have similarly called for coordinated, multi-level governance to shape the future of the GBR, they have found this difficult to achieve (Bellwood et al. 2019, Barnes et al. 2022). To support governance actors as they build coordinated, multi-level and cross-sector governance of SES in response to climate-driven transformation, researchers must explicitly examine areas of conflict between actors. Here I explore how governance actors with influence over decisions that affect the entire GBR system uphold or resist different narratives about priorities for GBR governance after mass coral bleaching events. I also consider how different actors in the region may benefit or suffer based on the outcomes of this negotiation.

In Chapter 3 I described that the core elements of the narrative policy framework include (Stone 2002, Jones and McBeth 2010, and Shanahan et al. 2018) : 1) context, 2) problem frame, 3) solution frame, 4) characters (i.e., who are the main heroes, victims, and villains); and 5) plot, i.e., what general plotline ties these elements together (e.g. identifying a "story of decline" (Stone 2002)). While Chapter 3 focused on problem and solution frames, here I focus on characters and plot. The previous chapter illustrates how multiple visions, rather than a single shared vision, emerge after crisis. Given that multiple visions arise, it follows that actors promote or resist one another's visions; this chapter uncovers alignment and tension between narratives about reef futures to articulate what the decision-making space looks like in contexts where a shared vision does not arise after crisis. I specifically explore how two dominant narratives assign responsibility for causing reef problems or realizing reef solutions, and the opportunities or barriers this creates as these actors build a path (or paths) forward for SES governance after extreme climate events.

Note that the narratives in Chapters 3 and 4 draw on the same set of interviews but are intentionally structured differently. This is to allow Chapter 3 to focus on the nuances of "what" governance actors envision for the future and "how" they see management assisting with realizing the future, while Chapter 4 focuses on "who" is implicated by the way problems and solutions are framed. I will however note here the connections between the narratives in each chapter for readers who may be interested. In Chapter 4, I simplify the "what" components of actors' narrative by merging the pathways in the previous chapter into two major pathways, which enables clearer identification of overlap and tension between them, and what implications this has for different actor groups. First, I combine "Assisted Return" and "Retain Key Sites" pathways into a single "Adaptation Narrative" as both of these pathways involve some degree of resisting change through implementing adaptation strategies like coral restoration. The "Directing Change" pathway is here encompassed by the "Mitigation Narrative" as the activities within this pathway relate to mitigating the drivers of change, while simultaneously accepting that some degree of change to the GBR will occur.

4.2 Research Questions

This chapter responds to the general research question: How do multiple emerging visions for the future of the GBR synergize or come into tension with one another? My specific objectives for this chapter are:

1) What dominant narratives do governance actors construct about the GBR after mass coral bleaching events?

2) What are the tensions and synergies between the narratives?

3) What do these tensions and synergies reveal about potential opportunities and barriers to addressing multi-level, cross-sector issues facing the GBR?

4.3 Methods

See Chapter 3 Methods for a description of interview methods used for this chapter. To generate the data used in this chapter, participants were asked to describe who supports or opposes the work of their organization, who or what they expect will benefit from their work, and whether there are any groups they feel are not well represented in reef

management. These questions elicited information on the social dimension of actors' narratives, following the narrative framework described in Chapter 3 and summarized in the theoretical framework section of this chapter. For this chapter, I amalgamated dominant narratives from all interview responses; each narrative is composed of a problem frame linked with solution frame, which was achieved using the matrix coding function in NVIVO. I identified "dominant" narratives as those frequently deployed or resisted by participants; problem or solution frames mentioned by two or less participants were not amalgamated into separate narratives. I then deductively coded the transcripts to identify key issues or problems facing reefs (e.g. water quality), solutions (e.g. regulations), and character roles including "supporters", "opponents", "victims" affected by reef issues or management solutions, and "beneficiaries" of reef solutions. This allowed me to examine the way that actors assign or resist responsibility for causing the problems facing reefs. I also assessed how actors assign responsibility for action on solutions, and consider who and what is affected by the proposed solutions.

Transcripts were also coded according to the focus (e.g. research, management) and type (e.g. government) of participants' organizations. This made it possible to perform matrix coding to detect patterns in the organizations participants were affiliated with and the narratives they upheld or resisted. Any one individual interviewed did not align rigidly with a particular narrative, but matrix coding made it possible to detect what types of actors utilized specific problem and solution frames, which made it possible to associate individuals with dominant narratives. For example, it was possible to assess which types of actors tended to uphold a specific problem frame (e.g. researchers tended to express the idea that "coral recovery is fragile"). If more than one actor upheld a certain problem or solution frame, this was reported as "upholding" or "leaning towards" the narrative associated with that frame. The intention is not to quantitatively generalize the perspective of all actors in the region, but to provide useful context for understanding the types of actors upholding or resisting dominant narratives specifically in high-level decision-making spaces (e.g. Reef Advisory Committee, GBRMPA).

After amalgamating dominant narratives, I identified areas of synergy and tension between the narratives. This approach allowed the author team to investigate how responses to

change shift the burden of action between actors, and how actors not only promote but also resist different solutions (O'Brien 2012, Blythe et al. 2018).

4.4 Results

4.4.1 Two dominant narratives

As participants grappled with the changes to reef governance after mass coral bleaching events, two dominant narratives emerged which I label, 1) the "Mitigation Narrative" and 2) the "Adaptation Narrative". The Mitigation Narrative brings a focus to drivers of reef condition (e.g. climate change, water quality) and holds those accountable for drivers as most responsible for action on solutions (Figure 12(I)). The Adaptation Narrative acknowledges drivers of reef change, but focuses on action at the local and regional level and holds actors with close livelihood connections to the reef responsible for action, in addition to those accountable for driving reef change (Figure 12(II)). The Adaptation Narrative was more popular amongst participants than the Mitigation Narrative. Figure 12(III) illustrates how the two narratives overlap and depart from one another. The next section identifies synergies and tensions across the five components of narratives illustrated in Figure 12(III).

(I) Mitigation Narrative

Problem Description: *The GBR is impacted by rising global temperatures driven by emissions. Recurring mass coral bleaching events are fundamentally shifting the future structure and function of coral reefs. Poor water quality also reduces reef resilience. There are localized stressors, but these are eclipsed by the threats of climate change and water quality.*

Problem Attribution: *The fossil fuel industry and governments who support it at the state, national, and international level are responsible for emissions. Citizens are contributing through their carbon footprint and support of fossil fuel-friendly politicians. The agriculture sector is responsible for the majority of poor water quality.*

Key Solutions: *Reduce emissions, transition to renewables, improve water quality.*

Responsibility for Solutions: *The Australian government and nations around the world must limit global warming to <2C. The UNESCO World Heritage Committee is responsible for holding national governments accountable for emissions reduction, as this affects World Heritage sites. NGOs and researchers are responsible for holding governments, industry, and others accountable for drivers of reef change. Australian and Queensland citizens can reduce their carbon footprints and vote for climate-friendly politicians. The Queensland Government must move towards renewable energy and away from coal mining, and support efforts to improve water quality. Agriculture peak bodies and Queensland farmers can improve water quality through best practices and complying with state water quality regulations.*

Justification for Solutions: *Solutions should focus on global, national, and regional drivers of change because local and regional reef management cannot otherwise succeed. Efforts to adapt to or reduce exposure to climate stressors locally will not be effective without first addressing drivers.*

(II) Adaptation Narrative

Problem Description: *The two biggest impacts to the GBR are climate change and water quality. Local stressors also affect reefs, with different stressors affecting different sites across the reef system. Even if emissions were reduced today, there will be a period in which temperatures continue to increase.*

Problem Attribution: *The fossil fuel industry and governments at the state, national, and international scale are driving emissions. Individual citizens are also responsible for their personal carbon footprints. The agriculture sector is primarily responsible for water quality issues, though port development and urban runoff can also have an impact. Commercial and recreational fishers cause overfishing in some areas. Boaters who drop anchors, and tourism overuse, also damage the reef in some localities.*

Key Solutions: *Improve water quality, restore reefs, reduce local stressors, and protect reefs during heat waves. Focus on these activities while others work to reduce emissions.*

Responsibility for Solutions: *Reef managers, tour operators, NGOs, farmers, and Australian citizens have a responsibility to care for the GBR, which they depend on for their livelihood and wellbeing. The private sector can offer novel techniques for restoring corals and protecting reefs during heatwaves. The state and national government, along with other nations, must reduce dependence on fossil fuels and transition to renewable energy. In the meantime, local and regional organizations and individuals must do all they can to build the resilience of the reef so that it can bounce back once emissions are reduced.*

Justification for Solutions: *Actors from the local to global level must coordinate to minimize impacts to the GBR. Local, state, and regional actors must maintain hope and take any action within their capacity at a local level while national and international actors address climate change.*
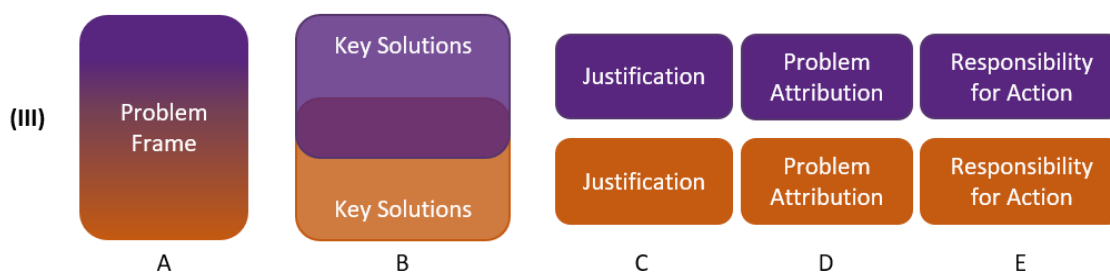
Figure 12. Two overlapping narratives about the GBR emerged after mass coral bleaching events—the Mitigation Narrative ((I) purple) and Adaptation Narrative ((II) orange). Narratives were compared across five components (III): A) problem frame, B) solutions, C) how solutions were justified, D) what types of actors were held responsible for problems ("problem attribution"), and E) which actors are held responsible for action. The two narratives included similar problem frames and had some overlap but also some

differences in proposed solutions. The narratives diverged when it came to solution justifications, problem attributions, and how responsibility for action was assigned.

4.4.2 Synergies and Tensions between the Mitigation and Adaptation Narratives

4.4.2.1 What problems do reefs face?

The Mitigation and Adaptation Narratives acknowledge climate change as the greatest threat to the GBR, followed by poor water quality. This suggests that actors representing a range of interests in the region largely agree on the problems facing reefs, even if they disagree in other areas. However, the Mitigation Narrative focused more intently on drivers of change like climate change, whereas the Adaptation Narrative is inclusive of large-scale drivers of change but also emphasizes more localized problems like coral-eating crown-of-thorns starfish. This slight difference begins to widen in the solutions component of the two narratives.

4.4.2.2 What are the solutions to reef problems?
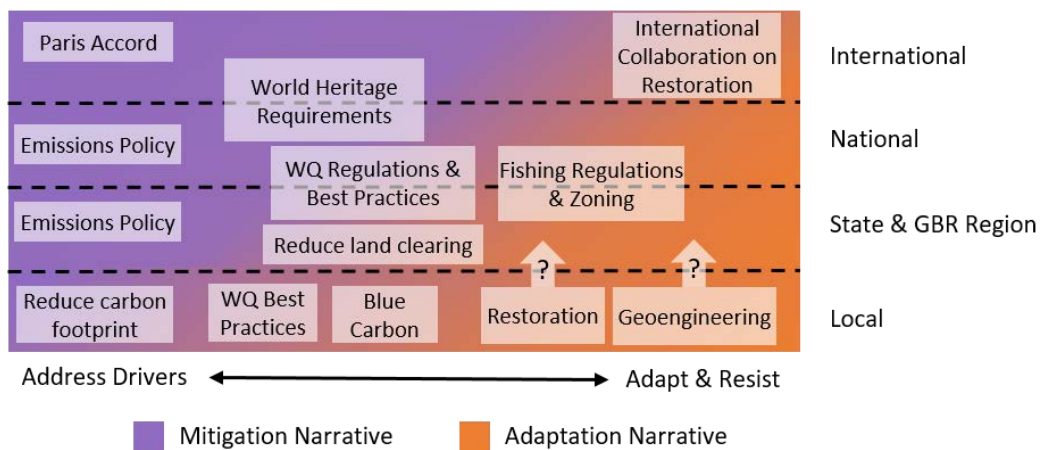
Figure 13. Summary of solutions relevant to each narrative. Solutions emphasized in the Mitigation Narrative (purple) tended to relate to action at higher levels (e.g. International) and actions focused on addressing drivers (left side of chart). Solutions emphasized in the Adaptation Narrative (orange) tended to focus at local and regional levels and include activities focused on resisting change through adaptation (right side of chart). Restoration and geoengineering are being tested at local level. Proponents of these solutions suggest they may be scaled up in the future but this is yet to be implemented; this is indicated by arrows with question marks.

Participants reported on activities undertaken in the wake of bleaching events. The Mitigation Narrative brings attention to drivers that can be addressed by actors at the international, national, and regional level (e.g. climate change, water quality) (Figure 13). Actors at these levels include researchers, state government, and NGO professionals. Researchers published articles on bleaching events in international journals, participated in government advisory committees, spoke regularly to the press and to government officials

seeking scientific advice, and shared their work via press releases and social media with international and national audiences. In 2019, the GBRMPA issued a public statement on climate change (GBRMPA 2019a). In addition, NGO professionals took on advocacy roles within national and state government, and with UNESCO at the international level, to hold government and industry accountable for problems such as climate change and water quality. Specifically, international NGOs lobbied the UNESCO World Heritage Committee to consider climate change in its World Heritage decisions. In 2022, a reactive monitoring mission led by representatives from UNESCO and the International Union for the Conservation of Nature led to the recommendation that the World Heritage Committee list the reef as "in danger" if adequate progress is not made towards improving water quality and taking climate action (Carter and Thulstrup 2022). State government professionals at the Office of the GBR had jurisdiction over the GBR catchment and therefore sought to address water quality issues through implementing regulations and encouraging voluntary best practices.

The Adaptation Narrative acknowledges extra-local drivers (e.g. climate change, water quality) but focuses more on scientific and technical solutions relevant to the work actors do at the regional and local level (Figure 13). For example, state NGOs and tour operators work to remove crown-of-thorns starfish and experiment with coral restoration techniques. Federal government and advisors to federal government focused on reefs also supported resilience-building actions on the reef, ranging from addressing water quality to trialing restoration techniques. Efforts to build reef resilience have led to a dramatic shift towards developing high intensity interventions to restore corals and reduce exposure to marine heatwaves through geoengineering technology (e.g. cloud seeding). This has manifested in the roll out of the AU$100 million RRAP through the Reef Trust Partnership, which focuses on research and development of novel interventions (e.g. breeding heat-resistant coral, dispersing coral spawn). The RRAP and government programs are also expanding engagement with Traditional Owner partners, providing training for employment related to interventions like coral restoration. Local not-for-profits work with farmers to implement best practices for improving water quality. The next section further explores the justifications offered for the solutions within each narrative.

4.4.2.3 How are solutions justified?

Tensions emerged around the solutions in each narrative and how they were justified (Figure 12 (III)C). Solutions in the Mitigation Narrative were justified primarily through an emphasis on ecological efficacy, with attention to climate change as the "single greatest threat" followed by water quality. The Adaptation Narrative explicitly aligns with the Mitigation Narrative in its emphasis on global and regional level stressors. However, the Adaptation Narrative brings additional attention to local stressors. Participants supporting the Adaptation Narrative expressed concern that the Mitigation Narrative under-attends to local and short-term stressors. For example, one NGO consultant explained:

> "...ultimately the coal industry, [Adani], port development, you name it. Those are huge drivers of change that are also affecting the reef [by causing poor water quality]. And people are at risk of forgetting that by just focusing on the climate story." (Participant 10)

This participant further elaborated:

> "Even if you had perfect mitigation, you have so much inbuilt residual global warming that the temperature's going to rise, even if you quickly cut all emissions, so you still need an adaptation strategy...And that is improving the ability of coral reefs to withstand heating at scale." (Participant 10)

This quotation illustrates a concern underlying the Adaptation Narrative that reefs might lose the ability to bounce back naturally while waiting for action on emissions reduction. The Adaptation Narrative thus has some synergy with the ecological concerns of the Mitigation Narrative, but encourages a "both/and" approach to dealing with both global and regional drivers *and* local threats and restoration.

In contrast, some justifying the Mitigation Narrative took a "zero-sum" approach to the Adaptation Narrative, arguing that local adaptation and restoration efforts will "fail" or "are a waste of time". One participant pointed out:

> "...the impact that you can have in terms of managing local threats, is kind of non-existent once you get beyond that sort of that temperature threshold [that causes bleaching]." (Participant 8 International NGO)

Some participants resisted the Mitigation Narrative due to frustration with this zero-sum approach, which they saw as misunderstanding the value of local action. Those justifying the Mitigation Narrative attempted to be sensitive to this tension by expressing some curiosity about local approaches like developing heat-resistant coral, but also some skepticism of its potential.

The two narratives diverged more distinctly in regard to sociopolitical justifications for solutions. Participants justified the Adaptation Narrative in terms of social or political feasibility. The Adaptation Narrative emphasized the importance of fostering agency through "tangible" or politically "feasible" actions that inspire "hope". This narrative suggested that action on emissions was outside local and regional actors' jurisdiction or capacity to address. This narrative was advanced by participants from state and national government, and other organizations working at the local or regional level (e.g. tourism operators), who expressed concern not only over their own agency to act, but also that of others. Some participants from NGOs and government emphasized the need to maintain hope among citizens and among national politicians who make decisions on funding reef management:

> "… the last thing that we need is for people to get to the point where they say let's give up…governments could say look…with all the priorities at the moment we're going to take our funding from the reef and put it into healthcare or education or something. I think it would be disaster, there's so many other things that depend on a healthy reef." (Participant 1 Federal Government (retired))

The Adaptation Narrative focuses on restoration and adaptation innovations as a means for maintaining a sense of hope that government and local actors have the ability to maintain coral reefs in a state similar to recent decades. In contrast, the Mitigation Narrative did not have as explicit of a focus on actors' capacity and hope, though it implied that reducing drivers is the only hope for maintaining reefs or navigating new reef configurations. Researchers and NGO professionals who resist justifications of the Adaptation Narrative emphasize that while there may be benefits to some actor groups, heat-sensitive coral and fish species will lose out if this approach is embraced without drivers being addressed. One researcher also cited taxpayers as indirectly losing out if the programs fail, given that their

money is used to fund them. Participants in the Adaptation Narrative did not dispute this, but justified adaptation as an approach that can nonetheless create short-term benefits and some possibility for future success while drivers are also addressed.

4.4.2.4 Who caused reef problems and who can implement solutions?

This section describes the interrelated 'problem attribution' and 'responsibility for action' components of each narrative (Figure 12(III) D, E). The Mitigation Narrative aligns accountability for reef problems with responsibility for solutions, with an emphasis on global, national, and regional actors. This puts the onus for action on the fossil fuel industry, agriculture sector, state government, federal government, and other national governments around the world, although participants were often vague in naming specific accountable actors. Instead, participants often spoke generally of a need to focus on "global temperature" and "strong action on climate" and referenced the Intergovernmental Panel on Climate Change (IPCC) goal of minimizing temperature increases to 1.5C. Researchers and representatives of organizations operating at the international and national level employed the Mitigation Narrative to hold actors accountable at the local (e.g. citizens), state (e.g. Queensland Government), national (e.g. Australian Government) and international (e.g. other governments) level. These participants called for the Australian government to reduce fossil fuel exports. Some participants pointed to the World Heritage Committee as responsible for setting standards for countries to address climate change for the GBR and other World Heritage sites. NGO participants also mentioned that some private sector "champions" such as Qantas were important for raising the issue of emissions to the public consciousness by participating in carbon-offset projects. Some participants called for the Australian government to lead on international emissions reduction:

> "We need to do everything that we can in Australia to lead on [emissions reduction], because we cannot do it on our own. We need Russia and China and India and the U.S. to play a role…it's going to be the really big polluters that also need to do it, but we can't tell them what to do. Unless we are leading by example." (Participant 22 Federal politician)

The Adaptation Narrative mentions these higher-level drivers and responsible actors, but focuses more closely on holding actors accountable for drivers at local and regional levels (e.g. fishers and farmers). In addition, the Adaptation Narrative further assigns responsibility

for enacting solutions to those who rely on the reef for their livelihoods (e.g. tour operators, local citizens), and invites new actors from the private sector to test innovations in reef management such as new coral restoration techniques. Restoration efforts in particular are beginning to shift who engages in reef management:

> "Sites and institutions cannot [scale up restoration], right? You're going to have to hand over to…other sectors, let's say commercial engineering and logistical firms that do stuff at scale in the marine environment."
>
> (Participant 11 Government researcher)

Participants emphasized a growing role for the private sector and a subset of the research sector, because government was not viewed as capable of developing and deploying reef adaptation approaches at scale, such as cloud-seeding to shade reefs during marine heatwaves. Overall, the Adaptation Narrative moves the responsibility for action to the local level and calls on new private sector actors in industry and research to scale solutions like restoration up to the regional scale. In contrast, the Mitigation Narrative maintains pre-existing onus for action on the agriculture sector, and strengthens attention to the role of national and international governments and industries associated with contributing to climate change.

