

Understanding Information Needs for Adapting Reef Ecosystem Management  
to a Changing Climate

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## DEDICATION

As scientists we are taught that our intellectual progress is attributed to those who came before us and from whom were we taught,

*“Bernard of Chartres say that we [the Moderns] are like dwarves perched on the shoulders of giants [the Ancients], and thus we are able to see more and farther than the latter. And this is not at all because of the acuteness of our sight or the stature of our body, but because we are carried aloft and elevated by the magnitude of the giants.”* John of Salisbury

I am grateful to the many that came before me and assisted me. Yet as a human, a woman, and this person I have become, I am the product of no gift greater than a Mother’s love.

To my most profound giant.

MaryAnne DeJoseph

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## Chapter 1. INTRODUCTION

This chapter serves to provide the context of this research study by detailing the background information before expounding the justification for this research study and research questions. The background section begins by presenting a narrative explaining the significance of tropical reef ecosystems and the ecosystem services they provide, the threats of climate change to these ecosystem services, and the challenges of management to address compounding threats from global and local stressors. It continues with an account of the history of *A Reef Manager's Guide to Coral Bleaching*, including its genesis; production, launch, and training efforts; and related products and activities both before and after its publication. Then the justification for this research study is promulgated by detailing its goals. The chapter concludes by presenting the research questions set forth in directing this study to improve the effectiveness of reef management tools and contribute information to support the preparations for the potential follow-up project to *A Reef Manager's Guide to Coral Bleaching*.

### BACKGROUND

Tropical reefs are valued for the vast ecosystem services they provide to millions of people globally (Millennium Ecosystem Assessment 2005, Vroom 2011). Rich biodiversity accounts for the compass of goods and services that extend from the tangible to the abstract: food for coastal communities, coastal protection from storms and erosion, maintenance for fisheries, nutrient cycling, tourism (Barbier et al. 2011), medicinal (Burke et al. 2011), recreational, cultural, and aesthetic (Ghermandi et al. 2011). Approximately 275 million people are highly dependent on these reef ecosystem services with an estimated total net benefit of U.S. \$29.8 billion/year (Cesar et al. 2003, Burke et al. 2011; see Table 1.1).

Table 1.1. Sample economic values listed in 2010 U.S.\$: annual net benefits from coral reef-related goods and services (Burke et al. 2011).

Extent of Study	Tourism	Coral-Reef Fisheries	Shoreline Protection
<b>Global</b> <sup>a</sup>	\$11.5 billion	\$6.8 billion	\$10.7 billion
<b>Caribbean (Regional)</b> <sup>b</sup>	\$2.7 billion	\$395 million	\$944 million-\$2.8 billion
<b>Philippines &amp; Indonesia</b> <sup>c</sup>	\$258 million	\$2.2 billion	\$782 million
<b>Belize (National)</b> <sup>d</sup>	\$143.1 million-\$186.5 million**	\$13.8 million-\$14.8 million**	\$127.2-\$190.8 million
<b>Guam (National)</b> <sup>e</sup>	\$100.3 million**	\$4.2million**	\$8.9 million
<b>Hawaii (Subnational)</b> <sup>f</sup>	\$371.3 million	\$3.0 million	Not evaluated
<p><b>*All estimates have been converted to U.S.\$ 2010.</b></p> <p><b>**Estimates of the value of coral reef-associated fisheries and tourism for Belize and Guam are gross values, while all other numbers in the table are net benefits, which take costs into account.</b></p> <p>a. Cesar et al. 2003.  b. Burke et al. 2004.  c. Burke et al. 2002.  d. Cooper et al. 2009.  e. Haider et al. 2007.  f. Cesar 2002.</p>			

### Threats of Climate Change to Reefs

Despite the vital and valuable ecosystem services supplied by reef ecosystems, anthropogenic pressures have increasingly proven to be detrimental to reef ecosystems (Burke et al. 2011).

Although direct and indirect human pressures vary widely among regions, they uniformly threaten the well-being of tropical reefs and have caused the loss of ~19% of reefs worldwide (Wilkinson 2008). Direct and local pressures on reefs are commonly the result of

overexploitation such as, destructive fishing techniques using dynamite or cyanide, overfishing, marine pollution and damage, sediment and pollution, and coastal development. However, it is the pernicious effects of the indirect and global pressures of climate change such as sea surface temperature rise, ocean acidification, sea level rise, and increasing storm frequency (Doney, Fabry, et al. 2009, Pachauri et al. 2014), that compounds these problems to a potentially irreversible level (Doney et al. 2012). The Reefs at Risk Revisited, a global analysis of the status

and threats to reefs, found 75% of the world's reefs to be threatened by local and global pressures (Burke et al. 2011).

Rising sea surface temperature (SSTs) and ocean acidification (OA) are direct effects of global climate change (Pachauri et al. 2014). Individually, each factor has been found to be detrimental to various species of tropical reef ecosystems. Elevated SST causes coral bleaching (Trench 1979, Glynn 1984, Brown 1997, Baker et al. 2008, Veron et al. 2009) and has been the genesis of mass bleaching events (Eakin et al. 2009) leaving coral more vulnerable to disease outbreaks (Bruno et al. 2007, Miller et al. 2009, Burge et al. 2014, Pratte et al. 2014), and other local stressors (Hoegh-Guldberg et al. 2007, Carpenter et al. 2008, Carilli et al. 2010, Santavy et al. 2011). OA disrupts the fundamental processes of scleractinian corals (Kleypas et al.) including, fertilization (Albright et al. 2010), settlement (Webster et al. 2011), development (Albright et al. 2011), calcification and dissolution (De'ath et al. 2009, Doney, Balch, et al. 2009, Eyre et al. 2014), and preservation (Anthony et al. 2008, Horwitz et al. 2014). Beyond corals, OA has been found to negatively impact many other reef organisms that will affect the ecosystem function of tropical reefs (Kleypas and Yates 2009), such as the calcification and dissolution rates of crustose coralline algae (Albright and Langdon 2011, Vroom 2011), and phytoplankton (Dutkiewicz et al. 2015), behavioral modifications of fishes (Munday et al. 2014), recruitment success of gastropods (Milazzo et al. 2014), etc.

In addition to the direct physiological effects, OA indirectly affects ecological factors such as reduced habitat complexity for macroinvertebrates (Fabricius et al. 2014) and reef fish (McCormick et al. 2010, Coker et al. 2014, Holbrook et al. 2015), food webs (Guinotte et al.), and many other species interactions (Wootton et al. 2008). According to Jokiel (2015), Cantin et al. (2010), and Manzello (2010) elevated SST and coral bleaching will have lethal effects before

those of OA; however, the synergistic effects of elevated SST and OA on tropical reef ecosystems will hasten the decline in reefs (Fabricius et al. 2011, Ateweberhan et al. 2013).

### Management Challenges

Addressing both local and global stressors is a complex and arduous task. Despite the fact that approximately 27% of the world's reefs are designated as marine protected areas (MPAs), many of them have proven to be ineffective and MPAs are no longer the preferred method of reef management (Jones et al. 2004, Burke et al. 2011, Rife et al. 2013). Apart from the Bahamas, systems management or resilience theory has not been included in most MPAs plans (Maynard et al. 2015). Managers are now focusing their attention on reducing the cumulative stressors specific to their area. This learning from experience approach is an example of how adaptive management serves as a common tenet in many marine management frameworks; a structured, cyclical process of decision making in the face of uncertainty utilizing system monitoring to reduce uncertainty over time.

### Genesis of Guide

*A Reef Manager's Guide to Coral Bleaching* (here after referred to as the "Guide"), was created as a collaborative effort of the National Oceanic Atmospheric Administration's (NOAA) Coral Reef Conservation Program (CRCP), the Australian Government's, Great Barrier Reef Marine Park Authority (GBRMPA), the International Union for Conservation of Nature (IUCN), and the World Conservation Union ([http://coris.noaa.gov/activities/reef\\_managers\\_guide](http://coris.noaa.gov/activities/reef_managers_guide)) in order to:

*"...assist managers in responding effectively to mass coral bleaching events... [It] is designed to provide pragmatic, science-based suggestions for adaptive management in this time of change. We commend it to reef managers worldwide..."*  
(Marshall et al. 2006).

In context to *A Reef Manager's Guide to Coral Bleaching* and this study, managers are defined as any people who make decisions about the use or protection of species, habitats, resources or other services from coral reef ecosystems.

The Guide was a product of a series of charges issued through the United States Coral Reef Task Force<sup>1</sup> (USCRTF), which was established in 1998 by Presidential Executive Order 13089 to lead U.S. efforts to preserve and protect coral reef ecosystems.

The 2002 USCRTF meeting passed two resolutions highlighting the impacts of climate change and coral bleaching on tropical reefs: 1) the Puerto Rico Resolution identified climate change and coral bleaching as one of six priority threats to U.S. reefs and encouraged development of local action strategies by state/territory and federal partners to outline local management strategies to address the problem, and 2) Coral Reefs and Climate Change called for an interagency, public/private partnership to advance understanding and management of this issue. In response to these resolutions and at the request of the task force, the Department of Commerce (NOAA), Environmental Protection Agency (EPA), and Department of the Interior (DOI) organized the Coral Reefs, Climate, and Coral Bleaching Workshop on O`ahu, Hawai`i, June 2003. It hosted more than 100 U.S. and international tropical reef managers and scientists charged to explore collaborative, interdisciplinary approaches to advance the science and tools for management of the threats to and impacts of climate change on reefs with an emphasis on coral bleaching.

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<sup>1</sup> The USCRTF is composed of leaders from 12 Federal agencies, seven U.S. States, Territories, Commonwealths, and three Freely Associated States. It is “responsible for overseeing implementation of the Executive Order, and developing and implementing coordinated efforts to map and monitor U.S. coral reefs; research the causes of, and solutions to coral reef decline; reduce and mitigate coral reef degradation from pollution, over fishing and other causes; and implement strategies to promote conservation and sustainable use of coral reefs internationally.” (<http://www.coralreef.gov/about/>)

The workshop was directed by three themes: 1) information sharing, as well as the identification of opportunities for collaboration and knowledge gaps; 2) the development of a management toolkit framework for field managers across all regions containing available strategies, techniques, and programs for adaptive management of tropical reefs amidst a changing climate; and 3) program planning, *“develop a framework for an integrated research program to improve the understanding of local and system-wide responses to climate change and establish partnerships that enhance our ability to develop management responses”* (<http://www.fws.gov/coralreef/proceedings/Workproc/index.htm>). As a result of the workshop, the development of the Guide was initiated with the goal *“to capture the state of the art and the existing knowledge relevant to management of reefs threatened by coral bleaching”* (<http://www.fws.gov/coralreef/proceedings/Workproc/index.htm>). The interagency project, led by Paul Marshall of the GBRMPA and Heidi Schuttenberg of the NOAA, capitalized on the assistance of various expert stakeholders to articulate how local managers can prepare for and respond to mass coral bleaching. Furthermore, the Guide supported one of five scientific goals<sup>2</sup> set by the U.S. Global Change Research Program’s - Goal 4, *“understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes”* (<http://www.globalchange.gov/engage/process-products/sap-summary>) - *“by providing managers with options for sustaining and improving ecological systems and related goods and services, given projected global changes”* (<http://www.noanews.noaa.gov/stories2006/s2717.htm>).

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<sup>2</sup> These five scientific goals served as the basis for the 21 Synthesis and Assessment Products (SAPs) series created by the U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program), which “integrated research on key climate science issues and aimed to support informed discussion by decision makers, stakeholders, and the general public” (<http://www.globalchange.gov/engage/process-products/sap-summary>).

## The Guide: Production, Launch, and Training Efforts

The cause of global climate change and its effects on ecosystem services, have long been a politically charged topic. As a result of this political sensitivity, elite interviews<sup>3</sup> reported that some experts could not be properly acknowledged for their contributions to the Guide at their employer's instruction. In addition, the Guide's publication was detained beyond its completion in 2004 to 2006. The Guide's release was accompanied with a full press launch led by NOAA followed by a series of affiliated trainings conducted around the globe.

NOAA's official press release was widely disseminated in various truncated forms among partners' websites. The full version of the press release reported the following about the Guide:

*"...reviews management actions that can help restore and maintain resilience of coral reef ecosystems. This review draws on a growing body of research on ways to support the ability of coral reef ecosystems to survive and recover from bleaching events. The reef manager's guide includes specific guidance and case studies on how to prepare bleaching response plans, assess impacts from bleaching, engage the public, manage activities that may impact reefs during bleaching events, identify resilient reef areas and incorporate information regarding reef resilience into marine protected area design."*

*(<http://www.noaanews.noaa.gov/stories2006/s2717.htm>)*

It continued with a promise to reef managers addressing mass bleaching events:

*"The guide identifies three key actions reef managers can take to help reefs survive and recover from mass bleaching events: (1) increase observations of reef condition before, during and after bleaching to increase information and understanding of impacts and areas that may be especially resistant to bleaching, (2) reduce stressors (e.g., pollution, human use) on reefs during severe bleaching events to help corals survive the event, and (3) design and implement reef management strategies to support reef recovery and resilience, including reducing land-based pollution and protecting coral areas that may resist bleaching and serve as sources of coral larvae for "reseeded" reefs."*

*(<http://www.noaanews.noaa.gov/stories2006/s2717.htm>)*

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<sup>3</sup> Elite interviews (Dexter 1970) were conducted to collect background information unique to experts of the subject area. Judgment sampling (Vogt et al. 2012) was employed to select knowledgeable, articulate individuals who met one or more of the criteria defined by this study (found below).

A training curriculum based on the Guide was developed as a collaborative, inter-agency effort and continued to evolve as result of participation feedback and lessons learned.

Responding to Climate Change workshops, led by NOAA, were conducted in Australia (2007), American Samoa (2007), Florida Keys (2008), and Hawai`i (2008). Once NOAA and The Nature Conservancy's (TNC) Reef Resilience merged their outreach efforts and curricula, the revamped Reef Resilience and Climate Change training series took place in Bonaire (2009), Guam (2009), and the U.S. Virgin Islands (2012). The partnered effort continued with the TNC led Reef Resilience and Climate Change, Training of Trainers workshops in the Caribbean (2010), Palau (2011), Bali (2012), and Zanzibar (2013).

Other actions to further the Guide have been discussed at subsequent USCRTF meetings; however, the outcomes and actions taken were not reported and remain unknown.

#### The Guide: Complementary Products or Actions

Activities seen as complementary to the Guide have occurred both during and after the Guide's production and affiliated training series. As is the customary manner in science, a series of publications has served as building blocks of knowledge as the concepts of tropical reef management progressed. A journal article by Jordan West and Rodney Salm, expert contributors to the Guide, identified "*...likely environmental correlates of resistance and resilience to coral bleaching...as a tool for identifying reef areas that are likely to be most robust in the face of continuing climate change and for determining priority areas for reducing direct anthropogenic impacts, this information has important implications for coral reef conservation and management*" (2003). In 2006, the IUCN's Climate Change and Coral Reefs Marine Working Group and TNC published the technical document, Coral Reef Resilience and Resistance to

Bleaching (2006). Anthony et al., (2015) was the principal product of the 2012 workshop, Operationalising Resilience for Management of Coral Reefs held in Australia; it utilizes the adaptive resilience-based management (ARBM) framework (Anderies et al. 2006) to identify effective management options to reduce reef ecosystem vulnerability and enhance environmental and socio-economic resilience.

Of direct relevance to this thesis, the Coral Reef Resilience Research and Management: Past, Present and Future! workshop held in Hawai`i, November 2014 was notable as the first gathering of resilience grantees and reef managers funded by NOAA CRCP. The workshop convened with the following two goals:

- 1) *To bring together NOAA scientists, external partners and managers who are currently engaged in assessing and managing reefs for resilience in a changing climate to create the opportunity for face-to-face dialogue and review recent advances, and*
- 2) *Identify priority research, products, and collaborative projects, and make plans to advance this body of work over coming years in direct partnership with coral reef managers* (Maynard et al. 2015).

These workshops goals specifically support the first climate change goal of NOAA CRCP's program goals and objectives (2010-2015): *"Increase coral reef resilience to climate change and ocean acidification through effective management strategies"* (NOAA Coral Reef Conservation Program 2009).

