# What conservation strategies support the adaptive capacity of coastal ecosystems in three island states facing a changing climate in Micronesia?

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Statement of authorship

I hereby certify that this thesis has been composed by myself and describes my own work, unless otherwise acknowledged in the text. All references and verbatim extracts have been quoted, and all sources of information have been specifically acknowledged. It has not been submitted in any other application for a degree.

Signed:

Dated: 01.02.2023

I agree that my thesis may remain at the disposal of each of the libraries, the one of the United Nations University Institute of Environment and Human Security and the library of the Department of Geography of the University of Bonn.

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**Abstract**

Coastal ecosystems, such as coral reefs, mangroves, and seagrass beds, are highly vulnerable to the impacts of climate change. The degradation and loss of these ecosystems, stemming from the increased impacts of climate change-related drivers, threaten the well-being of island communities in Micronesia, as they are very reliant on and connected with these coastal ecosystems. Supporting the adaptive capacity of ecosystems through climate adaptive conservation, and thus better equipping them to recover from and adapt to the potential impacts, in turn reduces the vulnerability of the social-ecological system. This thesis identified five main climate change-related drivers that impact coastal systems across three selected states in Micronesia.

First, based on a conceptual social-ecological systems (SES) framework, a literature review and analysis were conducted to identify and select three ecosystem adaptive capacity (AC) elements: Heterogeneity, connectivity, and ecosystem functioning. Building on that, second, a literature review aided the identification of climate adaptive conservation strategies and related actions that can support the adaptive capacity of ecosystems. Following a qualitative content analysis, eight climate adaptive conservation strategies and 26 activities were selected and categorized. Third, the extent of (1) the strategy effectiveness, (2) their integration in conservation policy and planning documents, and (3) their implementation on a national scale were evaluated through a semi-quantitative expert consultation in each of the selected states, exemplified with coral reefs.

The findings from this research showed that while the climate adaptive strategies and activities were considered effective in supporting the adaptive capacity of coral reefs in Micronesia, the extent of their implementation ranked low.  Strategies, such as "Addressing non-climatic drivers" were considered highly effective, however their implementation fell comparably short. Contrary, targeting heterogeneity was considered of least importance. Thus, as their regional implementation ranked low, the ability of the strategies to support coral adaptive capacity was limited for all three countries. Particularly, the upscaling and mainstreaming of these strategies was considered crucial by the experts. Therefore, this research proposed to prioritize addressing non-climatic drivers, supporting coral reef restoration, and recommended to integrate communities in the design of climate adaptive conservation. Further to apply actionable co-produced science to advance the evidence base and applicability of the strategies in supporting ecosystem AC.

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## Abbreviations

| | |
|---|---|
| AC | Adaptive capacity |
| CCA | Climate change adaptation |
| COS | Stanford Center for Ocean Solutions |
| FSM | Federated States of Micronesia |
| IAS | Invasive Alien Species |
| ICZM | Integrated Coastal Zone Management |
| IWRM | Integrated Water Resource Management |
| MPA | Marine Protected Area |
| MSP | Marine Spatial Planning |
| NGO | Non-governmental Organization |
| PA | Protected Area |
| PAN | Protected Area Network |
| RMI | Republic of the Marshall Islands |
| SES | Social-ecological system |
| SLR | Sea level rise |
| SST | Sea-surface temperature |

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# 1. Introduction

This section first introduces the research problem and its relevance, second the research assumptions and questions, and third the terminologies of this thesis research.

### 1.1 Problem statement and relevance

Tropical coastal ecosystems are increasingly confronted by climate change-related drivers that cause an unprecedented risk of ecosystem collapse, which would lead to a widespread loss of biodiversity, ecological functions, and ecosystem services (Kingsford et al. 2009; Jupiter et al. 2014). For example, an increasing tropical sea surface temperature (SST), which is projected to rise 50 to 80 percent over the next century in the Pacific, is one of the most significant threats to coral reefs (Spooner et al. 2017, p. 28). In many island settings, coastal ecosystems are ecologically tightly connected, and thus potential impacts of SST changes in coral reefs can affect other adjacent ecosystems and ripple through the coastal seascape.

Coastal and small island communities showcase the interlinkages of society and nature, with communities being highly dependent on marine and coastal ecosystems, and the ecosystem services these provide, as well as oceanic and coastal ecosystems being particularly vulnerable to climate change-related drivers (Marshall et al. 2013; McMillen et al. 2014). Thus, impacts of climate change-related drivers are particularly drastic in connected island systems where social-ecological components are closely interlinked. This connection creates a high social-ecological vulnerability to climate change (Weeks & Adams 2017; Thiault et al. 2018; Andrew et al. 2019).
Effective conservation of coastal ecosystems is imminently important for these closely linked systems and signifies an urgent need to include and account for climate change in conservation planning (Tittensor et al. 2019). Therefore, obtaining an enhanced understanding on how the vulnerability of coastal ecosystems towards climate change-related drivers can be reduced through conservation strategies and related actions is considered key for these islands' systems survivability.

Despite coastal ecosystems being highly sensitive and exposed to multiple climate change-related drivers they are, to a certain extent, equipped with adaptive capacity (AC). This AC enables ecosystems to recover from and adapt to non-climatic and climate change-related drivers (Stein et al. 2013). Hence, reducing the vulnerability and risk for negative impacts, such as ecosystem loss. Yet, ecological systems have a limited capacity to adapt to climate change, with more systems set to reach their limits or having already surpassed their limits (e. g. coral reefs) (IPCC 2022). Under a changing climate, with some ecosystems already transitioning to different states with altered community structures and functions, it is thus crucial to understand and support this ecosystem AC through conservation (Heller & Zavaleta 2009; Stein et al. 2013; van Kerkhoff et al. 2019).

This is considered particularly relevant for a continued effectiveness of marine and coastal conservation (Wilson et al. 2020). Hence, scholars have urged to integrate climate adaptive strategies into conservation from national policies to local implementation. As this is considered an effective way to integrate climate change adaptation (CCA) into conservation design, planning and management (Maxwell et al. 2020; Wilson et al. 2020), to address climate change, and to outline ways supporting the adaptive capacity of ecosystems (McLeod et al. 2019).

Concurrently, scholars have proposed a multitude of frameworks, strategies, guidelines, or conservation area design principles for climate adaptive conservation particularly for marine and coastal conservation, for example by protecting coral reef climate refugia (Rilov et al. 2019; van Kerkhoff et al. 2019). Despite these efforts, in practice conservation continues to insufficiently consider climate change. The uptake and implementation of climate adaptive conservation strategies in general, and specifically in marine and coastal conservation appears very limited and globally uncoordinated (Tittensor et al. 2019; O´Regan et al. 2021). An additional lack of empirical evidence and studies on the effectiveness, relevance, and practicality of climate adaptive strategies in conservation practice results in a constrained understanding of how and what strategies can support the adaptive capacity of ecosystems (Wilson et al. 2020).

A social-ecological system (SES) framework was established to better understand how social-ecological systems are equipped to adapt or to recover from climate change-related impacts and how the adaptive capacity of system elements can be supported through conservation to reduce the vulnerability of a SES to climate change-related drivers (Ban et al. 2013; Petersen et al. 2018; van Kerkhoff et al. 2019).

Despite the recognition that AC can offset the sensitivity of system elements and is thus regarded as essential for reducing social-ecological vulnerability, it has been mainly included as social AC within SES frameworks. Thus, while this theoretical SES framework has been applied to identify conservation strategies to support this capacity it has addressed ecosystem AC to a very limited extent (Petersen et al. 2018; van Kerkhoff et al. 2019). In this research, a conceptual SES framework helped to understand what climate adaptive conservation strategies, that are applied by parts of the social sub-system, can support the ecosystem AC, in turn helping to reduce the vulnerability of the ecosystem, and hence the vulnerability of the SES to drivers of change. Supporting ecosystem AC can facilitate that ecosystems continue to be equipped to provide ecosystem services, which are recognized as a key foundation for human well-being (Seddon et al. 2019).

To identify and select climate adaptive strategies that can support ecosystem-level adaptive capacity, the concept of ecosystem AC must be better understood. However, thus far this concept has been neglected in research (Angeler et al. 2019; Thronicke et al. 2020; Seaborn et al. 2021). Its uptake and advancement in research have been limited by a lack of knowledge and data on how ecosystems respond to certain drivers (Petersen et al. 2018). Further, due to a lack in agreement of its meaning, conceptualization, and the elements it is composed of, and hence methods or metrics to assess ecosystem AC (Angeler et al. 2019; McLeod et al. 2015). Hence, this lack of understanding the adaptive capacity of ecosystems can significantly reduce the effectiveness of conservation in the face of climate change, especially in marine ecosystems, such as coral reefs (McLeod et al. 2019; Rilov et al. 2019; Tittensor et al. 2019), seagrass beds (Bindoff et al. 2019; McKenzie et al. 2021a) and mangroves (Ellison 20018a) that are highly vulnerable to climate change.
Therefore, this research will apply a conceptual social-ecological system framework, and will, first aim to understand the concept of ecosystem AC more clearly, as well as the elements it is composed of. Second the thesis will examine what climate adaptive conservation strategies and related actions can support this ecosystem adaptive capacity. Before third, to validate and assess to what extent these strategies are considered effective, integrated, and implemented in conservation practice, exemplified with coral reefs, in the case study region, to overcome potential challenges and provide recommendations to enhance their implementation. Expert surveys were selected as a suitable methodological approach in this research to validate the theoretically suggested climate adaptive strategies and to gain empirical evidence of

their relevance and effectiveness in supporting coral AC in the case study region (McLeod et al. 2015).

The aim of this research aligns with the research needs and priorities identified for the Pacific region (Weeks & Adams 2017). The scholars listed related research questions namely "*How can protected areas be designed to address impacts of future climate change*" and "*Which characteristics of coral reefs confer resilience to natural and human disturbances?*" (Adams et al. 2021, p. 2ff).

### 1.2 Assumptions and research questions

The aim of this master thesis is to contribute to an enhanced understanding of the concept of ecosystem adaptive capacity and what conservation strategies can support this capacity by answering the following main research question: ***What conservation strategies and related actions support the adaptive capacity of coral reef, seagrass bed and mangrove ecosystems, and to what extent does this help them face potential climate change-related impacts in three states in Micronesia?***

Thereby it outlines, to what extent conservation strategies and related actions can support ecosystem adaptive capacity, exemplified with mangroves, seagrass beds, and particularly coral reefs, to face potential climate change-related drivers, and to what extent these strategies have been implemented by means of a multi case study approach. In addition, this research aims to provide knowledge-based lessons learned and recommendations for conservation planning and decision-making, to enhance the understanding of these strategies, and their implementation in practice in Micronesia and beyond.

The underlying assumption in this thesis research is that supporting ecosystem adaptive capacity is a key component in reducing the vulnerability of ecosystems and social-ecological systems. Supporting the adaptive capacity of ecosystems through climate adaptive conservation strategies is an essential element to make conservation more effective, climate adaptive, and help ecosystems adapt to drivers of change, even in the absence of change.

Concurrently, the following sub-research questions are addressed to answer the main research question:

1. *How is the adaptive capacity of ecosystems defined in the academic literature and what are options to support it?*

2. *Which conservation strategies support the adaptive capacity of coral reefs in three Micronesian states?*
3. *To what extent are the climate adaptive conservation strategies implemented in the three states?*

**1.3 Outline and terminology**

According, to the assumptions and the research questions of this research, building on key terminologies, the theoretical and thematic framing of this thesis is assembled, with a particular focus on the adaptive capacity of ecosystems and the conceptual social-ecological system framework of this research (section 2).

In the following, the three-fold methodological approach of this thesis is presented (Section 3). Thereafter, the research results are presented, first concerning the elements of ecosystem AC and, second the selected climate adaptive conservation strategies and related actions. Third, the expert survey validated the selected strategies and assessed the state of coral conservation in the three case study countries (section 4). Lastly, the findings are discussed, and recommendations are given concerning the conservation strategies and ecosystem AC according to the survey and literature results (section 5). Subsequentially, a critical reflection of the methods and is preceded by a conclusion of this research (section 6).

This thesis uses various key concepts to address this outline, which for the purpose of this study are defined as follows:

**Indirect and direct drivers of change:** Indirect and direct drivers of change affect natural systems globally (MEA 2005; IPBES 2019). A driver of change is defined as "any natural or human-induced factor that directly or indirectly causes a change in a system" (IPCC 2019b, p. 683). The term highlights the dynamic nature of this concept and is generally divided into:

| Indirect non-climatic anthropogenic drivers | Direct drivers on coastal and marine systems |
|---|---|
| • Demographic and sociocultural<br>• Economic and technological<br>• Institutions and governance<br>• Conflicts and epidemics | • Land or sea use change and (over)exploitation<br>• Climate change<br>• Pollution<br>• Invasive alien species |

*Table 1: Selection and categorization of indirect and direct drivers of change (based on MEA 2005; IPBES 2019; Bindoff et al. 2019).*

Indirect drivers are associated with human decisions that affect nature diffusely through positive and negative effects (Abram et al. 2019) (Table 1). Direct drivers (IPBES 2019), can be both natural or anthropogenic, are non-climatic, impact nature directly, and magnify ecosystem vulnerability to **climate change-related drivers** (Abram et al. 2019). Direct anthropogenic drivers are mainly considered for anthropogenic activities, such as human decisions and activities that positively (e. g. ecosystem restoration) or negatively affect nature (Oesterwind et al. 2016). While direct natural drivers are considered as beyond human control (e. g. ocean-related events) (IPBES 2019), some of which are attributed to human-induced climate change (IPCC 2019a). These direct drivers undoubtedly affect marine ecosystem processes (Oesterwind et al. 2016), ecosystem services and human well-being at various spatial and temporal scales (IPBES 2019), while non-climatic drivers are more likely to affect systems very locally. Such climate change-related drivers may act on different temporal and spatial scales (MEA 2005), and affect ecosystems differently depending on their specific vulnerability and exposure to other drivers.

Depending on the research field, the terms driver**,** disturbance, and stressor are used synonymously (Gallopín 2006; Burke et al. 2011; Anthony et al. 2015).

Drivers of change can affect a **social-ecological system**, which is defined as "an integrated system that includes human societies and ecosystems, in which humans are part of nature. The functions of such a system arise from the interactions and interdependence of the social and ecological subsystems. The system's structure is characterized by reciprocal feedbacks, emphasizing that humans must be seen as a part of, not apart from, nature" (IPCC 2019b, p. 697).

This system can experience the occurrence of **hazards** that originate from in and outside the system and refer to the "potential occurrence of a natural or human-induced physical event or trend", which can result in the loss of livelihoods or ecosystems (IPCC 2019b, p. 688).

Hazards can affect **exposed elements** of a system, which are "people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (IPCC 2019b, p. 685).

In addition, the **sensitivity** and **lack of capacity to adapt** of system elements can create a certain **vulnerability** to be negatively affected (Bindoff et al. 2019; IPCC

2019b), with human and ecosystem vulnerability considered interdependent (IPCC 2022).

Vulnerability can be positively influenced by the **adaptive capacity of an ecosystem**, which in this research is defined as the latent ability of an ecosystem to accommodate, respond, cope with, or adapt to potential impacts, such as climate change-related ones, and take advantage of opportunities, or to respond to consequences (adapted from IPCC 2019b, p. 678). The ecosystem AC is composed of different, in this research defined as elements.

The ability to respond to drivers can further depend on the resilience of a system (Berkes et al. 2003). This research considers the definition of **ecological resilience**, which "is the capacity of a system to absorb disturbance to avoid a regime shift (multiple equilibrium focus), and a measure of the amount of disturbance a system can withstand before collapsing" (Angeler et al. 2019, p. 14).

Furthermore, the **risk** of potential negative consequences or climate change-related impacts is created from the dynamic interactions between climate change-related hazards or drivers, exposure, and vulnerability on social and ecological systems, as well as the deterioration of ecosystem services (Abram et al. 2019; IPCC 2019b).

**Impacts** can either be adverse or beneficial and cause "effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure" (IPCC 2019b, p. 688). Potential climate change-related impacts may cascade across temporal, spatial, and system scales, generating unpredictable risks (Abram et al. 2019).

Finally, noting that **climate change adaptation** can counter the potential for negative impacts by striving to "reduce risk and vulnerability to climate change, strengthen resilience, enhance well-being and the capacity to anticipate, and respond successfully to change" (Ara Begum et al. 2022, p. 177).

Accordingly, for the means of this research, the term "**climate adaptive conservation**" describes a form of conservation that anticipates change and is planned flexible and adaptively by conservation planners and decision-makers (Van Kerkhoff et al. 2019). In this research it specifically aims to maintain, protect, and support the adaptive capacity of ecosystems, and concurrently habitats and species.

**"Climate adaptive" conservation strategies and related activities or actions**: For the means of this research climate adaptive conservation strategies and related activities will be defined as all strategies and activities that actors plan and implement adaptively, in and outside of protected areas (PAs) or protected area networks (PANs). These can be planned and implemented across different spatial scales to achieve defined (conservation) and related objectives that ultimately directly or indirectly maintain, protect, and support the adaptive capacity of mangroves, seagrass beds and coral reefs. In this sense, "strategy" is composed of "specific actions, tools, or techniques that may be used to achieve an objective" and can be integrated in national policies, action plans and local management plans (O´Regan et al. 2021, p. 3).

**Conservation activities** are tasks carried out by individuals or institutions that can take place at different spatial and administrative levels (Salafsky et al. 2008; Ban et al. 2013; CMS Open Standards 2020). The activities can be direct, implemented in specific conservation areas, or indirect that indirectly influence ecosystems positively. Within this research conservation areas are either officially defined protected areas or other effective area-based conservation measures.

Indirect conservation activities are defined as "conservation related activities or actions" that are carried out by different actors and can include the establishment of regulations (e. g. for water or fishing gear), laws, or area-based management and strategic planning approaches (e. g. watershed alliances) (Trombulak 2004; Geyer et al. 2015). Such activities oftentimes support PA effectiveness (Maxwell et al. 2020).

Hence, for the means of this research the term conservation activities shall underline and entail all activities and actions in and outside protected areas (Pas) that influence the adaptive capacity of coastal ecosystems positively.

# 2. Theoretical Background

This chapter, divided into four subchapters, introduces the concept of ecosystem adaptive capacity, and the social-ecological systems framework, which frames this work conceptually. Before, outlining conservation in a changing climate and the case study region.

## 2.1 The concept of ecosystem adaptive capacity

Understanding adaptive capacity and its role in reducing vulnerability has been recognized as key for climate change adaptation and effective conservation (Smit & Wandel 2006; Seaborn et al. 2021). Yet, its definition differs and how it relates to vulnerability depending on the context and field it is applied in, such as development studies, ecology, or interdisciplinary social-ecological research (Folke et al. 2003; IPCC 2019b; Seaborne et al. 2021).

In a social system, AC is composed of different characteristics, drivers, or determinants, by which individuals or communities have the capacity to respond to change or adjust in anticipation of change, while maintaining or improving their well-being over time (e. g. livelihood diversification) (Smit & Wandel 2006; Charles 2012; Cinner et al. 2013; Whitney et al. 2017).

Even though, also social AC has limitations (Abram et al. 2019), compared to human's, ecological systems are not able to change their behavior as quick, strategic, and future-oriented, to respond and adapt to potential climate change-related impacts (Petersen et al. 2018). Consequentially, ecological adaptive capacity differs from social AC (Angeler et al. 2019).

In an ecological system, an element (e. g. species, population, ecosystem) necessitates capacity to be enabled to undertake a process of adjustment to change. This element, even if equipped with adaptive capacity, may not be able to respond to changes due to external conditions not determined by its AC (e. g. topography) (Fernandes et al. 2012; IPCC 2019b).

Thus far, research (e. g. ecology or evolutionary biology) has focused on the AC of lower levels of biological hierarchical organization (e. g. species, genes) (Van Kerkhoff et al. 2019; Seaborne et al. 2021). Species respond to and cope with climate change-related drivers within their lifecycle through their AC traits (e. g. phenotypic plasticity, dispersal ability, and genetic diversity) (Beever et al. 2016). While their genes can adapt to changing conditions in a forward-looking fashion (Bernhardt & Leslie 2013).

Ecosystem AC includes both short-term coping and more long-term adaptive capacity, highlighting the dynamic and continuous adjustments of an ecosystem to changing environmental and climatic conditions (Fernandes et al. 2012; IPCC 2019b).

Thus, in the face of a changing climate scholars give increasing attention to and highlight the key importance of understanding and supporting ecosystem-level AC, and its elements, to address the vulnerability of ecosystems towards climate change (McLeod et al. 2015; Petersen et al. 2018; Seaborne et al. 2021).

Scholars cautioned that species AC often entails short-term coping. For example, species may respond to higher temperatures with phenological shifts (e. g. migration patterns), which can lead to disturbances in trophic interactions with a high impact on the overall ecosystem community functioning. The consequential community restructuring can result in a loss of ecosystem functioning and services, and conservation effectiveness (Rilov et al. 2019). Researchers further cautioned that assessing only specific aspects of AC, may not be representative of the general AC of an ecosystem. Hence, by overlooking other AC aspects, this may reduce an ecosystems capacity in other parts or in its entirety (Angeler et al. 2019). Since species are interconnected within an ecosystem (Abram et al. 2019), potentially creating negative trade-offs, and increasing the vulnerability of other parts of the ecosystem.

Yet, contrary to species level AC, few scholars have defined ecosystem adaptive capacity, and there is no broadly accepted and applied definition (Angeler et al. 2019; Seaborn et al. 2021). It also has been falsely framed or mistaken for other concepts, such as sensitivity (Beever et al. 2016; Petersen et al. 2018; Angeler et al. 2019). Among scholars, the definition of ecosystem AC differs regarding how and to which form of resilience it relates to (Angeler et al. 2019).

Many scholars increasingly view AC as an ecosystem property and as a subset of ecological resilience that modifies resilience in response to change (Angeler et al. 2019) or social-ecological resilience (Folke et al. 2016). Particularly since, both resilience and AC guide responses to adapt to change, such as conservation, an ambiguous application of both terms can negatively impact, inhibit or misconstrue research results and recommendations on entry points to enhance ecosystem AC (Petersen et al. 2018).

## 2.2 The concept of social-ecological systems

This sub-chapter outlines the concept of social-ecological system (SES) and its operationalization in conservation, the theoretical SES framework, and its adaptation as a conceptual framework for the means of this research.

Among climate change research, the SES framework became a central tool to understand systems undergoing change, as well as how to reduce the vulnerability of ecosystems and dependent societies and to prevent undesirable social-ecological system changes (Marshall et al. 2013; Thronicke et al. 2020).

The application of the SES framework for interdisciplinary research has been recognized as key to understand how systems are equipped to face climate change-related impacts, to analyze or assess ecological and/or social AC, and its role in reducing vulnerability (Seaborn et al. 2021). Considering this, the SES framework can increase the effectiveness of conservation under a changing climate (Ban et al. 2013), by helping to define conservation efforts that support the adaptive capacity of ecosystems, and hence facilitating the vulnerability reduction of the entire SES. It can further facilitate a deeper understanding of local social-ecological contexts (Cumming et al. 2017; Gladstone-Gallagher et al. 2019; Van Kerkhoff et al. 2019). Yet, if AC was integrated in such SES frameworks in the context of conservation, it was mostly social AC (e. g. Cinner et al. 2013; McLeod et al. 2015).

### The theoretical social-ecological systems framework

This research builds on the theoretical social-ecological vulnerability framework of Seddon et al. (2019) (Fig. 1). The framework centers around how Nature-based Solutions can reduce social-ecological vulnerability, and how ecosystems can support the well-being and climate change adaptation of human societies through the delivery of ecosystem services (Folke et al. 2016). The use and management of ecosystem services signifies the role societies play in supporting or limiting ecosystem health, such as through conservation, highlighting the interdependence of ecological and social vulnerability (Thiault et al. 2018).

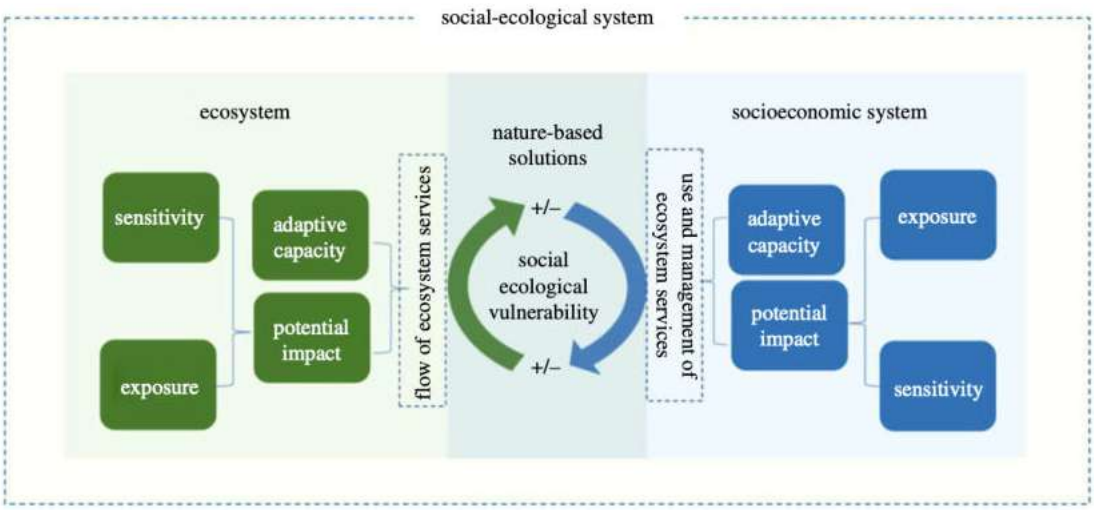



*Figure 1: Theoretical social-ecological vulnerability framework (Seddon et al. 2019, p.5).*

The framework´s social-ecological vulnerability has three dimensions - exposure, sensitivity, and adaptive capacity. Ecosystem vulnerability is formed through the combination of potential impact and adaptive capacity that regulates the delivery of ecosystem services a society depends on. Ecosystem vulnerability affects socioeconomic vulnerability and determines the extent to which the social system is negatively affected by change (Thiault et al. 2018; Seddon et al. 2019). Both SES subsystems, ecosystem and socioeconomic, are interconnected and can increase or decrease the vulnerability of the other to climate change, while all system elements and subsystems are linked and connected through reciprocal feedback mechanisms.

Exposure of the SES is shaped by the intensity, extent, and frequency of events or the degree of use and management of ecosystem and environmental resources by societies. The sensitivity describes the extent to which the system is affected by or reactive to climate change. Specifying ecosystem sensitivity as the extent to which ecosystem structure and function alter due to certain drivers of change, and together with its exposure generates a potential impact. Ecosystem sensitivity can be decreased by minimizing direct non-climatic drivers that influence the ecosystem´s function (Seddon et al. 2019).

Here, the system´s adaptive capacity plays an important role, because ecosystem AC reduces the potential impact on the ecosystem over time. Together with sensitivity it is “determined by the diversity, heterogeneity, and connectedness of the ecosystem and the characteristics and condition of its component species and habitats” (Seddon et al. 2019, p. 5).

In this framework, Nature-based Solutions act at the junction of both sub-systems to reduce SES vulnerability through conservation, restoration, as well as an adaptive ecosystem management, and hence can positively impact all three dimensions of socio-ecological vulnerability (Seddon et al. 2019).

**The conceptual social-ecological system framework**

The following section describes the conceptual SES framework of this research, which was adapted from Seddon et al. (2019) to fit the conceptual framing of this thesis (Kumar 2011). By conceptualizing a theoretical SES framework, complex interconnected components and thematic dimensions can be made understandable to comprehend their relevance and application in practice (Baur & Blasius 2014; McLeod et al. 2015; Preiser et al. 2018).

The framework of Seddon et al. (2019) was, due to its broad nature, well equipped to be adjusted and to be focused on coastal ecosystem adaptive capacity in an island setting. It helped to theorize the complex reality of the case study region into a conceptual framing, and hence enabled a better understanding of the local context. Applying a SES framework has relevance particularly in the Pacific region, where complex social, cultural, and political networks govern social-ecological dynamics. A lack of considering or understanding these dynamics has often caused the failure of conservation projects in the region (Keppel et al. 2012).

This conceptual framework builds on the definition (vulnerability = sensitivity * a lack of capacity to adapt). The system´s exposure to climate change-related drivers or hazards creates together with the social-ecological vulnerability a social-ecological risk of potential impacts that can negatively affect both subsystems that are embedded in the SES (Fig. 2; IPCC 2019b).

According to the main research question, this framing focused on (1) the selection of climate adaptive conservation strategies and related actions that are designed and implemented in, and hence part of the social sub-system. By applying said conservation strategies (2) the ecosystem AC of seagrass beds, mangroves, and coral reefs, and its elements, of the ecosystem sub-system, can be supported. This in turn can reduce their sensitivity to climate change-related drivers and thus facilitate the vulnerability as well as risk reduction of the entire SES towards potential climate change-related drivers the system is potentially exposed to (Bindoff et al. 2019, p. 5SM-13). Supporting ecosystem AC through the application of the strategies can ensure the continuous flow of ecosystem services to the social sub-system, on which it depends on, acknowledging the embeddedness of both sub-systems within the SES.

Yet, this approach is only a theoretical approximation because it is challenging, due the complex system connections, to determine to which extent these strategies can support ecosystem AC on the ground, which can be enhanced with a subsequent empirical validation (Preiser et al. 2018).

Setting spatial boundaries for the research framing, the identified climate change-related drivers (section 2.4) were conceptualized as external to the SES (based on section 1.3) and cannot be directly influenced (e. g. through conservation measures within the system). Thus, the conceptual SES framework differentiated between internal direct, mostly local, non-climatic, and external climate change-related drivers, focusing on the latter one.

Both are spatially and temporally varied, underlining the complexity of this system, and considered particularly relevant in a coastal seascape. Particularly in the marine environment ecosystem boundaries are porous, and processes outside a defined area (e. g. climate change-related drivers) will affect the ecosystem under management. Though, going beyond the scope of this study, it has been recognized that some of the climate change-related drivers can spatially and temporally interact with local drivers and thus potentially create cumulative and interacting impacts with a great risk for marine and coastal ecosystem collapse (Rilov et al. 2019).

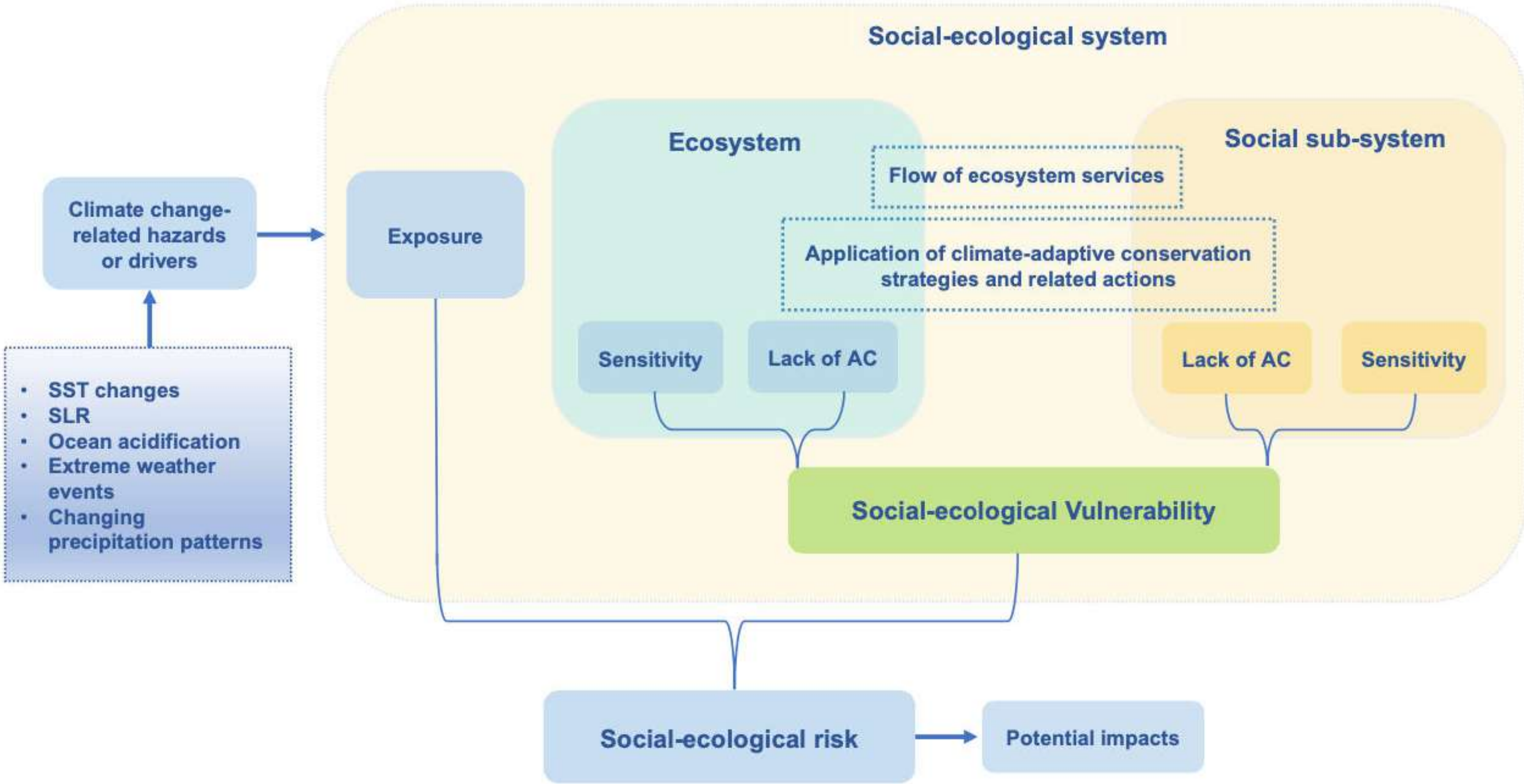



*Figure 2: Conceptual social-ecological system framework with the identified climate change-related drivers (left) (see section 2.4) (own illustration drawn from Seddon et al. 2019).*

## 2.3 Conservation strategies in the face of a changing climate

Considering the increasing impacts of climate change-related drivers that negatively affect ecosystems, scientists urge to integrate climate change adaptation options into marine conservation policy, planning, and implementation across administrative and planning scales to ensure the continued effectiveness of conservation and ecosystem service provision (Heller & Zavaleta 2009; Roberts et al. 2017; Maxwell et al. 2020; Wilson et al. 2020).

However up to date, there is no global overarching accepted definition, guideline, or standard that defines what constitutes "climate adaptive" conservation and how to integrate climate change into conservation (Maxwell et al. 2020; Wilson et al. 2020). This is likely due to the inconsistencies between CCA and conservation science (McLeod et al. 2015), as well as the differing definitions of vulnerability, risk, and adaptive capacity, ultimately, hindering the integration of both fields.

A structured literature review was carried out in this thesis. This review confirmed that based on the small number of publication titles addressing both fields together within peer-reviewed literature, their integration appeared minimal. Only 72 relevant titles, most of which were recently published, were indexed in *Web of Science* (Annex Ia). None of these titles focused on the Pacific, and only five had a marine or coastal focus (e. g. Green et al. 2014).

So far, biodiversity conservation has often been guided by ecological principles (e. g. ecological systems are connected across scales), sometimes combined with other principles (e. g. socioeconomic) (Trombulak et al. 2004). These principles can then be translated into specific conservation objectives to guide national or, for example state-level conservation policies, and action plans, and the creation of strategies and activities that can direct the design, planning and management of conservation, including specific sites, and from the national to the local scale (Green et al. 2014).

Yet, ecological principles are considered not enough to effectively manage and protect ecosystems due to the unprecedented risks and uncertainties ecological systems are facing under a changing climate (McLeod et al. 2019). Instead, conservation approaches must address the overarching threat of climate change, while tackling more immediate non-climatic drivers (van Kerkhoff et al. 2019). Therefore, which sites, ecosystems, and species (e. g. rare or resilient) are chosen for protection and how new or established conservation areas are designed, planned, and managed must be thought and prioritized differently under climate change (McLeod et al. 2019; O´Regan et al. 2021). Because some areas or management measures will not be effective anymore. The application of adaptive capacity in the design, planning and management of conservation can provide a key framing to link conservation measures to potential climate change-related impacts and either built on existing principles and strategies or on novel approaches (Preiser et al. 2018). Accordingly, it has been proposed to integrate climate adaptive, robust, smart, or resilient conservation principles, strategies, or other options into conservation (Tittensor et al. 2019; Shaver et al. 2022). Such principles or strategies have been suggested for different forms of conservation areas, most often Protected Area Networks (PANs) or Marine Protected Areas (MPAs) and coral reefs, as well as different administrative and spatial planning scales (O´Regan et al. 2021). Protected Area Networks have been well-recognized as a successful approach for marine and coastal conservation as it enhances the effectiveness of conservation and facilitates knowledge and data exchange among conservation practitioners and decision-makers. However, thus far PANs have been mainly guided by biodiversity, fisheries, or similar objectives (Green et al. 2014).

## 2.4 Case study area: Conservation, coastal ecosystems, and drivers of change in Micronesia

The following sub-chapter presents the reasons for the selection of the case study countries and the ecosystem focus. Before giving a brief overview of the conservation context in the region, the three selected countries, the coastal ecosystems, specifically coral reefs, and lastly the drivers of change the ecosystems are or likely will be vulnerable towards.

### Case screening and selection

To answer two sub-research questions a multi case study approach was adopted:

**Sub-research question 2:** *Which conservation strategies support the adaptive capacity of coral reefs in three Micronesian states?*

**Sub-research question 3:** *To what extent are the climate adaptive conservation strategies implemented in the three states?*

**Case screening and selection of case study countries:** A multi case study approach was chosen because the study of multiple countries can generate more robust and reliable results than a single case study (Baur & Blasius 2014). The spatial scope of this study was regional and covered three states in Micronesia: The Republic of Palau, the Federated States of Micronesia (FSM), and the Republic of the Marshall Islands (RMI). The scope of this approach was confined by framing the case study countries according to the main research question.

The case screening was focused on the Pacific since it is globally at the forefront of climate change, and simultaneously very reliant on the health and ecosystem service provision of its coastal ecosystems (Marra & Kruk 2017). Within the Pacific, the selection of the case study area Micronesia was considered relevant because of the region´s (1) high social-ecological interdependence due to a high reliance on climate sensitive livelihoods (e. g. coral reef small-scale fisheries), (2) a high coastal ecosystem vulnerability to climate change-related drivers, which is particularly significant as Micronesia only contains two populated islands with land more than 10 kilometers from the ocean and almost its entire population living within 5 kilometers of the ocean (Andrew et al. 2019). Further, (3) a high risk of loss of coastal ecosystem service benefits that are key to food security, livelihoods, climate change adaptation, and human well-being (Friedlander et al. 2017; Bell et al. 2018; Lebrec et al. 2019). These three factors result in an unprecedented social-ecological climate change vulnerability in these states (Marra & Kruk 2017; NEPC 2019; IPCC 2022).

Holding a disproportioned amount of global marine biodiversity (Kingsford et al. 2009), Micronesian states are global leaders in conservation. From a marine reserve in size larger than California, the Palau National Marine Sanctuary (PICRC & COS 2019), the establishment of large-scale shark sanctuaries, the first ever tourist eco-pledge to banning reef-toxic sunscreens, these states are writing the blueprint for what a possible future island conservation can look like (MAFE 2019; NEPC 2019; OPOC 2021).

In addition, communities in Micronesia have a strong culturally formed human-environment relationship. Living with an ever-changing environment, communities have dealt with uncertainty, variability, and adaptation, and thus have employed activities that increase ecosystem AC and climate change adaptation for centuries (McMillen et al. 2014; Carlisle & Gruby 2019; Pilbeam et al. 2019). This knowledge is increasingly relevant in a world where tropical coastal and island communities face similar challenges (McMillen et al. 2014) and making this a suitable case study region for the empirical study of the climate adaptive conservation strategies.

Nevertheless, these islands face tremendous issues, especially limiting and persistent capacity gaps challenge the implementation and effectiveness of conservation. And while, at the forefront of climate change, conservation includes measures addressing climate change to a very minor extent (Jupiter et al. 2014; Spooner et al. 2017). Hence, scholars voiced that there is a need for a deeper understanding of ecosystem AC elements in coastal marine ecosystems and climate adaptive conservation in the region, as well as ways to overcome limited capacities that inhibit its effective uptake (Adams et al. 2021).

Subsequentially, the selection of comparable states was based on similar traits on one hand. All the three selected states, are in free association with the United States, share joint regional policies, and are participants of a globally unique regional conservation initiative, the Micronesia Challenge (Houk et al. 2015; SPREP 2016; Hall 2018). All three states are unique cases for conservation planning due to their geographic isolation, as well as a high percentage of subsistence use of natural resources, traditional land tenure and governance systems (Pilbeam et al. 2019), that support for example landscape heterogeneity (McMillen et al. 2014).

On the other hand, it was based on their differences. Each country features a distinct political, cultural, and conservation management structure, as well as singular environmental and biodiversity features (Carlisle & Gruby 2019).

Overall, these conditions make Micronesia, and specifically FSM, RMI, and Palau an interesting setting to gain a deeper understanding of what conservation strategies and related actions are most effective to support the capacity of coastal ecosystems to face potential climate change-related drivers.

**Selection of ecosystems:** Most Micronesians live near the ocean or along the coast (Andrew et al. 2019). Thus, coastal ecosystems are of key importance for communities in RMI, FSM, and Palau, as they provide critical ecosystem services relevant to all aspects of Pacific Island communities' life´s, such as for food security and climate change adaptation (PCS 2016; Hall 2018; Lebrec et al. 2019; SPREP 2019; McKenzie et al. 2021). Due to their relevance, supporting their adaptive capacity to reduce coastal ecosystem vulnerability towards climate change-related drivers, has been recognized as imperative by conservation decision-makers of government agencies, national research agencies, and Non-Governmental Organizations (NGOs) (Hall 2018; NEPC 2019).