4.4.3 Resistance and alignment across levels and sectors

Here I reflect on the differences outlined in Section 4.2 and summarize the ways that governance actors contest one another's perspectives by resisting the Adaptation and Mitigation Narratives. Exposing patterns of resistance to narratives sheds light on some of the enduring barriers to, and potential opportunities for, achieving a coordinated response to crises like mass coral bleaching events. There were four key patterns of resistance between the two narratives.

First, governance actors' explicit resistance to each narrative focused on ecological effectiveness, sense of agency to act at different levels (local to international), and the relative importance of short-term action versus addressing drivers (see Section 4.2). There are thus clear conflicts across temporal and jurisdictional levels driving the division between the Adaptation and Mitigation Narratives. However, it is further evident that actors support the narrative that reflects action at the level and sector where they regularly engage with

reef management. The Mitigation Narrative draws support from representatives of actors at the international, national, and regional level primarily in the research and NGO sectors. Actors operating in government or the tourism sector at the local, state or regional scale tended to express views that align with the Adaptation Narrative. Thus one reason for the emergence of two separate, rather than one shared, vision, is that actors positioned at different levels and in different sectors are seeing the available options for action very differently.

Second, governance actors whose primary role was not related to reefs (e.g. mineral resources, agriculture) resisted solutions focused on modifying their activities. This included solutions related to reducing drivers (e.g. climate change). For example, those upholding the Mitigation Narrative criticized the mining industry on the grounds that although Australia's emissions are low compared to other nations, exporting coal contributes to climate change when it is burned elsewhere. A participant from the mineral resources sector offered the counter argument that while the industry bears some responsibility, agriculture and other industries also impact the GBR. Yet as both the Mitigation Narrative and Adaptation Narrative move to regional stressors like water quality and fishing pressure, cross-sector tensions intensify. Water quality was seen as an opportunity to achieve tangible results by reef-focused governance actors in the NGO, government, and research sectors, but was resisted by those in the agriculture sector. For example, one agriculture representative pointed out that NGOs had used bleaching to "bring the [water quality regulations] conversation back to the public consciousness" (Participant 14). For agriculture professionals, emphasis on water quality in the wake of bleaching events unfairly shifts the burden of action towards local farmers and away from those responsible for climate change at higher levels in other sectors. Cross-sector tensions thus created a pocket of resistance in the few areas where reef-focused governance actors upholding either the Adaptation or Mitigation Narrative aligned (e.g. climate change and water quality as priorities for action), hindering efforts amongst reef actors upholding different narratives to find common ground.

Third, some participants sought to dodge cross-sector tensions by avoiding some solutions altogether. For example, participants from some NGOs and the federal government argued that attempting to stop mining was not worthwhile because this was too divisive, rather

than hopeful, messaging that would therefore fail to inspire change. Similarly, some participants from regional NGOs focused on water quality emphasized best practices for water quality over stricter regulations to avoid alienating the agricultural sector. A similar pattern emerged with discussions of fishing pressure; a few governance actors in government, research institutes, and NGOs pointed out that expanding no take zones ("green zones" in the GBR context) could relieve local drivers of reef change. Yet the few actors who raised this option immediately doubted its political feasibility, citing that political backlash from commercial and recreational fishers after a previous re-zoning effort in the GBR would make additional zoning changes politically infeasible. Avoiding tensions in this way removed certain solutions from the decision-making arena.

Fourth, the majority of participants aligned around the Adaptation Narrative, particularly the portion focused on restoration and geoengineering solutions. This appeared to be because this part of the narrative avoids cross-sector tensions. The emphasis on action on restoration and adaptation is embraced by those tasked with taking action directly related to the reef—management agencies, NGOs, private sector coral restoration firms, research firms, tour operators, and Traditional Owners—*and* by those in the agriculture and mining industry. These activities were perceived to be within reef actors' capacity to act, and implicitly avoided placing the onus for action on other sectors or negatively impacting other actor groups. In addition, some approaches like coral out-planting are new to the region and thus bring new benefits– employment and economic activity–in addition to connecting to reef actors' desire to take action for the reef. Some researchers and NGO professionals resisted the Adaptation Narrative by emphasizing that while there may be benefits to some actor groups, heat-sensitive coral and fish species will lose out if this approach is embraced without drivers being addressed. Some resistors also cited taxpayers as indirectly losing out if the programs fail, given that their money is used to fund them. However, these views remained in the minority. Thus the solutions within the Adaptation Narrative appeared to dominate the decision space, potentially pushing other solutions to the margins.

Lastly, though differences exist between the narratives, overlap in the problem frame and priority solutions narrative components show that the two narratives are not as dichotomous as they first appear. The two narratives resonate with a global debate in the reef management that puts efforts to focus on climate mitigation and efforts to build local

resilience at odds. This conflict was sometimes explicitly mentioned in interviews, with participants rejecting their (simplified) versions of one another's narratives. Yet over the course of each interview, most participants were careful to validate the key concerns of each narrative, even if they ultimately expressed views that resonated more with one narrative than the other. For example, participants whose views reflected the Adaptation Narrative also acknowledged climate change as the ultimate threat to reefs. Meanwhile, some participants whose views resonated with the Mitigation Narrative expressed curiosity about the potential for short-term, site-specific restoration and other approaches promoted through the Adaptation Narrative. Though the dichotomy was reflected in participants' perceptions of each other's narrative, the narrative analysis identified more overlap between narratives than actors themselves perhaps anticipate. This indicates common ground between this subset of high-level governance actors that is otherwise obscured by debates in the academic literature, media, and social media.

5.0 Discussion

Our analysis paints a detailed picture of two dominant narratives that participants constructed, defended, and resisted in the wake of recurrent mass coral bleaching events. Where previous case studies focus on specific leaders that emerge after crisis with a particular vision that comes to be shared across actor groups, this study contributes needed empirical attention to situations where conflicting visions arise. My results uncover the tensions between diverging narratives about the future, reveal differences in how governance actors operating at different levels and sectors respond to and envision the future, and show how the dominance of two major narratives, one of which is more prominent than the other, may marginalize or entirely miss possible approaches to navigating change. This analysis of synergies and tensions between narratives helps to unpack areas of controversy, a critical step towards understanding conflicts that hinder coordinated, multi-level governance of SES (Moser 2012, Van Assche et al. 2022). Here I discuss the implications of these findings for governing coral reefs, and SES more broadly, in the context of climate change.

I approached this analysis inductively to allow dominant narratives to emerge organically, but found that discussions in the GBR region echo a broader global debate about the relative importance of mitigation versus adaptation (Wilbanks et al. 2003, Tompkins and

Adger 2005, Laundauer et al. 2015, Morrison et al. 2022). The Mitigation Narrative and Adaptation Narrative described here reflect the ways this global debate manifests in the marine management community as an argument about the relative importance of addressing drivers like climate change versus implementing novel solutions like coral restoration (e.g. Bellwood et al 2019 vs. Abelson 2020). Researchers have argued for decades that this apparent dichotomy between mitigation and adaptation is false and should be replaced by an approach that integrates both (e.g. Wilbanks et al. 2003, Laundauer et al. 2015). Yet my findings demonstrate that this dichotomy is, unfortunately, alive and well. However, my narrative analysis also gives some helpful indications of why this is so and where progress towards coordination might be made.

Participants in this study and previous studies in the region (e.g. Barnes et al. 2022, Walpole and Hadwen 2022) expressed concern about the intense animosity amongst actor groups grappling with climate change, and voiced a desire for a more coordinated path forward. These findings suggest that efforts to coordinate governance responses to climate change might begin with a narrative that better accounts for the differing needs and concerns of actors across levels and sectors. Participants explicitly framed justifications of the Adaptation or Mitigation Narrative in terms of ecological effectiveness or agency to act (see Section 4.3), yet attention to the role of participants in the region suggests that tradeoffs across both jurisdictional and temporal scales, and across sectors, are also driving divergence amongst participants' perspectives. This was evident in the finding that the Adaptation Narrative resonates with governance actors who represent government, industry, or small NGOs at a local or regional level, whereas the Mitigation Narrative finds support amongst international and national actors, particularly researchers and NGO professionals. This resonates with previous research findings that practical barriers prevent the integration of adaptation and mitigation activities as called for in the literature (Wilbanks et al. 2003). For example, one recognized barrier is that local level actors tend to focus on adaptation whereas actors at higher levels focus on mitigation, and that efforts to integrate the two activities are hindered by lack of attention to tradeoffs and conflicts that occur across levels (e.g. local to national) and sector (e.g. NGO, industry) (Moser 2012, Landauer et al. 2015). This suggests that governance actors might better coordinate responses to extreme climate events by building narratives and taking actions that explicitly

recognize that different balances of mitigation versus adaptation solutions are needed at different levels, and attending to situations where efforts at one level may detract from efforts at another. That participants already offered some acknowledgement of concerns across both narratives, regardless of the one they aligned with most (see Section 4.3), suggests that there may already be at least some appetite for such an approach in the region.

Though an approach more sensitized to the needs of different levels may improve coordination, it is evident that solutions that focus on addressing drivers face additional headwinds from cross-sector tensions, more so than solutions focused on adaptation (e.g. coral restoration). The narrative analysis techniques deployed in this study were developed by scholars seeking to illuminate the ways that different actor groups contest problem and solution frames in order to shift the burden of blame and the responsibility for fixing solutions to one another (Stone 2002, Jones and McBeth 2010). For example, participants from agriculture and mineral resources sectors resisted solutions focused on addressing water quality and climate change, respectively, pointing to the ways in which these efforts are situated within much broader societal concerns in the region. The mineral resources and agriculture sectors are mainstays of the Queensland economy (Hug and Larson 2006). As proponents of the Mitigation Narrative seek to connect regional reef management to the global issue of climate change, reef decision-makers and advisors may be forced to reckon with deeply political questions about the relative importance of different aspects of the regional and national economy (e.g. mineral resources versus the GBR tourism industry), and of the local and regional economic versus international world heritage value of the GBR. Truly coordinated governance requires intentional discussion inclusive of local actor groups to assess cross-sector tradeoffs and future economic opportunities (e.g. mining for metals needed for electric vehicles) for the region in the context of climate change. However, the current preference towards the Adaptation Narrative amongst participants suggest this politically contentious conversation may be avoided for as long as possible, as discussed further below.

Narrative analysis approaches typically assume actors intentionally frame one another as responsible for problems to shift the burden of action on solutions (Stone 2002, Angstadt 2020), but in some cases actors may avoid assigning blame in order to preserve

relationships within their networks (Angstadt 2020). The Mitigation Narrative follows the pattern of assigning responsibility by holding those driving climate change and water quality accountable for action on solutions, but the Adaptation Narrative reflects a pattern of avoiding blame. This narrative's focus on economic opportunities for local and regional action on restoration and adaptation, rather than holding actors in other sectors accountable for reducing drivers, may allow local and regional actors to avoid alienating other actors in their networks and focus on dimensions of action with which they are familiar. This, in combination with government subsidizing these activities through programs like RRAP, may partially explain why solutions promoted by the Adaptation Narrative are proliferating in the GBR region (e.g. Nyberg and Wright 2022, Great Barrier Reef Foundation 2023b), while other solutions are not (e.g. expanding green zones). The dominance of the Adaptation Narrative may also be reinforced by the RRAP program, which has received substantial government funding from Australian taxpayers and emphasizes key elements of Adaptation Narrative in public communications (e.g. the need for stopgap measures until emissions are reduced, and the promotion of adaptive actions like restoration) (Great Barrier Reef Foundation 2023b). The RRAP has come to dominate efforts to respond to bleaching events in the region and may therefore be perpetuating the greater focus on the Adaptation Narrative over the Mitigation Narrative (Lubell and Morrison 2021, Nyberg and Wright 2022). Though participants supporting either narrative shared a view that solutions to address drivers and implement adaptations should be pursued simultaneously, the dominance of the Adaptation Narrative suggests that there is still little appetite for more politically difficult conversations about mitigation and alternative economic pathways. The proliferation of adaptation-oriented solutions that emphasize scaling up novel coral restoration and geoengineering solutions also perpetuates the neoliberal turn in conservation by relying on the private sector for solutions (Fletcher 2020). In the case of the GBR region this involves utilizing government money from taxpayers as well as philanthropic funds to support private sector engagement in solution development. This may bring novel techniques to the table but also further delay needed attention to deeper discussions amongst actor groups about how to mitigate drivers and prepare for coming changes.

Though the Adaptation Narrative is more prominent than the Mitigation Narrative in the GBR region, the dominance of these two narratives together is also obfuscating other

possible approaches to governing in the wake of extreme climate events. Actors in the GBR are strongly considering both mitigation and adaptation, but giving less attention to the possibility of forced or intentional transformation in how coral reefs are managed. When discussing responses to climate change, Tompkins and Adger (2005) once pointed out that "dichotomies can create fractured and biased images of the world and reduce the possibility of finding holistic responses" (p. 563). Research on transformative governance (e.g. Chaffin et al. 2016b), anticipatory governance (e.g. Boyd et al. 2015), climate adaptation frameworks (e.g. Schuurman et al. 2022), and futures thinking (e.g. Munera-Roldan et al. 2022) outline governance approaches that focus on actively anticipating uncertain future changes or even intentionally encouraging expected fundamental shifts in ecosystems. Similar to Tompkins and Adger's (2005) call for "holistic" responses to change, Futures thinking approaches in particular encourage a pluralistic embrace of multiple strategies simultaneously to encourage both creativity and inclusivity in the face of change (Louder and Wyborn 2020, Munera-Roldan et al. 2022). In this study only a few participants supporting the Mitigation Narrative made suggestions about how addressing drivers can assist with navigating reef changes that they considered to be inevitable. In contrast, most participants supporting either narrative were primarily concerned with either halting or reversing change to coral reefs through mitigating drivers or implementing restoration or geoengineering solutions. Additional consideration of the option to direct change may open up new ideas and opportunities for shaping reef futures, especially if pursued by creating venues for the diverse range actor groups to contribute (e.g. Traditional Owners, farmers, fishers, tour operators, concerned citizens). There is a striking need to explore a wide range of interventions that address the root drivers of change (Morrison et al. 2022), while also adapting to the immediate impacts of climate change. Participants in this and previous studies (e.g. Barnes et al. 2022) are already advocating for deeper engagement with Traditional Owners and other local actors, and existing programs are beginning to do this. For example, the RRAP currently engages with a range of actors to gauge interest in novel restoration and geoengineering techniques for resisting change. Future research and practice in the GBR region could expand from this effort to engage a broader range of actor groups with an even broader range of approaches that accept future change and identify potential ways to navigate these changes while minimising, where possible, the social and ecological impacts of transitions to an alternative reef state.

6.0 Conclusion

This case study of mass coral bleaching on the GBR brings empirical attention to the emergence of conflicting visions, rather a shared vision, allowing us to contribute a unique and nuanced analysis of a range of high-level governance actors' differing first-hand perspectives navigating dramatic change in SES. The results and discussion offer suggestions for decision-makers, advisors, and other governance actors seeking to make progress towards a coordinated multi-level and cross-sector governance of SES as the climate changes. While achieving a "coordinated approach" tends to invoke assumptions about the need for a single shared vision, I encourage a tiered and pluralistic approach that broadens the number of options on the table and develops different suites of action appropriate to different levels of action (local to international). This suggestion emerges from the observation that participants representing different levels and sectors appeared to talk past one another, variously justifying proposed solutions based on ecological effectiveness or actors' own sense of agency to act, but failing to account for how their own actual and perceived capacity to take effective action might vary from others based on their position (i.e. level and sector) in the system. I further encourage high-level governance actors to foster open conversations with a broad range of actor groups at the local and regional level that open all possible climate action approaches, and that address directly the differential costs and benefits of different climate action, including cross-sector tradeoffs. This suggestion is based on the observation that solutions to mitigate drivers are nested within broader economic concerns in the region, and thus generated contention amongst participants. Creating intentional venues for candid discussion of the GBR's future and both impacts and opportunities for the Queensland and Australian economy may help to not only uncover additional arenas of conflict, but also unexpected areas of common ground that could generate creative solutions to navigating a climate-transformed future. The Queensland Government may be particularly well-positioned to lead the facilitation of such discussions amongst the diversity of actors it seeks to represent and serve in the GBR region.

As the history of environmental disasters and resilience-based conservation can attest, the best solutions take time and arise through guided albeit organic action, something coral reefs and SES sorely lack in the context of climate change. Nonetheless, high-level decision-

makers and advisors who formally represent different actors in the region are tasked with finding a path forward, and can maximize their chances of finding creative and inclusive solutions through direct engagement with their diverse constituents. I anticipate that future research could also gain much further insight from long term and intentional engagement with this broader range of actors across levels and sectors in a range of SES. A steadfast commitment to engaging diverse actor groups in candid conversations about the future and addressing rather than ignoring conflict is essential for moving past the haze of polarization and controversy that beguiles response to climate change, and towards clear-eyed and pluralistic approaches that invite the best possible future(s) for people and ecosystems.

Chapter 5: Discussion

General Discussion

Through this dissertation I tell the story of a region grappling with the most severe climate impacts to coral reefs this century, and in doing so I broaden and deepen theory on the influence of extreme climate events on environmental governance. Through social network analysis (Chapter 2) and qualitative interviews (Chapters 3 and 4), these chapters document a historic moment in time when individuals and organizations engaged in reef governance first grappled with the highly visible realities of *recurring* climate-driven marine heat waves on coral reefs, one of the many types of extreme climate events affecting SES globally. Coral reefs are especially vulnerable to climate change, and though mass coral bleaching events first occurred in 1998 on the GBR, the recurrence of mass bleaching events in back-to-back years (2016-17) was not expected until much later in the century (Donner et al. 2018). This case thus provides an early example of extreme climate events useful to researchers and governance actors seeking to realize adaptive governance as they navigate climate impacts to coral reefs and other SES.

In telling the story of mass coral bleaching events, this dissertation challenges assumptions underlying previous treatment of crisis in adaptive governance literature, and makes three major contributions to further develop the theory on the role of crisis in shaping adaptive governance. Previous adaptive governance research focused only on crises that lead to changes toward more adaptive governance. Previous research has operated from the normative assumption that a shared vision is necessary for effective governance, and that particular governance actors characterized as "leaders" spearhead efforts to change governance. Here, I first broaden attention from the actions of specific leaders after crisis by a) analyzing organizations' action across entire networks beyond high-level decision-making spaces (Chapter 2), and b) considering the perspectives of a range of actor group representatives within the decision-making space (Folke et al. 2005)) (Chapter 3 and 4). Second, I deepen attention to crises by articulating synergies and tensions between the multiple ways different governance actors envision the future after crisis (Chapter 3), and examining how actors contest or support these different visions (Chapter 4). Third, this research provides an empirical account of the influence of an extreme climate event as a

type of crisis of particular relevance to climate change, providing insight on the challenges SES governance faces as climate change progresses. Through this research, I show the ways in which crisis both does and does not affect governance, depending on what dimension of governance is considered (e.g. networks, individual actors).

My four research questions were:

Overarching Research Question: What are the implications of extreme climate events for adaptive governance of SES in the climate change era?

RQ 1 (Chapter 2): Are there shifts in the topics that receive attention or the organizations that participate in governing a large SES before, during, or after extreme climate events?

RQ 2 (Chapter 3): How do governance actors representing a range of interests in high-level decision-making processes envision the future after extreme climate events?

RQ 3 (Chapter 4): How do multiple emerging visions for the future of the GBR after extreme climate events synergize or come into tension with one another?

In the next section I first reflect on the findings of my data chapters, then respond to my overarching question by synthesizing findings and considering the collective implications of these chapters. A significant contribution of this dissertation is to demonstrate how recently developed theories and methods from strands of research in social network science, political science, and futures-thinking can be utilized to answer these questions and further develop adaptive governance scholarship. The second chapter draws on social network science and political science, while the third and fourth chapters draw on political science and futures-thinking.

