Incorporating climate change adaptation into large marine protected areas: the case of Ascension Island MPA

By

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“We owe the ocean everything.” – Sir David Attenborough

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ABSTRACT

The ocean, composed of many highly diverse and complex ecosystems, provides essential ecosystem services that contribute to human health, society and economy. Climate change presents an unprecedented threat to the world, and the ocean is particularly vulnerable. The impacts of climate change on the marine environment include sea level rise, ocean acidification, and changes in ocean circulation. These are expected to have severe deleterious effects on marine organisms and communities. Marine Protected Areas (MPAs) are an important tool for the conservation of biodiversity, and natural and cultural resources. There is a recognized need for climate-focused policy and management agendas, and yet, there continues to be barriers to their inclusion in MPA management. Ascension Island MPA is a large, relatively new MPA that comprises the entire exclusive economic zone (EEZ) of the island, a total of over 440,000km^2. The size, remoteness and the expansive pelagic ocean space, provide unique management challenges. To effectively conserve Ascension Island's marine biodiversity, habitats and ecological functions for long-term ecosystem health while also supporting sustainable socio-economic growth, a holistic, adaptive management approach which considers and accounts for the implications of climate change is needed. This project explores how Ascension Island MPA can integrate adaptive climate change measures into their management plan. By performing a vulnerability assessment on Ascension Island MPA and reviewing what climate change adaptive measures currently exist in large MPAs, recommendations for the site have been proposed. Recommendations for Ascension Island MPA include: increase research and monitoring to better understand impacts of climate change; reduce other stressors; encourage collaborative, multi-sector ocean governance and MSP to manage stressors and protect refugia; and adaptive management in the development of Ascension Island MPA Climate Change Resilience Strategy. This work will support the adaptive management plan of Ascension Island, and contribute to the larger conversation on incorporating climate change into MPA management.

Keywords: Climate change, adaptive management, marine protected area, Ascension Island, biodiversity protection

LIST OF ABBREVIATIONS

CBD – Convention on Biological Diversity

EEZ – Exclusive Economic Zone

MPA* – Marine Protected Area

OECM - Other Effective area-based Conservation Measures

RVA – Rapid Vulnerability Assessment

IUCN – International Union for Conservation of Nature

NASA – National Aeronautics and Space Administration

UN – United Nations

CEC – Commission for Environmental Cooperation

GPS – Global Positioning System

ICCAT – International Commission for the Conservation of Atlantic Tunas

AIG – Ascension Island Government

EBM – Ecosystem Based Management

DOSI – Deep-ocean Stewardship Initiative

INDEEP – International Network for Scientific Investigations of Deep-Sea Ecosystems

N/A – Not available/No answer

*There are various designations and a variety of nomenclature for protected areas in the ocean – MPAs, marine reserves, sanctuaries, conserved areas and more – which include different levels of protection and have different management structures. For the sake of this project, I have chosen to use MPA or "protected area" to incorporate all of these terms. In the context of this project, MPA will follow the IUCN definition, which is: a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN, 2012).

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CHAPTER 1: INTRODUCTION

1.1 Context

The ocean is integral in regulating the Earth's climate and, thus, its habitability. The ocean is composed of many highly diverse and complex ecosystems that provide a vast range of ecosystem services that contribute to human health, society and economy. And yet, human exploitation (in the form of fisheries, oil and gas extraction, shipping, waste disposal and more) is putting immense pressure on the sea, and its biodiversity. These direct impacts are compounded by the increasingly severe effects of anthropogenic climate change. These contributing factors may result in unprecedented impacts on the population dynamics and geographic distributions of marine communities (Halpin, 1997). The effects of climate change on marine and coastal organisms, ecosystems and services are already detectable, such as: range shifts in response to warming and deoxygenation (Poloczanska, et al., 2014), mass coral bleaching and mortality (Graham et al., 2015), and the thinning of calcium carbonate shells and skeletons produced by marine organisms (Meier et al., 2014). Moreover, the impacts of climate change are multi-faceted, and have complex interactions with one another, resulting in synergistic effects that can be difficult to predict (Thuiller et al., 2007). Climate change will also affect the relationship that society has with the ocean – impacting natural coastal protection offered by communities such as reefs, salt marshes and mangroves; reduction in yield of capture fisheries, particularly tropical fisheries (Jones & Cheung, 2015); decreases in tourism (Hoegh-Guldberg et al., 2014); and human health and safety as a result of increased storm events and epidemiological shifts (Rohr et al., 2011).

Marine protected areas (MPAs) and other effective conservation measures (OECMs) are an important tool for the conservation of biodiversity, as well as protection of both natural and cultural resources. Protected areas provide a space for species to grow, reproduce and restore the health of populations within and beyond their borders (Agardy, 1994). They also seek to manage human impacts, such as fishing and mineral extraction, within their borders. Over the last decade, the significance of MPAs was brought to center stage as countries worked towards the Convention on Biological Diversity (CBD) Aichi Target 11 – aiming to protect 17% of terrestrial and inland waters, and 10% of coastal and marine areas, particularly those of importance concerning biodiversity and ecosystem services (Convention on Biological Diversity, 2020). In response to this goal, the amount of area under protection has increased around the world. At the time of writing, estimates put the amount of ocean space under protection at 7.68% (United Nations, 2021), though the level of protection is variable between areas.

Marine protected areas can range in size from less than a kilometre squared to over a 1,000,000km^2, each of which provide benefits while also facing different challenges. For instance, protected areas on the larger end of this range have an expanded scope that covers diverse habitat and species assemblages. By protecting entire ecosystems, biologically connected systems can be included in the same area of management (Wilhelm et al., 2014). However, large MPAs have the disadvantages of difficulties associated with surveillance, enforcement and scientific monitoring – particularly in offshore areas.

Despite the increase in the number and coverage of protected areas, adaptation strategies to address climate change are often lacking in the design and management plans of MPAs (Tittensor et al., 2019). The majority of examples where MPA management plans do include adaptation strategies come from tropical reefs (Wilson et al., 2020), though these habitats account for just a small percentage of the ocean. There is a recognized need for climate-focused policy and management agendas, and yet, there continues to be barriers to their inclusion in MPA management. Cited barriers include lack of scientific knowledge and limitations due to governance and policy structures at the national and sub-national level (Wilson et al., 2020; Hagerman & Satterfield, 2014).

New MPAs are continuing to be established around the world. Introduced in 2019, Ascension Island Marine Protected Area (MPA) includes the entire Exclusive Economic Zone (EEZ) of the island. This encompasses over 440,000km^2 of ocean space. Currently, commercial fishing and mineral extraction are prohibited throughout the protected area, while recreational activities, artisanal fishing and scientific research are permitted (Ascension Island Government, 2020). While this provides a high degree of protection for the waters surrounding Ascension Island, there are still threats that remain – including sea level rise, ocean acidification, and changes in ocean temperatures and currents – all associated with climate change. Large and remote protected areas are essential for effective global conservation of biodiversity (Edgar et al., 2014). However, these very attributes which make protected areas successful also make them difficult to manage. Ascension Island MPA faces the combined difficulties of being a large, remote, offshore MPA and the inclusion of climate-smart adaptation measures in their management strategies.

1.2 Management problem

There is a deficit of information regarding current climate change adaptation measures in MPAs in pelagic and deep-sea habitats, as most research to date has focused on tropical corals and coastal habitats (Wilson et al., 2020). Thus, new and innovative strategies will be required when including climate change adaptation strategies in MPAs which include these less-studied habitats. This is of topical relevance as the global community works towards the United Nations' conservation target of protecting 30% of the ocean by 2030 (United Nations Summit on Biodiversity, 2020). Ascension Island MPA has a high level of legislative protection that prohibits mineral extraction and commercial fishing, however, the size of the MPA, the remoteness of the island and the fact that the vast majority of the MPA consists of the pelagic and deep-sea ecosystems provide unique management challenges. To effectively conserve Ascension Island's marine biodiversity, habitats and ecological functions for long-term ecosystem viability, while also supporting sustainable socio-economic growth, a holistic, adaptive management approach which considers and accounts for the implications of climate change is needed.

1.3 Research objectives

This research aims to provide recommendations on climate change adaptive management to inform and complement the developing management plan of Ascension Island MPA. In order to achieve this, the following questions are addressed:

1) What are the conservation priorities of Ascension Island MPA, and how are these vulnerable to climate change?