Mangroves, seagrass beds and coral reefs often depend on one another´s health, ecological functioning, and existence (Fig. 3), especially under a changing climate (Camp et al. 2016; Lowe et al. 2016; Sippo et al. 2016; Valdez et al. 2020). All three are ecologically strongly linked through chemical, physical, and biological interactions, embedded in a connected coastal seascape (Colin 2009; Waycott et al. 2011; Guannel et al. 2016). For example, mangroves protect connected coral reefs and seagrass beds from sedimentation or pollutants in RMI (Harwood 2016). Also, herbivorous fish are sustained by mangroves that enhance coral reef resilience to shifts from coral to algal dominated systems (Mumby et al. 2006).

In Palau, since having evolved in a dynamic, ever-changing environment, coastal ecosystems, such as coral reefs, have developed a capacity to adapt to and recover from the impacts of non-climatic and climate change-related drivers to some extent (Rivera et al. 2020). Hence, due to their high social-ecological relevance for the three island states, their ecological interdependency within a seascape, and at the same time their capacity to adapt to some climate change-related drivers, were reasons for the selection of these three coastal ecosystems.

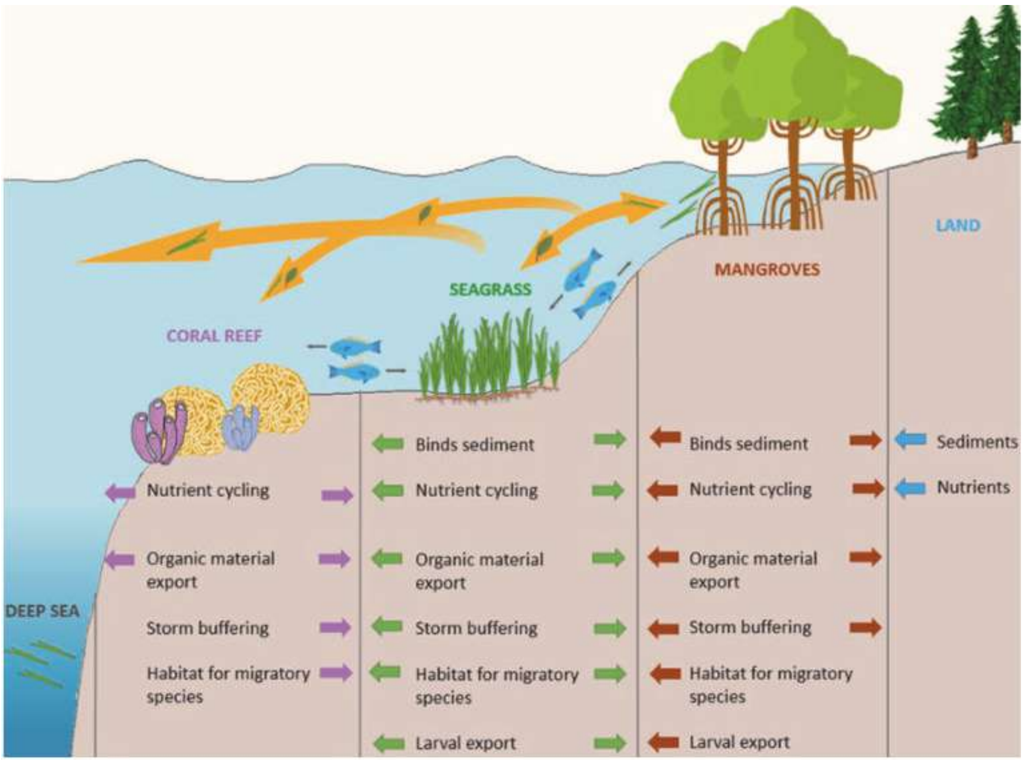



*Figure 3: Interconnectedness of mangroves, seagrass beds and coral reefs in a tropical coastal seascape, which is in turn linked to the landscape (Earp et al. 2018, p.127).*

**Selection of coral reef ecosystem as a focus within the expert survey:** While all three coastal ecosystems are considered relevant, coral reefs are selected as an exemplary ecosystem for this research, due to the following factors.

First, coral reefs are of great social-ecological significance in the three states, as most people depend on small-scale reef fisheries for their livelihood and food security (Bell et al. 2018; Lebrec et al. 2019). These reefs further effectively reduce wave attenuation rates (Hongo et al. 2017), and thus provide considerable protection from potential climate change-related impacts (Colin & Johnston 2020). For example, some Palauan reefs are highly effective to reduce wave height by 75 to 88 percent (Hongo et al. 2017).

Second, coral reefs are one of or the most important, diverse, and widespread ecosystem in all three countries (Ellison 2009; Houk et al. 2015). In addition, the regional significance of coral reefs aligned with a structured literature review the researcher undertook on the platform *Web of Science* (Annex Ib).

Third, they are highly affected by climate change. Thriving in a narrow range of environmental conditions, Micronesia's coral reefs feature an exceptionally high vulnerability to climate change (Colin & Johnston 2020). The IPCC (2022, p. 58) underlined this exceptional risk that warm water corals are facing with a very high risk to be negatively affected at a 1 Degree Celsius increase. In comparison, seagrass beds and mangroves are increasingly at high risk with a 2 Degree Celsius increase. In addition, Palau, RMI, and FSM are globally among the 27 countries that ranked the highest in threat exposure, the lowest in social AC, and the highest in reef-dependency. These three ranking factors create a high to very high social-economic vulnerability to reef loss (Burke et al. 2011, p. 73).

Fourth, because of the region´s environmental heterogeneity, the countries feature unique coral reefs that have shown a high tolerance and adaptive capacity to respond to acidification and heat stress that other coral reefs are set to face globally by 2100 (van Woesik et al. 2012; Shamberger et al. 2014; Rivera et al. 2022).

Consequentially, coral reefs in Micronesia are well suited to gain an understanding of the role of ecosystem adaptive capacity in climate adaptive conservation.

Since coral reefs are ecologically strongly linked to mangroves and seagrass beds within a seascape, and dependent on each other, this research acknowledges that all three coastal ecosystems are important and must be protected in a functional seascape unit (McLeod et al. 2009; Weeks 2017).

**Regional, country, and coral reef context:** The three states in Micronesia (Fig. 3) feature different island forms that reach from high volcanic islands with a diverse and heterogeneous environment to small islets that are mostly composed of corals (Fitzpatrick & Donaldson 2007). Most islands are low-lying atolls with a rich marine and coastal biodiversity that experience a tropical climate (Moverley 2019).

The biodiversity of the region´s seagrass beds, coral reefs, and mangroves, is highest in the west and decreases towards the east with increasing isolation (Table 2). Due to the region's isolation, it exhibits biogeographic complexity. Thus, each state is composed of distinctive species community structures with rare and isolated species, as well as characterized by a high endemism (Ellison 2009).

| Country | Mangrove[1] | Seagrass beds[2] | Coral reefs |
|---|---|---|---|
| **Palau** | 14 (1) | 10 | 70[3] genera |
| **FSM** | 15 (1) | 8 | 60[4] genera |
| **RMI** | 5 (incl. hybrid) | 4 | 50[3] genera |

*Table 2: Number of species or genera per ecosystem and country.*

Micronesia hosts one of the highest reef diversities globally (Houk et al. 2015), with some countries being almost exclusively composed of coral atolls, such as RMI (Beger et al. 2008). As biodiversity decreases from east to west, coral diversity is highest in Palau (Table 2). Regionally, as well as on small-spatial scales, due to environmental heterogeneity and the region´s biogeographic complexity, reefs greatly vary in structure, biodiversity, and exposure to drivers of change (Maragos & Williams 2011; Moritz et al. 2018). While acknowledging a loss of detail, for the means of this research the different reef types (e. g. Colin 2009) will be grouped in one category as "coral (reef) ecosystems".

[1] Ellison 2018a, p. 101
[2] McKenzie et al. 2021, p. 6
[3] Ellison 2009, p. 176
[4] Richards 2014, p. 663

*Figure 4: Fringing and barrier reef in the Pacific, Fiji (own image, 2014).*

Shaped by the local social-ecological context, conservation has been an integral part of Pacific Islanders lives for centuries and instead of biodiversity primarily strives to support resource-based livelihoods (Keppel et al. 2012). Traditional customary land tenure and management systems that have governed the use of natural resources and conservation (Friedlander et al. 2017) play an important role in conservation until today (Reimaan Planning Team 2008; Ahlgren 2016; Carlisle & Gruby 2019). Currently, such traditional systems still hinder the declaration of PAs and the design of a state-wide PAN, such as in FSM (Weeks et al. 2016; Hall 2018; SPREP 2019).

Particularly, community-based conservation approaches and the national and state-level Protected Area Networks are significant for the effective and climate adaptive conservation of representative and social-ecological significant coastal and marine ecosystems in the three island states. For example, while Palau´s PAN regulation of 2009 does not mention climate change specifically, it lists, under its site selection criteria resilience aspects (e. g. protecting bleaching resistant communities). Recently, it further defined the identification of resilient corals under multiple scenarios as a priority of the PAN (NEPC 2019).

RMI´s "Reimaanlok National Conservation Area Plan" is central to the country´s conservation that is strongly shaped by community-scale and traditional forms of conservation (Reimaan Planning Team 2008). The plan outlines several national-scale design principles to achieve conservation goals from a local to a national scale in an ecologically and socially acceptable manner, while helping to ensure the system remains resilient to climate change. Yet, intended to guide national efforts until 2012 there is yet to be an updated version including recent scientific and climate change information (Spooner et al. 2017).

Also, other area-based approaches, such as the Ridge to Reef approach are important for effective conservation in the region, aiming to integrate land- and seascape, sustainable land use, and resource management approaches into biodiversity conservation to achieve CCA and to facilitate sustainable livelihoods (Hall 2018).

Regional collaboration and capacity-building, such as through the Micronesia Challenge, has been recognized as an essential tool to ensure successful knowledge-based conservation and to facilitate climate adaptive decision-making in this data and capacity sparce region (Houk et al. 2015). Further, regional organizations, such as the South Pacific Regional Environment Program implement initiatives including the project Inform[5] to bridge data gaps on climate change vulnerability, adaptation, and effective conservation (SPREP 2022).

**The Republic of Palau** (Table 3): Palau features the smallest population among the three states (McKenzie et al. 2021), which is highly dependent on tourism and small-scale fisheries (Pilbeam et al. 2019). The country is one of the most geologically, biologically, and ecologically diverse island groups in the Pacific, and hosts one of the highest terrestrial, coral, and marine fauna diversity in Micronesia (Fitzpatrick & Donaldson 2007). Among the three states, Palau reaches the highest number and percentage of area protected (Muller-Karanassos et al. 2020).

**The Federated States of Micronesia** (Table 3): FSM is grouped into four states (Richards 2014) that are very diverse in culture, traditions, governance, legislation, and climatic conditions (Keppel et al. 2012). The country is part of the globally significant Polynesian-Micronesia biodiversity hotspot (CEPF 2007) and exhibits a diverse environment from low-lying atolls to high reaching volcanic islands. These islands feature a rich biodiversity and high endemism (Hall 2018). However, its internationally reported, PAs cover only a small percentage of its extremely diverse terrestrial and marine area (UNEP-WCMC 2022b).

**The Republic of the Marshall Islands** (Table 3): RMI is one of the lowest-lying atoll states globally with an average elevation of two meters above mean sea level (van der Geest et al. 2020, p. 110). It is hence recognized as one of the most vulnerable countries

[5] For more information, please visit: https://www.sprep.org/inform

to climate change globally and considered highly reliant on its coral reefs for erosion protection.

While RMI´s land area makes up less than 0.01 percent (Ahlgren 2016, p. 22), its Exclusive Economic Zone covers over 2 million square kilometers (Bordner et al. 2020, p. 2). Being mostly composed of atolls, RMI mainly hosts marine species, and a high percentage of endemic and rare species (OEPPC 2017). Its northern part totally lacking seagrass beds (Colin 2009). Yet, the country only protects 12 percent of its terrestrial and 0.27 percent of its fast marine area (UNEP-WCMC 2022c).

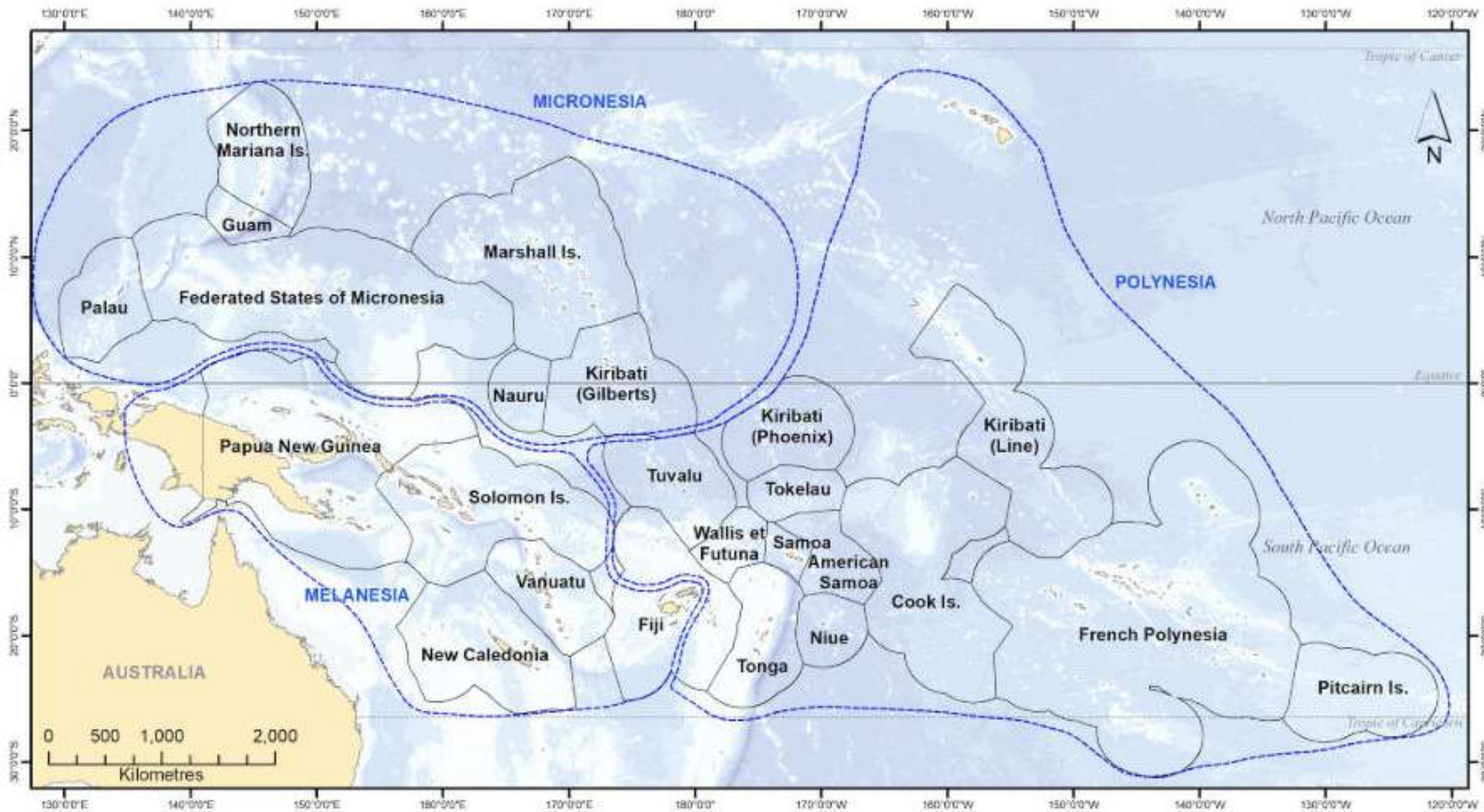



*Figure 5: Map of the Pacific Island countries and territories and their Exclusive Economic Zones. Within the region of Micronesia, on the top left of the figure, from left to right – are the countries Palau, FSM, and RMI depicted (Mc Kenzie et al. 2021a, p. 2 based on Burley 2013; Taylor & Kumar 2016).*

| Character-istics | Islands[6] | Highest elevation (m) | Population[6] | Land area ($km^2$)[10] | Coastline (km)[6] | Marine area ($km^2$)[10] | MPA area ($km^2$)[10] | PA area ($km^2$)[10] | Nr. of PAs[10] | Total land area protected (%)[10] | Total marine area protected (%)[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Palau** | 1 high island and 300 small islands | 242m[7] | 17,661 | 501 | 1519 | 608.152 | 608.173 | 221 | 66 | 44.18 | 100 |
| **FSM** | 607 atolls, with 4 volcanic and 1 emergent island | 782m[8] | 102,843 | 817 | 1295 | 3 Mio. | 475 | 0 | 5 | 0.05 | 0.02 |
| **RMI** | 34 low-lying islets and 607 atolls | 10m[9] | 53,158 | 282 | 2106 | 2 Mio. | 5.388 | 34 | 16 | 11.92 | 0.27 |

*Table 3: Characteristics of each state, including island features, population, and conservation.*

[6] McKenzie et al. 2021, p. 3
[7] Foster (2022)
[8] Hall 2018, p. 8
[9] PacIOOS (2022)
[10] UNEP-WCMC 2022a, b, c

**Drivers of change in Micronesia:** The selection was based on the classification of direct and indirect drivers of change (section 1.3).

**Non-climatic drivers:** The three coastal ecosystems in the three states are vulnerable towards the following non-climatic drivers: Pollution, eutrophication, invasive alien species (IAS), overexploitation and habitat change, which includes overfishing. These drivers have caused extensive degradation and losses in the three ecosystems (Houk et al. 2015; SPREP 2016; OEPPC 2017; Moritz et al. 2018; Moverley et al. 2019; NEPC 2019; Toki & Davies 2021).

The driver eutrophication reduces sunlight for photosynthesis in coral reefs (Burke et al. 2011) and seagrass beds (Waycott et al. 2011). It influences species sensitivity, and the rate of coral reef recovery, as well as interactions between desirable and undesirable system states (e. g. macro-algae dominated reef) (Anthony et al. 2015). In turn, eutrophication can lead to an increase in IAS that are already causing one of the highest extinction rates globally (Moverley et al. 2019). For example, the invader Crown-of-thorns starfish has resulted in a significant localized coral cover loss and altered community structures across Micronesia (Colin 2009; OEPPC 2017; Houk et al. 2020). Further, overfishing has led to a loss of herbivorous species that can elevate algae overgrowth on reefs, hence reducing ecosystem functioning and recovery (Houk & Musburger 2013; Moritz et al. 2018).

**Climate change-related drivers:** The literature review, based on peer-reviewed literature, national reports and expert workshops (Toki & Davies 2021), suggested that the coastal ecosystems of the three states are vulnerable towards and likely to experience the following climate change-related drivers more frequently: Sea level rise, ocean acidification, sea surface temperature increase, extreme weather events, and changing rainfall patterns (Marra & Kruk 2017; Colin 2018; Ellison 2018a; Donner & Carilli 2019; Lebrec et al. 2019; NEPC 2019; Hall 2020; Houk et al. 2020; Miles et al. 2020; Colin & Johnston 2020; McKenzie et al. 2021).

Both non-climatic and climate change-related drivers will impact the ecosystems differently depending on the adaptive capacity and sensitivity of the respective ecosystem, and the frequency and intensity of exposure to these drivers. Since the three coastal ecosystems are ecologically connected, the capacity to adapt to one driver or the lack thereof can likely affect other connected coastal ecosystems positively or negatively.

In the case of coral reefs, scholars caution that the ecosystem is unlikely to keep pace with climate change due to increasing frequency and magnitude of drivers. While regional coral cover appears stable, at smaller spatial scales some losses are significant, and several coral communities and species compositions are slowly transitioning towards dominant coral taxa, likely more stress-resistant, along with a decline of fish species that are essential to maintain reef resilience (Moritz et al. 2018).

Areas where multiple stressors and drivers overlap in space and time, are exhibiting the greatest risk of ecosystem collapse (Rilov et al. 2019), in seagrass beds (O´Brien et al. 2018), and in corals (e. g. in Palau, NEPC 2017; Guan et al. 2020), where it affects especially fast-growing competitively dominant species (Bruno et al. 2019).

Simultaneously, the recovery rate of coral habitats from single and chronic disturbances, at times overlapping, is expected to be insufficient (Moritz et al. 2018).

**Sea-level rise (SLR):** Frequent sea level drops, caused by El Nino, resulted in SST increase, and some coral degradation and mortality (Colin & Johnston 2020; Donner & Carilli 2019) in eastern Micronesia (Houk et al. 2020). However, in FSM even though some upper microhabitats will be unsuitable for certain species, SLR is projected to not significantly threaten coral reefs, or it is unknown (van Woesik & Cacciapaglia 2019). Yet increased wave heights at reef flats are projected to degrade coral ecosystems, which may result in beach erosion, saltwater intrusion, and destruction of infrastructure (Hongo et al. 2017). In FSM, it is likely to lead to altered coral compositions and habitat changes, as some shallower reefs may be unable to keep up with SLR (van Woesik & Cacciapaglia 2019).

Due to the AC of coral reefs, being adapted to a certain tidal range and short-term variations, as well as an upward growth ability to accommodate some extent of sea level change, it is expected that coral reefs will be able to buffer most negative changes of SLR (Colin 2009). Thus, while some habitats in the three states will be negatively impacted by SLR and likely cause altered coral compositions and habitat changes (Hongo et al. 2017), it is expected to either not significantly threaten coral reefs or positively affect some habitats. For example, SLR is set to positively affect shallow tide-dominated reef habitats by moderating and significantly lowering rising temperatures and high SST under future projections throughout the 21st century (Lowe et al. 2016). Yet, increasing sea-level may cause spatially differing impacts, depending on habitat and topography. It may lower wave energy reduction by reefs, causing physical damages to inner reefs, and seagrass beds, decreasing potential sites for seagrass growth (Brodie & De Ramon N´Yeurt 2018).

Contrary, SLR is considered the greatest climate change-related threat to mangroves in Micronesia (Colin 2009; Ellison 2018a). In seagrass beds, potential impacts are heterogeneous. While SLR will decrease growth due to decreased light availability and increased erosion, it will lead to landward seagrass colonization, thus potentially creating new habitat and increasing productivity (Björk et al. 2008).

**Changing sea-surface temperature (SST):** Climate change-related rising SST is the single greatest threat to coral reefs by increasing frequency and magnitude of exposure to thermal stress. Coral reefs can grow in a narrow temperature range and are thus extremely sensitive to temperature anomalies of one to two degree Celsius (Moritz et al. 2018). Higher temperatures have resulted in bleaching and coral mortality, depending on duration and intensity of increase, sensitivity, and extent of exposure (Bruno et al. 2019; Colin & Johnston 2020). In addition, such bleaching events make reefs less resilient to disease outbreaks and algae overgrowth (Berger et al. 2008; SPREP 2016). Additionally, a resulting reduced coral productivity affects mangroves indirectly due to an increased exposure to wave attenuation (Ellison 2018a).

In eastern and western Micronesia, periods of bleaching risk rose between 58 and 155 percent respectively per year since 1982 (Marra & Kruk 2017, p. 65). First occurring in shallow areas, and later in deeper ones as well (Marra & Kruk 2017; Colin & Johnston 2020). Across the Pacific, climate projections indicate coral thermal thresholds (e. g. 30 degree Celsius in Palau; Colin & Johnston 2020) and species recovery ability (Hughes et al. 2018a; Moritz et al. 2018; IPCC 2019b) will be exceeded more frequently by 2030, with most reefs likely experiencing some level of bleaching yearly (Moritz et al. 2018, p. 22), such as Palau by 2040 (Miles et al. 2020, p. 24). Ultimately, most of Micronesia will surpass thermal thresholds for corals by 2050 (Miles et al. 2020, p. 24).

In addition, the temperature threshold and recover ability among healthy reefs may differ among the highly diverse and complex environments from shallow to deeper reefs, close or distant to shorelines or estuaries. Reefs in Palau, and other parts of Micronesia experience great small-scale temporal, horizontal, and vertical temperature variabilities, and are hence characterized by environmental heterogeneity, leading to differing thermal stress in reefs (Colin & Johnston 2020; Miles et al. 2020).

In the Rock Islands of Palau, among the crest and top of barrier reefs and in sheltered bay reefs, species were less affected by bleaching, contrary to outer patch and barrier reef slopes (Rivera et al. 2022). With the first one likely hosting more thermally tolerant genotypes and corals adapted to high temperature stress at low tides. On Majuro dominant coral species (*Porites rus*) are more resistant to temperature change and sunlight exposure compared to other species and sites (OEPPC 2017), indicating a differential spatial species vulnerability towards bleaching.

Environmental factors, such as waves, tides, and shading (Rivera et al. 2022), can influence temperature dynamics beneficially to enable adaptation to heat stress in reef ecosystems (Colin & Johnston 2020), as well as SLR (Lowe et al. 2016). Also, tropical oceanographic variation and inter-annual warm thermal anomalies throughout the western Pacific are seen as a main driver of coral resistance to heat stress compared to other regions (McClanahan et al. 2020). In Kiribati, reefs experience globally unique conditions of high SST variability generating bleaching-level heat stress with a frequency unlikely to be experienced by other reefs for another several decades (Donner & Carilli 2019). While it showcases that certain species and coral habitats are resilient to higher temperatures and acidification, e. g. in Palau (Barkley et al. 2017), and can withstand and adapt to frequent heat stress, it led to an altered more thermal resistant species composition, and likely to biodiversity loss (Moritz et al. 2018; Donner & Carilli 2019). Projections indicate that some places in the Pacific may serve as bleaching refuges (Donner & Carilli 2019). However, area and size of spatial refuges is projected to decline (Hughes et al. 2018a). Also, deeper reefs will unlikely severe as climate refugia from bleaching conditions, as observed in Palau (Bruno et al. 2001; Colin 2018; Colin & Johnston 2020).

Opposingly, an increasing temperature is expected to have positive effects on mangroves and has led to changes in some species ranges (Ellison & Cannicci 2016), such as expansion into higher latitudes (Ward et al. 2016; Chow 2017). Yet, despite knowledge gaps and a lack of research in the Pacific (Ellison 2018a), generally less to no photosynthesis, growth, and reproduction occur under higher temperatures, particularly exceeding 40° Celsius (Waycott et al. 2011). Trees are expected to be moderately impacted, while fauna with a low thermal plasticity will be highly affected. Higher temperatures will further reduce connectivity of mangrove fauna populations and lead to altered species compositions (Ellison & Cannicci 2016).

A higher SSTs is also one of the most significant negative drivers on seagrass beds that causes lower productivity in Micronesia (Brodie & De Ramon N´Yeurt 2018; McKenzie et al. 2021) and can result in large-scale diebacks (Waycott et al. 2011; Collier et al. 2017). While a rising temperature up to 35°C has a positive effect on seagrass species, 40°C is a critical threshold, with 43°C causing total mortality after a few days (Collier & Waycott 2014, p. 483).

Temperature thresholds, tolerance, and optimum temperature for growth vary among seagrass species, and depend on timing (e. g. low tide), frequency, intensity, and duration of exposure (Collier et al. 2017; Brodie & De Ramon N´Yeurt 2018).

Across the PICTs few studies have assessed thermal tolerance of seagrasses (Brodie & De Ramon N´Yeurt 2018). In Micronesia, SST vulnerability is spatially stratified. On Yap, certain species, extending to shallow nearshore areas and exposed to low tide conditions, can tolerate extreme water temperatures and low salinity levels, while other species were less able to tolerate extreme conditions (Ellison 2009).

**Ocean acidification** is likely to continue under high emission scenarios and expected to affect entire marine ecosystems, reducing calcification and growth rates in **corals** and other calcifying organisms causing reef structure and bio-erosion in Micronesia (Miles et al. 2020; Rivera et al. 2022). For example, in FSM around 50 percent of reefs are expected to be highly threatened by acidification and thermal stress by 2030 (Burke et al. 2011).

However, coral reef vulnerability to acidification is highly variable due to species-specific physiological effects, which may vary throughout species life stages (Saba et al. 2019). In Palau, certain coral reef communities have adapted to naturally low pH levels (e. g. Rock Islands). For example, in Nikko Bay, reefs are adapted to conditions expected to occur by 2100 globally (NEPC 2017), and thus likely to withstand and able to adapt to future climate change conditions.

Higher $CO_2$ levels have shown a positive effect on seagrass beds (Hughes et al. 2018b; Brodie & De Ramon N´Yeurt 2018) and mangroves (Ellison 2018a). However, higher $CO_2$ levels and more acidic conditions can also reduce growth, productivity, and cause community structure changes in seagrass ecosystems due to algae shading and competition. Yet, seagrass species have shown a high resilience despite increases in algal biomass (Hughes et al. 2018b).

Like, seagrasses, mangrove roots absorb alkalinity (Sippo et al. 2016), and by buffering decreased pH levels in its surrounding ocean waters can enhance coral reef resilience to acidification (Manzello et al. 2012; Unsworth et al. 2012; Billé et al. 2013; Brodie & De Ramon N´Yeurt 2018; Bergstrom et al. 2019; Saba et al. 2019).

**Changing precipitation patterns**: In the region, droughts can improve water quality in reefs (Moritz et al. 2018). Whereas a higher rainfall will mostly negatively affect mangroves (Ellison 2018a), and seagrass beds (Colin 2009).

Because mangroves have a high sensitivity to salinity changes. Hence, a decrease in precipitation will cause less sediment supply to enable adaptation to rising seas, lower diversity, productivity, increase mortality, and a shift to more salt-tolerant species (Waycott et al. 2011; Ward et al. 2016; Ellison 2018a). Also decreased salinity levels, due to higher rainfall, are considered an environmental stressor on mangrove (Ellison 2018a), as well as seagrass growth and distribution, making them more vulnerable to potential diseases (Colin 2009; Albert et al. 2010). With some seagrass species being more tolerant to low salinity levels than others (Waycott et al. 2011). While higher precipitation may also increase sediment rates, thus facilitating the capacity of mangroves to adapt to SLR, and potentially cause higher growth rates in the Pacific (Ward et al. 2016).

**Extreme weather events:** Cyclones and storms cause short-term and long-term changes, such as lower salinity, modify sea level and cause large sediment movements or coastal erosion, damaging coral reefs (Gouezo et al. 2015; Moritz et al. 2018), seagrass beds and mangroves in Micronesia (Colin 2009; Brodie & De Ramon N´Yeurt 2018).

An increasing intensity, and to some extent frequency of such events can surpass coral recovery, which are already causing community changes and more robust corals surviving in the Pacific (Houk et al. 2015; Moritz et al. 2018).

Also, the physically strong mat formed by seagrass species, once damaged by storms and other extreme events, can be exposed to, and degraded by wave action, creating long-term or permanent loss in Palau (Colin 2009). Further, a heightened turbidity, e. g. due to storms, can reduce seagrass cover by decreasing light availability for growth (Brodie & De Ramon N´Yeurt 2018).

# 3. Methodology

This research thesis consists of three main methodological components to address the main research question, which will be outlined in this chapter. Regarding the research questions presented in the first chapter (section 1.2), the methodology of this thesis followed a deductive approach.

Therefore first, based on the theoretical understanding of ecosystem AC (section 2.1), the elements of ecosystem AC were identified and selected through a structured literature review and a subsequent series of snowball searches. This form of literature review and analysis was helpful to answer the first sub-research question and part of the main research question.

Based on the selected AC elements, a second step aimed to analyze what climate adaptive conservation strategies can support these. This research identified theoretically suggested climate adaptive conservation strategies through a literature review, which were selected and categorized according to the theoretical concept of the ecosystem AC elements and the research framing of this thesis.

A mixed method research design was pursued to obtain different types of data and to answer the main research question. This was done by validating and evaluating the selected climate adaptive conservation strategies and their role in supporting coral reef AC through empirical research in a case study region (Kelle 2014). Thus, the relevance and effectiveness of the selected strategies for conservation practice was validated by means of a semi-quantitative survey with experts from the case study region. Hereby, it must be considered that the empirical data collection must be guided by the theory of the relevant concepts of this thesis, which in turn relate to the main research question (Kumar 2011; Baur & Blasius 2019). Hence, building on the conceptual SES and its two theoretical parts – the selected climate adaptive strategies and the ecosystem AC elements, the survey can help to generate empirically valid and meaningful findings (Preiser et al. 2018).

The empirical approach of a semi-quantitative survey was chosen because, first the literature review revealed that there were little to no empirical studies, thus far, that have validated the relevance or effectiveness, and ultimately practical implementation of the climate adaptive strategies, in general, and concerning ecosystem AC specifically. Previous research showed that academic scholars and experts can have different perceptions of AC components, and hence the validation of such theoretical concepts in practice has relevance (McLeod et al. 2015). Therefore, this research started from a theoretical perspective, which facilitated to gain validity, and utilized the survey to determine the relevance of the strategies in practice (Berrang & Ford et al. 2015; Baur & Blasius 2019). A weakness of this research could be that the theoretical concepts are challenging to be validated or have little relevance in practice. By collecting quantitative and qualitative survey data, quantitative results were contextualized with qualitative results that provided a more in-depth insight on the perceptions of experts regarding the topic and research question.

In addition, methods applied in this research were aimed to be transparent and reproduceable, ensuring comparability and validity. The combination of different data sources and collection methods enhanced data credibility and the understanding of the research subject, thereby a potential method bias was aimed to be reduced (Bernard 2006; Doolittle 2015; Young et al. 2018).

**Definition and rationalization of literature review approaches**

To address the first two methodological components of this research, the selection of the ecosystem AC elements and the climate adaptive conservation strategies, both prerequisites to the survey, different forms of literature review were applied and combined, following Bernard (2006) and Baur & Blasius (2014).

**Snowball-based search and review**: A snowball search technique is analogous to "snowball sampling" (Baur & Blasius 2014, p. 1121). It starts with one or several known and relevant seed articles that have been broadly cited in other publications on the respective subject. Next, additional relevant literature is identified (Bernard 2006). By utilizing different academic search engines (e. g. *Google Scholar*) to identify and opportunistically add (1) additional publications within the framing of this research that cited these, and (2) literature cited by key papers that fit into the domain of interest of this research. Subsequential, the review continues until an extensive overlap concerning the research subject among sources can be identified. This form of literature review has been applied for similar research objectives (e. g. global assessment of CCA in MPA plans) (Djenontin & Meadow 2018; O´Regan et al. 2021). In the thesis this customized review framework was helpful to identify key literature and proved beneficial in a fragmented field of ecosystem AC and climate adaptive conservation options.

**Structured and scoping literature review**: This is a simplified version and part of a systematic review, which aims to review the literature in a focused manner to answer specific research questions utilizing pre-defined eligibility criteria for the literature (Fig. 6) (Grant & Booth 2009; Young et al. 2018). These clear-defensive inclusion criteria ensure that the thematic focus of the publications matched with the key terminologies and framing of the research. The application of such criteria enables a methodological systematization and the production of reproduceable results, offering transparency on the selection of publications. This has been recommended, for example for the review of CCA (Berrang-Ford et al. 2015).

This customized approach helped to gain a scoping overview of the state-of-the-art knowledge, based on the number of publications, of one, or the extent of integration of several research fields (e. g. CCA and conservation) (Grant & Booth 2009; Lau & Kuziemsky 2017). Combining this step with other forms of literature review and analysis can contextualize results and create inductive flexibility (e. g. snowball searches) (Berrang-Ford et al. 2015; Snyder 2019). This thesis applied a structured review method, with the following steps:

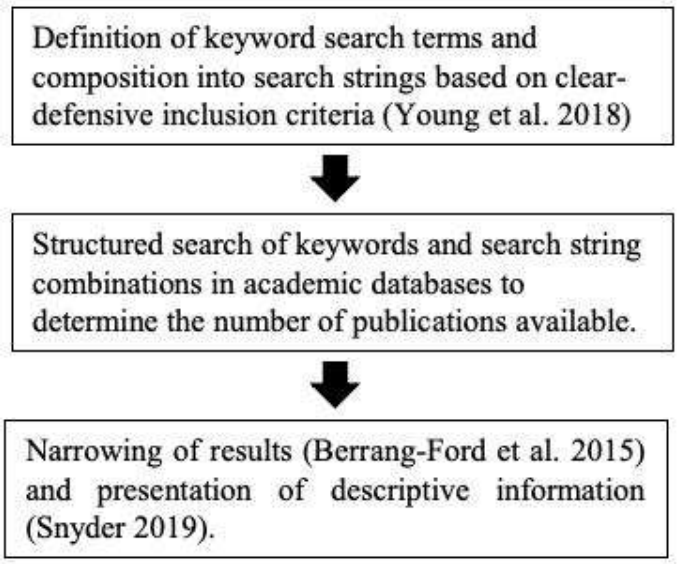



*Figure 6: Steps of the structured literature review as applied in this research(own illustration, based on Grant & Booth 2009; Young et al. 2018)*

### 3.1 Literature review and analysis: Identification and selection of ecosystem adaptive capacity elements

This step aimed to provide key information as a prerequisite to answer the main research question, and to answer parts of the first sub-research question. It was further key to build the theoretical foundation and conceptual understanding of ecosystem AC to identify and select climate adaptive conservation strategies that thereafter can be validated by means of the survey. The following Figure (7) describes the methodological process of the identification and selection of the ecosystem AC elements in this research:

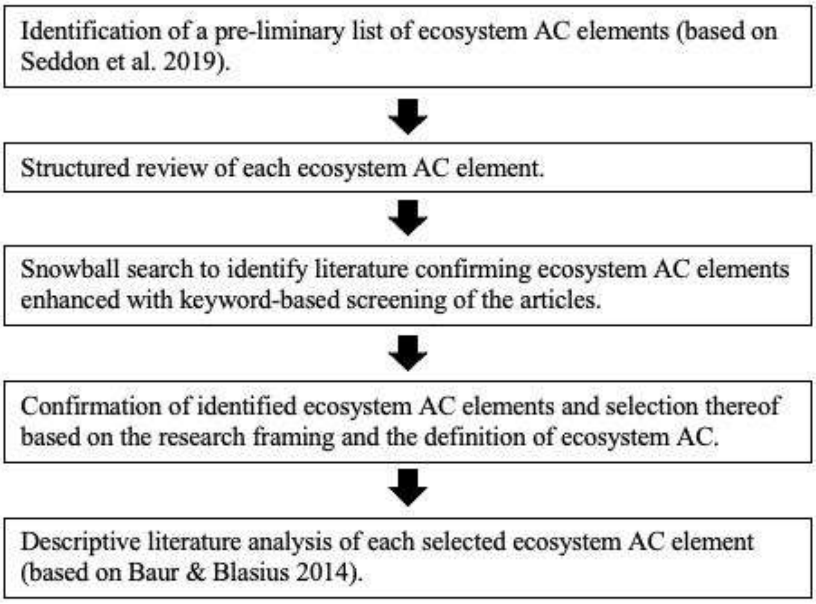



*Figure 7:Overview of the steps to identify and select the ecosystem adaptive capacity elements as applied in this research(own illustration, based on Baur & Blasius 2014; Mayring 2015).*

Building on the preceding steps of the literature review the final stage of this section was completed with a descriptive literature analysis that was broadly based on categories that were defined by means of the literature review results and the concept of ecosystem adaptive capacity (Baur & Blasius 2014). The deductively derived categories enabled to analyze the literature and group the findings accordingly. Thus, this step broadly oriented itself on the qualitative content analysis of Mayring (2015).

### 3.2 Literature review and analysis: Identification and selection of the climate adaptive conservation strategies and related actions

This section aimed to identify and select climate adaptive conservation strategies and related actions that support one or several of the selected ecosystem AC elements, and ecosystem AC overall. This can support the vulnerability reduction of the entire SES, since both the ecosystem and social system are connected through the provision of ecosystem services and the application of said climate adaptive conservation strategies. This step was helpful to address parts of the main research question and was a prerequisite to answer the sub-research questions two and three.

This step combined different forms of literature review and analysis, mainly comprised of a snowball search based on selection criteria (Grant & Booth 2009; Berrang-Ford et al. 2015) (Annex II), and proved to be a suitable methodological approach to identify and select climate adaptive conservation strategies and related actions that can support ecosystem AC. The methodological approach contained the following steps:

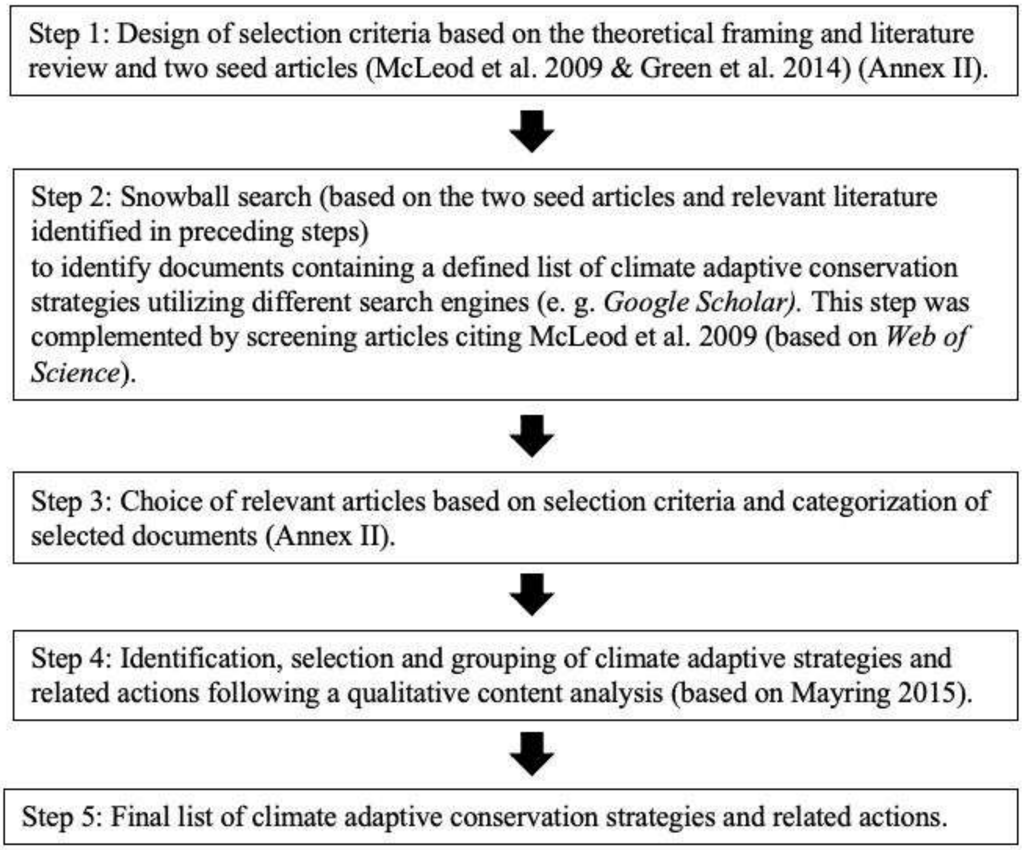



*Figure 8: Overview of the steps to select the climate adaptive conservation strategies and related actions as applied in this research (own illustration, based on Baur & Blasius 2014; Mayring 2015).*

**Process of selecting articles for the identification of the strategies and related actions:** Two seed articles formed the basis for the snowball search and the definition of the selection criteria for the articles (Annex II), and hence the identification of the conservation strategies (step 1). For example, Green et al. (2014) was identified through the structured literature review on CCA and conservation (Annex Ia). Both were selected due to their focus on marine and tropical coastal ecosystems, including coral reefs, and how to design and plan (marine) conservation in a climate adaptive manner. Hence, both aligned well with the thesis framing.