Key Contributions and Limitations

The contribution of network analysis: a bird's eye view of governance after crisis
Social network science offers a theoretical perspective that recognizes the importance of interrelationships between organizations or individuals in shaping outcomes for SES (Bodin and Prell 2011, Barnes et al. 2016), and provides analytical methods for examining these relationships. In Chapter 2 I present a network analysis of organizations' attendance at forums to examine whether there are changes in what topics (e.g. water quality) receive

attention and what organizations attend forums (e.g. meetings, conferences, collaboration) before, during, and after crisis. ***The first contribution of this chapter is to demonstrate an empirical method for detecting change or stability in the topics actors focus their energy on, and which actors are included in forums on these topics, across a large SES over multiple years.*** This makes it possible to consider the actions of governance actors in the wake of crisis at a much larger scale than most previous studies, essentially providing a bird's eye view of the activities of hundreds of organizations at numerous forums (n=53-89 annually) across eight years. Focusing on forums brings attention to an important dimension of environmental governance that has rarely been examined when considering the influence of crises (Berardo et al. 2015, Berardo and Lubell 2019). This approach goes beyond the priorities written on paper (e.g. government strategies) or voiced by governance actors (e.g. policymakers, resource managers), to reveal what collective actions are taken or not on the ground, particularly those actions related to collaborating or sharing information through meetings, partnerships, conferences, and jointly implemented reef management or conservation programs, among other forums. This enables analysis of what actually occurs in a system after crisis, and allows me to consider how network-level changes relate to the normative goals of adaptive governance, such as flexibility, creativity, and inclusivity.

Adaptive governance research and the multiple streams of research (e.g. collective action, common pool resources) this body of literature pulls from broadly support the ideas of flexibility, creativity, and inclusivity (e.g. Folke et al. 2005, Huitema et al. 2009, Chaffin et al. 2014), but do not offer widely shared definitions of these normative goals. In this chapter it was not my intention to draw comprehensive conclusions about all the ways governance actors' actions after crisis reflect flexibility, creativity, or support for inclusivity, but more specifically to consider how changes and stability in the GBR governance network may relate to these normative goals. I therefore examined flexibility, creativity, and inclusivity in the context of networks of actors' attendance at forums in the following ways. I considered flexibility as the ability of governance actors to convene at new forums or increase attendance at existing forums. I considered creativity as the potential emergence of new forum topics or changed prioritization amongst existing topics, as indicated by amount of participation. A governance network exhibiting flexibility and creativity might have been expected to show a proliferation of new forums or greater attendance at existing forums on

climate change, restoration, or related topics in the wake of an extreme climate event. In addition, an increase or at least stability in the types of organizations attending forums could have indicated inclusiveness, or at least not a decline in inclusiveness, within the formal sphere of governance as represented by well-documented forums. Limited previous studies have examined the emergence of new forums and extent of attendance at forums after crisis, but the research presented in Chapter 2 is one of the first efforts to consider forum topic and the types of organizations in the wake of crisis. Thus, previous studies have considered the flexibility of organizations to convene new forums, but do not account for the composition of forum topics and attendees, and therefore cannot speak to what the networks may indicate about creativity or inclusivity.

Contrary to previous work by Berardo et al. (2015), I found that in the case of the GBR, there are few new forums emerging in the wake of crises, and these are not more attended than other forums. Berardo et al. (2015) found the escalating frequency of out-of-control swidden fires in Argentina led to organizations in the region re-organizing at new forums focused on the fire events, suggesting that crises can trigger the re-organization of collaborations between organizations. Yet the GBR case indicates that the occurrence of a crisis did not stir the creation of a large number of new forums, or draw greater participation to existing forums focused on bleaching, climate change, or other related topics. In short, the answer to my first research question is "no"—there were not shifts in the topics that receive attention or the organizations that attend forums after extreme climate events. This is particularly striking in light of findings in later chapters that participants' universally agreed that extreme climate events impacted the reef to the point of climate being perceived as the clear number one driver of coral reef decline. The finding of little change in forum topics or participation suggests the flexibility and creativity of governance actors' was limited after an extreme climate event in this case, at least in regard to their ability or desire to organize around new forums. ***This is an important theoretical contribution of the chapter as it provides a useful counter-example to the Argentinian case (Berardo et al. 2015), and calls into question the hypothesis that crisis triggers change in governance networks.*** This raises the question of why crisis can trigger change in organizations' attendance at forums in some cases, but not others. The findings in Chapter 3 and 4 that crisis *did* trigger new activities at the organizational level and new ways of

thinking amongst individual governance actors raises the further question of what change or stability at the network level does or does not imply about the role of crisis in shaping governance more broadly. Does lack of flexibility, creativity, and stable inclusivity in regard to the convening and attendance at forums imply that these normative goals are also not being met more generally, or do governance actors respond to crisis in ways not captured by an analysis of forums? It is difficult to know what changes or stability in a network indicate about governance without qualitative data—this is explored further in the "qualitative insights into network stability" section below.

The contribution of the Pathways Framework: envisioning multiple coral reef futures

In Chapter 3 I articulate the multiple ways governance actors in high-level decision-making spaces imagined the future for the GBR after mass coral bleaching events. The theoretical contribution of this chapter is two-fold. ***First, I expand from previous studies that focused solely on the vision of key 'leaders' to consider the nuanced overlaps and differences in governance actors' visions for what reef futures should look like.*** These actors represent a range of interest groups at the highest level of GBR decision-making (e.g. Reef Advisory Committee, GBRMPA, Independent Expert Panel, etc.), essentially making them all 'leaders' in terms of leading a range of interests beyond the environmentally-focused leaders typically centered in adaptive governance case studies. ***Second, to achieve this I draw on narrative analysis approaches to build consideration of problem frames into existing climate adaptation frameworks*** (e.g. Petersen-St. Laurent et al. 2021, Schuurman et al. 2022), which to date primarily focused on guiding decisions about desired outcomes (e.g. "resist" change) and solutions to achieve this (e.g. restoration). This resulted in my Pathways Framework, which made it possible to see these overlaps and divergences in governance actors' perspectives on the current state of the system, what drives this, what role management should play in addressing it (i.e. how intensive should interventions be?), and what the ultimate aim of reef management should be. By examining multiple actors' perspectives and using this data to develop the Pathways Framework, I advanced understanding of how governance actors react to crisis within resilience-based governance scholarship while simultaneously responding to calls to advance climate adaptation frameworks (e.g. Schuurman et al. 2022).

A key empirical finding of this chapter is the clear indication that the experience of mass coral bleaching events has fundamentally transformed the way many governance actors are thinking about present threats and future realities for coral reefs, but it has triggered the emergence of different visions amongst different actors. As previously discussed, climate change has risen to the top of participants' list of threats to the reef post-bleaching events. In addition, many participants expressed doubt about current reef management approaches and some questioned the deeper purpose of management in the context of climate change. These doubts and questions are apparent in governance actors' abandoning the "natural return" pathway for reef management because it relied on the now-doubted assumption that reefs can "bounce back" once anthropogenic drivers of decline are removed. This rejection of a previously dominant approach to reef management is a notable impact that extreme climate events have had on governance actors. Yet from there, participants diverged on whether the best way forward is to hold on to the goal of restoring reefs to at least close to what they were (i.e. assisted return), to try to retain at least some key sites, or to accept that some or even much change is coming and to attempt to mitigate drivers and steer towards the best possible option(s) amongst emerging reef futures (i.e. direct transitions). In short, the answer to my second research question is that governance actors envision multiple futures in the wake of crisis, and that these visions overlap or diverge depending on what aspect is considered (e.g. problem frame versus desired outcome).

The contribution of narrative analysis: deconstructing the adaptation-mitigation dichotomy to better coordinate coral reef futures

In Chapter 4 I describe dominant narratives that underlie governance actors' perspectives on how the GBR should be managed after mass coral bleaching events. In this chapter I dive deeper into the tensions between governance actors' perspectives by turning attention to questions of "who" is affected in different ways by the different visions for the future. I focus on two dominant narratives that emerged amongst participants—the Adaptation Narrative and Mitigation Narrative. These narratives give less nuanced attention to differences in "what" actors envision (as in Chapter 3) in order to illuminate how different governance actors uphold or resist different narratives in the wake of extreme climate events. ***The contributions of this chapter are to: 1) illustrate the utility of narrative analysis for articulating similarities and differences in governance actors' views of 'who' is***

responsible for problems and solutions, and 2) uncover the cross-level and cross-sector conflicts at the roots of the divergence amongst governance actors after a crisis (rather than convergence on a shared vision or at least coordination across visions). Where adaptive governance theory to date has recognized the potential of crisis for catalyzing collaboration (Chaffin et al. 2018) or improved bioregional fit (Olsson et al. 2008), this case illustrates the ways crisis can cause division. Understanding conflict within SES is essential for understanding the realities of navigating climate-transformed futures in SES and identifying the barriers to more coordinated cross-sector and cross-level responses to change.

The narrative analysis approach allowed me to break dominant stories about reef futures into separate components—problem frame, solution frame, problem attribution, justification for solutions, and responsibility for solutions—making it possible to identify greater overlap between governance actors' collective visions for the future than expected in regard to problem frame, while also exposing possible reasons for differences based on problem attribution, justification for solutions, and who is considered responsible for implementing solutions. Analyzing how solutions were justified and who upheld or resisted which solutions revealed that differences between the two narratives stemmed at least in part from diverging views shared by governance actors from different sectors (i.e. industry, NGO) and levels (e.g. local, state). While the apparent mitigation-adaptation dichotomy is long-standing in SES governance (Moser 2012, Landauer et al. 2015), as are failures of cross-sector and cross-level coordination (Cash et al. 2006, Cumming et al. 2006, Huitema et al. 2009), this case illustrates that extreme climate events exacerbate these tensions rather than serve as a reason to overcome them, but also points to how tensions might be addressed. Overlap in problem frame and agreement that solutions must address drivers indicates the dichotomy is less distinct than participants' themselves may have expected. Tensions over the effectiveness versus feasibility of different solutions emerged amongst governance actors focused on reef issues at different levels. Simultaneously, tensions across sectors arose where narratives emphasized reducing drivers of change, illustrating the ways in which reef management concerns affect the agriculture and mineral resources sector, and vice versa. Thus, dissolving the mitigation-adaptation dichotomy and finding a coordinated path forward requires narratives that account for how actors' self-perceived capacity to act

differs across levels, and what the tradeoffs will be across sectors to achieve different possible reef futures.

Qualitative insights into network stability

A limitation of the network approach is that it can detect change or stability but cannot provide qualitative insight into the meaning of that change. Consider the observation that there was no serious re-organization around new forums or topics in the wake of bleaching events. Does this mean that new topics, such as coral bleaching or climate change, were not addressed at all? Or, were these topics addressed at existing forums, particularly management forums that tend to cover multiple topics (noted as "multi-issue" forums in the network analysis)? The network data tells the important story that there was no grassroots-style wave of action on climate change amongst reef actors widespread enough to receive region-wide attention, but cannot confirm or deny that actors took no action whatsoever. Why the governance network was stable, and what the stability in participation and topics may mean, can start to be explored only by considering forum documentation alongside subsequent interview data from Chapters 3 and 4. These interviews were not intended to be representative of all of the organizations in the network presented in Chapter 2, but do provide useful context regarding governance responses to the recurrent bleaching events. Participants were those who actively make or advise on region-wide decisions about the GBR and thus interviews provide insight into regional priorities in the wake of the bleaching events. Here I draw on interview and network data to consider the question of why crises trigger the emergence of new crisis-related forums in some cases but not others, and what stability or change in networks implies about how extreme climate events shape governance. Qualitative data can shed light on several possible reasons why the GBR network appeared stable in the wake of crisis:

- Governance actors may have responded to extreme climate events within existing forums or within individual organizations
- Governance actors may have responded to extreme climate events by creating small or poorly documented forums not detectable through document-based data collection
- Governance actors may have taken no action in response to extreme climate events

Regarding the first possibility, different data collection methods may reveal different dimensions of the network, so it is possible different methods miss or reveal some aspects of change but not others; change appearing to occur in one system but not another could be the result of methodological choices, not the reality of what occurred. As established above, governance actors formally represented in reef governance, who also attend documented forums like the Reef Advisory Committee, point to the use of existing forums within the formal dimension of GBR governance. But what might have occurred in more informal, grassroots dimensions of reef governance? The GBR network data was based on a review of documents and websites to map extremely large networks with many forums (n=53-89 per year), whereas the Argentinian network data was gathered from surveys of participants in a relatively small governance network (n=5-8 forums per year). The benefit of document-based data collection is the ability to construct large networks where a survey method would not be feasible, as when mapping large SES at any time, but especially during global emergencies that make travel and requesting survey participants' time difficult (i.e. COVID-19 pandemic). The document-method made it possible to collect timely data in the wake of bleaching events despite global circumstances. Small local-level forums were also excluded to keep the scope feasible (though here a survey method would face the same challenge due to the large number of forums). However, the risk is that the document-method misses poorly documented or informally convened forums, which survey methods may pick up. For example, it may not detect climate activists convening to protest fossil fuels in the wake of mass coral bleaching events, or reef NGOs meeting quietly to coordinate climate campaigns or restoration programs initially away from the public eye. The network data shows that there was no grassroots-style wave of action on climate amongst reef actors that was significant enough to receive region-wide attention. In addition, interviews conducted for this dissertation, and for preliminary work preceding this dissertation (Barnes et al. 2022), reinforce the notion that no region-wide grassroots actions occurred within the reef management and conservation space. Interviews revealed planning for restoration programs like RRAP occurred in the wake of bleaching events, but not for large-scale climate campaigns within high-level decision-making spaces in the reef sector. A few participants in government and NGOs reported grassroots level activities such as expanding citizen science approaches to reef monitoring, but noted that this was a standing priority more than an action taken directly in response to bleaching.

Regarding the second point, the structure of different governance systems varies across different contexts and may affect governance actors' ability or desire to create new forums or prioritize new topics. That one system may lack flexibility compared to another is not inherently "bad" but does have implications for how crisis impacts a governance system. Governance actors in a loosely structured system may choose to address a crisis through new forums, whereas governance actors in a highly stable system may choose to address crisis by introducing new activities at forums they already attend. For example, the Argentinian network study by Berardo et al. (2015) involved largely bottom-up engagement by NGOs in addition to government institutions, and this network of actors responded to crisis by re-organizing around new forums. In contrast, the GBR governance system is tightly structured around strong and longstanding national and international institutions (Morrison 2017) and governance actors did not respond to crisis by creating many new, well-attended forums. In the GBR context, limited documentation of forums such as the Reef Advisory Committee indicated that representatives at those meetings felt their existing committee and the Reef 2050 strategy that guides reef management was the best place to address the issue of climate change after the mass coral bleaching events of 2016-2017. Interviews conducted for this dissertation strengthened evidence that governance actors did indeed choose to respond to mass coral bleaching events within existing forums or individual organizations. Participants described the value of the existing Reef 2050 forum as a venue for addressing all issues related to the reef, including climate change. They also reported actions they took within their organizations (e.g. developed GBRMPA's statement on climate change) and occasionally in collaboration with other organizations (e.g. implementation of the RRAP). Thus, the mass coral bleaching crisis affected organization level action but did not dramatically change the configuration of forum-actor networks.

Relating to the third point, it is clear from interviews that governance actors responded to mass coral bleaching events but not through the creation of new forums, in most cases. The combination of network analysis and interview data indicates that networks can remain stable after crisis, which has several implications for understanding how extreme climate events influence the effectiveness of environmental governance in the context of climate change. Collaboration amongst organizations and individuals is a fundamental dimension of environmental governance (Armitage et al. 2009, Ostrom 2010, Berardo et al. 2015).

Insights from this research indicate that crises do not always change the patterns of collaboration in governance networks, even if the events do catalyze change within organizations. If existing forums are viewed as equipped to deal with crisis events, it may be that the venues at which governance actors convene to forward their priorities, share ideas, and coordinate responses remain stable (Berardo et al. 2015). The way actors organize themselves (i.e. social organization) is a key element of their adaptive capacity to respond to change (Bodin et al. 2006, Cinner and Barnes 2019). Berardo et al. (2015) point out that if actors re-organize around new forums after crisis, their coordination to address an emerging issue may improve. It follows that the stability of GBR networks suggests the ability of actors to coordinate to address emerging issues, and therefore govern effectively, was similar to what it was prior to the event. The impact of mass bleaching on this and other domains of adaptive capacity is explored qualitatively in Barnes et al. (2022). Governance actors' faith in existing forums, and the resulting stability in patterns of coordination after bleaching events, is important to consider alongside interview findings. This dissertation illustrates that tensions over multiple emerging visions for the future are rooted in cross-level and cross-sector conflicts, which suggests that problems of coordination remain one of the biggest barriers to effective governance. This raises the question about whether new forums are indeed needed to improve coordination or, alternatively, new activities to improve coordination can be incorporated into existing forums. This is discussed further in the "Future Directions" section.

Lopsided implementation: the prevalence of adaptation

Many study participants suggested that a tiered response that embraces multiple approaches (i.e. mitigation, adaptation) at multiple levels is necessary to successfully steer coral reefs through climate change. Futures thinking and adaptive governance literature further emphasizes the importance of developing multiple management options aimed at not only mitigating, resisting, or adapting to change but also directing change (Chaffin et al. 2016b, Munera-Roldan et al. 2022, Alexandra et al. 2023). Achieving a mix of adaptation, mitigation, and directed transformation requires first understanding which approaches are gaining traction or not, and why this is so. My chapters offer some insight but also raise new questions on this point.

It is evident from this dissertation that governance responses to mass coral bleaching disproportionately focus on adaptation, despite participants' own expressed wishes to simultaneously address both adaptation and mitigation. Of the few new forums arising in response to bleaching events, only five explicitly focused on bleaching and climate, and most were short-lived (i.e. collaborations to survey bleaching and share results). In contrast, seven focused on restoration and most persisted for several years or more; one of these forums was the ongoing and well-funded RRAP, indicating the strength of adaptation efforts in the region. Narrative analysis of what actors envisioned for the future (Chapter 3) similarly revealed that the majority of participants tended to emphasize pathways focused on resisting change (e.g. "retain key sites" and "assisted return"), which related directly to the popular Adaptation Narrative (Chapter 4). This pattern is not unique to the GBR—reef restoration and adaptation are proliferating globally (e.g. Global Coral Reef Alliance; Van Oppen et al. 2015, Kleypas et al. 2021). The justifications for the Adaptation Narrative offer some explanation for why this approach is so popular amongst reef actors—adaptation relates directly to their desire for tangible action that builds hope and falls within actors' perceived capacity. The growth of adaptation is not surprising in the wake of catastrophic bleaching events that clearly shocked local level actors (Marshall et al. 2019, Barnes et al. 2022), inspiring a desire to take immediate action. However, without parallel efforts to mitigate drivers of change and direct anticipated change, participants emphasized that adaptation efforts will fail. Additional research and practice-based efforts are needed to ensure all approaches are being implemented (see Future Directions). This includes attention to the power dynamics associated with who supports or resists each approach, and who may benefit from perpetuating only adaptation approaches, as discussed further in the next section.

The promise and peril of growing private sector engagement

A debate about *who* should govern reefs (Chapter 4) was embedded in the debate about *what* governance goals and activities should be pursued (Chapter 3). Specifically, the role of the private sector and the government in reef governance was an explicit point of discussion amongst many study participants, and was ingrained in the argument about adaptation and mitigation. Participants were skeptical about ability of government to address the fall out of extreme climate events like bleaching, as well as the longer-term impacts of climate change.

Doubts were raised by researchers, some in NGOs, and even by some in government, that the federal government could respond quickly enough to study bleaching impacts, which requires mobilizing substantial resources (e.g. funding, researchers, infrastructure) in a short time frame. These participants suggested researchers and NGOs may be better placed to take action. Simultaneously, NGO advisors, some researchers, and some in government, also raised the concern that government simply did not have the expertise or resources to implement adaptations at the regional level (e.g. scaling up restoration), and that the private sector could do a better job.