2) What climate adaptive measures currently exist in MPAs or other literature that could be applicable to Ascension Island MPA?

3) What knowledge gaps exist that can be addressed in future research?

To answer these questions, a vulnerability assessment of Ascension Island MPA was conducted – this tool identified consequences, vulnerabilities and adaptive capacities of habitats within the MPA. Additionally, the literature was reviewed for examples of large, pelagic MPAs which incorporate measures addressing climate change in their management plans. Those that could be of value to Ascension Island MPA were compiled. By combining literature examples, and the framework for incorporating climate-smart management measures developed through the vulnerability assessment, a toolbox of management actions was built. Lastly, through this work, knowledge gaps were identified and compiled to inform future research on this topic.

CHAPTER 2: BACKGROUND

2.1 Climate change and MPAs

The impacts of climate change are being increasingly felt around the globe, with the most significant impacts affecting the ocean (IPCC, 2013). Marine protected areas were originally conceived as a means to protect marine biodiversity from human impacts, such as overfishing. However, climate change will present a significant challenge as to how to protect biodiversity in a non-static, changing environment. The need for integration of climate change adaptations is recognized in a number of marine sectors (Santos et al., 2020). As the global community works towards the goal of protecting 30% of the ocean by 2030, it is paramount that climate change be accounted for to ensure long-term conservation of biodiversity. While the conceptual methods for incorporating climate change have existed for some time, the implementation has been limited (Tittensor et al., 2019).

To incorporate considerations for climate change into adaptive MPA planning and ongoing management, there are four main components (Figure 1). These are: setting conservation goals, vulnerability assessment, MPA design, and management. The considerations at the centre of the figure should ideally be incorporated into each step. Adaptive management is the process by which the success of a management action is monitored as it is carried out and the results are used to improve management by either reconsidering or refining the action in the future. It is an iterative process with many cycles of implementation, evaluation and review (Westgate et al., 2013).

The number of MPAs with objectives that clearly relate to climate change is low (Tittensor et al., 2019). In a recent review of 27 existing and future MPAs, Wilson et al. (2020) compiled a list of climate change adaptation strategies which have been incorporated into MPAs (Table 1). The planning and management of an MPA depends not only on the biological factors affecting the success of the site, but also the social, cultural and economic dimensions (Charles & Wilson, 2009).

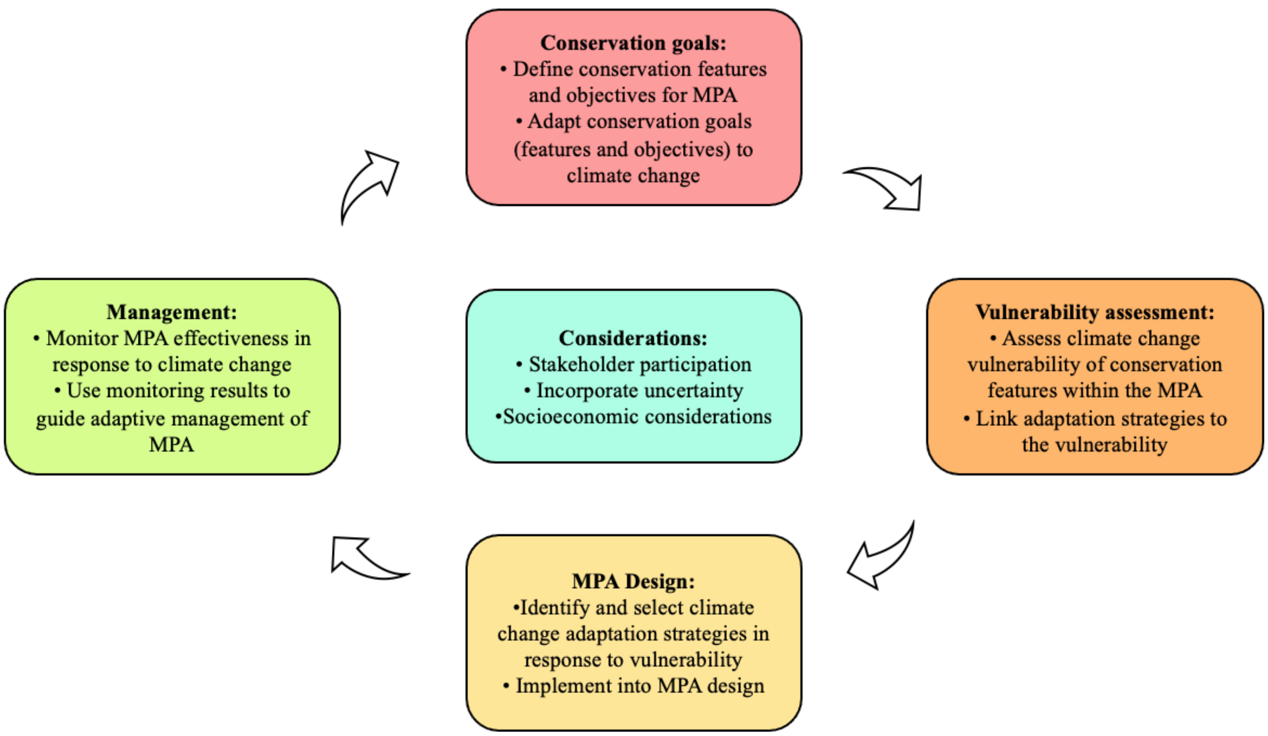

Figure 1. General planning framework for integrating climate change adaptation into the planning, design and management of MPAs (Adapted from: Wilson et al., 2020).

Table 1. Climate change adaptation strategies that have been incorporated into MPA design (Adapted from: Wilson et al., 2020)

Climate change adaptation strategies	Description
Increase resilience	Increasing a variety of resilience factors specific to the MPA (such as maintaining connectivity, reducing other stressors, and using EBM) to improve the ability of an ecosystem to resist, recover or adapt to climate change.
Protect climate refugia	Climate refugia are areas at a variety of scales that are slower to change, where species or ecosystems are more likely to persist. Protecting these areas may provide species time to adapt to climate changes.
Protect future habitat	A species or habitat's projected future distribution can be prioritized for protection within an MPA, or MPA boundaries can be redesigned to include these areas.
Increase connectivity	Connectivity within an MPA facilitates species persistence and increases the benefits of the MPA. Climate change may impact connectivity via ocean circulation and stratification. Current and future connectivity of larval dispersal and migration corridors should be considered.
Increase heterogeneity	By protecting a spectrum of sites with low and high exposure to climate impacts, MPA is providing protection across different spatial and temporal scales.
Reduce other stressors	Minimizing other stressors will lessen the synergistic impacts of climate- and non-climate stressors.
Dynamic MPAs	Dynamic MPAs can shift in space and time in response to climate stress or other factors, and can be used in conjunction with traditional MPAs.

2.2 Ascension Island MPA

2.2.1 Ascension Island

Ascension Island is part of the British Overseas Territory of Saint Helena, Ascension and Tristan da Cunha, that is located in the remote Southern Atlantic Ocean (Figure 2). The island, discovered in 1501 by a Portuguese sailor and officially settled by the British in 1815, has an area of 88km^2 and 47km of coastline. A 2016 census indicated that there are 806 people living on Ascension Island (St Helena Government, 2016). There has never been an Indigenous population on the island. The government structure of Ascension Island includes Governor, Administrator and an elected Council. The people of Ascension Island have close ties with the sea, and fishing, describing it as the 'essence' of the island (Canelas et al., 2019).

Ascension Island was visited in 1836 by Charles Darwin during the second *Beagle* voyage. In *The Voyage of the Beagle*, he described: "[I]magine smooth conical hills of a bright red color, with their summits generally truncated, rising separately out of a level surface of black rugged lava … To complete the desolate scene, the black rocks on the coast are lashed by a wild and turbulent sea." This would go on to inspire the English botanist and explorer Joseph Hooker to create an artificial forest on the island by importing plant species from Europe, Argentina and South Africa beginning in 1850. Green Mountain, the highest point on the island, is now consequently a mosaic of tropical cloud forest which includes eucalyptus, bamboo and banana trees. It is also today a national park that conserves endemic species, and one of few large-scale artificial forests in the world.