The following step (2) was helpful to identify several key articles that built the foundation for the selection of the climate adaptive conservation strategies. This step continued until a substantial overlap of conservation strategies was identified among the sources (step 3). The further this step proceeded the less relevant articles could be found, indicating a saturation point (Bernard 2006).

**Identification and selection of the climate adaptive conservation strategies (step 4):** The lists of climate adaptive or related recommendations, strategies, options, or principles authors suggested in the selected articles were analyzed, according to the definitions and research framing of this thesis, and in their relation of supporting the ecosystem AC elements. This step was in addition enhanced by screening the list of strategies with pre-selected keyword search terms of each adaptive capacity element to maximize the results (Annex VI). This step was complemented by broadly following a qualitative content analysis to analyze the selected documents according to Mayring (2015), which is characterized by a category-led approach. The basic assumptions of the concept of ecosystem adaptive capacity, offered a meaningful, conceptual basis for the qualitative content analysis against the background of the conceptual SES framework (Preiser et al. 2021). In addition, the selection of the climate adaptive strategies proposed was aimed to be applicable across planning scales and adaptable to different social-ecological contexts. So that these strategies can be integrated both in national conservation policies, action plans, or state-level PAN or individual PA planning documents. Hence, the selected strategies can also be implemented at an ecosystem and land- and seascape scale, such as in individual PAs, MPAs and networks or other area-based management approaches.

The selected strategies were composed into a final list when these aimed, directly or indirectly, to support one or several ecosystem AC elements, or overall ecosystem AC, and categorized accordingly (Annex III). A following step aimed to produce a non-exhaustive exemplary list of potential activities relevant to and supportive of each previously selected strategy. These were identified, selected, and categorized, following the outline of selected strategies and the ecosystem AC elements.

## 3.3 Expert consultation: Evaluation of the selected climate adaptive conservation strategies in the three states in Micronesia

The second part of this research entailed a semi-quantitative survey with experts in FSM, RMI and Palau. The survey was structured to answer parts of the main, the second and third sub-research questions, and thus was guided by the conceptual SES and the theoretical research framing of this thesis. Based on this structure, a set of questions was composed to consult experts with relevant expertise of the subject area and case study region (Annex VII).

This methodological approach was chosen to confirm which of the identified drivers of change have impacted reefs in the region (section 2.4) and to gain additional qualitative insights. In data sparce situations expert consultation is an effective approach to gain knowledge-based information on the type and quality of drivers affecting an ecosystem. Concurrently, this method has been applied by scholars in the region (Toki & Davies 2021).

This research method was further selected to validate the previously synthesized list of theoretical climate adaptive conservation strategies that can support the adaptive capacity of coral reefs in the case study region, by means of an expert consultation. Experts were not told that they were validating the strategies in the context of their effectiveness to gain unbiased results (Bernard 2006).

Expert consultation is considered helpful when scientific uncertainty is high and can aid decision-making and the identification of future research needs. It was considered a suitable approach since the literature review of this research identified a significant gap with very little empirical evidence of the climate adaptive conservation strategies (Tittensor et al. 2019). Yet, scholars highlighted the importance to empirically verify the relevance and effectiveness of such theoretical strategies in practice (Berrang & Ford et al. 2015). In Micronesia, expert consultation has been utilized as an effective way to validate and examine the relevance of such strategies for conservation (TNC 2014). Furthermore, this survey was designed to determine potential implementation gaps of the strategies and to provide recommendations based on which strategies expert would prioritize.

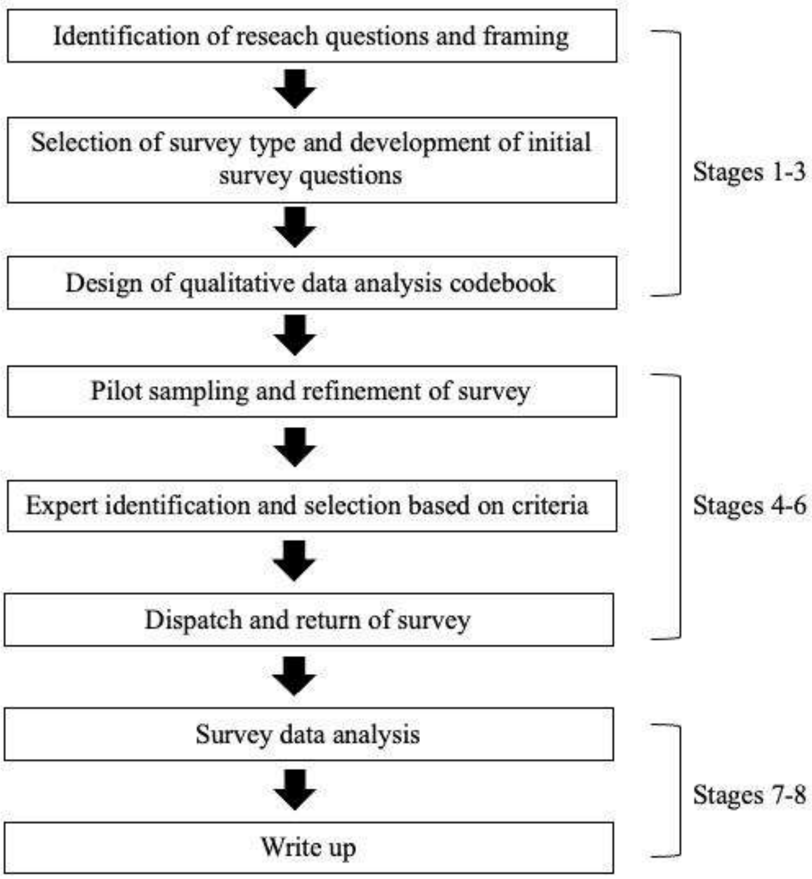


*Figure 9: Simplified stages of the survey process. Initial research design (stages 1-3), data collection (stages 4-6), analysis and composition (stages 7-8) (own illustration, based on Young et al. 2018).*

**Initial research design (stages 1-3):** The self-administrable questionnaire was composed of questions that were oriented according to the structure of the research questions and based on the conceptual SES framing (stage 1). It contained both quantitative and qualitative questions (stage 2). As quantitative and qualitative questions offer advantages and disadvantages, both were combined to create flexibility, comprehend complexity aimed to produce reproduceable and transparent results (Bernard 2006; Young et al. 2018).

The quantitative questions were composed of nominal and ordinal variables with several qualitative open-ended text-based questions to gather knowledge-based information and to contextualize the quantitative responses (Bernard 2006; Baur &Blasius 2014). Qualitative questions can be useful if there is much unknown about a topic or in case of a complex issue (Doolittle 2015). For example, a similar approach was applied to gain expert perceptions on conservation and CCA within a social-ecological setting (Hagerman et al. 2010).

To enable the analysis of the qualitative results a qualitative codebook was designed, based on the coding research method for qualitative research of Mayring (2000). A pre-liminary code list was created deductively, which was complemented with inductive codes based on the results, and structured according to the research questions, conceptual framing of this thesis, and the outline of the survey questions (stage 3).

Subsequentially, the questions were structured in a digital survey administered through the platform QuestionPro, containing different forms of questions, some with single or multiple answer options or a 5-point Likert rating scale (Taherdoost 2019).

**Data collection (stages 4-6)**

Before, selecting and contacting potential survey participants, the questionnaire was adjusted according to the evaluation and critical reflection of an expert, that had relevant expertise in the region (stage 4).

**Identification and selection of key informants (stage 5)**: Respondents for this survey were identified and selected based on a nonprobability sampling strategy, including chain-referral and snowball sampling, with a purposive identification and selection of key informants (Bernard 2006; Young et al. 2018).

The identification of key informants and potential survey participants was based on multiple strategies: (1) a literature review of conservation and related documents in the case study region, (2) an extensive online search and review of relevant institutions in the region, (3) an additional online research of stakeholder or steering committee meetings with participant lists, (4) the researcher´s own contacts in the Pacific Region, (5) and a chain-referral through participating experts (Annex V). Based on this step, a preliminary list of experts with experience in one or multiple of the three countries was created. Based on a set of selection criteria, the initial pool of participants was screened in several processes to determine the most suitable experts (Bernard 2006). The expert selection rationale was derived from the professional experience and knowledge relevant to the objectives and framing of this research.

**Administration of the survey (stage 6):** Experts were contacted via personalized E-Mails. The platform LinkedIn was utilized to reach additional experts. The survey participants were provided with a research overview, its aim, and the approval to confirm consent of participation (Crowe et al. 2011; Kumar 2011).

**Survey structure:** The survey addressed the following topics: (1) Introduction to the research objectives and survey structure; (2) professional background and what drivers of change had affected coral reefs; (3) the state of coral reefs and role of coastal ecosystems for coral reef AC; (4) the extent climate change has been included in conservation, and to what extent it was considered climate adaptive; (5) the extent of effectiveness, integration, and implementation of conservation strategies and related actions supporting coral reef AC; (5) insights on successful and prioritized conservation strategies, lessons learned; (6) and finally questions on the implemented activities, experienced implementation challenges and next steps.

**Survey data analysis and composition (stage 7-8):** The survey results were analyzed based on the data type - **Quantitative results:** The evaluation of the quantitative results was based on absolute and relative values and analyzed by means of the software Excel. The relative values were standardized to a 100 percent to enable the comparability and analysis of results, based on descriptive statistics. In case no answer was given to a question an additional category was added and the relative values calculated accordingly. Some questions were evaluated according to the categorization of the 5-point Likert scale (Table 4).

| Likert Scale | Question 7 | Question 15 |
|---|---|---|
| 1 | Excellent | Strongly agree |
| 2 | Very good | Agree |
| 3 | Good | Neither agree nor disagree |
| 4 | Fair | Disagree |
| 5 | Poor | Strongly disagree |

*Table 4: Rating system of the Likert scale survey questions (based on Taherdoost 2019).*

In addition, the responses of the survey participants regarding the climate adaptive conservation strategies were categorized to enable the evaluation to what extent these have been considered as effective, integrated, or implemented. Thus, the following classification was applied:

| **Rating scale** | **Relative frequency (%)** |
|---|---|
| Very high | >80 |
| High | 60 – 80 |
| Medium | 40 - 60 |
| Low | 20 - 40 |
| Very low | <20 |

*Table 5: Classification system to rank the survey responses (based on Baur & Blasius 2014).*

This classification system was based on academic scholars outlining that specifically the application and combination of multiple climate adaptive conservation strategies is understood as effective and more likely to support the AC of ecosystems (Wilson et al. 2020; O´Regan et al. 2021). Strategies were recognized as either effective, integrated, or implemented when the rating was above “very low” (Table 5).

**Qualitative results:** The text-based data was evaluated using a qualitative content analysis according to Mayring (2000). This approach is well suited to categorize qualitative responses of this research, as both the qualitative content analysis and the SES framing of this research are strongly theory-based. Thus, the categories were defined deductively based on the conceptual SES framing and the research framing. Consequentially, the codes were grouped and categorized into a codebook following the research thesis question and the survey structure (Annex VIII).

The coding system built first on deductive codes, and second on additional codes that were defined inductively based on to the research framing. The preliminary code list was reviewed and adjusted according to the respondents' answers, personal communications via E-Mail, and the researchers understanding of the local socio-ecological context. All qualitative survey responses were coded in the same manner, and answers were assigned to the suitable codes.

# 4. Results

Following the previous chapters that described the foundation of this thesis including the theoretical and thematic framing and the methodological approach of this research, this chapter presents the research results to answer the research questions of this thesis. First, by means of a literature review and analysis the ecosystem AC elements are selected that support the overall adaptive capacity of an ecosystem (section 4.1). Second, a set of climate adaptive conservation strategies are selected that support the AC of ecosystems and its elements, by means of a literature review and analysis. It further provides exemplary activities that target the three coastal ecosystems (section 4.2). Third, the empirical results of the semi-quantitative survey are presented (section 4.3).

### 4.1 The ecosystem adaptive capacity elements

The following section summarizes the research findings of the literature review and descriptive literature analysis of the ecosystem AC elements. This step was beneficial to select and analyze the elements of ecosystem adaptive capacity and hence to facilitate the answering of parts of the main research question, and the first sub-research question. This step was key to gain a clearer understanding of the ecosystem adaptive capacity and was a prerequisite to define and select the climate adaptive conservation strategies that support the ecosystem AC, and its elements.

#### 4.1.1 Identification and selection of the ecosystem adaptive capacity elements

To identify which elements the adaptive capacity of ecosystems is composed of in the literature, different review techniques were employed.

First, the researcher identified and used the ecosystem AC elements, defined in the theoretical SES framework of this research from Seddon et al. (2019, p. 5). These four AC elements included the "diversity, heterogeneity, connectedness" and the "characteristics and condition of its component species and habitats". Based on the literature, the element "characteristics and conditions" was defined as synonymous to and hence replaced with "ecosystem functioning".

Second, based on the identified AC elements from Seddon et al. (2019) and the theoretical understanding of the concept of ecosystem AC, keywords and search strings were defined (Annex VI). The keyword and search strings were analyzed based on *Web of Science* (Table 6). This structured literature review was helpful to gain a scoping overview on the number of peer-reviewed literature addressing each ecosystem AC element, and the overall ecosystem adaptive capacity.

| Ecosystem AC & elements | Search strings in Web of Science for returns between 1945 and 2022 | Returns "Titles" | Returns "All fields" |
|---|---|---|---|
| Ecological AC | "ecological" AND "adaptive capacity" | 29 | 1324 |
| Ecosystem AC | "ecosystem" AND "adaptive" AND "capacity" | 9 | 1288 |
| | "ecosystem" AND "adaptive capacity" | 9 | 746 |
| Species AC | "species" AND "adaptive capacity" | 15 | 871 |
| Connectivity | "connectivity" AND "ecosystem" AND "adaptive capacity" | 0 | 27 |
| | "connectivity" AND "adaptive capacity" | 2 | 150 |
| | "connectivity" AND "ecological" AND "adaptive capacity" | 0 | 48 |
| Heterogeneity | "heterogeneity" AND "adaptive capacity" | 2 | 130 |
| | "heterogeneity" AND "ecosystem" AND "adaptive capacity" | 0 | 23 |
| Ecosystem functioning | "ecosystem functioning" AND "adaptive capacity" | 0 | 22 |
| | "ecosystem functioning" AND "ecosystem" AND "adaptive capacity" | 0 | 0 |
| | "functioning" AND "ecosystem" AND "adaptive capacity" | 0 | 39 |
| Biodiversity | "biodiversity" AND "adaptive capacity" | 4 | 487 |
| | "biodiversity" AND "ecosystem" AND "adaptive capacity" | 4 | 487 |

*Table 6: Structured literature review of the adaptive capacity of an ecosystem and its elements. Search string returns for ecosystem AC and its elements in publication "titles" and "all fields" in Web of Science (analysis undertaken October 2022).*

**Ecosystem adaptive capacity:** The search string "ecosystem" AND "adaptive capacity" provided nine title returns. *Web of Science* categorized these mostly in ecology, environmental or development studies, or marine biodiversity conservation. Even though, these research fields are related to the framing of this research none of the articles discussed ecosystem AC, but either generally AC or species AC in relation to social, economic, or institutional adaptive capacity. In *Google Scholar* 39 titles were available for the same search string.

The 29 title returns for "ecological" AND "adaptive capacity", except for three publications, all addressed "adaptive capacity" together with social-ecological system, resilience, or landscape (Table 6). Hence the term "ecological" was most often embedded in the term social-ecological and did not relate to ecosystem AC. Yet, one publication included specifically "ecological adaptive capacity" (Petersen et al. 2018) and several papers, identified in this search, were relevant to, and had previously been included in this research (e. g. Whitney et al. 2017; Thronicke et al. 2020).

**Ecosystem AC elements:** Few or no returns were available for each element when combined with AC. For example, the two title returns for "heterogeneity" AND "adaptive capacity" did not address ecosystem AC, since one article was from the field of gastroenterology, while another focused on how the heterogeneity among clam harvesters influenced their social AC in a SES (Pellowe & Leslie 2019). Also, the two publication titles for "connectivity" AND "adaptive capacity" both related to social

AC in a fisheries context. Similar observations were made when screening several publications under "all fields". Opposing, the returns for each concept irrespective of "adaptive capacity" were significantly higher and thus the concepts appeared well addressed in academic research (e. g. "environmental" AND "heterogeneity", 806 title returns in *Web of Science*).

**Verification of the identified ecosystem AC elements:** Subsequentially a snowball search followed, which proved helpful as a prerequisite to answer parts of the main research question and the first sub-research question. This step was based on the identified ecosystem adaptive capacity elements from Seddon et al. (2019) and two seed articles (Petersen et al. 2018; Angeler et al. 2019), that were identified in section 2.1. The analysis of the articles, that were identified in this step, was enhanced by screening these based on keywords for each element (e. g. for connectivity "source") (Annex VI). The literature analysis confirmed a high agreement among authors concerning the four ecosystem AC elements of Seddon et al. (2019) (e. g. Foley et al. 2010; Bernhardt & Leslie 2013; Petersen et al. 2018; Rilov et al. 2019; McLeod et al. 2019; Wilson et al. 2020). While, not all authors named these specifically as ecosystem AC they defined that these composed elements support and make up the capacity of an ecosystem to adapt to change. Some scholars characterized ecosystem AC as the sum of the intrinsic capacity of its species, via physiological and behavioral plasticity (Fernandes et al. 2012) others included both species and ecosystem components and highlighted that in an ecological system such elements are connected across scales (Fernandes et al. 2012; Whitney et al. 2017) or defined it as separate (Angeler et al. 2019). These conceptual challenges complicated the identification and selection of AC elements. Nevertheless, based on a broad agreement among authors, this step was helpful to confirm the four elements of ecosystem AC, and provided key insights on definitions, conceptualizations, and ecological understanding of each element in relation to ecosystem adaptive capacity.

**Selection of the ecosystem AC elements:** While biodiversity was identified as an ecosystem AC element it was not included as an element for this research. Because there were several discrepancies in the literature concerning its definition and conceptualization on how and what forms of biodiversity (e. g. genetic) make up ecosystem-level AC. There were further inconsistencies that challenged a clear delineation of the concept in relation to other ecosystem AC elements. Nevertheless, as biodiversity was also addressed by the other AC elements it was broadly included in this research.

### 4.1.2 Descriptive analysis of the ecosystem adaptive capacity elements

The following section presents the results of the literature analysis, that broadly followed a qualitative content analysis (based on Baur & Blasius 2014; Mayring 2015). This step analyzed each element in further detail to understand what components, processes and functions make up, and are key for each individual ecosystem AC element, as well as how they are interrelated. It was thus helpful as a prerequisite to define and select the climate adaptive conservation strategies and related actions that can support these processes that drive each ecosystem AC element.

**Ecosystem AC element – Connectivity:** Here, connectivity is defined as the ability of species and other ecological flows to move among protected, linked and associated coastal ecosystems, specifically mangroves, seagrass beds and coral reefs (based on Maynard et al. 2015a). Along with diversity, ecosystem connectivity is essential for maintaining the element "ecosystem functioning" and recovery in marine ecosystems (Foley et al. 2010).

The ecological spatial connectivity describes the extent to which various spatially distinct habitats, populations, and ecosystems (Carr et al. 2017), are connected across different temporal (inter-annually, seasonally, and short-term) and spatial scales through biological, physical, and chemical processes in a dynamic, spatially heterogenous marine, land- or seascape (Gladstone 2009; Cumming & Allen 2017; Chambers et al. 2019). So, associated habitats or populations are vertically connected across ecosystems through exchange and movement (e. g. of organisms or nutrients) (Albert et al. 2010; Maynard et al. 2015b). For example, the flow of water transports sediment from catchments to coasts and thus supports mangrove species capacity to keep up with SLR (Gladstone 2009). Thus, spatial connectivity is either structural (seascape) or functional and based on mobility (Albert et al. 2010), which can be preserved through marine PANs (Mumby 2006; Carr et al. 2017; Weeks 2017; Hilty et al. 2020). Spatial connectivity is also observed in the functional linkages of tropical coastal ecosystems (Mumby et al. 2006; Peterson et al. 2020), between seagrass and coral habitats, or between mangroves and seagrasses, functioning as nurseries for reef fishes that ensure coral AC to drivers of change (e. g. herbivores) (Albert et al. 2010; Du et al. 2020).

Land- and seascape connectivity are key to measure spatial adaptive capacity of ecosystems to climate change. Loss or degradation of landscape connectivity affects the connectivity of its ecosystems including population density (Chambers et al. 2019). In a dynamic and spatially heterogeneous seascape, maintaining connectivity through conservation is critical to enable the offshore movement of organisms across different habitats throughout their lifecycle, across time (e. g. spawning), and the larval dispersal through ocean currents and upwelling in mangroves, seagrass beds, and coral reefs (Du et al. 2020). Hence, connectivity plays a key ecological role in marine ecosystems, and facilitates the distribution, abundance, and persistence of species, source-sink dynamics, colonization, risk spreading, and the movement to refugia to accommodate change (Gladstone 2009; Maynard et al. 2015b).

**Ecosystem AC element – Heterogeneity:** While scholars differentiated and studied heterogeneity either for landscapes and habitats (Foley et al. 2010) or environmental conditions in one area, less research and studies were available for ecosystem-level heterogeneity (Cumming & Allen 2017; Rilov et al. 2019). Within this research, particularly environmental heterogeneity is considered relevant for ecosystem AC and describes the spatial diversity and non-uniformity of key abiotic and biotic environmental features (e. g. climate, topography, vegetation) that change across space and time (Barajas-Barbosa et al. 2020) and are strongly dependent on the observed scale.

Abiotic parameters can be observed in small-scale mosaic patterns caused by local conditions (e. g. currents) resulting in heterogenous environmental conditions (Rilov et al. 2019). Topographic complexity may create greater heterogeneity, increasing the diversity and availability of suitable microclimatic habitats thus offering climate refugia, for example for coral species (Kavousi & Keppel 2018). The degree of topographic heterogeneity among ecosystems can differ depending on spatial scale (e. g. small-scale heterogeneous vs. large-scale homogenous) and data collection method. It impacts the ecosystem AC element “ecosystem functioning” directly and indirectly through the influence of diversity and community composition (Archambault & Bourget 1996).

High environmental heterogeneity is a main driver of ecosystem processes and diversity among ecological communities, and thus ecosystem health and functioning on oceanic islands (Archambault & Bourget 1996; Barajas-Barbosa et al. 2020; Thomsen et al. 2022).

**Ecosystem AC element – Ecosystem functioning:** Within this research, the ecosystem AC element "ecosystem functioning" is defined as the flow of biotic and abiotic ecosystem components and processes (e. g. tropic species transfer) (Hilty et al. 2020). Among others, it supports the maintenance of productivity and stable food web dynamics (Foley et al. 2010; Houk & Musburger 2013).

A functional ecosystem response to impacts of drivers of change relies on the functional (e. g. dispersal abilities) and response diversity of its species (Elmquist et al. 2013). Both are tightly connected and work synergistically to ensure ecosystem AC. Functional diversity ensures that multiple functional groups are present in an ecosystem that provide similar functions and biological processes (Foley et al. 2010). Since, species and functional groups respond differently to environmental variations, decreases of one group can be compensated through increases in another. If one becomes extinct it may be replaced by another species, group, or process, providing the same or similar ecological functions, thereby supporting adaptive capacity in ecosystems (Bernhardt & Leslie 2013; Angeler et al. 2019).

However, even in diverse marine ecosystems, species redundancy within functional groups can be low. Especially in marine ecosystems, functions and dynamics are mostly determined by a few key species that are essential for ecosystem functioning. For example, seagrass beds usually host many resident species (Alsaffar et al. 2020). Here, a loss of a single species can result in the loss of an entire functional group.

Depletion of top predators, keystone, foundation, or rare species, fulfilling essential functional ecosystem roles that are not supported by abundant species, may negatively affect ecosystem AC (e. g. top-down regulation of herbivorous fish due to overfishing) (Foley et al. 2010; Houk & Musburger 2013). So, both functional redundancy and response diversity are key drivers of ecosystem AC (Mori et al. 2013).

Particularly, connectivity, and ecosystem functioning were frequently mentioned among scholars in relation to ecosystem AC, whereas ecosystem-level heterogeneity was less often addressed, and if it was discussed it was so in less detail. Yet, environmental heterogeneity appeared as a key driver of ecosystem AC. Overall, connectivity was most often the focus in the literature within the framing of this research (e. g. ecology, conservation science, climate adaptive conservation) and in relation to ecosystem adaptive capacity.

Altogether, the descriptive analysis results, concerning the three selected ecosystem AC elements, showcased that each concept is characterized by a complex interplay of ecological processes and components that make up each adaptive capacity element.

## 4.2 The climate adaptive conservation strategies and related actions

This section outlines first the identification of relevant documents containing climate adaptive conservation strategies, and second the categorization of the documents and the selected climate adaptive conservation strategies and related actions.
This step aimed to answer parts of the main and the second sub-research question. It formed a basis for the creation of the survey to validate the selected strategies by experts. This step helped to select climate adaptive conservation strategies applicable across planning scales with exemplary activities adjusted to coastal marine ecosystems, including mangroves, seagrass beds, and coral reefs.

### 4.2.1 Identification of documents including climate adaptive conservation guidelines, principles, recommendations, or strategies

The two selected seed articles (McLeod et al. 2009; Green et al. 2014) formed the basis for the snowball search. Prior to the search, articles that cited McLeod et al. (2009) in *Web of Science* (titles=228) were screened to identify relevant articles and to gain an overview of what topics these articles discussed in relation to potential climate adaptive strategies (Supp. Mat. 3). The list of titles contained many applicable articles that had been incorporated in this research including several key review papers (e. g. Wilson et a. 2020; O´Regan et al. 2021). Most titles included “connectivity” (n=21), one comprised “heterogeneity”, while “ecosystem functioning” was not directly mentioned. Most mentioned coral reefs (n=47), less so seagrass beds (n=2) or mangroves (n=1). Three articles, that aligned with the defined selection criteria (Annex II), were included in the list of documents (Foley et al. 2010; Weeks & Jupiter et al. 2013; McLeod et al. 2019). The Pacific case study of Weeks & Jupiter (2013) provided one of the only implemented examples of climate adaptive conservation strategies.
Building on these articles the snowball search proceeded and six additional articles were selected. Based on the identified implementation gap of climate adaptive conservation, two articles were considered helpful as these provided recommendations for practitioners (Green et al. 2014; Gross et al. 2016).

Altogether, this step yielded 11 documents that aided the identification of the climate adaptive conservation strategies and related activities (Annex III & Supp. Mat. 3).

**Categorization of the selected documents (Annex II & Supp. Mat. 3)**

**Terminology:** The literature differed and included either climate adaptive or resilience conservation "principles", "recommendations", "guidelines", "framework" or "options". Several were general principles (n=4) aimed at guiding conservation more broadly and often related to ecological principles (e. g. Foley et al. 2010). Others entailed more actionable, specific, and clear strategies or activities of adaptation measures (e. g. Geyer et al. 2015) for the conservation design, planning, and implementation. Suggestions ranged from resilient MPA network design options supporting ecological resilience and climate change adaptation (McLeod et al. 2009; Fernandes et al. 2012) for different objectives (e. g. fisheries or CCA) (Green et al 2014; Gross et al. 2016), that were adapted to tropical ecosystems (Gladstone 2009), or to local or regional settings in the Pacific (Hills et al. 2011; Weeks & Jupiter 2013).

**Location, ecosystem type, and ecological scale:** Two were set in the Coral Triangle and two in the Pacific, with several targeting ecosystems (n=7). Five publications focused on coral reefs, three on marine or coastal systems generally, and three publications included options for both mangroves, seagrass beds and coral reefs (Gladstone 2009; Green et al. 2014).

**Purpose of proposed strategy and planning scale:** The suggestions were for different planning or spatial scales, including for the design (n=5), (adaptive) management (n=4), or planning of conservation measures, areas, or networks (n=3). Most proposed strategies or activities for PANs (n=6), individual PAs (n=3) or were non-specific (n=5).

**Theoretical concepts:** Most publications included both the concepts of resilience (n=8), ecological AC (n=3), or generally adaptation (n=4). Geyer et al. (2015) specifically defined ecosystem AC, while others proposed strategies supporting ecosystem AC without specifically naming or defining it. Yet, the ecosystem AC elements were addressed in more detail in several publications that fed into the list of selected strategies and related actions below (Annex III).

#### 4.2.2 Selection and categorization of the climate adaptive conservation strategies and related activities

Despite several of the differences depicted above, the authors provided greatly overlapping climate adaptive conservation strategies and related activities. The strategies and related actions were selected, grouped, and categorized according to the selection criteria (Annex II). This step broadly followed the qualitative content analysis and a category-led approach according to the selected ecosystem AC elements and their components (Mayring 2000 & 2015).

The selected strategies were assembled in a list of eight climate adaptive conservation strategies (Table 7) and 26 related actions that can support coastal and marine ecosystem AC directly through conservation (e. g. protected areas) or indirectly through related activities (e. g. Marine Spatial Planning (MSP)), independent of a specific climate change-related driver (Annex III).

| Nr. of strategies | Climate adaptive conservation strategy | Nr. of times the strategy was included in the documents |
|---|---|---|
| 1 | Reduction of non-climatic direct and indirect (local) drivers | 8 |
| 2 | Embedment within broader management frameworks | 6 |
| 3 | Representation and replication of all ecosystems | 11 |
| 4 | Preserve and enhance land & seascape connectivity | 11 |
| 5 | Maintain land- and seascape heterogeneity | 6 |
| 6 | Restoration of degraded ecosystems | 7 |
| 7 | Maintain ecosystem processes and ecological functioning | 10 |
| 8 | Knowledge of and addressing climate change-related drivers potentially impacting coastal ecosystems | 5 |

*Table 7: List of the selected climate adaptive conservation strategies and the number of times each strategy was included in the 11 documents.*

**Selected strategies:** All documents recommended multiple strategies, options, or principles. These ranged from spatial MPA design principles to climate adaptation ones (e. g. protection of refugia) (Supp. Mat. 3). Several combined social and ecological recommendations. Authors deemed strategies useful even in the absence of change yet highlighted certain strategies as more supportive towards specific drivers (e. g. coral bleaching). Since publication dates differed, a transition from ecosystem-based and resilience-based approaches to more climate adaptive ones could be observed. Several included suggestions to effectively manage local stressors, protect refugia, or ensure connectivity between different functional habitats, or to support social aspects, such as livelihood diversification options (e. g. McLeod et al. 2019).

Also, the combination of conservation with other area-based management approaches was frequently highlighted since these address multiple objectives and interacting, mostly local non-climatic drivers, including those that stem from outside of PAs or land-based sources (e. g. Foley et al. 2010; Green et al. 2014).

Not all documents had a separate strategy addressing climate change-related drivers, but either overall aimed to address their potential impacts or generally help ecosystems be better equipped to face change. According to the conceptual SES framing, this strategy (8) was defined as separate, since climate change-related drivers were defined as external to the SES, compared to the other strategies that are linked to processes within the system (Table 7). For example, to address complexity and uncertainty scholars suggested to apply a holistic knowledge management (Foley et al. 2010). This translates to the application of the precautionary principle (Activity 25), which is particularly beneficial in data-sparce situations. It further aids to identify and predict critical shifts in ecological states, for example through early warning systems (Activity 24) (Maynard et al. 2015a).

**Ecosystem AC in the selected strategies:** Three strategies were selected that focused specifically on the three selected ecosystem AC elements (Strategy 4, 5, 7). While the other strategies and their actions are supportive of one or several ecosystem AC elements. Most selected strategies that directly connected to the three ecosystem AC elements were focused on ecosystem functioning (strategy 7, n=10) and connectivity (strategy 4, n=11). While heterogeneity (strategy 5, n=6) was mentioned less (Table 7, Supp. Mat. 3). Several strategies were connected and supportive of each other. For example, according to the analysis of the AC elements in section 4.1.2, since strategy (3) aims to protect redundant ecosystems and functional groups it is supportive of the ecosystem AC element “ecosystem functioning” and thus connected to strategy (7).

Authors highlighted the importance to apply strategy (7) to ensure that species can recover and persist to fulfil key ecological roles, a prerequisite for ecosystem AC (Houk & Musburger 2013). For example, coral redundancy and diversity of functional reef fish groups are a sign of ecosystem AC in reefs (Houk et al. 2015).

Strategy (3) was considered relevant in areas with a lack of ecological data and regarded as one of the most effective approaches for including ecosystem AC in spatial MPA network design and planning, as well as to facilitate ecosystem recovery and adaptation (McLeod et al. 2009). For example, by identifying and prioritizing the conservation of habitats that are likely more adaptive to climate change-related impacts (e. g. areas with natural variable SST) (McLeod et al. 2009; Green et al. 2014). The authors viewed the combination of strategies as most effective to support ecosystem AC and to make conservation climate resilient and adaptive (McLeod et al. 2019).

**Selected activities:** Based on the selected strategies and actions authors suggested for these, 26 activities were selected (Annex II) to provide an exemplary non-exhaustive list of broad activities, focused on the land- and seascape of coastal ecosystems, that can support each strategy towards climate adaptive conservation. These can be extended and adapted to fit the local social-ecological context, environmental setting, and conservation needs. Some actions were overlapping among authors or also applicable and relevant to several strategies. Specifically, the activities 13 and 17 focused on critical areas in strategy (3) and (4). However, whereas the first focused on protecting critical areas (e. g. spawning sites), the second focused on restoring climate adaptive species and habitats.

### 4.3 Expert consultation: Validation of the climate adaptive conservation strategies based on the multi case study area Micronesia

The following section presents the results of the semi-quantitative survey, which aimed, among other components, to validate the identified drivers of change (section 2.4) and the selected climate adaptive conservation strategies and related actions to support the adaptive capacity of coral reefs (section 4.2). It thus was helpful to support the answering of the main research question, and the sub-research questions 2 and 3. For further details on the climate adaptive conservation strategies and related actions please refer to Annex IX and the Supplementary Material (4).

**Survey collection:** From a preliminary list of experts, a total of 140 participants were contacted via E-Mail or LinkedIn and were provided with the survey, administered through the website QuestionPro. Several E-Mail contacts were either not identifiable or incorrect (n= 28). Three experts declined participation based on expertise or capacity. Chain-referral overlapped with the contacts identified by this research (n=9), verifying the accuracy of the selected experts. Few new suggested contacts (n=3) indicated that most experts were likely reached. A total of 34 surveys were analyzed. In the following “Q” is short for “Question”.

### 4.3.1 Conservation context, state of coral reefs, and drivers of change

The experts were conservation scientists, ecologists, decision-makers, or employees that mostly worked at government agencies (Q2, Table 8) with a demonstrated expertise of the countries Palau (n=11), FSM (n=10) or RMI (n=13) (Q6). The participants were, for example (Marine) Protected Area or PAN Officers, Coastal Resource Managers, Climate Change and Environment Advisors or Ridge to Reef Project Managers. Experts worked, for example at the Conservation Society in Palau, Marshall Islands or Pohnpei, the Coral Reef Research Foundation in Palau, the Department of Marine Resources in FSM, or the Marshall Islands Marine Resources Authority.

| Type of Organization | Nr. and Type of Organization chosen per country | | | |
|---|---|---|---|---|
| | FSM | Palau | RMI | Total (Regional) |
| Academic / Research Institution | 1 | - | 2 | 3 |
| Foundation / Donor Organization | - | - | 1 | 1 |
| Governmental organization | 3 | 6 | 5 | 14 |
| International NGO | 2 | 2 | 1 | 5 |
| Other | 1 | - | 2 | 3 |
| Sub-national or national NGO | 3 | 3 | 2 | 8 |
| Total | 10 | 11 | 13 | 34 |

*Table 8: Type of organizations survey participants worked at (Q2).*

**Scale of work (Q3):** Experts worked on a local or community (n=10), national (n=8), regional (n=5) or sub-national (n=5) scale.

**Ecosystem focus of work (Q4):** Most focused on multiple ecosystems (n=21), coral reefs (n=10), or mangroves (n=1), and none on seagrass beds.

**Thematic focus of work (Q5):** The work of the respondents concentrated on ecosystems and biodiversity (n=15), climate change (n=5), fisheries (n=7), livelihoods and communities (n=3), or other (n=4).

**State of coral reefs (Q7):** The state of coral reefs regarding ecosystem health, biodiversity, and ecosystem services was regionally considered as good (1=Excellent to 5=Poor) (Table 9). One participant gave no answer and two listed ecosystem services as unknown. The state of ecosystem health and biodiversity appeared good to very good in Palau. The state of ecosystem services ranked lowest at 3.11 in FSM.

| Country | Nr. of experts | Ecosystem Health | Biodiversity | Ecosystem Services |
|---|---|---|---|---|
| RMI | 12 | 2.75 | 2.67 | 2.55 |
| FSM | 10 | 2.70 | 2.80 | 3.11 |
| Palau | 11 | 2.27 | 2.09 | 2.55 |
| Total | 33 | 2.58 | 2.52 | 2.71 |

*Table 9: State of coral reefs concerning ecosystem health, biodiversity, and ecosystem services. Mean values were calculated based on responses in a Likert scale ranking (1=Excellent to 5=Poor) (Q7).*

**Non-climatic drivers (Q8):** Respondents could select multiple drivers. Regionally, pollution (68%), habitat change (50%), and eutrophication (29%) ranked highest as having had a negative impact on coral reefs in the last 10 years (Fig. 10). Based on the literature review, the driver "habitat change" included overfishing. As multiple respondents named overfishing (21%) as a key driver under the "other" category, it was categorized as a separate driver.

There were considerable differences among countries. While pollution was the most significant driver on coral reefs in RMI (85%) and Palau (73%) it was of a lesser concern in FSM (40%). Eutrophication was not selected as a driver in Palau compared to RMI (54%). Overfishing was predominately an issue in FSM (44%) compared to Palau (9%). Under "Other" tourism, poorly planned development or dredging were listed as relevant non-climatic drivers (15%).

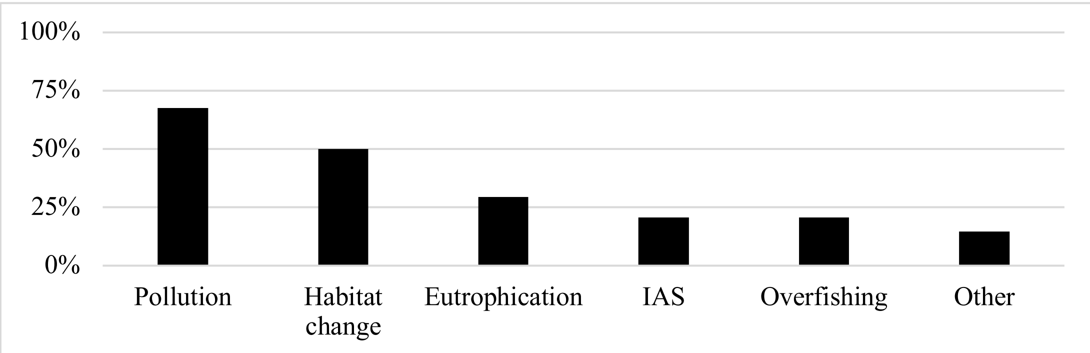



*Figure 10: Non-climatic drivers that negatively impacted coral reefs in the last 10 years. Results were aggregated for all three countries, depicted on the Y-Axis from highest (left) to lowest ranking (right). The X-Axis shows the relative values of the aggregated results from max 68 (%) to min. 15 (%) (Q8).*

**Climate change-related drivers (Q9):** Concerning the climate change-related drivers, responses were more evenly spread. Sea Surface Temperature (SST) changes (85%) and extreme weather events (71%) were the main drivers that have had a negative impact on coral reefs in the last 10 years (Fig. 11).

Extreme weather events (100%) and SLR (64%) had a much greater negative impact on coral reefs in Palau, compared to FSM and RMI. While acidification was of least concern in FSM (10%), it had negatively affected reefs in RMI (46%) and Palau (64%).

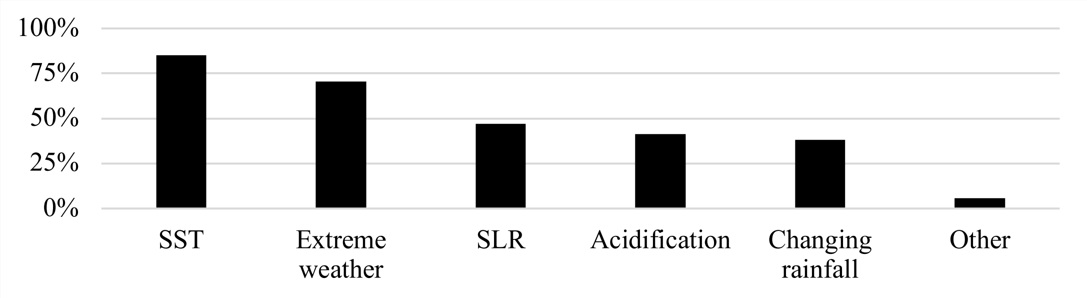



*Figure 11: Climate change-related drivers that have negatively affected coral reefs in the last 10 years, depicted on the Y-Axis from highest (left) to lowest ranking (right). The X-Axis shows the relative values of the aggregated country results from max. 85 (%) for SST to min. 6 (%) for Other. (SST=Sea Surface Temperature, SLR= Sea-level rise) (Q9).*

**Climate change-related driver with the greatest negative impact (Q10):** Respondents could select a driver based on their previous selection in Q9. Respondents overwhelmingly identified SST changes (59%) as the most significant driver that has negatively affected coral reefs in the last 10 years. It was followed by extreme weather events (29%), acidification (6%), and changing rainfall (3%), as the least significant climate change-related driver (Fig. 12). None of the respondents selected SLR and one expert gave no answer.