Participants often raised (without prompting) the observation that the RRAP program is intentionally bringing in corporate partners. This program partners with corporations and is administered through the Great Barrier Reef Foundation, which also includes board members from corporations like General Electric, Qantas, and Origin Energy Limited, as well as from backgrounds in climate action (e.g. Net Zero Australia) and reef management (e.g. GBRMPA) (Great Barrier Reef Foundation 2023a). Participants focused on adaptation raised this as a shining example of "corporate social responsibility", conceiving of corporations as leaders in innovation (e.g. research and development firms engaged in coral restoration), and as influencers capable of turning public attention towards emissions issue (e.g. participants gave the example of Qantas' funding of restoration and embrace of carbon offsets (Qantas Group 2023)). Yet some participants, particularly researchers, derided corporate engagement as "green-washing". Definitions of both terms vary, but corporate social responsibility generally involves private sector actors making ethical commitments to improve the quality of life of communities and the environment while also developing the economy (Dahlsrud 2008); in contrast, green-washing generally refers to companies that negatively impact the environment while publicly communicating that their actions are having a positive impact on the environment (de Freitas Netto et al. 2020). Opponents of corporations in the GBR region would sometimes equate any restoration and adaptation activity to greenwashing, while some governance actors representing local and regional actors offered the retort that rejecting corporate engagement is to miss a critical opportunity to use their influence and expertise to shift public opinion away from fossil fuels, while also robbing reef actors of employment opportunities and any sense of agency

over reef outcomes. In essence, this debate was tangled up in the issues of perceived agency, hope, and effectiveness of mitigation versus adaptation approaches.

Here it is not my aim to pick a side, but to raise the opportunities and risks associated with the shifting landscape of actors engaged in reef governance. The retreat of government and rise of the private sector is prevalent in environmental governance more broadly (Lemos and Agrawal 2006, Bixler et al. 2016). Government institutions in democratic settings provide stability and transparency (Craig et al. 2017), but government has shifted to a less central role in environmental governance as more polycentric approaches (nested and overlapping decision-making) have emerged alongside concepts of networked governance (Lemos and Agrawal 2006, Ostrom 2010, Bixler et al. 2016, Morrison 2017, Tosun and Schoenefeld 2017). Yet this networked governance approach comes with its own set of risks, including the risk of what Bixler et al. (2016) label "corporate capture" and "philanthropic capture", in which corporations and philanthropic organizations override the interests of other SES governance actors (e.g. community groups, NGOs) as they seek to forward their own objectives (Bixler et al. 2016, Pascual et al. 2022). *My narrative analysis contributes evidence that mass coral bleaching events are reinforcing a shift away from government and towards the private sector, making questions about the potential positive and negative role of corporations of immediate relevance to coral reef management*. Critical analyses are needed to investigate the promise of corporate social responsibility, and the risk of green-washing, in responding to extreme climate events in the GBR and other SES more broadly.

True corporate social responsibility could take the form of supporting the development of a tiered approach to reef management through open futures-thinking exercises to determine desired suites of adaptation, mitigation, and transformation actions at different levels, including mitigation at the national and international level. In contrast, greenwashing might look like supporting adaptation efforts while simultaneously supporting further development of fossil fuels, as the Morrison Administration did while also rolling out funds to the Reef Trust Partnership (Morrison et al. 2020b). With coal as Australia's second largest export, and Australia as a global leader in coal exports, this conflict is unlikely to disappear (Cunningham et al. 2018, Saint-Amand et al. 2022). The roll out of programs like the RRAP can support adaptive action desired by many study participants, but effort must be taken

within this rollout to avoid leaving a public impression that the reef can be fixed without mitigation. Corporations or governments that simultaneously support adaptation and fossil fuels, and that perpetuate a public narrative that reefs can be fixed without mentioning mitigation, are taking advantage of local and regional actors' desire to take action. They are encouraging these actors to protect their SES while in reality pursuing the opposite goal — the perpetuation of status quo dependence on fossil fuels as the GBR and SES globally continue to degrade (Morrison et al. 2022, Nyberg and Wright 2022). Perpetuating the debate about mitigation and adaption stands to benefit the fossil fuel industry by driving a wedge between reef governance actors. If reef actors are divided, they are not able to form a coalition powerful enough to pressure governments or industry to reduce emissions and adopt renewables. This underscores the importance of future research to develop means of differentiating the roles of different types of organizations and the positive or negative influence they have on achieving effective governance of SES in the Anthropocene (see Future Directions).

Limitations & Future Directions

There are several limitations to this thesis that point to future directions for research. There are also findings from this thesis that raise new questions for research. I briefly summarize these limitations here before elaborating future directions for research. *Italics* indicate topics that are further elaborated in the below subsections discussing future research directions.

Key limitations of this study include:

- I focus on one type of extreme climate event, but it is possible that different types of extreme climate events affect SES governance differently. Events that pose immediate or imminent harm to people (e.g. wildfires) may catalyze a more dramatic response than events like bleaching that directly harm ecosystems but not people. Future research might *compare the impacts of different types of extreme climate events* on environmental governance in both terrestrial and marine SES.
- This study focuses on the impacts of an extreme climate event on SES governance but does not investigate impacts on climate governance, or interactions between these two spheres of governance. It is possible that these events also had an impact

on climate governance, and that interactions with climate governance could cause challenges or opportunities for reef governance that are yet to be explored. Future research can further investigate *coral-climate governance connections.*

- The narrative analysis in this dissertation describes the views of high-level decision-makers and their advisors. This excludes the views of most local level actors, which can often differ from those formally engaged in state, national, and international governance (Leach and Fairhead 2002). Future research and practice can *extend the futures-thinking approach* to other coral reef governance actors.

Key findings that raise further questions for future research include:

- Extreme climate events affected reef governance differently at different levels, with little change in region-wide networks but substantial change in governance actors' priorities for the future. Additional research can *investigate interacting impacts across different dimensions of governance* (e.g. region-wide networks vs individual decision-makers vs state policies)*.*

- Adaptation is prevalent amongst responses to extreme climate events, but efforts to mitigate drivers and plan for future change are more limited. *Elevating futures-thinking* in practice may provide opportunities for broadening options for reef management in the context of climate change.

- Participants raised a strong disconnect between climate action and action for reefs. Research and practice-based efforts could focus on finding means to *build stronger connections between climate and coral reef governance.*

- Interview findings identify the beginning of a shift towards increased engagement of the private sector in reef adaptations, though the network analysis suggests that this shift is yet to occur at scale or is occurring through other avenues not visible in this analysis (e.g. funding streams). The outcomes of this shift for the GBR, and particularly the benefits and drawbacks of private sector growth requires empirical investigation. This can *strengthen reef sector coalitions while avoiding capture* by outside interests.

Compare the impacts of different types of extreme climate events on different SES

The type of extreme climate event that impacts an SES may affect the networks of actors it potentially activates and the degree of immediate response by governance actors generally. Birkland (1998) pointed out that crises are likely to trigger a response when they pose the threat of immediate harm to people. In the Argentinian case, fires were exacerbated by a drought related to climate change, but the connection to climate change was far less direct than with mass coral bleaching events; the fires may have triggered a response within the SES because they posed an immediate danger to both ecosystems and people in the region (Berardo et al. 2015). In contrast, mass coral bleaching events are distinctively climate-related events, and do not pose a threat of immediate physical harm to people though they do have consequences for ecosystems and can have longer-term impacts on livelihoods (e.g. Bartelet et al. 2022). Extreme climate events that are easily attributed to climate change (e.g. bleaching events) may be more likely to catalyze action in the climate governance sphere rather than in any particular SES governance system, because in some cases climate actors may see the events as a more direct threat. *Future research should compare network-level responses across different networks (e.g. climate governance vs specific SES governance), across different types of extreme climate events, and across different types of SES. This could build a more comprehensive picture of how extreme climate events might impact SES governance, and particularly climate responses within SES governance*.

Investigate interacting impacts across governance dimensions

It is evident from this thesis that the same crisis can change some aspects of environmental governance at some levels (e.g. local, national) while not changing other aspects at other levels. Considering the findings that mass coral bleaching events do not dramatically shift organizations' attendance at forums, but do shift the concerns of individual governance actors' who represent the views of different actor groups. Thus, the answer to the question of whether or not crises change governance depends on what part of the SES is considered. Despite this, governance studies typically only focus on one dimension of governance (e.g. networks (Berardo et al. 2015), policy-making (Birkland 1998), strategy development (Olsson et al. 2008, Chaffin et al. 2018)) at a single level (e.g. national policy-making arena (Nohrstedt et al. 2021), region-wide networks (Chapter 2)). Given that environmental governance is broadly conceived to include decision-making and influences on decision-

making; ranging from civic protests and policy-making, to strategy development and collaboration across networks of organizations, among other activities (Lebel et al. 2006, Lemos and Agrawal 2008); *investigating crises across these multiple dimensions can paint a fuller picture of the role of crisis in shaping governance*.

Utilizing both a social network approach and qualitative interviews in such an analysis can develop an understanding of where change does or does not occur in a governance system. This mixed methods approach can also consider how the influence of crisis on one aspect of governance might augment or hinder its impact on another aspect, or even how different aspects of governance might be intentionally aligned to leverage change in the wake of crisis. For example, if a crisis changes the topics that actors collaborate around, does this build momentum for policy changes? Or, if a crisis catalyzes policy change does this lead to collaboration around new issues or hinder efforts to coordinate around existing priorities? In the context of the GBR, some participants in the water quality sector interviewed for Barnes' et al. (2022) study of coral bleaching responses suggested that bleaching events catalyzed the Queensland Government to take a tougher stance on regulations aimed at agriculture runoff (Barnes et al. (2022) included as Appendix A). Participants in Natural Resource Management organizations noted that more stringent regulations caused some distrust between farmers and conservationists, and thus hindered efforts to engage farmers in conservation programs focused on agricultural best practices for improving water quality. In this case, other participants contested the idea that bleaching triggered new regulations, citing pre-existing pressure from the World Heritage Committee as the reason for new regulations. Regardless of the reality, this discussion illustrates the ways in which reaction to crisis in one dimension of governance (e.g. law-making) could potentially interact and detract from (or reinforce) reactions to crises in other dimensions (e.g. collaborative action). Studies such as Di Gregorio et al. (2019) have begun to explore such interactions, finding that local and national level interactions can hinder efforts to simultaneously pursue mitigation and adaptation. Interactions between different dimensions of governance will vary with context across SES; empirical attention to mutually beneficial or mutually destructive interactions in a given SES may help to catalyze more coordinated responses within a given context.

Addressing the climate-coral coordination conundrum

Problems of coordination are reflected in the perpetuation of the mitigation-adaptation dichotomy after extreme climate events, which is rooted in cross-level and cross-sector tensions between governance actors. Moving beyond this dichotomy and the tensions that come with it is essential for realizing a coordinated path forward for the GBR and other SES globally. It is evident from interviews and the findings of my chapters that the biggest hurdle for navigating the future of reefs is the need to connect coral reef governance with climate change governance in meaningful ways. This resonates with broader concerns about disconnects between climate change and local actors in SES more generally (Birkmann and von Teichman 2010, Jasanoff 2010, Di Gregorio et al. 2019). The combined insight of social network analysis and narrative analysis indicates three major challenges to connecting SES and climate governance.

The first challenge is to develop a tiered approach that adequately addresses both adaptation and mitigation needs. This must avoid alienating actors working at different levels from one another, and must give sufficient attention to the real cross-sector tradeoffs that will affect the livelihoods of thousands in both positive and negative ways. The second challenge is to intentionally build bridges between SES governance and climate change governance in terms of both policy and the interweaving of professional networks. In the context of the GBR, several participants who worked at the intersection of coral reefs and climate change shared that they felt relatively isolated at this intersection, and emphasized the need to build these connections. The third, perhaps less obvious challenge, is to prevent fissures within a given SES governance network from being widened and exploited by those in other sectors whose top priority is *not* the perpetuation of strong and mutually beneficial people-nature relationships. Doing so requires meeting the first two challenges, as well as giving substantially greater analytical attention to the positive and negative potential role of different types of organizations in SES governance—this is discussed further below. This thesis demonstrated the disconnects between actors and the types of fissures that are at risk for exploitation in the GBR SES, but any SES facing extreme climate events and longer-term climate impacts are likely to face similarly troublesome disconnects and fissures between actors (Stone 2002, Bixler et al. 2016, Morrison et al. 2019). The following

subsections discuss options for meeting these three challenges for connecting SES and climate governance.

Elevating futures-thinking in coral reef governance

The descriptions of differing visions for coral reef futures in my chapters understate the vitriol between governance actors in the GBR region. Efforts to forward specific pathways or to advocate for adaptation or mitigation are met with resistance, which was described by participants as including deeply personal attacks at times. This makes any effort to coordinate multiple paths forward or to find common ground, including the writing of a dissertation like this one, a difficult and intimidating endeavor. Yet intentional, open, and iterative conversations about the future are exactly what are needed to move SES governance forward in the Anthropocene in the GBR region and elsewhere. These conversations must be held not only amongst high-level decision-makers but also amongst the many local actor groups affected by decisions, for both ethical reasons and because this may bring new ideas to the table (Leach and Fairhead 2002, Armitage et al. 2009). Human cognition and imagination are recognized as key dimensions of actors' capacity to realize effective governance in the face of change (Chaffin et al. 2016b, Cinner and Barnes 2019, Alexandra et al. 2023). There is a growing number of tools aimed at unlocking this human potential to imagine new futures. These tools are under development by both researchers and practitioners and include climate adaptation frameworks (Petersen-St. Laurent et al. 2021, Schuurman et al. 2022), foresight planning exercises (Vervoort and Gupta 2018, Pereira et al. 2019, Muiderman et al. 2022, Alexandra et al. 2023), and other anticipatory approaches developed in SES outside of coral reefs. For example, the RAD framework was developed by practitioners seeking ways to manage climate change impacts in national parks, national forests, and wildlife refuges across the United States and Canada (Schuurman et al. 2022). Across the world, Vervoort and Gupta (2018) examined the policy implications of foresight processes in which governance actors engage in scenario-planning to steer toward sustainable food futures in Europe and Africa. The proliferation of futures-thinking tools and theories indicates the readiness of research and management professionals to embrace these approaches, despite the relative paucity of use of these tools in the realm of coral reef management.

My thesis demonstrates the relevance of futures-thinking approaches to coral reef governance through applying climate adaptation frameworks (Petersen-St. Laurent et al. 2021, Schuurman et al. 2022), and conducting narrative analysis (Stone 2002, Warner 2019). Climate adaptation frameworks present governance actors with a reasonably simple set of options for responding to change. The Pathways Framework I developed lays the groundwork for explicit conversations about differing views on the current needs of SES, desired outcomes for SES, the role of management in getting there, and the specific solutions to be implemented. This dissertation starts a conversation in reef SES space that desperately needs to be continued if reef governance actors are to meet coming changes to reefs with their eyes open and their management tools ready. At the same time, the developments offered in the Pathways Framework can also be applied back to other types of SES. However, although there are growing calls for truly inclusive and participatory futures-thinking exercises in SES governance (e.g. Vervoort and Gupta 2018, Rutting et al. 2022), this require resources, time, and energy from governance actors to host and attend workshops, and to develop the outputs of these workshops (Pereira et al. 2019). This will not happen unless key organizations like governments and NGOs recognize the importance of planning for the future by hosting such inclusive workshops.

Though futures-thinking approaches can be useful to many SES, there appears to be a particular gap in applying them in coral reef settings. Finding a way to take futures-thinking approaches to key actor groups in the GBR region can set a useful example for other coral reef SES to learn from. In this region, organizations capable of hosting futures-thinking workshops might include the GBRMPA, the Reef Trust Partnership, and the Great Barrier Reef Foundation, among others. This would require the creation of new forums, or expanding space within existing forums (e.g. Reef 2050 advisory bodies and regular planning meetings) to conduct exercises that open up multiple possibilities for reef futures; the Reef 2050 plan is intentionally focused on building resilience and resisting change to meet World Heritage standards (Commonwealth of Australia 2018, 2021). However, the 2021 revision of the plan places a greater emphasis on climate change and the possibility that full restoration of the GBR to its historic state is unlikely, laying the groundwork for more expansive futures-thinking exercises (i.e. greater consideration of directed transformation) (Commonwealth of Australia 2021). In this context, inclusive workshops could be a means of planning for the

future while also mending relationships that have been frayed by conflicts over initial reactions to mass coral bleaching events. Hosting a meaningful number of iterative workshops across a large SES requires substantial political will and funding, but the GBR governance regime has already laid the groundwork. Examining this groundwork lends insights into mechanisms for enabling futures-thinking that may also be possible to employ in other SES.

In the GBR and globally, the World Heritage Committee can wield strong political pressure on national governments seeking to keep their World Heritage sites off the in-danger listing (Morrison et al. 2020b). This committee is currently itself under pressure from international NGOs and researchers to consider the relevance of a nation's climate policies to the "in danger" status of World Heritage sites (discussed further below) (Carter and Thulstrup 2022). The committee already recognizes the creation and execution of regional management strategies like Reef 2050 as valuable management actions. As the committee grapples with adapting World Heritage management to the realities of climate change, counting efforts by governments to initiate and implement futures-thinking activities could provide a powerful political incentive that unlocks funding to enable SES governance actors to be proactive rather than reactive in the face of change. Similar questions of how SES governance regimes will grapple with climate change are being raised in other systems. For example, parties to the Ramsar Convention on Wetlands are questioning whether wetlands can maintain their status as sites of international value in the context of climate change, and researchers are encouraging the convention to expand its conservation approaches as a result (Bridgewater and Kim 2021). This illustrates the potential value of international conventions for building political support (or pressure) for building futures-thinking approaches into SES management.

The Australian Government has already demonstrated its willingness to pour millions of dollars into reef management to protect the GBR in response to World Heritage threats to list the reef as "in-danger". This funding, distributed through the Reef Trust Partnership, supports efforts to improve water quality, and experiment with restoration and adaptation activities. The RRAP receives a large portion of this funding, and is already engaging in conversations with a diversity of local reef actor groups to understand different perspectives on the values or risks of restoration and how this does or does not fit into their ideas about

reef futures (RRAP 2023). Thus, the program forwards the ideals of the Adaptation Narrative but also sets some precedent for potentially broader conversations about reef futures. Similarly, the GBRMPA has started the conversation about the future of the reef through a workshop which led to the creation of the Blueprint for Resilience, with the intention of iterative updates (GBRMPA 2017). The first version emphasized the need to build resilience through water quality, crown-of-thorns removal, and restoration and protection activities to build the resilience of priority reefs (GBRMPA 2017); future iterations could be developed through workshops that include other pathways for the future of the reef. Government funding, potentially incentivized through World Heritage, could open the conversation to multiple options for reef futures that include mitigation, adaptation, and directing anticipated change. This could be done through the Reef Trust Partnership and/or the GBRMPA. This would be a concrete step towards building a more coordinated response to climate change. These suggestions are specific to the GBR, but illustrate more generally the opportunity to build futures-thinking into existing structures and processes into other SES. Wherever possible, integrating this approach into established decision platforms and processes may help to minimize additional resource needs while bolstering existing endeavors within a given SES.

Building coral-climate governance connections

As climate change accelerates globally, global climate drivers become central to the dynamics shaping local and regional SES, thereby exacerbating problems of fit. As discussed in the introduction, a normative commitment of adaptive governance is to support governance actors to address problems at all relevant levels (Cash et al. 2006, Chaffin et al. 2014). Therefore, the impacts of climate change underline a need to connect SES governance to climate governance. No one set of governance actors in any given SES can single-handedly address the root causes of climate change. Many participants expressed that climate action and activism is essential for the future of reefs, but perceived these actions to be outside the jurisdiction of most reef organizations. If bridges are not built to allow actors across different SES to collectively draw the connection between SES degradation and the root cause of climate change, the transformation of SES towards states unintended and usually undesirable by governance actors dependent on maintaining existing SES functions will continue, and governance actors will continue to feel a lack of

agency to make change. Five study participants—three from separate NGOs, one from the Queensland Government, and one in research—worked specifically at the coral reef-climate intersection and discussed the connection between climate action and coral reef governance. The experiences of these governance actors point to several ways actors in coral reef SES are positioned to begin building bridges to climate governance efforts. The bridge-building actions of reef actors also indicate options for building connections between climate change and other SES, discussed further below.

One participant with legal expertise shared that mass coral bleaching events can be attributed to climate change more easily than with other events because of the clear connection to sea temperature as the main driving factor. Improvements in attribution science (the science of connecting extreme weather with human causes (e.g. emissions)), are anticipated to become useful for climate litigation (Marjanac and Patton 2018). In the legal sphere, climate attribution science is expected to be used to build causal connections between certain actors actions (or lack of action) (e.g. government or private parties) and extreme events. At the very least actors may be held accountable for not preparing to reduce harm from events that will now be "demonstrably reasonably foreseeable" (i.e. events made predictable by climate and attribution science); legal action may also be taken to attempt hold specific actors accountable for emissions (Marjanac and Patton 2018). As described by the study participant, coral bleaching is at the forefront of efforts to link attribution science with climate litigation (Herring et al. 2018, Marjanac and Patton 2018). Attribution scientists are now releasing annual reports of extreme events attributable to climate change in many other SES, ranging from severe droughts in Africa across 2015-2016 (Herring et al. 2018), to floods in California in 2015 and 2016 (Herring et al. 2018), to summer wildfires in Alaska in 2019 (Herring et al. 2021). NGOs and other actors in the GBR are currently testing out these emerging legal tools as part of their response to coral bleaching events, which may provide a useful example for governance actors seeking to build connections to climate change action in the many other SES where climate attribution research is underway (Herring et al. 2018, Marjanac and Patton 2018, Herring et al. 2021).