As the term resilience has become used more frequently in the vernacular, *"the concept of resilience remains vague, varied, and difficult to quantify"* (Standish et al. 2014). Thus, the workshop report began by defining operational resilience as described by Mumby et al. (2007) to be, *"the capacity of a reef to resist and/or recover in the future given its probable exposure regime and to maintain provision of ecosystem goods and services"* (Maynard et al. 2015). The

first portion is derived from ecological and engineering resilience and the later to the deep-seated connection between ecological and social resilience, “*especially in areas where communities are dependent on reefs for food security and livelihoods*” (Maynard et al. 2015). Additionally, Maynard et al. (2015) defined ‘resilience-based management’ as “*the application of resilience theory, thinking and tools to deliver ecosystem-based management outcomes into the future*” in order to reduce terminology confusion (Mumby et al. 2014).

The majority of the workshop evolved around the presentation of existing research and/or management actions and discussion of six themes: 1) mapping environmental disturbance/exposure, 2) field based resilience assessments (includes herbivorous fish), 3) connectivity, 4) land-based sources of pollution, 5) managers use of resilience assessments and reporting, and 6) training and capacity building. Training and capacity building encompassed the last, crosscutting sixth theme, discussed at each of the five theme and concluding sessions. With respect to training and capacity building participants concluded the following: 1) the employment of resilience science in management requires additional and improved guidance from all themes, and management “*needs to include reporting and information dissemination*” (Maynard et al. 2015); and 2) online guidance should be supplemented with in person training and mentorship opportunities. Next steps considered high priority by Maynard et al. (2015) include:

*“1. Keep guidance content current within key delivery mechanisms like TNC’s Reef Resilience toolkit, including most relevant tools and resources and lists current references for various working themes (such as the five covered during this workshop).*

*2. Undertake a comprehensive review of past and current programs that provide guidance and train coral reef managers. The review should result in a report that describes strengths and weaknesses and provides recommendations as to what kinds of guidance and training programs are needed by managers. The review also*

*needs to identify key stumbling blocks to management actions and what the key features of these programs should be both with respect to content and coordination (see also step 3).*

*3. Organize a workshop following on from step 2 to review and finalize the recommendations and discuss considerations related to sharing costs and coordination efforts across programs and agencies.”*

## JUSTIFICATION FOR RESEARCH STUDY

Since the Guide’s publication in 2006, managers have requested further guidance on new techniques for reef ecosystems especially those to proactively address climate change impacts. In response, NOAA’s CRCP and Australia’s GBRMPA are currently deliberating on plans for an expansion of the Guide to support regional capacity to manage tropical reef ecosystems in light of climate change. Hereinafter, the potential successor project is referred to as the “successor project”.

The goal for this thesis is to prepare the groundwork for a proactive, informational resource addressing the compounding stressors of tropical reef systems that will improve upon the current Guide. The revised resource might be titled: *Adapting to Climate Change: A Guide for Coral Reef Managers*. This study provides insight to the current information practices and needs of the reef management community. In addition an evaluation of the current edition Guide from the perspective of both practitioners and experts was performed. The feedback from the evaluations, formed the basis of this study’s recommendations.

## RESEARCH QUESTIONS:

### Major Questions Posed:

In order to improve the effectiveness of reef management tools and contribute information to support the preparations for the follow-up project to the Guide, I aim to answer three main research questions:

1. What are the current information use practices of the reef management community?
2. What are the strengths and weaknesses of the current Guide, *A Reef Manager's Guide to Coral Bleaching*, from the user's perspective?
3. What are the major advances in science (since the 2004 completion date of the Guide) to support management and any follow-up project/successor resource to the Guide?

I first posit an overall framework based on the tropical reef management literature that outlines a socio-ecological approach and then I develop the rationale for each of the main research questions.

The applied context of coupled social-ecological systems (Figure 1.1) supports the premise of ecosystem-based management (EBM) that ultimately, we are managing people's influences on the ecosystem, rather than managing the ecosystem itself (McLeod et al. 2009). To aid the implementation of EBM, the Millennium Ecosystem Assessment [MEA] (Millennium Ecosystem Assessment 2005) established a classification system of ecosystem services. Even though the MEA has been commended for its efforts, this system has been criticized in favor of a more context specific and purpose oriented system in order to manage the coupled social-ecological system more effectively (Fisher et al. 2009, Asah et al. 2012). Under this rationale, a management tool should be customized to the context, needs, and wants of the

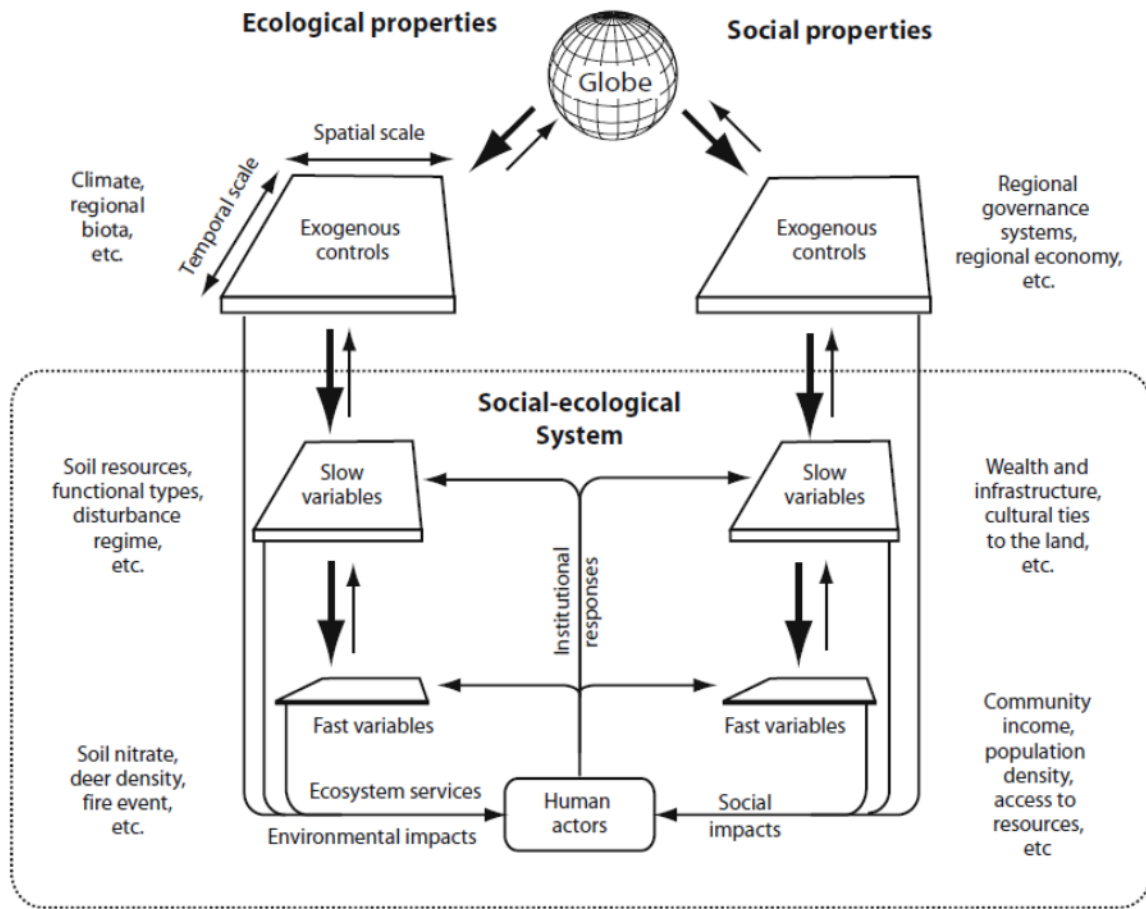


Figure 1.1. Social-ecological system (Chapin et al. 2009).

intended user groups and specific ecosystem. Because of this advice, I queried individual reef managers about what they need and want from an information management tool in a way that allows them to identify a more context specific and purpose oriented approach as necessary.

Adaptive management is an integral component of many resource management frameworks and tools. See Figure 1.2; as they pertain to Adaptive management, (Walters 1986, Lee 1993, Chapin et al. 2009). Examples of these frameworks and tools that employ adaptive

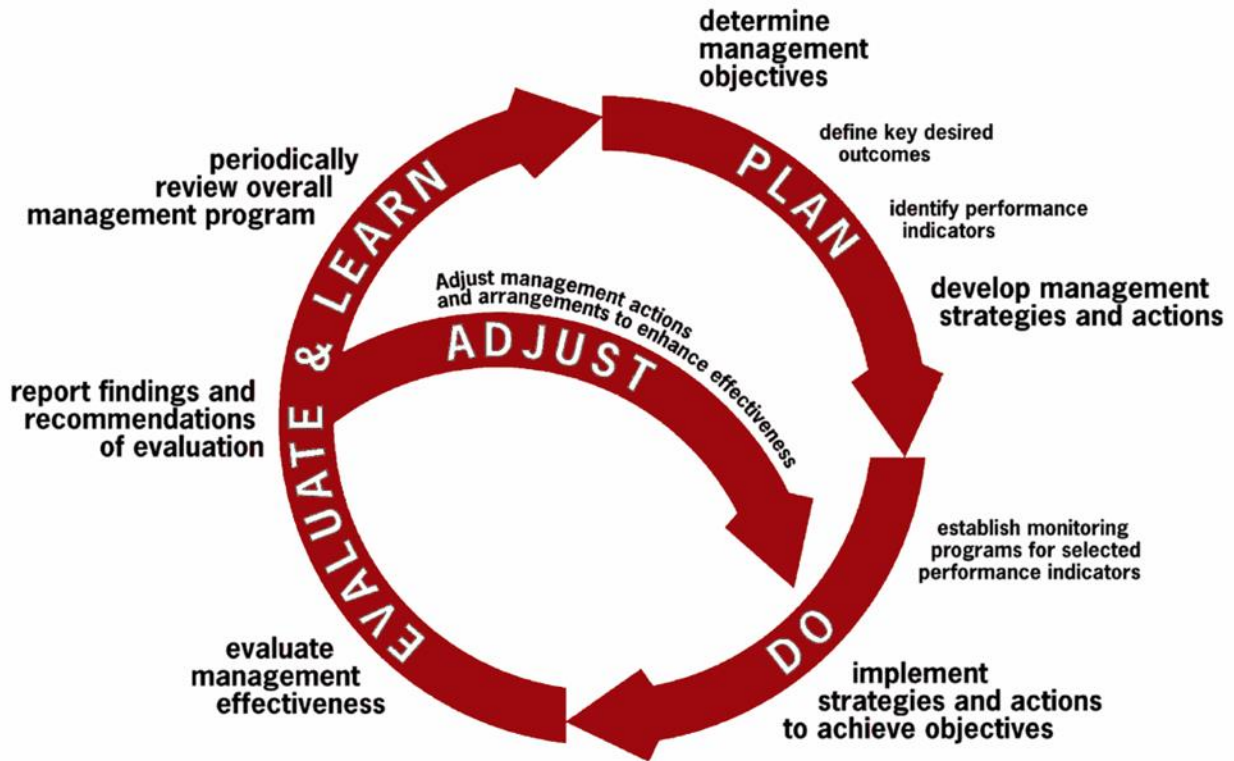


Figure 1.2. Adaptive Management Cycle, <http://www.cmar.csiro.au/research/mse/>.

management include: Coastal and Marine Spatial Planning (Center for Ocean Solutions 2011), EBM (McLeod and Leslie 2009, Agardy et al. 2011), Management-Strategy-Evaluation (MSE), (Butterworth et al. 1999, Sainsbury et al. 2000), Resilience-Based Natural Resource Management (Chapin et al. 2009), and Adaptive Resilience-based Management (Anderies et al. 2006). Weaving these frameworks together is the underlying principle of adaptive management; anticipating the unknown through the *“idealistic application of science to policy...[which] can produce reliable knowledge from unavoidable errors”* (Lee 1993). If successfully executed, Lee (1993) considers this double-loop learning to be adaptive learning, where practitioners reflect upon the outcome of past actions before moving forward (Argyris et al. 1978, Chapin et al. 2009), to foster “real learning”. Adaptive management is an iterative process by which scientific

monitoring and research provide information to refine decision making in light of uncertainty (Anderies et al. 2006). Maynard et al., (2015) finds the adaptive management process to be essential in integrating and applying resilience theory<sup>4</sup>. Despite its importance, the implementation of this stage of periodic review is too often absent.

*Research Question #1: What are the current information use practices of the reef management community?*

In order to construct an effective information resource in the future, we must first understand the current preferences of the reef management community. To explore this topic the following research questions were propounded:

1. Focus area: What topic/issue(s) do the community address in their work?
2. Information used: What type(s) of information are currently being used to support their work?
3. Resource type: What type(s) of information resources are currently being accessed to support their work?
4. Access: How do they access these information resources and what is the preferred method to learn about new information as it becomes available?
5. Information gaps: What do reef managers need from information tools to support their work?

These questions were addressed by multiple means including an on-line survey and elite interviews; through which both individuals who used and did not use the Guide were queried.

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<sup>4</sup> Resilience theory is based on the following definition of resilience: the “capacity of a social-ecological system to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity, and feedbacks as a result of recovery or reorganization in a new context.” (Chapin et al. 2009)

*Research Question #2: What are the strengths and weaknesses of the current Guide, A Reef Manager's Guide to Coral Bleaching, from the user's perspective?*

An evaluation of the 2006 *A Reef Manager's Guide to Coral Bleaching* aims to fill this adaptive management void and to contribute to choices to be made about the successor project. To reveal the strengths and weaknesses of the current Guide it is necessary to assess its utility, effectiveness, and format. The following research questions are assessed:

1. Utility: Who uses the Guide and why?
2. Effectiveness: Is the Guide effective and why?
3. Format: What format would be most beneficial for improved utility and effectiveness?
4. New information: What new information (scientific information, management tools, or frameworks) should be included in the upcoming successor project of the Guide to address the complex management needs of tropical reef ecosystems?
5. Recognizing compounding stressors especially the effects of climate change on reef ecosystems, what is needed for the successor project of the Guide to become a proactive, holistic, and adaptive management tool?

Once again, these questions were addressed by multiple means including an on-line survey and elite interviews. Only individuals who self-identified as having knowledge of the Guide were targeted to participate.

*Research Question #3: What are the major advances in science (since the 2004 completion date of the Guide) to support management and the successor resource to the Guide?*

Adaptive management addresses making decisions in the face of uncertainty due to the lack of information and/or incorrect information: observational error, process error, model error, and/or implementation error (Walters 1986, Lee 1993, Chapin et al. 2009). Although the call for monitoring (regional baseline data, current conditions, etc.) is frequently made and monitoring is

a main tenet of many management frameworks, capacity (i.e., most often funding) limits the production of this information. Far from meeting the demand, substantial advancements in science have been made since the completion of the Guide. A triangulated approach was employed to determine answers to the following research questions:

1. How is science being used in management?
2. How do managers take into account the changes in science?
3. What are the major advances in science since 2004?
4. What are the outstanding, scientific information needs required to support management address the combined threats to tropical reef ecosystems?

Proper documentation (exempt status) has been acquired from the University of Washington's Human Subjects Division to conduct the interviews and surveys proposed in this research study (University of Washington HSD study #43318).

## Chapter 2. METHODS

### METHODS

This study design employs a triangulated approach (Mathison 1988, Vogt et al. 2012) in pursuit of corroboration for its research goals. By triangulation, it is meant that several means are utilized to examine a phenomenon through validating, contradicting, or discovering variables. Specifically, multiple data sources were analyzed and mixed methods (Vogt et al. 2012) utilized to obtain perspectives on what is needed to produce a more effective reef manager's guide. This design is flexible (Robson 2002) in order to encompass a wide range of issues confronting tropical reef managers.

## Objectives

- Informal background interactions with “key players” provided historical context and background that shaped the research design.
- Elite interviews (Dexter 1970) were conducted to collect background information unique to experts of the subject area and solicit advice on survey participation.
- Tailored design online survey (Dillman et al. 2009) with open-ended questions queried a cross section of the broader reef management community about current information practices, outstanding management needs, and the strengths and weaknesses of *A Reef Manager’s Guide to Coral Bleaching*.
- Review of archival data (Weber 1990) pertaining to the Guide; workshop and training reports, and use of the Guide’s website.
- Literature reviews were conducted for various components of this study, i.e., 1) study design, and 2) review and update of the major scientific advancements (in the published literature) addressing the response of tropical reef ecosystems to the effects of climate change and compounding stressors and their implications for management.

## Data Collection and Analysis

### *Alpha and Beta Tests of Research Design*

The viability of this design was tested at the 2012 International Coral Reef Symposium in Cairns, Australia. It was presented to a snowball sample of the reef management community- as well as randomly encountered subjects during the poster session. Participants were asked to review of the design and give advice on how to solicit the targeted participants for the formal survey. Feedback was incorporated, and the amended design was then presented to two qualitative

design experts (defined below) for review. The survey and elite interview instruments were beta tested during June 2012 and 2013 by 16 individuals, either qualified representatives of the potential survey participants (e.g., 8 marine professionals , 4 social scientists, and 2 research experts from academia) or, as part of a purposive sample, three individuals outside the tropical reef management community to ensure clarity of instruction.