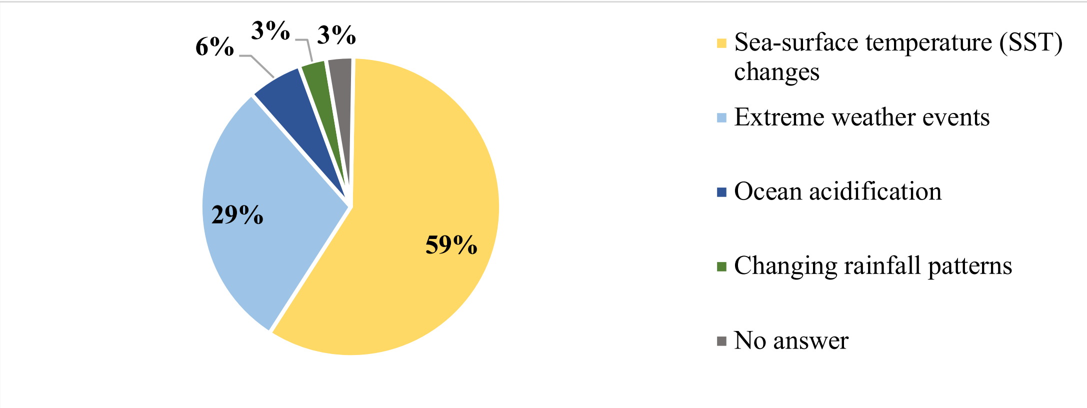



*Figure 12: Climate change-related drivers with the highest negative impact on coral reefs. Results are aggregated in relative values (Q10).*

**Coastal ecosystem most at risk (Q11):** The significance of these results is limited as several respondents selected multiple options (26%). Nevertheless, 97 percent of experts considered coral reefs most at risk from climate change, followed by mangroves (26%) and seagrass beds (24%). One respondent selected only mangroves.

**Reasons experts considered the ecosystem most at risk (Q11, Fig. 13):** In the text-based section of question 11, participants specified as to why they considered the selected ecosystem most at risk (n=16). Responses were categorized and analyzed according to the codebook (Mayring 2000; Annex VIII).

Multiple respondents outlined an increasing trend in the frequency, intensity, and duration of climate change-related drivers surpassing the recovery time of coral reefs, between impacts (n=5, C2.1.6). Bleaching (n=10) was the most pervasive impact on reefs due to SST changes (n=12, C0.2), which aside other causes most often resulted in skeletal collapse or coral mortality (n=7, C2.1.1) and degradation (n=8, C2.1.2), and thereafter in the loss of reef fishes. While a respondent described that "pockets of excellent biodiversity" remained, the expert outlined that corals were in much less pristine condition compared to before the global bleaching event of 2014 (C2.1.2).

As a secondary effect, due to overfishing of herbivores, algae overgrew corals (C2.1), which were consequentially unable to provide recruitment surfaces for coral (re)growth and again led to degradation or mortality (C2.1.1, C2.1.2). An expert from RMI reported that this caused a shift from coral-dominated to algae-dominated coral ecosystems resulting in a loss in biodiversity and ecosystem services, which particularly reduced coral reef shoreline protection close to urban and rural areas (C2.1.2; C2.1.6). A similar effect was reported for other reefs close to urban areas that shifted to mono species ecosystems of *Porites rus.* Likewise, in rural areas, due to SST changes, reefs with low species populations experienced phase shifts (e. g. *Microdictyon spp*.).

Experts highlighted that several drivers and impacts had affected all three ecosystems (n=7) and described that changing rainfall patterns (C0.5) had overwhelmed the ability of mangroves or seagrass beds to buffer sediment or run-off that caused degradation or mortality in corals (Palau, n=3, C2.1.1, C.2.1.2). Non-climatic drivers were emphasized as exacerbating climate change-related impacts on all three coastal ecosystems (n=3; C2.1) and reduced their capacity to respond to such drivers (n=4; C2.1.3). For example, by impacting their ecological functioning due to overfishing (C1.5) or low water quality adjacent to urban areas (C1.1).

The adaptive capacity elements, connectivity and ecosystem functioning, were most often mentioned as having been affected by drivers. Specifically, the role of connectivity was emphasized for all three ecosystems. Several respondents described that in case one of the three ecosystems was impacted by a driver, particularly extreme weather events (C0.4), connected coastal ecosystems were affected as well (C2.1).


*Figure 13: Word cloud concerning expert responses on the ecosystem most at risk. Largest words were mentioned most often, smallest the least (generated by QuestionPro) (Q11).*

**Do you see climate change-related drivers as a higher threat to corals compared to non-climatic drivers? (Q12):** While 12 percent did not agree, most experts confirmed that climate change-related drivers posed a greater threat to coral reefs, and that these had negatively affected ecosystem health (74%), biodiversity (62%), and ecosystem services (50%), less so conservation effectiveness and objectives (35%).

**Mangroves and seagrass beds are important to support coral reef AC (Q13):** Altogether, 97 percent of respondents agreed that both mangroves and seagrass ecosystems are essential in supporting the adaptive capacity of coral reefs. One respondent chose the option "none of the above".

**Climate change in conservation (Q14):** When asked if climate change was a concern in conservation in the country, and if so to what extent it had been addressed, experts mostly outlined that climate change was specifically (62%) or generally (26%) included in conservation policies, strategies, or plans. One participant cautioned that despite its specific inclusion its enforcement was constrained by low resources. None voiced that it was not a concern, few listed other reasons (3%), and Palauan experts said it was a concern but not addressed (9%).

**Extent of conservation being climate adaptive (Q15, Fig. 14):** Most experts agreed that conservation was climate adaptive (mean=2.44), that it supported coral reefs to face climate change (mean=2.32), and that Protected Area Networks were climate adaptive (mean=2.32).

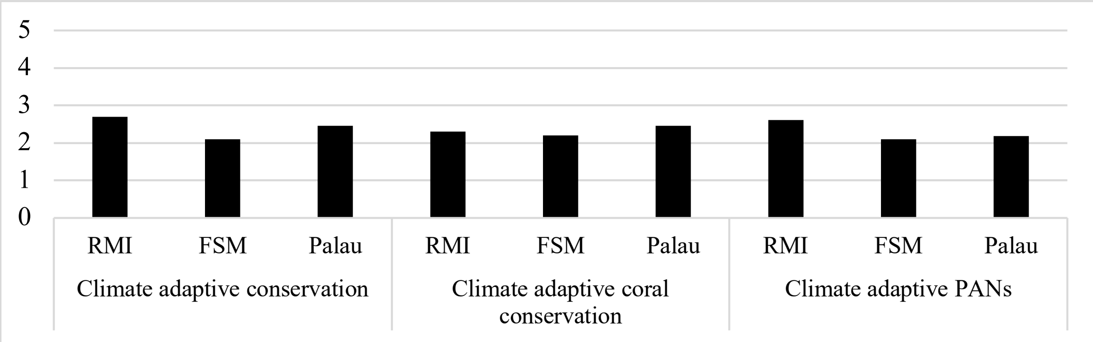



*Figure 14: Extent conservation was considered climate adaptive in the respective countries. The Y-Axis depicts the ranking for all three question options and countries. The X-Axis shows the results of the Likert scale ranking (1=Strongly agree to 5=Strongly disagree) with a mean from 2.10 (FSM) for climate adaptive conservation and PANs respectively to 2.69 (RMI) for climate adaptive conservation. (Q15).*

### 4.3.2 The climate adaptive conservation strategies in Micronesia: Extent of their effectiveness, integration, and implementation

Participants were presented with the eight climate adaptive conservation strategies and asked to what extent they considered these as effective in supporting coral reef AC (Q16). Further, to what extent they had been integrated in policies and planning documents (Q17) and ultimately implemented (Q18). Based on how many of the strategies were selected as effective, integrated, or implemented in each country, the percentage for each country was categorized according to the ranking of Table 5 (section 3.3) from very low to very high (Table 10). The following outlines the regional results of the three questions. Please refer for the country-based results of these questions to Annex IX.

| Question | Country | Mean (%) | Standard deviation | Rating of the extent of effectiveness, integration, and implementation |
|---|---|---|---|---|
| Q16 | RMI | 58 | 20,1% | Medium |
| | FSM | 38 | 19,8% | Low |
| | Palau | 69 | 12,8% | High |
| | **Regional** | **55** | 14,36% | **Medium** |
| Q17 | RMI | 38 | 22,13% | Low |
| | FSM | 34 | 26,46% | Low |
| | Palau | 45 | 25,76% | Medium |
| | **Regional** | **39** | 22,47% | **Low** |
| Q18 | RMI | 28 | 21,45% | Low |
| | FSM | 24 | 26,82% | Low |
| | Palau | 42 | 23,08% | Medium |
| | **Regional** | **31** | 20,03% | **Low** |

*Table 10: Rating of the extent of effectiveness, integration, and implementation of the conservation strategies. The table depicts country and regional-based results in relative terms. The rating is based on Table 5, section 3.3.*

As the standard deviation was lowest in Palau the values of the individual strategies selected per question lay closer to each other compared to RMI and FSM. Whereas RMI and FSM showed greater variability in their responses of the strategies.

**Extent of effectiveness of the climate adaptive strategies (Q16):** Regionally, the effectiveness of the conservation strategies in supporting coral reef AC ranked as medium (55%) (Fig. 15, Table 10). The strategy 1 “Non-climatic drivers” ranked highest (74%) compared to the strategy 5 “Heterogeneity”, which was ranked as least effective (26%).

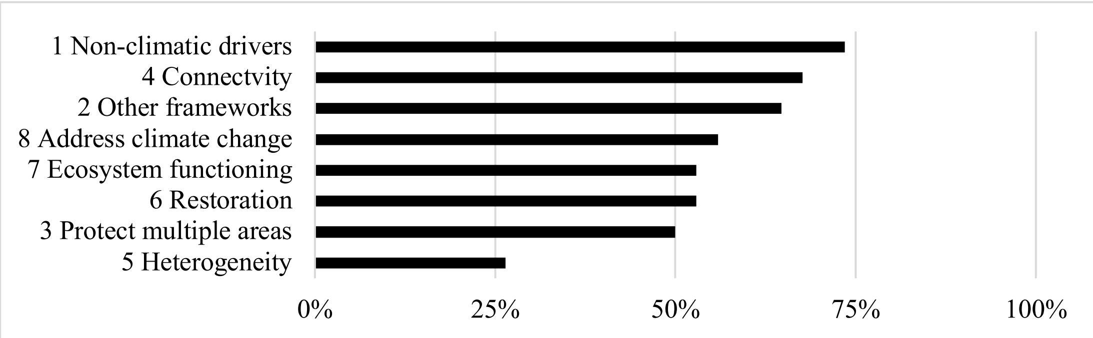



*Figure 15: Conservation strategies selected as most effective for all three countries (Q16).*

**Extent of integration of the climate adaptive strategies (Q17):** The integration of the strategies ranked regionally as low (39%) (Table 10). Only strategy 2 (82%) and 8 (53%) were selected as having been integrated to a very high and high extent. Again, strategy 5 (18%) was least selected and ranked as very low (Fig. 16).

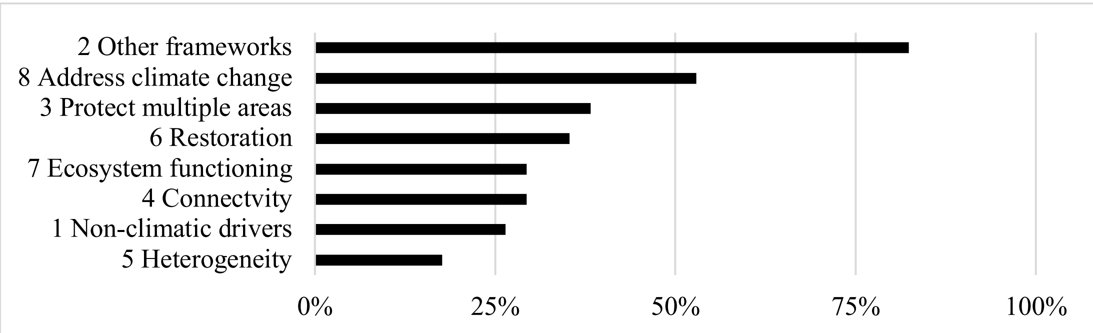



*Figure 16: Conservation strategies selected as integrated for all three countries (Q17).*

**Extent of implementation of the climate adaptive strategies (Q18):** Depending on which strategies experts selected in Q17, respondents were presented with the previously selected strategies in Q18, to further determine if they had been implemented as well. The implementation of the strategies ranked regionally as medium (42%). Again, strategy 2 ranked highest and was categorized as high (74 %), while strategy 5 was ranked as very low (12%) (Fig. 17).

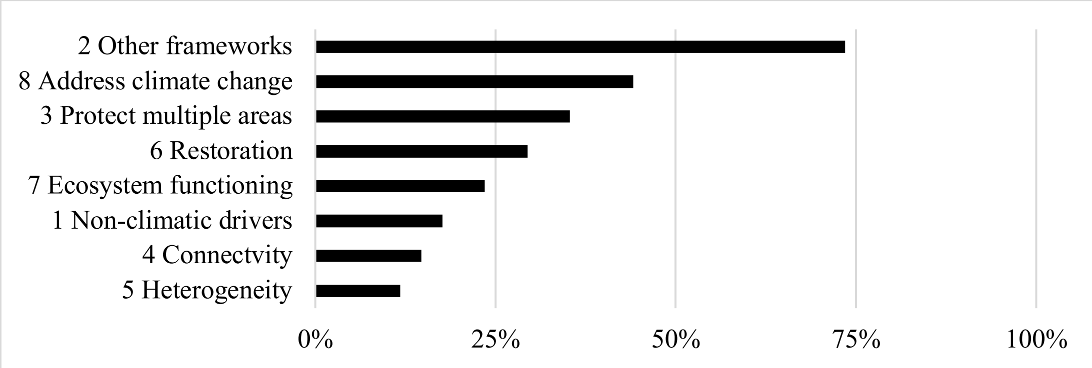



*Figure 17: Conservation strategies selected as implemented for all three countries (Q18).*

**Regional differences for question 16 to 18:** Comparing the results of the three questions, for example strategy 1 "Non-climatic drivers" was regionally ranked highest in effectiveness at 74 percent (high) its integration and implementation fell significantly short, both being the second lowest among the strategies in each question at 26 percent (low) and 18 percent (very low) (Fig. 18).

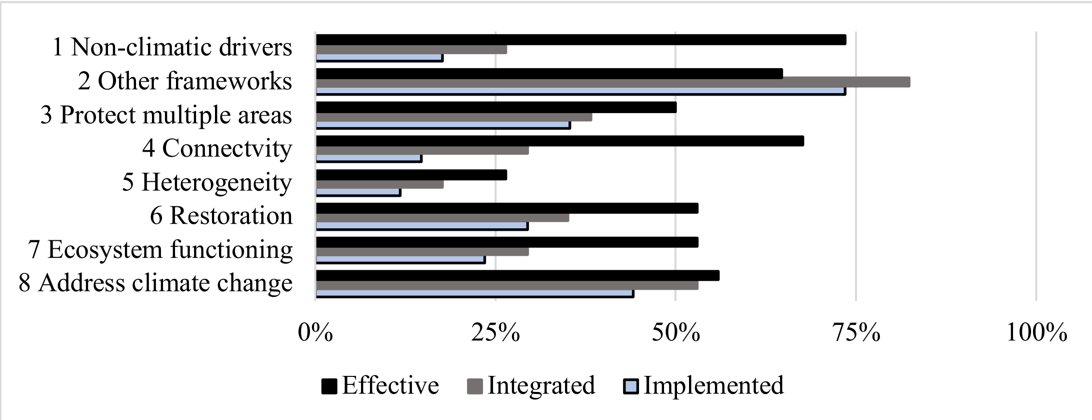



*Figure 18: Conservation strategies selected according to effectiveness, integration, and implementation aggregated for all three countries in relative terms (Q16-18).*

**Implemented conservation activities (Q19 – 26):** Based on which conservation strategies respondents selected as implemented in question 18, experts were presented with a follow-up question to each previously selected strategy. These questions listed activities for each strategy and asked which of these had been implemented (Annex IX). The quality and validity of the results of the questions 19 to 26 is limited, because the number of participants was too low to produce significant results, which is particularly apparent for this section of the survey. Two respondents gave no answers. Nevertheless, some valuable insights were gained. For example, in question 19, concerning strategy 2 "Other frameworks", Ridge to Reef (n=21) (e. g. Ridge to Reef

STAR Project[11] in FSM) and MSP (n=15) stood out and were the two most implemented approaches. An expert added that Integrated Water Resource Management (IWRM)[12] had been implemented as part of the Ridge to Reef STAR project.

**Ecological scale of the implemented conservation activities (Q28):** Activities were carried out at the ecological scale of an ecosystem (31%), targeted either species or species groups (11%), a single habitat (10%), or the land- or seascape (6%). A Palauan expert highlighted that the country´s conservation activities were often guided by the importance of a certain species and its habitat needs.

**Spatial scale of the implemented conservation activities (Q29):** Most activities were undertaken at the local scale (40%) or in multiple states within one country (33%), yet none were carried out at the regional or transboundary scale (0%).

**Broadness of the implemented climate adaptive activities (Q30):** Conservation activities were implemented at the PAN scale (29%), in individual PAs or related projects (26%), or on a broad national scale (21%), compared to only pilot projects (6%), others (6%), or on a sub-national scale (0%). Three experts gave no answer.

**Lessons learned, successful and prioritized conservation strategies (Q27.1 – Q27.3):** In the qualitative survey section, respondents gave details on implemented activities they regarded as most successful in supporting coral reef AC (n=24) (Q27.1), lessons learned (n=19) (Q27.2), and activities they would prioritize to support coral reef AC (n=26) (Q27.3) (Supp. Mat. 3). In the following the responses of the three questions were grouped under each strategy. A separate section thereafter outlines lessons learned (Q27.3).

**C3.1 Reduction of non-climatic direct and indirect (local) drivers:** Five experts recommended to prioritize this strategy (Q27.3) and another five described its success in reducing and controlling the impact of invasive alien species, specifically the Crown of Thorn Starfish (C1.3, Q27.1). Six experts would prioritize to (a) address coastal development (Q27.3) and erosion to ensure coral reef health in Palau (C1.4, Q27.2), (b) to design alternative food security measures and to address invasive macroalgae in RMI (C2.1.5, Q27.2), or (c) to address pollution resulting from urbanization on Majuro, RMI (C1.1, Q27.3). So far, these issues have been only partially addressed

[11] https://www.pacific-r2r.org/partners/member-countries/fsm?pid=103 (provided by expert)
[12] https://www.pacific-r2r.org/partners/member-countries/fsm (provided by expert)

and its success would be limited due to the increasing climate change-related risks (Q27.2). Experts from all three states prioritized addressing overfishing, by protecting functional herbivores. Reducing overfishing in or adjacent of PANs and before, during, or after El Nino events, was considered successful to support coral AC in RMI (C1.5, Q27.1).

**C3.2 Embedment within broader management frameworks:** Most respondents (n=9) listed the application of C3.2 as most successful (Q27.1), and specifically highlighted the Ridge to Reef or other integrated approaches (e. g. the "Reimaanlok" conservation process in RMI; Sustainable Fisheries management). For example, a Ridge to Reef approach helped to address conservation issues and to successfully protect reefs from pollution, sediment run-off, and coastal erosion in FSM (C1.1, C1.4, Q27.2).

Two respondents described marine conservation as insufficient and an expert from RMI stressed that conservation must be integrated and implemented together with other spatial management frameworks. Complementary to these frameworks, participants listed improved development regulations in Palau or the application of turbidity curtains for shoreline development projects in RMI, and education campaigns (C4.5, Q27.2). Seven participants prioritized C3.2 and highlighted community-based initiatives (C4.3), Ridge to Reef, sustainable land use, the establishment of MSP, or to expand and increase the enforcement of sustainable fisheries and coastal management (Q27.3).

**C3.3 Representation and replication of all ecosystems:** Multiple experts (n=9) named PANs as successful to support coral reef AC (C4.6, Q27.1). Especially approaches or tools concerning community-based conservation areas and MPAs, were regarded as most successful in FSM (C4.3, C4.4, C4.5). The protection of areas with resilient corals and identifying spawning locations in RMI, or areas with heat tolerant corals in Palau, were highlighted as successfully implemented activities, supporting coral AC (Q27.1). Reflective of the components considered as successful, the protection of coral reef climate refugia and the expansion of MPAs were also named as a priority (Q27.3). C3.3 was not mentioned under Q27.2.

**C3.4 Preserve and enhance land- and seascape connectivity:** One expert from Palau prioritized C3.4 by protecting climate refugia and areas tolerant to a higher SST, enabled to function as larval sources for adjacent impacted reefs to support coral AC

(Q27.3). An expert from RMI highlighted the importance to identify critical areas (e. g. spawning sites) by means of data on SST and currents (Q27.1).

**C3.5 Maintain land- and seascape heterogeneity:** No expert addressed C3.5 in the questions 27.1 to 27.3.

**C3.6 Restoration of ecosystems:** An expert from each state outlined the success of using resilient corals in replanting measures, and the restoration of degraded areas to ensure coral reef ecosystem functioning (Q27.1). Seven experts underlined coral reef restoration activities as priorities (Q27.3). Though, one expert cautioned that restoration must be scaled up to be effective (C4.4, Q27.1). Most often, the identification, protection, and restoration of "super" or resilient corals or restoration activities, such as the following, were prioritized: Coral reef propagation or proactive establishment of well-managed super coral nurseries, and the out planting of their fragments to strategic locations. One expert named multiple interconnected prioritized activities, such as mangrove and coral (re-)planting, protecting reefs, and monitoring marine species and habitats (Q27.3).

**C3.7 Maintain ecosystem processes and ecological functioning:** One expert mentioned C3.7 indirectly as a successful activity (Q27.1). Two experts prioritized C3.7 to protect areas and species key to healthy ecosystems and to give reefs time to recover (Q27.3).

**C3.8 Knowledge of and addressing climate change-related drivers potentially impacting coastal ecosystems:** The use of climate information to monitor and identify resilient reefs were listed as successful in RMI, or the increase of education and public awareness on and support for climate change actions in Palau and RMI (C4.3, C4.5, Q27.1). Respondents underscored the application of the precautionary principle and highlighted the success of reef surveys providing key information to enhance coral AC across atolls (C4.2, Q27.3). An expert cautioned that more climate change studies are necessary to enhance coral reef recovery following bleaching and to increase reef monitoring capacities to identify impacted reefs sooner (C4.2, Q27.2, Q27.3).

**Lessons learned (Q27.3, Fig. 19):** While some responses were heterogenous, challenging the assignment of each response to a specific code, several patterns emerged and are outlined in this section. Lessons learned mentioned in Q27.2, but not directly linked to a strategy, were grouped in this section as well.

The role of local communities and traditional knowledge was frequently mentioned (C4.3, Q27.2), and had been increasingly integrated by communities in conservation activities, adapted to the local environment, in Palau. Contrary, another Palauan PAN expert cautioned that no lessons were learned regarding traditional knowledge in the context of conservation. Thus, experts emphasized (a) to include traditional knowledge to enhance the effectiveness and implementation of CCA in affected communities in Palau, (b) to acknowledge the importance of implementing an inclusive conservation design to enable community participation and management of their own resources in FSM, and (c) to focus on and to increase awareness of the role of women in decision-making and resource use.

Resources and capacities were another concern (C4.2), experts described that (a) sustainable financing was key for the creation and effectiveness of a PAN in Palau (n=2; C4.1) and urged (b) to transfer the management of funds to NGOs as delayed payouts by the National Government postponed activities in FSM, as well as (c) to provide additional technical capacities at the local level to safeguard continuity in RMI (C4.3), and (d) to enhance monitoring capacities to enable early detection of coral reef bleaching risk in Palau (C3.8).

On a policy and planning level an expert summarized that biodiversity mainstreaming was insufficiently integrated in planning documents. Also, conservation and climate change, as well as "blue growth" have not been integrated in RMI (C4.4). In addition, under C3.8 an expert emphasized the limited effectiveness of local conservation activities concerning climate change, and the importance to reduce emissions fast to tackle climate change (Q27.1).

A key researcher, previously cited in this thesis, gave considerations on the concept of AC. The expert detailed that adaptive conservation would not be applicable to Micronesian reefs, particularly on low-lying islands. Reef AC was poorly defined and unmeasured in RMI, especially at the community level. This issue would inhibit any kind of monitoring or measuring of success or failure of implemented activities targeting the AC. Whereas, the expert added that conservation through MPAs and community-based areas could enhance reef persistence and ecosystem service provision, theoretically and as evidenced at different levels in RMI (C4.3). In addition, most outer atolls managed their reefs sustainably and were exposed to few non-climatic drivers. While the researcher considered that addressing sewage and waste disposal on the reefs surrounding Majuro could make a positive difference (C3.1), yet

it would not affect the potential impacts reefs are facing from climate change-related drivers. This was supported by an expert outlining that local agency to address reef degradation due to SST changes and flooding was low.
Finally, one participant described that either no lessons have been learned, and if so, that they have not translated into action.


*Figure 19: Word cloud for the question 27.3 on lessons learned (created by QuestionPro).*

**Challenges for the implementation of the climate adaptive conservation strategies (Q31):** Participants were asked to select three main challenges. Among others, the challenges were based on conversations with a regional expert, and the researchers previous research in Fiji. Most participants selected “resources” (including financial or technical) (68%) and “staff capacities” (59%) (Fig. 20).

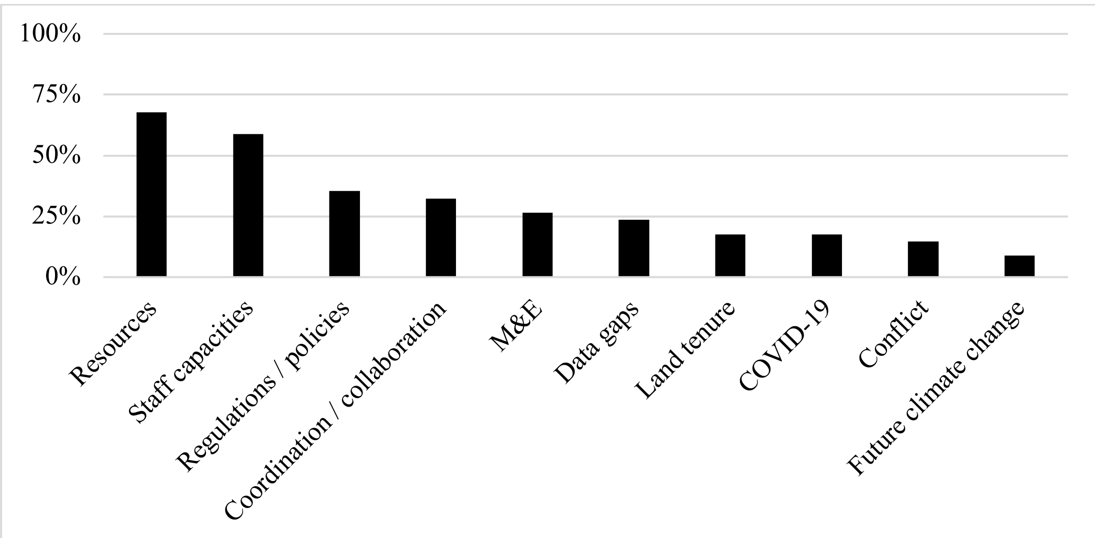



*Figure 20: Challenges of implementing climate adaptive conservation strategies. The X-Axis shows the relative values from 0 to 100 (%). The Y-Axis depicts the regional results of the selected challenges from high (left) to low (right). Four experts gave no answer. M&E = Monitoring and evaluation (Q31).*

Comparing the three states, differences become considerable for several challenges. For example, “Legislation, regulations and policies” was a challenge, both in Palau (64%) and FSM (40%), compared to RMI (8%). Concerning data gaps, an expert from FSM reported that the application of the precautionary principle has been recommended but limited resources have prevented monitoring thus far. Under “land tenure”, a respondent from FSM added that land tenure systems in the state of Yap and Chuuk challenged an implementation, as most reefs were privately owned.

**Key next steps to make conservation climate adaptive (Q32):** Most experts (63%) highlighted “Mainstreaming and upscaling of climate adaptive conservation activities, pilot projects, and programs” as a key next step to make conservation climate adaptive in their respective countries. This stood in contrast to experts (26%) selecting “Integration of conservation strategies that address climate change risks into policies and planning documents”. One expert highlighted that both were equally needed.

**Confidence of survey answers given (Q33):** Altogether, experts were very confident (6%), confident (56%), or moderately confident (29%), and three experts gave no answer here.

### 4.3.3 Validation according to the extent of effectiveness, integration implementation of the selected climate adaptive conservation strategies in Micronesia

The survey, among other components, aimed to validate the list of climate adaptive conservation strategies through experts and to determine to what extent these strategies have been integrated and implemented in the case study region. This step was helpful to empirically validate the relevance and potential effectiveness of the theoretical strategies in supporting the adaptive capacity of an ecosystem, exemplified with coral reefs (Bernard 2006). The following figure (21) gives an overview according to this outline and the aggregated results for the three countries of the survey. Strategies that were ranked as very low were excluded from this graph. According to the ranked responses of the regional results, three strategies were considered highly effective, three to a medium, and two to a low extent (Q16). Contrary, only strategy 2 “Other frameworks” was considered as highly integrated, heterogeneity was excluded based on its very low rating (Q17). Five of eight strategies were ranked as implemented (Q18).

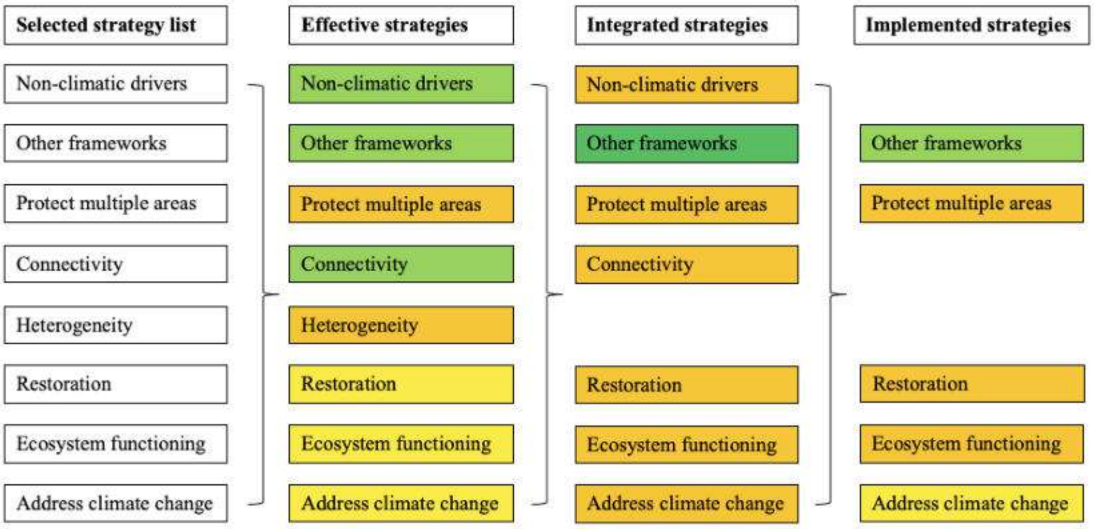



*Figure 21: Overview on the extent of effectiveness, integration, and implementation of the selected climate adaptive conservation strategies. First, from left to right, the selected strategies, second the strategies selected as effective by the experts (Q16), and third the strategies selected as integrated (Q17), and fourth as implemented (Q18). The strategies in the second and third row were included, when these rated as low (20-40%, orange), medium (40 to 60%, yellow), or high (60-80%, green).*

# 5. Discussion

This chapter discusses the key findings of this thesis, divided into four parts, and puts these into a broader perspective to answer the main research question of this thesis: ***What conservation strategies and related actions support the adaptive capacity of coral reef, seagrass bed and mangrove ecosystems, and to what extent does this help them face potential climate change-related impacts in three states in Micronesia?***

To answer this research question, the conceptual social-ecological systems framework for this thesis was assembled in the theoretical chapter (section 2.2). Thus, the two key components for this research were identified, first the ecosystem AC elements, and second the climate adaptive conservation strategies, that support the ecosystem AC and its elements. Correspondingly, this research defined the adaptive capacity of ecosystems, to identify and select AC elements it is composed of (section 4.1). Followed by the selection of the conservation strategies and related actions that support these elements, and thus the overall ecosystem AC (section 4.2). These findings were discussed in the context of differences in theory and implementation in practice, as well as by analyzing the role of the selected strategies in supporting ecosystem AC. This step was helpful to address the **first sub-research question**, which is discussed in section 5.1.1.

By questioning Micronesian experts (section 4.3), on the extent of the effectiveness of the selected climate adaptive conservation strategies, this research aimed to validate the selected theoretical strategies. It further examined the results according to the extent of the implementation of the climate adaptive strategies. Further, this step aimed to give insights to what extent the strategies can help the three ecosystems, exemplified with coral reefs, to face potential climate change-related impacts in Micronesia. These results are discussed in section 5.1.2 and helped to answer the **second and third sub-research question**.

After corresponding challenges for the implementation of the strategies are examined, the chapter concludes with several recommendations to enhance the implementation of the climate adaptive strategies in Micronesia (section 5.1.3). Finally, the chapter completes with a critical reflection of the research methods and the transferability of the results to other contexts (section 5.2).

### 5.1 Discussion of results

In this section, the first part of the main research question is addressed by outlining, ***what conservation strategies and related actions support the adaptive capacity of coral reef, seagrass bed and mangrove ecosystems.*** Ultimately, this analysis concludes with outlining general recommendations on how ecosystem adaptive capacity can be enhanced to increase the success of conservation under increasing climate change-related impacts.

#### 5.1.1 The adaptive capacity of ecosystems and options to support it

Accordingly, this section summarizes these findings to answer the first sub research question of this thesis: ***How is the adaptive capacity of ecosystems defined in the academic literature, and what are options to support it?***

As noted through the primary literature review, there was a remarkable gap in the literature concerning the understanding of the adaptive capacity of ecosystems (Seaborne et al. 2021). This became particularly apparent through a structured literature review, providing few returns for ecosystem AC, and the three selected elements (section 4.1). Since the literature review was not the focus of this thesis, it did not review all publications in-depth. However, the articles that were analyzed rarely addressed ecosystem AC, and if so, the publications displayed significant variations in its meaning and definitions (Angeler et al. 2019). Thus, there is more research needed to understand ecosystem AC as emphasized by Seaborne et al. (2021). Focusing on ecological AC and conservation, the scholars highlighted that if AC was addressed, it mainly focused on species but not ecosystems.

The definition of ecosystem AC has further been challenged by an inconsistent understanding on how and to which form of resilience the concept relates to (Angeler et al. 2019). Several scholars understand it as the capacity to sustain the ecological resilience of a system undergoing change (Stein et al. 2013; Angeler et al. 2019), while its state and functions are maintained. However, scholars cautioned that strategies that focused on resilience are insufficient or unable to prevent system changes since ecosystems are already transitioning (Stein et al. 2013; Van Kerkhoff et al. 2019). Thus, further research and dialogue is necessary to delineate both resilience and ecosystem AC.

Particularly, since ecosystem AC is relevant for and applied mostly interdisciplinary, a coherent definition across research fields is key (Seaborne et al. 2021). Thus, further research needs to be conducted to enhance its understanding and effective application in interdisciplinary research (Whitney et al. 2017), as well as to enable its operationalization in conservation practice. In this regard, Seaborne et al. (2021) suggested to utilize a SES approach and connect ecologists, conservation and social scientists, as well as systems theorists to define ecosystem AC for conservation. Since the suggested definition of ecosystem AC in this research (based on IPCC 2019b, section 1.3) stems from SES research, it can potentially serve as a first step to further harmonize this interdisciplinary research to enhance the uptake of ecosystem AC in conservation.

A clear definition of what elements ecosystem AC is composed of could help to address some of the conceptual challenges outlined previously. It could further aid the selection of climate adaptive conservation strategies to support the overall adaptive capacity of an ecosystem. However, very few empirical studies on ecosystem AC and its elements were found in the literature, indicating a significant gap regarding empirical work (McLeod et al. 2015; Angeler et al. 2019). For example, scholars underline the significant challenge to compare or standardize metrics of environmental heterogeneity across different systems (Seaborne et al. 2021).

While species AC traits are well defined, established and empirically tested (e. g. in vulnerability assessments), research advances on ecosystem AC have been limited (Petersen et al. 2018; Abram et al. 2019). This is likely due to the complexity of variables relevant to study ecosystem-level AC, limitations in data, and a lack of integration of ecology and climate science (Tittensor et al. 2019).

Some scholars further highlighted difficulties to separate ecosystem AC into specific elements and to delineate these from species-level AC, because both are interconnected across ecological scales (Whitney et al. 2017; Petersen et al. 2018). Nevertheless, scholars urge to focus on ecosystem-level AC, as it is a more cost-effective, practical, and robust concept for conservation planning (Petersen et al. 2018; Gladstone-Gallagher et al. 2019).

Corresponding to these findings, scholars have highlighted the benefits of applying a SES framework with a focus on ecosystem AC to define and operationalize climate adaptive conservation measures (Seaborne et al. 2021). However, if SES frameworks addressed ecological AC it was focused on species (Petersen et al. 2018). Whereas, within the literature review no specific comparable articles could be found that addressed ecosystem AC and its elements within a SES specifically. The SES framework of Seddon et al. (2019) was one of the few that focused specifically on ecosystem-level AC and defined its elements (section 2.2).

In the literature, researchers highlighted that many ecosystem functions and processes remain poorly understood (Groves et al. 2012), challenging an enhanced understanding of the respective ecosystem AC elements in theoretical and empirical ecology and thus its applicability for conservation planning.

Thus, while the descriptive literature analysis of this research focused on defining and understanding the components that are important to each ecosystem AC element in theory, it became clear that differences in theoretical definitions (e. g. spatial connectivity) and many research gaps remain. Because while ecological processes may be explainable to a greater extent in theory, empirical studies of these concepts, and a lack thereof, signified the complexity of understanding the ecosystem AC elements and the ecological processes involved (Bernhardt & Leslie 2013). For example, in the context of different environments, micro-habitats, species communities, and how these components interact to ensure connectivity, heterogeneity, and ecosystem functioning (Alsaffar et al. 2020). Empirical studies on connectivity, such as in and across tropical lagoon habitats have been mostly based on fish and mobile fauna, whereas other key ecological patterns of connectivity have been studied to a very limited extent (Alsaffar et al. 2020; Peterson et al. 2020). Such knowledge gaps limit an enhanced understanding of ecosystem adaptive capacity and hinder the ability to operationalize ecosystem AC, and its elements, for conservation.

Nevertheless, scholars have emphasized that supporting the AC of ecosystems through conservation can help these be better equipped to face potential climate change-related impacts (McLeod et al. 2019). However, the structured review in this thesis confirmed a significant gap in the academic literature concerning the integration of both CCA and conservation, with only four focusing on marine or coastal ecosystems, and none on the Pacific (Annex Ia). One reason, this research detected, could be that some conservation scholars continue to apply a definition of vulnerability (IPCC 2007, e. g. Anthony et al. 2015; Seddon et al. 2019), that is considered outdated in the field of CCA (IPCC 2019b), and that defines adaptive capacity differently. This definition is further applied in related contexts that inform conservation, for example in a coastal climate change vulnerability assessment in RMI (Crameri & Ellison 2022). The application of inconsistent definitions likely impacts the ability of researchers and decision-makers to effectively integrate climate change adaptation and conservation.

Recent studies have shown that CCA is included to a limited extent in conservation policies, planning documents (Wilson et al. 2020) or management plans globally (Tittensor et al. 2019; O´Regan et al. 2021). Considering this gap, this thesis identified eight climate adaptive conservation strategies and proposed 26 non-exhaustive exemplary activities, primarily aimed at tropical coastal ecosystems, that can support one or multiple of the three selected ecosystem AC elements to enhance the overall ecosystem AC (section 4.2 & Annex III).

Several of the selected documents this research identified focused on coral reefs and provided recommendations for the climate adaptive design of MPAs and marine PANs. A review of Wilson et al. (2020) confirmed that most studies that addressed CCA have targeted conservation planning for coral reef MPAs. This is understandable, since particularly coral reefs are impacted by increasing impacts of climate change that require effective and climate adaptive conservation (McLeod et al. 2019).

While the selected strategies often targeted ecosystem AC, they often did not name it specifically, but either focused on resilience (e. g. social and/or ecological) or applied inconsistent definitions and conceptualizations of both concepts (McLeod et al. 2019). Yet many strategies the authors proposed supported ecosystem AC, even if it was not labeled as such.

Among the 11 documents, authors mostly addressed the ecosystem AC elements connectivity and ecosystem functioning, highlighting the role of ecological connectivity for climate adaptive conservation in marine PANs (Gladstone et al. 2009; Carr et al. 2017; Tittensor et al. 2019). Because in a coastal seascape the ecological spatial connectivity of mangroves, seagrass beds and coral reefs, is significantly more relevant to maintain viable populations and ecosystem functioning, compared to other settings (Albert et al. 2010; Weeks et al. 2017). Other scholars criticized that connectivity has been overemphasized concerning its ability to improve ecosystem AC under a changing climate (Hodgson et al. 2009; Oliver et al. 2012), particularly in marine conservation where some habitats are isolated from each other (Maxwell et al. 2020). This is also the case in Micronesia, where due to the region´s biogeographic complexity some habitats, though spatially close, are highly isolated (Colin 2009; Ellison 2009; Muller-Karanassos et al. 2020).