Another major bridge-building effort underway in the GBR region is the effort by NGOs to advocate for UNESCO to consider climate policy as part of its criteria for adequate World Heritage site management by national governments. This effort arose in response to mass

coral bleaching in the GBR region (Morrison et al. 2020b, Barnes et al. 2022, Carter and Thulstrup 2022), but has widespread implications for World Heritage sites globally. This illustrates the value of international conservation initiatives and programs in creating venues for connecting individual SES climate impacts with efforts to mitigate climate change (Morrison et al. 2020b). *Future research and practice for coral reefs globally can investigate the potential of international initiatives such as the UNESCO World Heritage program and others that might provide political incentives for national policies and actions to connect reef issues with climate change*. Potential examples include Local2030 Hubs for implementing the United Nations Sustainable Development Goals, and international legal instruments like the Convention on Biodiversity and the Ramsar Convention on Wetlands.

Beyond international conservation initiatives, there are other actions that researchers and practitioners can take to build bridges to climate action in specific SES. Mixed methods approaches that combine social network analysis and qualitative interview or surveys could broaden understanding of connections between reef and climate governance networks, and potentially identify opportunities to build further connections. The network analysis I conducted was limited in scope to reef governance forums and did not examine climate governance forums. However, at least two participants suggested that mass coral bleaching events did get some attention within climate activism circles. *Future network analyses could be expanded to examine how mass coral bleaching events affect forum attendance or general collaboration across climate governance networks, including whether there are forums jointly attended by reef and climate governance actors.* Climate governance networks could include organizations engaged in climate action, ranging from national governments and international NGOs to civil society organizations, corporations, and research institutions, among others (Tosun and Schoenefeld 2017). The outputs of this network analysis could be used in coral SES and other SES as a basis for practice-based efforts to strengthen existing forums at the climate-SES intersection, or create new ones if necessary.

Jointly focused forums at the intersection of climate and specific SES governance could create venues for: 1) information exchange amongst climate experts and locally focused SES researchers, 2) coordinated messaging to ensure public communications in the specific SES

and broader climate sector build upon rather than detract from one another, and 3) creating management, policy, and communication strategies to ensure that extreme climate impacts on a given SES can be leveraged to move the needle on emissions reductions, renewable energy investments, and other climate actions. In the GBR, preliminary research presented in Barnes et al. (2022) indicated that information exchange and coordinated public messaging were a challenge even within the reef sector. During interviews conducted for that research, tour operators were frustrated that researchers' messaging about the severity of bleaching created an unnecessary negative impact on their industry (an important component of the national economic value of the GBR); meanwhile researchers were frustrated by tour operators' apparent downplaying of climate impacts, which potentially watered down the urgency of calls to climate action for reefs. Coordinating directly with climate governance actors could allow reef governance actors to gain valuable knowledge on how to better approach these issues based on others' long-term experience with climate action; simultaneously, those primarily concerned with climate can improve their own messaging and policy advocacy by leveraging the deep knowledge of reef governance actors regarding reef ecology, political dynamics, and how each are affected by extreme climate events. This is just one example of conflict between climate and local SES management; the specific conflicts that arise between SES actors and climate mitigation efforts will vary with the context of different SES. Nonetheless, improving information exchange, coordinated messaging, and joint strategy development across a wide variety of SES can help to manage conflict within individual systems while also building collective action to mitigate the drivers of climate change globally.

Managing reef governance fissures to strengthen coalitions and avoid capture

Meeting the first two challenges is essential for addressing a third more subtle, but nonetheless powerful, challenge to navigating SES futures. This is the challenge of navigating power dynamics between actors both within and exogenous to an SES impacted by extreme climate events. In an SES governance context, power has been conceived as the "uneven capacity of different actors to influence the goals, process, and outcomes" of governance (Morrison et al. 2019). Entrenched power dynamics may cause inertia that keeps SES on unsustainable trajectories, but emerging power dynamics, such as new actor coalitions, can also lead to positive changes in environmental governance (Leach and

Fairhead 2002, Chaffin et al. 2016b, Morrison et al. 2019). My narrative analysis reveals the ways in which fissures within the reef community have been exacerbated by mass coral bleaching events. The analysis also reinforces others' findings of a retreat of government and growing role of corporate actors in GBR governance, potentially resulting in a substantial shift in power dynamics in the region (Morrison et al. 2022, Nyberg and Wright 2022). It is critical for effective reef governance that these fissures be mended or at least managed in order to build a coalition powerful enough to deal not only with the impacts of climate change but also to avoid manipulation by the powerful actors who benefit when climate action is stymied (i.e. fossil fuel industries) (Bixler et al. 2016, Morrison et al. 2020a, Pascual et al. 2022). Unending debates about *what* should be done, intertwined with debates about *who* should do it, detract from building a coalition of reef actors that can truly simultaneously address mitigation, adaptation, and transformation, which is to the advantage of those who would maintain the status quo. Holistic and critical analyses of the negative *and* positive roles that different types of organizations (e.g. government, industry) can have in meeting the climate challenge in specific SES are under-developed in the environmental governance literature though a few scholars have begun this work (e.g. Bixler et al. 2016, Lubell and Morrison 2021, Vandenbergh and Johnson 2021). Filling this gap in knowledge is essential for protecting the interests of the diversity of actors who value coral reefs and other SES on the verge of climate-induced transformations.

Governance researchers can turn *analytical attention to the benefits and limits of the role of government, NGOs, community groups, researchers, and the private sector in navigating extreme climate events and their aftermath, and the implications of the shifting power dynamics between them* (Bixler et al. 2016, Morrison et al. 2019). Particular empirical attention is needed to *assess the opportunities presented by corporate social responsibility and the risks of greenwashing as the private sector becomes more engaged in reef governance*. This could be accomplished through qualitative research that draws on newly developed frameworks that identify and define greenwashing (e.g. de Frietas Netto et al. 2020), as well as existing research on corporate social responsibility (e.g. Dahlsrud 2008, Seele and Gatti 2015, Gatti et al. 2019). This research warns of the risks of green-washing to the environment, to corporations' reputations, and to the general reliability of green messaging in the public eye (Seele and Gatti 2015). Arguments about greenwashing versus

corporate responsibility are not unique to the GBR. For example, contested views of Qantas' role in reef governance have been raised in the GBR, but the aviation industry as a whole has been accused of greenwashing at the global scale (Gürçam 2022). On the other end of the greenwashing-corporate social responsibility spectrum, Allen and Craig (2016) emphasize that corporate social responsibility actions are now essential for addressing climate mitigation, and offer communication strategies for doing so. As hopes and accusations fly across reef governance networks in the GBR and other SES globally, critical analytical research drawing on greenwashing frameworks and researcher on corporate social responsibility offer a means to build an empirical understanding of the role of the private sector and implications for SES governance in the era of climate change.

Concluding Remarks

"What [my ears] heard was a signal, a call through time, which was answered with a mounting conviction: that never again would I allow myself to be made a foot soldier in a conflict I did not understand." – Tara Westover, Educated (2018)

"The future is an open space, but not a politically neutral one…" – Vervoort and Gupta (2018)

"'Ike i ke au nui me ke au iki. [Know the big current and the little current. Be well-versed.]" – Mary Kawena Pukui, ʻŌlelo Noʻeau No. 1209

By exploring how governance actors respond to mass bleaching events, and what challenges they face, this dissertation opens a window into the dynamics of governing SES as they transform under climate change. This research describes challenges and offers next steps for decision-makers, policy-makers, and others who will need to navigate extreme climate events and the lasting effects of climate change on SES around the world. I anticipate that this decade, the first in which recurring mass coral bleaching events occurred, will come to be seen as either a critical turning point, or a tragically missed opportunity, to prepare for a climate-transformed future for coral reefs and other SES. A moment when the urgency of addressing climate change finally manifested in action for coral reefs and inspired action for SES on the precipice of similar climate impacts. Or, a moment when attempts to respond collectively to extreme climate events were plagued by old challenges and conflicts that prevented diverse governance actors from finding a coordinated path (or paths) forward. This dissertation draws together key pieces of this story and suggests that so far, mass coral

bleaching has led to action in some areas but conflicts in others. There is more focus brought to action on climate change, and an upwelling of action on adaptation, but the challenges of navigating conflict between diverse actors remain, and may even have been exacerbated by mass coral bleaching events due to differences in priorities across sector and levels of reef governance. This offers a warning to SES governance actors elsewhere, and an opportunity to prepare for better navigating climate impacts and extreme climate events that continue to impact a variety of SES.

Interviews conducted for this dissertation indicate honest efforts by NGOs, government, and researchers to engage community and provide economic opportunities to locals, including Traditional Owners, while also raising the alarm about the impacts of climate change on coral reef SES. It is the responsibility of SES governance actors, particularly those with influence over high-level decisions, to protect the diverse interests of diverse actor groups in their SES (reef or otherwise) by identifying and removing the barriers to a coordinated response to climate change, and by preventing exogenous interests from widening or benefitting from existing fissures within the reef community. Navigating the future for SES also requires awareness of how the changing landscape of actors in SES governance shifts whose interests, or versions of a "desired state" for SES will be realized or not. Social network approaches, futures-thinking, and critical analysis of the role of the organizations that shape reef governance offer a way forward. The goals of adaptive governance, including supporting the flexibility and creativity of a wide array of SES actors, are essential to continue pursuing as climate change closes in on SES. This can be achieved by coordinating responses to minimize cross-level and cross-sector tensions, intentionally planning for multiple possible futures, and building a clear-eyed understanding of how the governance of any SES affected by extreme climate events is now intimately tied up in the politics of climate change. This thesis sheds light on the actions, imaginings, and murky conflicts that arose in the wake of mass coral bleaching events. These findings and proposed future directions are offered with the hope of enabling researchers and practitioners to become well-equipped soldiers in a battle we now know a little more about.

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Appendix A: Navigating climate crises in the Great Barrier Reef

In preparation for my dissertation research I worked with my co-advisor Dr. Michele Barnes as a research assistant. The purpose of our study was to understand the actions that governance actors took after mass coral bleaching events, and how these actions were enabled or constrained by various domains of adaptive capacity (Cinner and Barnes 2019). We conducted interviews with key informants who engaged in GBR governance at the local to international level across a range of sectors. The findings are reported in the attached research article.

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Title: Navigating climate crises in the Great Barrier Reef

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Navigating climate crises in the Great Barrier Reef

Abstract

A dramatic escalation of extreme climate events is challenging the capacity of environmental governance regimes to sustain and improve ecosystem outcomes. It has been argued that actors within adaptive governance regimes can help to steer environmental systems toward sustainability in times of crisis. Yet there is little empirical evidence of how acute climate crises are navigated by actors operating within adaptive governance regimes, and the factors that influence their responses. Here, we qualitatively assessed the actions key governance actors took in response to back-to-back mass coral bleaching – an extreme climate event – of the Great Barrier Reef in 2016 and 2017, and explored their perceptions of barriers and catalysts to these responses. This research was, in part, a product of collaboration and knowledge co-production with Great Barrier Reef governance actors aimed at improving responses to climate crises in the region. We found five major categories of activity that actors engaged with in the wake of recurrent mass coral bleaching: assessing the scale and extent of bleaching, sharing information, communicating bleaching to the public, building local resilience, and addressing global threats. These actions were both catalyzed and hindered by a range of factors that fall within different domains of adaptive capacity; such as assets, social organization, and agency. We discuss the implications of our findings as they relate to existing research on adaptive capacity and adaptive governance. We conclude by coalescing insights from our interviews and a participant engagement process to highlight four key ways in which the ability of governance actors, and the Great Barrier Reef governance regime more broadly, can be better prepared for, and more effectively respond to extreme climate events. Our research provides empirical insight into how crises are experienced by governance actors in a large-scale environmental system, potentially providing lessons for similar systems across the globe.

Keywords: environmental governance, adaptive capacity, climate change, coral bleaching, stakeholder engagement

Introduction

Ecosystems across the globe are facing rapidly changing social, political, and ecological pressures exacerbated by extreme climate events. Under such conditions, sustainably managing large-scale ecosystems; e.g. those that extend across multiple jurisdictions and include a diversity of stakeholders, often with conflicting interests; is increasingly challenging (Wyborn and Bixler 2013). Many argue that actors within adaptive governance regimes, which bring stakeholders together and emphasize learning, can help to steer environmental systems toward sustainability (Armitage et al. 2008, Bodin 2017), particularly

in times of crisis (Folke et al. 2005). Yet most of the scholarly focus to date has been on the emergence and principles of adaptive governance (Chaffin et al. 2014), with scant empirical evidence of how acute climate crises are navigated by actors operating within existing adaptive governance regimes, and the factors that influence their responses.

An adaptive governance regime is defined as a system that brings diverse stakeholders together, incorporates multiple types of knowledge, devolves and decentralizes decision-making, and facilitates adaptive, ecosystem-based management that addresses problems at nested scales (i.e. through polycentricity) (Folke et al. 2005, Chaffin et al. 2014, Morrison et al. 2017). The Great Barrier Reef (GBR); a UNESCO World Heritage Site located off the north-eastern coast of the state of Queensland, Australia; has long been considered a prime example of a large-scale environmental system managed under a robust, adaptive governance regime (Olsson et al. 2008). Yet its' ability to sustain the reef and improve ecosystem outcomes is currently being challenged by a dramatic escalation of extreme climate events (Hughes et al. 2017b, Morrison 2017). In 2016 and 2017, the reef experienced unprecedented back-to-back mass coral bleaching triggered by rising global temperatures. In 2016 the bleaching event affected 91% of the GBR and killed an estimated 67% of shallow corals in a large region of the northern section where bleaching was most severe (Hughes et al. 2017b). In 2017 severe coral bleaching affected the central third of the GBR, compounding the 2016 damage and other environmental (e.g. severe tropical cyclones and crown-of-thorns starfish outbreaks) and human pressures (Authority 2019). These cumulative impacts have stimulated increased concern over the state of the reef and led to intense public and scientific debate about the threat that climate change poses to the GBR, as well as other World Heritage listed coral reefs. As of 2020, amidst the backdrop of yet another round of coral bleaching, the GBR's conservation status had declined from "significant concern" to "critical" according to the International Union for Conservation of Nature's (IUCN) World Heritage Outlook report (Osipova et al. 2020).

In this paper we provide an empirical, qualitative assessment of the actions key GBR governance actors took in response to mass coral bleaching on the GBR in 2016 and 2017, and explored their perceptions of barriers and catalysts to these responses. Governance is broader than government, and includes the structures and processes for creating knowledge, prioritizing issues, formulating policy, delegating responsibility, and making decisions about how to intervene (Morrison et al. 2020). Governance actors therefore include both state and non-state actors (i.e., organizations and stakeholder groups) involved in and/or influencing these processes, including industry and civil society organizations in addition to formal government agencies. Critically, governance actors are argued to play a key role in steering social-ecological systems toward sustainability through times of crisis (Folke et al. 2005, Olsson et al. 2008). Our research provides empirical insight into how crises are experienced by such governance actors. We additionally investigate the barriers and catalysts that arise as these actors respond to crisis, filling an important need for empirical evidence of the strengths and weaknesses in the adaptive capacity of actors within adaptive governance regimes (Armitage and Plummer 2010, Dressel et al. 2020). Importantly, this research is, in part, a product of collaboration and knowledge co-production (Lemos et al. 2018) with governance actors aimed at improving governance

responses to extreme climate events in the GBR region (Schmidt et al. 2020), and potentially other regions around the world. We describe this collaboration in the Methods section following a discussion of the theoretical foundation for our overall research approach.

Theoretical foundation

Extreme climate events and other rapid change in social-ecological systems require quick and creative responses from governance actors (Folke et al. 2005, Plummer and Armitage 2010). In order to take such responses, it is now widely acknowledged that governance actors require governance institutions (e.g. laws, policies, social norms, decision-making processes) that allow for self-organization, learning, knowledge integration, and the ability to address problems at all relevant levels (e.g. local to national) (Dietz et al. 2003, Folke et al. 2005, Chaffin et al. 2014). These institutions are often collectively referred to as "adaptive governance" (Folke et al. 2005), and significant research has focused on how such arrangements emerge in a social-ecological system (Olsson et al. 2008, Chaffin and Gunderson 2016) and bolster the adaptive capacity of the overall system (Plummer and Armitage 2010). From this perspective, adaptive capacity – often referred to as the capability of a social-ecological system to be robust to disturbance and to adapt to actual or anticipated changes (Cinner et al. 2018) – has most often been assessed by examining the characteristics of institutions, policies, and specific governance arrangements that are argued to enable adaptive governance approaches (Pahl-Wostl 2009, Gupta et al. 2010, Brockhaus et al. 2012). These high-level efforts have been critical in furthering our understanding of the factors that facilitate the emergence of adaptive governance. However, there has been scant research regarding the capacity of governance actors themselves to effectively navigate crises within a system where these adaptive governance institutions have become established in formal management and policy arrangements. Yet understanding how governance actors respond to crises, and the barriers they face in doing so, is crucial for identifying areas where additional support may be needed to improve how governance regimes function in practice (Dressel et al. 2020), and can provide critical insight into the trajectory of the system as a whole. As the climate crisis unfolds, it is thus becoming increasingly critical that we gain a better understanding of the factors that enable (or constrain) how governance actors respond to crises.

From an actor-level perspective, adaptive capacity has been described as the suite of assets or resources (technical, financial, social, institutional, political) available to enable responses to change, and the social processes and structures through which they are employed and mediated (Plummer and Armitage 2010). Here, we follow recent work which organized the suite of resources, processes, and structures argued to be important for adaptive capacity into six broad domains; these include: (1) the *assets* that actors can draw upon, (2) the *flexibility* to change strategies, (3) the ability to organize and act collectively (i.e. *social organization*), (4) *learning* to recognize and respond to change, (5) the *socio-cognitive* constructs that enable or constrain human behavior (such as risk attitudes), and (6) the *agency* or power to determine whether to change or not (Cinner et al. 2018, Cinner and Barnes 2019). Though initially focused on the community-level (Cinner et al. 2018), this

framework was developed through a review of research on adaptive capacity in the context of environmental change across multiple social science disciplines that spanned different scales and levels of analysis, with the aim of bringing together disparate conceptualizations of adaptive capacity. The framework is thus widely applicable. Indeed, many of the adaptive capacity domains in the framework incorporate concepts that are commonly regarded as important for adaptive capacity at the system-level. For example, Plummer and Armitage (2010) identify *capacity and capacity building*, *social capital and social networks,* and *learning* as critical components of adaptive capacity for environmental governance, which are related to the *assets, social organization, and learning* domains, respectively. Critically however, the framework goes a step further by incorporating aspects of adaptive capacity which have received less attention in the governance literature focused on adaptive capacity, yet can be important for determining how governance actors respond to change (Mortreux and Barnett 2017), such as how risk is perceived and managed [*socio-cognitive constructs;* (Truelove et al. 2015)], and whether actors have the power and freedom to mobilize their capacities and shape future trajectories [*agency*; (Avelino and Rotmans 2009, Brown and Westaway 2011)]. In recognition of its broad applicability, this framework has now been adapted to conceptualize and measure adaptive capacity and the related concept of resilience among individual actors (Barnes et al. 2020), governance arrangements (Rubio et al. 2021), as well as entire social-ecological systems [including community, governance, and ecological-levels (Mason et al. 2021)]. Here, we draw on this framework to enable a clearer interpretation of the catalysts and barriers governance actors face in navigating a critical climate crisis.

As one of the original (and rare) examples of adaptive governance (Olsson et al. 2008), the GBR governance regime is a useful case for exploring how the adaptive capacity of governance actors influences responses to climate crises (Flyvbjerg 2006). Spanning 348,000km2, the GBR is recognised as the largest living structure in the world by UNESCO. Today, the reef is valued at an estimated $56 billion as an Australian economic, social, and iconic asset (DAE 2017). 52% of this value is from tourism (DAE 2017), and the GBR also holds significant value to a range of other key stakeholders, such as fishers, scientists, and the general public – both locally and globally (Gurney et al. 2017, Marshall et al. 2018). The GBR governance regime is characterized by multi-actor, collaborative arrangements involving knowledge sharing, formal and informal partnerships, joint projects, and joint rules that have evolved since 1975 through public participation, cooperative state and national law, international oversight, and a variety of other collaborative relationships (Morrison 2017). In 1998, the GBR Marine Park Authority (GBRMPA) initiated a major rezoning process that enabled the adoption of an ecosystem-based management approach and earned the GBR scholarly recognition as a best-practice example of adaptive governance (Olsson et al. 2008, Day 2017). Although the GBR governance regime is now challenged by climate change and mass bleaching events (Hughes et al. 2017a, Morrison et al. 2017), it retains its role as global leader in reef management. The GBR case is therefore of theoretical and practical importance because it provides a unique opportunity to investigate the strengths and weaknesses of actors' adaptive capacity in a rare and iconic example of an established adaptive governance regime.