### *Elite Interviews*

In order to construct a holistic understanding of reef management (past, present, and future), elite interviews (Dexter 1970) were conducted to collect background information unique to experts of the subject area. This interview technique aimed to discover trends in management per scientific, organizational, and operational standpoints that may be useful to the reef community and the Guide’s successor project. In addition, it solicited advice and assistance in the distribution and participation of the online survey. Judgment sampling (Vogt et al. 2012) was employed to select knowledgeable, articulate individuals who met one or more of the criteria defined by this study:

- ❖ Considered experts, or “go to” people in reef ecosystem management among peers.
- ❖ Associated with a high-level non-governmental organization (NGO).
- ❖ Leaders of national reef management program(s).
- ❖ Scientists and managers who have made a significant contribution to the peer reviewed literature.
- ❖ Those involved with the Guide’s production.

Elite interviews were conducted in person when possible (preferred method). At times when in-person interviews proved not to be feasible, phone or e-mail interviews were utilized in that order of preference. Seventeen elite interviews were conducted; nine in person, seven on the

phone, and one via e-mail. Notes were taken during in-person and phone interviews, and when permission was granted, interviews were recorded for future reference during analysis. All interviews were conducted under the premise that identifying information would remain confidential and the information collected would be presented in an anonymous manner.

Each elite interview started with an introduction briefly reiterating the description and purpose of the study at large and defining key questions. An interview script was used to prompt the interview on an as needed basis; the script was tailored to each elite interviewee based on her/his experience and knowledge. Standard topics of the interview script included the following: 1) strengths and weaknesses of the Guide (utility, effectiveness, and format); 2) management frameworks utilized/highlighted by the Guide, adaptive management and resilience; 3) thoughts for the next potential resource to support regional capacity to manage tropical reef ecosystems in light of climate change (i.e., outstanding needs); 4) use of science in management; 5) major advancements in science since the Guide's completion; and 6) ad hoc questions appropriate to each elite interviewee. The length of interviews ranged from approximately 45 minutes to one and a half hours.

Analysis of the elite interviews involved transcribing each interview which was followed by coding of common and unique themes (Rubin et al. 1995). Comparison of content, and its underpinning connotations, within and among themes was assessed for variations and nuances until the appropriate narrative was found (Rubin and Rubin 1995). Advice provided by the elite interviewee(s) about the advancements in science on tropical reefs for management was collected and used to direct the literature reviews.

### Online Survey

A tailored design (Dillman et al. 2009) online survey (Vogt et al. 2012), using REDCap<sup>5</sup> survey program, was created to collect the opinions from a cross sectional sample of the broad tropical reef ecosystem community. The survey consisted of three sections that aimed to: 1) collect demographic information about the participant's work and location, 2) discover participant's current use of information to support her/his work and existing needs, and 3) solicit feedback about the participant's use, or non-use, of the Guide. The survey comprised 70 possible questions of various types: multiple choice, open-ended, Likert Scale, ranking, and dichotomous yes/no. In some cases, language in the survey (questions and/or answer options) was derived from well-known projects; e.g., the survey question, "In what geographic region do you concentrate your efforts?," the regions offered as multiple choice options were adopted from Reefs at Risk Revisited, Threats and Response (see Figure 2.1; Burke et al. 2011). This also was to ensure

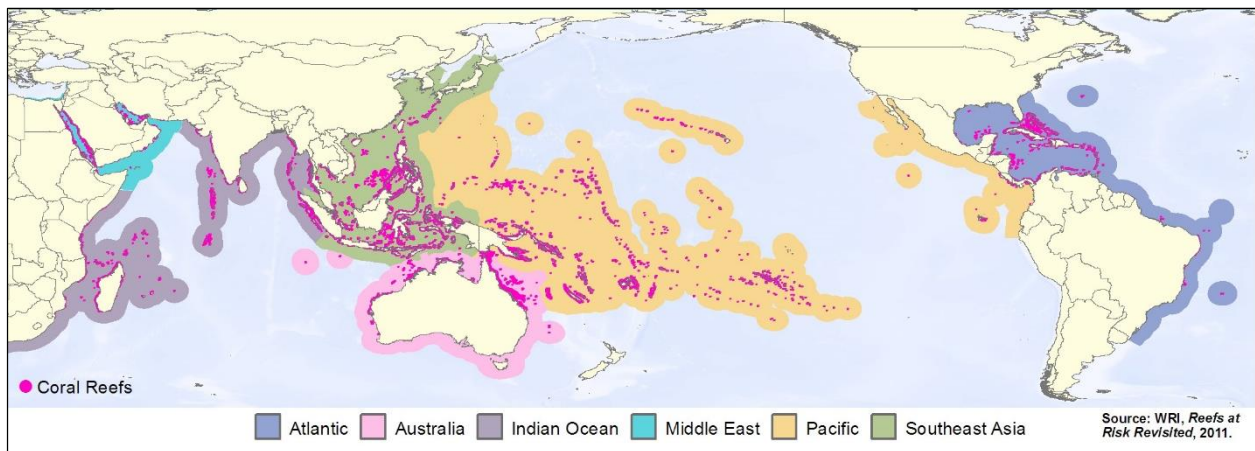


Figure 2.1. Major tropical reef regions of the world utilized in survey (adopted from Burke et al. 2011).

results of this survey could be compatible and compared with results from other works. The

<sup>5</sup> This thesis research was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR000423. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

number of questions answered by each respondent was determined by branching logic and preference as some questions were optional. The survey instrument is found in Appendix A.

Participants<sup>6</sup> were targeted via snowball (Atkinson et al. 2001, Vogt et al. 2012) sampling methods originating from a pool composed of the following: individuals who received *A Reef Manager's Guide to Coral Bleaching* from NOAA's Coral Reef Conservation Program and/or the Great Barrier Reef Marine Park Authority, nominations from experts, and voluntary self-nominated participation in response to requests posted to relevant online resources; e.g., newsletters (Coral Triangle Initiative, Marine Protected Area News, Marine Ecosystem and Management), blogs (Western Indian Ocean Marine Science Association), list serves (Australia Coastal Zone Information Network, Gulf and Caribbean Fisheries Institute/ Caribbean Marine Protected Areas Managers Network and Forum, NOAA's Coral List, Reef Resilience, TNC's Reef Resilience Toolkit Newsletter) websites (Open Channels, EcoAdapt), etc. In accordance with the snowball sampling method, the last question of the survey requested recommendations for additional survey participants. All individuals referred to take the survey were targeted via e-mail, with an explanation of the survey and request for participation. To fuel survey participation (Gubrium et al. 2012), the salience and potential direct benefit of the research topic were emphasized in all requests to the targeted sample population.

Upon completion of the survey, participants were informed they could access study results via the study website. A website was created using WordPress to support the online survey by also providing background information about the research and researcher, contact information, and an entry point to the survey.

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<sup>6</sup> Participation in this research was voluntary, confidential, and not permitted for minors as defined by their location's local jurisdiction.

The timeline of the online survey was designed to be flexible to allow for participation from each geographical region (see Figure 2.1; Burke et al. 2011). Participation by geographical region was monitored and results directed subsequent solicitation efforts and gentle reminders sent via the relevant networks (discussed above) accordingly in order to obtain global participation. Initially the survey was scheduled to be live for one month and/or to close when participation approached the desired geographical representation (i.e., when representation of all geographic regions were reflected by survey respondents who claimed to work in such geographic regions) or when efforts to do so had been maximized. The survey opened on September 25, 2013, shortly preceding the shutdown of the U.S. federal government from October 1<sup>st</sup> through 16<sup>th</sup>, 2013. The previous U.S. federal government shutdown was in 1995-96; thus was not specifically planned for in the study design. Another unplanned event came in the form of Super Typhoon Haiyan, which hit the Philippines on November 8, 2013. It rated as one of the deadliest tropical cyclones in Philippines history; thus, needless to say all solicitation efforts in the area were terminated immediately (NOAA National Centers for Environmental Information January 2014). Closing notice was posted through several online resources in early December 2013 and the survey was officially closed online December 18, 2013.

Survey responses, including demographic data, were exported from the REDCap survey program to a Microsoft Excel spreadsheet. First, the three sections of the survey were expanded into four to broadly categorize the responses as follows: 1) demographic information about the participants' work and location, 2) information participants use to support their work, 3) how participants prefer to learn about newly released information, and 4) participant feedback on the use, or non-use, of the Guide. Analysis then varied depending on the form of question. When

appropriate, an ad hoc coding scheme was developed and applied on the basis of data from empirical responses; e.g., multiple choice questions.

Despite the challenges of open-ended questions (e.g., larger item non-response, inadequate answers, and extensive coding), open-ended questions were used to capture the full range of opinions from participants without the potential bias of suggesting responses to individuals with closed-ended questions (Reja et al. 2003, Emde et al. 2012). As anticipated in the literature, the open-ended questions produced diverse, rich responses<sup>7</sup>. All responses were reviewed and categorized into separate themes or nested themes, constructs, and the presence or absence of related linkages as applicable and tallied.

In an attempt not to limit the respondents to the options provided in closed questions, an “other” and/or “please specify” option was offered where deemed appropriate to capture unique and applicable responses. Essentially an open-ended question, the “other” option elicited a broad range of responses from respondents; thus, it was analyzed in the same manner as described for open-ended questions above. A majority of “other” responses not unique or applicable to the question being asked is accredited to instrument error (question lacking clarity) and/or measurement error (reader misunderstanding) error (Dillman et al. 2009). Only unique and applicable responses were included in the analysis.

### *Archival Data*

Workshop and training reports (available through NOAA CRCP) were reviewed via content analysis (Weber 1990) for user feedback to answer this study’s research questions as stated

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<sup>7</sup> Open-ended questions in web surveys have been found to yield richer responses than other survey modes (Reja et al. 2003; Emdes and Fuch 2012).

above. Additionally, NOAA CRCP, GBRMPA, and the U.S. Environmental Protection Agency (EPA) provided in-kind assistance pertaining to the past and future processes of *A Reef Manager's Guide to Coral Bleaching*; e.g., background information of the project, future milestones, etc. Lastly, data were provided by NOAA's Coral Reef Information System (CoRIS)<sup>8</sup> to perform content analytics of the current Guide's [website](#); statistics of the Guide's Portable Document Format (PDF) downloads were calculated yielding the quantity of Internet Protocol (IP) addresses (representing unique sites per individual computers) and the total number of downloads of both the Guide in its entirety and individual chapters since the Guide's publication (2006-2015).

### *Scientific Literature Review*

An extensive, scientific literature review of tropical reef ecosystems in response to compounding stressors, including the effects of climate change, was conducted to support Research Question #3, what are the major advances in science to support management and the successor resource to the Guide. Literature post 2004 (time of the Guide's publication) was identified using the guidance provided by the elite interviews, journal databases<sup>9</sup> by searching keywords (e.g., tropical coral, resilience, coral reef management, ocean acidification, compounding stressors), environmental agency white papers and guides, etc. The scientific review is provided in Appendix C.

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<sup>8</sup> NOAA's Coral Reef Conservation Program's (CRCP) information portal that provides access to NOAA coral reef information and data products with emphasis on the U.S. states, territories and remote island areas.

<sup>9</sup> ISI Web of Knowledge, Google Scholar, and the University of Washington library over the length of the study ending in 2015.

## Potential Biases

### *Strengths and Limits of the Framework Approaches Used:*

Methodological precedents for reviews of guides such as this do not exist in peer review publications. Therefore, ad hoc methods of analysis have been employed that use the triangulated approach (Kvale 1996). This approach allows a broader understanding of the research goals (Vogt et al. 2012) for an effective management tool. Both the survey and interview components have been purposely designed to elicit responses to answer each of the research questions posed.

A coding system was employed to protect the confidentiality of all participants and the quality of data collected. Empirical information was gathered through coding analysis. Separate themes or nested themes, constructs, and the presence or absence of related linkages per response(s) comprised an interpretative narrative addressing the needs of reef managers. Tailoring these methods to meet the needs of the study, targeting a cross section of the reef community, and providing a secure and confidential format for them to express their management needs freely is the strength of this study. In addition, this evaluation substitutes user views as a surrogate for the monitoring component- normally the limiting factor- of the adaptive management framework. In that sense, the use of triangulated methods may be somewhat more subjective than objective monitoring of results of use of the Guide, however lacking other monitoring results the results of triangulated methods provides valuable insights.

Staying true to adaptive management, Weinberg (1975) advises that “*the first step to knowledge is the confession to ignorance*”. Even studies with boundless resources, are vulnerable to problems, and must implement a conscientious research design to combat anticipated problems. To plan accordingly, this flexible study design (Robson 2002), under the

constraints of limited resources (time and funding), anticipated plausible problems of each objective stated above.

Pertaining to the online survey, anticipated problems included coverage, sampling, non-response, and measurement survey error (Dillman et al. 2009). Coverage error occurs when survey results do not represent varying perspectives of a survey population due to the lack of equal opportunity for all members to participate. Despite our best efforts to target the entire survey population- via list-serves - Coral Triangle Initiative newsletter, Marine Protected Area News, Marine Ecosystem and Management, Australia Coastal Zone Information Network list-serve, Open Channels, NGOs, snowball sampling, etc. - responses may have been limited by internet capacity affecting the socio-demographic diversity of respondents. Additionally, since the survey was only offered in English, language limitations may have also affected the socio-demographic diversity of respondents and the responses. Failure to motivate an even distribution of the survey population to complete the survey may have resulted in nonresponse error and possibly affected the strength of the recommendations for the successor to the Guide.

Congruent with all sample surveys, a 100% survey response rate is unrealistic and sampling error was expected. Lastly, measurement error, inaccurate or imprecise survey answers due to the respondent(s) misunderstanding of the survey's question or construction, is possible when addressing a large pool of diverse peoples. To minimize these effects the survey instrument underwent review by the Thesis Supervisory Committee and experts in survey design. In addition, a purposive sample of individuals outside the tropical reef management community was solicited to beta test the survey before its official launch.

## Chapter 3. RESULTS

First I report on the themes found from the 17 elite interviews conducted over the span of this research project. Next, the results of the online survey are presented along with the related response rates for each question as it diverges from the original respondent pool of 85 individuals. Then the content analysis of the various forms of archival data (workshop and training reports and PDF downloads) is provided by category. Finally, the highlights of the scientific advancements since the Guide's publication in 2004 are summarized.

### Elite Interviews

Seventeen elite interviews were conducted over a time period of approximately 20 months at the availability of the interviewees. Interviews were conducted in person (9), on the phone (7), and via e-mail (1). Common themes were coded from the interview transcripts to identify commonalities and are reported accordingly. In order to capture all perspectives, unique or outlying views are also reported. The format of elite interviews does not follow a structured script of questions (Dexter 1970); thus, all interviewees did not answer identical questions.

### *Positive Attributes of the Guide*

Seven of the eight interviewees who discussed the qualities of the Guide noted positive attributes about its utility, effectiveness, and/or formatting. Most interviewees found it to be a credible reference providing a collection of the best information for managers at a critical time, i.e., following the major coral bleaching events in 1998 and 2005. Interviewee #3 commented that the *“Guide served a very good purpose in the broader reef science/management community. It helped get the attention focused.”* Agreement was expressed by Interviewee #10, stating it *“provided a community understanding of what we can do”*. Furthermore, direct utility of the

Guide is thought to be encompassed by senior level managers and scientists; those who know its credibility. Interviewee #5 reported that the training component<sup>10</sup> to the Guide in Australia was composed of a key group of managers, not scientists, and served as a “*great consolation*” to managers. Due to the Guide’s influence, GBRMPA’s Reef Assessment Survey System integrated monitoring for early signs of bleaching into its annual series of health and impact surveys across the Great Barrier Reef. Those involved in curriculum development (Interviewee #2), described referring to the Guide and similar resources on a “*regular basis... [as] it is one important consideration*”.

Five out of seven interviewees who discussed the Guide, reported it to be effective in relation to its intended purpose:

*“...assist managers in responding effectively to mass coral bleaching events... [It] is designed to provide pragmatic, science-based suggestions for adaptive management in this time of change. We commend it to reef managers worldwide...”* (Marshall and Schuttenberg 2006).