It was further criticized that recommendations rarely built on empirical ecological connectivity data that incorporated climate change considerations and was thus regarded as effective to a limited extent to support climate adaptive conservation (Rilov et al. 2019). Instead, scholars deemed ensuring environmental heterogeneity and reducing non-climatic drivers as more effective to address climate change in conservation (Hodgson et al. 2009). Rilov et al. (2019) argued that these conflicting views highlight that further discussion on the role of connectivity in the context of climate adaptive conservation is needed.

Environmental heterogeneity has been recognized to increase the AC of an entire conservation network and requires fewer resources and data, which is particularly advantageous in regions lacking these (Rilov et al. 2019). For example, scholars proposed to protect areas of islands with steep slopes (McLeod et al. 2009) as these offer habitats across environmental conditions. Despite this recognition, this ecosystem AC element was least included in the CCA options of the 11 documents (Barkley 2011; McLeod et al. 2019). Also in practice, heterogeneity has been integrated to a lesser extent as a CCA strategy in MPA design and planning. Only 22 percent of case studies, reviewed by Wilson et al. (2020 p. 3259), had integrated the concept by protecting areas across gradients of climate heterogeneity.

So far there is still a considerable gap between what strategies are theoretically recommended compared to what is empirically tested, integrated, and implemented practically. Reviews on the integration of climate adaptive strategies in MPAs and MPA networks detected only very few, mostly unimplemented examples (Tittensor et al. 2019). If climate adaptive strategies were integrated, it was mostly in isolation and less so in conjunction with other strategies (Wilson et al. 2020), even though particularly their combined application is considered effective. Yet, the screening of the publications citing McLeod et al. (2009) found that suggestions on climate adaptive marine and coastal conservation were mainly focused on connectivity.

Altogether, only one article of the 11 documents outlined the implementation of the strategies in a case study. This publication (Weeks & Jupiter 2013) matched with one of six globally implemented examples Tittensor et al. (2019a) identified.

Concerning the selected climate adaptive conservation strategies, scholars describe a multitude of challenges that could further explain the low degree of implementation of these, which can include but are not limited to: (1) A lack of empirical evidence how said climate adaptive strategies enhance ecosystem AC (Tittensor et al. 2019; Wilson et al. 2020), (2) no concrete guidance on how to prioritize strategies (Oliver et al. 2012; Anthony et al. 2015; Weeks 2017; Thiault et al. 2018), as well as a lack of flexible or enabling policy environment (Wilson et al. 2020), (3) a high uncertainty on how ecological systems fair under a changing climate (Rilov et al. 2019), and (4) a lack of knowledge of and challenges to define and measure ecosystem AC (Angeler et al. 2019).

Considering the latter one, an expert of the survey, an associate professor for conservation science, detailed "that the idea of adaptive conservation does not really work for Micronesia's reefs, especially for the low-lying islands. [..] Adaptive capacity of reefs remains poorly defined (esp at the community scale) and unmeasured - so it is hard to imagine how we would even monitor any success or failure of these activities". This statement confirms the disconnect of the theoretical ecosystem AC concept and challenges concerning its operationalization, relevance and understanding in conservation practice. It reinforces that further research is necessary to understand ecosystem AC.

Altogether, concerning the first sub-research question, in the absence of a single, broadly accepted, coherent or applied definition of ecosystem AC and its elements, it is thus not feasible to concisely answer the first sub-research question. In contrast, these research findings pose the question why such a significant gap in the academic literature concerning the ecosystem-level adaptive capacity exists.

Yet, despite the need for more research and empirical evidence, as well as theoretical challenges that must be overcome, the findings of this research indicate, concerning the main research question, as outlined by multiple scholars, that the selected strategies can help the coastal ecosystems recover from and adapt to change (McLeod et al. 2019).

### 5.1.2 From the effectiveness to implementation of the climate adaptive conservation strategies in Micronesia

The following section discusses the extent of the effectiveness, integration, and implementation of the selected climate adaptive conservation strategies in supporting coral reef AC in Micronesia, according to the survey results of question 16 to 18. It further compares the effectiveness with the extent of the implementation of the selected climate adaptive conservation strategies in Micronesia. These steps helped to answer the sub-research questions two and three:

***Which conservation strategies support the adaptive capacity of coral reefs in three Micronesian states?***

***To what extent are the climate adaptive conservation strategies implemented in the three states?***

The choice of coral reefs, as an exemplary ecosystem, to answer the main research question, and to validate the climate adaptive strategies concerning their effectiveness in supporting coral reef AC, appeared justified since 97 percent of experts confirmed that corals were most at risk from climate change (Q11). Additionally, climate change-related drivers were considered a greater threat compared to non-climatic drivers with 74 and 50 percent of experts stating that it had negatively impacted the ecosystem health and ecosystem services provision of coral reefs, respectively (Q12). These findings highlight that the impact of climate change-related drivers negatively affects both the social and ecosystem sub-system.

Altogether, the survey findings concerning non-climatic (Q8) and climate change-related drivers (Q9) aligned well with the literature findings. For example, SST changes (59%) was considered as the climate change-related driver with the single greatest negative impact on coral reefs, specifically in RMI and FSM (Q10). Extreme weather events (29%) had mainly caused negative impacts in Palau. Researchers at the Palau International Coral Reef Center supported this finding and reported that coral reefs have been negatively affected by super typhoons (Gouezo et al. 2015). The experts affirmed research findings (McKenzie et al. 2021) by reporting that an increase of the regionally highly heterogenous driver “changing rainfall” had negatively affected the ability of seagrass beds and mangroves to buffer sediments in turn negatively impacting reefs (Q11). Experts underlined that these drivers had adversely impacted the ecosystem AC elements connectivity and ecosystem functioning of the three ecosystems. These findings highlighted again that in a coastal seascape, ecosystems are tightly linked, and effective coral protection necessitates its conservation along with mangroves and seagrass beds. This was verified by 97 percent of experts emphasizing that both seagrass beds and mangroves are critical for coral reef AC (Q12).

Concurrently, experts were asked which of the theoretical conservation strategies they considered effective to support coral reef AC. Altogether, based on the survey findings, the second sub-research question can be answered, outlining that most experts considered multiple strategies as effective (Q16) to support coral reef AC in Palau and RMI, while in FSM effectiveness was comparatively low.

According to the survey findings, three strategies were effective to a high extent, particularly 1 "Non-climatic drivers" with 74 percent. Regionally, the selected strategies are effective to a medium extent (56%) in supporting coral reef AC (Table 10). Being 4 percent short of a high rating and because overall most strategies were ranked as effective in supporting coral reef AC in Micronesia, it validated that the synthesized list of conservation strategies has relevance for climate adaptive conservation, exemplified with coral reefs, in Micronesia. It further, validated all selected strategies, except for strategy 5. Yet, more research is needed because it must be considered that the significance of these findings is limited due the small sample size.

Nevertheless, the relevance of these climate adaptive strategies was also confirmed by several examples where these conservation strategies, or parts thereof, have been integrated or addressed for conservation planning in the region. For example, in a workshop local experts chose multiple of the selected strategies for Pohnpei´s PAN design (TNC 2014), for a MPA in FSM (Weeks et al. 2016), and for the (re-)design of PANs in Palau (Hinchley et al. 2007). Yet little information could be found on the extent of their integration, practical implementation, or evaluation. Parts of the strategies were further included in the objectives of the National Biodiversity Strategy and Action Plan of FSM to support climate change resilience in PAs (Hall 2020), and in Palau´s action plan in form of guiding principles to strengthen social-ecological resilience to potential climate change-related drivers (PCS 2016).

When comparing responses among countries, the strategies ranked low in effectiveness in FSM compared to medium, almost high (58%) in RMI and high (69%) in Palau (Table 10). Concerning, the main research question, this would indicate that overall, the identified strategies are to a low extent effective in supporting coral reef AC in FSM. Whereas they are effective to support coral AC in RMI and Palau.

According to the effectiveness in supporting coral AC, strategy 1 “Non-climatic drivers” ranked highest regionally and was the only strategy all three country experts considered effective to a high or very high extent. Its high ranking coincides with the findings of the literature and the survey, both viewing non-climatic drivers as threats to coral reefs that reduces its ability to face potential climate change-related drivers in Micronesia (Q8). Such as coastal pollution that can exacerbate the impacts of acidification on marine ecosystems (Billé et al. 2013). In RMI a greater inter-site coral heterogeneity and increasing isolation of reefs was caused by non-climatic drivers (Houk & Musburger 2013). Such drivers have further led to structural coral community changes (Donner & Carilli et al. 2019), and a lower abundance of competitive, stress-tolerant and generalist coral species, which are considered essential to maintain coral reef AC (Darling et al. 2019).

Evidently, tackling non-climatic drivers was considered central by experts and scholars to maintain coral AC and to help these be better equipped to face climate change. For example, research has proven that addressing such drivers can improve the capacity of corals to fair better under acidic conditions (Jury & Toonen 2019). Respondents urged to address particularly pollution and overfishing (Q11). In Palau this was done, for example by creating buffer zones around MPAs (Gouezo et al. 2015) or restoring water quality, such as in Yap (Weeks et al. 2016) (Activity 5).

Contrasting to this recognized importance of addressing non-climatic drivers, the survey findings showed a significant gap between effectiveness and implementation. Particularly in Palau where 73 percent of experts considered it as relevant, yet its implementation remained minimal at 9 percent. With its regional integration (26%) and implementation (18%) ranking among the lowest of all selected strategies.

Opposing, the strategy 5 “Heterogeneity” was considered effective to a very low (FSM), low (RMI) or medium (Palau) extent. Overall, it received low to very low rankings in question 17 and 18 and was considered as not implemented (0%) in FSM. This finding is not surprising, as heterogeneity was also included to a lesser extent in the strategies (n=6) of the 11 documents. However, scholars highlighted its relevance for effective coral conservation in Micronesia, where small-scale spatial heterogeneity is a distinct feature of some coral reef communities (Maragos-Williams 2011) resulting in reef clusters that exhibit a variable adaptive capacity to climate change, such as in Palau (Barkley 2011). Yet, the low expert rating could be explained due the fact that in conservation practice it is often not feasible to assess, plan or manage for such a fine-scale heterogeneity. Since this would require protecting, for example in an atoll lagoon system, almost the entire atoll (Pante et al. 2006).

Regionally, strategy 4 "Connectivity" was considered the second most effective strategy to support coral reef AC with a high extent (68%). While it was regarded as less relevant in FSM (40%) compared to RMI (77%) and Palau (82%).

Despite its lower rating in FSM, scholars highlighted the importance to understand and manage regional cross-border reef connectivity, such as between RMI and FSM (Richards 2014). However, considering that according to the survey respondents, conservation activities are undertaken at a local scale (40%) and none at a regional or transboundary scale (Q28), this may not be practical in the region.

Generally, scholars concur with these survey findings and consider connectivity as highly relevant for a successful climate adaptive coral reef conservation (Rivera et al. 2022). In Palau, a case study from the Babeldaob Watershed Alliance illustrated that protecting the connectivity between the coastal ecosystems had a positive effect on reef capacity to respond to climate change-related drivers (Victor et al. 2004; Golbuu et al. 2007). Also, the exposure to chronically higher temperatures and high coral diversity supports a species selection with a higher thermal tolerance, such reefs can replenish more heat stress sensitive reefs that are connected and nearby in Palau (Barkley et al. 2017; Rivera et al. 2022). Concerning the highly ranked risk of coral bleaching due to a higher SST (Q10 & 11), identifying, and ensuring connectivity of such source sites with other coral habitats is thus highly relevant in Micronesia. However, despite these positive findings further research is needed (e. g. on currents) (Foley et al. 2010), since an expert cautioned that based on the connectivity to larvae sources recovery following bleaching events was variable in Palau, which was also observed in Palau (Gouezo et al. 2019).

In addition, its integration (29%) and implementation (15%) among the states remained minimal and underlined a gap between considered effectiveness and implementation. This difference was particularly stark in RMI where 77 percent of experts considered the strategy as effective in supporting coral AC, yet its implementation fell significantly short at 8 percent.

Of all strategies, only strategy 2 “Other frameworks” was implemented to a high extent on a regional and country-based scale. Both its integration (82%) and implementation (74%) slightly surpassed its regionally rated effectiveness (65%). Accordingly, one of its corresponding activities, the application of the Ridge to Reef approach, was the activity most often selected as implemented (62%) regionally. This was supported by nine respondents describing it as a successfully implemented approach that supported coral AC (Q27.1). Particularly, in highly interconnected social-ecological island systems in Micronesia (Weeks & Jupiter 2013; McMillen et al. 2014), integrated approaches such as Ridge to Reef have been widely recognized as key for effective conservation (Hall 2018).

Aiming towards implementation, experts provided valuable insights on which climate adaptive activity they would prioritize (Q27.3). Even though, responses were heterogeneous among experts, as most experts highlighted the risk of coral degradation and mortality from bleaching, respondents prioritized the following activities: (1) To identify and protect heat tolerant or resilient reefs and potential refugia (Strategy 3, Activity 10), (2) to enhance coral reef restoration and its monitoring (Strategy 6, Activity 17 & 18), (3) to focus on key functional groups to maintain ecological functions (e. g. herbivores) (Strategy 3, Activity 8), (4) to address unsustainable fishing (Strategy 1, Activity 2), and (5) to conserve areas in form of multiple use MPAs (Strategy 2, Activity 7). These findings aligned with several research priorities and recommendations of scholars for the region (e. g. Weeks 2017; Adams et al. 2021).

Altogether, while experts considered multiple strategies as effective in supporting coral reef AC (Q16), significantly less of these strategies have been integrated (Q17) and implemented in Micronesia (Q18). According to both country-based and regional aggregated responses the extent of integration and implementation of the strategies ranked low to medium (Palau) (Table 10). Thus, to answer the second and the third sub-research question, the findings indicate that the extent to which the conservation strategies have been implemented, appear insufficient to support the adaptive capacity of coral reefs in RMI, FSM, and to a lesser extent in Palau.

Despite the low rating of the integration and implementation of the climate adaptive strategies, experts rated conservation generally, of coral reefs, and PANs as climate adaptive (Q15). Hence, further research would be recommendable to further comprehend what conservation practitioners understand under climate adaptive conservation in the region, and to potentially adjust the suggested strategies to the local social-ecological context and conservation priorities.

### 5.1.3 Challenges and recommendations regarding the implementation of the climate adaptive conservation in Micronesia

Building on the preceding parts of this chapter, this section discusses challenges for the implementation of the climate adaptive conservation strategies, and closes by providing recommendations to enhance their implementation, before summarizing the key findings of this thesis.

**Challenges for the implementation of climate adaptive conservation strategies:**
The survey findings provide several key challenges that must be overcome to advance the low extent of implementation of the climate adaptive conservation strategies and activities (Q31). Participants determined particularly (1) resources (68%) (including technical and financial), (2) staff capacities (59%), and (3) legislation, regulations, or policies (35%), as main challenges. Whereas the issue that climate change is being perceived as a challenge in the future was viewed as of least concern (9%).

Specifically, limited resources and capacities appeared to restrict the implementation of the strategies and activities and were generally frequently mentioned throughout the survey. For example, an experts detailed that constrained resources and gaps in monitoring and evaluation of coastal ecosystems inhibited the identification of risks to these systems.

The literature findings from the case study further confirmed the challenges experts listed. Despite several tremendous national and regional conservation initiatives (Hall 2018), limited capacities and resources continue to hinder the implementation of national conservation targets and efforts, as well as climate change studies of the coastal ecosystems (NEPC 2019). Thus, constraining a climate adaptive and effective conservation of coastal ecosystems across Micronesia.

For example, many protected areas lack management plans to guide activities to achieve defined conservation objectives (Miles et al. 2020). Further, established conservation areas are often unevenly distributed, which limits their effectiveness, and the representation and risk spreading of ecosystems (MAFE 2019). As voiced by an expert, this is particularly the case in FSM where tenure systems inhibit the establishment of PAs (SPREP 2019). Where measures are in place, effectiveness is additionally restricted due to minimal compliance and enforcement, as described by another survey participant. Outdated legislation and gaps in law enforcement and policies further exacerbate the situation (Spooner et al. 2017; Miles et al. 2020), which according to the findings appeared to be a particular challenge in Palau. For example, while most of Palau's marine environment is protected, none of its coral reefs are sufficiently conserved to ensure the viability of this ecosystem (NEPC 2017). Similar trends were also observed in RMI and FSM (Houk et al. 2015).

These challenges further affect the tackling of non-climatic drivers. For example, overfishing is often not mitigated, especially in coastal reefs, and conservation areas are either insufficiently protected or too small to effectively conserve coastal reefs (NEPC 201).

In addition, resources for conservation, for example for scientific research on the state and health of coastal ecosystems (NEPC 2017), including coral reefs (Richards 2014; OEPPC 2017; Moritz et al. 2018), and specifically seagrass beds in RMI and FSM (Annex Ib), are missing.

Most countries lack comprehensive monitoring systems and reliable high-quality climate, environmental, biodiversity, and risk data at local scales (Colin & Johnston 2020). Scholars caution that the lack of such information hinders the undertaking and consideration of climate change vulnerability assessments to inform climate adaptive conservation and prioritized activities (e. g. climate change risks in heterogenous reef systems), as well as studies on the adaptive capacity of ecosystems (Spooner et al. 2017; Andrew et al. 2019; Colin & Johnston 2020). Hence, limited resources and capacities hinder both the implementation of effective conservation, as well as to understand and effectively address climate change-related drivers that coastal ecosystems are facing.

**Recommendations to enhance the implementation of the climate adaptive conservation strategies:** Based on the research findings the following section provides several exemplary non-exhaustive recommendations to advance the implementation of the climate adaptive conservation strategies to support the ecosystem AC in general, and the AC of coral reefs in Micronesia specifically.

**Mainstream and upscale climate adaptive conservation efforts:** The experts considered this as a key next step to make conservation climate adaptive in Micronesia (Q32). It is thus recommendable to support the mainstreaming and upscaling of climate adaptive conservation activities in Protected Area Networks, as well as pilot projects, and programs at the ecosystem or land- and seascape-scale. This can be done, for example by:

- Prioritizing the strategies and activities that experts ranked as most effective or as a priority for implementation, upscaling, and mainstreaming.
- Collecting empirical evidence on the effectiveness of the individual strategies in supporting coral AC, and its elements, to facilitate knowledge-based decision making (Miles et al. 2020). For example, by including PAN managers and local conservationists in the collection of lessons learned and the design of national and state-level policies.
- Facilitating knowledge exchange and collaboration of conservation practitioners, scientists, and decision-makers on lessons learned and evaluation of measures to enable the upscaling of the strategies that are most effective in supporting coral AC and that are feasible to implement in practice (Hopkins et al. 2015; Wilson et al. 2020).
- Integrating concrete measurable CCA objectives into conservation policies, strategies, and action plans across planning and management sclaes, and design adaptive and flexible policies, legislation, and planning processes to enable their continued review as new information becomes available (McLeod et al. 2019; Rilov et al. 2019; Wilson et al. 2020).
- Mainstreaming climate adaptive measures into ongoing conservation and other area-based management projects, e. g. Ridge to Reef.
- Utilizing regional resources and initiatives to enhance knowledge sharing and capacities for the upscaling and mainstreaming of the climate adaptive strategies. Most recently the “Coral Reef Action Plan 2021-2030” highlighted the singular importance of healthy coral reefs for the well-being of the region and may serve as an entry point to upscale and mainstream climate adaptive conservation strategies

targeting reefs and more broadly adjacent coastal ecosystems (SPREP 2021). Also, the innovative regional initiative of the Micronesia Challenge, as well as the Pacific Islands Managed and Protected Area Community may offer key entry points, with the latter one having clear objectives to address climate change in conservation (PIMPAC 2017).

**Build local capacities and integrate communities and the civil society in conservation activities:**

- Include the civil society since it supports effective and climate adaptive conservation in Micronesia (Richards 2014). For example, by establishing and supporting citizen science observer networks (Djentonin & Meadow 2018). Such networks can enhance monitoring capacities for the early detection of climate change-related impacts or to fill key knowledge gaps on coastal and marine ecosystems (Gladstone-Gallagher et al. 2019; Tittensor et al. 2019; McKenzie et al. 2021). For example, a Palauan youth organization utilized the iNaturalist App to collect species data, or the use of novel approaches, such as a new computer-based education game from NASA[13], which functions as a coral reef assessment and bleaching monitoring tool, to increase information on coral reefs and to enable the identification of sites resilient to bleaching in Micronesia.
- Since Micronesia´s conservation is highly decentralized and strongly shaped by the traditional social-ecological context and community needs, include local communities in the design, planning and upscaling of climate adaptive conservation (Weeks et al. 2017; Pilbeam et al. 2019; Adams et al. 2021). Its inclusion is central for climate adaptive conservation and decision-making (Weeks & Jupiter 2013; Miles et al. 2020), such as to increase monitoring and implementation capacities (Baker et al. 2011; Weeks 2017), and to enhance social-ecological AC (Shaver et al. 2022). It is further important to include communities to avoid conflicting objectives (Pilbeam et al. 2019).
- Support the collaboration and connection of communities to facilitate the exchange of lessons learned and to overcome barriers of land tenure systems (Miles et al. 2020; Carlisle & Gruby 2019; SPREP 2019).

**Advance knowledge and capacities targeting coastal ecosystems, for example by:**

[13] http://nemonet.info/

- Focusing on coral reefs that are less vulnerable or better able to face climate change-related drivers. Further supporting coral reef AC by identifying, protecting and, restoring climate resilient and ecologically connected reefs, spawning areas, and "super" corals (Q27.1), such as through the International "Super reefs" research project collaborating with conservation practitioners in RMI (WHOI 2022).
- Monitoring and evaluating restoration activities together with climate data and considering ing adjacent mangroves and seagrass beds to enhance the effectiveness of such activities (Chambers et al. 2019; Miles et al. 2020; Adams et al. 2021).
- Addressing research gaps of seagrass beds in FSM and RMI (Annex Ib, Wilson et al. 2020).

**Advance research on ecosystem AC and climate adaptive conservation, for example by:**

- Enhancing scientific knowledge on how CCA can be practically integrated in marine and coastal conservation planning (Wilson et al. 2020).
- Conducting transdisciplinary studies to provide insights on the understanding of ecosystem AC among practitioners, and how this may differ from academia (e. g. McLeod et al. 2015). Such studies can help to advance the identification of applicable and scientifically sound ecosystem AC elements and indicators to assess ecosystem AC and in addition expand its current theoretical understanding.
- Applying co-produced actionable science, as applied in Hawaii (Laursen et al. 2018), to ensure that the defined climate adaptive strategies are applicable in practice and are meeting the needs and capacities of local conservation practitioners and decision-makers. This approach is especially relevant in the unique social-ecological and traditional conservation context of Micronesia. It can further inform and improve a knowledge-based decision-making of climate adaptive conservation, by helping to establish empirical evidence on the effectiveness and feasibility of the suggested strategies in supporting ecosystem AC in conservation practice (Djentonin & Meadow 2018; Laursen et al. 2018; Petersen et al. 2018). It further can be applied to ensure the success of climate adaptive coral reef restoration, where practitioners are included in all research phases to safeguard that the methods are practical, scalable, and affordable (Price & Toonen 2017; Shaver et al. 2022).

- Enhancing research to detect potential trade-offs between certain ecosystem AC elements, as well as thresholds and adaptation limits in ecosystems (Shaver et al. 2022).
- Utilizing ecological indicators that are based on climate-driven ecological thresholds to inform conservation management and monitoring MPA effectiveness (Wilson et al. 2020).
- Integrating and practically applying both social and ecosystem-level adaptive capacity elements in social-ecological systems research to advance the understanding and role of both in conservation (Hagerman et al. 2010).

Altogether, based on the identified theoretical and practical challenges for the implementation of the climate adaptive conservation strategies and related actions, there are several key entry points and recommendations, as outlined above, to overcome the identified barriers and to facilitate an enhanced implementation of the strategies in the three case study countries and beyond.

**Altogether, regarding the main and the sub-research questions, the following key findings can be summarized:**

(1) This research found that most research and literature is focused on species-level AC. Literature that centered on ecosystem-level AC depicted a fragmented field with a lack of a coherent definition, method, and metrics to define and analyze ecosystem AC, and its elements. It was further considered recommendable to facilitate research advancements on the adaptive capacity of ecosystems, and specifically its elements, to understand and enhance the applicability and operationalization of the concept in conservation practice.

(2) While this research recognized the application of a conceptual SES framing as a key tool to identify climate adaptive conservation strategies that can support the adaptive capacity of ecosystems, and hence facilitate the vulnerability reduction of the entire SES, few publications could be identified that included the ecosystem AC in SES research, in general, and in the context of conservation.

(3) Climate adaptive conservation strategies and actions mostly overlapped across the literature. Some strategies were limited to broad design principles, and there was generally a lack of implementation and empirical evaluation of their effectiveness in conservation practice.

(4) The selected climate adaptive conservation strategies were validated and considered effective by the experts to support coral AC in Micronesia. Despite some country-based differences, specifically strategy 1 "Non-climatic drivers" was regarded as important, whiles strategy 5 "Heterogeneity" was ranked as least effective.

(5) Overall climate adaptive conservation strategies have been integrated into policies and planning documents and have been implemented only to a limited extent in Micronesia. The main obstacles of implementing the selected climate adaptive strategies were limited resources, staff capacities, legislation, regulations, or policies. Several recommendations can help to overcome the identified implementation barriers. Experts highlighted specifically the mainstreaming and upscaling of climate adaptive conservation activities, as well as building local capacities.

## 5.2 Discussion of methods

This research thesis applied a deductive mixed-method approach to answer the main research question on what climate adaptive strategies can support the adaptive capacity of ecosystems, in the face of multiple climate change-related drivers, exemplified with coral reefs, in three states in Micronesia. Based on the applied methods and the researchers' perceptions, multiple issues or constraints must be mentioned. Thus, the following section offers a short description of these limitations and a critical reflection thereof.

**Literature review on the theoretical and thematic background (section 2):** The literature review was challenged by several factors. As outlined previously, differing meanings, conceptualizations and definitions of ecosystem AC challenged examining this concept within this research. As scholars confirmed, this was also challenging as ecosystem-level AC is not well studied yet, particularly in connection with the theoretical SES framing that was chosen for this research.

Secondary data, literature, and online sources relevant for the study of the case study region had several limitations. First, information was hard to obtain, scattered among reports, government websites, not existent or with conditional gaps. In multiple cases information was inconsistent or conflicting across sources (e. g. size and number of islands of RMI), particularly regarding ecosystems, climate change-related drivers and conservation. A concern also frequently voiced in several reports (e. g. NEPC 2019) and by multiple scholars (e. g. McKenzie et al. 2021). This showcased the challenges of relying on secondary sources and data for one's own research.

Hence, the researcher sought to verify each information, either through peer-reviewed sources, gray literature, or online sources. While this proved helpful in many cases, in other cases it resulted in the discovery of more inconsistencies or the reproduction of conflicting information, such in the case of mangroves and seagrass beds in the region. The structured review for the three ecosystems in the three states was helpful to confirm that little or no academic research has been undertaken, based on the low number of publications available (Annex Ib). Yet, valuable reports that provided key information to these ecosystems, such as from the Palau International Coral Reef Center, appeared to a limited extent within this review. This suggested that there is more knowledge available than the review reflects. Hence, even though this went beyond the scope of this research, the two structured reviews (Annex Ia & Ib) should be complemented with additional analysis steps to gain a holistic overview of current knowledge.

**Literature review, snowball search and analysis of the ecosystem AC elements (section 4.1):** The literature review aimed to identify and select the ecosystem AC elements as a foundation to identify and select climate adaptive strategies and related activities. The identification of elements was based on Seddon et al. (2019) and hence fit well with the conceptual framing of this research.

The structured review of the identified elements was helpful to gain an understanding on the number of publications available for each element in relation to AC, and to some extent what the publications addressed. While this helped to confirm that there a small number of publications for this research field available. Yet, the quality of this information is limited, as an analysis of these sources went beyond the scope of this research and no additional search engines were utilized.

Second, a subsequent snowball search helped to confirm the identified ecosystem AC elements. Yet, this method and its results are to a limited extent reproduceable and transparent, as the selection, focus on, and analysis of certain publications can be influenced by the researcher's knowledge or bias (Bernard 2006). While this limits the generalizability of results, this step was helpful to understand what elements are discussed, known, and agreed upon in the literature. The limitations of the review technique were aimed to be addressed by undertaking an extensive review of the literature to confirm the identified ecosystem AC elements. Yet, it confirmed and was further challenged by the fact that this concept is not yet well researched and that scholars conceptualize the ecosystem AC elements differently, some including both ecosystem-level and species level AC elements (Petersen et al. 2018). Based on this review it appeared that there were no empirical studies available to verify or measure the selected elements. By utilizing keywords to screen the selected literature a more targeted and comprehensive review and descriptive literature analysis was enabled. This was helpful to analyze each selected element. However, while this methodological step was primarily used as a prerequisite to define the strategies and the survey, an extended review and analysis of these elements went beyond the scope of this thesis yet is recommendable. Further excluding biodiversity can have impacted the results or provided an incomplete image. Nevertheless, the descriptive analysis of each element was helpful to understand these better in the context of ecosystem AC.

**Literature analysis and selection of the climate adaptive conservation strategies and related actions (section 4.2):** The snowball search method proved effective for this research to identify and select climate adaptive conservation strategies. Nevertheless, it must be pointed out that this form of review can result in incomplete and non-verifiable findings. This issue was aimed to be addressed by integrating different forms of documents and sources to gain a more comprehensive picture on what strategies authors suggested. By selecting two seed articles and screening publications that cited McLeod et al. (2009) a biased selection of documents was aimed to be reduced and to provide some form of replicability.

Some of the selected articles are comparable or integrable to a limited extent due to differing definitions of key concepts or planning or design scales. Yet, based on the conceptual framing and the selected ecosystem AC elements it was aimed to ensure that the strategies were selected and adapted according to the research framing. While most identified climate adaptive strategies aimed to support ecosystem AC directly or indirectly, not all publications named the concept directly. The risk of selecting strategies or related actions that do not aim to support ecosystem AC was strived to be reduced by following the thesis framing.

The methodological approach of this step proved suitable for the research aims. Since the selected strategies and activities supporting climate adaptive conservation and one or multiple ecosystem AC elements, appeared accurate due to their overlap among the documents, which was supported by additional literature (e. g. Wilson et al. 2020; O´Regan et al. 2021). Yet, again due to this approach the generalizability of the results is limited, and there is no guarantee for completeness.

Most scholars thus far, have suggested strategies for the PAN or MPA design or planning scale for coral reef ecosystems. This again fit well with the selection of strategies and activities focused on coral reefs.

The selection of the activities was helpful to propose exemplary actions on how each strategy can be undertaken to support ecosystem AC. While the selection was based on and confirmed among different literature sources, it can be influenced by the researcher´s knowledge and perception (Bernard 2006). Thus, it would be recommendable to verify this set of activities, and generally to adjust these depending on the intended objectives and local context. Further, since the conservation strategies were identified based on a snowball technique and mostly in academic publications, it would be recommendable to enhance this step with a strategic literature review to gain

a more comprehensive overview of additional empirical evidence and to further verify the selected strategies in the context of ecosystem AC. Also, the application of transdisciplinary research and inclusion of case studies from practice is recommendable, since scholars cautioned that there is undoubtedly more knowledge available outside academia (Wilson et al. 2020).
The qualitative content analysis was helpful since several authors used descriptive terms for ecosystem AC and activities supporting its elements that were not identifiable in the previous keyword search (Bernard 2006; Baur & Blasius 2014). Altogether, this step proved helpful as a prerequisite for the survey.

**Semi-quantitative expert survey (section 4.3)**: This research pursued to follow scientific standards by undertaking a semi-quantitative survey to achieve reproducibility and reliability of data that supports the answering of the main research question (Bernard 2006). Further, by transparently disclosing the applied methods and sampling strategy, selection of experts, choice of questions, and mode of analysis.
The methodological approach of a survey and the combination of quantitative and qualitative questions proved beneficial for this research. It enabled to contextualize the quantitative results with expert perceptions and to gain a better understanding of the usefulness of the theoretical strategies in supporting coral reef AC within the social-ecological contexts in practice.
The experts that participated in the survey matched well with the selection criteria. The participants also greatly overlapped with the chain-referral of other respondents, which also reduced a potential biased selection by the researcher’s own perception or sampling method (Young et al. 2018).
Administering surveys that participants could complete at one´s own discretion ensured to receive a maximum of potential replies. Yet, there are several advantages and disadvantages regarding this survey method. The possibility of bias amongst participants to provide likeable results cannot be excluded, or that questions were misunderstood, which can have affected the accuracy and quality of data (Bernard 2006).
Further, the researchers own perceptions, understanding of the local and more generally the research context, cultural and scientific background, language skills and intercultural sensitivity, can have biased the design, collection, and analysis of survey results (Young et al. 2018). Yet, during the entire research process, the researcher took

ethical considerations of intercultural research into account and critically reflected her role (Kumar 2011), as a researcher from the Global North, remotely researching a case study subject in the Global South.

The survey findings have multiple limitations. It must be considered that there were several question abstentions by three experts. One expert did not list any strategies as integrated or implemented and hence the following questions were not answerable for the respondent. Two experts gave no or incomplete answers in the last section. Yet, their preceding responses were considered relevant and thus included. Considering the results of the standard deviation and the small number of participants it was not possible to produce statistical significance and representative results.

However, the qualitative results gave valuable insights and several patterns emerged. Hence, the survey method proved useful for this research (Bernard 2006). Yet, some responses were heterogenous, and it is questionable if more homogenous or heterogeneous opinions exist among experts in the case study region than these results indicate. Also, the quality of results could have been increased. Because while the questions on activities provided some meaningful insights that were supported by the qualitative results, more significant findings could have been produced by asking participants to rank activities according to their effectiveness or success in supporting ecosystem AC.

The list of conservation strategies appeared appropriate and relevant according to the high extent experts validated the effectiveness of these. Yet, not disclosing the validation step can have influenced the results (Bernard 2006).

Multiple respondents added the non-climatic driver "overfishing", which was subsequently added in the results analysis. Yet this might have affected the quality of results concerning this driver (Q8).

Altogether even though, the survey results are generalizable to a very limited extent, since several distinctive patterns arose from the survey it allowed for a probable interpretation. Hence, it was useful to validate the strategies and to gain empirical information that helped to answer the main and two sub-research questions. The high resonance, extensive personal communication, and feedback from a multitude of participating experts highlighted the relevance of this research for climate adaptive conservation of coral reefs in Micronesia. Yet, due to presented considerations, further research, that builds on these results and collects further data, is recommendable.

**Transferability of the results to other contexts:** The research findings are constrained by the fact that the choice of the ecosystem adaptive capacity elements, as well as the selected conservation strategies and related activities, cannot be validated against other data or research, except through the literature review (Siders 2019).
Nevertheless, the strategies have been suggested by scholars across a suite of different coastal environments and planning scales, as well as validated by the experts in this research. But, since conservation activities are always embedded in social-ecological settings that are locally varied and context specific, the transferability is limited and must be adjusted to the local contexts in which strategies are planning. Yet, by applying a conceptual social-ecological system research framing this thesis strived to approximate transferability.

# 6. Conclusion

This research examined what conservation strategies can support the adaptive capacity of seagrass beds, mangroves, and specifically exemplified with coral reefs in Micronesia. By doing so this research analyzed how ecosystem AC can be defined, what elements it is composed of, and what climate adaptive conservation strategies and related actions can support this capacity, in turn facilitating to reduce the vulnerability of a social-ecological system. These theoretic findings were validated and further examined in the context of the case study region Micronesia with an expert consultation.

Focusing on ecosystem AC and gaining an enhanced understanding of the concept is relevant to understand how ecosystems can be supported through conservation to face continuous change. However, in this regard, concerning the research findings of this thesis, academia must increase its research efforts on the adaptive capacity of ecosystems. It further must become clear in the meaning of ecosystem AC and its elements by establishing a coherent definition applicable and accepted in interdisciplinary research to enable its advancement across research fields. Such identified knowledge gaps further appeared to limit its applicability for defining and operationalizing climate adaptive conservation measures that can target and support ecosystem adaptive capacity strategically. However, the application of climate adaptive options in marine conservation is also inhibited by a disconnect of climate change adaptation and conservation, as this research confirmed. Moving forward it is imperative to align definitions of what is considered climate adaptive conservation and to design a clarifying guideline how CCA and conservation can be integrated at different planning scales.

Scholars have suggested climate adaptive conservation strategies that can support the adaptive capacity and resilience of ecosystems, and recommended to integrate these into conservation policies, planning, and management. However, this research found that few of these publications addressed or defined the concept ecosystem AC and suggested strategies that specifically aimed to support this capacity. Further, there are generally few empirical case studies that have integrated, implemented, or empirically evaluated the suggested strategies, globally and regionally, and if so, it was mostly in isolation.

The literature review findings of the climate change-related drivers concerning the coastal ecosystems in Micronesia, and specifically coral reefs, found that the three coastal ecosystems have a differential AC to respond to these drivers. It is hence important to understand and support this distinct AC of each ecosystem to help these connected systems better face potential climate change-related impacts. Particularly, the capacity of seagrass beds and mangroves to buffer acidification in corals supports the relevance of protecting all three ecosystems, as well as the AC features of some coral reefs enabling these to withstand higher sea surface temperatures in Micronesia. Considering the findings regarding the three ecosystem AC elements, further research of the small-scale spatial heterogeneity in coral reefs, and the extent of ecological connectivity between these associated coastal habitats is of great relevance to inform climate adaptive conservation in the three states.

The survey approach was helpful to validate the effectiveness of the theoretically suggested strategies independent of their integration and implementation in Micronesia. The effectiveness of the selected conservation strategies was validated as supporting the AC of coral reefs in Micronesia, except for the strategy focused on the ecosystem AC element heterogeneity. Yet, the survey results confirmed that their implementation fell significantly short. According to these findings, the selected strategies are thus unlikely sufficient to support coral reef AC in the case study region. However, not all strategies were considered equally relevant. While at the same time conservation was generally regarded as climate adaptive and as helping corals face climate change. This finding confirms that the selection of strategies must be adapted to match the local social-ecological context, and that further research is necessary to understand how and what conservation measures and approaches are considered climate adaptive in a certain area, to strategically support these and inform further academic research.

Confirmed by several scholars, addressing non-climatic drivers ensures that coastal ecosystems are better equipped to face potential climate change-related drivers in the region. Concurrently strategy 1 “Non-climatic drivers” was considered highly effective in supporting coral adaptive capacity, specifically when tackling overfishing and pollution.

Since Micronesia is characterized by environmental and spatial heterogeneity resulting in differential coral AC, despite comparatively little recognition among experts, researchers highlighted the importance of understanding and maintaining heterogeneity to identify and protect climate resilient and adaptive reefs.

Contrary, strategy 2 “Other frameworks” was the only strategy reaching a high effectiveness and implementation rating, likely due to the significant role of area-based management approaches in Micronesia, specifically Ridge to Reef. In the region, this approach is important, both for successful conservation and coastal livelihoods, and because it can facilitate the protection of the ecologically connected mangroves, seagrass beds, and coral reefs that are often affected by land-based non-climatic drivers. Ridge to reef is hence considered key to support each other’s AC to non-climatic and climate change-related drivers. Integrating climate adaptive strategies in such approaches could likely facilitate the effectiveness, upscaling and mainstreaming of these options to successfully support the AC of the coastal ecosystems. These findings, along with further research, can be useful to decision-makers to prioritize strategies with the highest effectiveness and the lowest implementation rating.

Thus, while warm water coral reefs were considered most at risk from climate change by scholars globally and by the experts regionally, and whereas the implementation of such climate adaptive strategies may be most beneficial to coral reefs, their embeddedness in a wider seascape and ecological linking to adjacent mangroves and seagrass beds, must be considered. Thus, strategies should target the entire coastal seascape, recognizing its connection to the land and its embeddedness in a wider local and context specific social-ecological system.

Particularly, experts urged to address limited resources and staff capacities, which are well-known challenges for effective conservation in the region and must be tackled to facilitate an improved implementation of the climate adaptive strategies. In addition, the knowledge gaps identified in this research, concerning the peer-reviewed research of seagrass beds, must be addressed to advance the understanding of its AC and limits thereof, as well as to enable the design of climate adaptive conservation measures targeting the three ecosystems effectively.

Experts prioritized activities that focused on coral reef AC, specifically the restoration and monitoring thereof, as well as the identification of coral climate refugia, and to address overfishing. Respondents further emphasized the need to upscale and mainstream activities in the region, and accordingly highlighted the key role of communities to be included in the design and application of climate adaptive strategies to support coral AC. Considering the missing climate and ecosystem data at local scales, experts confirmed the benefits of and recommended to apply the precautionary principle and climate scenario planning in conservation.

The research findings showed that the main research question proved to have relevance for the experts in Micronesia and aligned with the research priorities identified for the region. Based on the findings from the literature and the expert opinions, it appears that these strategies are effective to support the coastal ecosystems, exemplified with coral reefs, to face potential climate change-related impacts. Hence it can be considered as relevant that the implementation of said strategies, specifically addressing non-climatic drivers, and related activities, such as Ridge to Reef approaches, are increased in the three states in Micronesia.

Altogether, with many low-lying island states globally featuring a high social-ecological interdependency and a high vulnerability towards climate change, this research was relevant to understand how conservation can maintain ecosystem health and functioning and support ecosystems to adapt to rapidly changing conditions. The unique social and ecological conditions made the three island states a valuable testing ground to validate the effectiveness and relevance of the theoretically suggested strategies. Applying such strategies, in a data sparce region, featuring a high social-ecological climate change vulnerability, such as Micronesia, likely offers a solution with few trade-offs and multiple social co-benefits to ensure the long-term sustainability of island communities and ecosystems under a changing climate throughout FSM, RMI and Palau.