Methods

We conducted confidential, semi-structured interviews with 31 participants who were asked to represent their organization and/or group which, following the definition in the above section, can be classified as 'GBR governance actors'. The GBR is both a national and global icon which is governed through a multilevel structure that includes the UNESCO World Heritage Committee. Official regulatory authority of the GBR region falls under the Australian commonwealth (e.g. Australian Federal Government) and state jurisdiction (e.g. Queensland Government). Other influential actors playing a role in the GBR governance (through direct or indirect involvement or advocacy) range from local to global and include a large number of both state and non-state actors, including industry and civil society organizations. We bounded our study by focusing on governance actors' (i.e., organizations/groups) whose livelihoods, well-being, or professional objectives depended on the GBR. With the guidance of key informants who collectively had extensive experience working with different sectors and groups in the GBR region, interviews were stratified to ensure that key actors from the following groups were represented (see Table 1 for a list of acronyms): UNESCO (n = 1); Policy-makers (i.e., Ministers/Members of Parliament; n = 1); Federal and State Government Agencies (n = 8; e.g. GBRMPA; the then Department of Environment & Energy; Office of the GBR; Queensland Department of Agriculture & Fisheries); Local, National, and International NGOs (n = 8; e.g. GBR Foundation; WWF); Research Institutions (n = 5; e.g. Australian Institute for Marine Science; CSIRO); the Tourism Industry (n = 4; e.g. Queensland Tourism Industry Council; Association of Marine Park Tourism Operators); the Fishing & Aquaculture Industry (n = 3; e.g. Cairns Recreational Fishing Industry Stakeholders; Provision Reef); and Traditional Owner Representatives (n = 1). Note that only one policy-maker agreed to participate despite repeated requests for interviews to several relevant Ministers and Members of Parliament. Similarly, though we reached out to several traditional owner representatives, only one participated. All other actor categories were well-represented.

Table 1. List of acronyms.

Acronym	Definition
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
IUCN	International Union for Conservation of Nature
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WWF	World Wildlife Fund
NGO	Non-governmental organization
CSIRO	Commonwealth Scientific and Industrial Research Organization
COTS	Crown-of-thorns starfish
AIMS	Australian Institute for Marine Science
RRRC	Reef and Rainforest Research Center
GBRF	Great Barrier Reef Foundation
AMCS	Australian Marine Conservation Society

Interviews were conducted in March and April of 2019 either in person or via telephone. The first half of our interviews were conducted jointly by the first and second author to

establish consistency in the interview process. The remaining were conducted by either the first or second author following the same format and approach. Interviews lasted 45 minutes to one hour and covered the following topic areas in relation to the 2016 and 2017 bleaching events: 1) impacts of coral bleaching events on participants' professional work, 2) how participants and/or their organization/stakeholder group responded to coral bleaching, 3) enabling conditions and barriers for their responses to coral bleaching, and 4) any responses participants expected of other actors. All interviews were transcribed verbatim using a transcription service (rev.com). The first and second author jointly developed the coding framework, and the second author coded all interviews using QSR International's NVIVO 12 qualitative data analysis software. Interviews were coded inductively to generate key themes within each of the four topic areas included in our interviews (listed above). Five broad categories of 'responses' to bleaching were uncovered through this analysis, which we discuss in the following section. Note that although our focal scale of analysis is the organization/group level, occasionally interviewees mentioned individual actions they had taken in response to bleaching that extended beyond their formal capacity within their organization or group. We included these activities where they were relevant to understanding key actions taken in the region. Key themes within the 'enabling conditions and barriers' topic area were coded deductively according to the six domains of adaptive capacity described in the above section [assets, flexibility, social organization, learning, socio-cognitive constructs, and agency (Cinner and Barnes (2019)]. Though our primary focus here is on responses to bleaching and their enabling conditions and barriers, we draw on data from topic area #1 in our interviews ('impacts') to first briefly summarize the various impacts the bleaching events had on different actor groups in the region.

Once we completed the analysis described above, we engaged directly with a core set of key stakeholders from diverse backgrounds who were also research participants to (1) improve the practical relevance of our research, and (2) stimulate processes of social learning to develop a better understanding of how actors in the GBR region might collectively address future crises in a way that accounts for diverse perspectives and interests (Schmidt et al. 2020). This part of the research involved iterative conversations regarding our results with six representatives from the tourism industry, research institutions, the NGO sector, and GBRMPA (the federal management agency responsible for management of the GBR). Each of these participants contributed feedback on our results; helped to interpret our results in the context of their unique knowledge base; and contributed insight and recommendations for how to overcome the barriers identified in our research. One of the final sections of our manuscript, 'Looking to the future', draws on the key themes derived from the fourth topic area included in our interviews ('responses expected of others') and was co-produced with this core set of key stakeholders through this engagement process. As a result, these six individuals were invited to be co-authors on this manuscript, and three accepted (X.X, X.X., X.X). This manuscript is thus in part a product of collaboration and knowledge co-production with practitioners aimed at improving governance responses to extreme climate events in the GBR region, and potentially other similar regions around the world (Lemos et al. 2018, Schmidt et al. 2020, Bojovic et al. 2021).

Impacts of bleaching on the Great Barrier Reef

Participants across sectors reported significant but varied impacts of bleaching. Most participants noted that the extent of the bleaching event took many by surprise, and that it was found to be quite confronting. Many expressed a combination of fear, helplessness, sorrow, and even depression regarding the impacts to the reefs they manage, depend on for their livelihoods, or associate with their group's identity.

Multiple dive tour operators noted that the effects of the bleaching event were patchy, i.e. some locations were affected, while others were not. Still, they expressed that bleaching, and particularly the coverage of it in the news media, caused a severe drop in visitation, though changes in demand varied across markets in different parts of the world. Fishing industry professionals (including aquarium collectors) reported little impact from bleaching on their trade, but did mention concerns about the possible long-term effects of bleaching and rising temperatures on fish habitat and behavior.

In the nonprofit and government communities, bleaching led to a mix of questioning and reinforcing motivation for various conservation and management activities. For the research community, the bleaching events reinforced the findings of some, and generated a shared recognition that climate change impacts were happening here and now. Similar to those working in government and nonprofits, bleaching brought researchers grief, but also a resolve to press forward with finding solutions.

Responses to bleaching on the Great Barrier Reef

We found five major categories of activity that actors engaged with in the wake of recurrent mass coral bleaching: (1) assessing the scale and extent of bleaching ('assessing bleaching'), (2) sharing information, (3) communicating bleaching to the public (public communication), (4) building local resilience, and (5) addressing global threats, which we describe in turn.

Assessing bleaching

Assessing the extent and scale of bleaching was one of the most immediate responses to the bleaching events. Researchers from around Australia, and internationally, created a "Coral Bleaching Task Force" in the lead up to the 2016 event in order to coordinate the collection and analysis of data, not only within Australia, but around the world. At the onset of the bleaching event on the GBR, these researchers conducted aerial surveys supplemented by in-water surveys of the reef. GBRMPA and the Australian Institute of Marine Science (AIMS, the Federal Government's tropical marine research agency) coordinated in-water surveys using existing, and some new, long term transect lines on the reef. Dive operators and concerned citizens conducted site-specific surveys of bleaching as well. Many of these efforts were coordinated by organizations like the Reef and Rainforest Research Center (RRRC), Citizens of the GBR, and GBRMPA through its Eye on the Reef program. Some large dive companies also conducted their own assessments of their more popular dive sites.

Sharing information

In addition to collecting data and information, actors needed improved means for sharing data and information in the wake of the bleaching events. Several participants mentioned the formation of new partnerships or collaborations across organizations and sectors for this purpose. For example, GBRMPA established an "Incident Management Group" that enabled partners to share information and collaborate on bleaching assessment actions, and in 2017 convened a Reef Summit involving more than 70 experts from around the world in response to the events. GBRMPA also used its networks and website to provide information on bleaching. Meanwhile, the Coral Bleaching Task Force provided a venue for academics to share study design protocols and data. New collaborations focused on information sharing also began occurring at smaller scales. For example, AIMS began coordinating with tour operators to generate fine scale data on the extent of bleaching.

Public communication

Responses to coral bleaching were not only focused on information and actions on the ground, but also on how to communicate the bleaching events to the public. Nineteen participants described communications as a major part of their response to coral bleaching events; this included individuals from the government, NGO, research, and tourism sectors, as well as a Traditional Owner representative. Researchers and NGOs put out press releases and social media posts (e.g. Twitter, Facebook), often detailing the extent of bleaching damage. The World Wildlife Fund (WWF) helped to break the news of the bleaching event internationally. Traditional Owners spoke at events about the impacts of climate change on their sea country. GBRMPA used its existing web platform to share information about the events, and shifted the topic of its educational Reef Guardians program to climate change. GBRMPA also hosted information sharing events requested by Traditional Owners. The tourism industry struggled to get the attention of the press, particularly internationally, but posted videos and other bleaching information on their websites in order to communicate that not all of the reef was affected by the bleaching events.

Building local resilience

Local management responses by government and NGOs were described by participants in terms of 'building resilience', and included activities at a range of scales. Participants from GBRMPA discussed how the Great Barrier Reef Blueprint for Resilience (hereafter, 'Reef Blueprint') the primary outcome of the Reef Summit, identified building local resilience as one of the key priorities for future management of the GBR (GBRMPA 2017). The blueprint detailed four on-the-ground actions to support this, including enhancing compliance, ramping up COTS control, protecting key species for reef recovery, and active localized restoration. The scaling up of COTS removal was specifically mentioned as a priority by participants in government and at the GBR Foundation (GBRF) – a registered Environmental Organization which in 2018 received a controversial Australian Government grant of AUD $443 million for projects on the GBR. Others in the Queensland government and at NGOs like Terrain Natural Resource Management discussed a renewed focus on reducing

agricultural runoff from watersheds across the GBR region, e.g., through policies and outreach regarding best management practices.

Participants from the Office of the GBR (an office of the Queensland government), AIMS, and the GBRF also mentioned supporting experiments with novel restoration approaches and new technical innovations for protecting the reef from bleaching events; such as transplanting or breeding corals that withstood the stress of bleaching events, dispersing coral spawn, and even experimenting with technologies to shade or cool the reefs during periods of extreme heat (e.g., cloud brightening, fogging, and surface films). In 2018, the Australian Federal Government allocated AUD $6millon for the development of the Reef Restoration and Adaptation Program, a partnership between scientists and government tasked with creating and trialing a suite of these types of interventions to help the GBR resist, adapt to, and recover from climate change impacts. The Queensland government hosted a competition for novel restoration approaches, promising to fund the winner, while Queensland Parks and Wildlife provided logistical support for coral larvae dispersal experimentation. AIMS and GBRMPA also conducted feasibility analyses for large-scale implementation of new restoration techniques. These activities were described as a major paradigm shift towards an interventionist approach and away from the more preservationist, "hands off" approach to reef management popular in the past. Participants from GBRMPA and the GBRF noted that the creation of the Reef Blueprint represented a fundamental pivot towards this more interventionist approach, and a move away from simply documenting bleaching extent and subsequent coral mortality.

Addressing global threats

It was well-recognized amongst GBR governance actors that a reduction in greenhouse gas emissions – the root cause of coral bleaching – is urgently needed to halt degradation of the reef. Yet major policy change to combat global warming has not occurred within Australia, despite repeated exposure to mass coral bleaching events and other significant climate crises, such as wildfires (Yu et al. 2020); echoing similar trends around the world (Nohrstedt et al. 2021). In response to back-to-back bleaching on the GBR, a few individuals and organizations pivoted their efforts in an attempt to address this policy gap and push for climate action. For example, the Australian Marine Conservation Society (AMCS) began supporting campaigns (such as 'Stop Adani') to advocate against coal export, and especially against mining in the GBR watershed. In 2019, two years following the coral bleaching events, GBRMPA published a position statement identifying climate change as the greatest threat to the GBR, which called for a swift reduction in greenhouse gas emissions. Some organizations' activities in response to coral bleaching on the GBR also influenced changes in their activities at a global scale. For example, as WWF Australia shifted to having a stronger focus on emissions, WWF International was inspired to pivot towards a greater global-scale focus on coral reef ecosystems. Similarly, a participant from UNESCO indicated that their experiences with actors and bleaching events in the GBR region inspired a deeper look at how climate change is affecting reefs and other ecosystems within World Heritage areas.

Some participants also mentioned changes in their personal professional choices. For example, a few researchers previously focused on the biophysical aspects of climate change

became inspired to focus on communicating their findings to the public, while others became engaged directly in policy advocacy. Advocacy activities included increasing climate science messaging on social media platforms, speaking in Parliament House, and engaging in climate-related lawsuits. One university researcher also mentioned novel collaborations with insurance companies to explore the option of insuring reefs to buffer against climate change impacts, which would allow payments to be disbursed to restore reefs in the wake of bleaching or storm events.

Catalysts and barriers to bleaching responses

Actions that governance actors took in response to the coral bleaching events in 2016 and 2017 on the GBR were both catalyzed and hindered by a range of factors that fall within different domains of adaptive capacity (Fig 1). Notably, some domains of adaptive capacity, such as agency and social organization, were described as both a catalyst and a barrier to responses by different actors. Moreover, participants often emphasized important interrelationships between adaptive capacity domains (Cinner et al. 2018), e.g. some described assets as a catalyst underpinning their response, but noted that having flexibility in the allocation of these assets was critical. We discuss these relationships and interactions in further detail organized by domain below.

Assets

The ability to access financial, technical, and service-related resources (Yohe and Tol 2002) was a frequently mentioned factor affecting actors' capacity to respond (or not) to the bleaching events. In particular, access to funding, information, and infrastructure for information sharing and in-water reef surveys affected actors' ability to share information with the public, conduct surveys ('assessing bleaching'), make changes to existing management/business practices, and/or implement new interventions to build reef resilience (e.g. water quality improvements). For example, some university research labs (e.g. James Cook University) had immediate access to funds that allowed them to conduct aerial and in-water surveys in real-time during the events. Some government entities, such as GBRMPA and AIMS, were able to reallocate some funds for in-water surveys. GBRMPA was also able to draw on existing staff and website infrastructure to support communications about the bleaching events. Other government organizations, such as the Queensland Government Office of the GBR, built upon existing funding and staff capacity to boost reef resilience through improving water quality. In more specific localities, tourism companies with diverse operations and range of permits found that they were able to adjust to visit less bleached sites as necessary. These were primarily larger businesses (e.g. Quicksilver, Inc.), who also possessed trained staff and materials necessary to conduct their own site-specific surveys.

A lack of assets prevented some organizations and actor groups from responding to the events in the way they hoped to. For example, insufficient funds prevented some government institutions from performing surveys as extensively as they might have otherwise. Participants from government research and management institutions also

mentioned chronic funding problems that affected their responses, such as a lack of sustained funding for long term monitoring, and the absence of a flexible contingency fund for post-bleaching surveys and other unexpected needs. Traditional Owner groups were interested in contributing to surveys and building reef resilience in the wake of bleaching, but were unable to access the reef in their traditional territories because they did not possess the boats, training, and other resources necessary.
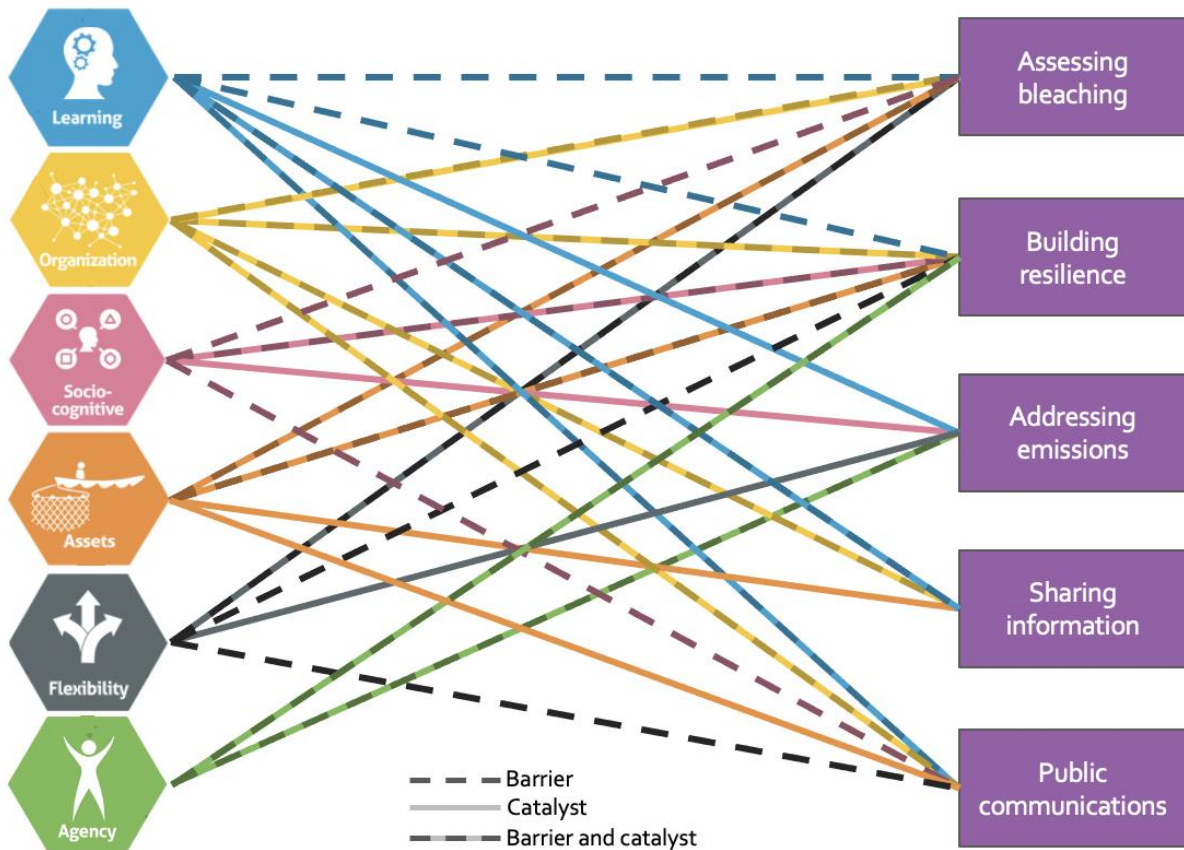
Figure 14. The five types of activities governance actors undertook in response to bleaching (right column) were underpinned by different domains of adaptive capacity (left column). Solid lines represent catalysing influences of a domain on an activity; dashed lines indicate barriers of a given domain (i.e. those that hindered an activity). In many cases, domains were discussed as both a catalyst and a barrier (represented by solid lines overlaid by darker dashed lines). Lines match the colour of their respective domain. Domains and activities appear in ascending order by the number of linkages they have across columns (aspects of learning were discussed as catalysts and/or barriers in relation to all five different response activities; as such, learning appears at the top of the left column). Adaptive capacity domains (left) adapted from Cinner and Barnes (2019) and Cinner et al. (2018).

Flexibility

Flexibility, or the ability to quickly switch to new strategies and activities (Mortreux and Barnett 2017), was critical for both short term and long-term responses to bleaching. We found that the flexibility of organizations was closely interconnected with other dimensions

of adaptive capacity, such as assets and social organization. For example, university institutions were able to conduct timely surveys during the peak of the bleaching events not only because they had sufficient funding, but because they had the administrative flexibility necessary to immediately access it. Existing relationships within the research sector also played a big part in coordinating surveys through the Coral Bleaching Task Force. One researcher described this flexibility:

> It was an informal network designed to be nimble, to be mobile and to do research. So it wasn't bureaucratic in any way. There was no bureaucracy. (Participant 2)

In contrast, government organizations like AIMS had funding, but faced challenges in redirecting it away from previously approved uses towards responses like large scale surveys directly preceding the events. Over a longer time scale, the GBRF, another organization responsible for using public funds, also found that close scrutiny on the allocation of the money awarded to them following the events made it difficult to change how it was used. Bureaucratic processes also slowed public messaging and permitting for experimentation with new approaches to build local resilience.