Interviewee #14 believes the Guide “*...has been used well beyond expectations*”, is “*still appropriate to its title*” and the “*framework it provided, [is] still useful*”. Furthermore, Interviewee #14 accredits the diagram, opportunities for management intervention (See Figure 1.4 in Marshall and Schuttenberg 2006), co-production of knowledge and diverse science, and the training sessions as strengths of the Guide. The “*publication is not effective, it is the trainings that are*” (Interviewee #14). Interviewee #2 assigns the strength of the Guide to its narrow scope; “*It is not trying to be all things...*”

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<sup>10</sup> Alludes to the training conducted by Paul Marshall focused solely on the Guide.

The consensus found the formatting to be fine for the time of publication. Yet, Interviewee #3 commented that it read more like a publication than a guide. Its formatting is discussed further under the themes to follow.

### *Limitations of the Guide*

While highlighting the benefits of the Guide, interviewees also shared its limitations. As for the utility of the Guide, Interviewee #2 found the narrow scope to be both its strength and limitation. Tools like the Guide that advise managers to limit or close access during periods of high stress are less relevant to those who rely on the sea for daily subsistence; that type of guidance is more applicable to systems in the Western world:

*“It is not trying to be all things, but managers need to better see how it mixes in with the rest of the tools in the toolkit.” “It is one tool when many are needed. Still [the Guide] informs a fishery manager of things to consider, but at the end of the day that person [is] having to consider a lot of other things as well, including food security and livelihood issues both short and long term” (Interviewee #2).*

Three interviewees specifically addressed the Guide’s utility being limited to individuals at a more senior level, this type of book is *“mostly going to high level managers to show to donors, saying this is what is needed, but [is] not for [the] hands-on, ground level” (Interviewee #10).* *“By what extent it is used by local managers, I cannot say. They are overwhelmed by all the guidance they get; [for they often] receive new, wonderful products and never use it again” (Interviewee #15).* Considering the divergence of laws, culture, and language among local areas, the interviewees acknowledged the difficulty in creating general global guidance that is applicable to all.

Similar feedback received from at least two of the interviewees touch on the effectiveness of the Guide, including such questions as, *“So what, we can predict coral bleaching. What can we do about it?” (Interviewee #3)* and *“How do we stop coral bleaching mid-stream?”*

(Interviewee #14). Interviewee #3 acknowledges that the Guide discusses many things one can do in response to a predicted bleaching event, but it fails to offer the information in a clear enough manner. *“It is too broad [and] needs to be brought in a little tighter”* (Interviewee #3). Interviewee #14 followed-up to explain that the most people can do to stop a bleaching event is to make reefs resilient. Interviewee #6 strongly disagrees, stating *“There is no evidence that reducing these other impacts will do much to prevent mortality due to high temperature.”*

Furthermore, Interviewee #6 believes that the Guide did not accurately address the source of coral bleaching; i.e., the increase of greenhouse gases in the Earth’s atmosphere:

*“The problem is the increase in pCO<sub>2</sub> due to burning of carbon fuels. This does not come out very strongly in the Manager's guide that works around the issue with a lot of information that is irrelevant to a solution. We get the false impression that we can do a variety of other things to help with the problem. The solution is cutting and eventually eliminating burning of carbon fuels. So managers must work to change human behavior in this area. All the rest is futile. Forget about reducing other stress factors (sediment, pollutants, overfishing, anchor damage, etc.). In the pristine Northwest Hawaiian Islands there was major bleaching and coral mortality in areas where there is no sewage pollution, sediment runoff, fishing, or any human contact. There is no evidence that reducing these other impacts will do much to prevent mortality due to high temperature. In Hawaii we have managers who say we can help the bleached corals by not touching them and by not going fishing while the corals are bleached. This is absurd. The reefs are being devastated by high temperatures due to increasing levels of greenhouse gasses. We are seeing massive bleaching in marine reserves as well as open area. ”*

### *Suggestions for Improvements of a Successor Project*

The discussion concerning the potential follow-up project to the Guide with aim to support regional capacity to manage reef ecosystems in light of climate change received mix responses. Most of the interviewees (9 out of 17 interviewees) talked to the importance of properly customizing one’s message to their target audience as *“different users have different needs”* (Interviewee #10), which served as an underpinning to the debate.

## Utility

Interviewee #10 determined that another guide directed to global audience would not be a benefit. Again, the issue of local communities' capacity to digest the information provided in such a manner as the current Guide was questioned, "*Asymmetrical information exchange has not been successful... We do not need more information right now. [We] need to empower local action instead of [an] all-knowing global [guide]*" (Interviewee #10). A sentiment with which Interviewee #11 agreed. However, Interviewee #14 diverges in opinion stating a workshop of 50 practitioners should kick-start a secondary project that addresses both global and local levels; a global framework and a training program that links it to local plans. Interviewee #2 acknowledged that managers using a guide for practical application (e.g., the operationalization of tools and integration across government scales and other tools), "*is a continual challenge... for all of the tools in the tool kit*".

To improve the utility of a follow-up project, all eight of the interviewees who commented on the Guide suggested a future product should be more practical and applicable to individual areas. The focus should be on the knowledge we have now and what we have learned to create a useful product for people that makes a difference as expressed by an interviewee.

*It "can build on the tools and technologies that we have used since it was published. For example: 1) Bleach Watch Report- good example of what would have been good to have for the first Guide. People can see and look at predictions, they take what is coming out of the coral watch program and see what they can do to apply it. 2) Coral watch- people around the world may know or heard about the Coral Watch [program], but can not access it or all the links in it"* (Interviewee #3).

Other suggestions pertaining to content of a future project on the practical level include guidance on the following: messaging to the public during a bleaching event; implementation of resiliency tools during bleaching events; and, more mitigation options post-bleaching.

## Content and Effectiveness

In response to the “*So what, we can predict coral bleaching. What can we do about it?*” question, Interviewee #3 advises managers to capitalize on education and outreach messages during a bleaching event. “*Use coral bleaching events as a lever to emphasize to the public that coral bleaching has a major impact to reefs; how it commonly results in the onset of coral diseases...and that the driving factors are SST, etc.*” (Interviewee #3). The public needs a more clear understanding that coral bleaching is related to climate change and the factors that drive it. “*So much of the American public still does not believe climate change is a real issue.*” Find[ing] *a way to use coral bleaching events to demonstrate to the public that this is real...[and] that we are not making this up...should help manager’s a little bit*” (Interviewee #3).

Refinements to how to support the resilience portion of the Guide were suggested by Interviewee #5 and #14. Application guidance on resiliency tools; i.e., how to apply them during an event (Interviewee #5) is needed. In addition there is a need for a systematic system for decision making to select the proper response; e.g., when to close a recreational area, etc. The post-bleaching timescale calls for more case studies explaining successful mitigation options. To fuel the implementation of such tool(s), guidance on how to acquire sustainable funding is required (Interviewees # 10 and 12).

The connectivity of a successor project proved to be an important point of discussion with five of the interviewees. When asked “what would make a follow-up guide project more effective and pragmatic?” Interviewee #2 continued on the thread of aligning and integrating it with other aspects of reef management. Linking it into other broader guidelines from the toolkit by moving it towards a Reef Manager’s Guide model rather than a specific guide for bleaching. “*Tie it more to the other management issues and the realities of heavily utilized coastal*

resources...[such as] *Ecosystem Approach to Fisheries Management for the fisheries sector and Ecosystem Based Management more generally*” (Interviewee #2). Others agreed on the importance of making it consistent with other resources, including TNC’s Reef Resiliency toolkit and local organizations to demonstrate sensitivity to local guidance (Interviewee #5). If there are too many different sources of information local users are left paralyzed on what to use. Hence, this means collaboration on this kind of guidance is vital.

The consensus of the group (6 out of 8 of those that critiqued the Guide) stated that the science component needed to be updated. Both Interviewees #2 and #14 agreed that the general guidance of the Guide is not obsolete and only the science section is in need of an update. Interviewee #10 concurred, sharing that updating the science component would be the only reason for proceeding with a similar effort. Interviewee #3 identified the need to put scientists out in front of events in order to understand more about the various triggers of bleaching. *“The more we can do that, the more managers [can] respond; e.g., get the word out to dive operators “our reefs are already stressed, in two weeks showing signs of bleaching” ensure divers and snorkelers are extra careful; times where we should close waters off; etc.”* (Interviewee #3). Knowing more allows a better response plan to be developed; something the current Guide did not do effectively (Interviewee #3). Interviewee #14 pointed out the two areas of knowledge that have grown since the Guide’s publication is ocean acidification and the utility of social-ecological systems. The advancements in science and increasing the relevancy of any future product accordingly revolved heavily around what an improved format should be.

### Formatting

Opinions were diverse pertaining to the format an improved guidance tool. The need for something more interactive and regional was expressed by Interviewee #14. Interviewee #2

agreed on a dynamic form, but only as a default for it would be a better format than a printed copy at this time with the following caveat: take advantage of the dynamic form and only update it when needed. *“When there is a pertinent change in the science or an understanding of the human dimension that could improve it you make that change”* (Interviewee #2). To implement such a format, an announcement and dissemination plan needs to be in place upon updating to ensure it is always current.

Interviewee #13 concurs that it is essential to update material and that a web component would serve that purpose, but is concerned about the capacity of local regions and questions whether people will engage at all. One has to understand the sociology of the audience (Interviewee #13). Beyond capacity, people at the local level often require something more tangible than the web by an author they know and trust (Interviewee #15). Interviewee #13 is careful to point out that one should not assume a website offers the most updated information. *“Many websites are out of date, it still takes someone to update them”* (Interviewee #13).

Others suggested the core content take a book form with online updates provided once a year (Interviewee #5). Interviewees #3 and #15 suggested smaller booklets that were *“more visual, more schematic, more drawings, links-lots of links for the capabilities of reaching out”* (Interviewee #3). Interviewee #15 cautioned targeting one’s audience appropriately and realizing that is not possible under one guide. Thus, they suggested creating different versions accordingly; a solid booklet and smaller versions that are more pictorial, etc. The *“audience is very diverse, having different packages are good as long as messages are consistent; different levels (communities to senior manager) are influenced by different kinds of products”* (Interviewee #15).

## Miscellaneous

All suggestions, whether focused on the utility, effectiveness, or format of the Guide returned to the fundamental component of serving one's audience. It was unanimous among the interviewees that a successor project should appeal to the local level. Even though the site managers often lack power, yet the common property literature (Ostrom 2010) continuously states that the process must start from the bottom up to succeed.

### *The Scientific Component of Tools*

Several interviewees mentioned the need for baseline data and/or increased monitoring.

Interviewee #2 believes the most important scientific need to be, *“What is the status of the resource and how is it changing? If you are lucky, why is it changing? So you can change your management.”* The local level is in need of baseline data about its resources (Interviewee #10); many countries in the Coral Triangle Initiative (CTI) have little or no baseline data (Interviewee #12). Interviewee #12 questioned, *“How can you manage what you don't know you have?”*

Interviewee #15 takes it further stating the need for long term data sets to help managers understand change through time. Furthermore, the need to get scientists in front of bleaching events was reiterated by Interviewee #3,

*“Almost like an emergency scrambling team; like fire fighters. You have an event that is about to happen, you have experts that can get in the field and start monitoring (in addition to the annual monitoring). Increase monitoring in order to increase understanding of various triggers and thresholds; e.g., measure from microscopic size to broad ecosystem scale.”*

Lastly, there was a call for CO<sub>2</sub> buoys in more areas.

According to Interviewee #3, the major advancements in science since the Guide's completion include microbial work and determining the connection of major links and drivers of bleaching to be temperature related (Ritchie 2011, Krediet et al. 2013, Ritchie et al. 2013).

Interviewee #8 made note that all corals (i.e., ignoring species, temporal, geographical variability) do not respond to the effects of climate change in the same way, “*Most people think all corals will respond the same way. Can’t be too simplified, must get a handle on the whole system and process.*” Interviewee #3 proposes to use the best technology and advances in research to be used in education and outreach, and direct management action.

Making decisions in the face of scientific uncertainty is “*always the case*” reports Interviewee #2. Science is one of the pieces of information used to make their decisions. It always needs to be updated along with clear communications of uncertainties. When asked, “How do managers take into account the changes in science into their decisions and actions?” Interviewee #3 reported, “*As we learn more, try to focus the science in more depth. We need more opportunities to share information.*”

Interviewee #13 brought to attention the importance of how science is messaged to various audiences, “*Whether you trust the science or not is based on how the science was communicated.*” It is key to figure out how to get people passionate about one’s work. Still, the best way to share information is in person. For example, Interviewee #13 credits the success of Westpac Fishery Information Network (FIN) to the time spent in the field sharing information.

### *Management Frameworks*

When asked the question, “Do the principles of adaptive management and resilience frameworks have traction on the ground or just at a theoretical level?” Interviewee #10 responded that most often these frameworks are only utilized in theory by the “*people who discuss coral at a global level, meetings, etc.*” The “*rest of the world who actually do work, no adaptive management and resilience [are] in practice. Unless those who have been touched by it [learned it], then yes. Those who have not been touched, no.*” Interviewee #12 also notes the challenges of

implementing such frameworks on the local level, “*Adaptive Management is important, but they need a good understanding of what it is. Terms like adaptive management can scare people away.*” Lastly, Interviewee #12 stressed that an Ecosystem Approach to Fisheries Management (EAFM) is not a new framework competing with others (e.g., Coastal Zone Management, MPAs, etc.), rather it brings them all together.

#### *What is needed in a tool to address climate change?*

Interviewees discussed many aspects of what is needed in the ideal toolkit to address climate change, apart from a specific Reef Manager’s Guide project. Possibly the most important component of adaptive management is recognizing error and/or the need for modification of approach. This process is exemplified by the view of a few interviewees pertaining to the use of MPAs as a conservation tool. Interviewee #2 explains that although they are supportive of MPAs, they alone are not a panacea for all management problems. “*They are postage stamps. Throw a lot of resources at these postage stamps, but they are so small. If that is where we bank all of our conservation it is going to fail!*” Interviewee #2. Interviewee #15 states, “*The number of MPAs does not equate to successful management. Different objectives need to be achieved, all your effectiveness measures [must be addressed].*” A holistic approach to management is needed; one that transcends all government scales. MPAs are part of the toolkit, but only managing from within the reserves is the easy part. Obtaining community buy-in is both a challenge and necessity. In addition Interviewee #12 notes, “*The advantage of molding from the bottom up is to make space for the local unit to take it over.*”

Appealing further to the adaptive management model, Interviewee #10 suggests addressing the gap(s) to incorporate existing strategies at the local level. All interviews that discussed the challenge of dissolving such obstacles from implementation called for capacity

building. Again, all interviewees agreed the nucleus of capacity building is properly appealing to your audience in order to identify the need(s) of each area and message the delivery of information accordingly. Capacity building needs reported by interviewees include the following: holistic/EBM approach to including stakeholders, all who use and impact resource ecosystem wide; empowerment of local groups; training; information; and, communication and messaging in outreach and education.

Many of the interviewees had views on trainings; who should participate, style, choosing curriculum, the challenges of various trainings, etc. Interviewee #12 recommends two considerations for participant selection: 1) the EBM approach dictates that one should select stakeholders who impact or are impacted by the resource; and 2) train those with the power to implement management actions within their programs and countries. Interviewees agree an interactive, hands-on style is more conducive to a lecture format. This includes allowing participants to help mold the curriculum to their specific needs. As explained by Interviewee #2, *“Why should we assume what they want to hear? Let’s let them tell us what they want more information on?”* The potential for different groups to confuse and/or to oversaturate participants by conducting various trainings is a continual challenge. Each individual training is a subset of holistic reef management with similar goals; collaboration, although resource intensive, is needed. Interviewee #12 suggests moving oversaturated participants forward to the planning process to produce a strategy with realistic timelines that involve continued post-training.

It was unanimously agreed that communication and proper messaging through outreach and education is key to reef management. Public buy-in is essential for any management plan to work. Interviewees #3, #6 and #8 independently commented on the need to educate the public on the connection of resource depletion with climate change. Interviewee #6 states, *“Managers of*

*coral reefs must work to educate people at all levels and must advocate for reduction of CO<sub>2</sub> emissions. Anything else does not address the real problem.*” Yet, Interviewee #15 warns against making the message too negative. For example, *Reefs at Risk: A Map-Based Indicator of Threats to the World’s Coral Reefs* (Bryant et al. 1998) was considered by some to be too negative, people were hopeless and saw no reason to take action. Hence, Interviewee #6 urges managers and the conservation community to take personal action and live as examples to the public. Only a few interviewees discussed the value of social media as a tool. It is a tool, but the importance remains in crafting the message properly. All interviewees also recognize the challenges of relying on web-based tools (e.g., webinars, social media, list-serves, etc.) due to capacity including access and language barriers. All criteria of the message is directly dependent on the audience to which is being delivered.