Important economic centres of Ascension Island include its military bases and its communications and relay stations. Chosen for its position in the Mid-Atlantic, Ascension Island is home to astronomical observational equipment of both NASA and the European Space Agency, as well as to one of four ground antennas of the Global Positioning System (GPS) navigation system. There is one school which provides education for children ages 3 through 16. Despite its rather inaccessible location and small size, there is a tourism industry on Ascension. The attractions include sport fishing, hiking and golf.

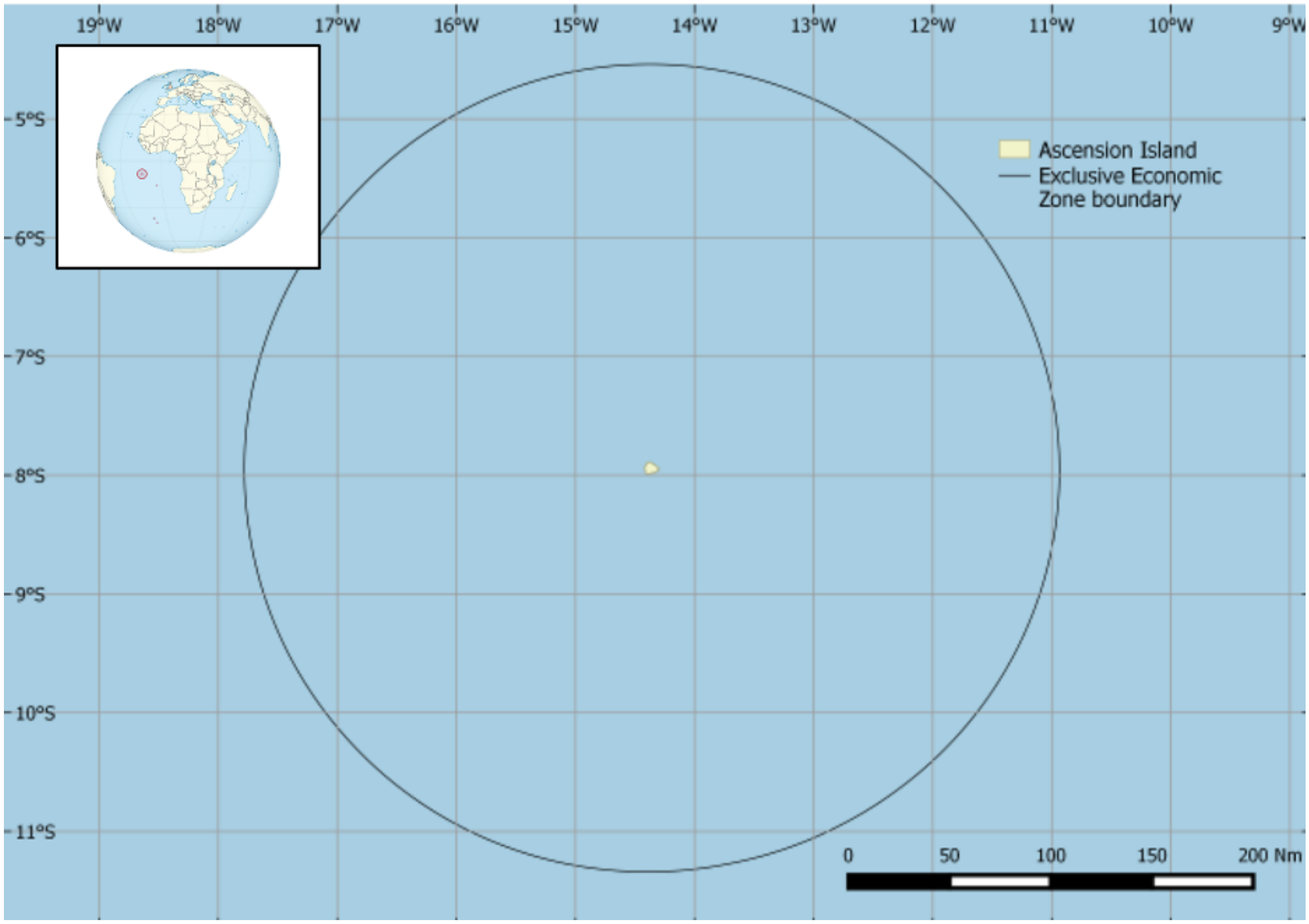

Figure 2. Location of Ascension Island and surrounding marine protected area (red circle), which covers over 440,000km^2 (Source: MPAtlas)

Island and coastal ecology

Ascension Island has a hot desert climate. The island is the result of an underwater volcano rising from the earth's crust less than a million years ago. There are a variety of coastal and shallow water habitats fringing the island which provide breeding grounds for numerous marine species. Many non-native species were introduced over the last two centuries, including cats, rats, rabbits, goats, sheep and a variety of plant species. Ascension Island is an important nesting site for turtles and seabirds of the Atlantic – both of which were previously threatened (the former due to their being hunted by humans; the latter for being hunted by feral cats). Both green turtle and seabird populations have rebounded thanks to conservation measures which have been put in place in recent years (Mortiner & Carr, 1987).

2.2.2 MPA Design

Ascension Island Marine Protected Area (MPA) was designated in August 2019. The MPA covers the entire EEZ of the island, comprising over 440,000km^2. This MPA seeks to protect the totality of its ecosystems rather than individual species or features (Table 2). It is one site within a network being developed as part of the United Kingdom Government's Blue Belt Programme. The goal of this programme is the long-term protection of over 4,000,000km^2 of ocean and working towards the larger goal of protecting 30% of the ocean by 2030. The majority of the MPA consists of open oceanic waters deeper than 500m, and descending to a maximum depth of 4000m. Once an important tuna fishing area, commercial fishing and mineral extraction are now prohibited throughout the MPA, though some small-scale and artisanal fishing is permitted (Ascension Island Government, 2020). Activities which are permitted in the MPA include: recreational and sports fishing, recreation and tourism, including SCUBA, swimming and cruise ships, supply of goods to the island via sea freight; sea vessels crossing the EEZ, military activity and scientific research.

Table 2. Management objectives of Ascension Island MPA (Adapted from Ascension Island Government, 2021).

What will the MPA achieve?   ***The MPA objectives***
1. To conserve Ascension Island's marine biodiversity, habitats, and ecological functions for long-term ecosystem health
2. To promote the sustainable development of socio-economic activities that are compatible with protection of the marine environment
3. To promote scientific research and share knowledge about Ascension Island's marine biodiversity in order to encourage support for marine conservation locally, nationally and internationally
Supporting objective: To achieve effective governance and management of the MPA that is transparent and underpinned by sustainable financial and human resources

Habitats and features of interest

Because the MPA is so large, there is a broad range of habitats within its boundaries. The inner boundary of the MPA begins at the high-tide mark, including many coastal habitats which include sandy beaches, coastal plateaus, and steep basaltic cliffs. There is little in terms of human coastal development along the shores of Ascension Island. Ascension Island is home to the second-largest breeding colony of green turtles, *Chelonia mydas*, in the Atlantic. In a 2017 census, over 50,000 nests were recorded. (Broderick et al., 2006; Ascension Island Government, 2021). This species is listed as Endangered on the IUCN Red List (IUCN, 2021). The Ascension frigatebird, *Fregata aquila*, is endemic to the island. Still listed as Vulnerable, this population has been increasing in recent years (Ascension Island Government, 2021). In shallow water habitats surrounding the island, there are over 133 fish species – 11 of which are endemic to the island, and a further 20 endemic to the cluster of islands (Wirtz et al., 2017). There are three prominent seamounts within the MPA. According to Weber et al. (2018), these seamounts have a greater diversity of zooplankton and large pelagic fish in comparison to the open ocean. Seamounts are hypothesized to be important for connectivity. Yellowfin tuna, *Thunnus albacares*, and Galapagos sharks, *Carcharhinus galapagensis*, are found in higher densities near these seamounts. The largest habitat within the MPA is the pelagic habitat. The deep benthic habitats of the MPA are mostly abyssal plain with a soft sediment bottom, but near the mid-Atlantic ridge, hydrothermal vents are home to unique species such as Vestimentiferan tubeworms and *Bathymodiolus* mussels (Ascension Island Government, 2021).