# 7. References

Abram, N., Gattuso, J.-P., Prakash, A., Cheng, L., Chidichimo, M. P., Crate, S., Enomoto, H., Garschagen, M., Gruber, N., Harper, S., Holland, E., Kudela, R. M., Rice, J., Steffen K. & K. von Schuckmann (2019). Framing and Context of the Report, In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* Pörtner, H.-O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama B. & N. M. Weyer (eds.), In press, 73-129 pp.

Adams, V. M., Weeks, R. & T. S. Doherty (2021). Advances in conservation science and practice in Oceania: Delivering on research priorities for the region, *Conservation Science and Practice*, 3(2), 1-6.

Adjeroud, M., Penin L. & A. Caroll (2007). Spatio-temporal heterogeneity in coral recruitment around Moorea, French Polynesia: Implications for population maintenance, *Journal of Experimental Marine Biology and Ecology*, 341, 204-218.

Aguilar-Medrano, R. & L. E. Calderon-Aguilera (2016). Redundancy and diversity of functional reef fish groups of the Mexican Eastern Pacific, *Marine Ecology*, 37, 119-133.

Ahlgren, I. A. (2016). The meaning of Mo: Place, Power, and Taboo in the Marshall Islands, The Australian National University: Canberra, Australia, 585 pp.

Albert, S., Bythell, G. A., Olds, A., Schwarz, A., Abernethy, K., Aranani, K., Sirikolo, M., Watoto, C., Duke, N., McKenzie, J., Roelfsema, C., Liggins, L., Brokovich, E., Pantos, O., Oeta, J. & B. Gibbes (2010). Building social and ecological resilience to Climate Change in Roviana, Solomon Islands, The University of Queensland: Brisbane, Australia, 264 pp.

Alsaffar, Z., Cúrdia, J., Irigoien, X. & S. Carvalho (2020). Composition, uniqueness and connectivity across tropical coastal lagoon habitats in the Red Sea, *BMC Ecology*, 20(61), 1-17.

Andrew, N. L., Bright, P., de la Rua, L., Teoh, S. J. & M. Vickers (2019). Coastal proximity of populations in 22 Pacific Island Countries and Territories, *PloS One* 14, e0223249.

Angeler, D. G., Fried-Petersen, H., Allen, C. R., Garmestani, A., Twidwell, D., Birge, H. E., Chuang, W., Donovan, V. M., Eason, T., Roberts, C. P., Sundstrom S. M. & C. L. Wonka (2019). Adaptive capacity in ecosystems, *Advanced Ecological Research*, 60, 1-24.

Anthony, K. R. N., Marshall, P. A., Abdulla, A., Beeden, R., Bergh, C., Black, R., Eakin, C. M., Game, E. T., Gooch, M., Graham, N. A. J., Green, A., Heron, S. F., Van Hooidonk, R., Knowland, C., Mangubhai, S., Marshall, N., Maynard, J. A., Mcginnity, P., Mcleod, E., Mumby, P. J., Nystrom, M., Obura, D., Oliver, J., Possingham, H. P., Pressey, R. L., Rowlands, G. P., Tamelander, J., Wachenfeld, D. & S. Wear (2015). Operationalizing resilience for adaptive coral reef management under global environmental change, *Global Change Biology*, 21, 48–61.

Ara Begum, R., Lempert, R., Ali, E., Benjaminsen, T. A., Bernauer, T., Cramer, W., Cui, X., Mach, K., Nagy, G., Stenseth, N. C., Sukumar R. & P. Wester (2022). Point of Departure and Key Concepts, In: *Climate Change 2022: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem A. & B. Rama (eds.), Cambridge University Press: Cambridge, UK & New York, NY, USA, pp. 121–196.

Archambault, P. & E. Bourget (1996). Scales of coastal heterogeneity and benthic intertidal species richness, diversity and abundance, *Marine Ecology Progress Series*, 136(130), 111-121.

Baker, N., Beger, M., McClennen, C., Ishoda, A. & F. Edwards (2011). Reimaanlok: A National Framework for Conservation Area Planning in the Marshall Islands, *Journal of Marine Biology*, 11, 1–11.

Ban, N. C., Mills, M., Tam J. & C. Hicks (2013). A social-ecological approach to conservation planning: embedding social considerations, *Frontiers in Ecology and the Environment*, 11(4), 194–202.

Barajas-Barbosa, M. P., Weigelt, P., Borregaard, M. K., Keppel G. & H. Kreft (2020). Environmental heterogeneity dynamics drive plant diversity on oceanic islands, *Journal of Biogeography*, 47, 2248–2260.

Barkley, H. C., Cohen, A. L., McCorkle, D. C. & Y. Golbuu (2017). Mechanisms and thresholds for pH tolerance in Palau corals, Journal of Experimental Marine Biology and Ecology, 489, 7-14.

Barkley, H. C. (2011). A scientific framework for evaluating coral reef resilience to climate change, Massachusetts Institute of Technology: Boston, 170 pp.

Baron, J. S., Gunderson, L., Allen, C. D., Fleishman, E., McKenzie, D., Meyerson, L. A., Oropeza J. & N. Stephenson (2009). Options for National Parks and Reserves for Adapting to Climate Change, *Environmental Management*, 44, 1033-1042.

Baur, N. & J. Blasius (2014) Handbuch Methoden der empirischen Sozialforschung, Springer: Wiesbaden, Germany, 1126 pp.

Beever, E. A., O´Leary, J., Mengelt, C., West, J. M., Julius, S., Green, N., Magness, D., Petes, L., Stein, B., Nicotra, A. B., Hellmann, J. J., Robertson, A. L., Staudinger, M. D., Rosenberg, A. A., Babij, E., Brennan, J., Schuurman, G. W. & G. E. Hofmann (2016). Improving Conservation Outcomes with a New Paradigm for Understanding Species´ Fundamental and Realized Adaptive Capacity, *Conservation Letters*, 9(2), 131–137.

Beger, M., Jacobson, D., Pinca, S., Richards, Z., Hess, D., Harriss, F., Page, C., Peterson, E. & N. Baker (2008). The state of coral reef ecosystems of the Republic of the Marshall Islands. In: *The state of coral reef ecosystems of the United States and Pacific Freely Associated States*, Waddell J. E. & A. M. Clarke (eds.), National Oceanic and Atmospheric Administration: Silver Springs, US, 387–417.

Bell, J. D., Cisneros-Montemayor, A., Hanich, Q., Johnson, J. E., Lehodey, P., Moore, B. R., Pratchett, M. S., Reygondeau, G., Senina, I., Virdin, J. & C. C. C. Wabnitz (2018). Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands, *Marine Policy*, 88, 303–314.

Berkes, F., Colding J. & C. Folke (2003). Navigating Social-ecological systems: Building resilience for complexity and change, Cambridge University Press: Cambridge, UK, 393 pp.

Bernard, H. R. (2006). Research Methods in Anthropology: Qualitative and Quantitative Approaches, 4$^{th}$ Edition, Altamira Press: Lanham, US, 803 pp.

Bernhardt, J. R. & H. M. Leslie (2013). Resilience to climate change in coastal marine ecosystems, *Annual Review of Marine Science*, 5, 371–392.

Billé, R., Kelly, R., Biastoch, A., Harrould-Kolieb, E., Herr, D., Joos, F., Kroeker, K., Laffoley, D., Oschlies A. & J.-P. Gattuso (2013). Taking action against ocean acidification: A review of management and policy options, *Environmental Management*, 52, 761-779.

Bindoff, N. L., Cheung, W. W. L., Kairo, J. G., Arístegui, J., Guinder, V. A., Hallberg, R., Hilmi, N., Jiao, N., Karim, M. S., Levin, L., O'Donoghue, S., Purca Cuicapusa, S. R., Rinkevich, B., Suga, T., Tagliabue A. & P.

Williamson (2019). Changing Ocean, Marine Ecosystems, and Dependent Communities, Supplementary Material. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* Pörtner, H. O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B. & N.M. Weyer (eds.), In press, 5SM-1-79 pp.

Björk, M., Short, F., McLeod, E. & S. Beer (2008). Managing seagrasses for resilience to climate change, Resilience Science Group Working Paper Series No. 3, IUCN: Gland, Switzerland, 56 pp.

Bordner, A. S., Ferguson, C. E. & L. Ortolano (2020). Colonial dynamics limit climate adaptation in Oceania: Perspectives from the Marshall Islands, *Global Environmental Change*, 61, 102054.

Boström-Einarsson, L., Babcock, R. C., Bayraktarov, E., Ceccarelli, D., Cook, N., Ferse, S. C. A., Hancock, B., Harrison, P., Hein, M., Shaver, E., Smith, A., Suggett, D., Stewart-Sinclair, P. J., Vardi T. & I. M. McLeod (2020). Coral restoration – A systematic review of current methods, successes, failures and future directions, *PLoS ONE,* 15(1), e0226631.

Boudouresque, C.-F., Blanfuné, A., Pergent, G. & T. Thibaut (2021). Restoration of Seagrass Meadows in the Mediterranean Sea: A Critical Review of Effectiveness and Ethical Issues, *Water,* (13) 1034, 1-34.

Brodie, G., Holland, E., De Ramon N´Yeurt, A., Soapi K. & J. Hills (2020). Seagrasses and seagrass habitats in the Pacific small islands developing states: Potential loss of benefits via human disturbance and climate change, Marine Pollution Bulletin, 160, 111573.

Bruno, J. F., Cote, I. M. & L. T. Toth (2019). Climate Change, Coral Loss, and the Curious Case of the Parrotfish Paradigm: Why Don´t Marine Protected Areas Improve Reef Resilience? *Annual Review of Marine Science*, 11, 307-334.

Burke, L., Reytar, K., Spalding, M. & A. Perry (2011). Reefs At Risk Revisited, Washington, USA: World Resources Institute, 130 pp.

Camp, E. F., Suggett, D.J., Gendron, G., Jompa, J., Manfrino C. & D. J. Smith (2016). Mangrove and Seagrass Beds Provide Different Biogeochemical Services for Corals Threatened by Climate Change, *Frontiers in Marine Science*, 3(52), 1-16.

Carlisle, K. M. & R. L. Gruby (2019). Customary Marine Tenure in Palau: Social Function and Implications for Fishery Policy, *Human Ecology*, 47(4), 527–539.

Carr, M. H., Robinson, S. P., Wahle, C., Davis, G., Kroll, S., Murray, S., Schumacker E. J. & M. Williams (2017). The central importance of ecological spatial connectivity to effective coastal marine protected areas and to meeting the challenges of climate change in the marine environment, *Aquatic Conservation: Marine Freshwater Ecosystems*, 27(S1), 6-29.

Critical Ecosystem Partnership Fund (CEPF) (2007). Ecosystem Profile. Micronesia-Polynesia Biodiversity Hotspot, Conservation International-Melanesia Center for Biodiversity Conservation, 128 pp.

Chambers, J. C., Allen, C. R. & S. A. Cushman (2019). Operationalizing Ecological Resilience Concepts for Managing Species and Ecosystems at Risk, *Frontiers in Ecology and Evolution*, (7)241, 1-27.

Charles, A. (2012). People, oceans and scale: governance, livelihoods and climate change adaptation in marine social – ecological systems, *Current Opinion in Environmental Sustainability*, 4(3), 351–357.

Cinner, J. E., Huchery, C., Darling, E. S., Humphries, A. T., Graham, N. A. J., Hicks, C. C., Marshall, N. & T. R. McClanahan (2013). Evaluating Social and Ecological Vulnerability of Coral Reef Fisheries to Climate Change, *PLoS ONE,* 8(9), e74321, 1-12.

Colin, P. L. & T. M. Shaun Johnston (2020). Measuring temperature in coral reef environments: Experience, lessons, and results from Palau, *Journal of Marine Science and Engineering*, 8(9), 1–23.

Colin, P. L. (2018). Ocean warming and the reefs of Palau, *Oceanography*, 31(2), 126–135.

Colin, P. L. (2009). Marine Environments of Palau. Indo-Pacific Press: San Diego, USA, 414 pp.

Courtney, C., Bacalso, R., Armada, N., Green, A. & R. Martinez (2017). Marine Reserve Network Design: A Case Study in Applying Ecological Design Principles to Danajon Reef Marine Key Biodiversity Area, USAID Philippines: Manila, Philippines, 35 pp.

Crameri, N. J. & J. C. Ellison (2022). Atoll inland and coastal mangrove climate change vulnerability assessment, *Wetlands Ecological Management,* 30, 527 – 546.

Cumming, G. S. & C. R. Allen (2017). Protected areas as social-ecological systems: perspectives from resilience and social-ecological systems theory, *Ecological Applications*, 27(6), 1709-1717.

Djentonin, I. N. S. & A. M. Meadow (2018). The art of co-production of knowledge in environmental science and management: lessons from international practice, *Environmental Management*, 61, 885-903.

Donner, S. D. & J. Carilli (2019). Resilience of Central Pacific reefs subject to frequent heat stress and human disturbance, *Scientific Reports,* 9(3484), 1-13 pp.

Doolittle, A. (2015). The best of many worlds: Methodological pluralism in political ecology, *The International Handbook of Political Ecology*, 515–529.

Du, J., Xie, M., Wang, Y., Chen, Z., Liu, W., Liao, J. & B. Chen (2020). Connectivity of fish assemblages along the mangrove-seagrass-coral reef continuum in Wenchang, China, *Acta Oceanologica Sinica*, 39(8), 43–52.

Duncan, J. M. A., Haworth, B., Boruff, B., Wales, N., Biggs, E. M. & E. Bruce (2020). Managing multifunctional landscapes: Local insights from a Pacific Island Country context, *Journal of Environmental Management*, 109692, 1-11.

Earp, H. S., Prinz, N., Cziesielski M. J. & M. Andskog (2018). For a World Without Boundaries: Connectivity between marine tropical ecosystems in times of change, 125-144, In: YOUMARES 8 – Ocean across boundaries: Learning from each other, Jungblut, S., Liebich, V. & M. Bode (eds), Proceedings of the 2017 conference for YOUng Marine RESeachers in Kiel, Germany, Springer: Cham, Switzerland, 125-144.

Ellison, J. C. (2018a). Effects of Climate Change on Mangroves Relevant to the Pacific Islands, *Science Review*, 99–111.

Ellison, J. C. (2018b). Pacific Island Beaches: Values, Threats and Rehabilitation. In: *Beach Management Tools - Concepts, Methodologies and Case Studies,* Botero, C., Cervantes O. & C. Finkl (eds.), Coastal Research Library, Springer: Cham, Switzerland, 24, 679-700 pp.

Ellison, J. C. & S. Cannicci (2016). Impacts and effects of ocean warming on mangrove species and ecosystems, In: Explaining Ocean Warming: Causes, scale, effects and consequences, Laffoley, D. & J. M. Baxter (eds.), IUCN: Gland, Switzerland, 135-146 pp.

Ellison, J. C. (2009). Wetlands of the Pacific Island region, *Wetlands Ecology and Management*, 17(3), 169–206.

Elmquist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker B. & J. Norberg (2003). Response diversity, ecosystem change, and resilience, Frontiers in Ecology and Environment, 1(9), 488-494.

Fernandes, L., Green, A., Tanzer, J., White, A., Alino, P.M., Jompa, J., Lokani, P., Soemodinoto,A., Knight, M., Pomeroy, B., Possingham, H. & B. Pressey (2012). Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle, The Nature Conservancy: Indonesia, 152 pp.

Ferrario, F., Beck, M. W., Storlazzi, C. D., Micheli, F., Shepard C. C. & L. Airoldi (2014). The effectiveness of coral reefs for coastal hazard risk reduction and adaptation, *Nature Communications*, 5, 1–9.

Fitzpatrick, S. M. & T. J. Donaldson (2007). Anthropogenic impacts to coral reefs in Palau, western Micronesia during the Late Holocene, *Coral Reefs*, 26(4), 915–930.

Foley, M. M., Halpern, B. S., Micheli, F:, Armsby, M. H., Caldwell, M. R., Crain, C. M., Prahler, E., Rohr, N., Sivas, D., Beck, M. W., Carr, M. H., Crowder, L. B., Duffy, J. E., Hacker, S. D., McLeod, K. L., Palumbi, S. R., Peterson, C. H., Regan, H. M., Ruckelshaus, M. H., Sandifer, P. A. & R. S. Steneck (2010). Guiding ecological principles for marine spatial planning, *Marine Policy,* 34, 955-966.

Folke, C., Biggs, R., Norström, A. V., Reyers B. & J. Rockström (2016). Social-ecological resilience and biosphere-based sustainability science, *Ecology and Society,* 21(3), 41.

Foster, S. (2022). Palau. Encyclopedia Britannica, Inc, Last accessed 2nd of October 2022: https://www.britannica.com/place/Palau/Climate

Foo, S. A. & G. A. Asner (2020). Sea surface temperature in coral reef restoration outcomes, *Environmental Research Letters,* 15(074045), 1-7.

Friedlander, A. M., Golbuu, Y., Ballesteros, E., Caselle, J. E., Gouezo, M., Olsudong D. & E. Sala (2017). Size, age, and habitat determine effectiveness of Palau's Marine Protected Areas, *PloS ONE*, 12(3), 1–18.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity, *Global Environmental Change*, 16(3), 293–303.

Geyer, J., Strixner L., Kreft S., Jeltsch F. & P. L. Ibisch (2015). Adapting conservation to climate change: a case study on feasibility and implementation in Brandenburg, Germany, *Regional Environmental Change*, 15, 139–53.

Gladstone-Gallagher, R. V., Hope, J. A., Bulmer, R. H., Clark, D. E., Stephenson, F., Mangan, S., Rullens, V., Siwicka, E., Thomas, S. F., Pilditch, C. A., Savage C. & S. F. Thrush (2019). Old Tools, New Ways of Using Them: Harnessing Expert Opinions to Plan for Surprise in Marine Socio-Ecological Systems, *Frontiers in Marine Science*, 6(696), 1-10.

Gladstone, W. (2009). Chapter 17: Conservation and Management of Tropical Coastal Ecosystems, In: *Ecological Connectivity among Tropical Coastal Ecosystems*, I. Nagelkerken (Ed.), 1st edition, Springer: Dodrecht, Netherlands, 565-605 pp.

Golbuu, Y., Victors, S., Penland, L., Idip Jr., D., Emaurois, C., Okaji, K., Yukihira, H., Iwase, A. & R. van Woesik (2007). Palau´s coral reefs show differential habitat recovery following the 1998-bleaching event, Coral Reefs, *Coral Reefs*, 26, 319–32.

Gonzales, A., Thompson, P. & M. Loreau (2018). Spatial ecological networks: planning for sustainability in the long-term, *Current Opinion in Environmental Sustainability* 29, 187-197.

Gouezo, M., Golbuu Y., Fabricius K., Olsudong D., Mereb G., Nestor V., Wolanski E., Harrison P., Doropoulos C. (2019). Drivers of recovery and reassembly of coral reef communities, *Proceedings Royal Society B*, 286: 1-10.

Gouezo, M., Nestor, V., Olsudong, D., Marino, L., Mereb, G., Jonathan, R: & Y. Golbuu (2017). 15 years of coral reef monitoring demonstrates the resilience of Palau´s coral reefs, PICRC technical report 17-01, PICRC: Koror, Palau, 20 pp.

Gouezo, M., Golbuu Y., van Woesik R., Rehm L., Koshiba S. & C. Doropoulos (2015). Impact of two sequential super typhoons on coral reef communities in Palau, *Marine Ecology Progress Series*, 540, 73 – 85.

Grant, M. J. & A. Booth (2009). A typology of reviews: an analysis of 14 review types and associated methodologies, *Health Information & Libraries Journal*, 26(2), 91 – 108.

Grantham, H. S., McLeod, E., Brooks, A., Jupiter, S. D., Hardcastle, J., Richardson, A. J., Poloczanska, E. S., Hills, T., Mieszkowska, N., Klein, C. J. & J. E. M. Watson (2011). Ecosystem-based adaptation in marine ecosystems of tropical Oceania in response to climate change, *Pacific Conservation Biology*, 17(3), 241–258.

Green, A. L., Fernandes, L., Almany, G., Abesamis, R., McLeod, E., Aliño, P. M., White, A. T., Salm, R., Tanzer J. & R. L. Pressey (2014). Designing Marine Reserves for Fisheries Management, Biodiversity Conservation, and Climate Change Adaptation, *Coastal Management,* 42(2), 143-159.

Gross, J. E., Woodley, S., Welling, L. A. & J. E. M. Watson (eds.) (2016). Adapting to Climate Change: Guidance for protected area managers and planners. Best Practice Protected Area Guidelines Series No. 24, IUCN: Gland, Switzerland, 129 pp.

Guannel, G., Arkema, K., Ruggiero, P. & G. Verutes (2016). The power of three: Coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience, *PloS ONE*, 11(7), 1–22.

Hagerman, A., Dowlatabadi, H., Satterfield T. & T. McDaniels (2010). Expert views on biodiversity conservation in an era of climate change, *Global Environmental Change*, 20(1), 192-207.

Hall, I. (2020). The Federated States of Micronesia: Sixth National Report to the Convention on Biological Diversity, Republic of the Federated States of Micronesia: FSM, 128 pp.

Hall, I. (2018). The Federated States of Micronesia: National Biodiversity Strategy and Action Plan 2018-2023, Republic of the Federated States of Micronesia: FSM, 63 pp.

Harwood, A. S. (2016). Mangrove Enhancement as a Climate Change Adaptation Strategy in the Republic of the Marshall Islands (RMI): Potential Ecosystem Service Shifts Following Colonization, *Master of Environmental Management Project Reports*, 51, 1–67.

Heller N. E. & E. S. Zavaleta (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations, *Biological Conservation*, 142, 14-32.

Hills, T., Brooks, A., Atherton, J., Rao, N. & R. James (2011). Pacific Island biodiversity, ecosystems and climate change adaptation: building on nature's resilience, SPREP: Apia, Samoa, 51 pp.

Hilty, J., Worboys, G. L., Keeley, A., Woodley, S., Lausche, B. J., Locke, H., Carr, M., Pulsford, I., Pittock, J., White, J. W., Theobald, D. M., Levine, J., Reuling, M., Watson, J. E. M., Ament, R., & G. M. Tabor (2020). Guidelines for conserving connectivity through ecological networks and corridors. Best Practice Protected Area Guidelines Series No. 30. IUCN: Gland, Switzerland, 122 pp.

Hinchley, D., Lipsett-Moore, G., Sheppard, S., Sengebau, F. U., Verheij E. & S. Austin (2007). Biodiversity Planning for Palau's Protected Areas Network: An Ecoregional Assessment, TNC Pacific Island Countries Report, The Nature Conservancy: South Brisbane, Australia & Koror, Palau, No. 1/07, 68 pp.

Hodgson, J. A., Thomas, C. D., Wintle B. A. & A. Moilanen (2009). Climate Change, Connectivity and Conservation Decision Making: Back to Basics, *Journal of Applied Ecology*, (46)5, 964-969.

Hongo, C., Kurihara, H. & Y. Golbuu (2017). Projecting the risk of damage to reef-lined coasts due to intensified tropical cyclones and sea level rise in Palau to 2100, *Natural Hazards and Earth System Sciences Discussions*, 1–23.

Houk, P., Yalon, A., Maxin, S., Starsinic, C., McInnis, A., Gouezo, M., Golbuu, Y. & R. van Woesik (2020). Predicting coral-reef futures from El Niño and Pacific Decadal Oscillation events, *Scientific Reports*, 10, 7735, 1–9.

Houk, P., Camacho, R., Johnson, S., McLean, M., Maxin, S., Anson, J., Joseph, E., Nedlic, O., Luckymis, M., Adams, K., Hess, D., Kabua, E., Yalon, A., Buthung, E., Graham, C., Leberer, T., Taylor, B., & R. Van Woesik (2015). The Micronesia Challenge: Assessing the relative contribution of stressors on coral reefs to facilitate science-to-management feedback, *PloS ONE*, 10(6), 1–17.

Houk, P. & C. Musburger (2013). Trophic interactions and ecological stability across coral reefs in the Marshall Islands, *Marine Ecology Progress Series*, 488, 23-34.

Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Díaz, S., Settele, J., Brondízio E.S., Ngo, H. T., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H. M., Chan, K. M. A., Garibaldi, L. A., Ichii, K., Liu, J., Subramanian, S. M., Midgley, G. F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Chowdhury, R. R., Shin, Y. J., Visseren-Hamakers, J., Willis, K. J. & C. N. Zayas (eds.), Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Bonn, Germany, 56 pp.

Intergovernmental Panel on Climate Change (IPCC) (2022). Summary for Policymakers, In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Pörtner, H. O., Roberts, D.C., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, A., Okem A. & B. Rama (eds.), Cambridge University Press. In Press, 35 pp.

IPCC (2019a). IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, Pörtner, H. O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama B. & N. M. Weyer (eds.), In press, 755 pp.

IPCC (2019b). Annex I: Glossar, Weyer N.M. (ed.), In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* Pörtner, H. O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama B. & N. M. Weyer (eds.), In Press, 677-702.

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden P. J. & C. E. Hanson (eds.), Cambridge University Press: Cambridge, UK, 976 pp.

Jupiter, S., Mangubhai, S. & R. T. Kingsford (2014). Conservation of Biodiversity in the Pacific Islands of Oceania: Challenges and Opportunities Pacific, *Pacific Conservation Biology*, 20(2), 206–220.

Jury, C. P. & R. J. Toonen (2019). Adaptive responses and local stressor mitigation drive coral resilience in warmer, more acidic oceans, *Proceedings Royal Society B*, 286, 20190614, 1-9.

Kavousi, J. & G. Keppel (2018). Clarifying the concept of climate change refugia for coral reefs, *ICES Journal of Marine Science*, 75 (1), 43 – 49.

Keener, V. W., Marra, J. J., Finucane, M. L., Spooner, D. & M. H. Smith (2012). Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment (PIRCA), Island Press: Washington DC, USA, 170 pp.

Kelle, U. (2014) Mixed Methods, In: Handbuch Methoden der empirischen Sozialforschung, Baur N. & J. Blasius (eds.) Springer: Wiesbaden, Germany, 153-166 pp.

Keppel, G., Morrison, C., Watling, D., Tuiwawa, M. V. & I. A. Rounds (2012). Conservation in tropical Pacific Island countries: why most current approaches are failing. *Conservation Letters* 5, 256-265.

Kingsford, R. T., Watson, J. E. M., Lundquist, C. J., Venter, O., Hughes, L., Johnston, E. L., Atherton, J., Gawel, M., Keith, D. A., MacKey, B. G., Morley, C., Possingham, H. P., Raynor, B., Recher, H. F. & K. A. Wilson (2009). Major conservation policy issues for biodiversity in oceania, *Conservation Biology*, *23*(4), 834–840.

Kumar, R. (2011). Research Methodology – A step-by-step guide for beginners, 3rd Edition, Sage Publications Ltd: London, UK, 440 pp.

Lau, F. & C. Kuziemsky (2017). Handbook of eHealth Evaluation: An Evidence-based Approach, University of Victoria: Victoria, Canada, 487 pp.

Laursen, S., Puniwai, N., Genz, A. S., Canale, L. K. & S. Ziegler-Chong (2018) Collaboration across worldviews: Managers and scientists on Hawai΄i Island utilize knowledge coproduction to facilitate climate change adaptation, Environmental Management, 62, 619-630.

Lebrec, M., Stefanski, S., Gates, R., Acar, S., Golbuu, Y., Claudel-Rusin, A., Kurihara, H., Rehdanz, K., Paugam-Baudoin, D., Tsunoda, T. & P. W. Swarzenski (2019). Ocean acidification impacts in select Pacific Basin coral reef ecosystems, *Regional Studies in Marine Science*, 28, 100584, 1-8.

Lowe, R. J., Pivan, X., Falter, J., Symonds, G. & R. Gruber (2016). Rising sea levels will reduce extreme temperature variations in tide-dominated reef habitats, *Science Advances*, 2(8), e1600825, 1-12.

Ministry of Agriculture, Fisheries, and Environment (MAFE) (2019). 6th National Report for the Convention on Biological Diversity, Republic of Palau, Ministry of Natural Resources, Environment and Tourism: Koror, Palau, 66 pp.

Maragos, J. E. & G. J. Williams (2011). Pacific Coral Reefs: An Introduction, In: Encyclopedia of Modern Coral Reefs: Structure, Form and Process, David Hopley (ed.), Springer Netherlands: Dodrecht, Netherlands, 753-825.

Marra, J. J. & M. C. Kruk (2017). State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate: 2017, NOAA NESDIS National Centers for Environmental Information (NCEI), 82 pp.

Marshall, N. A., Tobin, R. C., Marshall, P. A., Gooch M. & A. J. Hobday (2013). Social Vulnerability of Marine Resource Users to Extreme Weather Events, *Ecosystems*, 16(5), 797-809.

Maxwell, S. L., Cazalis, V., Dudley, N., Hoffmann, M., Rodrigues, A. S. L., Stolton, S., Visconti, P., Woodley, S., Kingston, N., Lewis, E., Maron, M., Strassburg, B. N. B., Wenger, A., Jonas, H. D., Venter, O. & J. E. M. Watson (2020). Area-based conservation in the twenty-first century, *Nature*, 586(7828), 217–227.

Maynard, J., McKagan, S., Raymundo, L., Johnson, S., Ahmadia, G., Johnston, L., Houk, P., Williams, G., Kendall, M., Heron, S., van Hooidonk, R. & E. McLeod (2015a) Assessing relative resilience potential of coral reefs to inform in the Commonwealth of the Northern Mariana Islands, NOAA Coral Reef Conservation Program, NOAA Technical Memorandum CRCP 22: Silver Spring, USA, 153 pp.

Maynard, J., Parker, B., Beeden, R., Tamelander, J., McGowan, P., Gramer, L., Heron, S., Kendall, M., McKagan, S., McLeod, E., Oleson, K. & S. Pittman (2015b). Coral Reef Resilience Research and Management – Past, Present and Future! Workshop Report, NOAA Technical Memorandum CRCP 20, 47 pp.

Mayring, P. (2015). Qualitative Inhaltsanalyse. Grundlagen und Techniken, Beltz (Beltz Pädagogik): Weinheim, Germany, 152 pp.

Mayring, P., 2000. Qualitative Content Analysis, Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 1(2), Art. 20, 10 pp.

McKenzie, L. J., Yoshida, R. L., Aini, J. W., Andréfouet, S., Colin, P. L., Cullen-Unsworth, L. C., Hughes, A. T., Payri, C. E., Rota, M., Shaw, C., Skelton, P. A., Tsuda, R. T. Vuki, V. C. & R. K. F. Unsworth (2021). Seagrass ecosystems of the Pacific Island Countries and Territories: A global bright spot, *Marine Pollution Bulletin*, 167, 24.

McLeod, E., Anthony, K. R. N., Mumby, P. J., Maynard, J., Beeden, R., Graham, N. A. J., Heron, S. F., Hoegh-Guldberg, O., Jupiter, S., MacGowan, P., McLeod, K., Nyström, M., Obura, D., Parker, B., Possingham, H. P., Salm, R. V: & J. Tamelander (2019). The future of resilience-based management in coral reef ecosystems, *Journal of Environmental Management*, 233, 291-301.

McLeod, E., Szuster, B., Hinkel, J., Tompkins, E. L., Marshall, N., Downing, T., Wongbusarakum, S., Patwardhan, A., Hamza, M., Anderson, C., Bharwani, S., Hansen L. & P. Rubinoff (2015). Conservation Organizations need to consider adaptive capacity: Why local input matters, *Conservation Letters*, 9(5), 351-360.

McLeod, E., Salm R., Green A. & J. Almany (2009). Designing marine protected area networks to address the impacts of climate change, *Frontiers in Ecology and the Environment*, 7(7), 362–370.

McLeod, E. & R. V. Salm (2006). Managing Mangroves for Resilience to Climate Change, IUCN Resilience Science Group Working Paper Series – No 2, IUCN: Gland, Switzerland, 64 pp.

McMillen, H. L., Ticktin, T., Friedlander, A., Jupiter, S.D., Thaman, R., Campbell, J., Veitayaki, J., Giambelluca, T., Nihmei, S., Rupeni, E., Apis-Overhoff, L. Aalbersberg, W. & D. F. Orcherton (2014). Small islands, valuable insights: Systems of customary resource use and resilience to climate change in the Pacific, *Ecology and Society*, 19(4): 44.

Millennium Ecosystem Assessment (MEA) (2005). Ecosystems and Human Well-Being: Synthesis. Island Press: Washington D. C., USA, 137 pp.

Miles, W., Grecni, Z., Matsurato, E., Colin, P., Kenner, V. & Y. Golbuu (2020). Climate Change in Palau: Indicators and Considerations for Key Sectors. Report for the Pacific Islands Regional Climate Assessment, East-West Center: Honolulu, USA, 66 pp.

Mori, A. S., Furukawa, T. & T. Sasaki (2013). Response diversity determines the resilience of ecosystems to environmental change, *Biological Reviews*, 88, 349-364.

Moritz, C., Vii, J., Lee Long, W., Jerker, T., Thomassin, A. & S. Planes (2018). Status and Trends of Coral Reefs of the Pacific, Global Coral Reef Monitoring Network, 218 pp.

Moverley, D. (2019). Battling invasive species in the Pacific. In: Veitch, C.R., Clout, M.N., Martin, A.R., Russel, J. C. & C. J. West (eds.) Island invasives: scaling up to meet the challenge, Occasional Paper of the IUCN Species Survival Commission No. 62, IUCN: Gland, Switzerland, 658–662 pp.

Muller-Karanassos, C., Marine, L. L., Otto, E. I., Bukurrou, A., Olsudong, D., Bukurou, L. M., Koshiba, S., Jonathan, R. & G. Mereb (2020) Assessment of Ngemai Conservation Area indicates a significant decrease in seagrass cover from 2018 to 2020, PICRC Technical Report No. 21-01, PICRC: Koror, Palau, 33 pp.

Mumby, P. J. (2006). Connectivity of reef fish between mangroves and coral reefs: algorithms for the design of marine reserves at seascape scales, *Biological Conservation*, 128, 215–222.

National Environmental Protection Council (NEPC) (2019). State of the Environment Report. NEPC: Koror, Palau, 99 pp.

National Environmental Protection Council (NEPC) (2017). State of the Environment Report, NEPC: Koror, Palau, 76 pp.

O´Brien, K. R., Waycott, M., Maxwell, P., Kendrick, G. A., Udy, J. W., Ferguson, J. P., Kilminster, K., Scanes, P., McKenzie, L. J., McMahon, K., Adams, M. P., Samper-Villarreal, J., Collier, C., Lyons, M., Mumby, P. J., Radke, L., Christianen, M. J. A. & W. C. Dennison (2018). Seagrass ecosystem trajectory depends on the relative timescales of resistance, recovery and disturbance, *Marine Pollution Bulletin,* 134, 166-176.

OEPPC (2017). Republic of the Marshall Islands Fifth National Report: Convention on Biological Diversity, Office of Environmental planning Policy Coordination, Republic of the Marshall Islands: Majuro, RMI, 47 pp.

Oesterwind, D., Rau, A. & A. Zaiko (2016). Drivers and pressures – Untangling the terms commonly used in marine science and policy, *Journal of Environmental Management*, 181, 8–15.

Office of the Pacific Ocean Commissioner (OPOC) (2021). Blue Pacific Ocean Report, Pacific Ocean Commissioner to the Pacific Islands Forum Leaders: Suva, Fiji, 248 pp.

Oliver, T. H., Smithers, R. J., Bailey, S., Walmsley C. A. & K. Watts (2012) A decision framework for considering climate change adaptation in biodiversity conservation planning, *Journal of Applied Ecology*, 49, 1247-1255.

Oppenheimer, M., Glavovic, B.C., Hinkel, J., van de Wal, R., Magnan, A. K., Abd-Elgawad, A., Cai, R., Cifuentes-Jara, M., DeConto, R. M., Ghosh, T., Hay, J., Isla, F., Marzeion, B., Meyssignac B. & Z. Sebesvari (2019). Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* Pörtner, H.-O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B. & N. M. Weyer (eds.), In press, 657-674.

O'Regan, S. M., Archer, S. K., Friesen S. K. & K. L. Hunter (2021). A Global Assessment of Climate Change Adaptation in Marine Protected Area Management Plans, *Frontiers in Marine Science*, 8, 711085, 1-16.

Pacific Islands Managed and Protected Area Community (PIMPAC) (2017). Strategic Plan 2017-2020, PIMPAC: Guam, 50 pp.

Pacific Islands Ocean Observing System (PacIOOS) (2022). Marshall Islands. Last accessed 2nd of October 2022: https://www.pacioos.hawaii.edu/education/region-rmi/

Palau Conservation Society (PCS) (2016). The Republic of Palau: Revised National Biodiversity Strategy and Action Plan 2015-2025, Ministry of Natural Resources, Environment and Tourism, Koror, Palau, 177 pp.

Pante, E., Adjeroud, M., Dustan, P., Penin, L. & M. Schrimm (2006). Spatial patterns of benthic invertebrate assemblages within atoll lagoons: importance of habitat heterogeneity and considerations for marine protected area design in French Polynesia, *Aquatic Living Resources*, 19, 207-217.

Petersen, B., Aslan, C., Stuart, D. & P. Beier (2018). Incorporating Social and Ecological Adaptive Capacity into Vulnerability Assessments and Management Decisions for Biodiversity Conservation, *BioScience*, 68(5), 371–380.

Peterson, C. H., Franklin K. P. & E. E. Cordes (2020). Connectivity corridor conservation: A conceptual model for the restoration of a changing Gulf of Mexico ecosystem, *Elementa Science of the Anthropocene*, 8(1), 016, 1-14.

PICRC & COS (2019). Palau´s National Marine Sanctuary: Managing Ocean Change and Supporting Food Security, PICRC & COS: Koror, Palau & Stanford, USA, 52 pp.

Pilbeam, V., van Kerkhoff, L. & T. Weir (2019). Conservation Decision-Making in Palau: An Example of the Parallel Working of Scientific and Traditional Ecological Knowledge, *Environmental Management*, 64(5), 564–579.

Preiser, R., García, M. M., Hill L. & L. Klein (2021) Qualitative content analysis, In: *The Routledge Handbook of Research Methods for Social-Ecological Systems*, Biggs, R., de Vos, A., Preiser, R., Clements, H., Maciejewski K. & M. Schlüter (eds.), 1st Edition, Routledge: London, p. 526.

Preiser, R., Biggs, R., Vos A. & C. Folke (2018). Social-ecological systems as complex adaptive systems: organizing principles for advancing research methods and approaches, *Ecology and Society*, 23(4), 46.

Price, M. R. & R. J. Toonen (2017). Scalping up restoration efforts in the Pacific Islands: A call for clear management objectives, targeted research to minimize uncertainty, and innovative solutions to a wicked problem, Pacific Science, 71(4), 391-399.

Reimaanlok National Planning Team (2008). Reimaanlok: National Conservation Area Plan for the Marshall Islands 2007–2012, Climate Change Directorate: Majuro, RMI, 79 pp.

Richards, Z. (2014). The status of hard coral communities at Kosrae, Micronesia, *Marine Biodiversity*, 45(4), 655–666.

Rilov, G., Mazaris, A. D., Stelzenmüller, V., Helmuth, B., Wahl, M., Guy-Haim, T., Mieszkowska, N., Ledoux, J.-B. & S. Katsanevakis (2019). Adaptive marine conservation planning in the face of climate change: What can we learn from physiological, ecological and genetic studies? *Global Ecology and Conservation*, 17, e00566.

Rivera, H., Cohen, A., Thomspon, J., Baums, I., Fox, M. & K. Meyer (2022). Palau´s warmest reefs harbor a thermally tolerant coral lineage that thrives across different habitats, Communications Biology, 5(1394), 1-21.

Roberts, C. M., O'Leary, B. C., Mccauley, D. J., Cury, P. M., Duarte, C. M., Lubchenco, J., Pauly, D., Sáenz-Arroyo, A., Sumaila, U. R., Wilson, R. W., Worm, B. & J. C. Castilla (2017). Marine reserves can mitigate and promote adaptation to climate change, *Proceedings of the National Academy of Sciences of the United States of America*, 114(24), 6167–6175.

Salafsky, N., Margoluis R. & K. H. Redford (2001). Adaptive management: a tool for conservation practitioners. Biodiversity Support Program: Washington D. C., USA, 100 pp.

Seaborn, T., Griffith, D., Kliskey A. & C. C. Caudill (2021). Building a bridge between adaptive capacity and adaptive potential to understand responses to environmental change, *Global Change Biology*, 1-13.

Secretariat of the Pacific Regional Environment Programme (SPREP) (2022). The Inform Project. Last accessed 2nd of October 2022: https://www.sprep.org/inform

SPREP (2021). Pacific Coral Reef Action Plan 2021-2030, SPREP: Apia, Samoa, 42 pp.

SPREP (2019). Federated States of Micronesia State of Environment Report 2018, SPREP: Apia, Samoa, 174 pp.

SPREP (2016). The Republic of the Marshall Islands: State of Environment Report, SPREP: Apia, Samoa, 160 pp.

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith A. & B. Turner (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges, *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375, 20190120, 1-12.

Shamberger, K. E. F., Cohen, A. L., Golbuu, Y., McCorkle, D. C., Lentz S. J. & H. C. Barkley (2014). Diverse coral communities in naturally acidified waters of a Western Pacific Reef, *Geophysical Research Letters*, 41, 499–504.

Shaver, E. C., McLeod, E., Hein, M. Y., Palumbi, S. R., Quigley, K., Vardi, T., Mumby, P. J., Smith, D., Montoya-Maya, P., Muller, E. M., Banaszak, A. T., McLeod, I. M. & D. Wachenfeld (2022) A roadmap to integrate resilience into the practice of coral reef restoration, *Global Change Biology*, 28, 4751-4764.

Shelton, A. J. & R. H. Richmond (2016). Watershed restoration as a tool for improving coral reef resilience against climate change and other human impacts, *Estuarine, Coastal and Shelf Science*, 183, 430-437.

Siders, A. R. (2019). Adaptive capacity to climate change: A synthesis of concepts, methods, and findings in a fragmented field, *WIREs Climate Change*, 10(3), 1–18.