### *Issues of Funding*

Funding determines the information that is collected (e.g. monitoring, research, etc.), the dissemination of that information, and the language used to discuss it. *“Certain products create a common language that everyone uses because it is still funded. Once it is not funded anymore, people won’t use it”* (Interviewee #10). It costs a lot to build capacity, there is never enough. Yet Interviewee #15 adds, *“Compared to the value of the resources, the amount of money going into [the effort] is quite small. It is a tiny fraction of national budgets.”* An evaluation of the impacts of the resource is needed, but difficult notes Interviewee #10.

Even though the importance and need for information from long-term, regional datasets is echoed by several interviewees, the challenge to fund such programs is also reported to be a significant obstacle. Interviewee #2 reports that a holistic approach to data collection (i.e., monitoring) is too expensive to produce *“but, what management is still limited on is*

*information.*” When asked if it was a matter of operational efficiency or funding, Interviewee #2 responded that 80% of monitoring costs are the people (i.e., human resources), then the remoteness of location. Furthermore, Interviewee #12 notes “*the technical level of science makes it difficult to teach groups to the level that they can operate independently*”. Interviewee #3 reports that success in some areas has stemmed from a combination of both *in situ* and satellite monitoring. Ideally both should be used, but *in lieu* of no monitoring at all scientists and managers should be granted access to satellite imaginary data. “*At least they will know on a broad brush scale. A lot of the info has been built [ground-truthed] from in situ data. [It is] better than nothing*” (Interviewee #3). Interviewee #3 adds that the needs of managers are very basic; “*most often their needs are the ability to access*”. Lastly, it was noted by Interviewee #2 that monitoring funds do not cover expenses for information dissemination. Another frequent request from stakeholders that is not supported.

Interviewee #12 warns the “*attitude of many to revisions of management [is], well we can't afford it so why even bother?*” and calls for the need of sustainable financing. Reallocating funds from conventional to ecosystem-based management is one proposal offered by Interviewee #12. This issue circles back to the need for outreach and education to the public; support from all levels provides a greater chance of appropriating funds. All guidance efforts should make it clear to managers that do not have to do it all themselves: “*lean on other stakeholders (e.g., universities, etc.) to share the burden of skill and finance or train insiders. No need to become an expert in all things*” (Interviewee #12).

### Online Survey

One hundred two entries were submitted to the REDCap online survey. Entries by respondents that failed to submit responses beyond the demographic section of the survey were removed prior

to data analysis; 17 entries were removed and 85<sup>11</sup> entries were analyzed for the purposes of this study. All survey response data are found in Appendix C.

### *Section I: Demographics*

Survey respondents were largely composed of professionals engaged in science and research (49% of respondents) and program management (34% of respondents) (Figure 3.1). Other job categories were scarcely represented including graduate students (7%), volunteers (4%), and those who identified as park ranger/conservation officer (day-to-day manager), policy maker, or other (1%). None of the survey respondents self-identified as a community leader or member. Most respondents affiliated their position with a government agency (47%), followed by academia (22%) and international Non-Governmental Organizations (NGO) (16%), and a smattering distributed among community-based organizations/NGOs (8%), business or industry group (2%), other (2%), and community member<sup>12</sup> (1%) categories.

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<sup>11</sup>Response rates are provided for each question throughout the results section if divergent from the original respondent pool of 85 individuals; thus, the percentages of responses apply only to that subset.

<sup>12</sup> To clarify, “community member” was provided as an option to the first two demographic questions inquiring respondents to select, 1) the job category best identifying their position and 2) the affiliation of that position. Zero respondents identified their job category with the “community member” option, yet one respondent did chose “community member” to describe the affiliation of his/her position.

### Select the job category that best identifies your position concerning tropical reef ecosystems:

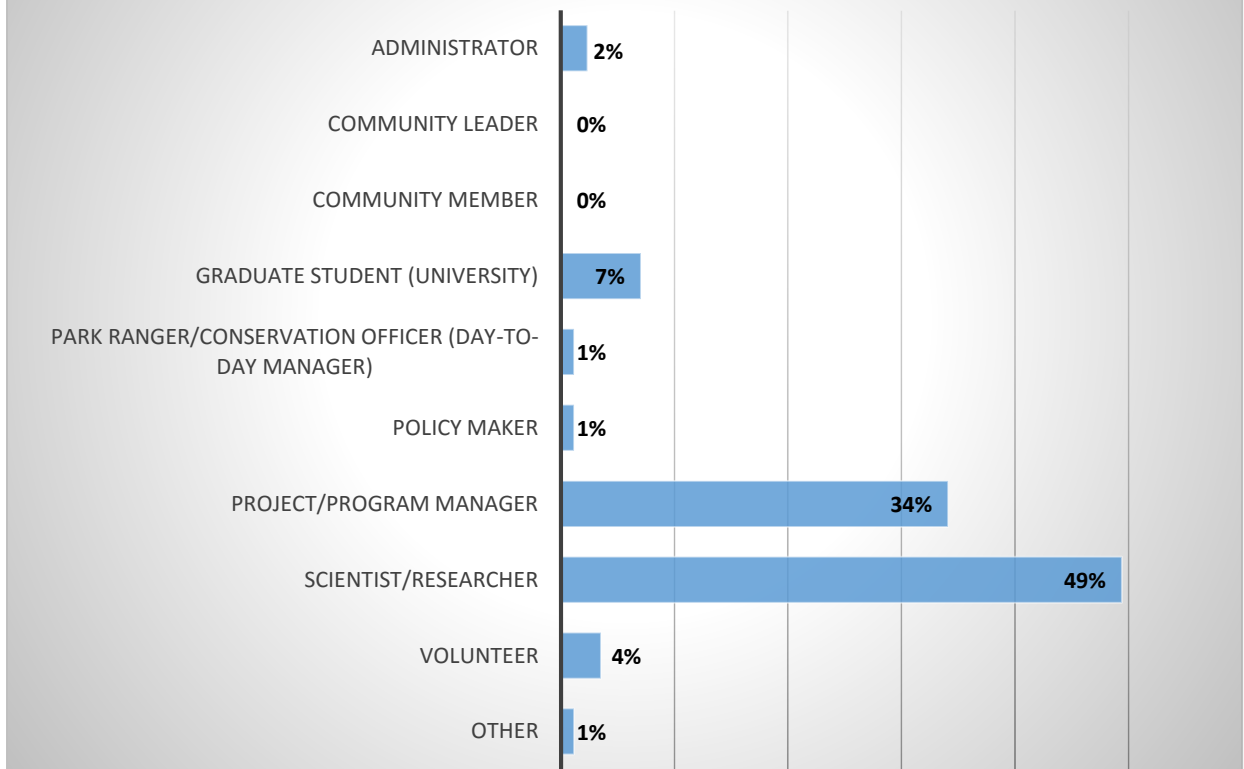


Figure 3.1. Demographics: Survey respondents self-identified the job category of their position concerning tropical reef ecosystems.

A wide range of activities was selected by respondents to describe their current position. Research/data collection accrued the most responses (16%), with communication (9%) and administration, grant writing, and public outreach (each 8%) the closest to follow. The least selected responsibilities were enforcement (2%), park management (3%), and policy-making (4%). Capacity-building was the primary response given under the option to specify the responsibilities of their position. The preponderance of respondents (73%) reported being charged with multiple responsibilities within his/her position. Each claimed to have an average of 4.6 responsibilities (1-14 range) assigned to his/her position.

The experience range of the respondents reveals a diverse contingent and good cross section of the reef ecosystem community. Most respondents have been working with reef ecosystems for a considerable amount of time; 5-10 years (29%) and 10-20 years (28%) experience. Still, those of both less experience, 1-5 years (18%), and more, 20 years or more (16%), were also represented among survey respondents. Using Figure 2.1 as a reference,

respondents were asked to select the geographic region(s) (all that apply) where he/she concentrated work efforts. The response did not yield any surprises in relation to the global distribution of reefs (Figure 3.2) with most working in the Pacific

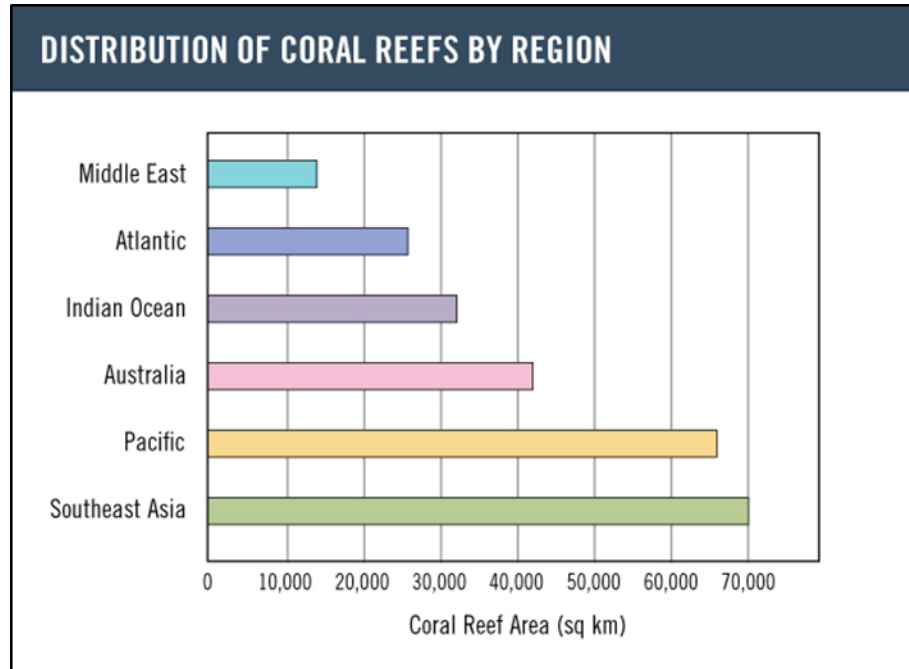


Figure 3.2. Distribution of coral reefs by region. Area of coral reefs (sq. km) for each region of the world as shown in Figure 2.1(Burke et al. 2011).

Table 3.1 Distribution of respondents' work efforts among geographic regions.

Options	Totals	% Total
Atlantic	40	31%
Australia	11	9%
Indian Ocean	10	8%
Middle East	6	5%
Pacific	45	35%
Southeast Asia	16	13%
<b>Total Responses</b>	<b>128</b>	<b>100%</b>
<b>Total Respondents</b>	<b>85</b>	

(35%) and Atlantic (31%) regions, and the least in the Middle East (5%) (Table 3.1). All regions were represented, albeit not equally. The survey instrument did not capture the specific areas of all respondents, but of those that offered (54% of responses), a wide representation of geographies was portrayed with a higher concentration working in the U.S. and affiliated

territories. Furthermore, only 19% of the 85 respondents worked in multiple regions over a range of 1-6 with an average of 1.5 regions per respondent.

## *Section II: Information Used to Support Work*

Among the wide array of current threats to reef ecosystems, the 85 respondents specifically address an average of four different threats simultaneously in each of their jobs. Of the seven response options provided, climate change (including thermal stress) is the most often contended with (18%) while the “other” (10%), miscellaneous self-declared options, was the least. It is noteworthy to state that the responses selected ranged across a narrow gradient. Thus, this demonstrates that all the threats listed should be considered a concern for the reef ecosystem community. This question was phrased: “Among the many threats to reef ecosystems, what issues do you specifically deal with in your job?” However, it became clear during analysis that a portion of the respondents focused on the “issues” they address in the jobs - or responsibilities in their current position - rather than the “threats”. Other responses (10%) commenting on threats to reef ecosystems included a range from cyanobacteria (3%) and off shore drilling (3%) to watershed-based pollution (8%), various management issues (16%), and anthropogenic impacts (41%).

Before addressing the information needs of the reef ecosystem community, it was first necessary to learn about the types of information individuals currently use to support their work and how they access it. The large number of respondents (18%) deemed reef ecosystem condition surveys (algae, coral, fish, invertebrates) as the preferred information resource. This was followed closely by human use of reef resource data and oceanographic data (including water quality), both at 14%. Interesting outliers submitted via the “other” category included local

knowledge (29%) and monitoring/surveys (29%). Specifically, bathymetric monitoring and Knowledge, Attitudes, and Practices (KAP) surveys were mentioned. Using the Likert Scale, reliance on trusted organization / technical reports and contact with experts or consultants was reported with 47 out of 84 responses and 46 out of 83 “frequently use” responses respectively. These entries with respect to trusted organizations/ technical reports and contact and experts were favored more than guides or manuals, which collected only 28 responses in comparison. When it comes to how one accesses the information that supports their work, the high-ranking options were the World Wide Web (14%) and scientific journals (14%); the latter can be easily correlated to the self-identified pool of researcher respondents. Conferences (10%), list-serves (9%), and workshop/trainings (9%) were also notable methods to access information. Followed by the library (7%), word of mouth (7%), social media (6%), community meetings (6%), newsletters (5%), online trainings (5%), newspapers (4%), television (2%), radio (1%), and other (1%) which included permits.

When asked in an open-ended question “what information required to support your work are you currently lacking”, 44 respondents reported 78 information needs. The most prevalent information themes were the following: 1) monitoring (12%) and research (12%), 2) economic and socio-economic information (10%), and 3) inter-stakeholder communication (9%). Updated, more frequent, and/or trends of the health status of reef ecosystems were the prevailing monitoring request. Water quality assessment closely followed and finally sea surface temperature (SST) was listed. The calls for research included investigating the biological responses to climate change (e.g., “*local data on resistance/adaptability of coral colonies to increased temperatures and acidity*”, “*ecological connectivity*”, “*coral species-specific response to threats*”, and “*mesophotic reef research on invertebrates*”. Economic and socio-

economic requests were pervasive; “*better economic information about the effects of marine management options*” and tourism valuation surveys are needed, as well as there is a “*lack of understanding best practices for developing alternative livelihoods and/or community based social marketing*”. The need for inter-stakeholder communication was pronounced (9%) and ranged from, “*Communication between researchers, managers, and community*” and “... [to] *solve problems and identify solutions*” to “*more outreach with community members*”. A wealth of feedback was submitted beyond the top three themes as displayed in Figure 3.3.

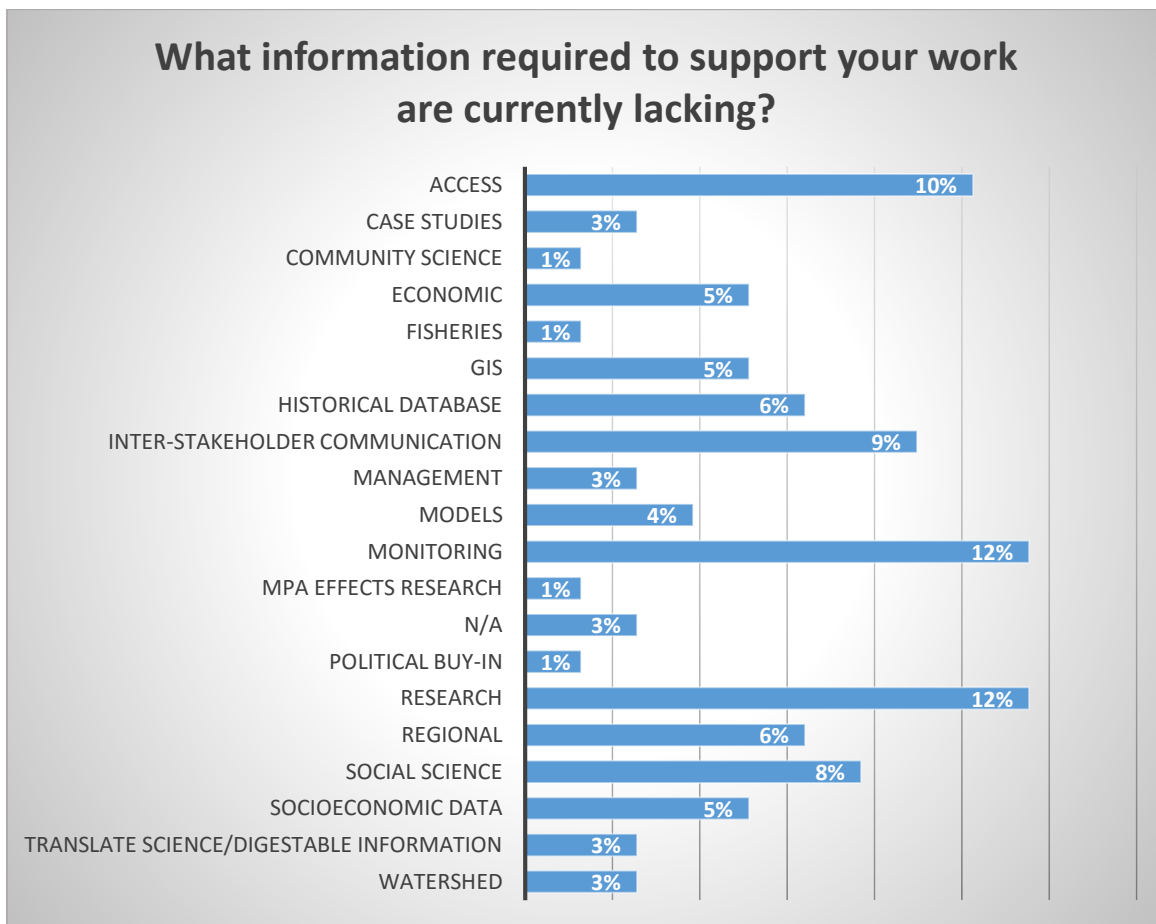


Figure 3.3. Needed information: the main themes categorized from the survey respondents’ open-ended responses to what information they are currently lacking to properly support his/hers work.