The flexibility of both government bodies (e.g. CSIRO, AIMS) and NGOs (e.g. WWF Australia, AMCS) was also frequently limited by obligations to focus on existing programs and contracts before shifting to efforts to respond to bleaching events. In the longer term, NGOs like WWF and AMCS eventually had the flexibility to move towards a greater focus on addressing emissions issues related to the Australian coal export industry.

Social organization

The role of social relationships between individuals and between organizations, in addition to social organization more broadly (Adger 2003), was frequently mentioned as either a barrier or a catalyst for actors' responses. For example, a researcher involved with the Coral Bleaching Task Force emphasized the importance of individual (rather than institutional) relationships in forming this group at several points in the interview and suggested that this enabled a quicker response than what they observed in government institutions. Similarly, one participant from the Queensland Government found that having pre-existing relationships with colleagues in the government and research sector sped up their response and also enabled them to receive the information they needed in a timely fashion. This participant stated:

> I think one thing about the GBR, it's an area of…long and established partnerships. So, I think we can take advantage of that, that we're able to really leverage off that work and I think that's why we've been able to step up so rapidly, particularly for government. Government, well we move slowly. And we really have moved really quite quickly in this and I think that's the strength of those partnerships. (Participant 22)

Participants in the NGO sector also expressed that they tended to have diverse partnerships that enabled their response. One participant from the GBRF noted that as a NGO, the

organization has an "innovative ability to leverage benefits across [sectors]" (Participant 8). This participant went on to express that although controversial, GBRF's partnerships with corporations and a myriad of researchers enables it to innovate and experiment with new ideas for building reef resilience.

Not all participants felt that their ability to respond was catalyzed by existing networks, and the overwhelming majority of participants emphasized that a lack of coordination and leadership more broadly acted as a significant barrier to responses. For example, participants described incompatible survey data formats between institutions, slow information sharing, and disagreements over the utility of citizen science survey data. In several cases, participants from the private sector and NGOs voiced a need for increased leadership to coordinate these activities. One NGO participant declared:

> If I could summarize in one sentence, it would be there was an absolute lack of leadership to respond. Lack of leadership at a political level. Lack of leadership at a bureaucratic level. And to be honest, a little bit of a lack of leadership at the scientific level. (Participant 10)

Participants also noted that an initial lack of leadership also left the tourism industry and individual researchers to individually spearhead communication about the events. This ultimately led to conflicting messages, exacerbating cross-sector conflict between tour operators and scientists over public communications about climate change. One government professional with experience working with communities in the region described conflicts between tour operators, the RRRC, AIMS, and GBRMPA as a "maelstrom of conflicting views that were going on at every level."

Some participants also suggested cross-sector tensions and interpersonal conflicts, in addition to inter-organizational coordination issues, impacted responses to bleaching across the region. For example, the bleaching events appeared to exacerbate cross-sector tensions between government and agricultural interests over efforts to build resilience by improving water quality. Several participants also mentioned that conflicts at the personal level fed into cross-sector tensions, and tensions amongst sectors engaged in the same activities, such as reef surveys.

Learning

Learning reflects the capacity to recognize change, attribute this change to causal factors, and assess potential response strategies (Lebel et al. 2010, Cinner et al. 2018). Governance actors' ability to draw on aspects of learning in their response was impacted by their past experiences and access (or not) to relevant data, information, and human capital assets. Although a few actors had experienced bleaching events in the past, a majority of participants noted that the 2016 and 2017 bleaching events were unprecedented in terms of scale and severity. However, a few actors were able to learn from past experiences with relevant conservation actions (rather than with bleaching itself) in their response. For example, AMCS was able to pivot to addressing global threats, specifically climate change, within a few years of the bleaching events. This was because key staff possessed past experience and knowledge on how to advocate for climate change solutions.

Several reef managers and decision-makers raised the issue of information availability and legitimacy. The extensive surveys of bleaching events at both the regional level and in specific localities (e.g. dive sites) provided a wealth of information that actors' could learn from in order to coordinate their response. However, differing methods for assessing bleaching led to challenges with collating bleaching assessments and rapidly distributing this data. This presented a barrier to decision-makers and others seeking to learn about the impacts of the event. For example, one decision-maker responsible for fisheries voiced a need for more readily available and finer scale data that could inform decisions about which specific areas to close to the harvest of species like beche-de-mer. In addition, researchers, government professionals, NGO professionals, and tour operators expressed differing opinions on what sources of knowledge regarding the extent of bleaching were considered legitimate. For example, tour operators and some NGOs tended to support the use of citizen science and surveys conducted by dive operators, whereas other NGOs and most researchers considered these sources of data less relevant to decision-making, while government professionals expressed a range of views.

Agency

Aspects of agency, described here as the power to influence change or make free choices regarding whether to change or not (Avelino and Rotmans 2009, Brown and Westaway 2011), were frequently mentioned as barriers to bleaching responses in our interviews. Many of our participants expressed feelings of helplessness or disempowerment given the scale of bleaching and a sense that its causes were global, inevitable, and beyond the control of any one individual, organization, or nation. For example, several professionals working in government and NGOs questioned the potential for their strategies and projects to have positive outcomes for the reef given the overwhelming impacts of bleaching, leading to a sense of disempowerment and uncertainty regarding how to respond. Most other participants similarly felt little sense of agency to undertake activities to address global threats. Moreover, any gains in addressing climate change were perceived as intangible, in that the benefits will not be experienced in the short term.

A number of participants suggested that organizations had the greatest agency when they undertook activities to build reef resilience, as this fit firmly within their respective jurisdictions:

> I've got no control over the climate change policy for Australia. It's not in my jurisdiction…it's not in my department's jurisdiction. So in the absence of being able to do anything there, you've got to be able to work within your remit and the outlets and tools that you have at your disposal to try and do something. So that's what you're seeing playing out. (Participant 15)

Participants in the NGO, government, and tourism sector frequently voiced that activities to build local resilience by addressing systemic issues (e.g. water quality and COTS outbreaks) or experimenting with new technology (e.g. coral breeding or reef shading) were most tangible and relevant to the work of organizations and government agencies across the

region – rather than a focus on global threats. Traditional owner groups however felt little sense of agency to undertake even locally based projects to build resilience, in part because of their lack of assets such as boats.

Many participants also shared dissatisfaction and a general sense of disempowerment regarding initial public messaging about the bleaching events. Individuals in the tourism sector felt that their message about the events was either unheard, or not heard loudly enough. For example, one participant from the tourism sector expressed frustration that the initial news coverage of the events incorrectly indicated that the entire GBR was dead while excluding other perspectives. This participant explained:

> We had all these [videos of the reef] but the only place we could use that was in social media. The main media wouldn't run it. They're not interested in the good story…the media will always try and balance it…but the one that gives the negative message is the one that'll get the main bloody thrust of the story. (Participant 19)

There were some cases where participants were able to exert agency in order to respond to the bleaching events in unique ways. For example, one of the researchers we interviewed stepped out of the traditional box of 'research' and found purpose in political activities to address global causes of climate change.

Socio-cognitive factors

Actors' perceptions of impacts and risk are a key dimension of the socio-cognitive domain of adaptive capacity (Mortreux and Barnett 2017, Cinner and Barnes 2019). Governance actors expressed a range of different views on the severity of the coral bleaching events and what risk the events pose to the future of the reef, which underpinned their responses. For example, researchers tended to emphasize that bleaching was severe and widespread, while representatives from the tourism industry pointed out that bleaching was patchy, with some sites only slightly affected. This disagreement around how the events were framed ultimately posed a barrier to clear public communications.

Varying perceptions of impacts and risk also led to differences of opinion across sectors regarding what management and policy actions were most important to focus on in the wake of the events, further exacerbating conflicts over messaging that were already playing out across the region. Specifically, government decision-makers, NGO professionals, and university researchers expressed conflicting opinions regarding how to balance management funds and activities between efforts to (1) build local resilience (e.g. breeding high heat tolerance corals), (2) address system-wide issues (e.g. water quality), and (3) address global causes (e.g. lobby for emissions reduction). Participants in research or NGO positions argued that back-to-back mass coral bleaching events challenged the idea that building the resilience of reefs at the local scale could help to reduce the impacts of climate change. NGO and government participants frequently mentioned that the bleaching events indicated the need for a myriad of responses across the spectrum of local, short-term actions (e.g. COTS removal) to more globally oriented long-term actions (e.g. emissions reduction). Yet even where there was agreement on this type of broader approach,

participants diverged from one another on how much attention and resources should be dedicated to activities at different ends of the spectrum. These differences appeared to arise not only from perceptions of risk, but also from varying perceptions of the scope of the capabilities and responsibilities of participants' organizations (which relates to agency, discussed above), as well as different perceptions about the types of actions that organizations receiving funding for reef management should or should not be responsible for. One NGO participant argued that mixed messages regarding bleaching severity and what responses should be prioritized resulted in confusion amongst politicians responsible for funding GBR management at the federal level, ultimately leading to less funding for the reef overall.

There were several areas where participants felt that public perceptions and public support had important impacts on responses to bleaching. Participants cited public climate change skepticism, hopelessness, a perception of the reef as 'too big to fail,' and a hesitance to embrace interventionist approaches to building reef resilience as barriers to effective bleaching responses. Several participants in government and NGOs argued that citizens in the GBR region are accustomed to the norm of a "hands-off" approach to reef management, and expressed an interest in convincing the public about the need for more direct interventions. For instance, one participant noted, "they're putting a nano layer of something on top of the water that will actually reflect some of the sunlight…but we need to get the community on our side" (Participant 27). Socio-cognitive factors in this case were closely related to the flexibility and learning of organizations seeking to trial novel management approaches.

Discussion

When faced with back-to-back mass coral bleaching caused by extreme global temperatures in 2016 and 2017, state and non-state actors involved in and/or influencing governance processes in the GBR overcame uncertainty and hopelessness in order to document the unfolding crisis, reinforce previous efforts to build resilience, design new interventions, and focused on communicating these efforts amongst themselves and with the public. A few actors pivoted their efforts to addressing the root causes of climate change. Others struggled with fundamental questions regarding their professional capabilities and responsibilities in light of a global threat seen as largely beyond their control.

We explored barriers and catalysts to these actions in reference to domains of adaptive capacity (Cinner et al. 2018, Cinner and Barnes 2019). We found that unequal underlying capacities among actors within specific domains led to responses being facilitated for some, yet impeded for others – this was particularly true when it came to *assets* and *social organization*. Though adaptive governance approaches emphasize capacity building, power sharing, and collaboration; these findings raise important questions regarding how these principles play out in practice in crisis situations, and who benefits (and who loses) in the process (Cleaver and Whaley 2018). Future research that interrogates how adaptive governance can be adjusted in practice to ensure that all relevant actors; including industry,

civil society, and traditional owners/indigenous peoples; have the capacity to flexibly navigate change when needed will be critical as the climate crisis unfolds (Schlosberg 2012, Karpouzoglou et al. 2016).

We also found that interrelationships between adaptive capacity domains (e.g., between *assets* and *flexibility*) had a critical impact on how adaptive capacity was translated into action (or not). Though important interrelationships in adaptive capacity domains have previously been theorized (Cinner et al. 2018), to our knowledge this study represents the first to illustrate them empirically. Our research focused on the organization/group level (with a specific focus on those whose livelihoods, wellbeing, and professional objectives depended on the GBR) and the ability of these governance actors to navigate a climate crisis. Yet adaptive capacity is critical across all levels of governance (Armitage and Plummer 2010, Dressel et al. 2020). Thus, future research that rigorously builds a more nuanced understanding of how different domains of adaptive capacity interact not only within levels (i.e., governance-actor level), but also across levels will likely be increasingly critical for navigating the novel and complex challenge of climate change not only within the GBR, but in other systems as well (Dressel et al. 2020).

A major barrier to climate crisis responses in our case was conflicting views among governance actors on pathways forward to ensure a sustainable future for the reef (*socio-cognitive* domain). Most actors agreed that a suite of actions aimed at both mitigation and adaptation are required to address the critical crisis of coral bleaching caused by climate change, but how funds and effort should be balanced between them was a key area of divergence between actors. Other major barriers included challenges associated with collaboration (*social organization* domain), and difficulty dealing with uncertainty and feelings of disempowerment associated with the scale of the problem (*socio-cognitive* and *agency* domains). These latter results largely echo similar findings in an analysis of barriers to climate change adaptation in coastal British Columbia, where several principles of adaptive governance are also in place (Whitney and Ban 2019); which suggests that aspects of social organization, socio-cognitive constructs, and agency may be more broadly relevant for determining how governance actors respond to change in other contexts as well. Taken together, our findings emphasize the utility of the adaptive capacity framework adopted here (Cinner et al. 2018, Cinner and Barnes 2019), which enabled a sharper picture of how these less studied factors may work to enable and constrain the actions governance actors can take as they navigate unprecedented change.

Looking to the future

Participants across sectors suggested several ideas for improving the ability of governance actors and the GBR governance regime more broadly to be prepared for, and respond to climate crises such as coral bleaching. Here we highlight four key ideas put forth in interviews and further elaborated through our participant engagement process, with the aim of inspiring future practical endeavours to improve the management and governance of the GBR, and perhaps other regional social-ecological systems. Our participants emphasized

that, while challenging, fostering hope amongst coral reef professionals is critical in the wake of coral bleaching events and other climate crises. We aim to inspire such hope by offering these tangible ways forward through the uncertainty wrought by climate change.

Venues for sharing information, coordinating actions, and building empathy

Despite the high level of collaborative processes embedded in current governance of the GBR, there was a strong desire among diverse GBR governance actors for greater coordination and collaboration in both preparing for, and responding to coral bleaching. This ranged from calls for a) improved planning for collaborative data collection and dissemination; b) coordinating networks for public communication; and c) providing targeted opportunities for stakeholders to interact directly (as opposed to via media or social media) to rebuild social relations, inspire empathy regarding one another's needs, and provide opportunities to locate untapped capacity for reef management through collaboration or sharing of resources. The importance of bringing networks of diverse actors together to draw on social memory (i.e. the accumulation of a diversity of experiences, in this case concerning the reef and its management), enhance learning and information flow, and create new interactions in order to navigate social-ecological crises has long been emphasized (Folke et al. 2005, Bodin 2017) and is a central argument in the inclusion of social organization as a key domain of adaptive capacity (Adger 2003, Cinner et al. 2018, Cinner and Barnes 2019). Yet the collaborative activities necessary to effectively respond to crises often include a diversity of actors and need to navigate a collision of different worldviews, interests, values systems, power asymmetries, and discrepancies in conceptualizations; which can sometimes lead to or exacerbate significant conflicts (Morrison et al. 2019, Bodin et al. 2020). Leadership from trusted organizations or professional facilitation can play a key role in navigating this collision to catalyze opinion shifts, establish consensus, or at the very least, identify opportunities for compromise (Folke et al. 2005, Ernst 2019). In our case, participants from NGOs and the private sector were often specific in nominating GBRMPA as the organization they felt best suited to lead coordination of bleaching responses. Among a broader range of interviewees particular emphasis was also placed on the role of GBRMPA in coordinating public communications, suggesting that the organization remains widely trusted and is viewed as a natural leader in this space.

Leading up to, and following the bleaching events GBRMPA coordinated several collaborative planning meetings, such as the Reef Summit in 2017. In the four years since, GBRMPA has invested in a platform to facilitate information and data sharing as a part of the Reef 2050 Plan; and in partnership with Tourism Events Queensland, GBRMPA has formed a task force to coordinate public messaging. Our research indicates that coordinated public messaging will need to strike a balance between capturing the severity of the challenges facing the GBR, while emphasizing the value of continuing efforts to navigate change. This is particularly important for NGOs and governments, who depend on the support of donors and/or politicians responsible for allocating funds. It is also important for tour operators seeking to inspire continued visits to the reef by tourists. We suggest that professionally facilitated meetings aimed at building trust and empathy, sharing knowledge

and resources, and ultimately guiding future responses to climate and other crises could add value to these current efforts (Turner et al. 2016). Creating space for reef professionals to share experiences, hardships, and hopes can also help to alleviate the grief that follows crisis events (Marshall et al. 2019), such as mass coral bleaching and the more recent COVID-19 crisis that is having a severe impact on the GBR tourism industry.

Contingency funds

Results from our interviews coupled with further iterative discussions with stakeholders illustrated that having assets, particularly funds, does not necessarily improve responses unless processes are in place to facilitate the flexibility to redirect them as necessary – emphasizing key interactions between adaptive capacity domains that play a critical role in how capacity is translated into action. To address this, some actors recommended creating a pool of contingency funds that could be spent on emergency situations like bleaching as they arose. Contingency funds form a critical component of risk management and disaster response strategies (de Guzman and Unit 2003), and have been identified as a form of social protection that can contribute to the adaptive capacity of vulnerable populations (Ulrichs et al. 2019, Tenzing 2020). Governance responses to extreme weather events can similarly be improved with pools of contingency funds by providing governance actors with the assets and flexibility to navigate these events (Hjerpe and Storbjörk 2016). In the case of the GBR, contingency funds set aside could be used to repair sites after cyclones or conduct surveys after bleaching or major flooding events. While bureaucratic processes facilitate the transparency and accountability needed to secure public legitimacy in democratic systems, especially in the use of public funds, finding ways to improve the flexibility of these processes will be critical moving into the future given the expected increases in frequency and intensity of extreme climate events (Cosens 2013).

Adapting policies and perceptions to pave the way for intervention

The need to create or adapt policies as well as change public perceptions to accommodate a more interventionist approach to reef management was often expressed throughout our research process, particularly among actors in government. To date, reef governance in the GBR and around the globe has primarily focused on local management efforts to reduce proximate stressors (such as overfishing and pollution), and on local restoration projects. Given the escalating scale of impacts caused by climate change, it has become clear that this approach is no longer tenable, and that some type of direct (as well as indirect) intervention is necessary to sustain reefs into the future (Morrison et al. 2020). As we discussed in the 'Building local resilience' section, the Reef Blueprint outlined key interventions that need to be undertaken to support the resilience and adaptation of the GBR to the mounting pressures associated with climate change, including novel COTS control options and active restoration (GBRMPA 2017). GBR governance actors have also begun to experiment with, and advocate for a range of other interventions, including enhanced marine bioengineering (e.g. coral seeding) and even geoengineering (e.g. cooling and shading reefs) (Morrison et al. 2020). Yet immediately following the coral bleaching events, the regulatory environment – which was initially designed in a very different context – was largely inadequate for dealing with the novel risks and impacts associated with many of these unconventional

interventions and the research needed to test them (McDonald et al. 2019, Taylor et al. 2019). Targeted policies to effectively govern and permit such interventions were urgently needed, and have only just started to emerge (GBRMPA 2020). Efforts are also needed to manage public perceptions regarding a more interventionist approach, which remains highly controversial amongst reef stakeholders (including many of our interview participants); though recent research suggests that the public appears to be more accepting of the idea (Taylor et al. 2019).

Expanding traditional owner engagement and capacity

Aboriginal and Torres Strait Islander people are the Traditional Owners of the GBR region and have an overwhelming desire to participate in, and influence GBR governance and research (Dale et al. 2016, Dale et al. 2018, Lyons et al. 2020). Many of the organizations represented in our research have active partnerships and programs to support Traditional Owner engagement (Evans-Illidge et al. 2020) and management of the reef (e.g. [Traditional Use of Marine Resources Agreements](#)). Notwithstanding, results from our work coupled with existing research (Dale et al. 2018) suggest that expanding these activities and ensuring Traditional Owners have the training, tools, and infrastructure (e.g. boats) to allow them to meaningfully engage in reef governance could play a significant role in improving responses to coral bleaching and other climate crises in the GBR region. Traditional Owners across Australia have valuable context specific knowledge and resources (Brugnach et al. 2017) and are already trialing and implementing a range of adaptation practices that have been forged over millennia (Nursey-Bray et al. 2019). These Traditional modes of adaptation have been argued to form the foundation for addressing the "new" challenge of climate change, whereby tailored, place-based responses can be co-designed with Traditional Owners (Nursey-Bray et al. 2019). Though the Reef Restoration and Adaptation Program is engaging with Traditional Owners as it seeks to establish interventions and other measures to protect the GBR, it has been argued that deeper engagement in this space is needed; such as researching Traditional Owner reef values, adopting best practices for participatory Indigenous research, and formally engaging Traditional Owners as leaders rather than 'stakeholders' in the co-design of the program from the outset (Taylor et al. 2019). Dale et al. (2018) provide further suggestions for improving Traditional Owner engagement in broader reef governance (e.g. in the Reef 2050 plan and beyond); such as creating a tripartite agreement between the Commonwealth, State government, and Traditional Owners that formally shares authority over reef management between the three entities.