Sippo, J. Z., Maher, D. T., Tait, D. R., Holloway C. & I. R. Santos (2016). Are mangroves drivers of buffers of coastal acidification? Insights from alkalinity and dissolved inorganic carbon export estimates across a latitudinal transect, *Global Biogeochemical Cycles*, *30*, 753-766.

Smit, B. & J. Wandel (2006). Adaptation, adaptive capacity and vulnerability, *Global Environmental Change*, 16(3), 282–292.

Spooner, D., Polhemus, D., Peterson, W., Gombos, M., Miles, W., Enomoto, S., Speicher M. & P. Fifita (2017). Climate Change Adaptation Planning in the U.S. Affiliated Pacific Islands: Assessment of Current Capacity and Recommendations for Future Opportunities, Pacific Islands Climate Change Cooperative: Honolulu, USA, 99 pp.

Stein, B. A., Glick, P., Edelson N. & A. Staudt (eds.) (2014). Climate-Smart Conservation: Putting Adaptation Principles into Practice, National Wildlife Federation: Washington, USA, 262 pp.

Stein, B. A., Staudt, A., Cross, M. C., Dubois, N. S., Enquist, C., Griffis, R., Hansen, L. J., Hellmann, J. J., Lawler, J. J., Nelson, E. J. & A. Pairis (2013). Preparing for and managing change: climate adaptation for biodiversity and ecosystems, *Frontiers in Ecology and the Environment,* 11(9), 502-510.

Taherdoost, H. (2019). What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale, *International Journal of Academic Research in Management (IJARM)*, 8(1), 2296–1747.

Tan, Y. M., Dalby, O., Kendrick, G. A., Statton, J., Sinclair, E. A., Fraser, M. W., Macreadie, P. I., Gillies, C. L., Coleman, R. A., Waycott, M., van Dijk, K., Vergés, A., Ross, J. D., Campbell, M. L., Matheson, F. E., Jackson, E. L., Irving, A. D., Govers, L. L., Connolly, R. M., McLeod, I. M., Rasheed, M. A., Kirkman, H., Flindt, M. R., Lange, T., Miller, A. D. & C. D. H. Sherman (2020). Seagrass Restoration Is Possible: Insights and Lessons from Australia and New Zealand, *Frontiers in Marine Science*, 7, 617, 1-21.

The Nature Conservancy (TNC) (2014). Pohnpei Protected Areas Network Design Workshop, Workshop Report, The Nature Conservancy: Pohnpei, FSM, 43 pp.

Thiault, L., Marshall, P., Gelcich, S., Collin, A., Chlous F. & J. Claudet (2018). Mapping social–ecological vulnerability to inform local decision making, *Conservation Biology*, 32(2), 447–456.

Thomsen, M. S., Altieri, A. H., Angelini, C., Bishop, M. J., Bulleri, F., Farhan, R., Frühling, V. M. M., Gribben, P. E., Harrison, S. B., He, Q., Klinghardt, M., Ramus, A. P., Schiel, D. R., Schneider, T., Siciliano, A., Silliman, B. R., Smale, D. A., South, P. M., Wernberg, T., Zhang, S. & G. Zotz (2022). Heterogeneity within and among co-occurring foundation species increases biodiversity, *Nature Communications*, 13, 581, 1-9.

Thronicke, K., Bahn, M., Lavorel, S., Bardgett, R.D., Erb, K., Giamberini, M., Recihstein, M., Vollan, B. & A. Rammig (2020). Advancing the Understanding of Adaptive Capacity of Social-Ecological Systems to Absorb Climate Extremes, *Earth´s Future*, (8)e2019EF001221.

Tittensor, D. P., Beger, M., Boerder, K., Boyce, D. G., Cavanagh, R. D., Cosandey-Godin, A., Crespo, G. O., Dunn, D. C., Ghiffary, W., Grant, S. M., Hannah, L., Halpin, P. N., Harfoot, M., Heaslip, S. G., Jeffery, N. W., Kingston, N., Lotze, H. K., McGowan, J., McLeod, E., McOwen, C. J., O´Leary, B. C., Schiller, L., Stanley, R. R. E., Westhead, M., Wilson, K. L. & B. Worms (2019). Integrating climate adaptation and biodiversity conservation in the global ocean, *Science Advances*, *5*(11), 1–16.

Toki, B. & P. Davies (2021). Pacific Coral Reef Action Plan 2021 – 2030. Secretariat of the Pacific Regional Environment Programme: Apia, Samoa, 55 pp.

Trombulak, S. C., Omland, K. S., Robinson, J. A., Lusk, J. J., Fleischner, T. L., Brown G. & M. Domroese (2004). Principles of Conservation Biology: Recommended Guidelines for Conservation Literacy from the Education Committee of the Society for Conservation Biology, *Conservation Biology*, 18(5), 1180-1190.

United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC) (2022a). Protected Area Profile for Palau from the World Database of Protected Areas, Last accessed 2nd of October 2022: https://www.protectedplanet.net/country/PLW

United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC) (2022b). Protected Area Profile for Federal State of Micronesia from the World Database of Protected Areas, Last accessed 2nd of October 2022: https://www.protectedplanet.net/country/FSM

United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC) (2022c). Protected Area Profile for Marshall Islands from the World Database of Protected Areas, Last accessed 2nd of October 2022: https://www.protectedplanet.net/country/MHL

Valdez, S. R., Zhang, Y. S., van der Heide, T., Vanderklift, M. A., Tarquinio, F., Orth R. J. & B. R. Silliman (2020). Positive Ecological Interactions and the Success of Seagrass Restoration, *Frontiers in Marine Science*, 7, 91, 1-11.

Van der Geest, K., Burkett, M., Fitzpatrick, J., Stege M. & B. Wheeler (2020). Climate change, ecosystem services and migration in the Marshall Islands: are they related? *Climatic Change* (161), 109-127.

van Kerkhoff, L., Munera, C., Dudley, N., Guevara, O., Wyborn, C., Figueroa, C., Dunlop, M., Hoyos, M. A., Castiblanco, J., & L. Becerra (2019). Towards future-oriented conservation: Managing protected areas in an era of climate change, *Ambio*, *48*(7), 699–713.

van Woesik, R., Houk, P., Isechal, A. L., Idechong, J. W., Victor, S. & Y. Golbuu (2012). Climate-change refugia in the sheltered bay of Palau analogs of future reefs, *Ecology and Evolution*, 2474-2484.

Ward, R. D., Friess, D. A., Day R. H. & R. A. MacKenzie (2016). Impacts of climate change on mangrove ecosystems: a region by region overview, *Ecosystem Health and Sustainability,* 2(4), e01211.

Waycott, M., McKenzie, L. J., Mellors, J. E., Ellison, J. C., Sheaves, M. T., Collier, C., Schwarz, A.-M., Webb, A., Johnson J. E. & C. E. Payri (2011). Chapter 6 Vulnerability of mangroves, seagrasses and intertidal flats in the tropical Pacific to climate change, Bell, J. D., Johnson J. E. & A. J. Hobday (eds.) *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*, Secretariat of the Pacific Community: Noumea, New Caledonia, 297–368.

Weeks, R. & V. M. Adams (2017). Research priorities for conservation and natural resource management in Oceania's small-island developing states, *Conservation Biology*, 32, 72–83.

Weeks, R. (2017). Incorporating seascape connectivity in conservation prioritisation, *PLoS ONE*, 12(7) e0182396.

Weeks, R., Terk, L., Gorong, B., Aulerio M. & B. Reyuw (2016). Spatial Analysis in Support of Development of the Yap Protected Area Network, Technical report, The Nature Conservancy, 57 pp.

Weeks, R. (2015). Pohnpei's Protected Area Network: Gap Analysis & Spatial Prioritisation, The Nature Conservancy Pohnpei: Pohnpei, FSM, 69 pp.

Weeks, R. & S. D. Jupiter (2013). Adaptive Comanagement of a Marine Protected Area Network in Fiji, *Conservation Biology*, 27(6), 1234-1244.

Whitney, C. K., Bennett, N. J., Ban, N. C., Allison, E. H., Armitage, D., Blythe, J. L., Burt, J. M., Cheung, W., Finkbeiner, E. M., Kaplan-Hallam, M., Perry, I., Turner, N. J. & L. Yumagulova (2017). Adaptive capacity: from assessment to action in coastal social-ecological systems, *Ecology and Society*, 22(2)22.

Woods Hole Oceanographic Institution (WHOI) (2022). Super Reefs, Last accessed 11nd November 2022: https://superreefs.whoi.edu/our-process/

Wilson, K. L., Tittensor, D. P., Worm B. & H. K. Lotze (2020). Incorporating climate change adaptation into marine protected area planning, *Global Change Biology*, 26(6), 3251-3267.

Young, J. C., Rose, D. C., Mumby, H. S., Benitez-Capistros, F., Derrick, C. J., Finch, T., Garcia, C., Home, C., Marwaha, E., Morgans, C., Parkinson, S., Shah, J., Wilson K. A. & N. Mukherjee (2018). A methodological guide to using and reporting on interviews in conservation science research, *Methods in Ecology and Evolution*, 9(1), 10–19.

# 8. Annex

## Annex Ia: Structured literature review on the integration of climate change adaptation and conservation

*Web of Science* platform keyword search-term results of publication titles focused on conservation and climate change adaptation. The review was completed in July 2022, please refer for further details to the Supplementary Material 1. With first, the total number of publications (all returns), second publications extracted based on duplication or topic, excluding articles focusing on e. g. social protection, and third the number of all relevant publications (n=72). Contrary, to these results the search terms "climate change" and AND "conservation" returned 679 results in publication titles on *Web of Science*.

| **Search terms included in Publication "Titles" in Web of Science** | **Timeframe** | **Timeframe of all publications** | **All returns** | **Extracted Doubles** | **Extracted based on topic** | **Final list of Publications** |
|---|---|---|---|---|---|---|
| Climate change adaptation* AND protection* | 1945-2022 | 2007-2021 | 19 | 1 | 16 | 2 |
| Climate change adaptation* AND protect* NOT protection* | | 2005-2021 | 21 | - | 3 | 18 |
| Climate change adaptation* AND conservation* | | 2008-2022 | 50 (56)[14] | 1 | - | 49 |
| Climate change adaptation* AND conserve* | | 2018-2022 | 2 | - | - | 2 |
| Climate change adaptation* AND preservation* | | 2019-2021 | 2 | - | 1 | 1 |
| Climate change adaptation* AND preserve* | | 2019-2021 | 2 | | 2 | 0 |
| Total | | 2004-2018 | 96 | 2 | 22 | 72 |

[14] *Web of Science* provided 56 results, whereas the Excel list, provided by *Web of Science,* only contained a total of 50 publications. For this review the provided 50 results were analyzed.

## Annex Ib: Structured literature review of the three coastal ecosystems and three countries in Micronesia.

Structured keyword-based literature review of publications focused on coastal ecosystems (coral, mangrove, seagrass) in three Micronesian states (Palau, RMI, FSM) via *Web of Science*. The review was completed in August 2022, please refer for further details to the Supplementary Material 2. First, the total number of publication titles (all returns) were screened to second extract titles based on duplication. After, publications were excluded if these set outside the three states, and third abstracts and articles of publications without a location in the title were screened and excluded if none of the these addressed the three countries.

| **Ecosystem** | **Country** | **Timeframe** | **Search terms in the database Web of Science** | **All title returns** | **Nr. of titles (doubles extracted)** | **Final list of titles (location extracted)** |
|---|---|---|---|---|---|---|
| Coral | Palau | 2012-2022 | Coral* AND Palau* (Title); Coral reef* AND Palau* (Title) | 42 (28; 14) | 25 | 24 |
| | FSM | | Coral* AND Federates States of Micronesia* (Title); Coral* AND FSM* (Title); Coral reef* AND Federated States of Micronesia* (Title) | 8 (4; 0; 4) | 4 | 4 |
| | RMI | | Coral* AND Marshall Islands* (Title); Coral* AND Republic of the Marshall Islands* (Title); Coral reef* AND Marshall Islands* (Title) | 9 (6; 0; 3) | 5 | 5 |
| | **Total** | | | **59** | **34** | **33** |
| Seagrass | Palau | 2012-2022 | Seagrass* AND Palau* (Title), (Topic), (All Fields) | 25 (0; 1; 23) | 14 | 13 |
| | FSM | | Seagrass* AND Federated States of Micronesia* (Title), (Topic), (All Fields) | - | - | - |
| | RMI | | Seagrass* AND Marshall Islands* (All Fields), (Topics), (Title); Seagrass* AND RMI* (All Fields) | - | - | - |
| | **Total** | | | **25** | **14** | **13** |
| Mangrove | Palau | 2012-2022 | Mangrove* AND Palau* (Title), (All Fields) | 28 (4; 24) | 18 | 15 |
| | FSM | | Mangrove* AND Federated States of Micronesia* (Title), (Topic), (All Fields) | 13 (2; 1; 10) | 10 | 10 |
| | RMI | | Mangrove* AND Marshall Islands* (Title), (All Fields) | 4 (0; 4) | 2 | 2 |
| | **Total** | | | **45** | **30** | **27** |

# Annex II: Identification and selection of the climate adaptive conservation strategies and related actions

**II.1 Selection criteria for the documents containing climate adaptive conservation strategies and related actions**

| Selection criteria | Description |
|---|---|
| Criteria for documents | • The respective article matched with the aim, scope and framing of this research (e. g. not broad national policy recommendations)<br>• The documents entailed a concrete list or outline of multiple recommendations, strategies, options, principles or frameworks to design, plan or manage conservation in and outside of protected areas, including related area-based management approaches (e. g. MSP) in a climate adaptive, resilient, or similar manner that addressed one or multiple ecosystem AC elements.<br>• At least two of the three ecosystem AC elements had to be directly or indirectly addressed in the proposed strategies or recommendations.<br>• The documents had to provide generic suggestions for climate adaptive conservation applicable or adjustable across environments or be focused on tropical marine and/or coastal ecosystems.<br>• The recommendations could contain species-level recommendations but had to focus mostly on ecosystem-scale AC supporting climate adaptive strategies or similar options. |

**II.2 List of strategies, recommendations or similar and list of authors forming the basis for the selection of the climate adaptive strategies and related actions**

The documents were composed of publications (n=6) from Journals that focused on conservation, global change biology, ecology, marine policy or environmental and coastal management and change, reports of (n=4), and a book chapter (n=1).

| **Title of Strategy, Principles, Options, Recommendations, Guideline or Framework** | **Authors** | **Location** |
|---|---|---|
| Goals for conservation and management of tropical ecosystems | Gladstone 2009 | Tropical coastal setting |
| General recommendations for resilient MPA network design | McLeod et al. 2009 | Non-specific |
| Guiding ecological principles for marine spatial planning | Foley et al. 2010 | Non-specific |
| Adaptation framework for biodiversity conservation in the Pacific | Hills et al. 2011 | Pacific |
| Biophysical design principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity, and climate change objectives in the Coral Triangle | Fernandes et al. 2012 | Coral Triangle |
| Guidelines for resilient marine protected area (MPA) network design to the adaptive-management process in Kubulau, Fiji | Weeks & Jupiter 2013 | Fiji |
| Ecological guidelines for designing marine reserve networks for fisheries management, biodiversity conservation, and climate change adaptation | Green et al. 2014 | Coral Triangle |
| Adaptation options and climate smart considerations | Stein et al. 2014 | Non-specific |
| Characterization of strategic options to adapt conservation to climate change extracted from the literature | Geyer et al. 2015 | Germany |
| Ecological principles and adaptation options (at different spatial and planning scales, e. g. individual PA or PAN) | Gross et al. 2016 | Non-specific |
| Management recommendation, evidence, and challenges to promoting reef resilience | McLeod et al. 2019 | Non-specific |

**II.3 Selection criteria for the identification and selection of the climate adaptive conservation strategies**

| Selection criteria & categorization of documents | Description |
|---|---|
| Categorization of selected documents | In addition, each selected article was further analyzed, based on the categories designed by the researcher (Supp. Mat. 3), to gain a more in-depth overview of the focus of each paper. The sources were analyzed based on the following categories:<br>• Form of publication (Journal, Book, Report)<br>• Aim of proposed strategies (e. g. design, management, planning)<br>• Theoretical concept (e. g. resilience, adaptation, ecosystem AC)<br>• Terminology of strategies (e. g. principles, guideline)<br>• Number of times each strategy of the synthesized list of strategies was included<br>• Ecological scale (e. g. species, ecosystem, seascape)<br>• Ecosystem type (e. g. non-specific, marine, coral) |
| Selection criteria for the strategies and related actions | • Strategies were included that addressed one or multiple ecosystem AC elements and activities were integrated when these addressed the ecosystem AC elements in relation to one or multiple of the selected strategies.<br>• General activities to support one or multiple ecosystem AC elements within conservation or related approaches (e. g. MSP)<br>• Specific activities that focused on coastal (tropical) ecosystems, species or ecosystems in the coastal seascape or connected landscapes (e. g. watersheds). |

# Annex III: Climate adaptive conservation strategies and related actions

| **Strategy 1: Reduction of non-climatic direct and indirect (local) drivers** | | | | |
|---|---|---|---|---|
| **Actions** | **References (general non-ecosystem specific or including all three ecosystems)** | **Additional exemplary references for**[15] | | |
| | | **Mangrove** | **Coral reef** | **Seagrass beds** |
| **1)** Reduction of non-climatic direct and indirect (local) drivers through different activities | Reimaan National Planning Team 2008; Baron et al. 2009; McLeod et al. 2009 & et al. 2019a; Hills et al. 2011; Green et al. 2014; Geyer et al. 2015; | Ellison 2018a | Barkley et al. 2017; Bruno et al. 2019; Jury & Toonen 2019 | O´Brien et al. 2018 |
| **2)** Sustainable fisheries management and practices, e. g.<br>• Ecosystem-based management<br>• Enforcement of non-destructive fishing practices and regulations (e. g. catch size)<br>• Provision of sustainable livelihood diversification options<br>• Trade restrictions on functional species groups | Gladstone 2009; Stein et al. 2014; Gross et al. 2016; Tittensor et al. 2019 | McLeod & Salm 2006 | Burke et al. 2011; Houk et al. 2015; Maynard et al. 2015a; Bruno et al. 2019 | |
| **3)** Sustainable coastal development and management<br>• Coastal zone planning<br>• Regulation and improvement of sewage treatment<br>• Coastal erosion-control measures during construction<br>• Regulation of unsustainable practices (e. g. dredging)<br>• (Removal of landward migration barriers)<br>• Management of buffer zones surrounding habitats and PAs | Grantham et al. 2011; Oliver et al. 2012; Gross et al. 2016 | McLeod & Salm 2006; Ward et al. 2016; Ellison 2018a | Burke et al. 2011; Bruno et al. 2019 | |
| **4)** Reduction of marine, land- or watershed-based pollution<br>• Reduction of damage from anchoring or fishing activities<br>• Regulations to reduce pollution (e. g. ballast water discharge) | Baron et al. 2009; Gross et al. 2016 | | Burke et al. 2011; Houk et al. 2015; Maynard et al. 2015a; Shelton & | |

[15] References listed under this section are non-exhaustive, and not identified through a targeted literature review. The references here are merely a starting point, based on the literature review of this thesis, and to give the reader a limited selection of exemplary publications regarding the three ecosystems in the context of climate adaptive conservation strategies and related activities.

| | | | | |
|---|---|---|---|---|
| • Marine debris removal<br>• Support of sustainable agriculture practices | | | Richmond 2016; Bruno et al. 2019 | |
| **5)** Maintenance and improvement of water quality along coasts, estuaries, lagoons, and atolls<br>• Regulation of natural resources, land and coastal use<br>• Reduction of riverine and coastal run-off<br>• Riverbank and estuary stabilization | Gladstone 2009; Stein et al. 2014; Courtney et al. 2017 | | Bruno et al. 2019 | O´Brien et al. 2018 |
| **6)** Preventing the introduction and tackling invasive alien species and reducing the spread of diseases | Gross et al. 2016; Moverley et al. 2019 | | Bruno et al. 2019 | |
| **Strategy 2: Embedment within broader management frameworks** | | | | |
| **7)** Embedment in comprehensive integrated frameworks, including planning and management at different scales<br>• Ecosystem- and/or area-based management tools and frameworks (e. g. IWRM, Integrated Coastal Zone Management (ICZM), MSP or Ridge to Reef)<br>• Comprehensive ocean zoning, integrated coastal zone, watershed, or riverine planning (e. g. remove barriers, ensure sediment supply to mangrove and seagrass ecosystems) | Gladstone 2009; Albert et al. 2010; Hills et al. 2011; Fernandes et al. 2012; Weeks & Jupiter 2013; Green et al. 2014; Weeks et al. 2016; Courtney et al. 2017; Ellison 2018a; Rilov et al. 2019; Peterson et al. 2020 | Ward et al. 2016; Ellison 2018a | Burke et al. 2011 | |
| **Strategy 3: Representation and replication of all ecosystems** | | | | |
| **8)** Protection of functional groups, ecologically coherent replicates of redundant ecosystems, species, and functional groups | Gladstone 2009, p. 10; Foley et al. 2010; Hills et al. 2011; Bernhardt & Leslie 2013; Mori et al. 2013; Weeks 2015; Weeks et al. 2016; Courtney et al. 2017; McLeod et al. 2019 | | Burke et al. 2011; Aguilar-Medrano & Calderon-Aguilera 2016 | |
| **9)** Risk spreading through the identification, prioritization, and protection of critical, isolated, highly diverse, and spatially separated areas | Green et al. 2007 & 2014; Reimaan National Planning Team 2008; McLeod et al. 2009 & 2018; Weeks & Jupiter 2013; Weeks 2015 & et al. 2016; McLeod et al. 2019 | McLeod & Salm 2006 | Burke et al. 2011; Maynard et al. 2015a | |

| | | | | |
|---|---|---|---|---|
| **10)** Protection of potential future climate refugia and ecosystems, habitats and species or areas showcasing a higher resilience to climatic and oceanographic changes across different thermal and environmental regimes (e. g. shaded or areas with cool upwelling, areas with historic highly variable SST, stress adapted species, coral, and seagrass habitats with healthy herbivore population). | McLeod et al. 2009; Green et al. 2014; Gross et al. 2016; Courtney et al. 2017; Rilov et al. 2019 | McLeod & Salm 2006; Ward et al. 2016 | Barkley et al. 2011 & et al. 2017; Burke et al. 2011; Van Woesik et al. 2012; Moritz et al. 2018; McLeod et al. 2019 | |
| **Strategy 4: Preserve and enhance land & seascape connectivity** | | | | |
| **11)** Identification, restoration, and protection of connectivity between associated ecosystems at different ecological spatial scales<br>• Maintain enough high regional habitat density to conserve viable metapopulations for network-level connectivity<br>• Protection of habitat quality and productivity in sites with fluctuating water movements and non-directional currents<br>• Knowledge and protection of upstream sites in case there is a strong unidirectional current | McLeod et al. 2009 & 2019a; Foley et al. 2010; Bernhardt & Leslie 2013; Green et al. 2014; Stein et al. 2014; Maynard et al. 2015b; Weeks 2015 & et al. 2016; Gross et al. 2016; Guannel et al. 2016; Weeks 2017; Gonzales et al. 2018; Angeler et al. 2019; Chambers et al. 2019; McLeod et al. 2019; Seddon et al. 2019; Hilty et al. 2020; Peterson et al. 2020 | Mumby et al. 2004; McLeod & Salm 2006 | Burke et al. 2011; Barkley et al. 2017 | |
| **12)** Creation and implementation of ecologically connected PANs | McLeod et al. 2009 & 2019a; Weeks & Jupiter et al. 2013; Stein et al. 2014; Gonzales et al. 2018 | | | |
| **13)** Identification and protection of critical areas including home ranges, nurseries, spawning sites (combined with other effective management tools outside of PAs, e. g. fisheries regulations) | Green et al. 2007 & 2014; McLeod et al. 2009 & 2019a; Weeks 2015 & et al. 2016; Tittensor et al. 2019; Peterson et al. 2020 | | Maynard et al. 2015b | |
| **14)** Identification and removal of barriers of migration and exchange | Gladstone 2009; Peterson et al. 2020 | Ward et al. 2016 | | |
| **15)** Identification and protection of migratory species or moving habitats (e. g. support of migration through flexible conservation) | Tittensor et al. 2019 | | | |
| **Strategy 5: Maintain land- and seascape heterogeneity** | | | | |
| **16)** Knowledge and protection of environmental, structural, or topographic heterogeneity at different ecological spatial scales | Folke 2006; Pante et al. 2006; Foley et al. 2010; Bernhardt & Leslie 2013; Geyer et al. 2015; | | Adjeroud et al. 2007; Albert et al. | |

| | | | | |
|---|---|---|---|---|
| • Protection of sites with different environmental gradients and (a)biotic characteristics (preferably at landscape or larger scale)<br>• Protection of structural heterogeneity within ecosystems<br>• Development of topographic heterogeneity in restored ecosystems | Cumming & Allen 2017; Lawrence et al. 2018; Petersen et al. 2018; Rilov et al. 2019; Seddon et al. 2019; Thomsen et al. 2022 | | 2010; Barkley 2011; Pante et al. 2006; Maynard et al. 2015a | |
| **Strategy 6: Restoration of ecosystems** | | | | |
| **17)** Restoration or rehabilitation of degraded, critical, or connected ecosystems, habitats, and vulnerable species at risk<br>• Restoration of landscape features enabling species movement, of corals via asexual (e. g. direct transplanting, coral gardening through micro-fragmentation), via sexual propagation (e. g. larval enhancement), artificial reef installation or macroalgae removal<br>• Restoration of seagrass beds via transplanting (e. g. re-stocking or habitat creation) with high seed density in clumped planting arrangements of differential aged species individuals (creating structural heterogeneity) that are adapted to stressful environments<br>• Restoration of mangroves (e. g. via active facilitation of sediment accretion rates through coastal structures) or dense seedling planting | Baron et al. 2009; Gladstone 2009; Hills et al. 2011; Oliver et al. 2012; Stein et al. 2014; Geyer et al. 2015; Gross et al. 2016; Ellison 2018a; Lawrence et al. 2018; McLeod et al. 2019; Tittensor et al. 2019; Rilov et al. 2019 | Ellison 2018a | Baker et al. 2008; Maynard et al. 2015a; Boström-Einarsson et al. 2020; Foo & Asner 2020 | Tan et al. 2020; Boudouresque et al. 2021; Brodie et al. 2020; Valdez et al. 2020; McKenzie et al. 2021 |
| **18)** Creation of new or future habitats or ecosystems in proximity to protected areas across different gradients (e. g. environmental)<br>• Translocation and support of population colonization to other or new areas through existing source populations or active reproduction<br>• Selection of sites close to population with long-distance facilitators | Oliver et al. 2012; Geyer et al. 2015; McLeod et al. 2019; Tan et al. 2020 | | | Valdez et al. 2020 |
| **19)** Restoration and related activities considering positive species interactions (e. g. seagrass and clams) | Brodie et al. 2020; Valdez et al. 2020 | | | |

| | | | | |
|---|---|---|---|---|
| **20)** Other related or non-conservation activities (e. g. building regulations & trade restrictions)<br>• Application of approaches that enhance restoration with natural elements (e. g. wooden sticks) to stabilize coastlines and support restoration efforts | Ellison 2018b | Ellison 2018a | | |
| **Strategy 7: Maintain ecosystem processes and ecological functioning** | | | | |
| **21)** Protect critical sites to protect ecological functions (e. g. support episodes of high coral recruitment more frequent than disturbances)<br>• Prioritizing and protecting topographic and oceanographic features, structures, and organisms forming the foundation of the ecosystem´s properties | McLeod et al. 2009; Foley et al. 2010; Hills et al. 2011; Fernandes et al. 2012; Gross et al. 2016, Weeks et al. 2016; McLeod et al. 2019; Tittensor et al. 2019; Rilov et al. 2019 | | Adjeroud et al. 2007 | |
| **22)** Maintain diversity of keystone species and functional groups with a high functional redundancy to support coastal ecosystem recovery | Cinner et al. 2013; Mori et al. 2013; McLeod et al. 2019 | | Houk et al. 2015 | |
| **23)** Long-term protection of functional (trophic) groups and ecosystems to allow time for recovery | Green et al. 2014; Courtney et al. 2017 | | | |
| **Strategy 8: Knowledge of and addressing climate change-related drivers potentially impacting coastal ecosystems** | | | | |
| **24)** Consideration and use of climate information<br>• Vulnerability and risk assessments (e. g. of ecosystems in certain places, various climate change-related drivers)<br>• Monitoring of SST changes and potential coral refuges<br>• Data collection sites on a sub-national basis<br>• Early warning systems (e. g. to modify catch limits)<br>• Data collection on species range shifts under climate change (e. g. to identify location of conservation buffer zones) | McLeod & Salm 2006; Hills et al. 2011; Green et al. 2014; Geyer et al. 2015 & 2017; Gross et al. 2016; McLeod et al. 2019; Moritz et al. 2018; Rilov et al. 2019; Duncan et al. 2020 | | Maynard et al. 2015a; Moritz et al. 2018 | |
| **25)** Application of precautionary principle and proactive risk reduction<br>• Prioritize areas with low risk of potential climate change-related impacts and high social AC<br>• Protect buffer-zones to accommodate potential species range shifts | Hills et al. 2011; Geyer et al. 2015 & et al. 2017; McLeod et al. 2019 | | | |

| | | | | |
|---|---|---|---|---|
| • Compensate for potential climate change-related drivers where possible (e. g. enable drainage of freshwater to reduce high salinity levels), translocate species populations<br>• Prevent the introduction, spreading and establishment of invasive alien species | | | | |
| **26)** Scenario planning to identify robust (climate adaptive) strategies and management activities under different climate scenarios<br>• Effective management of landscape multifunctionality<br>• Adaptive conservation planning and site management based on climate change projections (e. g. potential retreat, species shift, or elimination of certain sites based on threshold ranges)<br>• Prioritized conservation and activities of sites with suitable conditions across a range of climate scenarios | Baron et al. 2009; Geyer et al. 2015; McLeod et al. 2019; Gladstone-Gallagher et al. 2019; Duncan et al. 2020 | | | |

## Annex V: Selection criteria for key informants of the semi-quantitative survey

| Identification process and selection criteria | Description |
| --- | --- |
| Expert identification | • Literature review of publications, policy documents, reports to the Convention on Biological Diversity, conservation action or strategic plans of national and sub-national conservation actors, or reports of local activities (e. g. SPREP 2019).<br>• Extensive online research, which was structured by, (1) identifying relevant ministries, (2) policies, (3) state-level agencies, and (4) organizations or research institutions responsible for the planning and/or management of PAs, MPAs, PANs, and related measures (e. g. IWRM).<br>• Additional online research of stakeholder or steering committee meetings or participant lists of local, regional, or international conferences, workshops, trainings, or project reports to identify contact information and up to date staff lists of key organizations and governmental agencies. As most websites of regional actors did not disclose or contained up-to-date contacts of their staff.<br>• In addition, the researchers own contacts in the Pacific Region and a chain-referral of additional experts through the participants, were helpful to maximize results. |
| Selection criteria for key informants | • Knowledge of Micronesia, and/or FSM, RMI and/or Palau, and coastal (marine) ecosystems, specifically coral reefs.<br>• Knowledge of climate change-related drivers and potential impacts on coastal ecosystems, conservation and related (e. g. IWRM) objectives.<br>• Knowledge of local, national, and/or regional conservation strategies and related actions, as well as management frameworks, approaches, and projects, indirectly or directly supporting ecosystem AC (e. g. Ridge to Reef). This expertise could be either based on research, publications in peer-reviewed journals or gray literature, and/or several years long practical and professional experience. |

**Annex VI: Search strings for the screening of literature on the ecosystem adaptive capacity elements**

| AC Elements | Literature search terms |
|---|---|
| Biodiversity | "diversity", "biodiversity", "variability", "variation" |
| Connectivity | "connected", "connectivity", "connecting", "connection", "source", "sink", "refugia", "refuge", "corridor" |
| Heterogeneity | "heterogeneity", "heterogeneous" |
| Ecological or ecosystem functioning | "functioning", "function", "functional", "redundancy" |

# Annex VII: Survey questionnaire

## Climate adaptive conservation in Micronesia

Dear Participant,

This survey explores how conservation, through the implementation of climate adaptive conservation strategies and actions, can support the adaptive capacity of coral reefs facing climate change in Palau, the Federated States of Micronesia, and the Marshall Islands. The results will be provided to you and conservation actors in the three islands states.

The survey takes 10 to 15 minutes.

Your participation is completely voluntary, free to decline or stop at any time. Questions and information are impersonal and will be treated strictly confidential.

If you have questions or concerns please contact me, Marie-Isabell Lenz (lenz@student.unu.edu) or the data protection officer of the University of Bonn (joerg.hartmann@uni-bonn.de).

By clicking the checkbox you agree to participate in this survey.

☐ I Agree

**1. Which country does your work mostly focus on?**

- ◯ Republic of Palau
- ◯ Federated States of Micronesia
- ◯ Republic of the Marshall Islands
- ◯ Multiple
- ◯ Other

Please specify

**2. Which of the following best describes the organization you work for?**

- ◯ Governmental organization
- ◯ Sub-national or national NGO
- ◯ International NGO
- ◯ Academic / Research Institution
- ◯ Foundation / Donor Organization
- ◯ Community Organization
- ◯ Other

Please specify

**3. What scale does your work mostly focus on?**

- ◯ International
- ◯ Regional
- ◯ National
- ◯ Sub-national / Provincial
- ◯ District / Municipality
- ◯ Local or Community
- ◯ Other

Please specify

**4. What ecosystem(s) does your work mostly focus on?**

- ◯ Mangroves
- ◯ Seagrass beds
- ◯ Coral reefs
- ◯ Mulitple
- ◯ Other

Other (please specify)

**5. What topic does your work mostly focus on?**

- ◯ Ecosystems and biodiversity
- ◯ Agriculture
- ◯ Fisheries
- ◯ Livelihoods and communities
- ◯ Human health
- ◯ Infrastructure
- ◯ Climate change
- ◯ Other

Please specify

**6. For which country will you answer the survey?**

- ◯ Republic of Palau
- ◯ Federated States of Micronesia
- ◯ Republic of the Marshall Islands

7. What is the current state of coral reefs on a national scale?

| | Excellent 1 | 2 | 3 | 4 | Very poor 5 | Unkown |
|---|---|---|---|---|---|---|
| Ecosystem health | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity | ○ | ○ | ○ | ○ | ○ | ○ |
| Provision of Ecosystem Services | ○ | ○ | ○ | ○ | ○ | ○ |

8. Which non-climatic drivers have negatively impacted coral reefs on a national scale in the last 10 years?

- ☐ Pollution
- ☐ Eutrophication / Algal Bloom
- ☐ Invasive Alien Species
- ☐ Habitat change
- ☐ Other
- ☐ None of the above

Please specify

9. Which climate change drivers have negatively impacted coral reefs on a national scale in the last 10 years?

- ☐ Sea-level rise (SLR)
- ☐ Sea-surface temperature (SST) changes
- ☐ Ocean acidification
- ☐ Extreme weather events
- ☐ Changing rainfall patterns
- ☐ Other
- ☐ None of the above

**10. What climate change driver had the highest negative impact on coral reefs on a national scale in the last 10 years?**

- ◯ Sea-level rise (SLR)
- ◯ Sea-surface temperature (SST) changes
- ◯ Ocean acidification
- ◯ Extreme weather events
- ◯ Changing rainfall patterns
- ◯ Other
- ◯ None of the above

**11. What coastal marine ecosystem do you think is most at risk from climate change in the country, and why?**

- ☐ Coral reefs
- ☐ Mangroves
- ☐ Seagrass beds
- ☐ **Please shortly explain:**

Why?

**12. Do you see climate change as a higher threat to coral reefs compared to non-climatic drivers? If yes, to which of the following aspects?**

- ☐ Biodiversity
- ☐ Ecosystem health
- ☐ Ecosystem services
- ☐ Conservation (effectiveness and objectives)
- ☐ No, I don´t see climate change as a higher threat
- ☐ Other

Please specify

Ecosystem **adaptive capacity** is the ability of an ecosystem to recover from, cope with, or adapt to environmental change including climate change. It relates to resilience.

"**Climate adaptive**" conservation is adaptively planned as new information becomes available. It relates to climate resilient or smart conservation approaches. It aims to maintain, protect and support the resilience and adaptive capacity of ecosystems, habitats, and species.

**13. Do you think mangroves and seagrass beds are important to support coral reef adaptive capacity?**

- ◯ Yes, both mangrove and seagrass beds are important
- ◯ Mainly mangroves are important
- ◯ Mainly seagrass beds are important
- ◯ No, both are not important
- ◯ None of the above

**14. Is climate change a concern in conservation in the country? If yes, how is it addressed in conservation policies, strategies or plans?**

- ◯ No, it is not a concern.
- ◯ Yes, it is a concern. But climate change is not addressed.
- ◯ Yes, climate change is generally addressed.
- ◯ Yes, climate change is specifically addressed in objectives and targets.
- ◯ Other
- ◯ None of the above

Please specify

**15. Do you agree that the country´s current conservation efforts are climate adaptive?**

| | Strongly agree 1 | 2 | 3 | 4 | Strongly disagree 5 | N/A |
|---|---|---|---|---|---|---|
| Conservation is climate adaptive | ○ | ○ | ○ | ○ | ○ | ○ |
| Conservation helps coral reefs face climate change | ○ | ○ | ○ | ○ | ○ | ○ |
| Protected Area Networks (PANs) are climate adaptive | ○ | ○ | ○ | ○ | ○ | ○ |

The following final sections asks questions based on a list of climate adaptive conservation strategies and actions aimed to support the adaptive capacity of coral reefs and coastal ecosystems.

Researchers and practitioners have identified a number of strategies, options or activities to enable climate change resilient and adaptive conservation planning. These strategies aim to effectively support the resilience and capacity of species and ecosystems to recover from and adapt to changes.

They are viewed as important to make conservation effective under climate change in the long-term and can be integrated into policies, strategies or action plans, and invidivual Protected Area Plans.

**16.**

**Which of the following conservation strategies do you think is most effective in supporting the adaptive capacity of coral reefs?**

- ☐ Reduce non-climatic drivers
- ☐ Integration of Marine Protected Areas (MPAs) within other management frameworks
- ☐ Protect multiple areas of the same ecosystems
- ☐ Protect and support connectivity
- ☐ Maintain land- and seascape heterogeneity
- ☐ Restore degraded ecosystems
- ☐ Maintain ecosystem function
- ☐ Address potential climate change impacts
- ☐ Other

Please specify

**17. Which of these conservation strategies have been integrated in the country´s policies or planning documents?**

- ☐ Reduce non-climatic drivers
- ☐ Integration of Marine Protected Areas (MPA) within other management frameworks
- ☐ Protect multiple areas of the same ecosystems
- ☐ Protect and support connectivity
- ☐ Maintain land- and seascape heterogeneity
- ☐ Restore degraded ecosystems
- ☐ Maintain ecosystem function
- ☐ Address potential climate change impacts
- ☐ Other

Please specify

**18. Which of these integrated conservation strategies have been implemented in the country?**

- ☐ Reduce non-climatic drivers
- ☐ Integration of MPAs within other management frameworks
- ☐ Protect multiple areas of the same ecosystems
- ☐ Protect and support connectivity
- ☐ Maintain land- and seascape heterogeneity
- ☐ Restore degraded ecosystems
- ☐ Maintain ecosystem function
- ☐ Address potential climate change impacts
- ☐ Other

Please specify

**19. Reduce non-climatic drivers: Which of the following conservation activities have been implemented in the country?**

- [ ] Sustainable Fisheries Management
- [ ] Sustainable Coastal Management
- [ ] Reduction of Pollution
- [ ] Ensuring Water Quality
- [ ] Addressing invasive alien species and diseases
- [ ] Other

Please specify

**20. Have Marine or Coastal Protected Areas been integrated in the following "area-based management frameworks" in the country?**

- [ ] Marine Spatial Planning (MSP)
- [ ] Integrated Coastal Zone Management (ICZM)
- [ ] Integrated Water Resource Management (IWRM)
- [ ] Ridge to Reef approaches (R2R)
- [ ] Ecosystem-based approaches
- [ ] Water quality regulations
- [ ] Other

Please specify

**21. Protect multiple areas of the same ecosystems: Which of the following conservation activities have been implemented in the country?**

- [ ] Protection of multiple areas with the same habitat and species
- [ ] Risk spreading - protection of unique, isolated areas, functions and species
- [ ] Identification and protection of future climate refugia
- [ ] Other

Please specify

**22. Protect and support land- and seascape connectivity: Which of the following conservation activities have been implemented in the country?**

- ☐ Identification, restoration, protection of connectivity
- ☐ Implementation of ecologically connected Protected Area Networks (PANs)
- ☐ Identification and protection of key areas (e. g. spawning or nursery sites)
- ☐ Identification and removal of migration barriers
- ☐ Identification and protection of migratory species or moving habitats
- ☐ Other

Please specify

**23. Maintenance of land- and seascape heterogeneity: Which of the following conservation activities have been implemented in the country?**

- ☐ Protection of different land- and seascapes, ecosystems and habitats
- ☐ Protection of areas with different environmental conditions (e. g. corals in lagoons with different temperatures, currents)
- ☐ Other

Please specify

**24. Restoration of degraded ecosystems: Which of the following conservation activities have been implemented in the country?**

- ☐ Identification and restoration of degraded habitats and vulnerable species
- ☐ Activities to protect positive species relationships (e. g. seagrass and clams)
- ☐ Creation of new or future habitats close to Protected Areas
- ☐ Other non-conservation activities (e. g. development regulations)
- ☐ Other

Please specify

**25. Maintenance of ecosystem processes and functioning: Which of the following conservation activities have been implemented in the country?**

- [ ] Prioritize and protect areas and species important to healthy ecosystems
- [ ] Maintain diversity of key species with similar functions (e. g. different parrot fish species)
- [ ] Other

Please specify

**26. Addressing potential climate change impacts: Which of the following conservation activities have been implemented in the country?**

- [ ] Consideration and use of climate information
- [ ] Application of precautionary principles
- [ ] Managing and reducing risk (before impacts or disasters)
- [ ] Planning for different scenarios
- [ ] Other

Please explain

**27. Which of the implemented activities above do you think are most successful in supporting coral reef adaptive capacity, and why?**

**27. What were lessons learned?**

**27. What activity would you prioritize to support coral reef adaptive capacity?**

**28. At what ecological scale are most conservation activities implemented in the country?**

- ◯ Target species or species group
- ◯ Single habitat
- ◯ Ecosystem
- ◯ Land- or seascape
- ◯ Other

Please specify

**29. At what spatial scale are most activities implemented in the country?**

- ◯ Regional / Transboundary
- ◯ National scale
- ◯ Multiple states within one country
- ◯ Sub-national scale
- ◯ Local scale

**30. How broad have climate adaptive conservation strategies and activities been implemented in the country?**

- ◯ Only pilot projects
- ◯ In individual Protected Areas or projects (e.g. Ridge to Reef)
- ◯ In Protected Area Networks (PANs)
- ◯ On a sub-national scale
- ◯ On a broad national scale
- ◯ Other

Please specify

**31. What are the 3 main challenges for the implementation of such climate adaptive conservation strategies and activities in the country? (Please select max. 3)**

- ☐ Climate change seen as a challenge in the future
- ☐ Financial or technical resources
- ☐ Monitoring and evaluation
- ☐ Data gaps
- ☐ Staff capacities
- ☐ Legislation, regulations, and policies
- ☐ Conflict of interest
- ☐ Coordination and collaboration of actors (e. g. state and federal)
- ☐ Land tenure systems
- ☐ Challenges related to COVID-19
- ☐ Other

Please specify

**32. What do you think are key next steps to make conservation climate adaptive in the country?**

- ○ Integration of conservation strategies that address climate change risks into policies and planning documents
- ○ Mainstreaming and upscaling of climate adaptive conservation activities, pilot projects, and programs
- ○ Other

Please specify

**33. How confident are you with the answers you provided in this survey?**

○ Very confident ○ Confident ○ Moderately ○ Not confident

○ Not sure ○ NA

34. Please fill in your

* Job Title

* Name of your Institution

* E-Mail Address to send the research results to

35. Do you have any questions or comments to the list of conservation strategies and actions or other parts of the survey?