Among the high-ranking requests for information, access (10%) rather than information itself proved to be limiting for many respondents, as expressed by the following: “*Access to*

*scientific literature is often limited or difficult to obtain.*” (project/program manager) and *“Access to collected data in general. Many agencies and contractors within the region collect data, almost none of it is readily available.”* (Scientist/researcher). Social science (8%) composed of behavioral studies, community level KAP surveys, traditional ecological knowledge (TEK), etc. was the next most desired information. This was followed by the call for historical databases (6%) and regional data (6%). The need for models was mentioned at a lesser degree (4%): *“Additional connectivity and current models (some in development now)”*, *“Finer scale regional climate (temp and acidification) models”*, and *“Easily accessible updated information about CC [climate change] predictions would be good too.”*

Information trends became apparent when respondents were openly asked for any other comments concerning the information needs of reef managers; e.g., what is needed, preferred format, etc. Paramount among the requests (Figure 3.4) was inter-stakeholder communication (25%), access to timely data (19%), and the translation of scientific information into digestible information (19%). Collaboration among stakeholders and needs assessments led the communication theme. *“Strong collaboration amongst researchers and partners to solve problems and identify solutions [is needed]. Everyone works in their boxes in the research world. We need to adopt the Stand Up to Cancer model.”* The plea for *“increased timely data on coral health and bleaching”* and marine biodiversity data echoed throughout responses; the former more prevalent than the latter. The call for easily digestible information was also

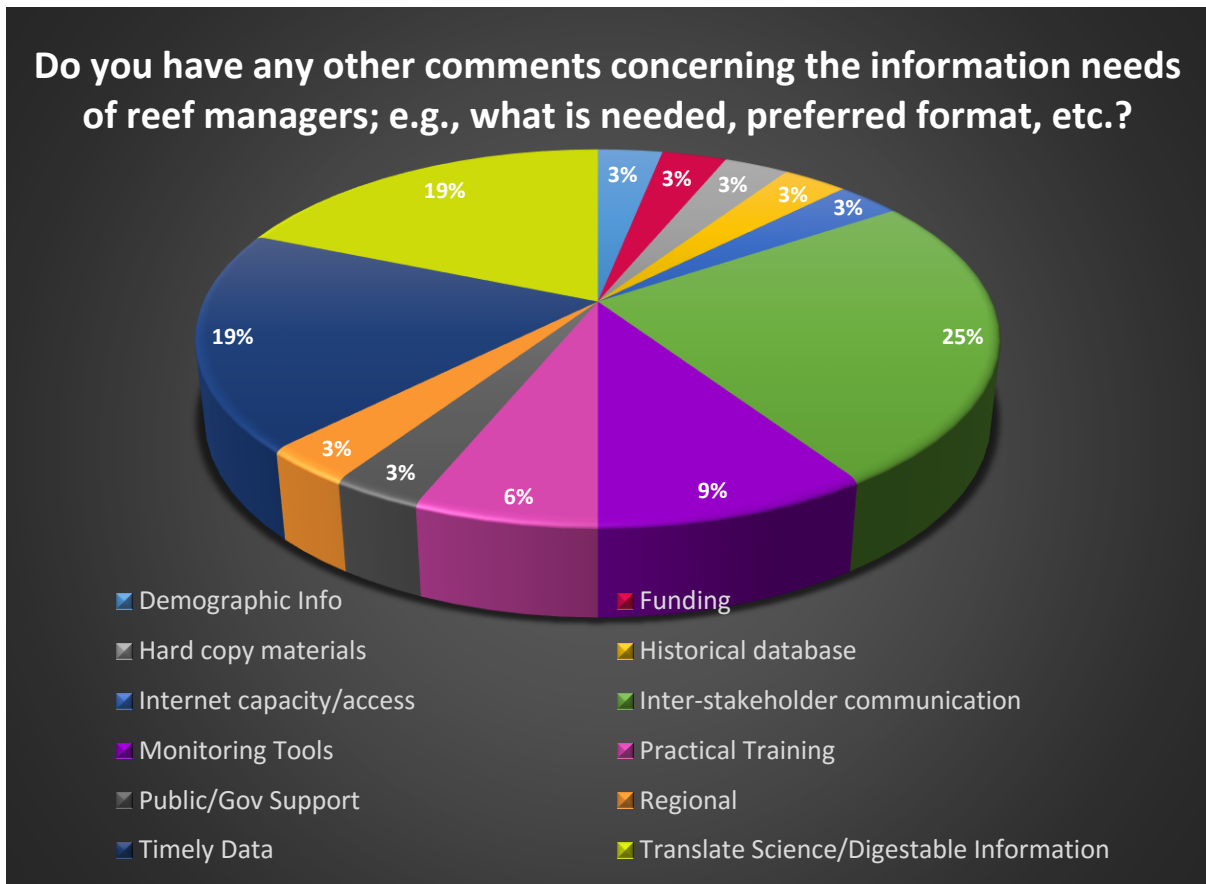


Figure 3.4. Categorized themes of survey respondents’ open-ended answers addressing the information needs of reef managers.

common among responses. *“Almost everything is way too complicated”, “more integration between the scientific community and social media”* is vital. *“Documents / resources [should be limited to] 20 pages or less. With clear application and obvious critical summaries at the outset of each document.”*

### *Section III: New Information*

With the evolution of technology and social media the options to share and receive information have vastly increased. To find out what method works best for people and their busy schedules, respondents were asked “when new information is released, what is the best way for you to learn about it?” Eighty-two respondents provided feedback that produced a narrow range of responses

across the options specified. At the low end of responses, online training and “other” miscellaneous responses each collected 17% of responses while the option to receive a paper copy and/or webinars topped the list with 22% and 23% respectively. Twenty-eight respondents provided 37 responses under the “other” option. Leading responses included learning about new information through list-serves (30%) and by having electronic access (22%). E-mail notification (16%), being notified by their community (14%), journals (8%), and social media (8%) were also reported.

Respondents were queried about their participation in trainings in an effort to determine their exposure to the Guide and its contents through attendance at trainings (Table 3.2).

Table 3.2. Participation of survey respondents in trainings affiliated with the Guide.

Training	Date	Location
NOAA’s Responding to Climate Change Workshop: A Workshop for Coral Reef Managers	2007	Australia American Samoa
	2008	Florida Keys Hawai’i
		2009
NOAA/TNC’s Reef Resilience and Climate Change Workshop	2012	U.S. Virgin Islands
	TNC’s Reef Resilience and Climate Change, Training of Trainers Workshops	2010
2011		Palau
2012		Bali
2013		Zanzibar

Responses revealed the majority of the 76 respondents had not attended one of the associated trainings (42%); Figure 3.5 provides a breakdown for the distribution of training participation among respondents. Of the trainings attended, the combined endeavor of NOAA and

## Have you participated in one of the following reef ecosystem workshops/training events within the last 10 years?

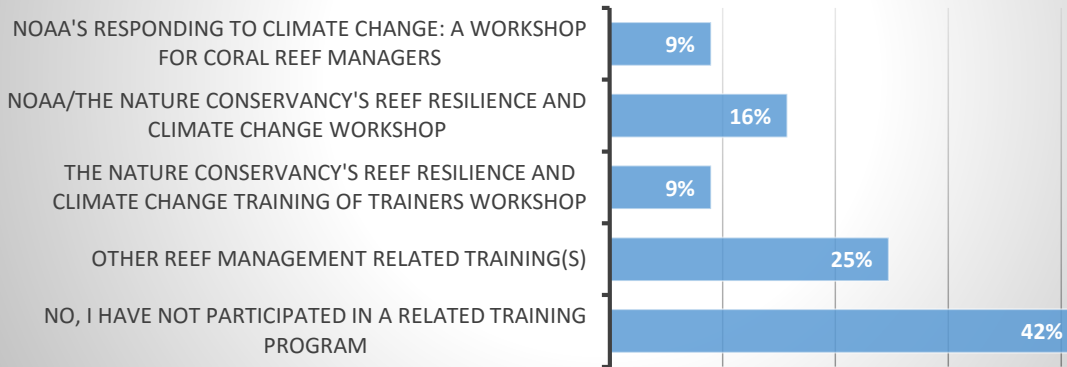


Figure 3.5. Distribution of respondents' participation in reef management associated trainings

TNC's Reef Resilience and Climate Change Workshop was the highest ranking (16%). Figure 3.6 displays the respondents' participation in the affiliated trainings by location and role (participant or trainer). The second axis represents the total percentage of total participation per training (i.e., the green bar in Figure 3.6).

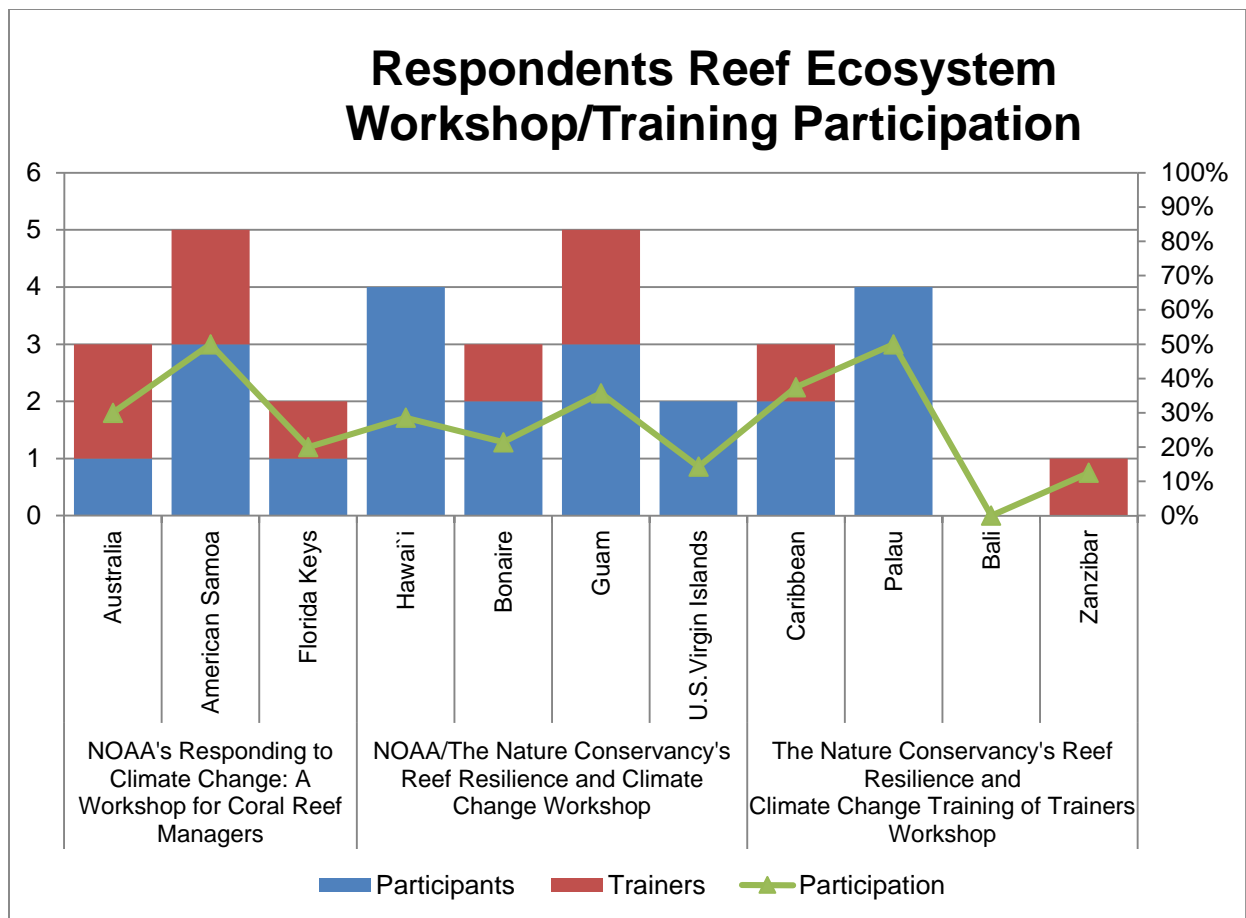


Figure 3.6. Respondents' participation in affiliated reef ecosystem trainings per location and role in training. Percentage line shows the total percentage of participation among locations of each training.

Of the 23 respondents who attended the three affiliated trainings (Figure 2.5), 91% had knowledge of the Guide. This portion of training participants represented 39% of all respondents who reported knowledge of the Guide. In comparison, respondents who participated exclusively<sup>13</sup> in trainings other than the affiliated three listed above and those who did not attend a related training program accounted for 19% and 35% of those who responded to have knowledge of the Guide respectively.

<sup>13</sup> In order to avoid double counting, this calculation only accounts for the number of respondents that exclusively selected the "Other reef management related training(s)" option to the training question noted in Figure 2.3.

## *Section IV: The Guide*

### *Utility*

From a pool of 80 respondents, 68% affirmed they had knowledge of the Guide. The majority of these 54 respondents with knowledge of the Guide reported to have used (35%) and/or read or reviewed it (35%) - constituting 70% of the total responses. Significantly fewer heard of the Guide, but never used or reviewed it (18%), those who contributed to the Guide (7%), and/or provided a miscellaneous response (4%). Those that answered “I have heard of the Guide, but have never used or reviewed it” were asked an open-ended follow-up question, “Why have you not read or reviewed the Guide?” Amidst a 100% response rate, “Not Applicable” proved to be the principal theme among responses. Lack of time and resorting to other resources within the reef management community both claimed 15% of responses. Residual responses included the following themes (8% each): find guides undesirable, lacked a hard copy, and found it too applied. The cross-comparison analysis assessing “who” uses the Guide (i.e., the demographic information of those survey respondents who reported having knowledge of the Guide), is presented in Table 3.3.

Table 3.3. Cross comparison of respondents that had knowledge of the Guide and demographic data.

Job Category	% Total	Affiliation	% Total	Region	% Total	Experience	% Total
Administrator	2%	Academia	24%	Atlantic	46%	> 1 year	0%
Community Leader	0%	Business or industry group	2%	Australia	15%	1-5 years	15%
Community Member	0%	Community-based organization/NGO	9%	Indian Ocean	13%	5-10 years	31%
Graduate Student (University)	6%	Community member	0%	Middle East	7%	10-20 years	35%
Park Ranger / Conservation Officer (day-to-day manager)	0%	Government agency	44%	Pacific	54%	≥20 years	19%
Policy Maker	0%	International NGO	17%	Southeast Asia	22%		
Project/Program Manager	41%						
Scientist/ Researcher	48%						
Volunteer	2%						
Other	2%	Other	4%				

The preponderance of respondents with knowledge of the Guide (33%) first learned of it by receiving a copy directly from one of the partner agencies (NOAA, GBRMPA, and IUCN). The website (with PDF) (28%) and a related training or workshop (22%) were also found to be prevalent ways respondents were introduced to the Guide. A portion of respondents (11%) had contributed to the Guide; thus, learned of it during the planning and production phases. Under the “other” option, 11% of respondents reported first learning of the Guide during their tertiary education and work at a partner agency, at a conference, and at the library.

Reference (self-education) (25%) was the chief purpose respondents (43) reported to have used the Guide. Outreach and education (19%) and coral bleaching response planning (18%) also ranked highly among 114 total responses provided by 43 respondents. Notably less respondents used the Guide to support management decisions/actions (12%), management planning (11%), and training staff (10%). Employing a Likert Scale, 43 respondents stated they

referenced the Guide for his/her purposes as noted above “occasionally” (27 responses). In comparison, the rest of the Likert Scale options received far fewer responses: “never use” (5 responses), “almost never” (6 responses), “frequently use” (5 responses), “every time” (0 responses).