CHAPTER 3: APPROACH

3.1 Vulnerability assessment

Vulnerability assessments aim to evaluate the vulnerability of conservation features of interest to climate change. The Marine Protected Area Rapid Vulnerability Assessment Tool is one example of a framework created by the Commission for Environmental Cooperation (CEC) for use by MPA managers and stakeholders to guide the adaptation strategy development process (Commission for Environmental Cooperation, 2017). In contrast to a standard vulnerability assessment (such as that developed by IPCC), a rapid vulnerability assessment combines the likelihood and consequence of a stressor to determine risk, whereas the former determines the potential impact of a stressor through a combination of exposure and sensitivity (Figure 3). A rapid vulnerability assessment is meant to be conducted simply at first, and built upon through successive iterations. The present study will follow a modified version of the CEC tool. This tool helps MPA managers to consider the impacts of climate change as it relates to issues of concern (such as ecosystem services, habitat management and species conservation). Furthermore, vulnerability assessments act as an aid to streamline the ongoing consideration of climate change within MPAs by reviewing or reapplying the tool as new information becomes available, or at another temporal or spatial scale. Though the threat of climate change to species and ecosystems is known, the challenge can be daunting, and the resources to help managers integrate climate change consideration and adaptation into management decisions are not always available. The tool also provides insight into which resources and habitats are most likely to be impacted by the changing climate, which informs priorities for management response (Glick et al., 2011). Rapid vulnerability assessments can be conducted by a single manager or researcher, or as a collaborative enterprise involving a variety of stakeholder groups. For this study, I solely performed the rapid vulnerability assessment by using information from the literature, information provided by Ascension Island Government, and through informal interviews and consultation with MPA managers of Ascension Island.

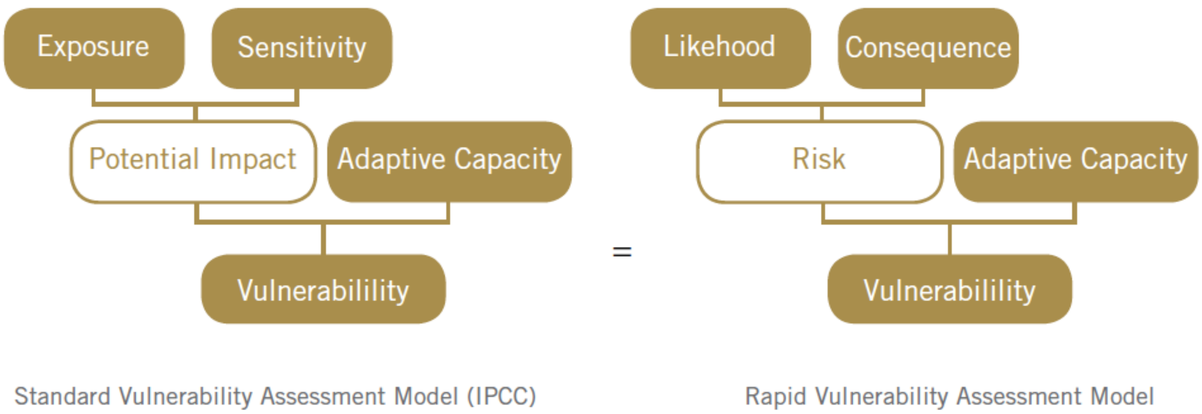

Figure 3. A standard vulnerability model compared with the rapid vulnerability assessment model (Source: CEC, 2017).

3.2.1 Scope of the assessment

A vulnerability assessment, as with MPA planning generally, involves setting clear conservation goals. The first step of the vulnerability assessment involved defining the scope and parameters of the RVA. This included habitats, timescale, climate change-related variables**,** non-climate stressors. For habitat type, habitats of management concern were prioritized, including those with species of importance or which may be particularly vulnerable to climate change. In the case of the broad scale and diversity of habitat types throughout the Ascension Island MPA, five general habitat types which are representative of the whole site were chosen. Secondly, the timescale for the assessment was determined. For continuity, as different timescales rely on different data and assumptions, this was aligned with the management plan review cycle of Ascension Island MPA, which is five years. After this, significant climate change related variables to the previously-decided habitats were identified. The final stage of defining the scope of the assessment was identifying what non-climate stressors currently impact these habitats. Each of these steps were conducted in collaboration with management from Ascension Island MPA.

3.2.2 Assessment matrices

The assessment process includes producing several matrices for each habitat which are then combined to create the complete vulnerability assessment. The first of these is the consequences matrix, wherein the impact of non-climate stressors on habitats is assessed, as well as the anticipated combined impact of the non-climate stressor and climate stressors. These are defined as either: catastrophic (habitat will cease to exist or have its function permanently altered), major (key species or functions may be dramatically altered, such that value is undermined), moderate (species numbers may decline, function may be diminished, such that habitat is seen as degraded but still present), minor (habitat will continue to function but activities such as recovery will be impaired) or negligible (habitat and its key components will not be visibly or functionally affected). Next, a matrix investigating the adaptive capacity of each habitat was constructed. This assessed the adaptive capacities of the habitat types across ecological and social criteria. The condition of each feature assessed on a scale of 1 to 5, where 5 is superior condition (this factor exemplifies the ideal condition), 4 is good (this factor does a better than adequate job but could use improvement), 3 is fair (this factor is adequate but could be easily improved), 2 is poor (this factor is not adequate, but it provides modest function) and 1 is critical condition (this factor is not functional or does not exist). An average for each feature is then calculated where 3.7-5 is high adaptive capacity, 2.4-3.6 is moderate adaptive capacity and 1-2.3 is low adaptive capacity.

3.2.3 Vulnerability assessment matrix

The vulnerability assessment matrix was constructed by combining the consequence and adaptive capacity matrices for each of the four habitats for a total of four vulnerability assessments. For assessment, the four identified climate stressors, the observed or predicted direction of change was described. In the next column, the anticipated effects on the habitat type were described. Based on these, an estimated likelihood score was provided of: almost certain (>50% probability), likely (50/50 probability), possible (less than 50% but not unlikely), unlikely (probability low but not zero) or rare (probability very low, close to zero). In the next column, the risk is presented as a product of likelihood and consequence (Figure 4). In the last column, vulnerability is presented as a product of risk and adaptive capacity (Figure 5).

	Consequences				
Likelihood	Negligible	Minor	Moderate	Major	Catastrophic
Rare	Low	Low	Low	Low	Low
Unlikely	Low	Low	Moderate	Moderate	Moderate
Possible	Low	Moderate	Moderate	High	High
Likely	Low	Moderate	High	High	Extreme
Almost certain	Low	Moderate	High	Extreme	Extreme

Figure 4. Risk = likelihood x consequence (Source: CEC, 2017).

Risk	Adaptive Capacity: Low	Adaptive Capacity: Moderate	Adaptive Capacity: High
Low	Low	Low	Low
Moderate	Moderate	Moderate	Low
High	High	Moderate	Moderate
Extreme	High	High	Moderate

Figure 5. Vulnerability = risk x adaptive capacity (Source: CEC, 2017).

3.2 Literature Review

In order to address the research objectives, a literature review was conducted. This analysis method was selected to review the current state of climate change adaptation strategies in MPAs. The literature review was conducted with three objectives: 1) Identify and evaluate examples of climate change adaptive measures in MPAs, 2) Apply the lessons learned to Ascension Island MPA, 3) Identify barriers surrounding the incorporation of climate change measures in MPA management that may apply to Ascension Island MPA. To begin, current reviews were examined. This study then used a scoping literature review to identify other large MPAs with considerations for climate change in their management. This review was performed by searching Google Scholar Database for literature on MPAs using a combination of the keywords, “MPAs,” “marine protected areas,” “climate change,” “adaptive management,” “large MPA,” and “pelagic MPA” while filtering for peer-reviewed journal articles published after 2010. The relevant articles were then used as a means to identify further related literature by looking at the sources that each article cited that referenced any other large MPAs. The same procedure was then used for these articles. This was continued until no additional articles were identified. Ideally, by doing the literature search in this manner, the most recent articles would be uncovered by the initial search, with the less recent publications included in their literature cited.

The literature used included primary literature, case studies, meta-analyses, interviews with MPA managers, and grey literature. The literature review resulted in the identification of relevant examples of climate change adaptive measures that could be useful to Ascension Island.