Conclusion

Significant uncertainty remains over whether effective policies limiting greenhouse gas emissions will be enacted in Australia and across the world. Environmental governance regimes are thus likely to continue facing climate crises with increasing frequency, and will be faced with fundamental questions regarding how to navigate them to the best of their ability. Our research provides empirical insight into how climate crises are experienced by diverse governance actors in a governance regime that is largely considered to be adaptive,

and the barriers and catalysts that arise in determining their responses. We also identified several ways in which some of these barriers might be overcome to improve responses to future crises, including creating and improving venues for collaboration, and adapting policies to pave the way for intervention. Our research contributes new knowledge answering longstanding calls to help build the evidence base needed to evaluate, and then improve upon the institutional arrangements of established adaptive governance regimes (Plummer and Armitage 2010). Though these pathways forward should help to improve responses among governance actors to future crises events, action depends on the willingness of diverse actors to negotiate a shared path forward, and ultimately on international and national commitments to address the root cause of climate change.

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Appendix B: Information Sheet, Consent Forms, and Interview Guides

Three versions of the same interview guide were used for interviews in this study: "main guide", "stakeholders guide", "follow-up guide". The main guide was used for participants whose work focused primarily on reefs (e.g. resource managers, researchers), while the stakeholders guide was used for participants who intersected with the reef space but whose primary focus was industry (e.g. agriculture, mineral resources). The questions in these two guides were the same but were ordered slightly differently to better build rapport and keep an easy conversation flow. For example, I asked industry actors several questions about their organizations' role and the impacts of bleaching events, before asking reef-specific questions, whereas in the main guide I start with discussing the status of the GBR. Some interviews were with the same participants interviewed for Barnes et al. (2022), so the wording of some questions refers to following up on topics touched on in previous interviews. The guide for Barnes et al. (2022) is also included below. All guides cover the same topics and many of the same questions, but with some questions worded slightly differently to suit different participants. The information sheet and consent form were the same for all participants

SUBJECT INFORMATION AND INFORMED CONSENT

Study Title: Great Barrier Reef governance after mass coral bleaching events.

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Purpose:

You are being asked to participate in a research study examining the approaches of influential or prominent organizations engaged with different aspects of Great Barrier Reef management. You have been invited to participate in this study because of your professional relationship with coral reef management and governance. The purpose of this research is to understand different organizations' reef-related goals and priority management actions. The study focuses especially on management and governance after back-to-back mass coral bleaching events. Questions will focus on evolving priorities for GBR management, and how these are affecting long term institutional arrangements (e.g. rules, processes, collaborations). The results of this research will be provided to study participants and to the general public through public presentations, scientific journals articles, and potentially popular media. The names of all participants will be kept confidential. You must be 18 or older to participate in this research.

Procedures:

If you agree to take part in this research study, you will be asked to answer a series of questions about your perspective on the current and future status of coral reefs, and on priority management or governance actions related to coral reefs. You will also be asked about what organizations or groups you collaborate with when developing or implementing

coral reef management actions and strategies. You will be asked to participate in an in-person or online interview by the principal investigator. The interview will include open ended questions about your views. The interview will be recorded with your permission only, for use only by the research team in analyzing data. After you have completed the interview, the principal investigator may contact you if they need to clarify their understanding of any of your responses. The interview will take 45 minutes to 1 hour to complete.

Risks/Discomforts:

There is no anticipated discomfort for those contributing to this study, we anticipate risk to participants is minimal. However, answering the questions could cause you to think about feelings that make you upset. You will be informed of any new findings that may affect your decision to remain in the study.

Benefits:

There is no promise that you will receive any benefit from taking part in this study. However, your participation may inform coral reef management in Australia and beyond about perspectives and priorities for reef management after back-to-back mass coral bleaching event, and the long term changes to governance that result.

Confidentiality:

Your records will be kept confidential and will not be released without your consent except as required by law. Your information will be combined with information from other people taking part in the study. When we write about the study to share or publish our results, we will write about the combined information we have gathered. You will not be personally identified in these written materials; we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. Your responses are confidential, including the identities of those in your personal network. Your interview will be given a randomly assigned ID code. This ID number will be the way that the research team matches your responses to the interview data. This random ID will never be reattached in any way to your name. Any signed consent form will be stored in a secure place separate from the data.

Voluntary Participation/Withdrawal:

Your decision to take part in this research study is entirely voluntary. You may refuse to take part in or you may withdraw from the study at any time without penalty. If you decide to withdraw after you have completed and submitted your survey responses, please contact the principal investigator, Amber Datta, at   or amber.datta@umontana.edu.

Questions:

If you have any questions about the research now or during the study, please contact the principal investigator, Amber Datta, at   or amber.datta@umontana.edu. If you have any questions regarding your rights as a research subject, you may contact the UM Institutional Review Board (IRB) at   .

Statement of Your Consent:

I, _____, have read the above description of this research study. I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study. I understand I will receive a copy of this consent form for my records.

Sign here: _____ Date:_____

Main Interview Guide

Before Interview:

- Make sure recording device is working
- Record the participant number
- Record audio consent (unless written consent provided)

Introduction:

Thank you for agreeing to do this interview, I appreciate your time. My name is Amber, I am a PhD student at James Cook University and University of Montana. This interview is for a study on governance of the Great Barrier Reef after mass coral bleaching events. Through these interviews I aim to build an understanding of different perspectives on reef management challenges and priority solutions to move GBR governance forward. I am also interested to hear about the current priority activities of your organization related to GBR management. I will ask about your organization's activities but invite you to speak as an individual, rather than on behalf of your organization.

This interview will take 45 minutes or less. Before we start, I want to let you know that we will keep your identity confidential throughout this study. Your responses will not be shared with any other participants—I will be the only one to handle the interviews, with oversight from my advisors. In addition, your name will not be used in any written reports or academic journal articles, we will only refer to general groups of actors (e.g. tour operators). If it is okay with you, I would like to record the interview. This ensures that your views are accurately recorded, and allows me to focus on our conversation. Is that okay with you?

QUESTIONS

Participant Info (5m): Let's start with some background about you.

1. How long have you been in your current role, and what are your main responsibilities?
   a. How long have you been working in the reef space?
   b. What reef issues does your work focus on?

Reef Challenges (15m): Next I would like to hear your perspective on where the reef and its management is at today.

2. How would you describe the current condition of the GBR?
   a. What is the role of coral bleaching events, versus other issues, in affecting the condition of the reef? What drives these impacts?
   b. What will reefs look like in the future (~20-30 years) if these issues go unchecked?

3. What management outcomes for coral reefs are reasonable to aim for given the context you have just described?

    a. Who do you hope will benefit from these reef outcomes? (Beyond the reef in general…)

4. What reef management approaches in the region have the most potential to realize outcomes for the reef? (get at how: regs, best practice)
    a. What organizations or groups should lead this work?
    b. Which approaches are less important?

Reef Management (20m): Next, I am interested in the specific work of your organization.

5. Can you briefly summarize your organization's main priorities related to the reef?
    a. Did the bleaching events have any effect on your organization's priorities or activities?

6. What types of organizations or groups do you partner with to undertake priority activities? Why?
    a. Have there been any changes in who (org type, scale) your organization works with in recent years?

7. Do any organizations or groups make it challenging for your organization to realize its goals? How so?
    a. How have you navigated this challenge?

Regional reflections (10m): We are getting towards the end here. I would like to step back to consider the big picture of reef management in the region, and where it might head next.

8. Are there any groups or sectors that historically have had little involvement in reef management, but that you feel could bolster the capacity of the region to manage the GBR?
    a. How do you think these groups could be brought to the table?

9. We have spoken a lot about the bleaching events today. Are there other major events or changes in the last five years do you see as important in shaping reef management today?

Conclusion (5m)

10. Has your organization made any public statements or reports in response to the bleaching events?
If so, what outputs should I be aware of?

11. Are there other important organizations I should speak to that take a different approach or express different views than yours does?

12. Is there anything on the topic of reef management or bleaching that we didn't cover that you would like to share?

Thank you for taking the time to speak with me, I really appreciate your sharing your thoughts. As a reminder, all of the information you have shared with us will remain confidential, and your name will not be mentioned in any publications. We will let you know of any publications or reports that arise from this study. Our next step will be to process the interviews; if we need to clarify anything that you've said, do you mind if we contact you?

Other Actors Guide

The introductory page is the same as the m.

QUESTIONS:

Participant Info (5m): Let's start with some background about you.

1. What is your current role, and what does that entail?
   a. How long have you been with this organization?

Reef Management (20m): Next, I am interested in the specific work of your organization.

2. Can you briefly describe the role of your organization in the region?
   a. What areas of your organization's work intersect with Great Barrier Reef management?
   b. How long have you personally been working on reef-related issues?

3. Did the bleaching events in 2016, 17 or 2020 have any effect on your work related to the reef? Why or why not?
   a. Alternate: Did the bleaching events generate any discussion within your organization about management of the reef?
   b. If not, what has been more important than the bleaching events in shaping your reef-related work in recent years?

4. What types of organizations or groups do you partner with or support in activities related to reef management? Why?
   b. Are any of these new partnerships in the last 5 years?

5. What or whom stands in the way of your organization realizing goals related to the GBR? How so?
   a. Do any actions taken for reef management themselves get in the way of goals for your organization?
   b. How have you gotten around this barrier?

Regional reflections (10m): Now we'll take a step back from your organization to reflect more generally on the reef and other's work in the region.

6. How would you describe the current condition of the GBR?
   a. What has been the role of coral bleaching events, versus other impacts, in affecting the health of the reef?
   b. What do you think reefs will look like in the future (~20 years) if these issues go unchecked?
   c. Who or what will be most affected if these issues are not addressed?

7. What outcomes for coral reefs are reasonable to aim for in the region overall given the context you have just described?

a. i.e. What do you expect reefs could look like assuming some level of successful management?

b. Who do you hope would benefit from these outcomes? (Beyond the reef in general…)

8. What reef management approaches in the region have the most potential to realize outcomes for the reef? (get at how: regs, best practice)

a. What organizations or groups should lead this work?

b. Which approaches are less important?

Regional reflections: I would like to conclude our discussion with a few questions about where management of the reef has been, and where it is headed.

9. Are there any groups or sectors that historically have had little involvement in reef management, but that you feel could bolster the capacity of the region to manage the GBR?

a. How do you think these groups could be brought to the table?

10. We have spoken a lot about the bleaching events today. Are there other major events or changes in the last five years do you see as important in shaping reef management today?

Conclusion (5m)

11. Has your organization made any public statements or reports in response to the bleaching events?
If so, what outputs should I be aware of?

12. Are there other important organizations I should speak to that take a different approach or express different views than yours does?

13. Is there anything on the topic of reef management or bleaching that we didn't cover that you would like to share?

Follow-Up Guide

Before Interview:

- Make sure recording device is working
- Record the participant number
- Record audio consent (unless written consent provided)

Introduction:

Thank you for agreeing to do this interview, I appreciate your time. As you may remember, I am a PhD student at James Cook University and University of Montana. This interview is for a study on Great Barrier Reef management and decision-making after mass coral bleaching events. Previously we spoke about how the bleaching events may have impacted your organization's work, and what actions your organization took in response to the bleaching events. It was evident from our last round of interviews that there were different perspectives on the current condition of the reef and what managers might aim for today, so that will be the first thing I will ask about today. After that, I would like to follow up to see what new activities or progress has been made within your organization, and then discuss what direction reef management in the region is headed as a whole. Through these interviews I aim to build an understanding of how GBR management is evolving in the period since the bleaching events. I will ask about your organization's activities but invite you to speak as an individual, rather than on behalf of your organization.

This interview will take 45 minutes or less. Before we start, I want to let you know that we will keep your identity confidential throughout this study. Your responses will not be shared with any other participants—I will be the only one to handle the interviews, with oversight from my advisors. In addition, your name will not be used in any written reports or academic journal articles, we will only refer to general groups of actors (e.g. tour operators). If it is okay with you, I would like to record the interview. This ensures that your views are accurately recorded, and allows me to focus on our conversation. Is that okay with you?

QUESTIONS

Participant Info (5m): Let's start with some background about you.

1. You described your role as consisting primarily of X. You mentioned you had been working in the reef space for X number of years. Are there any changes or other things I should note about your role?

Reef Challenges (10m): Now we'll discuss challenges facing the GBR in general.

2. Problem frame: We previously discussed coral bleaching events and the effects of these events and other factors on the GBR. It has now been 5 years since the bleaching event in 2016. How would you describe the current condition of the GBR?
   a. What is the role of coral bleaching events, versus other issues, in affecting the condition of the reef? What drives these impacts?
   b. What will reefs look like in the future (~20-30 years) if these issues go unchecked?

3. What management outcomes for coral reefs are reasonable to aim for given the context you have just described?
   a. Who do you hope will benefit from these reef outcomes? (Beyond the reef in general...)

4. What reef management approaches in the region have the most potential to realize outcomes for the reef? (get at how: regs, best practice)
   a. What organizations or groups should lead this work?
   b. Which approaches are less important?

Reef Solutions (25m): Now we can move on to what solutions your organization is specifically focused on.

5. We previously discussed the actions your organization took in response to bleaching and, more generally, the priority threats or impacts your organization is concerned with. Have there been any changes to your organizations main priorities or activities?
   a. Get at how priorities are approached (e.g. regs, best practices, etc.)

6. What types of organizations or groups do you partner with to undertake priority activities? Why?
   c. Have there been any changes in who (org type, scale) your organization works with in recent years?

7. Do any organizations or groups make it challenging for your organization to realize its goals? How so?
   a. How have you navigated this challenge?

Regional reflections (10m): We are getting towards the end here. I would like to step back to consider the big picture of reef management in the region, and where it might head next.

8. Are there any groups or sectors that historically have had little involvement in reef management, but that you feel could bolster the capacity of the region to manage the GBR?
    a. How do you think these groups could be brought to the table?

9. We have spoken a lot about the bleaching events today. Are there other major events or changes in the last five years do you see as important in shaping reef management today?

Conclusion (5m)

10. Has your organization made any public statements or reports in response to the bleaching events?
    If so, what outputs should I be aware of?

11. Are there other important organizations I should speak to that take a different approach or express different views than yours does?

12. Is there anything on the topic of reef management or bleaching that we didn't cover that you would like to share?

Thank you for taking the time to speak with me, I really appreciate your sharing your thoughts. As a reminder, all of the information you have shared with us will remain confidential, and your name will not be mentioned in any publications. We will let you know of any publications or reports that arise from this study. Our next step will be to process the interviews; if we need to clarify anything that you've said, do you mind if we contact you?

Information Sheet, Consent Form and Interview Guide for Barnes et al. (2022)

These are the interview materials used for Barnes et al. (2022), which is attached as Appendix B.

INFORMATION SHEET

Impacts and responses to bleaching on the Great Barrier Reef

You are invited to take part in a research project about how different stakeholders in the Great Barrier Reef (GBR) have been affected by and responded to recent bleaching events and their aftermath. This research is part of a larger study on responses to changes in environmental systems and how social networks, or relationships among people (such as collaboration and information sharing relationships), might affect these responses. This study is being conducted by Dr. Michele Barnes, a Senior Research Fellow at James Cook University. Her student, Amber Datta, is a co-investigator, and this work will contribute to her PhD in Agriculture, Environmental, and Related Studies at James Cook University.

If you agree to be involved in the study, you will be invited to be interviewed. The interview, with your consent, may be audio-taped, and should only take approximately 30-45 minutes of your time. The interview will be conducted in person at a venue of your choice, or over the phone. As part of your interview, you will be asked about your role in the GBR region and about recent bleaching events and their aftermath. This will include questions about whether and how you have been affected by and/or responded to recent coral bleaching, and what actions might be taken in response to coral bleaching in general. Later this year, you will be invited to participate in a follow-up online survey focused on how different stakeholders in the GBR interact with each other through informal and formal social networks.

Taking part in this study is completely voluntary, and you can stop taking part in the study at any time without explanation or prejudice.

Your responses will be strictly confidential/anonymous. The data from the study will be used in research publications and reports. The results will be published in peer-reviewed journals and associated media releases. You will not personally be identified in any way in these publications.

If you have any questions about the study, please contact Dr. Michele Barnes or Amber Datta.

Principal Investigator:	**Co-investigator:**
Michele L Barnes	**Amber Datta**
James Cook University	**James Cook University**
Phone:	**amber.datta@my.jcu.edu.au**
Michele.barnes@jcu.edu.au	

If you have any concerns regarding the ethical conduct of the study, please contact: Human Ethics, Research Office James Cook University, Townsville, Qld, 4811 Phone: (07) 4781 5011 (ethics@jcu.edu.au)

INFORMED CONSENT FORM

| PRINCIPAL INVESTIGATOR: Michele L Barnes |
| PROJECT TITLE: Impacts and responses to bleaching on the Great Barrier Reef |

I understand that the aim of this research is to understand how different stakeholders in the Great Barrier Reef (GBR) have been affected by and responded to recent bleaching events and their aftermath, and that this research is part of a larger study on responses to changes in environmental systems and how social networks, or relationships among people (such as collaboration and information sharing relationships) might affect these responses. I consent to participate in an interview for this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve an interview and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary, and I am aware that I can stop taking part in it at any time without explanation or prejudice and withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential/anonymous and that no names will be used to identify me with this study without my approval

(Please tick to indicate consent)

I consent to be interviewed ☐ **Yes** ☐ **No**

| **Name:** *(printed)* | |
| **Signature:** | **Date:** |

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INTERVIEW GUIDE

Before Interview:

- Make sure recording device is working
- Record the subject number
- Record audio consent (unless written consent provided)

Introduction:

Thank you for agreeing to do this interview, I appreciate your time. My name is Amber, I am a PhD student at James Cook University. This interview is for a study on how coral bleaching has affected both individuals and governance of the Great Barrier Reef. We are interested in learning how the coral bleaching events of 2016 and 2017, and the aftermath of these events, has impacted you or influenced your work. We hope this research will inform future efforts to govern and manage the reef in a way that meets the needs of all reef users and other stakeholders. This project is led by Michele Barnes at JCU, I am a research assistant.

This interview will take 45 minutes or less. Before we start, I want to let you know that we will keep your identity confidential throughout this study. Your responses will not be shared with any other participants—Michele and I will be the only ones to handle the interviews. In addition, your name will not be used in any written reports or academic journal articles, we will only refer to general groups of actors (e.g. tour operators). If it is okay with you, I would like to record the interview. This ensures that your views are accurately recorded, and allows me to focus on our conversation. Is that okay with you?

QUESTIONS

<u>**Participant Info:**</u> **Let's start with some background about you. (5m)**

1. What is your current role on the GBR and what does that entail?
2. Were you in this role during the 2016/17 bleaching events?

<u>**Experience of bleaching:**</u> **I would now like to ask about your experience of the 2016 and 2017 bleaching events. (20m)**

3. Have the bleaching events affected your work? (5 m)
    a. During your past position (2016/17) and current position (if different now)
    b. Professionally?
    c. Directly? Indirectly?

4. Has your organization taken any specific actions to respond to the bleaching events? (5 m)
    a. If so, what actions? (Cover during and after bleaching events)
    b. Specific actions including moving tourism operation location, lobbying govt, starting a volunteer campaign, joining a response team, increasing monitoring effort, etc.

5. What are the key factors that you feel enabled your organization to respond in this way?
   a. *may cycle back to #4

6. How do these actions compare to actions taken in response to previous bleaching events?
   a. i.e.: Was there anything different about how your organization responded to these events versus previous events?

7. Has anything prevented you from responding in the way you feel is necessary?
   a. For example, are there other actions you wish your organization had taken?
   b. If you could go back in time, what do you wish your organization had done differently, or what would you change?

Responding to bleaching: We are interested in hearing your perspective on general actions needed to respond to bleaching. (15m)

8. Do you think actions or interventions by others are needed to address bleaching on the GBR?
   a. If so, what actions should be taken?
      Ex actions: Policy, public opinion and engagement, technical fixes, planning, management actions, regulatory structures, emissions, restoration efforts, increased coordination
   b. Who is responsible for taking these actions?

9. Who or what is key to preventing these actions?

Conclusion (5m)

10. (optional) As young professional scientists, we would really like to hear your perspective on how we as researchers could contribute to moving your vision for the GBR forward?

11. Right now, we are only interviewing a few key people, but in the next few months we will be sending out a follow up online survey. Are there any other individuals either in your sector or other sectors that we should consider speaking with that could provide a range of perspectives?

12. Do you have any final thoughts on the topics we covered that you would like to share?

Thank you for taking the time to speak with us, we really appreciate your sharing your thoughts. As a reminder, all of the information you have shared with us will remain confidential, and your name will not be mentioned in any publications. We will let you know of any publications or reports that arise from this study. Our next step will be to process the interviews; if we need to clarify anything that you've said, do you mind if we contact you?