The open-ended question, “In what ways might the Guide be improved to be more useful to your work?” prompted an array of responses from 17 respondents:

*“Update it to include more information about planning and management for resilience. More on what to do with the information collected during a bleaching event to translate it into management action. Any new management options and science. Include information on how ocean acidification may affect bleaching and resilience. Also more information/ resources for communicating clearly with policy makers and community (website with PowerPoints, videos, etc.) regarding climate change, coral bleaching, and ocean acidification.”*

*“Updated with more relevant information. Incorporate more information how to promote and implement community-based monitoring, responses, make standards more rigorous but with enough detail so intelligent lay person can implement.”*

*“1) Link to work on Fisheries Management being undertaken presently. 2) Provide e-version that is regularly updated. 3) Link to CAKE to provide case studies and additional materials.”*

*“The guide is a great start but offers no practical solutions just information on how message what is going on. More focus should be put on finding on the ground solutions and/or changing policy to allow other solutions such as reducing pressure during bleaching to actual occur. Right now in most the guide presents a bunch of nice to do's but they are not all that practical in the real world.”*

Practical “how to” information (18%) was the only true stand-out theme. Additional themes of significance included the call for the Guide to be updated (9%) to a regularly maintained web-based (6%), user friendly (6%) version with case studies, supplementary materials (9%), and regionally specific information (6%). Various language translations (6%) are also desired.

## Effectiveness

The predominance (74%) of 42 respondents found the Guide to be effective in meeting its stated goals to assist managers. The high-ranking themes offered to corroborate this claim describe the Guide as comprehensive (33%), clear (28%), and a “good starting place” (22%):

*“Yes, I think that the Guide has communicated management measures well and covers a range of issues concerning long-term resilience which is what reef managers want to achieve.”*

*“It has provided a base accessible for reef management in all areas and by reef managers of all expertise levels. The greatest benefit has been in how managers have built onto this platform.”*

Among those that found the Guide to be effective, 31% also voiced the need for it to be updated:

*“I think it did a great job of getting a lot of information into a concise and easily accessed format and guide - it's been incredibly useful in organizing our response to bleaching and developing our bleaching response plan. It does need to be updated as a lot of new science, tools, and other information have come out since it was developed.”*

*“I have a lot of information (knowledge) about managing reefs during a time of changing climate. Since its publication, our understanding of the problem has changed, but when it was published it was a perfect tool.”*

In contrast, of those that found the Guide ineffective, only 9% noted it to be out-of-date and added that “*the way people learn has changed*”. Rather, their most notable concern (38% of responses) was that it is not a practical tool to assist managers as stated in its goals:

*“The guide provides valuable theory for managing reefs, but is too vague in that it does not adequately look at the role of society and how best to engage local communities in actions which would enhance success.”*

*“The management and restoration solutions presented are not practical without policy/law changes within reef areas (i.e., ability to close areas) and the response/restoration solutions often have no money.”*

In addition, it was articulated that “...at a local site manager level, it [the Guide] assumes that managers have the authority or resources to act” (6%). Lastly, in lieu of a “not versed with

Guide's contents to answer/don't know" option in the survey, 25% of the responses were placed in the "Not applicable" category.

Sixty-six percent of 38 respondents asserted that exposure to the Guide did not cause them to change their approach to management in any way. This portion of respondents represents 46% of the 54 respondents who had knowledge of the Guide. Yet approximately one quarter of those respondents with knowledge of the Guide (24%) deduced that it did cause change in management. Nine respondents- 89% of 13 respondents who answered "Yes" to the previous question- provided feedback to the follow-up, open-ended question "How?" They believed it to be effective as a planning resource (33%) and providing issue awareness (22%) and new ideas (22%) "*for how to improve outcomes in the face of climate change*" and "*options to include in research activities*":

*"We started planning our bleaching response efforts. We developed a draft bleaching response plan and set up response teams to address acute reef impacts including bleaching".*

To further evaluate the effectiveness of the Guide a series of open-ended questions were posed that provoked a diverse collection of opinions. Fourteen respondents highlighted the following themes of strength for the Guide from 19 responses: clear and concise (16%), planning resource (16%), and providing quality information (16%). With respect to its suggested weaknesses, the 10 respondents spread their responses (13) thinly across a narrow gradient. Once again, respondents reported the Guide to be out-of-date (23%) and lack regional information (15%). Additionally implementation tools, the lack of associated outreach materials, more information needed (ocean acidification, community monitoring, and resilience adaptation information), and that the Guide is verbose were themes used to categorize criticisms of the

Guide. Specifically the “verbose” theme is directed to the “*Lengthy text to say almost only that reefs must be kept in the healthiest state, which I think is of no use against Bleaching.*”

Among the suggestions to improve the Guide’s effectiveness, “updating the Guide” (24%) and providing “regionally specific information” (18%) consistently led the respondent’s (11) responses (17):

*“Update links and resources available. Update on latest climate science & management. Provide more [information] on communication, new management options for events, and supporting resources. Expand the management section - include references / supporting documentation for why a particular approach works (help provide the tools & info necessary to educate policy makers).”*

The now familiar list of suggestions was concluded by the following themes: case studies (12%), monitoring (12%), link to existing tools (6%), more communication tools (6%), more management information and tools (6%), and converting it to a regularly updated Web-based version (6%).

With respect to the purpose of the Guide supporting their work 37 respondents ranked the overall effectiveness of the Guide on a scale of 0-100; markers were defined at zero (not at all satisfied), 50 (moderately satisfied), and 100 (extremely satisfied). The scores encompassed a range of 0-90, with an average of 65. The cross-comparison analysis assessing the demographics of who ranked the Guide, is presented in Table 3.4.

Table 3.4. Cross comparison of respondents that ranked the overall effectiveness of the Guide and demographic data.

Job Category	% Total	Affiliation	% Total	Region	% Total	Experience	% Total
Administrator	0%	Academia	27%	Atlantic	26%	> 1 year	0%
Community Leader	0%	Business or industry group	0%	Australia	11%	1-5 years	11%
Community Member	0%	Community-based organization/NGO	11%	Indian Ocean	10%	5-10 years	35%
Graduate Student (University)	5%	Community member	0%	Middle East	5%	10-20 years	32%
Park Ranger / Conservation Officer (day-to-day manager)	0%	Government agency	43%	Pacific	35%	≥20 years	22%
Policy Maker	0%	International NGO	14%	Southeast Asia	13%		
Project/Program Manager	43%						
Scientist/ Researcher	51%						
Volunteer	0%						
Other	0%	Other	4%				

## Format

Nearly all (95%) of the 37 respondents reported that they were satisfied with the format options of the Guide (printed book or online PDF). Hence, only 10 respondents proposed specific formatting improvements for the Guide. Converting it to a Web-based format (42%) linked to existing tools (17%) with more multimedia (pictures and video) “for training and application” (17%) topped the list:

*“Online, integrated into the Climate Adaptation Knowledge Exchange so it can contain case studies of how people have used the guide in their own work to improve management outcomes, plus links to other relevant literature which can be housed in the CAKE library.”*

Others felt an online, self-paced course utilizing real data in the exercises (8%), a shorter version (8%), or redirecting funds to support “developing response actions that have the potential to limit effects on high value reefs” (8%) maybe best in the future. Lastly, incorporated into a

response from an earlier question, a respondent noted that “*formats [should] vary based on information needs, cultures, and literacy levels.*”

### Overall Impression of the Guide

Thirty-six respondents scored their overall impression of the Guide using the same scale, 0-100, as above. The scores ranged from 0-91 with a 70 average. Seven respondents who completed the entire survey provided feedback to the final question (open-ended) soliciting any last “observations, ideas, etc. on how to improve the follow-up resource project to the guide, which is intended to support regional capacity to manage tropical reef ecosystems in light of climate change?” Primarily respondents requested improvements to affiliated training (33% of responses):

*“Develop an updated training that includes creation / updating of response or management plans, or using bleaching data to develop strategies / plans to build reef resilience would be useful. I got a lot out of the AS training and the Palau Train the Trainers workshops, but even online or webinar could help make the information more accessible. I personally would like something (webinar or online training) that just highlights the updates on science and management options, but for folks that haven't used the guide and attended other trainings a full training on the information and guide would likely increase its use by managers.”*

In addition, a call to support Micronesian-focused workshops in Guam was made. The residual responses reiterated similar themes from throughout the survey: 1) Create a user-friendly website with the option for users to contribute by “*add[ing] case studies, experiences of managers, results from a trial etc.*” that is regularly moderated with “*A regionally-specific version embedded in [the] Global Coral Reef Monitoring Network (GCRMN) nodes could be perfect.*” 2) Rather than support another Guide, redirect funding and efforts.

*“I do not feel the Guide should be further supported, at least as it is currently constructed. It's a ploy for funding.”*

*“There are in fact only two things reef scientists and managers can do in front of global change : - preserve a maximum of reef biota in liquid nitrogen ; - act politically to mitigate CO<sub>2</sub> rise.”*

Furthermore, respondents also provided feedback to this question indirectly. The following was extracted from previous open-ended questions in the survey; yet it is more applicable to this context than the question answered:

*“...it is formally more appropriate (and useful and economic) to conduct a requirements analysis or needs assessment of managers' needs FIRST before developing something. Case in point: Who really can use the information supplied in the Reef Managers Guide to Coral Bleaching to do anything about it? It's a good information source; other than that, what good is it?”*

*“I don't think information is holding managers back from doing anything. Public support and government will is severely lacking. To me we need to focus way more emphasis on best ways to change behavior of the public and government. Then managers might be able to accomplish way more towards protecting reefs!”*

*“Rather than redo the guide spend the money on developing response actions that have the potential to limit effects on high value reefs.”*

## Website Analysis

Over the temporal range from 2006 to 2015, 13,522 unique Internet Protocol (IP) addresses downloaded a PDF of the Guide in its entirety a total of 34,458 times from its website via CoRIS. The frequency of downloads spanned from 1-624 per individual IP address with an average of 68, which was skewed by one IP address that downloaded it 624 times. Thus, the median (37) and mode (one) of downloads per IP address provides more clarity. Notably, the three IP addresses that downloaded the Guide most frequently (624, 598, and 468 respectively) belonged to NOAA; e.g., noaa.gov domain name.

PDFs of individual chapters were downloaded from the website (Table 3.5) much less frequently than the whole document over the same time frame (2006-2015). Chapter One, “Managing for Coral Bleaching” was downloaded the most frequently; 93 times ranging from

1-8 downloads per individual IP address with an average of 3.5, median of 2.5, and mode of one.

Table 3.5. Download statistics for individual chapters of the Guide; data provided by NOAA CoRIS.

	Unique IP Addresses	Total # of Downloads	Min	Max	Range	Average	Median	Mode
<b>Chapter 1</b>	79	93	1	8	7	3.5	2.5	1
<b>Chapter 2</b>	31	33	1	3	2	2	2	1
<b>Chapter 3</b>	2	2	1	1	0	1	1	1
<b>Chapter 4</b>	8	10	1	3	2	2	2	1
<b>Chapter 5</b>	0	0	0	0	0	0	0	0
<b>Whole</b>	13522	34458	1	624	68	37	9440	623

The frequency of downloads decreased substantially with Chapter Two, “Responding to a Mass Bleaching Event”, at 33 total downloads by 31 unique IP addresses. A drastic decline continued thereafter as Chapter Three, “Building Long-Term Reef Resilience”, and Chapter Four, “Coral-Bleaching- A Review of the Causes and Consequences” totaled two and 10 downloads by two and eight unique IP addresses respectively. Chapter Five, “Enabling Management- A Policy Review” has never been downloaded.

### Content Analysis

Participation feedback, provided at the conclusion of trainings affiliated with the Guide, revolved around the central, overarching theme on the difficulty of presenting information to a diverse audience. *“It is a little difficult to know what level the presentations are aimed at- participants cover a range of knowledge and expertise”* (American Samoa 2007 Participant). For some there was too much or too little information. One participant from the Florida Keys 2008 training found it to be both, there was *“too much redundancy but not enough specifics. Too much focus on corals, and not enough on the rest of the coral reef community (sponges, plankton, fish, invertebrates)”*. Several other participants commented rather on the sources of information, and how *“sources of info[rmation] should be provided”* (Bonaire 2009 Participant). Whereas a

participant from the Australia training in 2007 expressed their concern for the capacity of the audience to follow along without trouble: *“I wonder if delivery of the presentations was too fast for the participants who are speaking English as 2nd/3rd language. Otherwise, wow! Very rich and informative.”*

However the need to have more specific and practical guidance on management strategies (i.e., pragmatic solutions) at the local level was generally agreed upon by most participants.

*“This was interesting—we need more real action items and techniques”* (American Samoa 2007 Participant). More specifically, the tools must be relevant and accessible to specific localities.

*“Good explanations of online resources! But might be too advanced for most islands. Need low tech examples or other ways to get info”* (American Samoa 2007 Participant). Another American

Samoa 2007 Participant *“Found this section [assessing mass bleaching, resilience, & socioeconomic impacts] out of touch with the reality of island national and their resources at hand. Island nations have very limited resources and capacity to implement some of the measures prescribed.”* A Florida Keys 2008 Participant found the module on resilient MPAs and MPA networks to be *“...interesting, but this was an Atlantic workshop but all the studies and pictures related to Western Pacific. Our situation is slightly different.”*

Another central theme was the participant’s feeling that the Guide made the assumption that managers have the tools and are empowered to implement the changes suggested in the Guide. For example, the participants from the following trainings noted that,

*“Maybe incorporate some discussion re: the political climate in each of our areas. The reality is we can communicate and advocate for action at the local level. However, if the political will to address climate change is absent, then our efforts are limited in scope”* (Florida Keys 2008 Participant).

*“Most of us probably do not have the authority to interact independently with the media to interact independently with the media but are required to act through our agency’s media coordinator”* (American Samoa 2007 Participant).

The necessity for attention to cultural diversity also emerged as an important evaluation theme. For example an American Samoa 2007 Participant stated, *“Also felt there were some generalizations that can be applied, but for really being able to implement would need to recognize that some solutions would need to be culture-specific.”* Another American Samoa 2007 Participant echoed, that they *“need more concrete things the villagers can do to help.”*

The inclusion of socioeconomic impacts was praised by several participants and the request for more on the use and creation of socioeconomic analysis was made by U.S. Virgin Islands 2010 Participant. This request was expanded by a Participant from the American Samoa 2007 training, *“I hope you’ll have more information on this soon [the socio-economic component]- and more guidance on how to incorporate this.”*

Most commented that they found the later modules focused on communication and creating a crisis response plan to be the most useful. One participant elaborated further to say,

*“I believe more time should be spent on modules 7 and 8, because the majority of the attendees are aware of the overview info but need more examples + discussions of the types of things we can do regarding climate change, coral bleaching, resilience. So perhaps a shift in the use of time. Build in Caribbean-specific examples and species. Although we have a lot to learn from MPAs outside our region, it also helps to see what is being done locally.”*

(Florida Keys 2008 Participant)

The later module specifically received the most praise among participants with comments such as it being the *“main purpose for attending workshop”* (American Samoa 2007 Participant) and *“this is very important to us”* (U.S. Virgin Islands 2010 Participant). Participants from all the trainings felt rushed through this module and that it deserved more time. *“More time getting the response plans fleshed out- [when] we have most of the players in the room”* (American Samoa

2007 Participant). *“There was too little time to prepare the drafts and could be really interesting to hear the ideas of the different groups at the end. Time administration”* (Florida Keys 2008 Participant). An overarching theme was the request for less lecture style training and more opportunities for active engagement with the material and other participants. Field and discussion/interaction time were highly valued, *“I suggest a more example-based approach over a “teaching” approach”* (Florida Keys 2008 Participant).

Overall the evaluations captured a sense of satisfaction and gratitude for the trainings and the efforts of the trainers.

*“Well done. Thanks for getting this concept into a working system. This workshop is a good starting point to initiate actions to allow us to address an otherwise overwhelming problem. A good toolbox to begin education other decision-makers, stakeholders, and the community. Thank you”* (Australia 2007 Participant).

Many participants were eager to be updated with new information and findings over time such as this Florida Keys 2008 Participant who stated, *“Please keep me posted if new ideas are developed or if changes are made”*. The main take away is that the trainings brought the lessons of the Guide to life for many participants, yet they were left with wanting to know ‘what to do’ beyond the scope of the Guide (survey respondent).