CHAPTER 4: FINDINGS

4.1 Vulnerability assessment

4.1.1 Scope of assessment

For the scope of the RVA, it was determined that the MPA would be assessed in terms of its five general habitat types (Table 3), and on a 5-year timescale to align with the MPA plan review cycle. The major climate and non-climate stressors were determined through consultation with MPA managers of Ascension Island and through review of the literature (Table 4). Consequence, adaptive capacity and vulnerability assessments were conducted for coastal habitats (Tables 5, 6, 7), shallow water habitats (Tables 8, 9, 10), pelagic habitats (Tables 11, 12, 13), and deep benthic habitats (Tables 14, 15, 16). Where an answer of "N/A" or "unknown" has been provided, there was insufficient data to make an informed estimate.

Table 3. General habitat types identified within Ascension Island MPA.

Habitat types	Characterization
Coastal habitats	Includes rocky shores, sandy shores.
Shallow water habitats	Includes habitats less than 20m in depth.
Pelagic habitats	Includes the open surface and sub-surface pelagic waters throughout the MPA.
Deep benthic habitats	Includes all habitats associated with the benthos, including seamounts.

Table 4. Significant climate and non-climate stressors for Ascension Island MPA.

Climate stressors	Non-climate stressors
Increased sea temperature	Introduction of non-native species
Shifts in ocean currents and upwelling	Illegal fishing activity
Ocean acidification	Indirect effects of fishing activity outside of MPA
Sea level rise	Marine pollution

Coastal habitats

Table 5. Consequences assessment of coastal habitats.

Coastal habitats					
Non-climate stressor	**How does this stressor affect this habitat type?**	**What is the combined impact on the habitat of this non-climate stress and…**			
		Increased sea temperatures	**Shifts in ocean currents/upwelling**	**Ocean acidification**	**Sea level rise**
Pollution to marine habitat	Plastic and other litter washing up on beaches degrading habitat, consumption of plastic fatal to birds, mammals, fish and turtles; light pollution impacts migration of juvenile turtles (Broderick et al., 2002)	May impact amount and distribution of microplastics, storm events may increase terrestrial runoff	Changes in circulation may result in greater macroplastic pollution of Ascension Island; redistribution of nutrients	Plastic pollution may exacerbate ocean acidification (Shen et al., 2020), and vice versa. Both are harmful to coastal species, particularly green turtles	Rising sea level will decrease/erode already-limed coastal habitat availability, may result in increased competition for space; bring marine plastics higher up the shoreline
Introduction of non-native species	Stresses native populations; historically non-native species have had severe impacts on coastal species	Changing sea temperatures may cause range shifts in non-native species	Changing sea currents may cause range shifts and redistribution of marine organisms, particularly planktonic species	May affect the type of species that are able to persist and colonize	Rising sea levels may make it easier for non-native species to colonize coastal habitat
Overexploitation of fished species/indirect effects of fishing	May impact food sources of coastal species; sport and recreational fishing from shore may disturb nesting areas	May cause changes in target fish species, bycatch	Changing sea currents may cause range shifts and redistribution of nutrients, may have unexpected effects on fished species and fisheries	N/A	N/A
	Consequence:	Major	Moderate	Moderate	Catastrophic

Consequences scale:

Catastrophic	Major	Moderate	Minor	Negligible
(Habitat will cease to exist or have its function permanently altered)	(Key species or functions may be dramatically altered, such that value is undermined)	(Species numbers may decline, function may be diminished, such that habitat is seen as degraded but still present)	(Habitat will continue to function but activities such as recovery will be impaired)	(Habitat and its key components will not be visibly or functionally affected)

Table 6. Adaptive capacity of coastal habitats

Coastal habitats		
Ecological potential	**Score**	**Rationale:**
Extent, distribution & connectivity	2	There is a limited amount of coastal space, connectivity with other islands is extremely limited, except for nearby Boatswain Bird Island.
Past evidence of recovery	4	Green turtle population has seen recovery since protection measures were put in place.
Value/importance	4	Habitats are of value and importance.
Physical diversity	3	A variety of habitats exist on the coast, however, some are more inhabited than others (i.e. lava flows).
Biodiversity	3	Biodiversity has been reduced, but is still fair.
Keystone & indicator species	3	Species are threatened but management measures are adequate.
Ecological potential average:	3.2	
Social potential:		
Staff capacity (training, time)	3	Some coastal species are outside of boundary of MPA, but are otherwise accessible to staff.
Stakeholder relationships	5	Because stakeholders can picture, see and interact with coastal species, these are highly valued.
Stability/longevity	2	Coastal habitats are in flux and unstable due to climatic pressures.
Existing mandate	4	Between the MPA and national park protection, mandates are in place.
Monitoring & evaluation capacity	5	Proximity to coastal habitats makes monitoring and evaluation accessible.
Science/technical support	4	Proximity to coastal habitats makes science and technical support accessible.
Social potential average:	3.85	
Combined potential average:	3.5	
Adaptive capacity:	Moderate	

Adaptive capacity scale:

3.7 - 5	2.4 - 3.6	1 - 2.3
High	Moderate	Low

Table 7. Vulnerability assessment of coastal habitats.

Coastal habitats						
Climate stress	**Anticipated effects on habitat**	**Likelihood**	**Consequence**	**Risk**	**Adaptive capacity**	**Vulnerability level**
Increased sea temperatures	Changes in sex ratio of green turtles; increased storm events	Likely	Major	High	Moderate	Moderate
Shifts in ocean currents/upwelling	Changes in nutrient distribution and primary productivity	Possible	Moderate	Moderate	Moderate	Moderate
Ocean acidification	Loss of shell density of calcifying organisms	Possible	Major	High	Moderate	Moderate
Sea level rise	Loss of nesting habitat for green turtles, frigate birds; greater competition for space and resources; coastal erosion	Almost certain	Catastrophic	Extreme	Moderate	Moderate

Likelihood scale:

Almost certain	Likely	Possible	Unlikely	Rare
(>50% probability)	(50/50 probability)	(Less than 50% but not unlikely)	(Probability low but not zero)	(Probability very low, close to zero)

Table 8. Consequences assessment of shallow water habitats

Shallow water habitats					
Non-climate stressor	**How does this stressor affect this habitat type?**	**What is the combined impact of this non-climate stress and…**			
		Increased sea temperatures	**Shifts in ocean currents/upwelling**	**Ocean acidification**	**Sea level rise**
Pollution to marine habitat	Ingesting of plastic by marine species, noise and light pollution impacting navigation, terrestrial pollutant runoff, spill incidents.	May impact amount and distribution of microplastics, changes in species range	Changes in circulation may result in greater plastic pollution of Ascension Island; redistribution of nutrients	Plastic pollution may exacerbate ocean acidification (Shen et al., 2020), and vice versa.	N/A
Introduction of non-native species	Disrupt marine ecosystems through predation, competition or uncontrolled growth smothering native species. Shallow water habitats are more vulnerable due to their degree of isolation.	Increased sea temperatures may facilitate non-native species outcompeting native species	Non-native species may be more likely to become established and outcompete native species if prevailing currents and conditions change	N/A	Rising sea levels may make it easier for non-native species to colonize shallow water habitat
Overexploitation of fished species/indirect effects of fishing	Some shallow water species may be caught as bycatch by legal onshore fisheries; loss of apex predators may have cascading trophic effects	Range shifts in species distribution may occur	Changing sea currents may cause range shifts and redistribution of nutrients, may have unexpected effects on fished species and fisheries	N/A	May result in higher competition for resources
	Consequence:	Moderate	Major	Major	Moderate

Catastrophic	Major	Moderate	Minor	Negligible
(Habitat will cease to exist or have its function permanently altered)	(Key species or functions may be dramatically altered, such that value is undermined)	(Species numbers may decline, function may be diminished, such that habitat is seen as degraded but still present)	(Habitat will continue to function but activities such as recovery will be impaired)	(Habitat and its key components will not be visibly or functionally affected)

Table 9. Adaptive capacity of shallow water habitats.