## Annex VIII: Codebook and coding category system for the qualitative survey analysis

The codes were developed both, deductively and inductively, and were based on Mayring (2000 & 2015).

| Code | Category | Description |
|---|---|---|
| **C0** | **Climate change-related drivers** | Climate change-related drivers that have affected coral reefs on a national scale in the last 10 years (2012-2022). |
| C0.1 | Sea-level rise (SLR) | Impact of SLR on coral reefs |
| C0.2 | Sea-surface temperature (SST) changes | Impact of SST |
| C0.3 | Ocean acidification | Impact of ocean acidification |
| C0.4 | Extreme weather events | Impact of extreme weather events |
| C0.5 | Changing rainfall patterns | Impact of changing rainfall patterns |
| **C1** | **Non-climatic drivers** | Non-climatic drivers that have affected coral reefs on a national scale in the last 10 years (2012-2022). |
| C1.1 | Pollution | Impact of pollution on coral reefs |
| C1.2 | Eutrophication | Impact of eutrophication |
| C1.3 | Invasive Alien Species | Impact of invasive alien species |
| C1.4 | Habitat change | Impact of habitat change |
| C1.5 | Overfishing | Impact of overfishing or unsustainable fishing practices |
| **C2** | **Current risks of potential impacts** | Description of expert observations on non-climatic and climate change-related drivers impacting coral reefs |
| C2.1 | Cumulative factors | Drivers that increase the potential vulnerability to climate change-related drivers on coral reefs (e. g. ecological functioning degraded by pollution) |
| C2.1.1 | Mortality | Ecosystem and/or species loss |
| C2.1.2 | Degradation | Ecosystem, species, or biodiversity degradation (e. g. due to erosion) |
| C2.1.3 | Resilience reduction | Lower resilience and ability to withstand and recover from climate change-related drivers |
| C2.1.4 | Ecosystem health | Reduced or loss of ecosystem health and functioning |
| C2.1.5 | Food security and livelihoods | Reduced or loss of food security, as well as changes in and/or loss of livelihoods |
| C2.1.6 | Quality | Changes in the quality, frequency, duration, and intensity of drivers impacting ecosystems |
| **C3** | **Climate adaptive conservation strategies** | List of the selected climate adaptive conservation strategies (For further information please refer to Annex III) |

| | | |
|---|---|---|
| C3.1 | Reduction of non-climatic direct and indirect drivers | Strives to lower the potential impact of non-climatic drivers (e. g. pollution) on affected ecosystems connected with coral reefs or directly coral reefs |
| C3.2 | Integration of MPAs within broader area-based management frameworks | Strives to embed PAs or MPAs into or generally the application of other area-based management approaches that, for example address multiple non-climatic drivers outside of the protected areas (e. g. MSP) |
| C3.3 | Representation and replication of all ecosystems | Strives to protect different types of ecosystems by conserving replicates of these ecosystems and their habitats across multiple protected areas |
| C3.4 | Preserve and enhance land- and seascape connectivity | Strives to protect different forms of ecological and spatial connectivity |
| C3.5 | Maintain land- and seascape heterogeneity | Strives to identify and preserve different forms of environmental and spatial heterogeneity |
| C3.6 | Restoration of degraded ecosystems | Strives to restore degraded or lost ecosystems and habitats, and their functions, or to apply novel forms of restoration to enhance their ecosystem AC (e. g. active breeding) |
| C3.7 | Maintain ecosystem processes and ecological functioning | Strives to preserve ecological processes and functioning in ecosystems |
| C3.8 | Address potential climate change impacts | Strives to apply approaches that help to adapt to and mitigate potential climate change-related impacts and drivers |
| **C4** | **Priorities, challenges, and lessons learned** | Challenges, lessons learned, and preferred priorities on implemented conservation and related activities |
| C4.1 | Financing | Role of finances for the development and effective implementation of conservation |
| C4.2 | Resources | Role of technical, financial or staff resources and capacities for management, including monitoring and evaluation, and data collection |
| C4.3 | Local communities / Traditional knowledge | Role of traditional practices or communities and resource users, their awareness, participation, and inclusion to enhance the design and implementation of successful conservation |
| C4.4 | Planning, management, and enforcement | Role, quality, and stage of conservation planning and development, as well as enforcement of conservation relevant regulations (e. g. water quality; coastal development) |
| C4.5 | Education and Awareness | Role of public, community, resource users, and decision-makers at different administrative scales (local, state, national) |
| C4.6 | PAs and PANs | Role of different conservation areas and Protected Area Networks for supporting the AC of coral reefs |

## Annex IX: Quantitative survey results

The following section lists the quantitative survey results. Please refer to Supplementary Material 4 for additional details, as well as for the results of the questions 11 and 27.1 to 27.3.

Question 3: What scale does your work mostly focus on?

| Country | District / Municipality | International | Local or Community | National | Regional | Subnational / Provincial | Other | No answer | Total |
|---|---|---|---|---|---|---|---|---|---|
| FSM | - | - | 6 | - | 2 | 2 | - | - | 10 |
| Palau | 2 | 1 | 2 | 2 | - | 3 | 1 | - | 11 |
| RMI | - | 1 | 2 | 6 | 3 | - | - | 1 | 13 |
| Total | 2 | 2 | 10 | 8 | 5 | 5 | 1 | 1 | 34 |

Question 4: What ecosystem(s) does your work mostly focus on?

| Country | Coral reefs | Mangroves | Mulitple | Other | Total |
|---|---|---|---|---|---|
| FSM | 2 | - | 8 | - | 10 |
| Palau | 1 | 1 | 8 | 1 | 11 |
| RMI | 7 | - | 5 | 1 | 13 |
| Total | 10 | 1 | 21 | 2 | 34 |

Question 5: What topic does your work mostly focus on?

| Country | Climate change | Ecosystems and biodiversity | Fisheries | Livelihoods and communities | Other | Total |
|---|---|---|---|---|---|---|
| FSM | 2 | 4 | 1 | 2 | 1 | 10 |
| Palau | 1 | 5 | 2 | 1 | 2 | 11 |
| RMI | 2 | 6 | 4 | | 1 | 13 |
| Total | 5 | 15 | 7 | 3 | 4 | 34 |

Question 7: What is the current state of coral reefs on a national scale? (The results are depicted in mean values based on the Likert Scale selection from 1=Excellent to 5=Poor.)

| Coutry | Experts (Nr.) | Ecosystem Health | Biodiversity | Ecosystem Services |
|---|---|---|---|---|
| RMI | 12 | 2.75 | 2.67 | 2.55 |
| FSM | 10 | 2.70 | 2.80 | 3.11 |
| Palau | 11 | 2.27 | 2.09 | 2.55 |
| Total | 33 | 2.58 | 2.52 | 2.71 |

Question 8: Which non-climatic drivers have negatively impacted coral reefs on a national scale in the last 10 years?

| Country | Experts (Nr.) | Pollution | Eutrophication | IAS | Habitat change | Over- fishing | Other |
|---|---|---|---|---|---|---|---|
| RMI | 13 | 11 | 7 | 2 | 4 | 2 | 1 |
| FSM | 10 | 4 | 3 | 2 | 6 | 4 | 1 |
| Palau | 11 | 8 | 0 | 3 | 7 | 1 | 3 |
| Total | 34 | 23 | 10 | 7 | 17 | 7 | 5 |
| % (Regional) | | 67,6% | 29,4% | 20,6% | 50,0% | 20,6% | 14,7% |
| % (RMI) | | 84,6% | 53,8% | 15,4% | 30,8% | 15,4% | 7,7% |
| % (FSM) | | 40,0% | 30,0% | 20,0% | 60,0% | 40,0% | 10,0% |
| % (Palau) | | 72,7% | 0,0% | 27,3% | 63,6% | 9,1% | 27,3% |

Question 9: Which climate change drivers have negatively impacted coral reefs on a national scale in the last 10 years?

| Country | Experts (Nr.) | SLR | SST | Acidification | Extreme weather | Changing rainfall | Other | N/A |
|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 5 | 12 | 6 | 8 | 3 | 1 | 0 |
| FSM | 10 | 3 | 9 | 1 | 5 | 5 | 0 | 0 |
| Palau | 11 | 8 | 8 | 7 | 11 | 5 | 1 | 0 |
| Total | 34 | 16 | 29 | 14 | 24 | 13 | 2 | 0 |
| % (Regional) | | 47% | 85% | 41% | 71% | 38% | 6% | 0 |
| % (RMI) | | 38% | 92% | 46% | 62% | 23% | 8% | 0 |
| % (FSM) | | 30% | 90% | 10% | 50% | 50% | 0% | 0 |
| % (Palau) | | 73% | 73% | 64% | 100% | 45% | 9% | 0 |

Question 10: What climate change driver had the highest negative impact on coral reefs on a national scale in the last 10 years?

| Q10 | Changing rainfall | Extreme weather | Acidification | SST | No answer | Total |
|---|---|---|---|---|---|---|
| FSM | 1 | 2 | 0 | 7 | 0 | 10 |
| Palau | 0 | 6 | 2 | 3 | 0 | 11 |
| RMI | 0 | 2 | 0 | 10 | 1 | 13 |
| Total | 1 | 10 | 2 | 20 | 1 | 34 |
| Total (%) | 3% | 29% | 6% | 59% | 3% | 100% |

Question 11: What coastal marine ecosystem do you think is most at risk from climate change in the country, and why?

| Country | Experts (Nr.) | Coral reefs | Mangroves | Seagrass beds | Multiple answers |
|---|---|---|---|---|---|
| RMI | 13 | 12 | 2 | 1 | 1 |
| FSM | 10 | 10 | 2 | 2 | 2 |
| Palau | 11 | 11 | 5 | 5 | 6 |
| Total | 34 | 33 | 9 | 8 | 9 |
| % (Regional) | | 97% | 26% | 24% | 26% |
| % (RMI) | | 92% | 15% | 8% | 8% |
| % (FSM) | | 100% | 20% | 20% | 20% |
| % (Palau) | | 100% | 45% | 45% | 55% |

Question 12: Do you see climate change-related drivers as a higher threat to corals compared to non-climatic drivers?

| Country | Experts (Nr.) | Biodiversity | Ecosystem health | Ecosystem Services | Conservation Effectiveness | No | Other | N/A |
|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 10 | 9 | 10 | 8 | 1 | 0 | 0 |
| FSM | 10 | 5 | 6 | 2 | 1 | 2 | 0 | 0 |
| Palau | 11 | 6 | 10 | 5 | 3 | 1 | 0 | 0 |
| Total | 34 | 21 | 25 | 17 | 12 | 4 | 0 | 0 |
| % (Regional) | | 62% | 74% | 50% | 35% | 12% | 0% | 0% |
| % (RMI) | | 29% | 26% | 29% | 24% | 3% | 0% | 0% |
| % (FSM) | | 50% | 60% | 20% | 10% | 20% | 0% | 0% |
| % (Palau) | | 18% | 29% | 15% | 9% | 3% | 0% | 0% |

Question 13: Do you think mangroves and seagrass beds are important to support coral reef adaptive capacity?

| Country | Experts (Nr.) | Yes, both mangrove and seagrass beds are important | Mainly mangroves are important | Mainly seagrass beds are important | No, both are not important | N/A |
|---|---|---|---|---|---|---|
| RMI | 13 | 12 | 0 | 0 | 0 | 1 |
| FSM | 10 | 10 | 0 | 0 | 0 | 0 |
| Palau | 11 | 11 | 0 | 0 | 0 | 0 |
| Total | 34 | 33 | 0 | 0 | 0 | 1 |
| % (Regional) | | 97% | 0% | 0% | 0% | 3% |
| % (RMI) | | 92% | 0% | 0% | 0% | 8% |
| % (FSM) | | 100% | 0% | 0% | 0% | 0% |
| % (Palau) | | 100% | 0% | 0% | 0% | 0% |

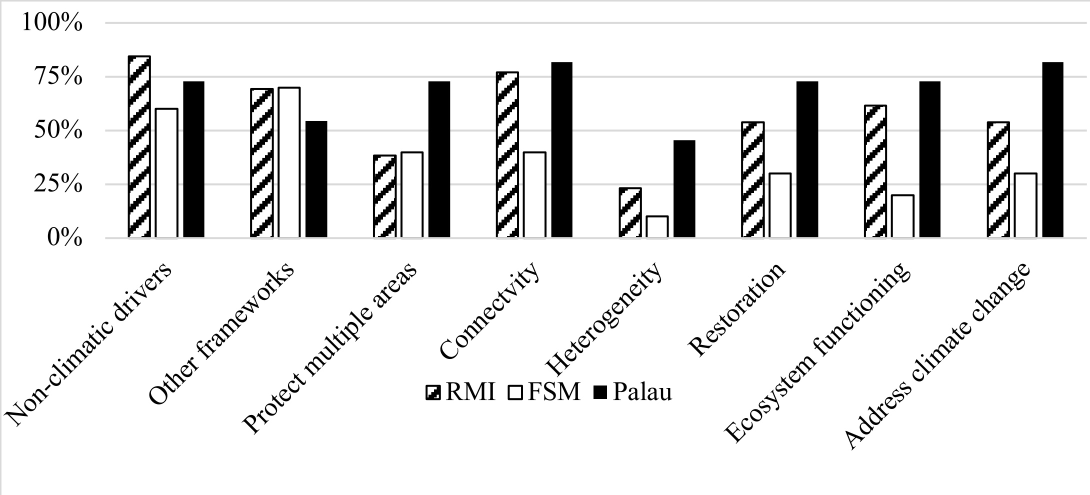
Question 14: Is climate change a concern in conservation in the country? If yes, how is it addressed in conservation policies, strategies or plans?

| Country | Experts (Nr.) | No, it is not a concern. | Yes, it is a concern. But climate change is not addressed. | Yes, climate change is generally addressed. | Yes, climate change is specifically addressed in objectives and targets. | Other | N/A |
|---|---|---|---|---|---|---|---|
| RMI | 13 | 0 | 0 | 3 | 10 | 0 | 0 |
| FSM | 10 | 0 | 0 | 3 | 6 | 1 | 0 |
| Palau | 11 | 0 | 3 | 3 | 5 | 0 | 0 |
| Total | 34 | 0 | 3 | 9 | 21 | 1 | 0 |
| % (Regional) | | 0% | 9% | 26% | 62% | 3% | 0% |
| % (RMI) | | 0% | 0% | 23% | 77% | 0% | 0% |
| % (FSM) | | 0% | 0% | 30% | 60% | 10% | 0% |
| % (Palau) | | 0% | 27% | 27% | 45% | 0% | 0% |

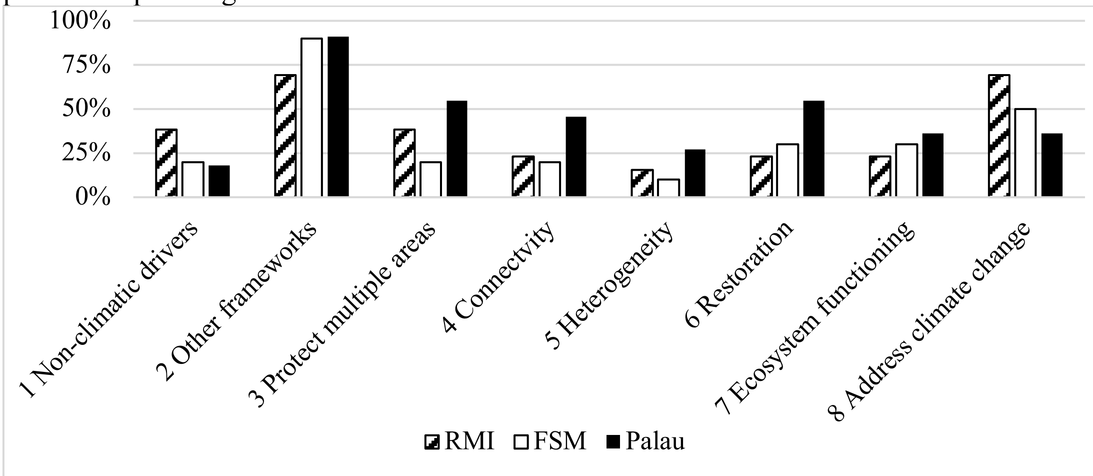
Question 15: Do you agree that the country´s current conservation efforts are climate adaptive? (The results are depicted in mean values based on the Likert Scale selection from 1=Strongly agree to 5=Strongly disagree.)

| Country | Experts (Nr.) | Conservation is climate adaptive | Conservation helps coral reefs face climate change | Protected Area Networks (PANs) are climate adaptive |
|---|---|---|---|---|
| RMI | 12 | 2.69 | 2.31 | 2.62 |
| FSM | 10 | 2.10 | 2.20 | 2.10 |
| Palau | 11 | 2.45 | 2.45 | 2.18 |
| Total | 33 | 2.44 | 2.32 | 2.32 |

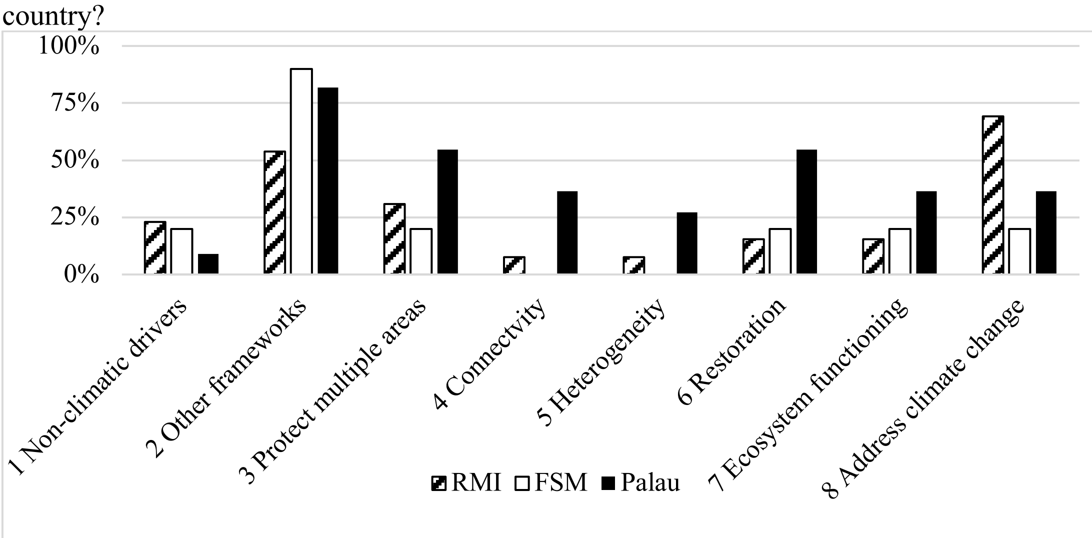
Question 16: Which of the following conservation strategies do you think is most effective in supporting the AC of coral reefs?



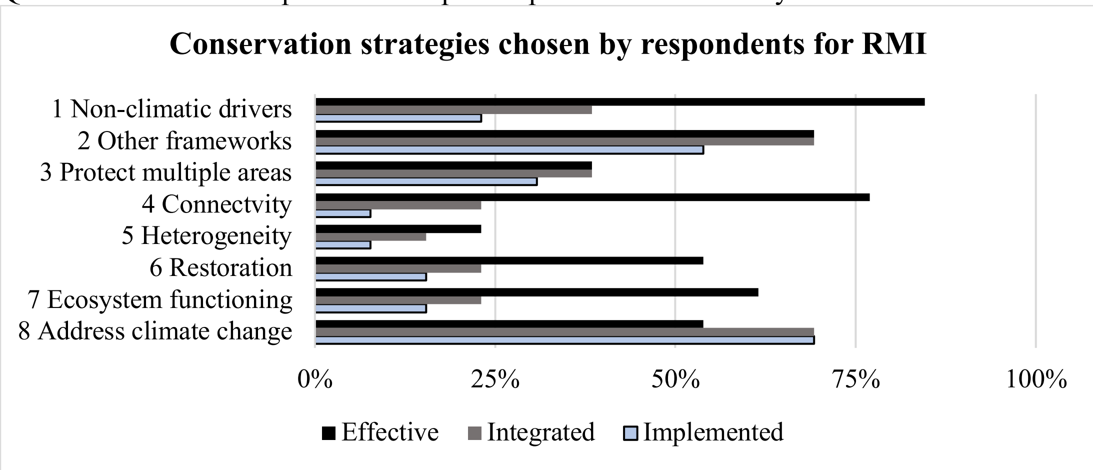

Question 17: Which of these conservation strategies have been integrated in the country´s policies or planning documents?

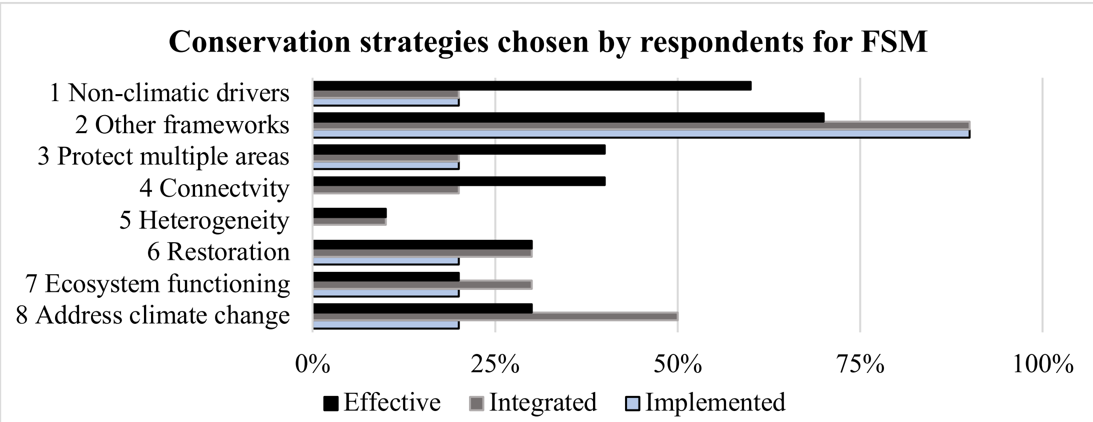


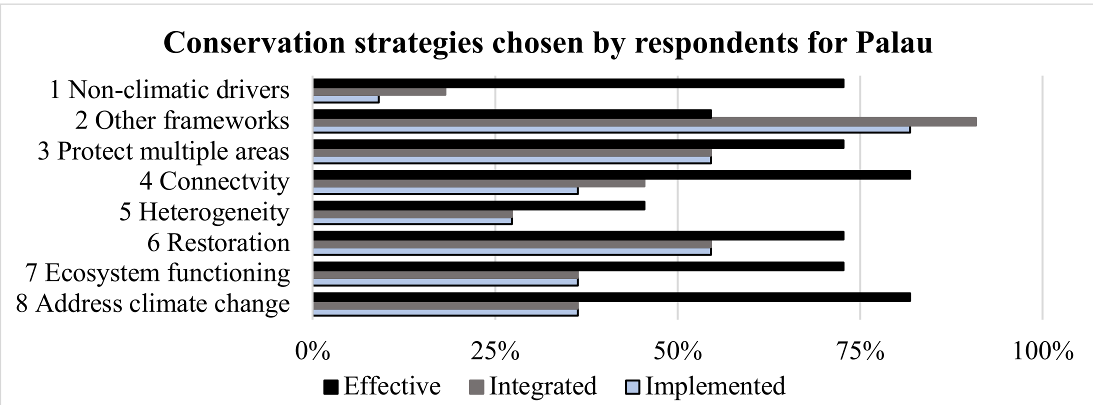

Question 18: Which of these integrated conservation strategies have been implemented in the country?



Question 16 to 18: Comparison of responses per individual country:



Question 16 to 18: Country-based and regionally aggregated results for question 16 to 18 depicted with the rating scale from Table 5, section 3.3.

| Question | Country | 1 Non-climatic drivers | 2 Other frameworks | 3 Protect multiple areas | 4 Connectvity | 5 Heterogeneity | 6 Restoration | 7 Ecosystem functioning | 8 Address climate change | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Q16 | RMI | 85% | 69% | 38% | 77% | 23% | 54% | 62% | 54% | 58% |
| | FSM | 60% | 70% | 40% | 40% | 10% | 30% | 20% | 30% | 38% |
| | Palau | 73% | 55% | 73% | 82% | 45% | 73% | 73% | 82% | 69% |
| Q17 | RMI | 38% | 69% | 38% | 23% | 15% | 23% | 23% | 69% | 38% |
| | FSM | 20% | 90% | 20% | 20% | 10% | 30% | 30% | 50% | 34% |
| | Palau | 18% | 91% | 55% | 45% | 27% | 55% | 36% | 36% | 45% |
| Q18 | RMI | 23% | 54% | 31% | 8% | 8% | 15% | 15% | 69% | 28% |
| | FSM | 20% | 90% | 20% | 0% | 0% | 20% | 20% | 20% | 24% |
| | Palau | 9% | 82% | 55% | 36% | 27% | 55% | 36% | 36% | 42% |
| Q16 | Regional | 74% | 65% | 50% | 68% | 26% | 53% | 53% | 56% | 56% |
| Q17 | Regional | 26% | 82% | 38% | 29% | 18% | 35% | 29% | 53% | 39% |
| Q18 | Regional | 18% | 74% | 35% | 15% | 12% | 29% | 24% | 44% | 31% |

| Rating | Color scheme | Range |
|---|---|---|
| Very high | (dark green) | >80 |
| High | (light green) | 60 – 80 |
| Medium | (yellow) | 40 – 60 |
| Low | (orange) | 20 - 40 |
| Very low | (red) | <20 |

Question 16 to 18: Country-based and regionally aggregated results for question 16 to 18 including responses on strategies not integrated or implemented.

| Question | Country | 1 Non-climatic drivers | 2 Other frameworks | 3 Protect multiple areas | 4 Connectvity | 5 Heterogeneity | 6 Restoration | 7 Ecosystem functioning | 8 Address climate change | 9 Not integrated / implemted |
|---|---|---|---|---|---|---|---|---|---|---|
| Q16 | RMI | 85% | 69% | 38% | 77% | 23% | 54% | 62% | 54% | - |
| | FSM | 60% | 70% | 40% | 40% | 10% | 30% | 20% | 30% | - |
| | Palau | 73% | 55% | 73% | 82% | 45% | 73% | 73% | 82% | - |
| Q17 | RMI | 38% | 69% | 38% | 23% | 15% | 23% | 23% | 69% | 8% |
| | FSM | 20% | 90% | 20% | 20% | 10% | 30% | 30% | 50% | 0% |
| | Palau | 18% | 91% | 55% | 45% | 27% | 55% | 36% | 36% | 0% |
| Q18 | RMI | 23% | 54% | 31% | 8% | 8% | 15% | 15% | 69% | 15% |
| | FSM | 20% | 90% | 20% | 0% | 0% | 20% | 20% | 20% | 10% |
| | Palau | 9% | 82% | 55% | 36% | 27% | 55% | 36% | 36% | 9% |
| Q16 | Regional | 74% | 65% | 50% | 68% | 26% | 53% | 53% | 56% | - |
| Q17 | Regional | 26% | 82% | 38% | 29% | 18% | 35% | 29% | 53% | 3% |
| Q18 | Regional | 18% | 74% | 35% | 15% | 12% | 29% | 24% | 44% | 12% |

Question 16 to 18: Standard deviation and mean for the country-based and regionally aggregated results.

| | Q16 | Q17 | Q18 | Q16 | Q17 | Q18 |
|---|---|---|---|---|---|---|
| Country | Standard Deviation | Standard Deviation | Standard Deviation | Mean | Mean | Mean |
| % (Regional) | 14,36% | 22,47% | 20,03% | 55,51% | 36,03% | 31,25% |
| % (RMI) | 20,14% | 22,13% | 21,45% | 57,69% | 33,65% | 27,88% |
| % (FSM) | 19,82% | 26,46% | 26,82% | 37,50% | 31,25% | 23,75% |
| % (Palau) | 12,80% | 25,76% | 23,08% | 69,32% | 43,18% | 42,05% |

Q19 - Reduce non-climatic drivers: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Sustainable Fisheries Management | Sustainable Coastal Management | Reduction of Pollution | Ensuring Water Quality | Addressing IAS & diseases | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 3 | 2 | 2 | 2 | 1 | 0 | 2 | 0 |
| FSM | 10 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 0 |
| Palau | 11 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| Total | 34 | 6 | 5 | 5 | 4 | 4 | 0 | 4 | 0 |
| % (Regional) | | 18% | 15% | 15% | 12% | 12% | 0% | 12% | 0% |
| % (RMI) | | 23% | 15% | 15% | 15% | 8% | 0% | 15% | 0% |
| % (FSM) | | 20% | 20% | 20% | 10% | 20% | 0% | 10% | 0% |
| % (Palau) | | 9% | 9% | 9% | 9% | 9% | 0% | 9% | 0% |

Q20 - Have Marine or Coastal Protected Areas been integrated in the following "area-based management frameworks" in the country?

| Country | Experts (Nr.) | MSP | ICZM | IWRM | Ridge to Reef | Ecosystem-based | Water quality | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 3 | 3 | 2 | 5 | 3 | 2 | 0 | 2 | 2 |
| FSM | 10 | 7 | 2 | 2 | 8 | 4 | 1 | 0 | 1 | 0 |
| Palau | 11 | 5 | 2 | 5 | 8 | 6 | 5 | 0 | 1 | 0 |
| Total | 34 | 15 | 7 | 9 | 21 | 13 | 8 | 0 | 4 | 2 |
| % (Regional) | | 44% | 21% | 26% | 62% | 38% | 24% | 0% | 12% | 6% |
| % (RMI) | | 23% | 23% | 15% | 38% | 23% | 15% | 0% | 15% | 15% |
| % (FSM) | | 70% | 20% | 20% | 80% | 40% | 10% | 0% | 10% | 0% |
| % (Palau) | | 45% | 27% | 55% | 82% | 64% | 55% | 55% | 55% | 55% |

Q21 - Protect multiple areas of the same ecosystems: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Protection of multiple areas with the same habitat and species | Risk spreading | Future climate refugia | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|
| RMI | 13 | 2 | 2 | 0 | 0 | 2 | 1 |
| FSM | 10 | 2 | 1 | 1 | 0 | 1 | 0 |
| Palau | 11 | 6 | 4 | 1 | 0 | 1 | 0 |
| Total | 34 | 10 | 7 | 2 | 0 | 4 | 1 |
| % (Regional) | | 29% | 21% | 6% | 0% | 12% | 3% |
| % (RMI) | | 15% | 15% | 0% | 0% | 15% | 8% |
| % (FSM) | | 20% | 10% | 10% | 0% | 10% | 0% |
| % (Palau) | | 55% | 36% | 9% | 0% | 9% | 0% |

Q22 - Protect and support land- and seascape connectivity: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Identification, restoration, protection of connectivity | PANs | Key areas | Migration barriers | Migratory species | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 0 | 1 | 1 | 0 | 1 | 0 | 2 | 0 |
| FSM | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Palau | 11 | 3 | 3 | 4 | 0 | 2 | 0 | 1 | 0 |
| Total | 34 | 3 | 4 | 5 | 0 | 3 | 0 | 4 | 0 |
| % (Regional) | | 9% | 12% | 15% | 0% | 9% | 0% | 12% | 0% |
| % (RMI) | | 0% | 8% | 8% | 0% | 8% | 0% | 15% | 0% |
| % (FSM) | | 0% | 0% | 0% | 0% | 0% | 0% | 10% | 0% |
| % (Palau) | | 27% | 27% | 36% | 0% | 18% | 0% | 9% | 0% |

Q23 - Maintenance of land- and seascape heterogeneity: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Protection of different land- and seascapes, ecosystems and habitats | Different Environmental Conditions | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|
| RMI | 13 | 1 | 0 | 0 | 2 | 0 |
| FSM | 10 | 0 | 0 | 0 | 1 | 0 |
| Palau | 11 | 3 | 2 | 0 | 1 | 0 |
| Total | 34 | 4 | 2 | 0 | 4 | 0 |
| % (Regional) | | 12% | 6% | 0% | 12% | 0% |
| % (RMI) | | 8% | 0% | 0% | 15% | 0% |
| % (FSM) | | 0% | 0% | 0% | 10% | 0% |
| % (Palau) | | 27% | 18% | 0% | 9% | 0% |

Q24 - Restoration of degraded ecosystems: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Restoration degraded habitats | Positive species relationships | Future habitats | Non-conservation activities | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 2 | 0 | 1 | 2 | 0 | 2 | 0 |
| FSM | 10 | 2 | 1 | 0 | 1 | 0 | 1 | 0 |
| Palau | 11 | 7 | 5 | 2 | 5 | 0 | 1 | 0 |
| Total | 34 | 11 | 6 | 3 | 8 | 0 | 4 | 0 |
| % (Regional) | | 32% | 18% | 9% | 24% | 0% | 12% | 0% |
| % (RMI) | | 15% | 0% | 8% | 15% | 0% | 15% | 0% |
| % (FSM) | | 20% | 10% | 0% | 10% | 0% | 10% | 0% |
| % (Palau) | | 64% | 45% | 18% | 45% | 0% | 9% | 0% |

Q25 - Maintenance of ecosystem processes and functioning: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Prioritize areas and species | Maintain diversity | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|
| RMI | 13 | 2 | 1 | 0 | 2 | 0 |
| FSM | 10 | 2 | 2 | 0 | 1 | 0 |
| Palau | 11 | 3 | 4 | 0 | 1 | 0 |
| Total | 34 | 7 | 7 | 0 | 4 | 0 |
| % (Regional) | | 21% | 21% | 0% | 12% | 0% |
| % (RMI) | | 15% | 8% | 0% | 15% | 0% |
| % (FSM) | | 20% | 20% | 0% | 10% | 0% |
| % (Palau) | | 27% | 36% | 0% | 9% | 0% |

Q26 - Addressing potential climate change impacts: Which of the following conservation activities have been implemented in the country?

| Country | Experts (Nr.) | Climate info | Precautionary principle | Risk reduction | Scenario planning | Other | Not implemented | No answer |
|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 6 | 4 | 6 | 5 | 0 | 2 | 1 |
| FSM | 10 | 2 | 1 | 2 | 2 | 0 | 1 | 0 |
| Palau | 11 | 3 | 2 | 3 | 2 | 0 | 1 | 0 |
| Total | 34 | 11 | 7 | 11 | 9 | 0 | 4 | 1 |
| % (Regional) | | 32% | 21% | 32% | 26% | 0% | 12% | 3% |
| % (RMI) | | 46% | 31% | 46% | 38% | 0% | 15% | 8% |
| % (FSM) | | 20% | 10% | 20% | 20% | 0% | 10% | 0% |
| % (Palau) | | 27% | 18% | 27% | 18% | 0% | 9% | 0% |

Question 28: At what ecological scale are most conservation activities implemented in the country?

| Country | Experts (Nr.) | Target species or species group | Single habitat | Ecosystem | Land-or seascape | Other |
|---|---|---|---|---|---|---|
| RMI | 13 | 0 | 2 | 6 | 2 | 0 |
| FSM | 10 | 2 | 1 | 4 | 3 | 0 |
| Palau | 11 | 4 | 1 | 3 | 2 | 1 |
| Total | 34 | 6 | 4 | 13 | 7 | 1 |
| % (Regional) | | 18% | 12% | 38% | 21% | 3% |
| % (RMI) | | 0% | 15% | 46% | 15% | 0% |
| % (FSM) | | 20% | 10% | 40% | 30% | 0% |
| % (Palau) | | 36% | 9% | 27% | 18% | 9% |

Question 29: At what spatial scale are most activities implemented in the country?

| Country | Experts (Nr.) | Regional / Transboun. | National scale | Multiple states | Sub-national scale | Local | No answer |
|---|---|---|---|---|---|---|---|
| RMI | 13 | 1 | 4 | 1 | 1 | 3 | 3 |
| FSM | 10 | 0 | 0 | 3 | 2 | 5 | 0 |
| Palau | 11 | 0 | 1 | 4 | 1 | 5 | 0 |
| Total | 34 | 1 | 5 | 8 | 4 | 13 | 3 |
| % (Regional) | | 3% | 15% | 24% | 12% | 38% | 9% |
| % (RMI) | | 8% | 31% | 8% | 8% | 23% | 23% |
| % (FSM) | | 0% | 0% | 30% | 20% | 50% | 0% |
| % (Palau) | | 0% | 9% | 36% | 9% | 45% | 0% |

Question 30: How broad have climate adaptive conservation strategies and activities been implemented in the country?

| Country | Experts (Nr.) | Only pilot projects | In individual PAs | In PANs | On a sub-national scale | On a broad national scale | Other | No answer |
|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 0 | 4 | 3 | 0 | 2 | 1 | 3 |
| FSM | 10 | 0 | 2 | 3 | 0 | 3 | 1 | 0 |
| Palau | 11 | 2 | 3 | 4 | 0 | 2 | 0 | 0 |
| Total | 34 | 2 | 9 | 10 | 0 | 7 | 2 | 3 |
| % (Regional) | | 6% | 26% | 29% | 0% | 21% | 6% | 9% |
| % (RMI) | | 0% | 31% | 23% | 0% | 15% | 8% | 23% |
| % (FSM) | | 0% | 20% | 30% | 0% | 30% | 10% | 0% |
| % (Palau) | | 18% | 27% | 36% | 0% | 18% | 0% | 0% |

Question 31: What are the 3 main challenges for the implementation of such climate adaptive conservation strategies and activities in the country? (Country-based results)

| Country | Experts (Nr.) | Future climate change | Res-ources | M&E | Data gaps | Staff capacities | Regul-ations & policies | Conflict | Coordination / collaboration | Land tenure | COVID -19 | No answer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RMI | 13 | 1 | 8 | 3 | 2 | 6 | 1 | 1 | 3 | 2 | 1 | 4 |
| FSM | 10 | 1 | 7 | 2 | 1 | 7 | 4 | 1 | 3 | 3 | 3 | 0 |
| Palau | 11 | 1 | 8 | 4 | 5 | 7 | 7 | 3 | 5 | 1 | 2 | 0 |
| Total | 34 | 3 | 23 | 9 | 8 | 20 | 12 | 5 | 11 | 6 | 6 | 4 |
| % (Regional) | | 9% | 68% | 26% | 24% | 59% | 35% | 15% | 32% | 18% | 18% | 12% |
| % (RMI) | | 8% | 62% | 23% | 15% | 46% | 8% | 8% | 23% | 15% | 8% | 31% |
| % (FSM) | | 10% | 70% | 20% | 10% | 70% | 40% | 10% | 30% | 30% | 30% | 0% |
| % (Palau) | | 9% | 73% | 36% | 45% | 64% | 64% | 27% | 45% | 9% | 18% | 0% |

Question 32: What do you think are key next steps to make conservation climate adaptive in the country?

| Country | Experts (Nr.) | Integration of conservation strategies that address climate change risks into policies and planning documents | Mainstreaming and upscaling of climate adaptive conservation activities, pilot projects, and programs | Other | No answer |
|---|---|---|---|---|---|
| FSM | 10 | 5 | 5 | 0 | 0 |
| Palau | 11 | 2 | 7 | 2 | 0 |
| RMI | 13 | 2 | 7 | 1 | 3 |
| Total | 34 | 9 | 19 | 3 | 3 |
| Percentage (Regional) | | 26% | 56% | 9% | 9% |
| Percentage (FSM) | | 50% | 50% | 0% | 0% |
| Percentage (Palau) | | 18% | 64% | 18% | 0% |
| Percentage (RMI) | | 15% | 54% | 8% | 23% |

Question 33: How confident are you with the answers you provided in this survey?

| Level of Confidence | Confident | Moderately | Very confident | No answer | Total |
|---|---|---|---|---|---|
| FSM | 7 | 3 | 0 | 0 | 10 |
| Palau | 8 | 3 | 0 | 0 | 11 |
| RMI | 4 | 4 | 2 | 3 | 13 |
| Total | 19 | 10 | 2 | 3 | 34 |
| Percentage (Regional) | 56% | 29% | 6% | 9% | 100% |
| FSM | 70% | 30% | 0% | 0% | 100% |
| Palau | 73% | 27% | 0% | 0% | 100% |
| RMI | 31% | 31% | 15% | 23% | 100% |