*“Overall, I thought this was a useful workshop. I’d like to see more time spent on management actions, field exercise- to include looking at stresses (watershed, fishing, etc.) that may impact bleaching. Also bring in more examples of existing management actions to address the impacts of bleaching.”*

(American Samoa 2007 Participant)

## Chapter 4. DISCUSSION and CONCLUSION

### DISCUSSION

Reef managers are tasked to sustain the health of tropical reef ecosystems and the services they provide. In order to effectively manage they need the proper tools specific to their local jurisdiction/area. The widespread effects of global climate change have increased the need to know the status of the resource, how it is changing, and (ideally) why it is changing. The efforts of the Intergovernmental Panel on Climate Change<sup>14</sup> and others have increased our knowledge and awareness of global climate change and its effects on ecosystems, which will prove especially detrimental to tropical reef ecosystems. Tropical reefs are the most biodiverse marine ecosystems providing critical habitat to ~25% of marine species and are highly valued for the myriad ecosystem services they provide to the millions of people worldwide that are dependent on them (Buddemeier et al. 2004). The dependency on these services is highly vulnerable to the combined effects of climate change and local stressors on tropical reef ecosystems; the Millennium Ecosystem Assessment study identified coastal ecosystems as *"among the most productive yet highly threatened systems in the world"* (Millennium Ecosystem Assessment 2005). Reef ecosystems are impacted by both the direct effects of stressors on species and populations as well as by changes in species interactions, including competition, predation, parasitism, and mutualism (reviewed in Kordas et al. 2011). The economic damage of climate change on the value of global reefs and services is anticipated to have an annual loss of U.S. \$3.72 to U.S. \$23.78 billion (Chen et al. 2015).

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<sup>14</sup> <http://www.ipcc.ch/>

The current study was designed to evaluate the information needs of reef managers in addressing climate change and specifically *A Reef Manager's Guide to Coral Bleaching* (Marshall and Schuttenberg 2006). We did this by examining three research questions:

- 1) What are the current information use practices of the reef management community?
- 2) What are the strengths and weaknesses of the current Guide, *A Reef Manager's Guide to Coral Bleaching*, from the user's perspective?
- 3) What are the major advances in science (since the 2004 completion date of the Guide) to support management and the successor resource to the Guide?

These questions were addressed through a flexible design using a triangulated approach<sup>15</sup> including the collection of background information from “key players”, elite interviews with experts as defined by this study, tailored design online survey, and review of archival data. The study findings are applied to the research questions accordingly:

#### Strengths and Limitations of the Guide

Overall the study population considered the Guide to be a great reference with limitations. It was heralded as a creditable reference providing the best information to the reef manager community at a critical time. It converged the attention onto coral bleaching and offered an understanding of resilience-based measures for management. “*It can get a discussion going where one does not exist*” (online survey respondent). “*It's been incredibly useful in organizing our response to bleaching and developing our bleaching response plan*” (online survey respondent).

Early training workshops focused solely on the Guide, whereas later trainings incorporated its content into broader curricula in which participants were not always aware of the

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<sup>15</sup> Meaning that several means are utilized to examine a phenomenon through validating, contradicting, or discovering variables.

Guide. Survey respondents who attended the early trainings appeared to assign the Guide more credit for its influence on their monitoring and/or bleaching response plans than others. Out of a pool of 38 respondents, 66% reported that exposure to the Guide did not cause them to change their approach to management in any way. This portion of the online survey sample population represents almost half (46%) of the 54 respondents who had knowledge of the Guide. However, feedback provided elsewhere in the survey offers insight that the Guide failed to provide practical tools for implementation such as tangible outreach tools to inform the community and policy makers and build support. In addition, many found it assumes local management is authorized with the resources and power to act, which is often not the case.

The chief critique of the Guide is that is simply not practical enough for application in most regions of tropical reefs. A global guide is not able to consider the divergence of laws, culture, and language among local areas. An online survey respondent commented, *“the guide provides valuable theory for managing reefs, but is too vague in that it does not adequately look at the role of society and how best to engage local communities in actions which would enhance success.”* For example, managers in the U.S. and Australia may have the ability to close areas during a bleaching event, but those in the Coral Triangle or Africa do not. The benefit of the global guide is that it provides an overarching framework that can be tailored to regional and local levels. However, it cannot be all things to all people in one form.

There is clear consensus among the sample population of this study that the Guide offers a plethora of information, yet it was found to read more like a publication than a guide to strategic management; thus, limiting its audience and practically among the management community. Most respondents with knowledge of the Guide received a hard copy directly from the one of the partner agencies. Downloading it from the website was the second most prevalent

way respondents encountered the Guide. Several respondents recommended expanding the online presence for Guide updates and/or future projects (e.g., online trainings modules, links to other references, case studies, etc.). Albeit the internet is irrefutably a beneficial tool for knowledge transfer, it is not without its limitations: internet capacity is still limited in some regions, messaging is difficult to customize with one website (e.g., diverse cultures, languages, etc.), possible over-saturation of web-based tools, and often times websites are not updated and provide outdated information.

Several among the study's sample population asserted that the Guide does not address the root of the problem (i.e., of coral bleaching) that is global climate change. Most likely this was due to the political "climate" at the time of publication. Moreover, it was mentioned that action needs to extend beyond keeping reefs in the healthiest state for remote reefs are still suffering from increased and prolonged bleaching events and sequential effects. Thus, it is seen as detrimental to solely focus on increasing the resilience of reefs to reduce bleaching.

#### What is needed

The responses of the sample population demonstrate the diversity in their responsibilities, focus area(s), and needs. This speaks to the complex and common challenge of managers to simultaneously address an incongruous combination of local and global stressors. The wide scope of responses introduces a common thread in these findings that is the importance of targeting one's audience.

Possibly the most common need among all regions is that of public and government support, which is fundamental to securing funding and enforcing management action(s). Some respondents considered it to be the utmost limiting factor in reef management, above any information need.

Information must be focused and oriented around the goals of the project, policy, etc. at hand and developed/messaged to target one's audience. Moving forward, the call to address needs at the regional level and empower local managers is apparent. These needs vary greatly among regions and along the vertical and horizontal hierarchies. For example, it was reported that many Americans are still not aware of the implications of climate change, its root causes, and why we should address it. Whereas those in developing countries understand that climate change and ocean acidification are important, but know little about them. All planning and action development should be made with consideration of the target audience.

The information needs are plentiful and start with resource status. It is imperative to know the condition of one's resource and changes over time in order to manage it. Even though monitoring information is a major tenet of many management frameworks, it is increasingly difficult to fund ecosystem-based monitoring. Even developed countries struggle to fund long term monitoring programs, which are seen as vital resources of information. Hence, many regions lack baseline data on their resources. Regional monitoring requests expand further to include spatial data, biodiversity data, and ocean acidification monitoring. Research needs expand even further and consist of the following: interdisciplinary, social science, socioeconomic, biological responses to elevated SST and ocean acidification, ecological connectivity, invertebrates, life history data, etc.

Although the information needs seem profuse, many reported lacking access to existing information over requesting new information. Along with the call for improved access, to scientific literature, there was a desire for summarized scientific literature, and scientific and management related information delivered in an easily digestible manner. The issue of receiving

data in a timely manner was also noted by several respondents, commenting that there is a large lag time to receiving the information collected by various agencies's monitoring programs.

### Implications

In order to target the needs of one's audience and message the information accordingly, a needs assessments should be conducted prior to trainings, product development, and information delivery. It is equally important to involve all stakeholders in the entire development process. Often all stakeholders, those that either affect or benefit from the resource, are not involved in its management. The results of the needs assessment will shape everything- actions, content, language, style, and formatting- as well as increase cost effectiveness. It is important to understand the need transcends that of information sharing and access to the complex art of brokering knowledge (Meyer 2010) as well.

The use of knowledge brokers is highly recommended in all steps of the management development process. Knowledge brokering is encompassed by a broad definition that is to be tailored on an ad hoc basis (Oldham et al. 1997) by the context and opinions expressed in the needs assessment. William Becker, Executive Director of the Presidential Climate Action Project, elaborates that *“good knowledge brokers do not simply serve as a pipeline through which information flows from one place to another. The “broker” role involves assimilating, interpreting, sorting, translating, and integrating information to create new or derivative language”* (Healey et al. 2015).

Survey results suggest having a greater web presence regarding improvements of the Guide/possibility of a follow up project to house updates, modules, links to other resources, etc. The use of the web as a vessel for information should depend on its target audience. Survey

respondents who readily suggested the use of the web obviously had access to internet; thus, it is cautioned to extrapolate this finding without considering the capacity of one's target audience.

It is recommended to empower managers on the regional level with respect to the findings of the needs assessment. Reported regional needs consist of the following: resource status data, sustainable funding, intra-stakeholder communication, implementation, providing accountability, and outreach and education. Funding is the common dominator of limitations among all regions, developed and developing alike. Financial counseling on how to acquire sustainable financing should be incorporated in all information sharing efforts in order to implement and sustain management actions long-term. This would fuel collaboration among stakeholders to share the burden of data collection and dissemination, skill, finance, or training.

Survey respondents made repeated calls to increase intra-stakeholder collaboration and communication. History has proven that asymmetrical information delivery is not effective. A two-way dialogue must be established among the community, management, and researchers to address both local and global problems and identify ad hoc solutions. Collaboration is a must to optimize limited resources (i.e., information, funding, etc.) and achieve long-term, sustainable management of regional resources. Additionally, the evaluation phase of adaptive management can not be omitted in future endeavors. Evaluations are needed not only to adjust management, but for use to report back to stakeholders in order to build and maintain support.

It is recommended to assist managers in taking the next step past writing the plan towards implementation. Many have reported that if local regions are given the flexibility to make it their own plan, it increases the probability they are more likely to sustain a long-term plan. Assistance does not stop at the end of a training. Providing accountability with participants through check-ins and mentor type programs, etc. also increases the likelihood for sustained implementation.

For example, TNC Reef Resiliency Toolkit training program did an evaluation in 2012 (Cerroni), and found that before the evaluation there was little follow through with projects post training. In response TNC changed their protocol for the Zanzibar training in 2013, which included more in person help, writing action plans, follow-up mentoring, etc. As a result the follow through increased exponentially (personal communication, The Nature 2015). Post-training or prolonged assistance are equally as important as the product or training, but are difficult to fund.

There is still a pressing need for outreach and education in all regions and throughout the horizontal and vertical hierarchies. Although it is not as simple as we once thought in the ‘educate them and they will care’ model. Cormick’s work (2012), has shown the appropriate message and delivery must be crafted intelligently in order to reach one’s audience. NOAA’s Office for Coastal Management’s Climate Adaptation for Coastal Communities training (<https://coast.noaa.gov/digitalcoast/training/climate-adaptation>) is an example of a customized training effort that incorporates local needs, examples, and experts into the curriculum to optimize its practicality for local practitioners. However more difficult it may be, outreach and education is still considered to be a stepping stone to build support and stakeholder buy-in, compel government entities to act in accordance, and ideally initiate both bottom up and top-down action. Bleaching and other disastrous events caused by the effects of local and global stressors should be used as outreach and education opportunities. Messaging should always be honest and accompanied with forthcoming actions or alternatives. Lastly as an interviewee pointed out, everyone is unique, but not unique; meaning people are more alike than different. Both should be acknowledged and respected both in all engagement efforts.

## LIMITATIONS OF STUDY

The results of this study are to be interpreted with caution for the following reasons: access, time constraints, funding, and human error.

Access to elite interviewees (Kvale 1996) and survey respondents was a constant concern throughout this study. Holistically, this research study is limited by the closely connected issues of time constraints and funding. More time and funding could have eased access to elite interviewees. The feasibility boundaries of this study were well understood and were therefore designed without the expectations of either elite interview saturation via an opportunistic approach or solely in person interviews.

The scientific advancements on this topic since 2004 are plentiful, if not overwhelming. An appropriate literature review is extremely time-intensive. The review conducted for this study is extensive, yet it seems impossible for it to be completely comprehensive.

Open-ended questions were included in the online survey over the exclusive use of close-ended questions (i.e., multiple choice, ranking, etc. questions) to avoid imposing unintentional biases onto respondents (Foddy 1994). Even though studies have found responses to open-ended questions have a better success rate online than paper surveys (Kwak et al. 2002, Denscombe 2008), the high cost behavior of answering open-ended questions (Bosnjak 2001) may have caused increased drop-out rates (Knapp et al.).

The demographic information of the survey clearly identifies how these results should be interpreted: the majority of respondents identified themselves as a scientist/researcher (49% of respondents) and program management (34% of respondents); affiliated with a government agency (47%), academia (22%), and international Non-governmental Organizations (16%); and concentrating their work efforts in the Pacific (35% of responses) and Atlantic (31% of

responses) regions. The survey successfully reached those producing knowledge to support management decisions. Community representatives were not well represented in this study. Even though the snowball sampling methods consisted of some community-based NGOs in the original pool targeted, it is possible that the targeting methods limited the survey's exposure to individuals that would solely identify as a "community member" among the options provided. However, since the survey only permitted the respondent to select one option to best describe his/her job category and affiliation, it is also possible that this may have contributed to community efforts in addition to their primary occupation.

Upon review of responses of the online survey it became clear that certain questions addressing the knowledge and use of the Guide should have included a "Not applicable" or "Do not know" option.

#### FUTURE RESEARCH DIRECTION

In future research, a more comprehensive study or needs assessment targeting a greater geographical representation of the reef management community along both the local and government levels would be ideal. The local level, to understand the status and needs of management and the government level, to seek the capacity of management tools. More realistically, a series of studies/needs assessments tailored by geographic region may be more pragmatic and informative. Within a comparable range, methods should be selected with regional considerations/context (i.e., culture, language, internet capacity, etc.), and conducted by a team of researchers including regional representatives (i.e., knowledge brokers). Incentives to increase the compliance rate of good-intentioned experts that agreed to an elite interview and then failed to follow up.

It would be useful for future endeavors to 1) evaluate and quantify the ability or power of local managers to alter resource use, what actions they have taken, and the effectiveness rate; and 2) evaluate the reach of the trainings; opportunity vs. need and willingness.

## CONCLUSION

There is no question that climate change is affecting the physical, chemical, and biological systems of the oceans, as well as human uses of ocean resources. Like most management issues, a panacea does not exist for management of reef ecosystems. Addressing local stressors is no simple task, but it is much more manageable than addressing global climate change. However, both issues must be addressed through personal, professional, and political action.

Even though the Guide is now out of date, following up with updated information in a similar format is not the overarching need of the reef management community. The Guide galvanized the reef community's attention to coral bleaching and addressing local stressors to improve resilience of reef ecosystems. Since the Guide's publication, knowledge has increased and different approaches and tools have been developed. It is important to make this information accessible to reef managers, and to use a needs assessment to shape that delivery. This study suggested that using established methods such as consultations with experts make a useful form of information transfer; e.g. the TNC Reef Resilience toolkit.

Conducting a needs assessment prior to action planning research, management, information exchange, training, etc. is a proactive step to increase efficiency for multiple reasons. This directs what information is needed where and the best method to shape that delivery. It offers the opportunity for intra-stakeholder communication, participation, and buy-in; idea and resource sharing; collaboration/partnerships; and empowerment of regional stakeholders.

Beyond providing information in the traditional sense, it is time to empower local managers at the regional level to implement action. Any effort must be tangible and practical to the target audience. Recognize that advocating individuals need to take personal action, also positions them to do more on larger scales. Once involved and invested on a small scale, people are more likely to participate on a larger scale. Creating community buy-in, and empowerment of local managers to direct government regulations is seen to be needed more than any information request as it is the root to all paths forward.

Notably, collaboration and communication among stakeholders is also resource intensive (funding and time), yet successful collaboration can optimize funding and improve the success rate and sustainability of management actions. Open communication and collaboration must also exist among the various entities that support regional stakeholders in order to increase continuity and decrease the confusion of mixed messaging.

Too often the limitation of resources leads to the omission of post-training follow-ups, data collection and/or information dissemination, and the evaluation phase of adaptive management. Although justifiable, the sustainability of tropical reef ecosystems and management efforts can not afford these omissions to continue. Both regional managers and funding entities share the burden to improve matters. Regional managers must find creative ways to redirect and share resources to improve the effectiveness of their management actions. Where as funding entities must recognize that such omissions reduce overall effectiveness and increase longterm cost. The process and outcome of a needs assessment along with tailored messaging and improved communication, collaboration, and sustainable finance counseling can empower regional managers to optimize their resources and support a network to further their management goals.

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## Appendices