Shallow water habitats		
Ecological potential	**Score**	**Rationale:**
Extent, distribution & connectivity	3	Connectivity is limited; there are few shallow water habitats.
Past evidence of recovery	3	There is limited evidence of past recovery.
Value/importance	4	Important for many juvenile life stages; may be stressed by changing climatic conditions.
Physical diversity	3	There is an adequate amount of physical diversity in the shallow water habitat.
Biodiversity	3	Biodiversity has seen a slight decline in this habitat.
Keystone & indicator species	3	Indicator species somewhat vulnerable to increasing temperature.
Ecological potential average:	3.2	
Social potential:		
Staff capacity (training, time)	3	Shallow waters are somewhat able to be managed by staff.
Stakeholder relationships	3	Stakeholders are concerned with some of the species that inhabit the shallow waters.
Stability/longevity	3	Shallow water habitats are reasonably stable but may be subject to climatic pressures.
Existing mandate	3	Mandates are in place; however permissibility of onshore sport and recreational fishing may have a negative impact
Monitoring & evaluation capacity	4	Proximity to shallow water habitats makes monitoring and evaluation somewhat accessible.
Science/technical support	3	Proximity to shallow water makes science and technical support somewhat accessible.
Social potential average:	3.2	
Combined potential average:	3.2	
Adaptive capacity:	Moderate	

Adaptive capacity scale:

3.7 - 5	2.4 - 3.6	1 - 2.3
High	Moderate	Low

Table 10. Vulnerability assessment of shallow water habitats

Shallow water habitats						
Climate stress	**Anticipated effects on habitat**	**Likelihood**	**Consequence**	**Risk**	**Adaptive capacity**	**Vulnerability level**
Increased sea temperatures	Thermal stress, particularly on juvenile life stages; reduction in primary production. Little is known about the thermal thresholds of many shallow water species. Algae, sponges and bryozoans threatened by increasing temperatures.	Likely	Moderate	High	Moderate	Moderate
Shifts in ocean currents/upwelling	Shift in the Southern Equatorial Current could cause a large and permanent decrease in the productivity of Ascension's waters with knock on effects for species diversity and abundance. Affects retention of floating eggs and larvae.	Possible	Major	High	Moderate	Moderate
Ocean acidification	Calcifying organisms such as molluscs, corals and coralline algae ability construct shells and exoskeletons will be impacted with the reduced availability of carbonate ions in the water, leading to potentially widespread loss of these species (Orr et al., 2005).	Likely	Major	High	Moderate	Moderate
Sea level rise	Loss of shallow water and intertidal habitat	Likely	Moderate	High	Moderate	Moderate

Likelihood

Almost certain	Likely	Possible	Unlikely	Rare
(>50% probability)	(50/50 probability)	(Less than 50% but not unlikely)	(Probability low but not zero)	(Probability very low, close to zero)

Pelagic habitats

Table 11. Consequences assessment of pelagic habitats

Pelagic habitats					
Non-climate stressor	**How does this stressor affect this habitat type?**	**What is the combined impact of this non-climate stress and…**			
		Increased sea temperatures	**Shifts in ocean currents/upwelling**	**Ocean acidification**	**Sea level rise**
Pollution to marine habitat	Noise pollution; light pollution; terrestrial runoff; ingestion, entanglement and poisoning from plastics, bioaccumulation	One study suggests increasing marine plastics will affect physical properties of ocean, including scattering solar radiation (VishnuRadhan, et al., 2019); changes in sea temperature affect travel of sound through water medium	Changes in primary productivity; nutrient distribution; trophic cascades	N/A	N/A
Introduction of non-native species	Pelagic ecosystems are at lower risk because of the natural degree of mixing caused by ocean circulation and the highly mobile nature of many pelagic species.	Increased tourism may present an increased risk of the introduction of non-native species through ballast water exchange	Non-native species may be more likely to become established and outcompete native species if prevailing currents and conditions change	N/A	N/A
Overexploitation of fished species/indirect effects of fishing	Legal fishing outside of MPA targets top predators, other species at risk of being bycatch. Illegal fishing may occur within MPA boundaries.	N/A	Changes in primary productivity; nutrient distribution; trophic cascades	N/A	N/A
	Consequence:	Moderate	Moderate	Minor	Negligible

Catastrophic	Major	Moderate	Minor	Negligible
(Habitat will cease to exist or have its function permanently altered)	(Key species or functions may be dramatically altered, such that value is undermined)	(Species numbers may decline, function may be diminished, such that habitat is seen as degraded but still present)	(Habitat will continue to function but activities such as recovery will be impaired)	(Habitat and its key components will not be visibly or functionally affected)

Table 12. Adaptive capacity of pelagic habitats

Pelagic habitats		
Ecological potential	**Score:**	**Rationale:**
Extent, distribution & connectivity	5	Connectivity is limited; there are few shallow water habitats.
Past evidence of recovery	4	There is limited evidence of past recovery.
Value/importance	4	Important for many juvenile life stages; may be stressed by changing climatic conditions.
Physical diversity	3	There is an adequate amount of physical diversity in the shallow water habitat.
Biodiversity	3	Biodiversity has seen a slight decline in this habitat.
Keystone & indicator species	4	Indicator species somewhat vulnerable to increasing temperature.
Ecological potential average:	3.8	
Social potential		
Staff capacity (training, time)	2	Shallow waters are somewhat able to be managed by staff.
Stakeholder relationships	3	Stakeholders are concerned with some of the species that inhabit the shallow waters.
Stability/longevity	4	Shallow water habitats are reasonably stable but may be subject to climatic pressures.
Existing mandate	3	Mandates are in place; however permissibility of onshore sport and recreational fishing may have a negative impact
Monitoring & evaluation capacity	3	Proximity to shallow water habitats makes monitoring and evaluation somewhat accessible.
Science/technical support	3	Proximity to shallow water makes science and technical support somewhat accessible.
Social potential average:	3	
Combined potential average:	3.4	
Adaptive capacity:	Moderate	

Adaptive capacity scale:

3.7 - 5	2.4 - 3.6	1 - 2.3
High	Moderate	Low

Table 13. Vulnerability assessment of pelagic habitats.

Pelagic habitats						
Climate stress	**Anticipated effects on habitat**	**Likelihood**	**Consequence**	**Risk**	**Adaptive capacity**	**Vulnerability level**
Increased sea temperatures	Changes in sea temperature affect travel of sound through water medium; species may be unable to migrate if changes occur too rapidly.	Likely	Moderate	High	Moderate	Moderate
Shifts in ocean currents/upwelling	Shift in the Southern Equatorial Current could cause a large and permanent decrease in the productivity of Ascension's waters with knock on effects for species diversity and abundance.	Possible	Moderate	Moderate	Moderate	Moderate
Ocean acidification	Calcifying organisms such as molluscs, corals and coralline algae ability construct shells and exoskeletons will be impacted with the reduced availability of carbonate ions in the water, leading to potentially widespread loss of these species (Orr et al., 2005).	Likely	Minor	Moderate	Moderate	Moderate
Sea level rise	N/A	Unlikely	Negligible	Low	Moderate	Low

Likelihood

Almost certain	Likely	Possible	Unlikely	Rare
(>50% probability)	(50/50 probability)	(Less than 50% but not unlikely)	(Probability low but not zero)	(Probability very low, close to zero)

Deep benthic habitats

Table 14. Consequences assessment of deep benthic habitats.

Deep benthic habitats					
Non-climate stressor	**How does this stressor affect this habitat type?**	**What is the combined impact of this non-climate stress and…**			
		Increased sea temperatures	**Shifts in ocean currents/upwelling**	**Ocean acidification**	**Sea level rise**
Pollution to marine habitat	Microplastic contamination of benthic environment	N/A	N/A	N/A	N/A
Introduction of non-native species	N/A	N/A	N/A	N/A	N/A
Overexploitation of fished species/indirect effects of fishing	Changes in nutrient availability to some benthic communities	N/A	N/A	N/A	N/A
	Consequence:	N/A	N/A	N/A	Negligible

Catastrophic	Major	Moderate	Minor	Negligible
(Habitat will cease to exist or have its function permanently altered)	(Key species or functions may be dramatically altered, such that value is undermined)	(Species numbers may decline, function may be diminished, such that habitat is seen as degraded but still present)	(Habitat will continue to function but activities such as recovery will be impaired)	(Habitat and its key components will not be visibly or functionally affected)

Table 15. Adaptive capacity of deep benthic habitats.

Deep benthic habitats		
Ecological potential	**Score:**	**Rationale:**
Extent, distribution & connectivity	N/A	N/A
Past evidence of recovery	N/A	N/A
Value/importance	N/A	N/A
Physical diversity	N/A	N/A
Biodiversity	N/A	N/A
Keystone & indicator species	N/A	N/A
Ecological potential average:	N/A	N/A
Social potential:		
Staff capacity (training, time)	N/A	N/A
Stakeholder relationships	N/A	N/A
Stability/longevity	N/A	N/A
Existing mandate	N/A	N/A
Monitoring & evaluation capacity	N/A	N/A
Science/technical support	N/A	N/A
Social potential average:	N/A	N/A
Combined potential average:	N/A	N/A
Adaptive capacity:	N/A	N/A

Adaptive capacity scale:

3.7 - 5	2.4 - 3.6	1 - 2.3
High	Moderate	Low

Table 16. Vulnerability assessment of deep benthic habitats.

Deep benthic habitats						
Climate stress	**Anticipated effects on habitat**	**Likelihood**	**Consequence**	**Risk**	**Adaptive capacity**	**Vulnerability level**
Increased sea temperatures	Possible changes in species range/distribution (Yasuhara & Danovaro, 2016).	N/A	N/A	N/A	N/A	N/A
Shifts in ocean currents/upwelling	N/A	N/A	N/A	N/A	N/A	N/A
Ocean acidification	Impacts to species with calcium carbonate shells/exoskeletons	N/A	N/A	N/A	N/A	N/A
Sea level rise	N/A	N/A	N/A	Negligible	N/A	N/A

Likelihood

Almost certain	Likely	Possible	Unlikely	Rare
(>50% probability)	(50/50 probability)	(Less than 50% but not unlikely)	(Probability low but not zero)	(Probability very low, close to zero)

4.2 Strategy development

Based on the review of the literature, climate change adaptation measures which are currently, or will be, implemented in MPAs from around the world have been compiled, as well as other pertinent case studies (Table 17).

Table 18. Climate change adaptation strategies from the literature.

Habitat	Climate stressor(s) addressed	Climate change adaptation strategy	Source	Relevance to Ascension Island MPA
Deep benthic	Altered currents and upwelling/mixing	Increased research and monitoring to better understand impacts of climate change	Fernandez-Arcaya *et al.,* 2017	Fernandez-Arcaya et al. highlight the knowledge gaps surrounding anthropogenic and climate change impacts on the deep-sea floor and canyons and propose the need for monitoring of these sites to inform management.
General	General resilience	Encourage collaborative, multi-sector ocean governance and MSP to manage stressors and protect refugia	DOSI (https://www.dosi-project.org)	Development of Zotero-based bibliographic database for deep-sea ecosystems and climate change
General	General resilience	Reduce non-climate stressors to enhance resilience to climate changes (e.g., commercial fishing, oil and gas extraction, pollution), until more is known about these systems and how they interact with climate change and human activities	INDEEP (http://www.indeep-project.org/0	Global collaborative scientific network dedicated to the acquisition of data, synthesis of knowledge, and communication of findings on the biology and ecology of our global deep ocean.
Beach/coastal habitat	Sea level rise	Restoration and natural infrastructure to increase resilience. When necessary, supplement or mimic natural barriers.	Hawaiian Islands Climate Vulnerability and Adaptation Synthesis	Protection and fortification of green turtle nesting habitat

CHAPTER 5: DISCUSSION

The rapid vulnerability assessment provided insight into which habitats within Ascension Island MPA could be priorities for management. Coastal habitats are at risk from both climate and non-climate stressors, however, have a moderate adaptive capacity as it is the most accessible site in which monitoring and management action can be taken (Table 8). There is generally more support from stakeholders when sites within an MPA are able to be visited, and even more so when they have charismatic species, such as green turtles (Table 9). Based on this assessment, coastal habitats could be a priority for management with Ascension Island MPA. Coastal habitats are highly threatened – but, as staff can take physical action, they have a higher adaptive capacity (Table 8). Also, there is more information about coastal habitats as they are easier to access. Shallow water and pelagic habitats face moderate threats from climate change (Tables 14, 11) and have moderate adaptive capacities. Compared with coastal habitats, there are less opportunities for management intervention. This assessment highlighted the significant knowledge gap surrounding how the deep sea will be impacted by climate change. There is almost no information about the compounding effects of climate change and non-climate stressors in the deep sea. It is thus difficult to make any informed predictions about the vulnerability or adaptive capacity of this habitat (Table 17). It is supposed that the conditions of deep water are influenced by climate conditions at the surface and a general warming has been found in the deep Mediterranean over the last 30 years (Danovaro et al., 2001). Overall, the rapid vulnerability assessment provides a framework to consider how climate change also has the potential to interact with other threats to increase both their likelihood and severity. For example, some non-native species may be more likely to become established or outcompete native species if there are shifts in ocean currents and changes in prevailing conditions. Pollution from sediment run off may be higher if the frequency of extreme rainfall events increases, and rising sea levels could lead to calls for the development of coastal defences.

5.1 Recommendations for Ascension Island MPA

Recommendation #1: Increase research and monitoring to better understand impacts of climate change.

In particular, there is a need for fine-scale climate models in this region, as well as species distribution models for species of management concern. There is a significant knowledge gap in particular concerning deep benthic habitats, how they will be impacted by climate change, and how these impacts will interact with non-climate stressors.

Recommendation #2: Reduce other stressors.

The most actionable strategy to improve the resilience of species and ecosystems is to continue to work to reduce other stressors with management action. Illegal fishing activity and indirect effects of fishing (Figure 6), marine pollution and non-native species have been indicated as the most prominent non-climate stressors. While these were the main threats investigated in the present study, other threats to the MPA include: legal recreational and sports fishing, development, noise pollution, spill incidents and disturbances from tourism.

The Scottish Association of Marine Science has identified the following non-native marine species as risks to Ascension Island MPA, as factors of their likelihood of arrival and establishment, and severity of impact: Mediterranean mussel (*Mytilus galloprovincialis*), Pacific oyster (*Magallana gigas*), Asian green mussel (*Perna viridis*), Bivalva (*Semimytilus algosus*), Orange cup coral (*Tubastraea coccinea*), Ascidian (*Ciona robusta*), and Lionfish (*Pteriosis miles*). The most likely routes of introduction for all of these species (except Lionfish) is through ballast water and vessel hulls. The Ballast Water Management Convention applies to vessels flagged to many states and requires that ballast water is not discharged within 200NM of land, and that by 2024 all vessels will have to treat their ballast water. The most likely introduction of Lionfish would be release from aquaria. There are no saltwater aquaria on Ascension Island (Ascension Island Government, pers. comm), but there is a chance of introduction from superyachts which are occasional visitors to the island. This seems unlikely, however, Lionfish can be devastating to the native population once introduced to an area, so it is worthwhile noting. Biosecurity Ordinance (2020) restrict the import of ornamental fish and reserve the right to inspect the hulls of visiting vessels. There are currently no reports of non-native marine species within Ascension Island MPA, however, non-native terrestrial species, such as mice (*Mus musculus*), rats (*Rattus rattus*) and cats (*Felis catus*) have had serious impacts on coastal species such as turtles, seabirds and land crabs.

Marine pollution in the form of marine litter and ghost gear are often found around the coast of Ascension Island. The main impacts of marine litter on organisms is through entanglement, ingestion or poisoning. Predators are especially vulnerable to plastic poisoning as a result of bioaccumulation through prey. Improvements to waste management on the island, and a commitment to reduction in single-use plastic through better public engagement should reduce the marine litter that is generated on the island. Regulations prohibit the unauthorised dumping of material within the MPA (Ascension Island Government, 2021). However, plastic pollution from international sources remains an issue due to poor waste management practices and the long-term persistence of plastics in the ocean environment (Monterio et al., 2018).

Large-scale commercial fishing is prohibited within the MPA, but tracking studies have shown that large species such as tuna and marlin migrate over long distances in and outside of the MPA boundaries. As such, legal longline fishing on the high seas may impact biodiversity within the MPA (Ascension Island Government, 2021). According to ICCAT, bigeye tuna, Atlantic swordfish, sailfish, and blue marlin are overfished and possibly unsustainable (ICCAT 2017; 2018). Improvements in regional stock management are required. There is a risk of bycatch to non-target shark species, turtles and seabirds. Ascension Island MPA has an Inshore Fisheries Advisory Committee who will be tasked with collecting data on the number of fish caught by small-scale fishing from the island. A well-managed recreational fishery is essential to the conservation and socio-economic goals of the MPA.

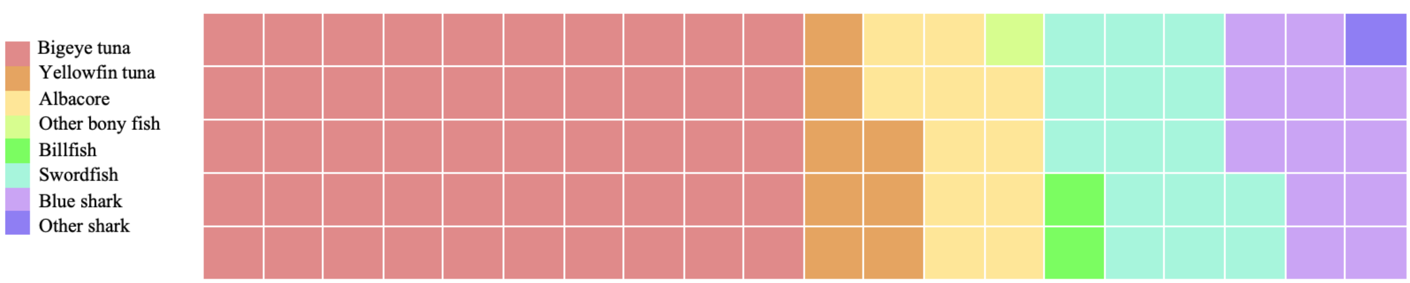

Figure 6. Plot of target and bycatch species weight as a proportion of total catch weight in the longline fishery operating in the mid-Atlantic from 2010 to 2015. Each square represents one percent of the total catch (Data source: ICCAT; Adapted from Ascension Island Government, 2021).

Recommendation #3: Encourage collaborative, multi-sector ocean governance and MSP to manage stressors and protect refugia, both within the community of Ascension Island and Ascension Island MPA, and the global marine management community. Through the initiation and planning process, MPA managers of Ascension Island had a high level of stakeholder engagement. Advisors to the management of Ascension Island MPA include: The Governor, Ascension Island Council, MPA steering group, MPA youth committee, Inshore fisheries advisory committee, Scientific advisory committee, Blue belt partners. The COVID-19 pandemic has shown that the ability to connect remotely is not only possible, but highly beneficial in some spaces. Ascension Island may be remote in geography, but the digital connectedness of scientists, managers, policy-makers and concerned citizens around the world seems to be at an all-time high. Continue outreach and education.

Recommendation #4: Adaptive management, development of Climate Change Resilience Strategy

5.2 Future work

Moving forward with this work, the RVA, could be used to guide a future working group or review meeting. It could be done at a different scale, or investigating different habitats or stressors for a different perspective of vulnerabilities. Important future work will involve addressing the data deficit for climate change management measures addressing deep-sea habitats and large protected spaces. There is a need for the development, maintenance and use of databases which centralize climate adaptation information. Some of these already exist, such as the Climate Action Knowledge Exchange (CAKE).

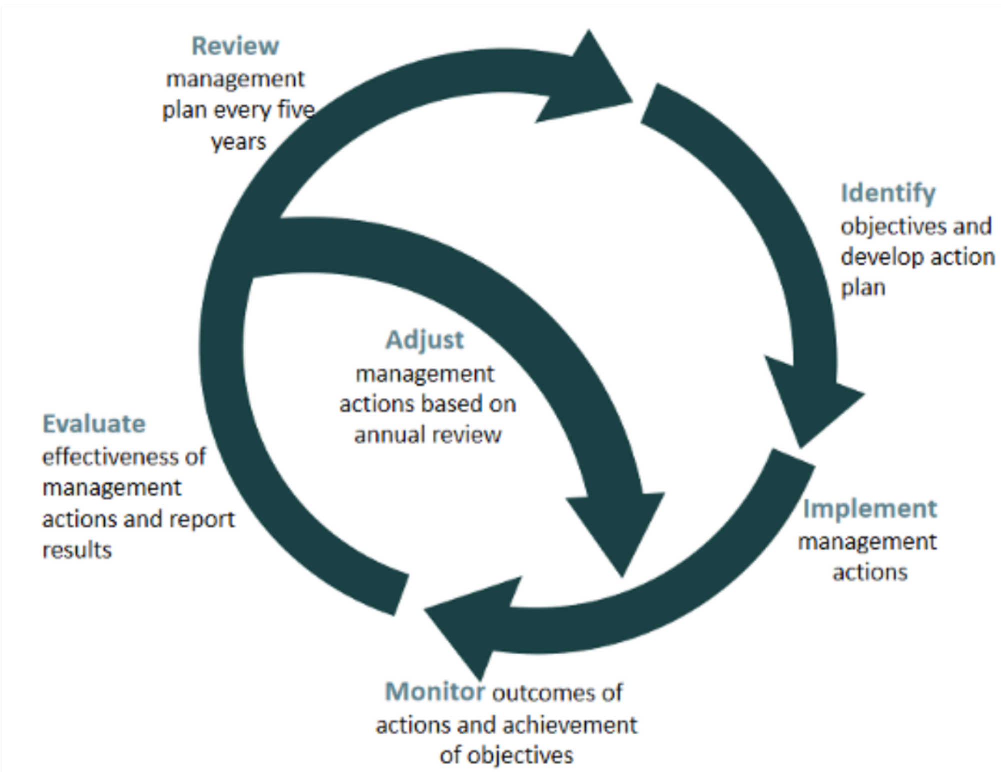

Figure 5. Adaptive management cycle of Ascension Island MPA (Source: Ascension Island Government, 2021).

The Ascension Island Government Conservation Marine Team, the Ascension Island Council, the community of Ascension Island and the independent scientists and groups which have contributed to the development of this management plan have done a commendable job. Just weeks before the time of writing, the MPA Management Plan for 2021–2026 for Ascension

Island was finalized and made public (Ascension Island Government, 2021). This plan was developed in partnership with a range of stakeholder groups including the community members of Ascension Island, as well as collaborators and researchers from around the world. The intention is that this plan will act as a legal, daily guide to direct the operations within the MPA. It is an adaptive management plan, meaning that the results of monitoring will be continually incorporated into the plan, and changes will be made when necessary. This plan guides the next five years of management, and will be reviewed after that time. By the end of 2021, the managers of Ascension Island plan to construct a Climate Change Resilience Strategy for the MPA. As is noted by Billé et al. (2013), responses to climate change are grouped into four categories: mitigate, protect, adapt and repair. This project has focused on protection and adaptation. While each of the four are essential, important tools, only mitigation, wherein CO_2 emissions are reduced, addresses the fundamental issue that will result in long-term sustainable change.

CHAPTER 6: CONCLUSION

Marine protected areas act to manage and limit human activities within a geographical boundary for the long-term conservation of the ecosystem and its services. As ocean ecosystems continue to be increasingly stressed by the effects of climate change, it is imperative that MPAs incorporate climate-smart adaptive management strategies into their management plans. Ascension Island MPA, a newly designated MPA comprising over 440,000km^2 of mostly open ocean, seeks to include such measures in the foundation of their management plan in order to develop an adaptable, resilient MPA. This project has aimed to provide recommendations for integrating climate change adaptive management practices into Ascension Island MPA. By conducting a rapid vulnerability assessment, and reviewing the literature for on-the-ground climate adaptive management strategies, a toolkit of strategies has been assembled. The following recommendations for incorporating climate change adaptation were provided to the managers of Ascension Island MPA: 1) increase research and monitoring to better understand the impacts of climate change 2) reduce other stressors to increase resilience, 3) encourage collaborative ocean governance and management, 4) continue to use adaptive management and the development of a Climate Change Resilience Strategy to provide guidelines in parallel with the MPA management plan.

Moving forward, there is a need for a globally coordinated effort to adapt existing and future MPAs to climate change. Improved, adaptive, climate-smart management represents an important and necessary paradigm shift in ocean management as we work towards the goal of protecting 30% of the ocean by 2030. And though adaptation and increasing resilience to climate impacts is valuable, I will here note that reducing CO_2 emissions, globally, immediately and significantly, is the only way to prevent the massive impacts of climate change on ocean ecosystems and the services they provide to society.

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